THE DISTRIBUTION OF GAS

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BY

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THIS VOLUME

IS DEDICATED TO

CHARLES S. ROBINSON, Esq.

FORMERLY ENGINEER TO

THE LEICESTER GAS COMPANY,

IN ACKNOWLEDGMENT OF

THE AUTHOR'S INDEBTEDNESS TO HIM

FOR COUNSEL AND ASSISTANCE AT THE

OUTSET OF HIS CAREER

INTRODUCTORY NOTE TO FIRST EDITION

THIS is the first and only Work in any language that deals exclusively with the important subject of the Distribution of Gas, and if the author is careful, as edition after edition is called for, to maintain its up-to-date character, it is not likely to be superseded in the future.

It was sufficiently evident, as the chapters appeared week by week in the pages of *The Gas World*, that the writer had set himself to treat the subject in a painstaking and thorough manner, leaving no phase of any of the multifarious questions undiscussed. This publication in serial form, by inviting criticism from many readers, has enabled him to profit by the expressed opinions of others and their varied practice, and, where necessary, to revise any judgments he had already formed from insufficient data. In this way the published volume may be considered as embodying almost all that is required as an outfit on the subject of Distribution, not only to Students, but also to Managers of Gasworks everywhere.

The copious illustrations are an admirable feature of the Book, and, of course, add greatly to its intrinsic value and usefulness.

The author's credentials are unquestionable, as he is the Superintending Engineer of the Distribution Department of one of the largest gasworks in the country, where the opportunities for observation and experience are of the very best. That he has availed himself of these advantages is evident from the contents of the Book throughout.

THOMAS NEWBIGGING.

5, Norfolk Street, Manchester,
May 1907.

INTRODUCTORY NOTE TO SECOND EDITION

From my extended knowledge of the Work, and of the improvements and additional chapters in this second edition, I can not only repeat, but emphasize, what I have said in my note to the first edition.

T. N.

November 1909.

INTRODUCTORY NOTE TO THIRD EDITION

It is of good augury for the Gas Industry that a Work of this high quality finds its third edition within such a comparatively brief time since its first publication—a Work giving an account, with infinitude of detail, of all the latest appliances relating to Gas Distribution and Consumption.

I have had the opportunity of examining the additions and improvements that have been made in this third edition, and am struck with the up-to-dateness of them all, and the exhaustive treatment of the various articles.

The reception which the Book has met with by the members of the Gas Profession is a striking proof of its value. The industry of its author is beyond praise, and his efforts to place before, not students only, but the experienced engineer, all that is being accomplished in the progress of gas supply, deserve the reward which those efforts will not fail to secure.

T. N.

September 1912.

PREFACE TO FIRST EDITION

THIS Book brings together a series of Articles contributed by the author to *The Gas World.* These he has been urged to republish in book form. For this purpose they have been carefully revised, and a chapter upon "Fusion and Electrolysis" added.

It has been the aim of the author to deal in a comprehensive manner with the Problems and Practice of Gas Distribution from the Gasholder to the Consumer, and to make this a serviceable Text-Book for the Student and an up-to-date Handbook for the Gas Manager. As far as possible, therefore, the illustrations have been produced in section, and detailed descriptions of the mechanism and operation of the various types of apparatus mentioned have been given.

The Book embodies the result of twenty-five years' practical experience and observation in the actual work of Gas Distribution. Where the author has been conscious of indebtedness to others, acknowledgment has been made and references given.

In the preparation of the Work the following authorities have been consulted :—

King's *Treatise on the Science and Practice of the Manufacture and Distribution of Coal Gas* ; Dr Pole on *Motion of Fluids in Pipes* ; F. S. Cripps on *The Flow of Gases and the Proportioning of Gas Mains* ; Professor Unwin on *The Flow of Gas in Mains and Distribution at High Pressure* ; C. W. L. Alexander on *Flow of Water in Pipe Bends* ; *Report of the Ohio Gas Association on Discharge Formulae* ; J. D. von Maur on *Cement Joints* ; Thos. Glover on *Action of Dry Meters* ; R. M. Parkinson on *Subway Systems for Municipal Conduits* ; Professor H. Drehschmidt on *Inverted Incandescent Gas Burners* ; Professor W. Wedding on *The Efficiency and Practical Importance of Common Sources of Light* ; K. Anderson on *The De Laval Steam Turbine* ; C. and B. Hopkinson and E. Talbot on *Electric Tramways* ; Dr W. Leybold on *Destruction of Gas Pipes by means of Electricity* ; *Report of the German Commission on Electrolysis* ; *Report of the American Commission on Electrolysis* ; *Regulations of the Board of Trade for Electric Tramways* ; Newbigging's *Handbook for Gas Engineers and*

Managers; Spon's *Engineer's Pocket-Book*; Molesworth's *Engineer's Pocket-Book*; *Transactions of the District Associations of Gas Engineers*; *Transactions of the Institution of Civil Engineers*; *Report of Royal Commission on London Traffic*; *The Gas World Analysis of Accounts of Gas Undertakings*, 1905-6; the Gasworks Clauses Amendment Act; the Sale of Gas Act; *The Gas World*; *Journal of Gas Lighting, Water Supply and Sanitary Improvement*; *American Gas Light Journal*; *Surveyor and Municipal and County Engineer.*

WALTER HOLE

LEEDS, May 1907.

PREFACE TO SECOND EDITION

ADVANTAGE has been taken of the demand for a second edition of *The Distribution of Gas* to revise, bring up to date, and considerably extend the scope and purpose of the work.

In response to suggestions which have reached the author from many quarters, seven new chapters have been added, dealing with the principal aspects of supply and consumption of gas upon the consumer's premises. To keep the size of the book within manageable proportions, it has been found necessary to compress certain portions of the work as first published. It is hoped that the additions and alterations will give an increased value to the book, and fulfil still further the aim of the author, to make it a "serviceable Text-Book for the Student and an up-to-date Handbook for the Gas Manager."

In preparing the additional chapters, the following authorities have been consulted :—

Hopkinson on *The effect of Mixture-Strength and Scavenging upon the Thermal Efficiency of the Gas Engine*; Hiscox on *Gas, Gasoline and Oil Vapour Engines*; Mathot on *Gas Engines and Producer Gas*

Plants; Bryan Donkin on *Gas, Oil and Air Engines*; Tookey's *Gas Engine Manual*; and Huxley's *Physiology*; in addition to the *Transactions of the Institution of Gas Engineers, Transactions of the District Associations of Gas Engineers,* and the Technical Press.

W. H.

LEEDS, November 1909.

PREFACE TO THIRD EDITION

THE issue of a third edition has afforded the author an opportunity, of which full opportunity has been taken, of revising and bringing up to date the subject matter of this book. The very great recent developments in many branches of distribution, particularly in relation to various phases of illumination, of heating, and of combustion, have involved the addition of a good deal of new matter. It has only been possible to include this, and yet keep the size of the book within reasonable limits, by a considerable and careful compression of the old material. The aim of the author has been to carry out this necessary condensation without detracting from the value of the book.

In place of the original single chapter, the subject of high-pressure distribution has been expanded and rearranged in four separate chapters. In addition, that upon high-pressure gas for public lighting has been almost entirely rewritten. Most of the old chapters have considerable additions. It is therefore hoped and believed that this third edition will in no whit fall behind its predecessors in carrying out the original object of the author, viz., to produce a volume which shall be "a serviceable Text-Book for the Student, and an up-to-date Handbook for the Gas Manager."

W. H.

LEEDS, September 1912.

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THE DISTRIBUTION OF GAS

CHAPTER I

RIGHTS AND DUTIES OF GAS UNDERTAKINGS

One of the first duties of any person, either occupying or aspiring to occupy a position of responsibility and authority in connection with the practice of gas distribution, should be to fully acquaint himself with the rights and privileges conferred, and the duties and obligations imposed, upon a gas undertaking by the legislature of the country.

The importance of having some knowledge of the subject will be very readily appreciated by those who, from practical experience, are made painfully aware how frequently such questions arise in the every-day work of gas distribution. The distributing engineer is the representative, to its many consumers, of the gas undertaking with which he is connected. It is part of his duty to receive and attend to all complaints and requests, both reasonable and unreasonable, and to meet them all with unfailing courtesy and urbanity. Whilst fully maintaining the rights and privileges of his department, it is for him to harmonize these with the public convenience, and the obligations which the rights involve. Human nature being what it is, it is hardly possible for such duties to be carried on for long without some more or less serious questions of this kind arising. It is, therefore, imperative that a very clear conception of the limitations of privilege on the one hand, and responsibility upon the other, should be obtained.

No apology can therefore be needed for giving the matter some attention at the very commencement of a work dealing with the subject of gas distribution.

Power to break up streets, etc.—The general power to open the public streets for the purpose of laying gas mains is dealt with in clause 6 of the Gasworks Clauses Act, 1847, which runs as follows, viz. :—" The undertakers, under such superintendence as is hereinafter specified, may open and break up the soil and pavement of the several streets and bridges within the limits of the special Act, and may open and break up any sewers, drains or tunnels within or under such streets and bridges, and lay down and place within the same limits pipes, conduits, service pipes and other works, and from time to time repair, alter or remove the same . . . and for the purposes aforesaid may remove and use all earth and materials in and under such streets and bridges . . . and do all other acts which the undertakers shall from time to time deem necessary for supplying gas to the inhabitants of the district included within the said limits, doing as little damage as may be in the execution of the powers hereby or by the special Act granted, and making compensation for any damage which may be done in the execution of such powers."

The undertakers are, however, not allowed to enter on private land without the consent of the owner and occupier, except for the purpose of relaying or repairing an existing pipe, as described in clause 7, which provides that "nothing herein shall authorize or empower the undertakers to lay down or place any pipe or other works into, through, or against any building, or in any land not dedicated to public use, without the consent of the owners and occupiers thereof; except that the undertakers may, at any time, enter upon and lay or place any new pipe in the place of an existing pipe in any land wherein any pipe hath been already lawfully laid down or placed in pursuance of this or the special Act, or any other Act of Parliament, and may repair or alter any pipe so laid down."

The interests of the highway or other authority responsible for the general control of the streets are safeguarded by clauses 8 and 9. Clause 8 provides that:—"Before the undertakers proceed to open or break up any street, bridge, sewer, drain, or tunnel, they shall give to the persons under whose control or management the same may be, or to their clerk, surveyor, or other officer, notice in writing of their intention to open or break up the same, not less than three clear days before beginning such work, except in cases of emergency arising from defects in any of the pipes or other works, and then so soon as is possible after the beginning of the work, or the necessity for the same shall have arisen."

The arrangements for due superintendence of the work by the local authority are made in accordance with clause 9, which provides that:—"No such street, bridge, sewer, drain, or tunnel shall, except in the cases of emergency aforesaid, be opened or broken up except under the superintendence of the persons having the control or management thereof, or of their officer, and according to such plan[1] as shall be approved of by such persons or their officer, or, in case of any difference respecting such plan, then according to such plan as shall be determined by two justices. . . ."

"Provided always, that if the persons having such control or management, as aforesaid, and their officer, fail to attend at the time fixed for opening of any such street, bridge, sewer, drain, or tunnel, after having had such notice of the undertakers' intention as aforesaid, or shall not propose any plan for breaking up or opening the same, or shall refuse or neglect to superintend the operation, the undertakers may perform the work specified in such notice without the superintendence of such persons or their officer."

[1] By decision of the courts, the plan must show the depth of the proposed main, and the mode in which the underground work is to be carried out.

All work involving the breaking up of roadways must be carried out with despatch ; the streets opened up must be sufficiently lighted and guarded ; and on the completion of the work must be promptly and properly made good, as provided for in clause 10 :—" When the undertakers open or break up the road or pavement of any street or bridge, or any sewer, drain or tunnel, they shall, with all convenient speed, complete the work for which the same shall be broken up, and fill in the ground, and reinstate and make good the road or pavement, or the sewer, drain or tunnel, so opened or broken up, and carry away the rubbish occasioned thereby, and shall, at all times, whilst any such road or pavement shall be so opened or broken up, cause the same to be fenced and guarded, and shall cause a light sufficient for the warning of passengers to be set up and maintained against or near such road or pavement where the same shall be open or broken up, every night during which the same shall be continued open or broken up, and shall keep the road or pavement which has been so broken up in good repair for three months after replacing and making good the same, and for such further time, if any, not being more than twelve months in the whole, as the soil so broken up shall continue to subside."

Penalty for delay in reinstating streets.—The penalties for failure on the part of the undertakers to observe the requirements of clauses 8 to 10 are set out in clause 11, which provides that :—" If the undertakers open or break up any street or bridge, or any sewer, drain or tunnel, without giving such notice as aforesaid, or in a manner different from that which shall have been approved of or determined as aforesaid, or without making such temporary or other works as aforesaid when so required, except in the cases in which the undertakers are hereby authorized to perform such works without any superintendence or notice, or if the undertakers make any delay in completing any such work, or in filling in the ground, or reinstating and making good the road or pavement, or the sewer, drain, or tunnel, so opened or broken up, or in carrying away the rubbish occasioned thereby, or if they neglect to cause the place where such road or pavement has been broken up to be fenced, guarded, and lighted, or neglect to keep the road or pavement in repair for the space of three months next after the same is made good, or such further time as aforesaid, they shall forfeit to the persons having the control or management of the street, bridge, sewer, drain, or tunnel, in respect of which such default is made, a sum not exceeding five pounds for every such offence, and they shall forfeit an additional sum of five pounds for each day during which any delay as aforesaid shall continue after they shall have received notice thereof."

Clause 12 provides further for the contingency of undue delay in carrying out the reinstatement of disturbed roadways, by giving power to the local authority to step in and execute the work at the cost of the undertakers. " If any such delay or omission as aforesaid takes place, the persons having the control or management of the street, bridge, sewer, drain, or tunnel, in respect of which such delay or omission shall take place, may cause the work so delayed or omitted to be executed, and the expense of executing the same shall be repaid to such persons by the undertakers; and such expenses may be recovered in the same manner as damages are recoverable under this or the special Act."

Gasworks Clauses Act, 1871.—The Gasworks Clauses Act Amendment Act of 1871 is to be read and construed with the 1847 Act. The 1871 Act states that "The provisions of this Act shall apply to every gas undertaking authorized by any special Act hereinafter passed or any Provisional Order made under the authority of the Gas and Waterworks Facilities Act 1870," unless these provisions are varied or excepted by the special Act or Provisional Order.

Supply of gas.—In dealing with the obligation to furnish a supply of gas, clause 11 enacts that, "The undertakers shall, upon being required so to do by the owner or occupier of any premises situate within twenty-five yards from any main of the undertakers, or such other distance as may be prescribed, give and continue to give a supply of gas for such premises, under such pressure in the main as may be prescribed, and they shall furnish and lay any pipe that may be necessary for such purpose."

But this obligation is not imposed unconditionally. It is not usual to make any charge for laying a gas service to any intending consumer nowadays unless the length of piping is excessive. But the Act clearly confers the right to charge for the whole of a service laid upon private property, and for the length of pipe, and labour involved in laying it, which exceeds 30 feet in length, whether laid upon private property or not. "The cost of so much of any pipe for the supply of gas to any owner or occupier as may be laid upon the property of such owner or in the possession of such occupier, and of so much of any such pipe as may be laid for a greater distance than 30 feet from any pipe of the undertakers, although not on such property, shall be defrayed by such owner or occupier" (clause 11).

Any person desirous of obtaining a supply of gas to his premises shall "serve a notice upon the undertakers at their office, specifying the premises in respect of which such supply is required, and the day (not being an earlier day than a reasonable time after the date of the service of such notice) upon which such supply is required to commence."

To protect the undertaking from risk of bad debts, undesirable customers, or insufficient return upon capital expenditure, any applicant for a supply of gas may be required to enter into a written agreement "to continue to receive and pay for a supply of gas, for a period of at least two years, of such an amount that the rent payable for the same shall not be less than twenty pounds per centum per annum on the outlay incurred by the undertakers in providing any pipe to be provided by them for the purpose of such supply; and give to the undertakers (if required by them so to do) security for the payment to them of all moneys which may become due to them by such owner or occupier in respect of any pipe to be furnished by the undertakers, and in respect of gas to be supplied by them. Provided always that the undertakers may, after they have given a supply of gas for any premises, by notice in writing, require the owner or occupier of such premises, within seven days after the date of the service of such notice, to give to them security for the payment of all moneys which may from time to time become due to them in respect of such supply, in case such owner or occupier has not already given such security, or in case any security given has become invalid, or is insufficient, and in case any such owner or occupier fails to comply with the terms of such notice, the undertakers may, if they please, discontinue to supply gas for such premises so long as such failure continues" (clause 11).

The Meters to be used.—Then as regards registration of the gas supplied. Every meter used must comply with the provisions of the Sale of Gas Act of 1859, and any consumer may claim to be supplied through any meter which, on being tested according to the rules laid down in the Act, is proved to comply with its requirement. No "meter shall be used unless the same shall be a legal meter within the meaning of the said Act, and . . . the undertakers shall not refuse to approve of any meter which, when duly tested according to the rules contained in the said Act for regulating measures used in sales of gas, is found to be correct within the meaning of the said Act" (clause 13).

Referring to the Sale of Gas Act, 1859, we see that a meter is defined to mean a "gas meter inclusive of every kind of machine used for measuring gas."

It is the duty of the inspector appointed under the Act to test meters to ensure that no meter shall be stamped which shall be found by the inspector "to register, or be capable of being made by any contrivance for that purpose, or by increase or by decrease of the water in such meter, or by any other means practically prevented in good meters, to register quantities varying from the true standard measure of gas."

Limits of error allowed.—But as the absolutely perfect machine, either for measuring gas or for any other purpose, has still to be made, the Act allows a certain well defined variation from absolute accuracy to the extent of "two per centum in favour of the seller or three per centum in favour of the consumer; and every meter, whether stamped or unstamped, which shall be found by such inspector to register, or be so capable of being made to register, quantities varying beyond the limits aforesaid, shall be deemed incorrect within the meaning of this Act; and every meter which shall be found by such inspector to measure and register quantities accurately, or not varying beyond the limits aforesaid, and shall be found incapable by any such means as aforesaid of being made to register quantities varying beyond the limits aforesaid, shall be considered to be correct."

Undertaking to supply meter.—Reverting to the Gasworks Clauses Amendment Act of 1871, we find that it is the duty of the gas undertaking to supply the necessary meter, but if thought desirable, they may require the intending consumer, previous to receiving such meter, to give to the undertakers security for payment to them of the price of such meter, if he desires to purchase the same, or of the rent of such meter if he desires to hire the same (clause 14).

Gas undertakings are protected from any meddlesome interference on the part of unauthorized persons with the service pipe or meter by clause 15, which is to the effect that "No consumer shall connect any meter with any pipe through which gas is supplied by the undertakers to such meter, or disconnect any meter from any such pipe, unless he shall have given to the undertakers not less than twenty-four hours' notice in writing of his intention so to do."

Every consumer supplied with gas through his own meter must, at his own cost, keep such meter in thorough repair and capable of correctly registering the gas supplied, or in default the undertakers may cease to supply gas through it. In addition "the undertakers shall have access to and be at liberty to take off, remove, test, inspect, and replace any such meter at all reasonable times, such taking off, removal, testing, inspecting, and replacing to be done at the expense of the undertakers if the meter be found in proper order, but otherwise at the expense of the consumer" (clause 17).

No gas meter belonging to a gas undertaking shall be subject to distress, or to the landlord's remedy for rent of the premises where the same may be used, nor to be taken in execution under any process of a court of law or equity, or any proceedings in bankruptcy against the persons in whose possession the same may be (clause 18).

The registration of the meter is accepted as *prima facie* evidence of the quantity of gas supplied. Cases of dispute may be "determined, upon the application of either party, by two justices, who may also order by which of the parties the costs of the proceedings before them shall be paid, and the decision of the justices shall be final and binding on all parties" (clause 20).

With respect to the right of entry by officers of the undertaking to any building supplied with gas, for the purpose of meter inspection, "any officer appointed by the undertakers may at all reasonable times enter any building or land lighted with gas supplied by the undertakers, in order to inspect the meters, fittings and works for the supply of gas, and for the purpose of ascertaining the quantity of gas consumed or supplied" (clause 21).

Discontinuance of supply.—Then with respect to the vexed and vexing question of discontinuing a supply of gas to a consumer, in all cases in which an undertaking is authorized to cut off the supply of gas to any premises, twenty-four hours' notice must be given in writing by the secretary or other properly authorized person "to the occupier, or if unoccupied then to the owner or lessee, or to the agent of the owner or lessee, of any premises in which any pipes, meters, fittings or apparatus belonging to the undertakers are laid or fixed, and through or in which the supply of gas is from any such cause discontinued, to enter such premises between the hours of nine in the morning and four in the evening, for the purpose of removing and to remove such pipes, meters, fittings or apparatus, repairing all damage caused by such entry or removal" (clause 22).

Tampering with meter.—Tampering with a meter on the part of any consumer, either by altering the index, abstraction of water, or in any way preventing the meter from registering correctly, is a serious offence, for which the penalty of a heavy fine may be imposed, and cost of repairs necessitated recovered. In addition, the supply of gas may be discontinued pending the remedy of the particular matter complained of. The existence of any artificial means for interference with the proper registration of meters "shall be *prima facie* evidence that such alteration, prevention, abstraction, or consumption, as the case may be, has been fraudulently, knowingly, and wilfully caused by the consumer using such meter" (clause 38).

Prompt attention to leakage enforced.—In the matter of leakage from mains or services, considerations of self-interest are reinforced by legal obligation in clause 24 of The Gasworks Clauses Act of 1847, which enacts that "Whenever any gas shall escape from any pipe laid down or set up by or belonging to the undertakers, they shall, immediately after receiving notice thereof in writing, prevent such gas from escaping; and in case the undertakers shall not within twenty-four hours next after service of such notice effectually prevent the gas from escaping, and wholly remove the cause of complaint, they shall for every such offence forfeit the sum of five pounds for each day during which the gas shall be suffered to escape after the expiration of twenty-four hours from the service of such notice."

CHAPTER II

PRELIMINARY CONSIDERATIONS

It is not likely that any of those who may read these lines will have to undertake the task of proportioning, arranging, and laying the mains necessary to supply a town of any considerable size for the first time with gas. In this respect we enter into the labours of those who have gone before.

But new districts are continually being opened up on the outskirts of our large towns and cities. These are expanding their borders, until villages, but a few years ago quite outside the area of gas supply, are being rapidly approached and absorbed. In addition to this, the local conditions in some places already supplied are continually undergoing change. That which was but a few years ago a high-class residential district has become the busy centre of factory, warehouse, or city life, whilst, on the other hand, the bustling industrial centres of comparatively recent years have undergone a complete change of character, owing to modern business developments.

These changes and additions render it incumbent upon us to keep the first principles of efficient gas distribution continually before us. These are the same in character, varying only in degree, for the village to be added or the new district to be supplied, as for towns where distribution has to be begun *de novo.* They may be summed up as follows, viz. :—

1. To ensure that the most adequate supply of gas for all requirements shall be available for each consumer.

2. The maintenance of the distributing system in a thoroughly sound condition, and the lowering to a minimum of leakage due to concurrent working.

3. The planning of all new work with a prudent foresight, in view of possible future requirements ; due consideration being given to wise economy in capital expenditure.

It is the object of the writer to show, as far as possible in the space at his disposal, the methods and instruments adopted, and, generally, the manner in which these principles are carried into the realm of actual practice.

We will therefore assume that a new area of supply is to be added to an existing undertaking, and that we have to determine what work will be necessary to carry our first principle into effect. It will also be assumed that the proper parliamentary powers to afford a supply at all have been previously obtained. The first step, then, will be to obtain a correct ground plan, or large scale map, of the whole of the area which is to be supplied. Having possessed ourselves of this, there are several matters upon which we shall need information with respect to the new district before we can proceed to develop our plans.

We must endeavour to form some conception as to the probable future developments of the district, and the direction these developments may take. By means of inquiries, the use of a little imagination, the exercise of judgment based upon knowledge of local conditions and the progress of extensions in neighbouring areas, a very fair estimate should be obtained.

Then the character of the new district must be taken fully into account. It is obvious that measures which would be quite adequate for a residential may be altogether inadequate for an industrial district, where large quantities of gas will probably be required for manufacturing or industrial purposes.

The general position of the district, whether high or low lying in relation to the source of supply, is also a factor which must be considered, along with possible variations of level in the district itself.

The question of the distribution of the demand for gas must also be carefully considered. It will be necessary to ascertain whether this is likely to be spread equally over the district, or unequally, and, if the latter, in which directions the greater quantities of gas will be needed.

It is also most important to take into consideration the relation which the new district bears geographically to the distributory system which is to be its source of supply. Naturally, the mains at points furthest from the gasworks become usually very small, and the question whether the available mains are of sufficient size to pass the additional quantity of gas likely to be required for the adequate supply of the district to be added becomes a very serious one. Should these prove to be inadequate for the purpose, then it will be further necessary to determine which of the three following alternative courses it will be best to adopt to surmount the difficulty, namely—

(*a*) whether to replace the existing mains with larger ones to the extent necessary to furnish the desired supply, or

(*b*) to lay a small high-pressure main for the supply of the new district by means of a local governor, or

(*c*) whether in view of all the local circumstances and conditions, and possibly a very considerable increase in the demand for gas, it would be advisable to build a new sub-station, and erect a gasholder in the district, so that not only should the latter be adequately supplied, but that the surplus gas made during the daytime at the works may be stored there ready for the hours of consumption.

The very great cost involved in the third course, as compared with alternatives (*a*) and (*b*), would, however, rule it out as absolutely unwarranted in other than very exceptional circumstances.

Finally, remembering that the ascensive power of gas is great, it will be well for us to take advantage of the fact in our work, by so arranging our mains that the principal or trunk mains shall run through the lowest part of the district, if possible. Not only is this the best course as far as the distribution of gas is concerned, but it also tends to confine the main syphons to comparatively few points on the largest mains.

Having determined all the above factors in our problem, we shall be in possession of a clear idea, not only of immediate needs, but also of probable requirements during the few following years, and be ready to consider the important question of the size of mains which will be required. This leads us naturally to a consideration of the formulæ dealing with discharges from pipes, by which the question may be answered.

CHAPTER III

DISCHARGES FROM PIPES

THE fourfold factors which determine the rate of discharges from pipes are (1) diameter, (2) friction, (3) pressure, and (4) specific gravity. It may be well to consider each of these in brief detail.

Diameter of pipe.—The influence of the diameter, or the area of cross section, involving as it does the cubical capacity of the pipe and consequently the quantity of gas which may be transmitted at any given velocity, is so obvious as to make comment quite unnecessary. For comparative purposes, however, it may be well to remember, that as the area of any circle is equal to πr^2 (r = radius) the relative area of cross section of circular tubes is proportional to d^2 (d = diameter).

Friction.—This is of two quite dissimilar kinds, namely, (*a*) side or skin friction and (*b*) internal molecular friction or viscosity. Skin friction is caused by the molecules of gas rubbing against the internal surface of the pipe during flow. Unlike that generated by the movement of solid upon solid, this friction is uninfluenced by either pressure or position. It is no greater at a pressure of 5 lbs. per square inch than at a pressure of 5 inches head of water. It is no greater in a horizontal than in a vertical tube. The effect of side friction is to introduce a retarding action along the internal surface of the pipe,

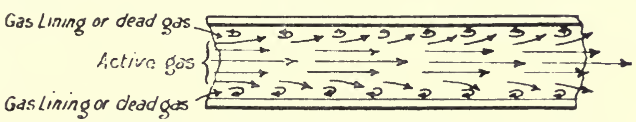


FIG. 1.—Diagram showing retarding Action of Side Friction.

which in the case of pipes of great internal roughness may amount to a practical cessation of movement of the film of gas next to the wall of the pipe. This is brought out very clearly in the diagram, Fig. 1, designed by Mr F. S. Cripps, Assoc.M.Inst.C.E. It is obvious that the effect of side friction is much greater in proportion to delivery in small than in large pipes. Dr Pole laid down the principle that side friction is directly proportionate to the rubbing surface. Double the internal surface of pipe will give double the side friction. The latter also varies with the velocity, but exactly in what proportion has never been determined.

(*b*) Internal molecular friction or viscosity has been defined by Crookes as "the resistance which is offered to the gliding of one portion over another." This is evidently a much more subtle and evasive factor than skin friction. It is quite independent of density. It is greatly affected by the composition and temperature of gases, and also by the quantity of moisture present. It is also increased by a rise of temperature. Molecular friction is also affected by velocity of flow, increasing, indeed, in simple proportion to the velocity. Double the velocity and the molecular friction is also doubled.

The effect, therefore, of internal molecular friction and skin friction combined is to cause a stream of gas to move at a greater velocity at the centre than at the circumference. There is a continual relative displacement of molecules due to viscosity, and this internal work is done, of course, at the expense of velocity.

Pressure or loss of head.—The flow of a fluid through any tube is due to an absence of equilibrium at both ends. When the tension at one end is not balanced by an equal and opposite tension at the other, the contained fluid, seeking to restore an equilibrium, moves toward the point of lowest tension. When speaking of pressures in relation to discharges, it is important to remember that what is meant is loss of head. It is not either inlet pressure or outlet pressure, but the difference between the two ($P_1 - P_2$). The discharge from any pipe varies as the square root of the difference between the squares of the inlet and outlet pressures ($\sqrt{(P_1^2 - P_2^2)}$). When, therefore, the initial pressure (P_1) becomes very great in comparison with the final pressure (P_2) the latter becomes more and more negligible. So that as the difference increases the quantity discharged becomes more and more proportional to the square root of the initial pressure squared ($\sqrt{P_1^2}$). In other words, in such cases there is a growing approximation of the discharge to one of simple proportion to the initial pressure. The practical experiments of Mr D. Chandler, published in 1910, fully confirms this theoretical reasoning in connection with the small losses of head in transmission, usual in low pressure distribution.[1]

Velocity.—The question of velocity is intimately bound up with that of pressure. It has already been shown that the velocity of a moving fluid is not uniform throughout the area of a pipe. When speaking of velocity, therefore, the mean velocity is always meant, except where otherwise stated. The filament of mean velocity is found at 0.707*r*, where *r* is the internal radius of the tube. The mean velocity of transmission multiplied into the area of the pipe gives the discharge ($AV = D$).

By increasing the velocity of transmission we may arrive at a point, varying according to the diameter of the pipe, where the flow changes from the linear to the turbulent form. The point at which this takes place is called the critical velocity. According to Prof. Reynolds, " there is a definite relation between velocity and diameter for any given fluid, which causes a definite velocity to be critical.

[1] *The Gas World* 5th February 1910, p. 153; 26th February 1910, p. 250.

Up to that point the flow is in straight lines—above it the straight flow turns to eddying." There may be more than one critical velocity with a given pipe over a considerable range of pressures. With very low pressures the friction is probably simply proportional to velocity. At greater speed the friction may become proportional to the square of the velocity (V^2). Unfortunately, as far as the author is aware, the exact relation of friction to varying velocities has never been precisely determined. Bending or distortion of cross section of the pipe increases friction, and therefore affects the critical velocity point. There is, however, no very sharply defined point at which the linear becomes transformed into the turbulent flow. Rather the two merge into each other.

Specific gravity.—In the early part of last century Faraday demonstrated that diffusion of gases through orifices and tubes varies inversely as the square root of the density. This was later confirmed by Graham, who proved that the velocity of flow of gases through orifices was inversely proportional to the square root of the density. This has again been proved in later years by Knudsden, of Copenhagen.

It is, therefore, seen that the various factors which must be taken into account in any formula for calculating discharges from pipes are extremely complex and variable. It would almost appear that if extreme accuracy were required, a different formula would be necessary for each set of circumstances. Fortunately, strict mathematical accuracy is unnecessary. Conditions of supply ; the degree of roughness of the interior surface of the pipe ; and of the deviation from straight lines, among other things, make it imperative that a fairly wide margin must be provided in actual practice to cover all these contingencies.

Pole's formula.—Grouping all these factors together in algebraical form, Dr Pole about the middle of last century published the famous formula which has since been associated with his name, which is as follows :—

$$V = 1350 d^2 \sqrt{\frac{p\,d}{s\,l}}$$

where V = volume of gas discharged in cubic feet per hour

d = diameter of pipe in inches.
p = pressure in inches of water.
s = specific gravity of gas (air = 1).
l = length of main in yards.

and 1,350 is a constant deduced from practical experiment.

It is interesting to note in passing that subsequent experiments showed this figure to be about 15 per cent. too high. It should, therefore, be reduced to 1,148.

The formula is vitiated to a slight extent by the fact that Dr Pole assumed the co-efficient of friction to be as great in the case of large as in that of small mains, and made no allowance whatever for the variations due to degrees of roughness of the internal surface of the pipe.

Coefficient of friction.—Professor Unwin gives the following table of the coefficient of friction for various sized mains, from which it will be seen that very considerable variation occurs in its value with pipes of different diameters :—

Size of main.	Value of coefficient of friction.
2 inch	0.0082
4 ,,	0.0063
6 ,,	0.0057
8 ,,	0.0053
12 ,,	0.0050
16 ,,	0.0049
18 ,,	0.0048
24 ,,	0.0047

It will be noticed, therefore, that the coefficient of friction in a 2-inch, as compared with a 24-inch main, is nearly as two to one. The uniform value assumed by Dr Pole was 0.006. The constant employed by him is therefore too high for small mains and services. Although professedly only approximately true, the formula has proved sufficiently so for all practical purposes with the comparatively small differences between initial and final pressures obtaining under the usual conditions of gas supply in this country. For calculating discharges at high pressures, the formula needs considerable modification.

Inversion of Pole's formula.—It is obvious that under Dr Pole's formula, if we know any four of the factors, the fifth may be readily ascertained. In the place of having to determine the quantity of gas which will be discharged under certain conditions, it more frequently happens, in practice, that we require to ascertain the size of main necessary to deliver a certain quantity of gas, at a given point, under a given pressure. Proceeding, therefore, to transpose the formula we obtain :—

$$V = 1350d^2\sqrt{\frac{pd}{sl}}.$$

Square both sides

$$V^2 = (1350)^2 d^4 \frac{pd}{sl}.$$

By multiplication

$$V^2 sl = (1350)^2 d^5 p.$$

By transposition

$$d^5 = \frac{V^2 sl}{(1350)^2 p}.$$

$$\text{or } d = \sqrt[5]{\frac{V^2 sl}{(1350)^2 p}}.$$

Similarly, we find that the other values taken in succession, are as follows, viz. :—

$$l = \frac{(1350)^2 d^5 p}{V^2 s};$$

$$p = \frac{V^2 s l}{(1350)^2 d^5};$$

$$s = \frac{1350 d^5 p}{V^2 l}.$$

It will be seen, therefore, that the following proportions hold as regards the discharges, viz. :—

V varies directly as $\sqrt{p}$;
V ,, ,, ,, $\sqrt{d^5}$;
V ,, inversely ,, $\sqrt{l}$;
V ,, ,, ,, $\sqrt{s}$.

Simple rules.—By reducing the preceding equations into elementary terms we are able to formulate a series of simple rules, easily remembered, which will assist us materially in this branch of our subject. They have been variously stated by Newbigging, Cripps, and others, somewhat as follows :—

(1) By increasing the pressure fourfold the discharge is doubled.
(2) By increasing the length fourfold the discharge is halved.
(3) By increasing the length fourfold, four times the pressure will be necessary if the discharge is to remain the same. And as a further deduction from this,
(4) The pressure necessary to the discharge of a stated quantity of gas through a pipe of given diameter varies directly as the length of the pipe.
(5) By decreasing the length to one-fourth the discharge is doubled.
(6) By increasing the diameter four times the discharge is increased thirty-two times.

Based upon the above formula a series of tables, showing the discharges by pipes of different diameters with varying falls of pressure, was compiled and published by Mr T. G. Barlow. These have since been greatly amplified by Mr Newbigging, and will be found in Appendix I.

Pocket-book chart.—In connection with these several formulæ and rules, it is frequently found convenient, by those with whom such questions are continually arising, to carry in handy form a basis for making rough and ready calculations at a moment's notice. It is impossible to always carry a set of Barlow's tables with one, but a simple chart, which may be easily constructed by anyone to suit his own requirements, may be made sufficiently correct to serve most ordinary purposes. This is done by plotting in diagrammatic form, using discharges as ordinates and lengths as abscissæ, the delivery of gas from the commoner sizes of pipes at a drop of pressure equal to 0.1 inch head of water.

Such a chart is shown in Fig. 2, which reveals at a glance the discharge from 3-inch, 4-inch, 6-inch, and 8-inch mains at any length up to 1,000 yards with a loss of pressure of 0.1 inch. If, then, the rules

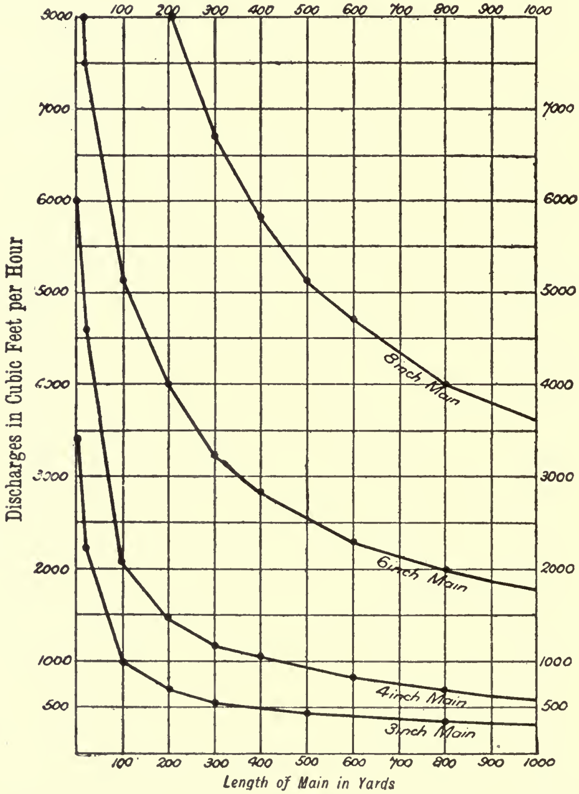


FIG. 2—Chart showing discharges with loss of head of 0.1 inches; sp. gr. of gas = 0.45.

be written out upon the back of the chart, it is obvious that, putting the two together, we have such a basis for calculation as will enable us to arrive at approximately correct conclusions.

Cripps' charts.—An elaborate series of charts or diagrams were published some years ago by Mr F. S. Cripps, Assoc.M.Inst.C.E., in connection with his book on "The Flow of Gases and the Proportioning of Gas Mains," covering a range of ¼ inch up to 60 inches in diameter; from 10 yards to 20 miles in length; from 1-tenth to 100-tenths pressure; from 0.4 to 0.7 specific gravity; from 5 cubic feet to 1,000,000 cubic feet discharge per hour.

Loss of head.—In the equations given the pressure is understood to be that necessary to force the given quantity of gas through the pipe. The latter is assumed to discharge into the air at atmospheric pressure, the outlet pressure equalling 0. If the discharge is to take place at a given pressure, then that pressure must be added to the pressure necessary to the discharge and applied at the inlet end of the pipe. For instance, if it requires a pressure of 0.3 inch to discharge a given quantity of gas from a main of given length and size, and it is required that the pressure at the outlet be 2 inches, then an initial pressure of 2.3 inches will be necessary to obtain the desired result.

Sloping mains.—For the purpose of the calculation it is further assumed in Dr Pole's formula that the pipe line is perfectly straight and level. As, however, these conditions do not exist in actual practice, it becomes necessary to inquire what modifications will be needed in order to meet the requirements of any particular case.

In the case of deviation from the true horizontal line, it is usually assumed that the pressure is augmented by an amount equal to a column of water 1 inch in height for each rise of 100 feet, and is decreased by the same amount for each fall of 100 feet. It is obvious, however, that this will vary according to the specific gravity of the gas. Mr Hewitt has found that with Birmingham gas, the average variation is one-tenth of an inch for each 12 feet 6 inches of rise or fall. If, therefore, a given length of main, laid in a horizontal plane, will discharge a certain quantity of gas, with a given difference as between the initial and outlet pressures, that difference will be lessened with the net rise of the main and augmented with the net fall, and the diminution or augmentation will be approximately in the proportion stated. Consequently, a lower initial pressure will be necessary to deliver an equal quantity of gas through a rising as compared with a level main, the decrease being about equal to 0.1 inch for each rise of 10 feet; and, conversely, the initial pressure must be increased by 0.1 inch for each 10 feet of fall, if the same discharge is to be maintained.

If the pressures at both ends of a given main are known, and it is required to determine the force or pressure necessary to maintain a given discharge, the following rule is given by Dr Pole, in his work, for a sloping main :—" From the pressure at the supply end of the pipe deduct the pressure at the discharging end; then add or subtract, as the case may require, the gravitating influence of a column of the fluid equal in height to the difference in level, if any, of the two ends of the pipe; the result will be the true motive pressure or head, and may be used as such in the rules." Prof. Unwin, however, suggests an exact formula covering such cases, to which reference will be made in a subsequent example dealing with the case of sloping mains.

Bends.—The disturbing influence of bends upon the discharge from pipes is most important. There is, first of all, the absorption and partial destruction of the kinetic energy of the gas. "Every particle of matter once set in motion tends to continue moving on in a straight line, and it carries with it a certain amount of momentum, or *vis viva*, which it received at first starting. If this is absorbed or destroyed it cannot be regained, except by a fresh expenditure of power." The first effect of a bend or series of bends is undoubtedly to reduce the kinetic energy of the gas. And, secondly, the increased friction due to bends not only retards the velocity of the gas, but also, by setting up a process of eddying in the current, diminishes the discharge very considerably. As might have been expected, it is found that these disturbing influences vary greatly with the character of the bend. The interesting series of experiments and investigations carried out by Mr C. W. L. Alexander at Birmingham into this branch of the subject will be referred to when considering formulæ and discharges under high-pressure distribution.

Cripps' formula for determining back pressure thrown by bends.—In his book on "The Flow of Gases and the Proportioning of Gas Mains," Mr F. S. Cripps, whose work in this matter the present writer desires to acknowledge, gives the following rules for determining the resistance offered, and, consequently, the back pressure caused by a bend of radius equal to $2\frac{1}{2}$ times the diameter :—

"(*a*) Determine the velocity in feet per second by dividing the quantity (Q) of gas discharged from a straight pipe by twenty times the diameter of the pipe (in inches) squared.

$$\frac{Q}{20d^2} = \text{velocity.}$$

"(*b*) Square the velocity of the gas in feet per second and divide by the constant 10,700. The quotient will be the back pressure (p) caused by the bend.

$$\frac{V^2}{10{,}700} = p.$$

"Then p is the pressure to be added to the original initial pressure of gas [for each bend of that radius] if the quantity of gas passing is not to be reduced."

With regard to shorter bends, as a rough approximation the relative resistances offered by bends of different proportions is stated by Mr Cripps as follows :—

(1) "Where the radius of a quarter bend equals the diameter of the pipe, the resistance is double of that determined by the foregoing rules.

(2) "For a radius three-quarters of the diameter, the resistance is four times ; for a sharp corner (*i.e.* radius of bend = half the diameter)

it is fourteen times ; and for the right angle branch of a tee pipe drawing from a trunk main, twenty times."

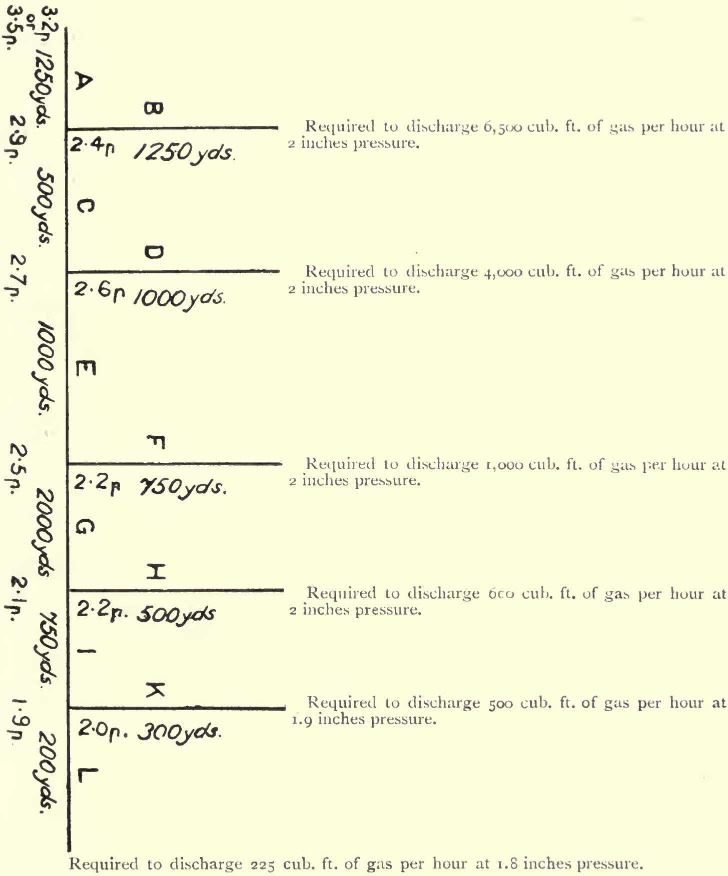


FIG. 3.—Diagram of supposed system of Mains.

Practical example : I.—It may be well for us here to take a couple of concrete examples and show how the above formulæ are applied in actual practice. In the first place, we will assume that the series of mains shown in diagrammatic form in Fig. 3 are to be part of the distributory system of some new district, the section A L of which supplies at various points the mains B, D, F, H, and K. The requirements to be met are as follows :—

Section.	Length in Yards.	Discharge in Cubic Feet per Hour.	Final Pressure in Inches of Water.	Specific Gravity of Gas.
A . . .	1,250			0.45
B . . .	1,250	6,500	2.0	0.45
C . . .	500			
D . . .	1,000	4,000	2.0	0.45
E . . .	1,000			
F . . .	750	1,000	2.0	0.45
G . . .	2,000			
H . . .	500	600	2.0	0.45
I . . .	750			
K . . .	300	500	1.9	0.45
L . . .	200	255	1.8	0.45

To simplify the calculation it is assumed that mains A, C, E, G, and I are not tapped for any local supply, a condition hardly likely to arise in practice, but which may easily be allowed for by adding the expected local demand to the quantity passing through the section affected.

It is also assumed to be a condition that the pipes throughout are laid perfectly straight and level; that the drop of pressure on any one section must not exceed 0.6 inch head of water; that an initial pressure of 3.5 inches head of water shall not be exceeded; and that the only supply to the group of mains is through pipe A.

We shall solve our problem in the easiest and most convenient manner by commencing with section L and working backwards towards A.

The pipe L is 200 yards long, and must discharge 255 cubic feet of gas per hour, of 0.45 specific gravity, and at a final pressure of 1.8 inches. We have here only three factors out of the five of our formula, namely, length, discharge, and specific gravity. We must, therefore, assume a fourth to obtain the remaining one. As this particular main is a short one of only 200 yards in length, we will assume that the drop of pressure (h) shall be equal to 0.1 inch head of water. Applying the inversion of Dr Pole's formula

$$d = \sqrt[5]{\frac{V^2 s l}{(1350)^2 p}};$$

we obtain

$$d = \sqrt[5]{\frac{(255)^2 \times 0.45 \times 200}{(1350)^2 \times 0.1}}$$

$$= \sqrt[5]{\frac{65{,}025 \times 0.45 \times 200}{1{,}822{,}500 \times 0.1}}$$

$$= \frac{22}{11} \text{ approximately}$$

$$= 2.$$

Therefore a 2-inch main of 200 yards in length would discharge 255 cubic feet of gas, of 0.45 specific gravity, per hour, with a drop of pressure equal to 0.1 inch head of water. Adding this drop of pressure to the final discharge pressure, ex hypothesis, 1.8 + 0.1 brings the pressure required at the junction of I L to 1.9 inches on account of L.

K is 300 yards long and must discharge 500 cubic feet of gas per hour at an ultimate pressure of 1.9 inches. Assuming in this case again a drop of pressure in the length of main equal to 0.1 inch head of water, and stating in terms of our formula as above, we obtain

$$d = \sqrt[5]{\frac{(500)^2 \times 0.45 \times 300}{(1350)^2 \times 0.1}}$$

$$= \frac{32}{11} \text{ approximately;}$$

$$= 3 \text{ approximately.}$$

So that a main slightly less than 3 inches in diameter would give the discharge required with a loss of pressure of 0.1 inch head of water. Again, adding this loss to the final pressure as stated in the problem, we obtain 2 inches as the pressure at which the gas must start on its travel through K.

The main I must therefore discharge 755 cubic feet of gas (255 + 500) at a pressure equal to 2 inches head of water.

We have, however, the sharp corner at I K to take into consideration. To determine the back pressure caused here we work from Cripps' formula.

$$\frac{Q}{20d^2} = V \text{ and } \frac{V^2}{10,700} = p;$$

$$\text{we find } \frac{500}{20 \times 3^2}$$

$$= \frac{500}{180}$$

$$= 2.7 = \text{velocity;}$$

$$\text{and } \frac{(2.7)^2 \times 20}{10,700}$$

$$= 0.01 = p.$$

The back pressure thrown by the sharp turn of the outlet of the tee is therefore equal to 0.01 inch of water. This is so small, owing to the low velocity, that as our main is slightly larger than the actual requirement we may safely leave the one to balance the other.

We have therefore to provide a main for section I of such diameter that it will discharge the 755 cubic feet required at a final pressure of 2 inches. We will again assume a drop of pressure through the section equal to 0.1 inch. Stating the problem in terms of the formula, we have

$$d = \sqrt[5]{\frac{(755)^2 \times 0.45 \times 750}{(1350)^2 \times 0.1}}$$

$$= \frac{45}{11} \text{ approximately}$$

$$= 4 \text{ approximately.}$$

We find, therefore, that a main of 4 inches in diameter will pass the quantity of gas required with a drop of pressure equal to 0.1 inch head of water. Adding this to the final pressure necessary to supply K and L, as shown, we obtain 2.1 inches $(2 + 0.1)$ as the initial pressure necessary at junction of H I.

H is 500 yards long and is to pass 600 cubic feet of gas per hour at a final pressure of 2 inches. By the formula

$$d = \sqrt[5]{\frac{(600)^2 \times 0.45 \times 500}{(1350)^2 \times 0.2}}$$

$$= \frac{38}{13} \text{ approximately}$$

$$= 3 \text{ approximately.}$$

A 3-inch main will therefore be sufficiently large to discharge the required quantity of gas. Adding the loss of pressure to the final pressure $(2 + 0.2)$ makes 2.2 inches as the initial pressure required on section H.

To find the back pressure thrown by the sharp angle at junction of H with G, working from the formula as before, we obtain

$$V = \frac{600}{20 \times 9} = 3.3$$

$$\text{and } p = \frac{(3.3)^2 \times 20}{10{,}700} = 0.02\,;$$

a quantity which may again be considered negligible.

The main G, 2,000 yards in length, must therefore be capable of discharging 1,355 cubic feet of gas at an ultimate pressure of 2.2 inches.

Applying our formula again, we obtain

$$d = \sqrt[5]{\frac{(1355)^2 \times 0.45 \times 2000}{(1350)^2 \times 0.3}}$$

$$= \frac{70}{14}$$

$$= 5.$$

A 5-inch main, therefore, will meet the requirements of this section, and as the pressure lost is 0.3 inch, this quantity, added to the 2.2 required for section H, gives an initial pressure necessary for G equal to 2.5 inches head of water.

Section F is, by hypothesis, 750 yards long and must discharge 1,000 cubic feet per hour, with an ultimate pressure of 2 inches. In the same way as before, we find that

$$d = \sqrt[5]{\frac{(1000)^2 \times 0.45 \times 750}{(1350)^2 \times 0.2}}$$
$$= \frac{51}{13} \text{ approximately}$$
$$= 4 \text{ approximately.}$$

A 4-inch main, therefore, with loss of pressure of 0.2 inch head of water, will give sufficient supply for the needs of this section. Adding pressure lost to final pressure gives a total of 2.2 inches as the pressure necessary at junction of F with E.

The back pressure thrown by outlet F is

$$V = \frac{1000}{20 \times 16} = 3.1\ ;$$

$$\text{and } p = \frac{(3.1)^2 \times 20}{10,700} = 0.01\ ;$$

which may be treated as a negligible quantity.

The main E, it will be seen, is required to discharge 2,355 cubic feet of gas, and it must be at a final pressure of 2.5 inches to meet the requirements of section G. Applying the formula, we obtain

$$d = \sqrt[5]{\frac{(2355)^2 \times 0.45 \times 1000}{(1350)^2 \times 0.2}}$$
$$= \frac{76}{13} \text{ approximately}$$
$$= 6 \text{ approximately.}$$

A 6-inch main will, therefore, give us the carrying capacity necessary with a loss of pressure of 0.2 inch. The latter added to the final pressure on this section, as above, gives an initial pressure for this main of 2.7 inches.

Coming now to section D, this main, by the hypothesis, is to be 1,000 yards long, and of capacity sufficient to discharge 4,000 cubic feet of gas at a final pressure of 2 inches. Setting out in terms of the formula, and assuming a drop of 0.6 inch pressure we have

$$d = \sqrt[5]{\frac{(4000)^2 \times 0.45 \times 1000}{(1350)^2 \times 0.6}}$$
$$= \frac{94}{16} \text{ approximately}$$
$$= 6 \text{ approximately.}$$

So that a 6-inch main of this length would give the required quantity with a drop of pressure equal to 0.6 inch head of water. This is a greater loss than in any previous case ; but as the initial pressure on main E has to be 2.7 to meet previous requirements, and as the 0.6 inch added to the final pressure on section D (0.6 + 2) equals 2.6 inches—0.1 inch less than must be obtained at that point on account of E—we are perfectly safe in facing it.

The back pressure thrown by the sharp angle at junction of C and D is

$$V = \frac{4000}{20 \times 36} = 5.55\,;$$

$$\text{and } p = \frac{(5.55)^2 \times 20}{10{,}700} = 0.05\,;$$

so that the 0.1 inch of pressure at junction of C D over that necessary to meet the requirements of main D well covers the loss due to this cause.

The main C, of 500 yards in length, must be capable of discharging 6,355 cubic feet at an ultimate pressure of 2.7 inches. Stating this again in terms of the familiar formula, and in this case assuming a drop of 0.2 inch, we have

$$d = \sqrt[5]{\frac{(6355)^2 \times 0.45 \times 500}{(1350)^2 \times 0.2}}$$

$$= \frac{98}{13} \text{ approximately}$$

$$= 8 \text{ approximately.}$$

Therefore the main C must be of 8 inches in diameter, and, owing to the loss of 0.2 inch, the initial pressure on this section must not be less than 2.9 inches.

We now come to main B, which is 1,250 yards in length and must discharge 6,500 cubic feet of gas at a final pressure of 2 inches head of water. Applying the formula and assuming a loss of 0.4 inch, we find

$$d = \sqrt[5]{\frac{(6500)^2 \times 0.45 \times 1250}{(1350)^2 \times 0.4}}$$

$$= \frac{119}{15} \text{ approximately}$$

$$= 8 \text{ approximately.}$$

The main through this section may be of 8 inches diameter, and as the final pressure is to be 2 inches, and there is a fall of 0.4 inch through the length of main, the initial pressure must be in that case equal to 2.4 inches. But we must have a pressure of 2.9 inches at the junction of A and C to meet the requirements of the latter—a difference of 0.5 inch. We may therefore adopt the alternative of substituting a 7-inch main for the 8-inch suggested, which would be capable of discharging the same quantity of gas with a drop of pressure equal to 0.8 inch, and thus bring up the initial pressure needed to 2.8 inches. Perfect symmetry would seem to demand that this should be done. But, in the first place, it is hardly advisable to plan for so great a drop of pressure in the length if it can be avoided; and, secondly, a 7-inch main is a very odd size, and it is found in practice to be much more convenient to take 8-inch as the next size of main to 6-inch, in order to reduce stocks of irregulars as much as possible. We will therefore adopt the 8-inch main as first suggested.

It will also be found that the back pressure thrown by the tee piece A B C is much more than covered by the difference in the initial pressures of B and C.

The main A, 1,250 yards in length, must be capable of discharging 12,855 cubic feet of gas at a final pressure of 2.9 inches. Applying the formula again, we find

$$d = \sqrt[5]{\frac{(12,855)^2 \times 0.45 \times 1250}{(1350)^2 \times 0.3}}$$

$$= \frac{156}{14} \text{ approximately}$$

$$= 12 \text{ approximately.}$$

$$\text{or } d = \sqrt[5]{\frac{(12,855)^2 \times 0.45 \times 1250}{(1350)^2 \times 0.6}}$$

$$= \frac{156}{16} \text{ approximately}$$

$$= 10 \text{ approximately.}$$

So that we may take one of two alternatives in section A. Either we may lay down a 12-inch main, which will pass the quantity of gas required with a fall of 0.3 inch of pressure, or we may put down a 10-inch main, which will equally discharge up to the requirements of the case, but with a drop of pressure twice as great, namely, 0.6 inch. The latter would, of course, be much the cheaper main to lay. Should this course be adopted, the initial pressure on A must be 3.5 (2.9 + 0.6) inches head of water, while if a 12-inch main were laid, the initial pressure would be 3.2 inches (2.9 + 0.3) head of water.

Results obtained tabulated.—Summing up the results obtained in tabular form, we get the following :—

Main.	Length.	Size.	Initial Pressure.	Final Pressure.	Discharge in Cubic Feet.
A	1,250	12 / 10	3.2 / 3.5	2.9	12,855
B	1,250	8 / 7	2.4 / 2.8	2.0	6,500
C	500	8	2.9	2.7	6,355
D	1,000	6	2.6	2.0	4,000
E	1,000	6	2.7	2.5	2,355
F	750	4	2.2	2.0	1,000
G	2,000	5	2.5	2.2	1,355
H	500	3	2.2	2.0	600
I	750	4	2.1	2.0	755
K	300	3	2.0	1.9	500
L	200	2	1.9	1.8	255

We have, therefore, solved the problem, which was to so arrange the proportions of the various mains, and the pressures necessary under the given conditions, as to afford the supply specified.

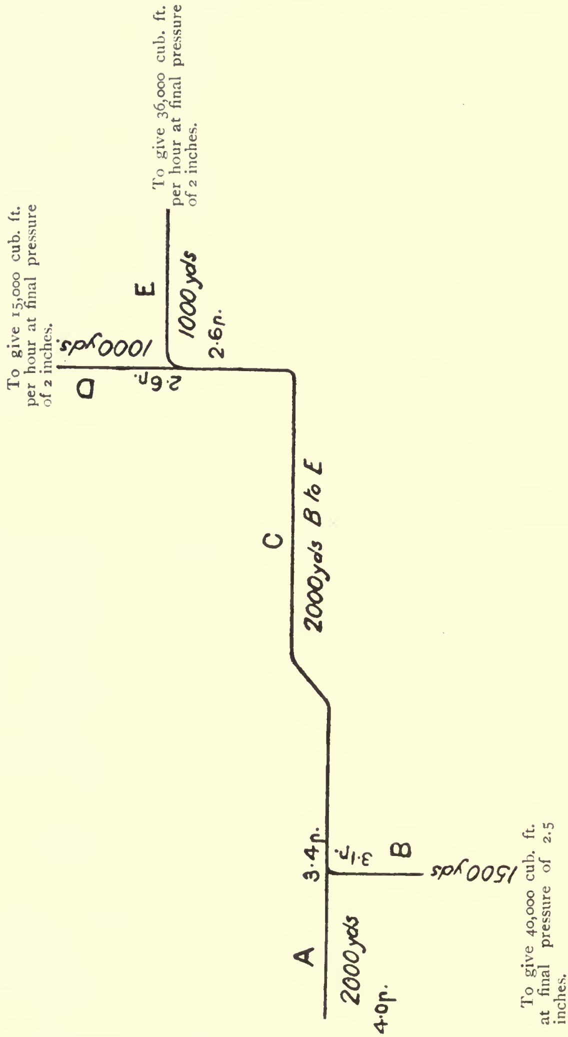


Fig. 4.—Diagram of supposed system of Trunk Mains.

Practical example : II.—We may now turn to another case, shown in diagrammatic form in Fig. 4. Although dealing with much larger quantities of gas, the same general principles and the same formula must be applied. Suppose A, B, C, D, and E are parts of a suggested trunk main line system. It is required to find the size of pipes and initial pressures necessary to fulfil the following conditions :—

A is 2,000 yards long, and is the sole supply for B, C, D, and E.

B is 1,500 yards long, and is required to discharge 40,000 cubic feet of gas per hour at a final pressure of 2.5 inches.

C is a continuation of A, is 2,000 yards long, is the sole supply for D and E, and into the length of this it has been necessary to introduce two $\frac{1}{8}$ bends and one short $\frac{1}{4}$ bend of radius equal to half the diameter. As far as distributing mains are concerned, this is a bend of most unusual character, and is introduced here merely for the sake of example.

E is a branch main 1,000 yards long, supplied from C by means of a bend tee, the radius of outlet of which is $2\frac{1}{2}$ times the diameter of the pipe, and it is required to deliver 36,000 cubic feet of gas at a final pressure equal to 2 inches head of water.

D is a continuation of C for a further 1,000 yards beyond the junction of E, and is required to deliver 15,000 cubic feet of gas per hour at a final pressure of 2 inches head of water.

It is assumed that the specific gravity of the gas is 0.45, as before, and that the initial pressure at A is not to exceed 4 inches.

As in the previous example, we shall find it most convenient to commence with section E and work back towards section A.

Applying the formula as before, and assuming a fall of pressure through the section equal to 0.6 inch head of water, we get

$$= \sqrt[5]{\frac{(36,000)^2 \times 0.45 \times 1000}{(1350)^2 \times 0.6}}$$

$$= \frac{226}{16} \text{ approximately}$$

$$= 14 \text{ approximately.}$$

Consequently, a 14-inch main will give the required quantity of gas with a fall of pressure of 0.6 inch in the section. This fall, added to the final pressure of 2 inches $(2+0.6)$ brings the necessary initial pressure for E up to 2.6 inches head of water.

Section D is specified as being 1,000 yards in length and must be capable of discharging 15,000 cubic feet of gas per hour at a final pressure equal to 2 inches head of water. Worked out by the formula, and assuming a drop of pressure equal to 0.6 inch, we obtain

$$d = \sqrt[5]{\frac{(15,000)^2 \times 0.45 \times 1000}{(1350)^2 \times 0.6}}$$

$$= \frac{159}{16} \text{ approximately}$$

$$= 10 \text{ approximately.}$$

It will therefore be necessary to adopt a 10-inch main through section D. Adding the fall of pressure to the outlet pressure we get 2.6 inches (2 + 0.6) as the initial pressure which must be applied on this section to obtain the desired result.

It now becomes necessary to ascertain the back pressure thrown by the bend tee to outlet E, that we may know the final pressure to provide for on section C.

$$\text{Velocity} = \frac{36,000}{20 \times 196} = 9.18\,;$$

$$\text{and } p = \frac{9.18^2}{10,700}$$

$$= \frac{84.2724}{10.700}$$

$$= 0.007,$$

a quantity which may be treated as negligible. The final pressure necessary on main C must, therefore, be equal to 2.6 inches head of water.

As section C is of considerable length, one may assume a rather larger fall of pressure than in previous cases, putting it in this case as high as 0.7 inch ; and as this is the main supplying both D and E it must be capable of discharging at least 51,000 cubic feet of gas per hour, and, as has been seen, at a pressure of 2.6 inches.

$$\text{Therefore } d = \sqrt[5]{\frac{(51,000)^2 \times 0.45 \times 2000}{(1350)^2 \times 0.7}}$$

$$= \frac{298}{17} \text{ approximately}$$

$$= 18 \text{ approximately.}$$

It will be necessary, therefore, to adopt a main of 18 inches diameter through this section. Before, however, fixing our initial pressure we must find the amount of back pressure thrown by the three bends which have been introduced. Proceeding as before, we obtain the velocity as follows :—

$$\text{Velocity} = \frac{51,000}{20 \times 18^2}$$

$$= \frac{51,000}{6480}$$

$$= 7.87\,;$$

$$\text{and } p = \frac{(7.87)^2}{10,700}$$

$$= 0.005\,;$$

which is the back pressure thrown by one bend of radius equal to $2\frac{1}{2}$ times the diameter. If we assume that our two $\frac{1}{8}$ bends are together equal to three such bends we shall be well on the right side. But the $\frac{1}{4}$ bend introduced is of radius of only one-half the diameter, and the back pressure thrown by it will be about fourteen times that of a bend of $2\frac{1}{2}$ diameter radius. Putting these together we obtain

$$\begin{aligned}(3 \times 0.005) + (14 \times 0.005) \\ = 0.015 + 0.070 \\ = 0.085.\end{aligned}$$

If, therefore, we allow 0.1 on account of the bends, in addition to the 0.7 inch drop of pressure on this section, we obtain 3.4 inches head of water as the initial pressure for main C.

The main for section B is 1,500 yards long and must discharge 40,000 cubic feet per hour at a final pressure of 2.5 inches head of water. Assuming in this case a drop of pressure of 0.6 inch, and inserting this value in the formula, we find

$$\begin{aligned}d &= \sqrt[5]{\frac{(40,000)^2 \times 0.45 \times 1500}{(1350)^2 \times 0.6}} \\ &= \frac{255}{16} \text{ approximately} \\ &= 16 \text{ approximately.}\end{aligned}$$

A 16-inch main, therefore, will meet the requirements of section B, with a drop of pressure equal to 0.6 inch head of water. Adding this to the 2.5 inches of final pressure, we obtain 3.1 (2.5×0.6) inches as the initial pressure necessary for this main.

The back pressure thrown by the tee piece at junction of B with A is as follows :—

$$\begin{aligned}\text{Velocity} &= \frac{40,000}{20 \times (16)^2} \\ &= \frac{40,000}{5120} \\ &= 7.81 ; \\ \text{and pressure} &= \frac{(7.81)^2 \times 20}{10,700} \\ &= 0.114 ;\end{aligned}$$

against which we have 0.3 inch of pressure difference in the initial pressures of mains C and B in favour of the latter, so that the back pressure is met many times over by the provision necessary for main C. We may, therefore, proceed to consider the problem of the last section, A.

The main through section A is 2,000 yards in length and must be sufficiently large to pass 91,000 cubic feet of gas per hour at an outlet pressure of 3.4 inches head of water. Assuming a fall of pressure through the section of 0.6 inch, we obtain

$$d = \sqrt[5]{\frac{(91,000)^2 \times 0.45 \times 2000}{(1350)^2 \times 0.6}}$$
$$= \frac{375}{16} \text{ approximately}$$
$$= 24 \text{ approximately.}$$

It will be necessary, therefore, to adopt a 24-inch main for this section, which will discharge the 91,000 cubic feet per hour required with a fall of pressure equal to 0.6-inch head of water. Adding the latter to the outlet pressure previously ascertained, we arrive at 4 inches (3.4 + 0.6) as the initial pressure necessary at inlet of A to force the required quantity of gas through the branches B, D, and E under the conditions specified.

As has already been stated, the equations of Dr Pole, from which the foregoing examples have been worked, all assume that the pipes are laid in a horizontal line. We have now to consider the case of a sloping main.

Professor Unwin's formula.—We may work such an example from Dr Pole's formula, making corrections for variations of level on the basis of increase of pressure equal to 1 inch head of water for each 100 feet rise of main, or in a much better way by using the formulæ suggested by Professor Unwin. These are as follows :—

(1) $Q = \frac{\pi}{4} d^2 v$;

(2) $v = 4.012 \sqrt{\frac{d h}{\zeta l}}$;

and (3) $h = 780 \frac{y_1 - y_2}{s} + (z_1 - z_2)\left(1 - \frac{1}{s}\right)$;

where Q = the discharge in cubic feet per second.
d = diameter of pipe in feet.
v = velocity in feet per second.
h = head in feet of gas.
y_1 = initial pressure in feet of water.
y_2 = outlet " " "
z_1 = initial position with respect to horizontal datum line.
z_2 = final " " "
ζ = coefficient of friction.
s = specific gravity of gas.
l = length of pipe in feet.

Concrete example : a falling main.—Assume, as a concrete case, that it is required to determine the discharge per hour from a 9-inch main, 1,000 yards long, which falls 100 feet in its length, as shown in Fig. 5 (p. 31). The initial pressure is equal to 4 inches head of water, and the final pressure is equal to 2 inches head of water. The fall of pressure in actual practice would not, of course, be so great as

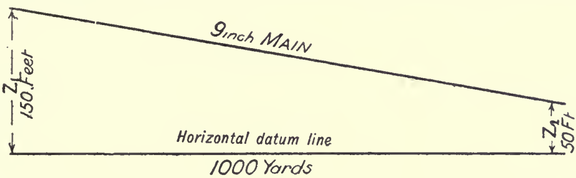


FIG. 5.—Diagram showing falling main in relation to datum line.

this under the conditions stated, unless the mains were either very rough or badly corroded. The specific gravity of the gas is 0.45, and the coefficient of friction is assumed to be 0.0053.

Thus, first of all working out the value of h, we find

$$h = 780\frac{y_1 - y_2}{s} + (z_1 - z_2)\left(1 - \frac{1}{s}\right)$$

$$= 780\frac{1}{6 \times 0.45} - 122$$

$$= 288 - 122$$

$$= 166 = \text{head in feet of gas.}$$

Inserting this value of h in formula (2) we obtain

$$v = 4.012\sqrt{\frac{d\,h}{\zeta\,l}}$$

$$= 4.012\sqrt{\frac{0.75 \times 166}{0.0053 \times 3000}}$$

$$= \frac{4.012 \times 11.1}{4}$$

$$= 11.13 = \text{velocity, in feet per second.}$$

Then (1)

$$Q = \frac{\pi}{4}d^2v$$

$$= \frac{3.1416 \times (0.75)^2 \times 11.13}{4}$$

$$= 4.9169 \text{ cubic feet per second.}$$

$$= 17{,}700 \quad ,, \quad ,, \quad \text{hour.}$$

The required discharge is therefore found to be 17,700 cubic feet per hour.

Case of a rising main.—The preceding example assumed a fall in the main, in relation to the horizontal, of 100 feet. In a case the reverse of this, where the main rises, the correction in the equation for slope of main will be a minus quantity. Suppose in the example just given the mains had risen 100 feet, the equation determining the value of h would be

$$h = 780 \frac{1}{6 \times 0.45} + (-100)(-1.22).$$

Molesworth's & Spon's formulæ.—Many other formulæ have been suggested from time to time for calculating the discharges of gas from pipes. Among these probably the most commonly known are the following from Molesworth's and Spon's Engineers' Pocket Books respectively :—

$$(1)\ Q = 1000\sqrt{\frac{d^5 h}{\frac{1}{2} l}}\ \text{(Spon)};$$

$$\text{and } Q = 1000\sqrt{\frac{d^5 h}{s\,l}}\ \text{(Molesworth)};$$

where Q = Quantity of gas discharged.
d = diameter of pipe in inches.
h = pressure in inches head of water.
s = specific gravity of gas.
l = length of main in yards.

It may be interesting to compare the results obtained by each of these formulæ. Taking 1,000 yards of 6-inch main with gas of 0.45 specific gravity and 0.6 inch drop of pressure, and applying each formula in succession, we find a considerable variation, as follows :—

Dr Pole—

$$Q = 1350 \times 6^2\sqrt{\frac{0.6 \times 6}{0.45 \times 1000}} = \frac{92,340}{21} = 4397.$$

Spon—

$$Q = 1000\sqrt{\frac{6^5 \times 0.6}{500}} = \frac{68,000}{22.5} = 3022.$$

Molesworth—

$$Q = 1000\sqrt{\frac{6^5 \times 0.6}{0.45 \times 1000}} = \frac{68,000}{21} = 3238.$$

From which it will be seen that Dr Pole's formula gives a greater discharge by 45 per cent. than Spon's formula and 35 per cent. more than that of Molesworth. As Dr Pole's formula is very generally credited with giving results which have been borne out in practice whenever it has been possible to test it, the other formulæ should only be accepted with considerable reserve.

Tests of German Gas Association.—It is interesting, in this connection, to find that, according to the report for 1907 of the Technical Committee of the German Gas Association, that Committee found, as a result of a number of practical tests carried out under working conditions on a main of 3.16 inches in diameter and 12½ miles in length, that at pressures of from 5 to 6 inches head of water the actual discharges were less than those calculated by Dr Pole's formula, varying to as much as 11.61 per cent. below. At the highest pressures at which tests were taken, namely, 154.4 inches head of water, the observed discharges were much higher than those given by Dr Pole's formula, reaching to a maximum of 19.26 per cent. greater than the calculated quantity.

Qualifying circumstances.—There are several matters in connection with the pipes and joints themselves which materially affect the discharge from any given main. It is obvious that the degree of smoothness of the interior of the pipe is one of these. The discharge from a rough or corroded series of pipes must be very considerably less than from a similar length of main with a comparatively smooth internal surface.

The same thing applies to any projections into the interior of the pipe or cavities left at the joints such as may be caused by "breaking joint"; or by yarn or lead getting through to the interior of the pipe through imperfect jointing; or by the bedding material between flanged joints being badly placed; or in any one of many other ways. These all, by setting up a process of "eddying" in the stream of gas, tend very materially to reduce the discharge.

Another disturbing cause acting in the same manner may be found in the sudden throttling or equally sudden enlargement or even alteration of form of the main. It may be taken as an axiom that all transitions from one size to another, and also from one form to another, must be made as gradual as possible by taper pieces, if the best results are to be obtained.

Margin for contingencies.—And lastly, in all the examples given it has been assumed that the pipes are perfectly straight and level; except where bends and tees are specifically mentioned. But every practical man knows that these ideal conditions never exist in actual work. There must be rises and falls, and slight turns to right or left, in any considerable length of main laid under present day conditions. Common prudence, therefore, must impress the necessity of leaving a sufficient margin for contingencies in all calculations, if anything like satisfactory results are to be obtained.

CHAPTER IV

DISCHARGES FROM PIPES UNDER HIGH PRESSURE

It has already been suggested that the comparatively simple formula of Dr Pole for ascertaining the discharges from pipes, while correct enough for all practical purposes in connection with the low pressures usually associated with gas distribution in this country, yet needs considerable modification for use with high-pressure distribution. It fails to take account of the varying densities of the gas, and of the varying volumes occupied when subjected to different pressures extending over a range which has only been adopted in connection with gas distribution during the last few years. Whereas, until recently, it has been usual to measure the differences of pressure in inches and fractions of inches of head of water, pressures amounting to pounds per square inch are now being used. And this wide difference in the degree of compression to which the gas is subjected introduces an element of error in the results obtained by Dr Pole's formula which must be considered.

To take a simple illustration. We know by Marriotte's law that the volume of a gas varies inversely with the pressure to which it is subjected. Suppose, therefore, that a certain length of pipe contains a certain volume, say 10 cubic feet, at a given pressure, if double that pressure be applied the gas will be compressed to half the volume. But when we consider that gas is in many places being distributed not at three or four inches of pressure, but at a pressure of more than as many lbs. per square inch, we may appreciate the disturbance which this degree of compression introduces into a formula designed for use under far different circumstances.

Then there is also the process of expansion continually going on and progressively increasing as the gas travels further away from the point at which the initial pressure is applied. Suppose a quantity of gas is passed through a pipe at an initial pressure of 20 lbs. per square inch and discharged at 1 lb. per square inch, the consequential expansion of the gas represents a certain amount of work, and this factor must, in all cases, be taken into account, to whatever degree it has been operating.

Professor Unwin's formula.—In his investigation of the subject, as described in a paper read before the Institution of Gas Engineers in 1904, Professor Unwin arrived at the following equation as an approximately exact formula for the flow of gas in pipes, the changes of volume and density being duly taken into account :—

$$Q = \frac{\pi}{4} d^2 u_2 = \frac{\pi}{4} \frac{p_1}{p_2} d^2 u_1 ;$$

where Q = the discharge in cubic feet per second measured at the pressure p_2.
d = the diameter of the pipe in feet.
u_1 = the velocity in feet per second at the inlet of the pipe.
u_2 = the velocity in feet per second at the outlet of the pipe.
*p_1 = the pressure at the inlet of the pipe.
*p_2 = the pressure at the outlet of the pipe.

The value of u_1, may be obtained from the following formula :—

$$u_1 = 468 \sqrt{\left\{ \frac{d}{\zeta s l} \frac{p_1^2 - p_2^2}{p_1^2} \right\}} ;$$

where u_1 = velocity in feet per second measured at the inlet of the pipe.
d = diameter of the pipe in feet.
l = length of pipe in feet.
s = specific gravity of the gas.
p_1 = pressure at the inlet of the pipe.
p_2 = pressure at the outlet of the pipe.

and

$$u_2 = \frac{p_1}{p_2} u_1 .$$

The coefficient of friction may be obtained from the formula

$$\zeta = 0.0044 \left(1 + \frac{1}{7d} \right)$$

or from the table given on p. 14.

Suppose, then, it is required to determine the discharge per hour from a 15-inch main three miles in length at an initial pressure equal to 50 feet head of water and final pressure equal to 20 feet head of water. It is assumed that the specific gravity of the gas is 0.45 (air = 1) and that the coefficient of friction is 0.0049.

Then by the above formula

$$\begin{aligned} u_1 &= 468 \sqrt{\left\{ \frac{d}{\zeta s l} \frac{p_1^2 - p_2^2}{p_1^2} \right\}} \\ &= 468 \sqrt{\left\{ \frac{1.25}{0.0049 \times 0.45 \times 15{,}840} \times \frac{(50+34)^2 - (20+34)^2}{(50+34)^2} \right\}} \\ &= 468 \sqrt{0.035 \times 0.586} \\ &= 468 \times 0.14 \\ &= 65.52 ; \end{aligned}$$

and

* The pressure may be taken in any units, but must be absolute pressure (p + 34 feet head of water).

$$u_2 = \frac{p_1}{p_2} u_1 = \frac{84}{54} \times 65.52 = 101.92 ;$$

$$\therefore Q = \frac{3.1416 \times (1.25)^2 \times 101.92}{4}$$

= 125 cubic feet per second,
or 450,000 cubic feet per hour.

For the purpose of avoiding three separate calculations Professor Unwin's formula may be expressed as follows :—

$$Q = 1{,}323{,}250 \sqrt{\frac{p_1^2 - p_2^2}{p_1^2}\left(\frac{p_1}{p_2}\right)^2 \frac{d^5}{\zeta s l}}$$

where the units are precisely as in the original formula except that Q = discharge in cubic feet per hour.

Mr Sturgeon's charts.—A valuable series of charts by Mr R. A. Sturgeon has recently been published by Messrs John Allan & Co., showing discharges, calculated from Professor Unwin's formula, covering pipes from ½ inch to 24 inches in diameter ; lengths of main from 200 to 6000 yards ; pressures up to 100 pounds per square inch and specific gravities ranging from 0.3 to 1.2.

American investigations.—As might naturally be expected, considering that the practice of high-pressure distribution has been considerably developed in the United States, this question of the discharge from pipes at high pressure has received a much greater amount of attention there than in this country. They have also had the advantage, in some instances, of being able to check theoretical formulæ by actual practical experience, owing to the great distances natural gas has had to be conveyed in many cases. A serious attempt has, therefore, been made to arrive at a formula which, whilst easy of application, shall be approximately correct.

Professor Lowe's formula.—In a paper read before the Pacific Coast Gas Association in 1904, Professor Lowe suggested the following as a formula which may be considered fairly reliable :—

$$Q = C \times \frac{P_1 + 14.7}{14.7} \sqrt{\frac{D^5 \times (P_1 - P_2)}{0.0761 \times S \times \frac{P_1 + 14.7}{14.7} \times L}}$$

where

Q = the discharge of gas in cubic feet per minute at atmospheric pressure.
C = a variable constant (see table, p. 37).
P_1 = initial gauge pressure in pounds.
P_2 = final „ „ „
D = diameter of pipe in inches.
L = length of pipe in feet.
0.0761 = weight of 1 cubic foot of air at atmospheric pressure.
S = specific gravity of gas.

The value of the variable constant C is as follows for the different sizes of pipes :—

For pipes	$\frac{1}{2}$-inch	in diameter,	C = 36.8
,,	2	,,	C = 52.7
,,	3	,,	C = 56.1
,,	4	,,	C = 57.8
,,	5	,,	C = 58.4
,,	6	,,	C = 59.5
,,	7	,,	C = 60.1
,,	8	,,	C = 60.7
,,	9	,,	C = 61.2
,,	10	,,	C = 62.1
,,	14	,,	C = 62.3
,,	16	,,	C = 62.6
,,	18	,,	C = 62.7
,,	20	,,	C = 62.9
,,	22	,,	C = 63.2
,,	24	,,	C = 63.2

The results obtained by this formula are claimed by Professor Lowe to be almost identical with the practical results noted over a line of pipes conveying natural gas in Connecticut. The observations were recorded at various points in the pipe line throughout an entire winter, and totalled to about 20,000 in all; with the remarkable result that the quantity of gas discharged did not vary more than 1 to $1\frac{1}{2}$ per cent. from that given by the formula.

Oliphant's formula.—A very much more simple formula, in which the fifth power calculation has been eliminated, is that suggested by Mr F. H. Oliphant, an American gas engineer, for calculating discharges from pipes at high pressures, and which is as follows :—

$$Q = 42a\sqrt{\frac{p_1^2 - p_2^2}{l}};$$

where Q = the quantity discharged in cubic feet per hour.

p_1 = the absolute pressure in pounds per square inch ($p + 15$) at the inlet.

p_2 = the absolute pressure in pounds per square inch ($p + 15$) at the outlet.

l = length of main in miles.

The values of a for different size of pipes are as follows :—

For pipes of	3 inches	diameter	a = 16.5
,,	4	,,	a = 34.1
,,	5	,,	a = 60.0
,,	6	,,	a = 96.0
,,	8	,,	a = 198.0
,,	10	,,	a = 350.0
,,	12	,,	a = 556.0
,,	16	,,	a = 1160.0
,,	18	,,	a = 1570.0
,,	20	,,	a = 2055.0
,,	24	,,	a = 3285.0
,,	30	,,	a = 5830.0
,,	36	,,	a = 9330.0

Investigation by the Ohio Gas Association.—The interest aroused in the subject being so great, and the practical importance of obtaining reliable formulæ being so widely recognized, the Ohio Gas Association some time ago authorized a sub-committee to collect and collate information having reference to high-pressure distribution from all available sources.

In presenting the report of the sub-committee, the chairman, Mr J. D. Shattuck, mentioned that, amongst others, the following formulæ had been collected, in addition to those mentioned above :—

Pittsburg formula :—

$$Q = 3450\sqrt{\frac{d^5(P_1^2 - P_2^2)}{lf}}, \text{ when } g = 0.6;$$

Coxe's formula :—

$$Q = 41.3\sqrt{\frac{d^5(P_1^2 - P_2^2)}{L}}, \text{ when } g = 0.65;$$

where

Q = discharge in cubic feet per hour.
P_1 = absolute initial pressure in pounds per square inch (gauge pressure + 14.7).
P_2 = absolute terminal pressure (gauge pressure + 14.7).
d = internal diameter of pipe in inches.
L = length of main in miles.
lf = „ „ feet.
g = specific gravity (air = 1).

That these formulæ give very diverse results is shown clearly by Mr Shattuck, who tested them against a case brought to the knowledge of the committee in the course of their inquiries, but for the accuracy of the measurement of which he was unable to vouch from personal knowledge. At Newton (Mass.) a 6-inch main 9,600 feet long delivered 18,200 cubic feet of gas per hour, the initial gauge pressure being 10 lbs. per square inch and the terminal pressure 9.28 lbs. per square inch. Taking these conditions, he obtained the following variable results with the formulæ given above :—

The Pittsburg formula	gives	a discharge of	18,380	c. ft.	per hour.
„ Oliphant	„	„	16,260	„	„
„ Coxe	„	„	16,000	„	„
„ Unwin*	„	„	31,870	„	„
„ Lowe	„	„	26,910	„	„

It is understood that these formulæ apply to straight pipes laid perfectly level. Any deviation from these conditions would, of course,

* Obtained with an older form of Professor Unwin's formula than that given on p. 35.

affect the observed result. It does not, therefore, follow that because the practical and theoretical results do not always harmonize the latter are necessarily incorrect. Practical results must always show differences from those obtained by formulæ, however correct the latter may be, simply because it is never possible to represent all the factors influencing the result in any equation.

It is interesting to note the similarity of results obtained by the Coxe and Oliphant formulæ, the difference being only 260 cubic feet in 16,000, and each being about 2,000 cubic feet per hour below the result obtained in practice. The Pittsburg formula gave results almost identical with the measured delivery, whilst the Lowe and Unwin formulæ gave results much higher than those obtained in the practical experiment referred to.

Experiments of Mr Geo. Helps.—At the meeting of the Institution of Gas Engineers in London in 1904, Mr Geo. Helps, of Nuneaton, stated that he had obtained measured results, from a 3-inch main three miles long, as follows :—

Inlet Gauge. Pressure. Lbs.	Outlet Gauge. Pressure.	Discharge in Cubic Feet per hour.
5	*nil*	5,000
10	*nil*	10,000
18	*nil*	18,000

Applying the five formulæ given above to these conditions, we obtain the following varying results :—

Formulæ.	Discharge at 5 lbs. Gauge. Pressure.	Discharge at 10 lbs. Gauge. Pressure.	Discharge at 18 lbs. Gauge. Pressure.
Prof. Unwin . .	4,852	7,429	11,268
Prof. Lowe . .	5,520	8,700	13,500
Pittsburg . . .	6,226	9,629	14,136
Oliphant . . .	5,287	8,011	11,773
Coxe . . .	5,541	7,448	12,318

Comparing these results, it appears evident that a formula is not necessarily equally true under differing conditions as to fall of pressure. The formulæ which give results approximating most closely to the measured discharge at the lower pressure are the most imperfect when used for the higher pressure, and *vice versa.* The Pittsburg formula, which gives nearly correct results with a fall of 10 lbs. pressure, gives much too high a discharge when the drop is only half as much.

It is interesting to note in passing how completely the results of Mr Helps' experiments, alone of those quoted, conform to the law previously mentioned, that discharges are proportional to $\sqrt{(P_1^2 - P_2^2)}$. In these experiments P_2 was atmospheric pressure, the end of the main being simply an open port, and therefore the discharges became proportional to $\sqrt{P_1^2}$, or simply P_1.

In a paper read at the annual meeting of the American Gas

Institute in 1905, by Mr H. L. Rice, the following interesting results of actual experiments were given amongst others :—

Length of main, $22\frac{3}{4}$ miles.
Size of main, 4-inch.
Specific gravity of gas = 0.6.

The length of main included 16 long sweep bends and 4 one-eighth bends.

			Theoretical Delivery.	
Inlet Pressure. Lbs.	Outlet. Pressure. Mercury.	Measured Delivery. Cubic Feet.	Pittsburg Formula. Cubic Feet.	Oliphant. Formula. Cubic Feet.
35	2 inches	16,170	15,645	14,882
50	3.1 ,,	22,860	20,743	19,731

Need for further research.—There must evidently be a great deal more independent experimental research before it is possible to educe a formula which shall be approximately accurate under all conditions of pressure. The information we have at present is much too scanty for the purpose. Meanwhile it is apparent that none of the above formulæ give anything approaching to the observed results at the higher pressures, and therefore considerable allowance must be made in working out calculations from them.

Bends.—The disturbing effect of bends and sharp angles in the case of low-pressure distribution has been discussed. All that was said in that relation applies with much greater force to the case of high-pressure distribution. The immense importance of preserving the kinetic energy of the flowing gas to as great an extent as circumstances will allow is too obvious to need emphasizing. " One quarter bend introduced midway in a 4-inch main one mile long, through which gas is being passed at an initial pressure of 10 lbs. per square inch and is being discharged at atmospheric pressure, throws a back-pressure of 9 per cent., necessitating, if the outflow is to be maintained, the initial pressure being raised to 10.9 lbs. per square inch. If three sharp bends are used the back pressure thrown will be raised to 13 per cent. If the quantity discharged is to be kept constant, the initial pressure must be raised to 11.3 lbs. per square inch.

" With largely augmented pressures the percentage loss is very greatly increased. If in the above instance an initial pressure of 50 lbs. per square inch be substituted for the 10 lbs. quoted, with discharge at atmospheric pressure, the back pressure thrown by three sharp bends would be equal to 10.3 lbs., necessitating the initial pressure being raised to 60.3 lbs. per square inch, if the same discharge is to be maintained as that through a straight pipe, an increase of 20.6 per cent." *

The experiments of Mr C. W. L. Alexander.—The question of the resistance offered by bends of varying radii to flow of water has been

* Professor Lowe.

investigated by Mr C. W. L. Alexander, M.Sc., B.E., Assoc.M.Inst.C.E., with results which are not without interest to the gas engineer, and which are embodied in a paper read before the Birmingham Association of Students in 1904. The author gives particulars of some most valuable experiments carried out by him in 1901-2 at the University of Birmingham, in the search for an answer to the question "whether the loss of head is dependent only on the angle and curvature of the bend, or whether the resistance is not also dependent on the nature of the internal surface of the pipe."

The bends used in the experiments were eleven in number, of 1¼ inches diameter, cut out of solid blocks of pine, and varying in curvature from 0.100 to a sharp elbow. Each bend had 6 inches of straight pipe on each side of it, with a piezometer-tube connection at a distance of 2 inches from either end.

It was found that the resistance offered is least when the radius of the bend is equal to five times the radius of the pipe; and, curiously enough, it increases from that point for bends of greater as well as for those of sharper curvature. Taking the bend of least resistance and those at the extreme on either side of it, the loss of head was found to be in the following proportions:—

Experiment.	Curvature of Bend.	Proportionate Resistance.
1	0.1	0.000987
6	0.2	0.000874
11	Elbow	(0.022050)[1]

The loss experienced is traceable to the eddying motion set up in the current by change in the direction of the flow, and is found to be dependent on

(*a*) The roughness of the pipe.
(*b*) The hydraulic radius of the pipe.
(*c*) The curvature of the bend.
(*d*) The length of the bend measured along the centre line.

The ratio existing between the length of the bend measured along the centre line and the length of straight pipe offering the same resistance as the bend is shown, for cast-iron asphalted pipes, to be as follows:—

Diameter of Pipe. Inches.	Curvature.	Ratio.
12	0.125	2.93
12	0.460	11.65
16	0.133	3.33
30	0.125	2.210
30	0.210	3.400

If, therefore, a 12-inch bend of radius equal to eight times that of the pipe and 4 feet long be taken as an example, the resistance offered by the bend would be equal to that of $4 \times 2.93 = 11.72$ feet of straight pipe.

It is suggested by Mr Alexander that the most convenient method of stating the resistance offered by bends is in terms of the equivalent length of straight pipe which offers the same resistance to flow as the extra resistance due to the bend. This may be determined by means of the formula

$$L = 12.85\left(\frac{r}{R}\right)^{0.83} l;$$

where

r = half the diameter of the pipe.
R = radius of curve.
l = length of curve measured along the centre line.

"The length so found is added to the actual length of the bend, and the net length so obtained is used in calculations as being equivalent for purposes of discharge to the actual pipe with its bends."

Two additional points of interest clearly brought out by the investigations were :—

(*a*) "The resistance offered by bends is of the same nature as that offered by straight pipes, being due to internal eddy motions set up and the dislocation of the proper stream lines causing this to be aggravated.

(*b*) "A curve of 180° did not show more than 1 per cent. additional loss of head above one of 90°, but if a tangent were introduced between them the loss of head in the second curve is materially increased.

"The resistance of a bend of the curvature of 0.2 would be

$$\begin{aligned} L &= 12.85\left(\frac{r}{R}\right)^{0.83} l \\ &= 12.85(0.2)^{0.83} l \\ &= 3.38\, l; \end{aligned}$$

where l is the length of the curved portion of the pipe measured along the centre line."

CHAPTER V

STATION GOVERNORS

In the preceding chapter it will have been noticed that one very important factor in connection with the discharges of gas from pipes is the initial pressure at which it is supplied. This brings us, by a natural sequence, to the means adopted for regulating pressures throughout a district, namely, the station governor.

In the absence of any special contrivance, such as fans, compressors, and the like, the pressure in the gas mains is obtained from the weight of the gasholder, which in turn is ultimately lifted by the works exhauster. But this pressure is, in the very nature of the case, a variable quantity in gasholders with more than one lift. It is increased or diminished with the number of lifts in use or, in other words, with the stock of gas. Take the case of a three-lift gasholder throwing a pressure of, say, $3\frac{1}{2}$ inches, $4\frac{1}{2}$ inches, and $5\frac{1}{2}$ inches, according as one, two, or three lifts are being used. Apart from every other consideration, it is obvious that to have a variation of pressure, at different times, upon the distributing mains equal to 2 or 3 inches head of water would be, not only extremely inconvenient, but positively dangerous.

But apart from the fluctuations referred to, and even if the holder always maintained the same pressure, in whatever position it happened to be for the time, the minimum pressure suggested above would still be too great for the normal requirements of any ordinary district at all hours of the day and night. Especially would this be the case in hilly districts where the original works pressure would be considerably augmented in the areas of higher attitude. The application of such pressures would, by the ejection of water from consumers' wet meters, cause grave inconvenience, through cessation of supply.

Then, again, although the multiplication of gas engines in use, and the great development of the use of gas for cooking, heating, and various industrial purposes, have gone far in many places to reduce the inequality between the day and night load, it is still unhappily true that consumption varies very considerably at different hours of the night and day. Not only so, but it may vary greatly as between the same hours of successive days. It is obviously impossible, therefore, with any regard for economical administration, to maintain the pressures necessary for an adequate supply during the hours of heavy consumption throughout the time when the demand for gas is much lighter. It is equally impossible, under present-day conditions, that the supply of a district should be at the mercy of a man stationed at the works, opening and closing valves at discretion as the demand for gas is supposed to fluctuate.

All these, and other reasons which might be adduced, make it imperative that some ready means of controlling and regulating pressures, which shall be, to some extent, if not altogether, automatic in its action, shall be adopted. The instrument used for this purpose is that known as the station governor.

The construction and action of a station governor are very simple in principle, although the apparatus itself may be more or less complicated. In its primary form, it is an instrument so arranged that any variation of pressure thrown by the gasholder, or any fluctuation of demand for gas, shall convey motion to a valve of such construction, with such accessories, and placed in such position, that the effect shall be the partial opening or closing of the gas-way, proportionately to the requirements of the moment. If, therefore, the demand for gas increases, the valve is opened to allow a greater volume to pass through, while if the consumption diminishes, the gas-way is proportionately closed, thus maintaining a regular and uniform pressure upon the distributing mains.

Qualities of an efficient governor.—An efficient station governor, therefore, must be—

(*a*) Capable of reducing the excess of pressure thrown by the gasholder to that required for the supply of the district.

(*b*) It must be capable of adjusting itself to any variation of initial pressure due to cupping, uncupping, or change of gasholder.

(*c*) It must be sensitive to any fluctuation, small as well as great, in the consumption of gas in its district.

(*d*) It must work quite steadily and without the least oscillation.

The exact way in which these objects are attained, the form of valve used, and the conditions under which it is worked, will be readily understood by reference to the various illustrations, which show some of the principal types of governors used in this country.

Braddock's governor.—Fig. 6 shows a sectional elevation of the balance governor made by Messrs J. & J. Braddock, of Oldham. The base consists of a rectangular chamber, divided by the partition, A, into inlet chamber, B, and outlet chamber, C. There are two openings between the chambers, one at either end of the inlet chamber. Each of these is fitted with a parabolic valve, D and E, usually made about 1⅓ times the diameter in length, the area of the base being one-half to two-thirds of the area of the main. These are turned up true in the lathe, and ground to their seats, so as to be perfectly gas tight, and properly balanced that they may hang plumb. The valves open in opposite directions to each other, E opening upwards and D downwards. Through these valves the gas passes from the inlet to the outlet chamber. The valve, E, is connected by rod, G, and chain, H, to the balance beam, K, the centres of which turn upon knife-edge pivots carried by the central pillar, I. The rod, G, attached to the valve, E, which opens upwards, passes out of chamber, B, through

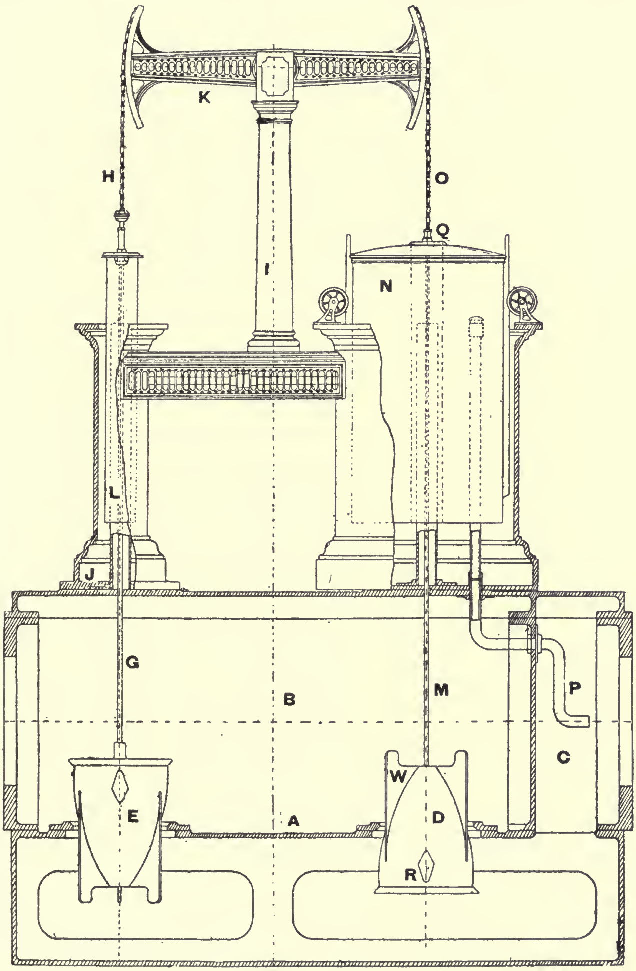


FIG. 6.—Section through Braddock's Balance Governor.

an ordinary water seal, L, contained in pillar, J, attached to the top of the inlet chamber.

The valve, D, which opens downwards, is suspended by the rod, M, which passes through another ordinary water seal to the top of the bell, N, which, in turn, is attached by the chain, O, to the balance beam, K.

The controlling tube, P, is carried from the outlet chamber, C, through inlet chamber, B, to above the water line in the bell, N, and is, of course, open at both ends, and intended to admit gas from the outlet to the bell.

It is obvious that for efficient governing an equal travel of the

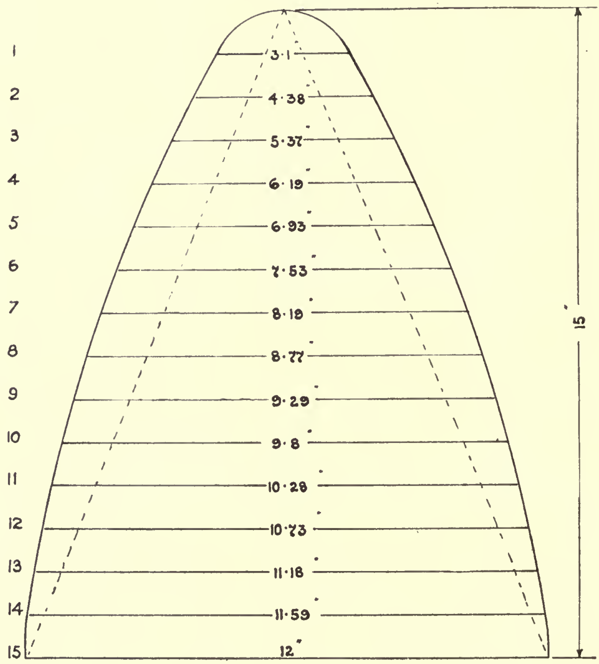


FIG. 7.—Section through Parabolic Cone.

governor bell either up or down must control an equal amount of valve area. To effect this the cone must be of special and particular design. This will be seen at once by reference to the dotted lines in Fig. 7. Assume that we have a straight-sided triangular cone, 12 inches in diameter at base and 15 inches long, divided by horizontal lines into fifteen equal parts of 1 inch each. The full area of the valve opening will be 113.1 inches.

The diameters of the cone at horizontal lines 5 and 6 would be 4 inches and 4.8 inches, giving an area of 12.56 inches and 18.09 square inches respectively. The area of valve openings at these points would therefore be $113.1 - 12.56 = 100.54$ and $113.1 - 18.09 = 95.01$

square inches, or a difference corresponding to 1 inch vertical of travel of the cone of 5.53 square inches. Take now divisions 12 and 13. The diameter at 12 is 9.6 inches and at 13 is 10.3 inches, giving an area respectively of 72.38 and 83.32. In this case, therefore, the area of valve openings would be $113.1 - 72.38 = 40.72$ and $113.1 - 83.32 = 29.78$, a difference of 10.94 square inches. In other words, a vertical travel of 1 inch in the second case gives 100 per cent. more valve area than in the first. Other comparisons might be made showing an even greater disparity. The cone must, therefore, not be a straight-sided triangular, but a parabolic one. Dividing the whole valve area into fifteen equal steps corresponding to our horizontal lines, we find first of all the area of cross section necessary to give equal increments of area for equal increments of rise and fall of governor bell, and then the diameter of a circle giving the area required, as follows :—

Division	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Diameter of Parabolic Cone in inches.	3.10	4.38	5.37	6.19	6.93	7.53	8.19	8.77	9.29	9.8	10.28	10.73	11.18	11.59	12.0
Area of Cross Section.	7.54	15.08	22.62	30.16	37.70	45.24	52.78	60.32	67.86	75.40	82.94	90.48	98.02	105.56	113.1
Diameter of Straight-sided Cone.	0.7	1.5	2.4	3.2	4.0	4.8	5.6	6.4	7.1	7.9	8.2	9.6	10.3	11.1	12.0

The two great objections to cone valves, namely, the risk of oscillation and the difficulty of graduating finely when only small quantities of gas are being passed, are surmounted in Braddock's valve in a most ingenious manner. Upon the cone are cast three wings, W, which throughout the whole of their length are of slightly smaller diameter than the valve openings, through which they are made to pass easily. The arrangement of the wings is shown in plan in Fig. 8. These wings effectually prevent any lateral movement, whatever the position of the cone may be at any given time.

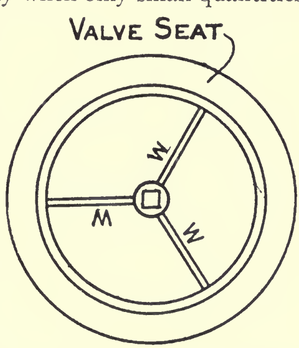


Fig. 8.—Plan of Wing Attachment of Braddock's Cones.

To assist in the adjustment of pressures when very small quantities of gas are passing through the governor, diamond shaped notches are cast in the valve wall, as shown at letter R (Fig. 6). These depressions permit small quantities of gas to pass through them, in addition to that passing between the cone and valve seat, thus admitting of great nicety of adjustment, even when the valve is nearly closed.

The action is as follows :—If the pressure in the outlet chamber is diminished, owing to increasing consumption, the diminution is communicated by pipe, P, to the interior of the bell, which, losing part of its support, proportionately falls, thus opening valve, D. The valve, E, being on the opposite arm of the balance, and opening in an upward direction, is correspondingly raised. The two valves, being thus opened, allow more gas to pass through from the inlet to the outlet chamber, to maintain the desired pressure in the mains.

If, on the other hand, the pressure in the outlet chamber becomes augmented, owing to lessened consumption, the action described becomes exactly reversed. The increased pressure is communicated through tube, P, to the interior of the bell, N, which proportionately rises, carrying with it and partially closing valve, D. A reciprocating motion is conveyed by beam, K, through rod, G, to cone, E, correspondingly closing that valve. The two valves being now closed, in proportion to the rise of pressure in the outlet, the passage of gas is restricted, thus causing the pressure to fall back to the desired level.

In this form of governor the weights to give the necessary pressure may either be added by hand at the weight plate, Q, upon the top of bell, N, as shown in the illustration, or the water-loading arrangement shown in Fig. 9 may be adopted.

Provision is made for reaching the valves and other working parts of the governor, for purposes of cleaning and repair when necessary, by a system of easily removable plates arranged upon each side of the valve, which may be taken off without deranging any part of the mechanism of the governor.

By arranging the controlling tube suitably, the inlet and outlet chambers may be readily reversed. In that case the tube must be carried from the inlet to the bell. The inlet chamber, B, then becomes the outlet, and the outlet chamber, C, becomes the inlet, and the governor may be connected up accordingly.

Braddock's counterbalance governor.—A very good form of governor, where floor space is limited, is the counterbalance governor made by the same firm, which has its two conical valves arranged on one spindle, counterbalanced by weights as shown in Fig. 9.

The base of this is a narrow, deep rectangular valve box, containing within itself a separate inlet chamber, A, as shown in the illustration. The gas enters the inlet chamber and passes through the valves, C and D, which in this case both open in the same direction, into the outlet chamber, B. As in the balance governor, these valves are faced true and ground to fit their seating, and contain the cone depression, R, to assist in governing small quantities of gas, and wings, W, to prevent any lateral movement of the cone. They are supported by the single rod, E, from the bell, F, which, in turn, is connected by chain, G, to end of balance beam, H. The valve and bell are counterbalanced by weights suspended by chain, K, from the opposite end of beam, H ; and the controlling tube, I, open at both ends, is carried from the outlet chamber, B, to above the water line in bell, F.

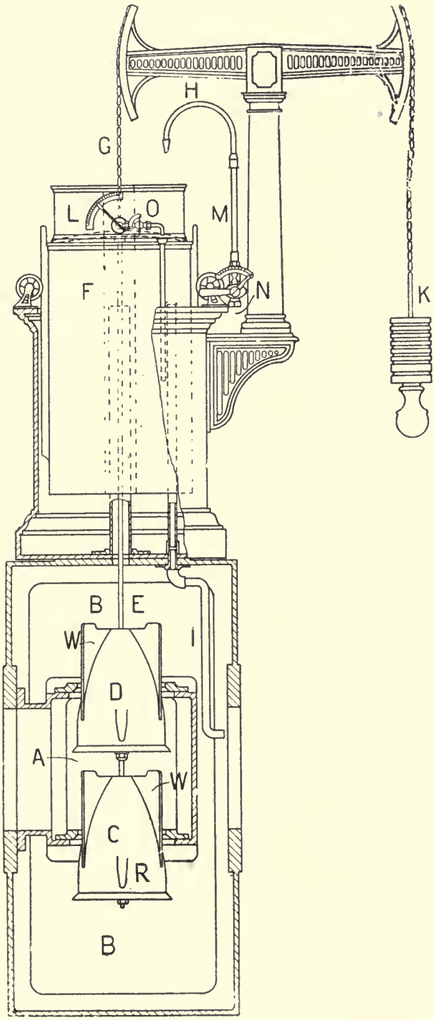


Fig. 9.—Section through Braddock's Counterbalance Governor.

It is evident, therefore, that after the governor has been adjusted, any increase of pressure in the outlet chambers, due to lessened consumption, will cause the bell to rise. This carries with it the two valves, C and D, and proportionately, closes the gas-way. If, on the other hand, the pressure in the outlet chamber is decreased, owing to increasing demand for gas, the bell falls and opens the valves, thus maintaining the desired pressure. As the rise and fall of the bell is absolutely coincident with the fluctuations in the output of gas, the governor automatically maintains a steady and regular pressure.

The initial pressures may be varied either by means of weights, or by the water-loading arrangement, as shown. If the former method is adopted, the weights may be either placed upon the bell, F, or removed from the counterbalance, K. But undoubtedly the water-loading arrangement is the better, as it enables the pressure to be increased gradually, and without the sudden fluctuations inseparable from the use of weights.

The water-loading arrangement consists of a water tank, L, fixed upon the top of the governor bell and supplied with water from pipe, M. The rate of flow of water in the pipe is governed by a tap, N, carrying a graduated quadrant and index pointer. The index pointer allows pressure to be put on with any degree of acceleration which may be previously decided upon. Suppose that it is desired to spread the increase of pressure from minimum to maximum over the space of one hour. It is found by experiment what position of the index pointer allows a sufficient supply of water to pass in the given time, to increase the pressure to the desired extent. When this has been once ascertained, the only attention necessary is to open the tap to the proper degree at the usual time for increasing pressure, and close it again when the maximum pressure has been reached. The increase of pressure is thus made very gradual, and is evenly spread over the predetermined length of time.

The converse of this holds in the matter of taking pressure off again. The tank is unloaded through pipe, O, which also carries a tap with a similarly graduated quadrant. It may be desired to spread the unloading of the governor over the space of two hours. The position of the tap necessary to accomplish the unloading in the specified time is found by experiment, and when ascertained it is only necessary for the attendant to open the tap to the proper extent at the correct time, and to close it again when the operation is complete.

At any time of sudden demand, it is obvious that the pressure may be increased, under this arrangement, at any rate up to the delivering power of the full open bore of the supply pipe. The waste water in leaving the loading tank passes into the governor tank, thus keeping the water in the latter sweet and clean. Any surplus is passed away through an overflow provided for the purpose.

In both of these types of governor the cone valves are duplicated. In the earlier type of governor one valve only was used. It was proved, however, by experience, that, suspended as it was from the bell into the inlet chamber, and therefore having gasholder pressure acting directly upon its base, a certain amount of the weight of the cone was supported by the pressure. As this pressure varied with the changing of initial pressure due to cupping, uncupping, or change of gasholders, so the weight on the bell varied, causing an alteration of pressure in the district, but in an opposite direction. That is to say, the effect of an increase in the inlet pressure, by correspondingly increasing the support of cone and bell, caused the valve to close proportionately and decrease the pressure in the outlet mains. Consequently the governor required to be freshly adjusted with each change of initial pressure, to maintain a uniform pressure in the district.

The single cone governor also proved very liable to oscillation, set up by varying initial pressures due to the cupping, uncupping, or change of gasholder acting upon the cone, and imparting a lateral movement to it. It was also unduly influenced by sudden fluctuations in the consumption of gas, due to the fog or gloom which so frequently settle upon our large towns. Having once commenced to oscillate, the cone would continue to do so for a long time, unless special means were adopted to stop it. This oscillatory movement was, of course, conveyed to the gas, and led to a considerable unsteadiness in the flow, to the great annoyance of consumers, who were troubled with consequential blinking of lights at the point of consumption.

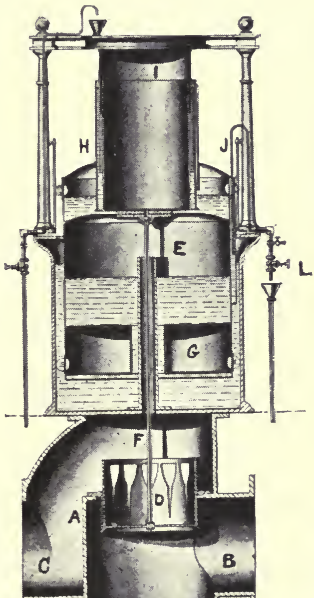


Fig. 10.—Section through Cowan's Compensating Governor.

In each of the governors already described this evil has been entirely eradicated by the method of balancing adopted, by the use of the parabolic valves in opposite directions, by the wings, W W, and, in the case of the counterbalance governor, by the method of arranging the valves in relation to the flow of gas.

Parkinson & Cowan's compensating governor.—The compensating governor made by Messrs Parkinson and W. & B. Cowan is of a different type altogether, and is shown in Fig. 10.

The base of the governor consists of a cast-iron chamber divided by the partition, A, into inlet chamber, B, and outlet chamber, C. The valve, D, is suspended from the roof of the bell by the hollow rod, F. The weight of the valve and bell is balanced by the float, G, which is an air-tight annular chamber fixed to the interior of the bell.

The three oustanding features of this governor are (*a*) the shape of the valve; (*b*) the compensation arrangement; and (*c*) the provision for water-loading.

The valve, which is shown in enlarged section in Fig. 11, is a short cylinder closed at one end, and having conical ports cut through the sides. The form of these ports admits of the greatest nicety of adjustment being attained. As it is impossible for the valve to move in any but a vertical direction, it is not liable to even the least oscillation through variation of pressure thrown by the gasholders. The great

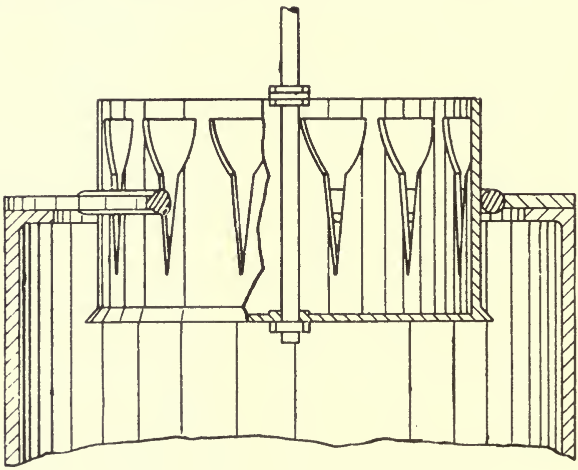


FIG. 11.—Section through Cowan's Valve.

disadvantage originally attaching to it, namely, that it was somewhat difficult to get at for purposes of cleaning, has been entirely removed in the latest patterns. In these the base chamber is fitted with removable plates, which greatly facilitate the work of inspection, cleaning, and repair.

The compensation is obtained in the following manner:—On the roof of the bell there is fixed an annular tank, H, into which dips a second bell, I, which is suspended from and fixed to the cross-bar above. This bell corresponds in diameter with the valve, and forms with the annular tank a water lute, which encloses an area equal to that of the valve base. The pipe rod, F, which suspends the valve, D, conveys gas from the inlet chamber, B, to the interior of bell, I. The pressure exerted on the bell, I, exactly balances the pressure on the valve base, as both are of the same area. When, therefore, increased inlet pressure would tend to force the valve upward, with the effect of altering the pressure the governor was loaded to maintain, this action is completely neutralized by a corresponding pressure exerted over a similar area above the bell, E, in the water lute, H, and thus the adjusted pressure remains unaffected. In a similar manner, when, through the gasholder uncupping or other cause, the inlet pressure is lessened, and thus, by diminished support, tends to increase the weight of the bell and valve, and so cause the valve to open and derange the outlet pressure, the diminished support of the bell is accompanied by an exactly equally diminished pressure on the roof of the bell, with the result that equilibrium is maintained.

The third special feature of the Cowan governor is the water-loading and unloading arrangement. When the governor is being loaded, the water is delivered by a pipe, which is connected to the town supply, first of all into the water lute of the compensating chamber, from which it overflows into the loading tank below. By this means the seal of the compensating chamber is always maintained at its full depth. Any variation here would, of course, alter the load on bell, E, and so tend to derange and disturb the compensating balance. As this, under the method adopted for loading, is practically impossible, the compensation is perfect, and the governor maintains a steady outlet pressure under all normal conditions.

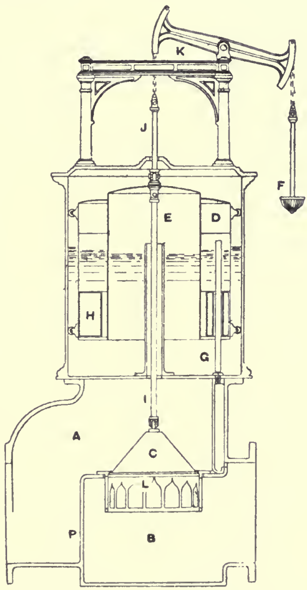


FIG. 12.—Section through Peebles' Governor.

The unloading is accomplished by means of the brass tube, J, which forms a syphon, one arm of which dips into the water-load, while the other communicates through the water tap, L, with the water escape pipe. The air must first be expelled from the inverted U-tube, through the small tap provided for the purpose, and after this is done the syphon is ready for working. When it is desired to unload the governor, the syphon tap, L, is opened, and the water-load is run off to the extent desired. By this means the pressure is steadily and gradually reduced. The great advantage this affords over the sudden action of reducing pressure by taking weights off the bell will be readily appreciated. Both addition and reduction can be arranged for at any desired speed.

Peebles' station governor.—The station governor, manufactured by Messrs Peebles & Co., Limited, of Edinburgh, is another excellent type of governor, which has distinctive features of its own. It is shown in Fig. 12. As will be seen from the illustration, the governor is very compact and simple in design ; and it is effective even under the most trying conditions.

The base of the governor consists of the usual inlet chamber, A, and outlet chamber, B, divided off from each other by the partition, P, and communicating only through valve, C.

The valve.—The latter is formed of valve seat, L, which is a short cylinder, open at both ends, in the side of which openings of a more or less conical form are cut. The valve, C, is pyramidal in form, and is suspended by its apex by rod, I, from the roof of compensating chamber, E. It is made to slide easily in a vertical line within the cylinder forming the valve seat. As shown in the illustration, the valve is closed. As the bell descends and with it the valve, the ports are gradually uncovered, and gas is allowed to flow through the conical openings from A to B. The arrangement admits of great accuracy in adjustment and sensitiveness to fluctuations in the demand for gas.

The bell, D, encloses a second chamber, E, which is concentric with the former and of the same diameter as the base of the valve. The outlet pressure on the latter is thus equilibrated. The weight of the two bells is balanced by the float, H, which is an air chamber attached to the interior of the bell and of such area as to afford the requisite support. The bell is attached by rod, J, to one arm of balance beam, K, the other arm of which carries the weight rod and seat, F.

Unlike the governors previously described, in this case the bell is entirely enclosed ; and owing to the efficient way in which it is guided, any tilting or dislocation of the bell is rendered quite impossible, as it cannot move in any but a true vertical line.

The controlling pipe, G, is carried from the outlet chamber, B, to above the water level in the bell, D, and the effect of this, and the action of the governor generally, is similar to that of those to which reference has previously been made.

The valve and bell, being of the same diameter, are always in perfect equilibrium under all practical conditions as to fluctuations of inlet pressure, as the inlet gas acts equally upon both, but in opposite directions.

The weights necessary to actuate the governor are applied, or taken from, the end of the counterbalance arm, F, a much more get-at-able position for the purpose than the crown of the bell, even when the latter is unenclosed.

If desired, the counterbalance weights, arm, and pillar may be dispensed with, and the Peebles' pneumatic loading and unloading apparatus (described more fully in connection with district governors, p. 75) may be employed. One advantage of this arrangement is that the governor may be operated at any distance and from any convenient point, either the manager's office or other suitable place, thus obviating the necessity of having a man continually in attendance in the governor house.

The method of calculating the capacity of the float necessary to support the weight of the bell and valve in the foregoing governors is based upon the displacement of water by an air chamber. One cubic foot of water weighs 62.425 lbs., whilst one cubic foot of air weighs, approximately, 1.22 ozs. It is not, however, enough to exactly balance the bell by means of the float. A sufficient degree of buoyancy must be given to the bell to ensure a firm pressure of the valve upon its seating, so as to make sure of a complete shut off when desired. It is usual, therefore, to allow 1.25 cubic feet of air to every 62.425 lbs. (the weight of a cubic foot of water) weight of bell and valve, which gives the well known and easily remembered rule of 1 cubic foot area of float to every 50 lbs. weight of bell.

It is quite as simple to calculate the weight necessary to be added to the bell to give any desired pressure. The factors are (*a*) the area of the bell, and (*b*) the pressure required. Assume that weights are added to the bell to exactly neutralize its over buoyancy and reduce it to equilibrium. Then $W = PA$

where W = weight to be added,
P = pressure desired,
A = area of the bell in feet.

As an example, take the case of a 36-inch governor. This would probably have a bell of 4 feet 8 inches in diameter, giving an area of 17.1 feet. Suppose it is required to find the weight necessary to give a pressure of 4 inches head of water. Then, as a cubic foot of water weighs 62.425 lbs., the pressure exerted by 4 inches will be $62.425 \div 3 = 20.8$ lbs. upon each area of one foot of bell. The area has been shown to be 17.1 square feet, therefore $17.1 \times 20.8 = 355.68$ lbs. = weight necessary to give 4 inches pressure with such a governor.

Cowan's automatic pressure changer.—It will have been noticed that in each of the governors to which reference has been made, with the exception of the suggestion above with regard to pneumatic loading, all alterations of pressure have to be made in the governor house, by the man in charge loading the governor bell. This has long been felt to be but an imperfect method of working, and many attempts have been made to introduce the automatic principle in connection with the governor, so as to obviate the necessity of continual personal attention, and render the governor absolutely self-working.

One of the earliest steps along this road was taken when Mr Wm. Cowan introduced his automatic pressure changer, which consists of a clock, weighted pulleys, a number of levers, a revolving disc containing a series of tappets, and a couple of small gasholders. The clockwork releases the levers at the predetermined time by means of the tappets placed in the revolving disc, and permits the weighted pulley to rotate the water tap of the loading arrangement into the open position. When the desired pressure is attained, the pressure, acting through the gasholders, releases another lever, which allows the pulleys to rotate the tap into the closed position once more. The operations may be continued or repeated with such interval as may be desired, and to whatever degree may be determined, by setting the tappets in the revolving disc and weighting the gasholders accordingly. The position of the tappets in the disc is altered weekly to suit the changing requirements as to times at which pressure shall be put on and taken off, and when once set they need no further attention. The whole operation is entirely automatic.

It is obvious, therefore, that such an instrument, when working properly, renders personal attention to the governors, for the purpose of adjusting pressures, absolutely unnecessary, and ensures that they shall be augmented or reduced at the exact time which has been decided upon, and for which the tappets have been set. But it is apparent, also, that while this may be in many respects an advance upon the method of alteration by hand, yet it is very far from a perfect solution of the problem. Being a machine it is quite unintelligent. If for any reason it proved desirable to accelerate or retard the times for increasing or decreasing the pressure, personal attention would be absolutely necessary.

In a variable climate, such as that of our country, there are frequently cases, at certain times of the year, of partial and sudden fogs, or of thick, heavy, overhanging clouds settling down over a district, which necessitate an immediate increase of pressure. Or there may come some equally sudden and irregular demand for gas, at times of considerable business pressure, owing to the gas being used largely for industrial purposes, sometimes in establishments working through the night. These are cases, and others might be cited, where any machine, however perfect, being arranged for a set time, is bound to prove unsatisfactory by itself, and to need supplementing by personal attention.

And in addition to the above considerations it must be remembered that even the best arranged time-table for the increase and decrease of pressure is bound, from the very nature of the case, to be unsatisfactory. The most that can be done is to arrange the time-table to suit average weather conditions, and the usual gas consumption for the time of the year. But particular days, or a series of days, may be much brighter and lighter than the average, and thus the pressure, augmented according to the table, may be put on long before it is actually required. And, more serious still, there is the real danger that on days overcast and gloomy above the average, the pressure may not be put on soon enough to meet the accelerated demand.

The consumption of gas, too, may, and very frequently does, vary very much from day to day, even in the same week, so that on the days of minimum supply there may be more pressure, and on the days of maximum supply less pressure, put on than is necessary to meet the requirements of the moment.

The only way to meet these varying requirements is to give the "pressure man" a certain amount of discretion to advance or retard the pressures, according to the weather conditions of the time. Even then, be the man ever so intelligent, he can only be acquainted with these conditions as they exist in his own immediate neighbourhood, which may be quite different from those obtaining in other parts of the area of supply.

Self-loading devices.—With a view to meeting the several practical difficulties previously enumerated, various self-loading arrangements for the station governor have from time to time been devised. The great ideal constantly before the mind of the gas engineer has been to perfect some arrangement by which the governors should be automatically adjusted to meet the varying requirements of the hour, whenever and to whatever extent the demand may be made. The two best-known solutions of the problem, namely, that of Messrs Braddock and that of Connelly, will now be described.

Braddock's device.—In the self-loading arrangement patented by Messrs J. & J. Braddock, the outlet pressure is varied automatically with the consumption of gas. To effect this object, a special water-loading apparatus is connected to their ordinary station governor, as shown in Fig. 13 (p. 58).

The arrangement consists of a water-loading dish, or vessel, B, which is coupled up to the load chamber on the governor bell by means of a flexible tube, A. The loading vessel is fixed at such a height, relatively to the governor, that as the bell of the latter falls below a certain predetermined point, owing to the increase of consumption, water flows by gravity from the loading tank to the governor bell, thus increasing the pressure. The extent of the increase is, of course, determined by the amount of fall of the governor bell, and is strictly proportional to it.

When the governor bell rises, owing to the decrease of the consumption, the water-load is, by gravity, gradually transferred back again to the loading vessel, and the pressure correspondingly decreased. The action is perfectly automatic, and will be readily intelligible on reference to the illustration.

In order to counteract the action on the governor bell due to varying inlet pressure, in consequence of cupping or uncupping or change of gasholders, the water-loading vessel, B, is also carried on a bell, similar to that of the governor. This is equally actuated, both in point of time and degree, with the latter by any fluctuations of pressure upon the inlet of the governor, which are conveyed through pipe, C, to the interior of bell, D. Consequently the relative positions of loading dish and governor remain unaltered.

The maximum and minimum pressures having been fixed, and the water-loading vessel suitably adjusted, in relation to the movement of the governor, to give these pressures at the time of greatest and least consumption, no further attention is needed.

The pressure is not increased or decreased at fixed and stated times, but is varied, within the limits desired, strictly according to the demand for gas. Any governor, however, operated by this water-

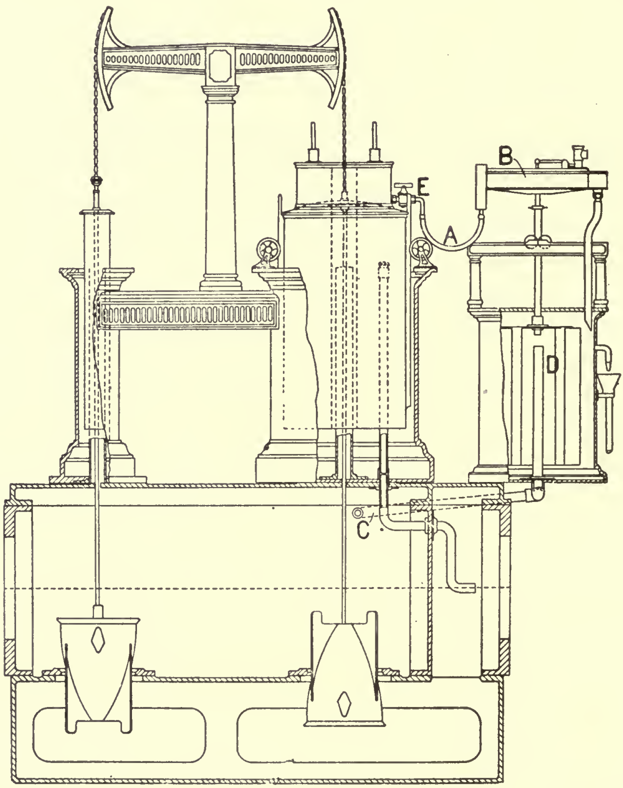


FIG. 13.—Section through Braddock's Water-loading Arrangement.

loading apparatus should have an independent and separate district to supply, as, if there is any " backing up " from the governors in the other parts of the district, the action of the self-loading arrangement is not likely to prove very satisfactory.

At special times, when stocks are low, or when from any other cause it may be thought to be desirable, the water-loading apparatus may be detached by disconnecting the flexible tube, or by closing tap, E, and the governor loaded by hand by means of weights in the ordinary manner.

Connelly's Governor.—Perhaps one of the most interesting and ingenious forms of automatic station governor is that associated with the name of Connelly, one of a type which is being widely used in the United States and Canada, and which attracted a good deal of attention at the gas exhibition held at Earl's Court in 1904.

As will be seen from the illustration, the governor consists of the usual parts, the base containing the inlet and outlet chambers, A and B, and valves, C and D. These are surmounted by an annular tank, E, in which floats the bell, F, which actuates the governor. The interior of the bell is in communication with the outlet main by means of a pipe, G, which is fitted with a valve so that it may be closed from the outside. The rod, H, carrying the valves, C and D, is connected to the bell so that any variation in the pressure on the street main, conveyed to the bell by pipe, G, and causing corresponding movements of the bell, proportionately opens or closes the valves as in the ordinary governor.

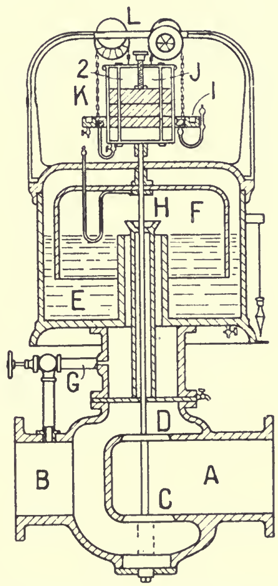


Fig. 14.—Section through Connelly's Automatic Governor.

The special feature of the apparatus consists of an ingenious arrangement for automatically loading or unloading the governor, in accordance with the consumption of gas for the time being. The way this is carried out is as follows. The annular ring, I, contains mercury, and is connected with the glass receptacle, J, by means of a piece of flexible tube which is connected to the head of the valve rod and consequently to the valves. Any increase of weight in the glass receptacle tends to depress the governor bell, and consequently to open the valves. The annular ring, I, is attached to the glass receptacle by means of chains, K, which pass over the frictionless pulleys, L. Any increase of weight in I therefore tends to elevate the governor bell, F, and to close the valves, C and D.

When, therefore, after the governor has been properly adjusted, the pressure in the outlet mains is decreased, owing to greater consumption, the bell falls and proportionately opens the valves. The glass receptacle falls with the bell, and the annular ring, I, is correspondingly elevated by means of the chains. In so doing, part of the mercury flows from the annular ring, through the flexible tube, into the receptacle, thus increasing the load and giving an increase of pressure.

Where, on the other hand, the pressure in the outlet mains is increased, owing to the lessened consumption, the bell rises, carrying with it the glass receptacle, J, while the annular ring, I, is correspondingly lowered. There will thus be a flow of the mercury back again from the receptacle, J, to the annular ring, I, until the balance is once more restored.

To adjust the governor, the bell is first of all weighted with shot or weights to give the minimum pressure desired. Then sufficient mercury is added to the glass receptacle to weight the governor to such an extent as to give the maximum pressure the governor is required to maintain.

One of the unique features of the governor is seen in the system of sliding ports in the valve shown in Fig. 15. The openings shown at B B in the illustration may be either closed altogether or opened so far as will enable the governor to accommodate itself to the requirements of the district it has to supply. The sectional ring is moved by means of the braces, A A, as shown, and when once adjusted needs no further attention. The ring is differently placed with varying sizes of governors, those of 6 to 12-inch in diameter having the ring on the lower valve, as shown; the 16-inch size has the ring on the top valve, whilst the 20-inch to 36-inch sizes have the adjustable ring on both top and bottom valves.

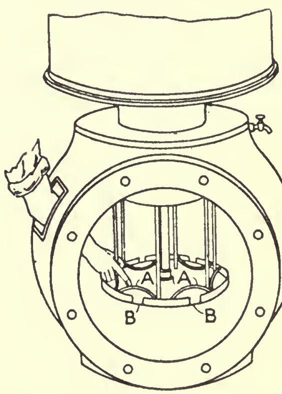


Fig. 15.—Connelly's Governor Valve.

The governor, then, is seen to be simple in design, easily adjustable, has few parts to get out of repair, and these well open to inspection, and is perfectly automatic in its action.

The development of the self-loading arrangement has thus been traced through its first two great steps. The automatic pressure changer of Mr Cowan, whilst in many respects a great advance upon the expensive and often irregular adjustment of pressures by the governor-house attendant, has been seen to be a purely mechanical arrangement, without power to adapt itself to various changes and fluctuations of consumption as they arise from day to day.

The second step was taken when Messrs Braddock invented their self-loading apparatus. Just as Cowan's pressure changer was a great advance upon manual labour, so Braddock's self-loading arrangement is a great advance upon the pressure changer. But the self-loading apparatus of both the Braddock and Connelly governors still leaves something to be desired, inasmuch as they are actuated by variations of pressure on the mains in the immediate vicinity of the governor house. But the district in close proximity to the governor house is, and in the very nature of the case must be, if not absolutely the best, at any rate one of the best supplied districts in the whole area of supply. The pressures, however, have ultimately to be

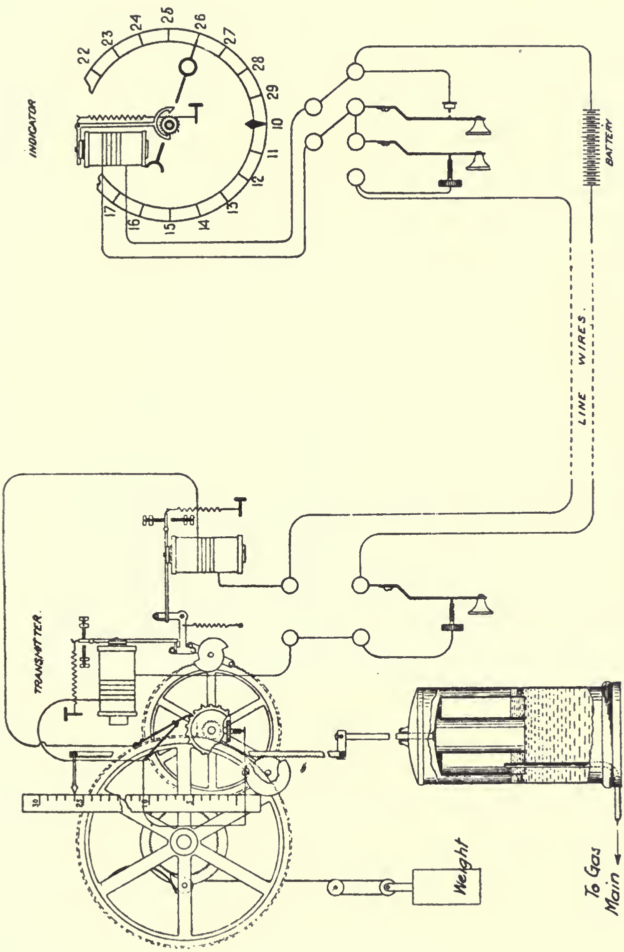


FIG. 16.—The Union Telemetric Pressure Gauge (see p. 62).

regulated to that amount which will give a sufficient supply to the worst served parts of the district. The aim, therefore, should be to actuate the station governor from one of these poorly-supplied points, where any diminution of pressure in the mains is felt first, longest, and most acutely.

Signalling fall of pressure from distant areas.—There are several ways in which this desirable object may be attained. One of the simplest of these is to fix a small gasholder bell, similar to that shown in Fig. 19 (p. 64), at a convenient spot in the worst supplied part of the district. This may be balanced to descend when the pressure falls below a certain predetermined minimum. The bell may be so fitted that when it descends it completes an electric circuit, the other end of which is an alarm bell fixed in the governor house at the gas works. When, therefore, the governor bell falls owing to increased consumption, and the circuit is completed, the alarm bell is rung and

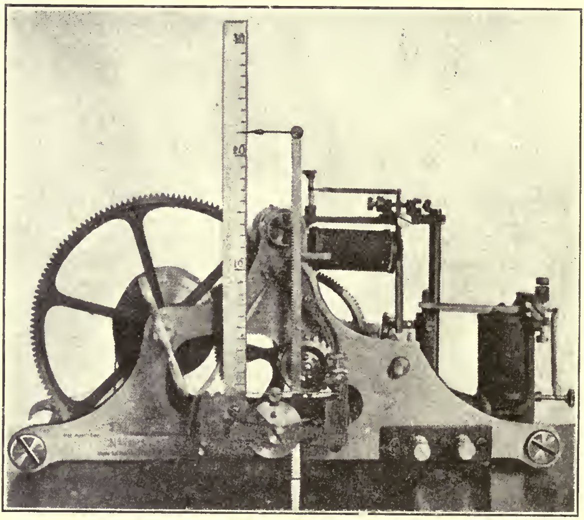


FIG. 17.—Enlarged View of Transmitter Movement of U.T.P. Gauge.

continues ringing until sufficient pressure is put on at the works to restore the balance at the distant area in question, lift the gasholder bell, and so break contact. In this way an immediate and continuous notice is given at headquarters of any possible drop in pressure, due to increased demand for gas, within a moment or two of its taking place.

Another method is that known as the "Union Telemetric Pressure Gauge," described by Mr James S. Kennedy in a paper on "Apparatus designed for Remote Control of District Pressure," read at the annual meeting of the American Gas Institute, in October 1910. This instrument consists of a transmitter and an indicator. The transmitter, shown in Fig. 16, consists of a small gasholder bell floating in a tank and connected to the street mains, capable of rising and falling with the fluctuation of pressures in the main. It is fixed in some remote district from which it is desired to transmit fluctuations of pressures. At the top of the float a vertical rack communicates its motion to a sensitive differential gear mechanism, which is also part of a weight-driven clockwork gearing held in check by an electro-magnet, shown in Fig. 17. This magnet is in the electric circuit which extends from the transmitter to the indicator, Fig. 18, in the governor house. When the pressure changes, the transmitter mechanism operates and transmits the proper signal to the indicator. The pointer of the indicator always points to a figure on the graduated dial, which is the pressure at the distant transmitter. Whenever the pressure at the transmitter changes, the indicator pointer changes synchronously, operating with a perceptible click which attracts the attention of the

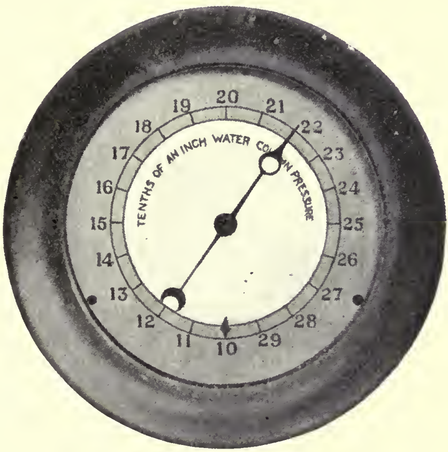


FIG. 18.—Indicator U.T.P. Gauge.

pressure man. If he adjusts or changes the governor pressure the indicator pointer will, after the lapse of fifteen or twenty seconds, the interval required for the gas wave to reach the distant transmitter, respond to the change and shift its position to a new indication. The accuracy of the instrument may be tested at any time by means of a very simple device, and so possibility of error is, as far as possible, eliminated. The instrument may be duplicated, of course, to any desirable extent, so that by means of a series of indicators fixed in the governor house the attendant may see at a glance the pressures existing at any number of remote points in the area of supply.

This arrangement is a considerable advance on the mere ringing of a bell, inasmuch as not only is the fact of a fluctuation of pressure immediately transmitted to headquarters, but also the extent of the variation. It still, however, requires the intervention of the attendant to restore the balance of pressure by himself loading the station governors. The ideal arrangement is, of course, a self-contained and perfectly automatic instrument.

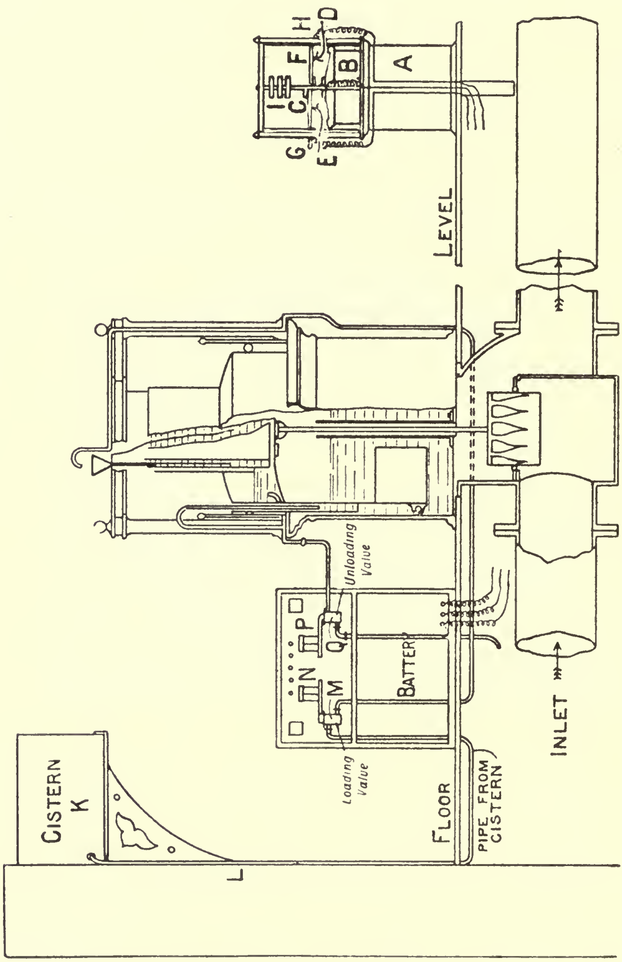


Fig. 19.—Cowan's Electric Self-loading Apparatus.

Cowan's self-loading apparatus.—An apparatus which meets the above requirements has been designed by Mr William Cowan, and is shown in Fig. 19. This device puts the water-loading arrangement of the station governor in direct communication with the pressure at the selected low-lying or ill-supplied district. Actuated from this point, the initial pressure is either augmented or diminished, at the exact time, and to the requisite degree, necessary to meet the demand of the moment. It is automatic in its action, thus dispensing with the necessity for personal attention, and, by reason of the ready adjustment of pressures to the consumption of the time, tends to decrease the leakage account.

The principle and action of the apparatus will be readily understood by reference to the illustration, Fig. 19. The pressure vessel is connected by a service pipe to the main in the selected district remote from the works. This vessel is, in reality, a small auxiliary gasholder, working freely in tank, A. The bell, B, carries two arms, C and D, which are electrically insulated from the bell itself by suitable non-conducting material.

These arms have their counterpart in two other adjustable and pivoted arms, E and F, fixed upon, but insulated from, columns, G and H, and which, by means of suitable wires, are in connection with the loading arrangements in the station governor house.

" In order to limit and regulate the falling and rising of the gasholder bell, the weights, I, are suspended in such a position that as the bell falls, in consequence of a reduction of pressure, weights in proportion to the reduction are left off ; and, in like manner, during a rise of the bell, owing to increased pressure, weights are taken on. But for this arrangement the bell would either fall to the bottom or rise to the top whenever the pressure rose or fell. The rising or falling of the bell in response to pressure is, in the first instance, determined by the bell's own weight, which may be varied according to circumstances, but it is also further regulated by the suspended weights coming into and going out of operation."

In the governor house, in place of the direct water-loading and syphon unloading arrangement, there is fixed a water cistern, K, supplied by means of an ordinary ball tap. The supply of water for loading the governor is carried by means of pipe, L, to a special valve, M, capable of being acted upon electrically by the electromagnet, N, fixed either upon the governor tank or in its immediate vicinity. A similar valve, Q, actuated by its own electromagnet, P, is fixed upon the syphon discharge pipe.

Immediately, therefore, that the pressure in the remote district falls below the prearranged minimum, the drop of the auxiliary gasholder bell brings the arms, C and E, into contact, and completes the circuit of which the electromagnet, N, is part. The latter opens valve, M, which admits water to the loading chamber of the station governor. When the augmented pressure given by this increased load has restored the pressure in the selected remote district, the gasholder bell rises. The contact, and consequently the circuit, is therefore broken, and the valve, ceasing to be acted upon, closes, and the loading ceases.

When, on the other hand, the pressure in the remote district rises, contact is made between the other pair of arms, D and F, thus completing the circuit of which electromagnet, P, is part. The latter in turn operates on valve, Q, opening the syphon discharge pipe,

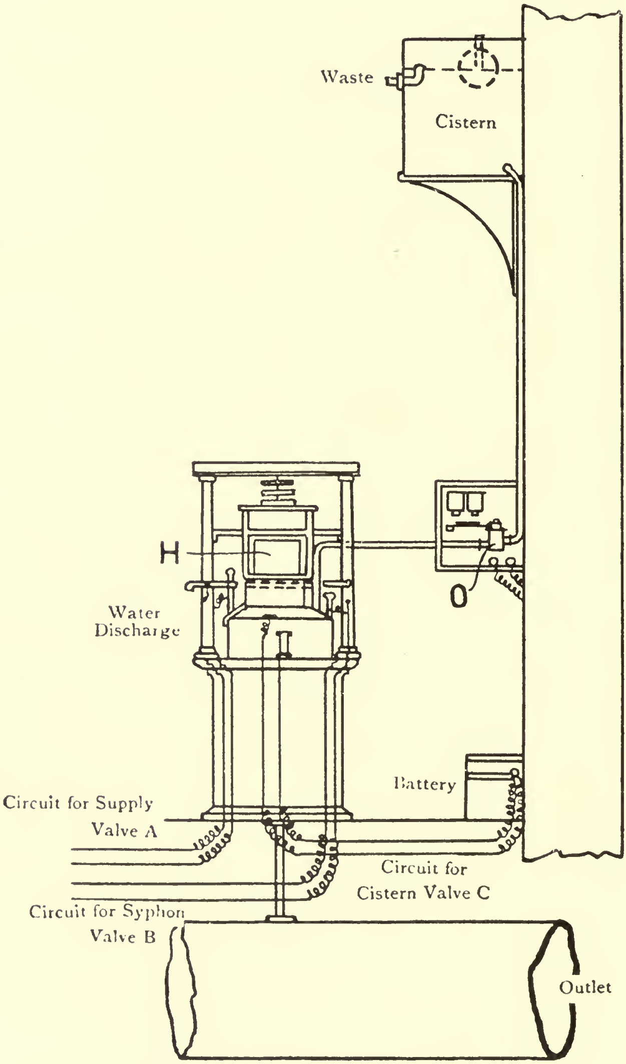


FIG. 20.—Cowan's Auxiliary Apparatus.

and unloads the governor until the pressure at the gasholder falls sufficiently to break contact with arms, D and F.

The maximum and minimum pressures having been fixed for the mains actuating the gasholder, and the adjustable arms regulated accordingly, it is obvious that the limits in either direction can never be exceeded so long as the apparatus is maintained in good working order. As soon as either limit is reached, action is immediately set up in the governor house, which restores the balance again.

It will be understood from the foregoing description that this system of regulating pressures is only applicable to water-loaded governors, and, also, that for its efficient working it can only be used where different districts are separately supplied. If in large towns several districts are independently governed, then a separate apparatus would be necessary, acting from the worst supplied part of each.

Arrangement to vary the pressures on the district as required.—A still further development of the same principle has been made to suit the requirements of the comparatively small number of cases where it is necessary to vary the pressure in the district selected to set the standard. This is also carried out quite automatically, in the following way :—" A loading tank is added to the roof of the auxiliary gasholder bell, and to this tank water is supplied when any undue fall of pressure, and consequently of the bell, takes place. The load of water thus added prevents the bell from rising (and therefore keeps the valve which supplies water to the governor loading tank from closing) until the pressure is sufficiently increased to raise the gasholder bell with its added load of water. When increasing pressure, due to a lessening of demand, makes the gasholder bell rise, notwithstanding the added weight of water it becomes necessary to remove the water more or less gradually, because its weight is no longer required.

" To effect this, a displacer is employed, and is fixed in a stationary position over the loading tank. As the bell rises, the water in the tank is pressed slowly up against the displacer, and is thus gradually forced out through the suitable passage provided. When all the water has been so removed, the normal or constant pressure will be re-established, the occasion for its increase having passed away."

It will be understood that this modification is especially adaptable to those places where very irregular and intermittent demands for gas are likely to be made. Suppose that the requisite normal pressure at the auxiliary gasholder is ascertained to be 2.5 inches head of water. If, now, a sudden demand be made for gas in large quantities, as frequently occurs in industrial centres, in connection with special work, it would probably be found desirable to increase the normal pressure to, say, 3 or even 3.5 inches head of water for the period over which the special demand extends. This and similar cases is very successfully met by the arrangement described. The pressures may be varied between any reasonable limits, by a suitable adjustment of the loading tank upon the auxiliary gasholder bell.

Advantages claimed.—The advantages legitimately claimed for the Cowan automatic loading apparatus may be summed up under the following four heads :—

(*a*) That it ensures a constant and regular supply to the lowest part of the district, and, by inference, to the whole area.

(*b*) It is perfectly automatic in action, requires no personal attention, and adapts itself to any irregularity in the demand for gas.

(*c*) It reduces the average pressure at the outlet of the governor.

(*d*) The pressure is increased only for so long as is necessary to maintain the standard pressure in the selected district.

CHAPTER VI

DISTRICTING

In very close connection with the governing of the supply of gas there arises another question of great practical importance which must be determined, namely, that of the general arrangement of the mains desirable in the case of large areas of supply. This will, of course, greatly depend on the local conditions of the district—the relation of its parts geographically; the general character of the area, whether hilly or flat; and the extent to which it will lend itself to any one of the several systems by which gas may be distributed. These may be roughly divided into four separate classes, as follows:—

I.—An arrangement of mains whereby the supply of gas to separate districts, arbitrarily divided off from the remainder, should be independently governed.

II.—The arrangement of the mains into two or more general divisions, supplying respectively the high- and low-lying parts of the area of supply, so that each may be separately governed.

III.—The arrangement of the distributing mains on the model of the arterial system; in other words, having the whole of the mains more or less linked up together.

IV.—The combination of either of the preceding with a system of high pressure boosting mains.

There is a considerable difference of opinion as to which of these arrangements is to be preferred. Each has its own advantages and disadvantages. It is not often, however, that a perfectly free choice can be exercised. Local considerations and the heritage of the work of predecessors, together, tie the hands of those responsible, so that they are frequently unable to carry out fully their own wishes in the matter. The present distributory systems of our large towns have been a slow growth, spread over many years, and perhaps not always developed with that wise foresight of future needs which might have been exercised.

Advantage of separate districts.—The advantage of dividing the district into separate and distinct areas of supply, quite independently governed, is that the particular character of the district may be fully considered, untrammelled by the necessity of taking the needs of other districts into account. Thus, whether the locality is an industrial or residential one, whether there is a heavy day load or a comparatively light one, whatever the local conditions may be, the pressures and supply generally may be arranged accordingly, without reference to other districts where the conditions may be very different. If, however, there happen to be great differences of level in the particular district, the high-lying parts will receive much heavier pressures than are necessary, if the lower-lying areas are to obtain an adequate supply, unless recourse is had to district governors.

Advantage of division into high- and low-lying areas.—This brings us naturally to a consideration of the advantages accruing from the adoption of the second alternative. These are sufficiently obvious to command general assent. Where widely differing levels in any area of supply may be governed separately, the pressures in the lower levels may be made fully adequate without the fear of flooding the upper districts with heavy pressure. The latter having their own mains and governors, the supply may be so controlled as to give a sufficient but not excessive pressure to the consumer. There must thus be a very considerable saving in the leakage account. But it also involves, to some extent, varying with different localities, a duplication of mains. Apart altogether from the question of cost, this is a very real disadvantage in the case of our large towns, where the subsoil is so crowded with pipes and cables of one kind and another that it becomes increasingly difficult to find room for them all. To the extent to which duplication of mains is necessary, it also increases the capital account of the undertaking. It therefore becomes necessary to ascertain whether the general convenience of the system, and the saving likely to be effected, will more than balance the increased interest charges upon the necessary outlay. In many cases where levels vary very considerably, and the extent of the duplication is limited, this would undoubtedly be so. In others the economy of the arrangement may be questionable, and the problem might more fittingly be solved by means of district governors.

The arterial arrangement.—One great advantage of the arterial arrangement is that a breakdown along any route, even though this should occur in connection with a trunk main, can never lead to a total cessation of supply. In addition to this, the system of linking up the mains together is especially valuable in those districts where the naphthalene trouble is acute. If a stoppage, either partial or entire, takes place upon any main, no total discontinuance of supply can occur, as the area involved will be, in some measure, even if not fully, supplied by the various connected mains, and thus, except, perhaps, in the immediate vicinity of the fault, no great inconvenience can arise.

This is not all gain, however. The arrangement inevitably involves the possibility of one or more of the less important mains becoming gradually choked, either with corrosion or naphthalene deposits, or waterlogged in consequence of subsidence of the subsoil, without immediate discovery, thus impairing the efficiency of the main or mains affected.

Another substantial advantage of this method of connecting mains together is that it is calculated to equalize the pressures in any given

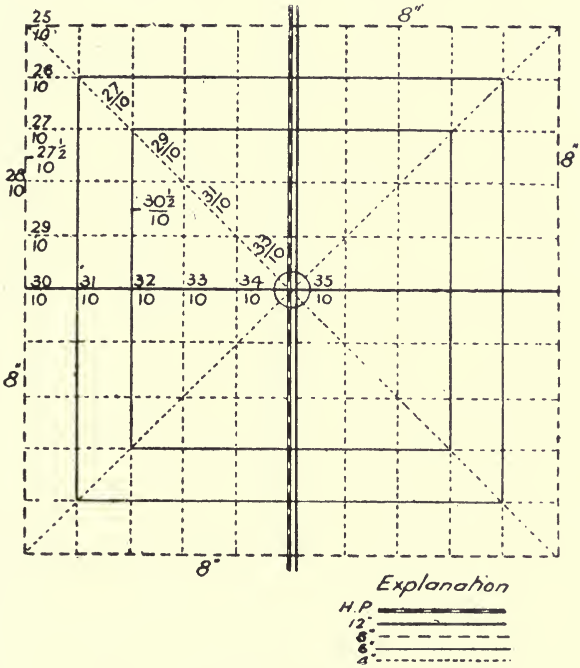


FIG. 21.—Cowdery's Ideal "Lay-Out."

area. In case of heavy or fluctuating demand for gas, the temporary deficiencies of any one portion of the distributing system is at once made good by a supplementary supply from others.

In cases, too, where repairs become necessary, or large connections have to be made to any main, involving "bagging off," the system of linking mains up proves of great practical convenience. Failing this, either the supply must be stopped for a time, the extent of which is dependent on the work in hand, or special arrangements for continuing the supply by means of a by-pass must be made, involving additional work, delay and expense.

In considering the question of arranging the gas mains on the model of the arterial system, however, the physical features of the district must be taken into account. In areas of widely differing levels it is possible that all the above advantages may be somewhat dearly purchased by a swollen leakage account, due to excessive pressures on the high-lying portions of the district.

Districting by means of high-pressure mains.—The advent of high-pressure distribution, however, makes a thorough districting of any large area possible, without such a duplicating of mains as would be necessary in a low-pressure system. The whole area of supply might be divided up into suitable districts, comprising, say, two to four square miles in each, as may be found most convenient, and a high-pressure supply main laid from the works through these districts, ultimately returning to the works again. Such a main would thus form a circular trunk main under high pressure, from which each separate district would be supplied through local governors, as will be described in a later chapter when dealing with "boosting."

Such a method as this makes possible at once the laying out of mains to supply each district on such ideal lines as those described by Mr J. von Maur in his paper on "High-Pressure Distribution in St Louis," read before the American Gas Institute in 1908. In that case units of one square mile were taken, which would be unnecessarily small in the case of English cities. Fig. 21 (p. 71) shows the proportioning of mains for such a district of one square mile on the basis of a peak load of 100,000 cubic feet per hour. The governor is denoted by the circle in the centre of the square, from which is supplied the system of 12, 8, 6, and 4-inch mains shown. The figures in the top left hand corner of the diagram denote the gradual diminution of pressures from the governor to the borders of the particular district, actually obtained in one such system. Towns and cities on this side are not laid out with the orderliness characteristic of some American cities, and consequently any similar arrangement applied to English conditions would be very irregular as compared with Mr Cowdery's ideal plan. But the idea is undoubtedly a good one where it can be carried out, and even where, for one reason or other, it is found impossible of adoption either entirely or in part, it still forms an ideal toward which to work. The saving involved in having one trunk main working at high pressure instead of several under low pressure would be enormous, whilst the plan of supplying the whole area in comparatively small units would make for almost absolute efficiency in distribution.

The route to be taken by such a main could be so arranged as to avoid principal thoroughfares. By carrying the main through unimportant streets and lanes, the first cost would be lessened, access to the main facilitated at a minimum of public inconvenience, and maintenance and reinstatement costs kept as low as possible.

CHAPTER VII

DISTRICT AND SERVICE GOVERNORS

In cases where the area of supply embraces districts of greatly varying altitudes, and where for any reason it has not been found convenient to govern the upper portion of the district independently from the works, the evil of excessive pressures on the high-lying portion is generally corrected by means of district governors.

These are usually differential in their working—that is to say, they are constructed to reduce the pressure received at the inlet by a definite amount. Thus, if in a hilly district it is found that the pressure in the mains rises to as much as, say, equal to 5 inches head of water, and it is desired to reduce that pressure to 2 inches, the governor, after being adjusted to give that reduction, will give it under all conditions of inlet pressure above that of the amount of the reduction. Thus, whilst the district governor is in many places a very useful instrument, it is at the same time somewhat clumsy and mechanical in its operation.

This is no doubt due in some measure to the necessity of the case. The district governor is usually fixed under the roadway upon the line of main which it is intended to control, and thus it is not get-at-able for adjustment, as is a station governor. This difficulty has, however, been solved in a very ingenious manner by Messrs Peebles & Co., Limited, by means of their pneumatic loading arrangement, which is described later.

Braddock's district governor.—One of the best types of district governor is that manufactured by Messrs. J. & J. Braddock, and shown in Fig. 22 (p. 74).

The base of the governor consists of a circular cast-iron box divided by partition, A, into inlet chamber, C, and outlet chamber, B. The valve, D, is semicircular in section, and is turned and ground to fit tightly into valve seating, E. The valve is carried by the hollow rod, F, which, fixed to the roof of the bell, H, moves easily through bushing piece, G, and over guiding rod, I. The double guide effectually prevents any oscillation in the flow of gas due to lateral movement of the valve. The weight of the bell, rod, and valve is supported by the float, J, which, as in the station governor, is an air vessel attached to the interior bottom side of the bell and concentric with it, and of such capacity as to afford the necessary support. The tube, K, is intended to serve a double purpose—first, to act as an overflow pipe to the tank, L, for which purpose it is carried right down through the inlet chamber to the well in the base chamber, so as to prevent any spraying of water on to the valve or its seating, and thereby setting up corrosion; and, secondly, to act as a controlling tube, through which the gas passes from the inlet chamber to the interior of the bell, H. For this purpose a series of holes are drilled in the side of the tube. The space between the crown of the bell, H, and the cover plate is

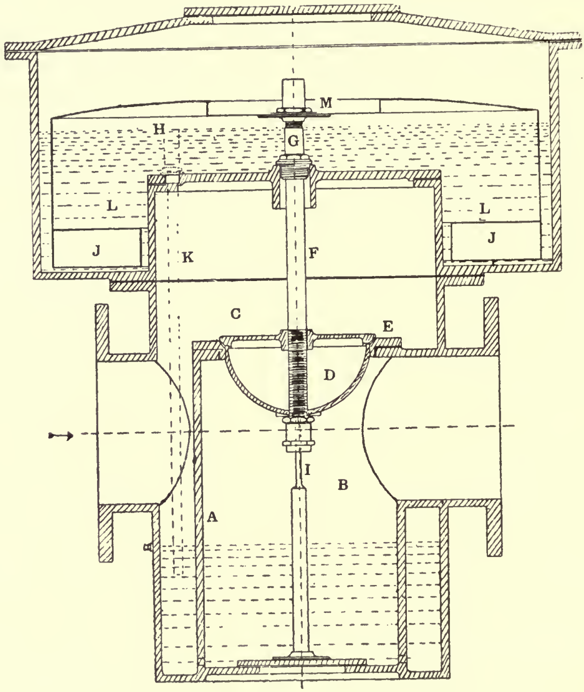


Fig. 22.—Braddock's District Governor.

in free communication, through the hollow rod, F, with the outlet chamber, so that the bell has perfect freedom of action in rising and falling; and the governor is adjusted by means of weights placed upon the dished portion of the bell, M.

It will be seen, therefore, that the action of this governor varies very considerably from that of the station governor. With the latter instrument the object is to maintain a constant outlet pressure, under all fluctuations of inlet pressure and of demand for gas. The work of the district governor is differential only, the aim being simply to reduce the pressure as between inlet and outlet by a predetermined amount. When, therefore, the governor has been adjusted properly to effect the reduction desired, if the pressure upon the inlet is increased the increase communicated through the tube, K, to the interior of the bell, H, lifts the latter proportionately, and with it the valve, D, which in this governor opens upward, and thus allows more gas to pass and correspondingly increases the pressure on the outlet. If the inlet pressure be increased by 1 inch, the outlet pressure will be increased by a like amount, whilst if the inlet pressure is reduced the outlet pressure is reduced likewise. There is, therefore, a definite relationship continually maintained between inlet and outlet pressure, or, in other words, the governor is a differential one.

Peebles' district governor.—Of an altogether different type is the district governor manufactured by Messrs Peebles & Co., which is shown in Fig. 23 (p. 76). This is used for placing on mains underground and in inaccessible places.

The base of the governor consists of a cylindrical tank, A, within which the bell, B, is floated. Above the bell the governor is divided by the partition, C, into inlet chamber, D, and outlet chamber, E, which are in communication through the two valves, F and G. The latter, which are carried by the roof of the bell, are pyramidal in form and placed apex to apex, and made to slide easily within the valve seats, H and I. The seats are formed of short cylinders, open at each end, in the sides of which conical-shaped ports are cut for the passage of the gas, similar to those in the Peebles station governor. These cylinders, therefore, give just sufficient play to enable the valves to work easily, effectually prevent any lateral movement of the valves, and render oscillation absolutely impossible. Any variations of inlet pressure which may take place are completely neutralized by being brought to bear equally, but in opposite directions, upon the faces of the valves.

For the purpose of regulating the pressure a small chamber or recess is formed in the governor cover, in which weights can be put on or taken off the spindle to obtain the required outlet pressure. In this arrangement the governor bell is always provided with a float.

If, however, it is intended that the governor shall be used to maintain a uniform outlet pressure, and the exigencies of the situation have led to its being fixed in a busy thoroughfare or other position inconvenient for frequent adjustment, the loading may be effected by means of pneumatic pressure, which is obtained from a small airholder fixed in some convenient building or street pillar box more or less adjacent to the governor. This is the arrangement shown in Fig. 23 (p. 76). The bell of this auxiliary holder is sustained by a float, weights placed on the top of the bell giving the pressure necessary to actuate the governor. In this arrangement neither weights nor float are required for the governor bell.

The method of working is exceedingly simple. Suppose the governor when in action is adjusted to maintain a certain outlet pressure. If the pressure on the outlet, and consequently upon the roof of the bell, becomes diminished, owing to increasing consumption, the weight upon the air-holder remaining constant, the governor bell rises, carrying with it the valves, F and G. The latter in their

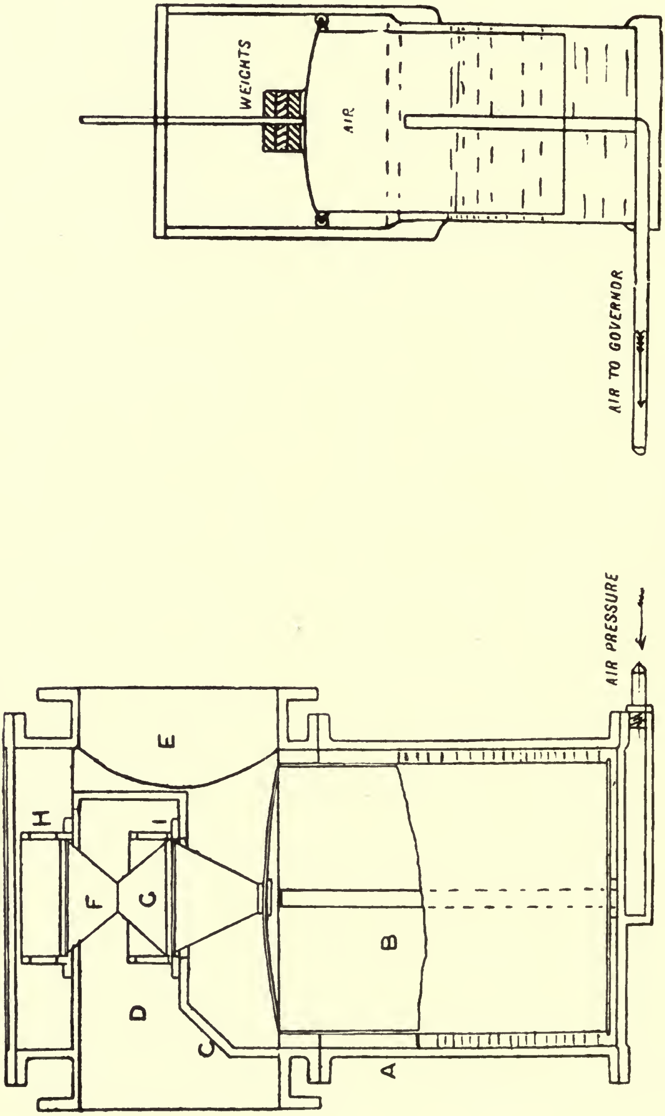


Fig. 23.—Section through Peebles' Governor, with Water-Seal, showing Pneumatic Loading Arrangement.

travel uncover a proportionately greater area of the ports in the valve seats, thus allowing more gas to pass to restore the balance. If, on the other hand, owing to lessened consumption, the pressure upon the outlet and upon the roof of the bell becomes increased, the downward thrust depresses the bell and valves, thus diminishing the area of the ports uncovered and reducing the quantity of gas passing, until equilibrium is again restored.

By the addition of more weights upon the air-holder bell, the pressures may be augmented at any time to suit the requirements of the moment, and when once loaded the governor will maintain the pressure at whatever the weights are adjusted to give. As the inlet pressure does not act directly upon the water seal, this governor is calculated to act as well with high-pressure distribution as with the pressures usually adopted.

A distinctive feature of this governor is the large area of the bell in comparison with that of the valves, by which great sensitiveness of action is obtained, thus securing a perfect uniformity of outlet pressure.

The Venturi tube control.—The principle of the Venturi tube has also been recently applied to the controlling of district governors by Herr H. Kaiser, of Berlin. The law of the Venturi tube is that "a fluid flowing through a pipe of diminishing area gains velocity, while

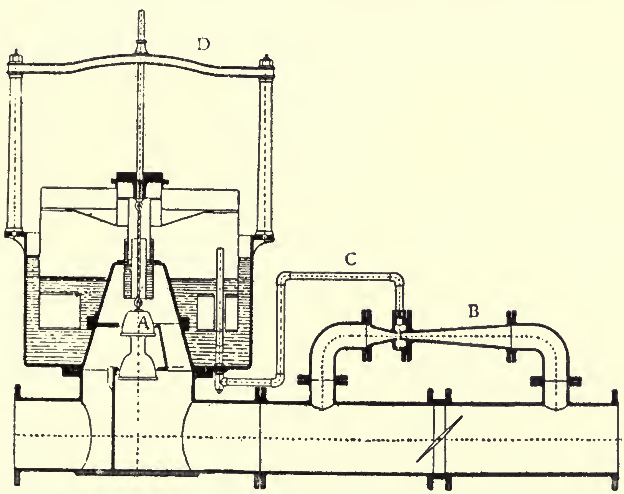


FIG. 24.—Section through District Governor with Venturi Tube Control.

losing the pressure it exerts laterally; and as it flows through the expanding tube it loses its speed and gains pressure. Thus, there will be a difference of pressure between a point in the full-sized pipe and at the ' waist ' of the constricted pipe. This difference is known as the ' Venturi head.' It increases with the velocity of the flow."

Fig. 24 shows how this principle has been applied by Herr Kaiser. Upon the outlet of a two-coned district governor the Venturi tube, B, is connected up, and from the " throat " a small tube, C, is carried to the interior of the governor bell. When the flow of gas is sluggish, the pressure at the throat is the same as in the main, and there is no differential pressure or head. When, however, consumption and consequently the velocity of flow increases, the tube, C, communicates a reduced pressure to the interior of the bell, and the latter, losing a portion of its support, falls, and with it the valves, A. An equivalent result is therefore obtained to increasing the load on the bell. As consumption falls off again, the action is reversed and the bell rises, thus closing the valves and reducing the quantity of gas passing until equilibrium is again restored. The Venturi tube and the governor may be fitted up in any relative position as may be desired or convenient.

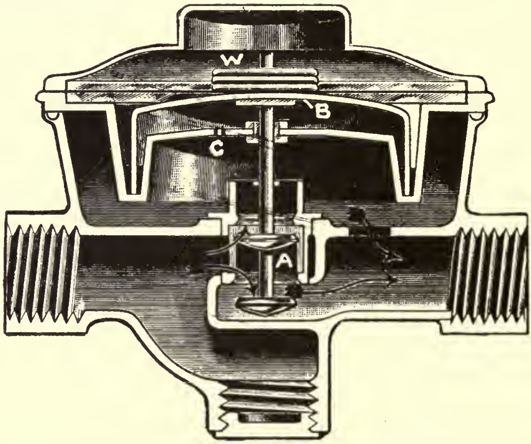


FIG. 25.—Section through Peebles' Mercurial Service Governor.

It is obvious that if more than one trunk main supplies the district to be governed, there must be a governor fixed upon each of them, and that the governors should be adjusted to work together ; also that if the higher altitudes are reached by a long, steady rise, or if the differences of level are great, it may be advisable to fix more than one district governor upon a single line of main to the extent of, say, one for every 100 feet of rise. This allows the pressures to be progressively reduced, instead of having a large reduction at a single point, with all the disadvantages the latter course involves.

Service Governors.—It is becoming increasingly recognized that, with modern distribution at far higher pressures than were formerly thought necessary, together with the sensitiveness of the inverted burner to fluctuations of pressure and the necessity for the efficient working of fires, cookers and burners of a regular and uniform pressure, local governing must be adopted. This may be carried out by separate unit regulators or one general regulator for the whole premises. Where the latter are not large, and are adequately fitted, the service governor will prove most convenient. These may be either of the mercurial or diaphragm type.

Peebles' mercurial governor, shown in Fig. 25, is an excellent one of this kind. The action will be readily understood from what has gone

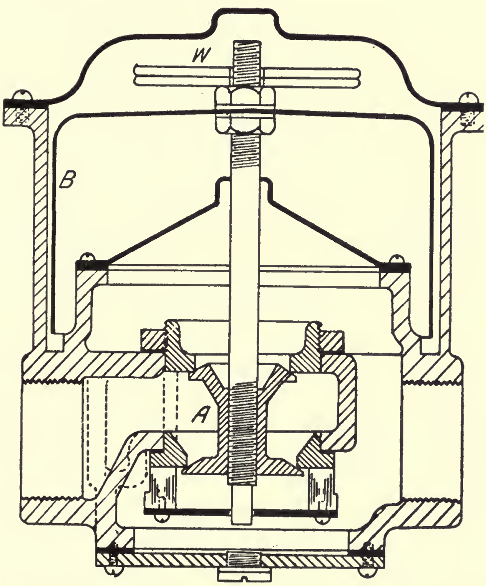


FIG. 26.—Section through the Horsfall Governor.

before in relation to station governors. The valves, A, are of equal area, and as the entering gas exerts its pressure upon them in opposite directions they are uninfluenced by varying inlet pressures. The pressure of gas on the outlet side passing through hole, C, supports the bell, B, which floats freely in a mercury seal. The pressure to be maintained is adjusted by the weights, W, upon the bell. Fluctuations in the demand for gas are conveyed to the bell, B, which rises or falls accordingly, carrying with it the valves, A, and opening or closing the port as may be required to maintain the outlet pressure at the predetermined standard. One great advantage of this form of governor is that being wholly metallic it is practically indestructible. The second is that the mercury seal permits the bell and valve to move with the minimum of friction, and consequently the governor is extremely sensitive.

Another mercurial governor of a very robust type is shown in Fig. 26 (p. 79). The operation will be readily followed from the preceding description, the parts being similarly lettered. The governor is strong, cheap and reliable, and is being taken up very largely by the London, among other, gas undertakings.

The service governor of the diaphragm type is shown in Fig. 27. This consists of an upper and lower chamber separated by the metallic

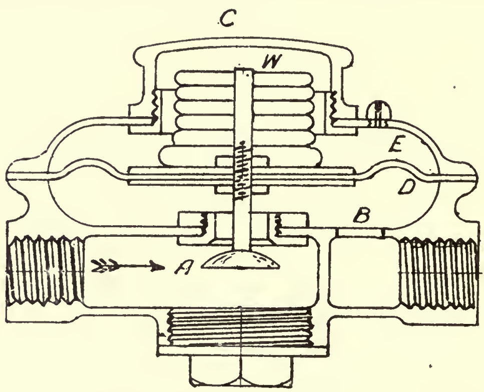


Fig. 27.—Section through Peebles' Diaphragm Governor.

disc, from which the valve, A, is suspended and the diaphragm, D. The base is divided into an inlet and outlet chamber communicating through valve A. The upper chamber accommodates the weights, W, and is secured by the cap, C. The weights are adjusted to give the desired outlet pressure. Fluctuations in demand leading to varying pressures are communicated from the outlet, B, to the under side of diaphragm, D, causing it to rise or fall accordingly, which by carrying with it the valve, A, varies the port area proportionately and so restores the balance.

CHAPTER VIII

CAST-IRON PIPES AND IRREGULARS

If the distributory system of any gas undertaking is to be as perfect as possible, it is imperative that the medium through which the distribution takes place should be of the very best, both in kind and quality. The "efficiency" and "economy" so frequently spoken of, but not quite so often attained, clearly make this essential.

In the early history of gas lighting many very ingenious suggestions were made as to the cheapest and most suitable kinds of pipes for use in the distribution of gas. The first mains, laid by Winsor in Pall Mall, were of sheet lead bent to cylindrical form, and soldered at the edges. Murdoch's first mains were made of tinned iron and copper. In succession to these, pipes made of wood and asphalt, cement, concrete, bitumenized paper, slate refuse, brickwork and earthenware have been seriously suggested as suitable for use as gas mains.

In this connection, probably one of the most interesting exhibits at the Gas Exhibition held at Earl's Court in December 1904 was a piece of 9-inch earthenware or fireclay gas main, similar to those shown in Fig. 28 (p. 82). This had formed part of a main which was laid for the Cambridge Gas Light Company, to whose engineer, Mr James W. Auchterlonie, the writer is indebted for the photograph shown, and for the following brief description.

"As far as can be ascertained, the main, approximately 1000 yards in length, was laid about sixty years ago by Mr John Grafton, a London engineer. The pipe is, roughly, 9 inches in internal diameter. The joints were all made with Roman cement, and the main was also coated internally to the thickness of about $\frac{3}{8}$-inch, and on the top and sides to the thickness of $\frac{1}{4}$-inch, with the same material. The blocks of which the main is built are about 12 inches long, and the bend in the foreground is in two halves, divided longitudinally. The hole on the right hand of the rule in the figure is about $1\frac{1}{2}$ inches diameter in the clear, and was probably used for the attachment of a service or small main connection. It is somewhat difficult to imagine that such a connection could remain gas-tight for a very long period. The ordinary cement joints of this piece of the main are quite good and sound, and have every appearance of being perfectly gas-tight."

The interest attaching to all the above descriptions of pipes, however, is now merely of an historical character, for none of them have stood the practical test of extended experience.

In a far different category must be classed the pipes associated with the name of M. Chameroy, which have been used very extensively on the Continent, and some of which the author saw being taken out of the ground when he was recently in Paris. These were made of tinned sheet iron bent to the required size, and the edges strongly riveted and soldered. The pipes were then tarred and wrapped with

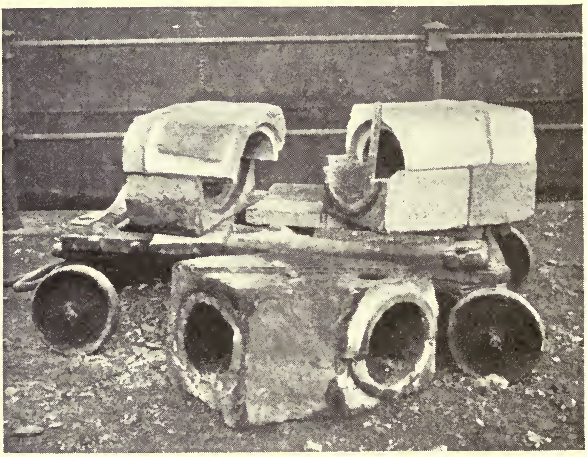


FIG. 28.—Photograph of 9-inch Earthenware Main excavated at Cambridge.

coarse canvas, and further coated with a mixture of bitumen and sand to the depth of from $\frac{1}{4}$-inch to $\frac{5}{8}$-inch, according to the size of the main and the local conditions. In the smaller sizes, male and female cast screws, composed of an alloy of lead and antimony, were soldered at the ends for connecting one pipe with another. Services of lead pipe are soldered to the Chameroy main and the portion disturbed re-asphalted.

In some districts of the United States considerable use has been made of Tamarch logs, bored out to the required size, as pipes for the conveyance of gas. These have proved cheap and very durable, especially in wet and marshy soils. Pipes made of wood staves $1\frac{1}{2}$ inches to $1\frac{5}{8}$ inches thick, banded together with $\frac{1}{2}$-inch round rods, are even to-day being used in various parts of the States for water mains up to 36 and 44 inches in diameter.

At the present time, however, as far as the United Kingdom is concerned, we have to consider but two kinds of material for our main pipes, namely, cast-iron, and, under certain conditions, its young and pushing rival, steel. For all ordinary purposes cast-iron "holds the field." It is strong, durable, adaptable, easy of manipulation, and cheap.

There is, however, one drawback, and that is its liability to fracture, especially in pipes of small diameter, owing to its inability to withstand heavy and suddenly applied loads. The recent great development in the use of steam road rollers, traction engines, and other heavy traffic along our thoroughfares, has, of course, greatly increased the possibility of such fracture taking place.

Improvement in cast-iron pipes.—As might have been expected, the enormous growth of the cast-iron pipe industry, during the past half century or more, has caused a great amount of time and attention to be given, on the part of ironfounders, to the improvement of the

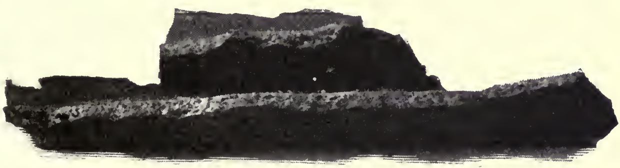


FIG. 29.—Faulty Cast-Iron Pipe.

quality and workmanship of the goods placed upon the market. Whereas twenty or thirty years ago it was not at all unusual for pipes to be found of such a spongy character or so badly cast as to be almost, if not quite, porous, or so hard that it was very difficult indeed to drill and tap them, such things are almost unknown to-day. Fig. 29 is a reproduction of a photograph of a piece of old pipe of a not uncommon character recently taken out of the ground by the author.

The quality of the iron to be used for pipes is of the utmost importance to the gas engineer. It should be dense, tough, perfectly homogeneous and of great tensile strength—not so soft as to be porous, yet not sufficiently hard as to crack when cut with a chisel. A solid bar of the metal of 2-inch by 1-inch section, placed on supports 3 feet apart, should be capable of sustaining a load of at least 28 cwts. in the centre, with a maximum deflection of 0.3 inch. As a test for tensile strain, a similar rod should be capable of sustaining a load of not less than 7 tons per square inch of section.

In consequence of the rather wide range of variation in the characteristics and grades of iron ore to be found in different parts of the country, it is practically impossible to specify at all minutely the chemical composition of the iron to be used. The following table, however, gives the composition of iron used by three of the principal pipe founders in the country.

Constituents.	Works.		
	A	B	C
	Per cent.	Per cent.	Per cent.
Iron	92.32	92.62	92.476
Combined Carbon	0.28	0.37	0.46
Graphitic Carbon	3.10	2.79	2.80
Manganese	0.85	0.53	0.63
Silicon	2.00	2.45	2.36
Sulphur	0.05	0.05	0.074
Phosphorus	1.40	1.19	1.20
Arsenic	0.00	0.00	0.00
	100.00	100.00	100.00

The proportion of sulphur should be as low as possible. Phosphorus may vary from 1 per cent. to 1.50 per cent. For silicon the minimum limit should be 1 per cent., and it should not rise to more than 2.50 per cent. If under 1 per cent. the iron will prove too hard for the purpose, while if the 2.5 per cent limit be exceeded the iron will probably be too soft and open in texture.

The great importance attached to the quality of the raw material applies equally to the method of casting. All pipes down to and including those of 3 inches in diameter should be cast vertically. The reason for this stipulation is that, however great care may be exercised by workmen, there is always the danger that if the pipes are cast horizontally, or at an inclination, the metal may be unequally distributed through the section of the pipe, caused by a slight shifting of the core from its true position. It was usual at one time to cast all the smaller sizes either horizontally or at an angle; and frequently, when taking old pipes out of the ground, it is found that the metal is much thicker upon one side of the pipe than upon the other. Fig. 30 shows a few samples of pipes of this kind recently excavated, and Fig. 31 shows a particularly bad specimen. Such pipes have often been the cause of imperfect connections, and consequential leakage, through the impossibility of obtaining sufficient depth of thread for a good attachment, when it has been necessary to drill the main upon the thin side.

Test for uneven pipes.—A pipe in which the metal is thus unequally distributed through its section may be easily detected, by the simple device of rolling it upon a couple of level rails or lengths of wrought-iron tube. If it always comes to rest with one particular side of the pipe uppermost, it may reasonably be inferred that, when in that position, the lower portion of the pipe is the heavier, and consequently the thicker.

Pipes cast with sockets downward.—Although at some of the

French ironworks the method is adopted of casting pipes with their sockets upwards, the exact opposite is the rule in the best of our English ironworks, and that for a very simple reason. When the

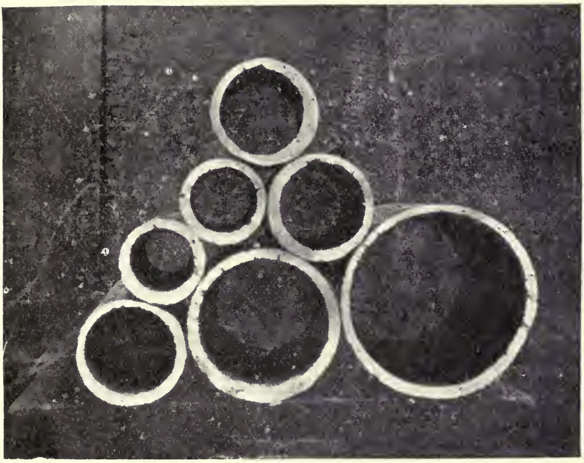


FIG. 30.—Section through uneven pipe castings.

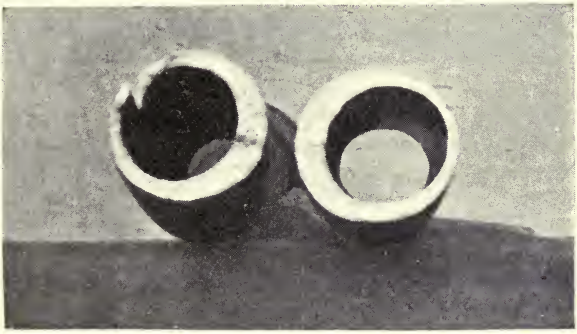


FIG. 31.—Section through 4-inch bend showing uneven casting.

pipe is cast with the socket downward, the latter, by reason of the weight of metal above it, is rendered very dense in solidifying. It is thus more capable of withstanding the great strain to which it is subjected in the process of jointing, and the risk of split sockets is reduced to a minimum. Few things are more exasperating than to have a length of main well and truly laid, only to find the work rendered useless through split sockets evidencing themselves, entailing the additional expense of cutting out and rejointing, in addition to the accompanying inconvenience and delay.

Precaution to ensure density of spigot end.—It has been the custom generally for engineers to specify that pipes should be run with enough head of feed to ensure a sufficient density of the iron at the spigot end. Then any slag or impurity present, rising naturally to the top of the feed, would be removed with the surplus material when it was turned off in the lathe. This specification is frequently maintained even now. It is found, however, in modern practice, to be almost a superfluity of caution. By keeping a sufficiently

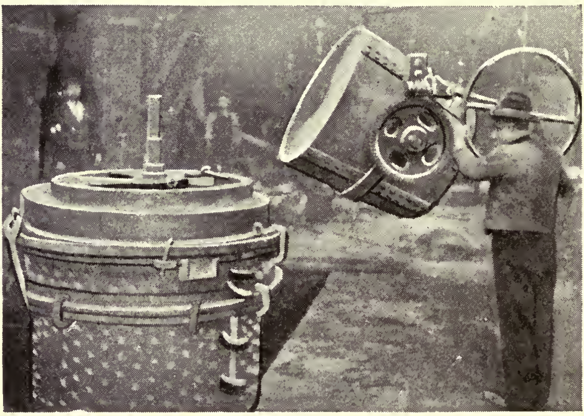


FIG. 32.—Casting large pipes at the Staveley Ironworks.

high percentage of graphitic carbon, silicon and phosphorus in the mass, the molten iron may be made to run so easily that the slag and impurities present rise freely to the top of the ladle, and are not allowed to enter the mould at all.

Lengths of pipes.—A development which we owe probably, in the first instance, to the American ironfounders has lately been made in the direction of casting pipes in greater lengths than was previously the case. Until a few years ago it was the common practice for pipes of 3-inch diameter up to those of 8-inch or 10-inch diameter to be cast in lengths of 9 feet. Those of 12-inch diameter and upwards were, and are still, cast in 12-feet lengths. The best pipe founders are now commencing to cast all sizes of pipes above 3-inch diameter in 12-feet lengths. The resultant economy in weight of material alone, in a long length of main, is very considerable. Suppose 1000 yards of 8-inch main be taken as an example. If 9-feet pipes be used there would be 333.3 sockets in the length. If 12-feet pipes, the number would be reduced to 250, or 80.3 sockets less. These represent a weight of metal equal to 1 ton 11 cwts. 0 qrs. 14 lbs., clearly saved in each 1000 yards. In other words, as a socket is approximately equal to 1 foot of pipe in weight, there is a saving equal to 80.3 feet of main in each 1000 yards run.

But this is only the commencement of the economy. It costs approximately 2s. to make an 8-inch joint in the usual way, with yarn and lead. There would, therefore, be a saving of 83.3 times 2s. on jointing, whilst a less amount of excavation would be necessary

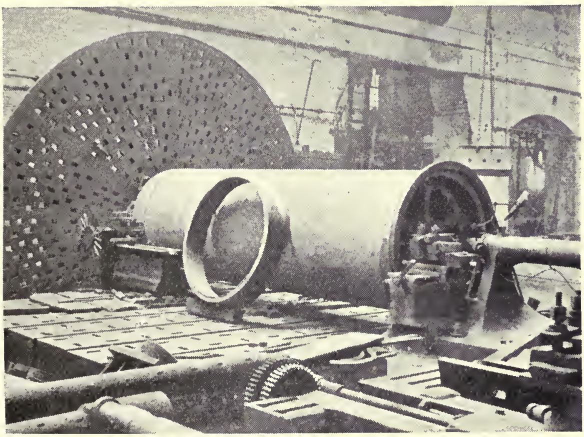


FIG. 33.—Spigot end of 44-inch pipe being cut off in lathe.

for this purpose. And, in addition, the lessened number of joints would also imply fewer potential points of leakage, so that the unaccounted-for gas should be proportionately reduced.

Advisability of casting longer lengths in the larger sizes of pipes.—Unfortunately, the forward movement referred to appears to have spent itself for the present upon the smaller sizes of pipes. There is no doubt, however, that the increasing need of keeping down capital expenditure, and the other advantages to be derived, will inevitably act in the direction of causing engineers to specify longer lengths than those at present usually cast for pipes of 14-inch diameter and upwards. There seems to be no sufficient reason why the larger sizes of pipes should not be cast in 15-feet, or even 18-feet lengths. There would then be a reduction in the number of sockets necessary in each 1000 yards run of main from 250 to 200 or 166.6, according to the length chosen, which would represent a very considerable weight of metal, besides the reduction in cost of jointing. If the saving thereby effected were multiplied out over a few years' main-laying operations of any large gas undertaking, it would total up to a very considerable sum.

The following table shows the economy accruing from the use of 12-feet, as compared with 9-feet, pipes, worked out over 1000 yards run of a few sizes of pipes as examples :—

Size of Main. Inches.	Weight of Metal Saved. Tns.	Cwts.	Qrs.	Lbs.	Value of Metal Saved. £	s.	d.	Cost of Joining Saved. £	s.	d.	Total Saving. £	s.	d.
4	0	13	3	20	3	16	7	4	19	4	8	15	11
6	1	2	0	9	5	18	8	7	10	9	13	9	5
8	1	11	0	14	8	3	5	9	15	4	17	18	9

Working out in the same way the saving effected by substituting 15-feet lengths for the 12-feet lengths at present used, over three of the larger sizes of pipes, we obtain the following results :—

Size of Main. Inches.	Weight of Metal Saved. Tns.	Cwts.	Qrs.	Lbs.	Value of Metal Saved. £	s.	d.	Cost of Joining Saved. £	s.	d.	Total Saving. £	s.	d.
18	2	18	2	18	13	11	3	16	3	2	29	14	5
24	4	12	1	3	21	6	9	25	10	10	46	17	7
30	6	18	1	16	32	0	0	33	11	8	65	11	8

The prices taken are as follows :—

	£	s.	d.	
4-inch pipes . . .	5	10	0	per ton.
6 ,, . . .	5	7	6	,,
8 ,, . . .	5	5	0	,,
18 ,, . . .	4	12	6	,,
24 ,, . . .	4	12	6	,,
30 ,, . . .	4	12	6	,,

Standardization of pipes.—It is a matter for regret that, so far, it has not been found possible to standardize the various sizes of cast-iron pipes. Engineers and ironmasters alike have their own preferences, which, within certain limits, vary considerably. The inconveniences which frequently arise when pipes from different works have to be jointed together is perfectly well known. The table and key illustration given on the next page will be found to give a fair average specification for good serviceable pipes.

Pipes of 60 to 80 inches in diameter are cast to specification. Two-inch cast pipes have not been included in the above list. Owing to their extreme liability to fracture, coupled with the difficulty of making proper service connections without greatly weakening an already over-weak pipe, and throttling the gas flow in the process, cast pipes of under 3 inches diameter are being rapidly discarded. The increased first cost of 3-inch pipes is amply compensated for by their greater strength and the possibility of attaching the larger service pipes which a general use of gas cookers has rendered necessary.

Light pipes.—The very severe competition during recent years amongst the various pipe founders has resulted in quantities of light pipes being placed upon the market. Whilst by the use of these pipes some saving may be made in the initial cost per mile of main, it must prove a very false economy. Thinner pipes inevitably mean a shorter pipe life, less perfect service connections, increased danger of fracture in cutting, or from road traffic, and risk of splitting of sockets and spigot ends in handling, carting and mainlaying.

MEASUREMENTS AND WEIGHTS OF CAST-IRON PIPES.

Measurements in Inches.												Ft.	Average Weight			
A	B	C	D	E	F	G	H	I	K	L	M	N	Tns	Cts	Qrs	Lbs
3	$3\frac{3}{4}$	$4\frac{1}{2}$	$5\frac{5}{8}$	$6\frac{7}{16}$	4	$3\frac{3}{4}$	$2\frac{1}{2}$	$\frac{3}{4}$	$3\frac{15}{16}$	$\frac{3}{4}$	1	9	0	1	0	14
4	$4\frac{7}{8}$	$5\frac{5}{8}$	$6\frac{7}{8}$	$7\frac{3}{4}$	$5\frac{3}{16}$	4	$2\frac{1}{2}$	$\frac{3}{4}$	$5\frac{1}{16}$	$\frac{3}{4}$	$1\frac{1}{8}$	12	0	2	0	12
6	$6\frac{15}{16}$	$7\frac{11}{16}$	$9\frac{1}{4}$	$10\frac{1}{4}$	$7\frac{1}{4}$	$4\frac{1}{4}$	$2\frac{3}{4}$	$\frac{3}{4}$	$7\frac{1}{8}$	$\frac{7}{8}$	$1\frac{1}{4}$	12	0	3	1	16
8	$8\frac{15}{16}$	$9\frac{11}{16}$	$11\frac{1}{4}$	$12\frac{1}{4}$	$9\frac{3}{8}$	$4\frac{1}{2}$	3	$\frac{3}{4}$	$9\frac{3}{16}$	$\frac{7}{8}$	$1\frac{1}{4}$	12	0	5	1	23
10	$11\frac{1}{4}$	$12\frac{1}{8}$	$13\frac{11}{16}$	$14\frac{11}{16}$	$11\frac{11}{16}$	$4\frac{1}{2}$	$3\frac{1}{4}$	$\frac{3}{4}$	$11\frac{1}{2}$	$\frac{7}{8}$	$1\frac{1}{4}$	12	0	7	2	10
12	$13\frac{1}{4}$	$14\frac{1}{8}$	16	17	$13\frac{3}{4}$	$4\frac{1}{2}$	$4\frac{1}{4}$	1	$13\frac{5}{8}$	$\frac{7}{8}$	$1\frac{3}{8}$	12	0	9	1	18
14	$15\frac{1}{2}$	$16\frac{3}{8}$	$18\frac{5}{8}$	$19\frac{5}{8}$	16	$4\frac{1}{2}$	$4\frac{1}{4}$	1	$15\frac{7}{8}$	1	$1\frac{3}{8}$	12	0	10	2	0
16	$17\frac{1}{2}$	$18\frac{3}{8}$	$20\frac{7}{8}$	$21\frac{7}{8}$	18	$4\frac{1}{2}$	$4\frac{1}{4}$	1	18	1	$1\frac{3}{8}$	12	0	13	2	0
18	$19\frac{1}{2}$	$20\frac{3}{8}$	$22\frac{7}{8}$	$23\frac{7}{8}$	$20\frac{1}{8}$	$4\frac{1}{2}$	$4\frac{1}{4}$	1	20	$1\frac{1}{8}$	$1\frac{1}{2}$	12	0	16	0	0
20	$21\frac{3}{4}$	$22\frac{3}{4}$	$25\frac{1}{2}$	$26\frac{1}{2}$	$22\frac{5}{8}$	$4\frac{1}{2}$	$4\frac{1}{4}$	1	$22\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{1}{2}$	12	0	18	2	8
22	$23\frac{3}{4}$	$23\frac{3}{4}$	$26\frac{1}{2}$	$27\frac{1}{2}$	$24\frac{5}{8}$	$4\frac{1}{2}$	$4\frac{1}{4}$	1	$24\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{1}{2}$	12	1	0	2	14
24	$25\frac{3}{4}$	$26\frac{3}{4}$	$29\frac{3}{4}$	$30\frac{3}{4}$	$26\frac{5}{8}$	5	$4\frac{1}{4}$	1	$26\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	12	1	4	0	0
30	32	33	$36\frac{1}{8}$	$37\frac{5}{8}$	$32\frac{7}{8}$	5	$5\frac{1}{4}$	1	$32\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{3}{4}$	12	1	16	0	0
36	38	39	$42\frac{1}{4}$	$43\frac{3}{4}$	$38\frac{7}{8}$	5	$5\frac{1}{2}$	$1\frac{1}{4}$	$38\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{3}{4}$	12	2	3	2	18
42	$44\frac{1}{4}$	$45\frac{1}{4}$	$48\frac{1}{2}$	50	$45\frac{1}{8}$	5	$5\frac{1}{2}$	$1\frac{1}{2}$	$44\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{3}{4}$	12	2	16	0	0
48	$50\frac{1}{4}$	$51\frac{1}{4}$	$54\frac{1}{2}$	56	$51\frac{1}{8}$	5	6	$1\frac{1}{2}$	$50\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{3}{4}$	12	3	4	0	0
54	$56\frac{1}{2}$	$57\frac{1}{2}$	$60\frac{3}{4}$	$62\frac{1}{4}$	$57\frac{3}{8}$	5	6	$1\frac{1}{2}$	57	$1\frac{1}{4}$	$1\frac{3}{4}$	12	3	19	2	0

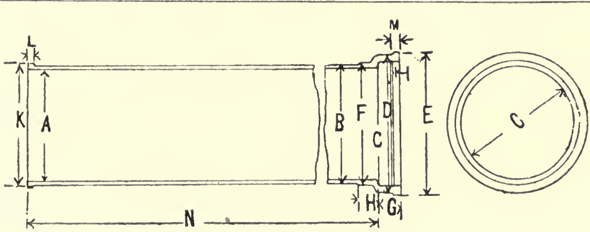


FIG. 34.—Dimensions and weights of cast-iron pipes.

Protective coating.—It is usual now for pipes to receive at the ironfounders a coating of Dr Angus Smith's composition, consisting of a mixture of tar and pitch, into which the pipes are dipped. The pipes should either have been previously heated themselves, or be allowed to remain in the solution sufficiently long to attain the temperature of the latter. The small additional first cost is amply recouped in the protection afforded to the pipes, and consequently by their increased durability. The coating should be limited to the exterior of the pipe; the portion of the spigot entering the socket being also left uncoated. Coating the interior of the socket and the spigot end prevents a good joint being made, while the coating on the interior of the pipe is dissolved in time by the hydrocarbons of the gas, and, finding its way to the syphons, becomes deposited there as a thick viscous mass which frequently seals the dip pipe and prevents the syphon being pumped.

Tests for soundness.—With the object of making quite certain that pipes do not contain any flaws, cracks or sand holes, it is of the utmost importance that they should be thoroughly tested for soundness, under heavy hydraulic pressure, before being coated at the foundry. It is usual, in the case of pipes to be used for gas mains, to specify a test of 150 feet to 200 feet head of water, approximately equal to 75 to 100 lbs. per square inch. Those to be used for water mains are specified to be tested to a pressure equal to 500 feet head of water. But, as a matter of fact, some of our best ironfounders seldom make any difference between the two, and test their pipes up to pressures of 500 to 600 feet head of water, ordinarily. The higher test is not only useful for the discovery of actual defects, but should the iron be at all open in texture, the water is forced into the pores of the metal, and, by oxidation, completely closes them.

For special high-pressure mains these tests are greatly increased by the use of intensifiers, and may range up to as much as 3000 lbs. per square inch. When pipes are to be used for distribution of gas at high pressures, a pneumatic test should also be applied at a minimum of 50 per cent. greater pressure than the pipes are to be worked at.

Milbourne's "twin pipe."—A very ingenious suggestion was made some few years ago by Mr R. J. Milbourne, Assoc.M.Inst.C.E., for

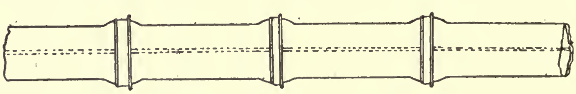
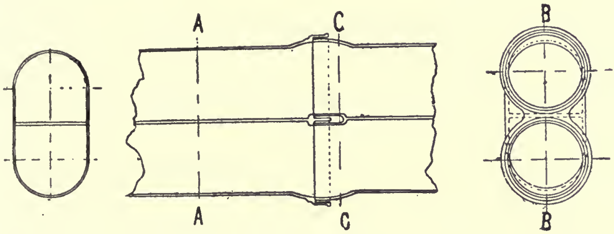


FIG. 35.—Milbourne's "Twin Pipe." Plan showing pipe in position.

a "twin pipe." With a view to saving in cost of excavation, and economy of space required where two pipes have to lie side by side for some distance, as is frequently the case with the inlet and outlet of gasholders, purifier connections, etc., Mr Milbourne suggests that "a pipe of an oval shape, divided into two parts, each having the same capacity or area as the single pipe," should be used. The suggestion will be readily understood by reference to the illustrations. Fig. 35 is a plan showing two 12-feet lengths of "twin pipe" in position. Fig. 36 shows sections on lines A—A, B—B, and C—C respectively.



Section on line A A. Section on line B B. Section on line C C.

FIG. 36.—Milbourne's Twin Pipe—Sections.

(Figs. 35 and 36 are reproduced by the courtesy of the Editor of the *Journal of Gas Lighting*.)

It will be seen that there are practically two pipes in one casting, each 12 feet long, and having double spigot and socket ends for jointing in the usual way with yarn and lead.

The advantages claimed are "economy of space, material, and labour required, combined with facility of handling." It is admitted by the designer that there is an obvious disadvantage in the fact that a fault or fracture in one would inevitably affect both pipes. It would also be impossible to use the ordinary forms of irregulars for connections; but as such pipes seldom require branches that is not a very important point. In the few cases where such are required it would be perfectly easy to design joints to suit the local conditions.

Irregulars.—A few of the commoner stock patterns of irregulars

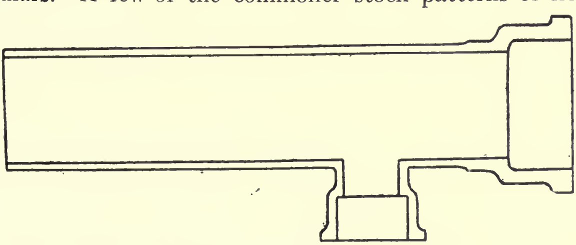


FIG. 37.—Tee-Piece.

are shown in Figs. 37 to 52, the measurements of which, with the exception of plugs, caps, and collars, generally follow those of the same-sized pipe. Fig. 37 shows the usual form of tee-piece, which is made in all sizes from 3-inch diameter to 36-inch, either equal throughout or with outlets of smaller diameter than the main pipe. They may also be cast specially of any form within reasonable limits, either with centres of greater diameter than the run of pipes or diminishing at either socket or spigot end as may be required. It frequently happens that a tee-piece such as that shown on Fig. 37, has to be laid so that the condensation flows through the outlet of the tee. In such cases the tee is cast with the outlet eccentrically placed as shown in Fig. 38, so as to prevent any water lying in the larger pipe. Such a form of casting is also useful, when placed the other way about, for rising over cables or other pipes lying in close proximity.

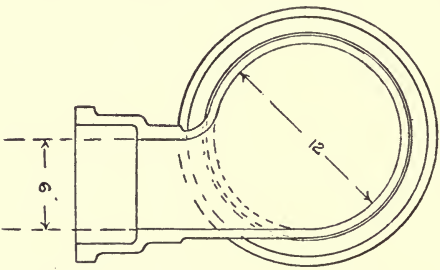


FIG. 38.—Tee with eccentric outlet.

FIG. 39 shows a section through a bend tee, a type which, as was shown in the chapter on discharges, interferes much less with the flow of gas than the sharp right-angle tee shown in Fig. 37.

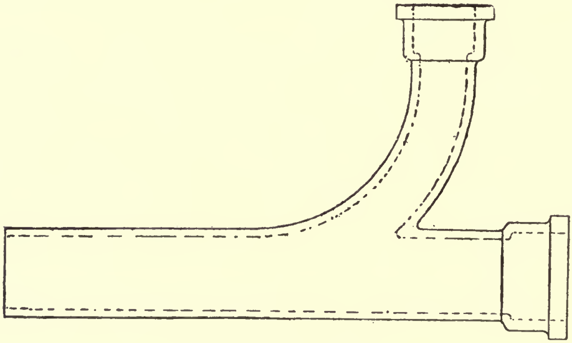


FIG. 39.—Bend Tee.

Fig. 40 shows a section through an angle tee, much used, as its form would suggest, in positions where roadways fork off from each other. In an emergency a one-eighth bend may be used in the outlet to convert this into an irregular bend tee.

The cross tee shown in Fig. 41 is a very valuable irregular, for use where roadways cross at right angles, not only in the equal sizes, as shown, but also for connecting up smaller lateral pipes to trunk or large distributing mains, in which cases the outlet sockets are cast of a size to suit requirements.

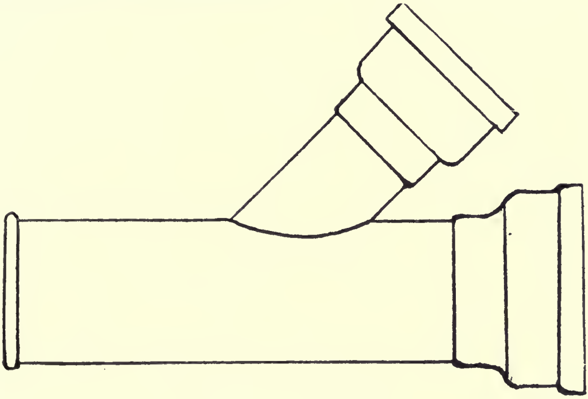


FIG. 40.—Angle Tee.

Figs. 42 and 43 show eighth and quarter bends, respectively. The quarter bends should, where possible, be made of a radius equal to five times the radius of the pipe, for reasons explained in Chapter IV, p. 41. In places where it is found necessary, a wide sweep round may be made by jointing two eighth, or even three twelfth, bends together.

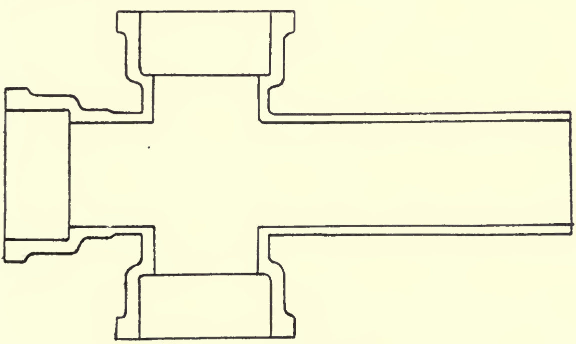
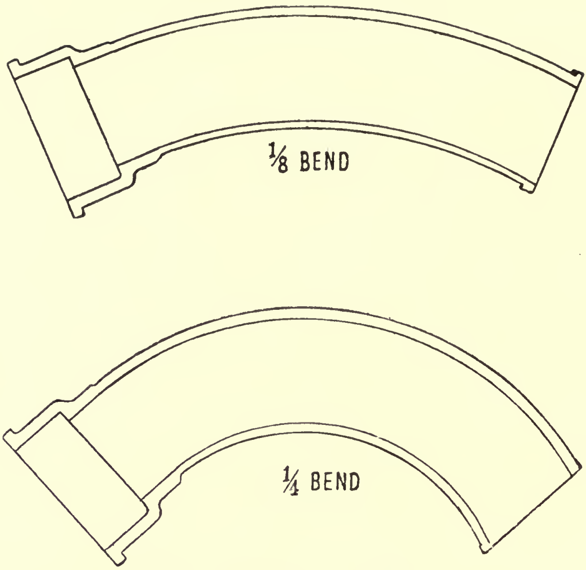


FIG. 41.—Cross Tee.

The double S bend shown in Fig. 44 is a most useful irregular where the line of pipe has to be sharply deflected. It has this great advantage over the use of two quarter or eighth bends, that the joint in the centre is avoided and the even flow of gas through it is not prejudiced through eddyings caused by possible roughness or cavity at the back of the joint.



Figs. 42 and 43.—Bends.

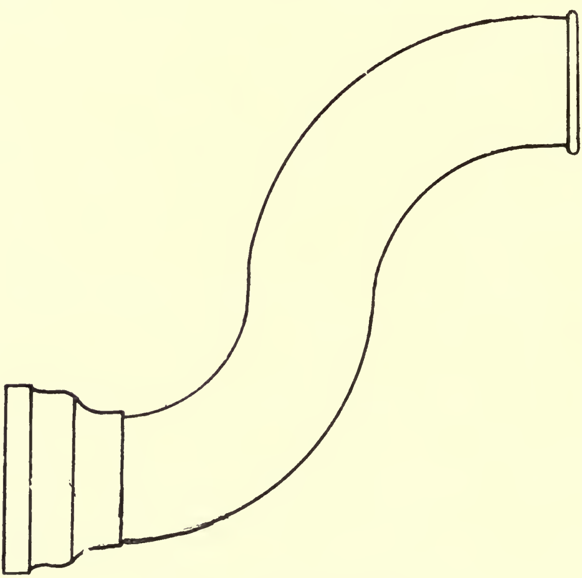


Fig. 44.—Double S Bend.

Syphons.—The Horsley syphon, shown in Fig. 45, is much superior to and more convenient in form than the old deep syphon so generally used a few years ago. It is cast in one piece, and there is therefore no joint, loose top piece or bolts, to trouble with or to get out of order. It also has a greater cubical capacity, and its use results in economy of labour in laying, due to less excavation being necessary.

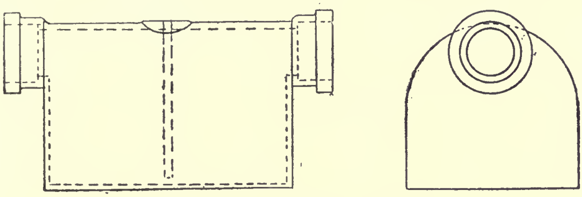


FIG. 45.—Horsley Syphon.

With ordinary care and fixing, the broad base ensures a good bearing surface to support the weight, and to prevent drawn joints, due to possible subsidence of the subsoil. The arched form of top tends to relieve the syphon of a portion of the weight of the superincumbent earth.

In order to afford access to clear out any dirt or tar from the bottom of these syphons, they are now being cast by Messrs James Oakes & Co. with a longitudinal web and cover plate as shown in Fig. 46. So long as the bottom of the diaphragm is sealed, the cover-plate may be removed and any deposit taken out.

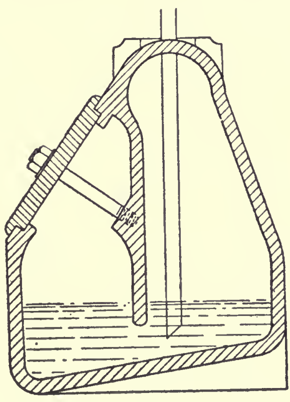


FIG. 46.—Section through webbed syphon.

Belton's "Facile" syphon, shown in Fig. 47 (p. 96), has some advantages even over the Horsley. The contained liquid may be more completely removed, the excavation necessary to accommodate the syphon is lessened, in filling in, the restored earth may be packed and rammed more tightly under and round the body of the syphon, and thus a firm bed is secured. As will be seen from the curve section at A, the design is of the strongest possible, to resist the strains of heavy surface traffic. It is easy to fix, and for its capacity is comparatively light. It also shares with the Horsley syphon the advantages attaching to the arched top. An enlarged section through the suction pipe attachment is shown at K.

The small bottle syphon shown in Fig. 48 is of the form usual for fixing to service pipes. It has a couple of 1-inch holes tapped into two opposite sides, and one of the same diameter upon the top, through which its contents may be withdrawn. It may be fixed either upon the line of service, in the same manner as a main syphon,

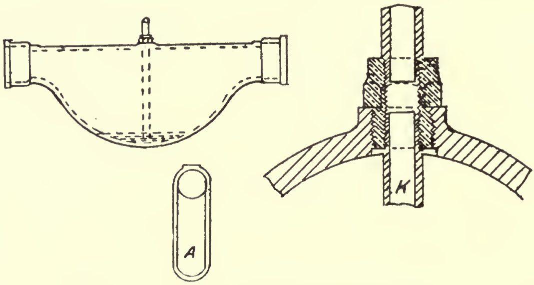


Fig. 47.—Belton's "Facile" Syphon.

or, if the service is more than 1 inch in diameter, it may be connected at the end of the latter by means of a diminishing piece, should the fall be to the end, or it may be attached to the service at the lowest point, by means of a tee-piece and bend, the latter being screwed into the outlet of the tee, which is fixed to look downward.

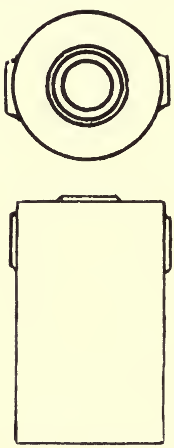


Fig. 48.—Bottle Syphon.

The taper piece shown in Fig. 49 is of the pattern generally used, although it may be also obtained with the socket at the larger and the spigot at the smaller end. The latter is, however, an ill-balanced casting, besides reversing the requirements of the great majority of cases in practical work.

Collars.—With respect to the collar shown in Fig. 50, the author has found it very convenient in actual work to have these made of slightly larger diameter than the socket of the corresponding size of pipe, as shown in Fig. 50 and the accompanying table. They are used so largely for connections, often with specials of uncommon kinds, cast slightly thicker than the usual types, that it is found convenient to allow more jointing space than is necessary with the ordinary socket. A slight deflection of pipes from the straight line, which

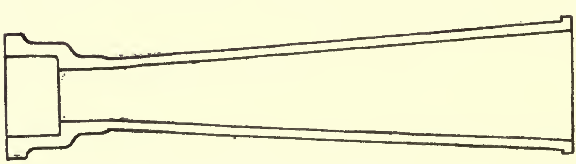


Fig. 49.—Taper Piece.

should be avoided whenever possible, is nevertheless sometimes absolutely necessary, and may frequently be obtained better by means of a collar than by the ordinary socket joint. In the table below, the most useful dimensions for collars of each size are given, the letters referring to the corresponding letters in the figure.

An interesting and useful type of collar is that shown in Fig. 51, manufactured by the Pont-à-Mousson Foundry Company, and

Diam.	A	B	C	D	E	F	G	H
Pipe.	Ins.	Ins.	Ins.	Ins.	Ins.	In.	In.	In.
2	$3\frac{3}{4}$	$6\frac{1}{4}$	8	$5\frac{1}{4}$	1	$\frac{11}{32}$	$\frac{1}{2}$	$\frac{1}{8}$
3	$4\frac{3}{4}$	$7\frac{1}{4}$	$9\frac{1}{2}$	$6\frac{1}{4}$	1	$\frac{11}{32}$	$\frac{1}{2}$	$\frac{1}{8}$
4	$5\frac{3}{4}$	$8\frac{1}{4}$	$9\frac{1}{2}$	$7\frac{1}{4}$	1	$\frac{7}{16}$	$\frac{5}{8}$	$\frac{1}{8}$
6	8	$10\frac{1}{2}$	12	$9\frac{1}{2}$	$1\frac{1}{4}$	$\frac{7}{16}$	$\frac{3}{4}$	$\frac{1}{8}$
8	10	$12\frac{1}{2}$	12	$11\frac{1}{2}$	$1\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{16}$
10	$12\frac{3}{8}$	15	14	14	$1\frac{1}{4}$	$\frac{9}{16}$	$\frac{3}{4}$	$\frac{3}{16}$
12	$14\frac{1}{2}$	$17\frac{1}{4}$	15	$16\frac{1}{4}$	$1\frac{1}{2}$	$\frac{9}{16}$	$\frac{7}{8}$	$\frac{3}{16}$
14	$16\frac{1}{2}$	$19\frac{1}{2}$	15	$18\frac{1}{2}$	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{3}{16}$
16	$18\frac{1}{2}$	$21\frac{1}{2}$	18	$20\frac{1}{2}$	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{3}{16}$
18	$20\frac{5}{8}$	$23\frac{3}{4}$	18	$22\frac{3}{4}$	$1\frac{1}{2}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{3}{16}$
20	$22\frac{3}{4}$	$26\frac{1}{2}$	18	25	$1\frac{1}{2}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{3}{16}$
24	27	$30\frac{3}{4}$	18	$29\frac{1}{4}$	2	$\frac{15}{16}$	1	$\frac{3}{16}$
30	$33\frac{1}{4}$	37	18	$35\frac{1}{2}$	2	1	1	$\frac{3}{16}$
36	$39\frac{3}{4}$	$43\frac{3}{4}$	18	$42\frac{1}{4}$	2	1	1	$\frac{3}{16}$

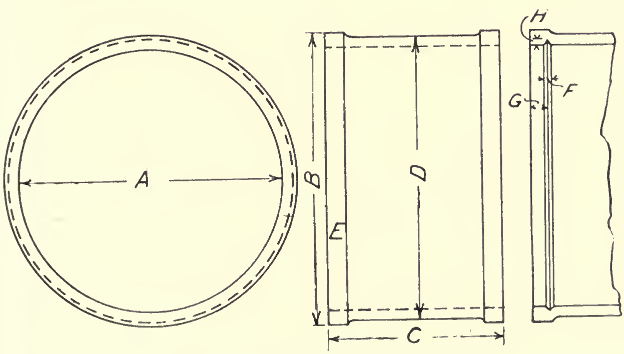


Fig. 50.—Dimensions of Collars.

designed for use with pipes with plain ends. As will be noticed, the collar is slightly tapered on its interior surface, and whilst, on the one hand, allowing for a perfectly tight joint, on the other, affords facilities for pipes to be taken apart. The collar may with little difficulty be driven off with a wooden mell, and the pipe taken out without any of the trouble and risk involved in cutting out in the usual way.

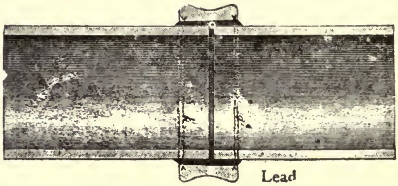


FIG. 51.—Taper Collar.

Plugs and caps.—The plugs and caps shown in Fig. 52 are usually cast about 8 inches in length, the other measurements, A and B, corresponding to those of the spigot and socket ends of the main pipes of similar size. To facilitate their removal, in the event of

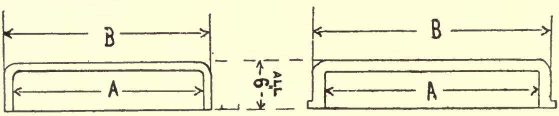


FIG. 52.—Plugs and Caps.

extensions being required, the plug is cast without any bead on the end and the cap without any groove in the interior of the socket.

CHAPTER IX

STEEL PIPES AND CONNECTIONS

ALONG with the enormous development during recent years of the steel industry has come the introduction on an extended scale of the use of steel for gas and water mains. Especially is this so in such cases as the crossing of bridges, where lightness and minimum number of joints are the great objects to be attained, or in districts where freightage is considerable and the cost of carriage for cast-iron pipes becomes almost prohibitive. Steel mains have also been used to great advantage in places where the subsoil has been liable to subsidence, and where, owing to their more elastic properties, they have accommodated themselves to deflection without either the drawing of joints or fracture of pipes which would have been incidental to the use of cast-iron mains. Steel mains will bend or flatten, but not break.

Durability.—Very considerable doubt has been expressed as to the advisability of using either wrought-iron or steel for main pipes, owing to their supposed greater liability to corrosion and consequent shortness of life as compared with cast-iron. It is obvious that this is a matter which only an experience extended over many years can finally solve. Fortunately for our knowledge of this subject, the exigencies of supply have caused steel and wrought-iron pipes to be used rather extensively in Australia and America, and more recently on the Continent and in this country. Consequently, practical experience as to their durability and general adaptability is now beginning to accumulate. In the year 1884 a wrought-iron water main of 30 inches diameter and about seven miles in length was laid in connection with the Melbourne Water Department. It is reported that, after being in use for eighteen years, the main is as sound in every particular as when laid. A similar 24-inch main, also laid in Melbourne, examined after having been buried in the ground for sixteen years, was found to be in perfect working order. Similar testimony is reported from the Continent, where, at Pola and at Ischl, steel mains have been employed under conditions that would have been absolutely fatal to cast-iron. In our own country, the experience gained at Nuneaton, Swansea and Cardiff amply confirms the testimony from abroad. The South Staffordshire Mond Gas Company have laid over thirty miles of mild steel main in their distributory systems, ranging from 26 inches to 36 inches in diameter. Some of the latter mains are laid in ground of the very worst description from the point of view of the durability of the mains. The subsoil contains sulphurous and other compounds, which are most harmful to the life of steel, and is, in addition, very liable to subsidence. Taken altogether, these mains are being subjected to a most severe durability test, and considerable interest will be evinced as to the practical results. If the pipes withstand this test, then they may be used almost anywhere.

There is no doubt that one secret of the durability of steel mains is in the effectual application of a good protective coating. Steel pipes can be readily and efficiently coated, either by being dipped when hot in a hot bath of Dr Angus Smith's solution or by two such dippings, before and after being wrapped with strong Hessian or jute canvas. The latter affords a thick, tough jacket which effectually resists injury. The pipes may also be dipped in Assyrian rubber solution, which forms a tough and adhesive coating, but is somewhat more expensive.

Another excellent protective covering for pipes is that specified in connection with the Brooklyn 72-inch main. This mixture consists of not less than 99.3 per cent. of pure bitumen, consisting of not less than 70 per cent. of petroline soluble in petroleum ether, and not more than 30 per cent. of asphaltene, soluble in chloroform. The coating was to be not less than $\frac{1}{32}$ inch and not more than $\frac{1}{16}$ inch thick.

Advantages.—Should the present favourable evidence as to durability, coming from such widely different places as Australia, America, and Germany, as well as nearer home, be confirmed by ever-increasing experience, there is doubtless a great future for steel pipes in this country, especially if the cost of production can be kept within reasonable limits. They have great advantages over cast-iron mains in the following, amongst other, respects :—

(1) Fewer Joints.—The longer lengths in which these pipes are obtainable necessarily implies the employment of fewer joints, and consequently a very considerable saving in materials and labour for jointing, as well as in labour for excavation.

Steel pipes may be made in any convenient lengths up to 40 feet. The joints may therefore be reduced in number to one-half, or even to one-third, of those necessary with cast-iron pipes.

The immense saving thus made in cost of jointing will be realized at once by a glance at the following table of comparisons. Assuming that in a length of 1000 yards of main of each of the following six sizes of pipes, steel pipes of 36 feet in length are substituted for cast-iron pipes of 12 feet in length, the reduction on this item alone would be as shown in the table on the next page.

The cost of jointing steel mains will, of course, vary with the description of joint adopted, particularly in the case of mains of large diameter. The calculations are, therefore, made on the

Description of Pipe.	Size of Main in Inches.	Length of each Pipe in Feet.	Number of Joints.	Cost per Joint.	Total Cost of Jointing.	Difference, being Reductions in Cost.
				s. d.	£ s. d.	£ s. d.
Cast-iron	4	12	250	1 0.25	12 15 2	—
Steel main	4	36	83.3	—	4 5 0	8 10 2
Cast-iron	6	12	250	1 6.7	19 9 7	—
Steel main	6	36	83.3	—	6 9 10	12 19 9
Cast-iron	8	12	250	2 0.6	25 12 6	—
Steel main	8	36	83.3	—	8 10 10	17 1 8
Cast-iron	18	12	250	5 9	71 17 6	—
Steel main	18	36	83.3	—	23 19 10	47 17 8
Cast-iron	24	12	250	9 2	114 11 8	—
Steel main	24	36	83.3	—	38 3 10	76 7 10
Cast-iron	30	12	250	11 10	147 18 4	—
Steel main	30	36	83.3	—	49 6 1	98 12 3

assumption that the cost per joint would be equal in both cases, which is probably sufficiently accurate for the immediate purpose.

A very great advantage arising incidentally from the diminution of the number of joints, over any given length of main, is that just in proportion as they are reduced, the potential sources of leakage are also diminished. In other words, if the number of joints can be reduced by one-half or one-third, the leakage account should be proportionately benefited.

(2) Lessened weight of material.—The expense of carriage and cartage is becoming a very serious item of costs, not only in country districts, where mainlaying operations have frequently to be carried on at a considerable distance from the nearest railway station, but also in connection with the work necessary to keep pace with the rapid developments upon the outskirts of most of our large cities.

It is obvious, therefore, that if the weight of pipes for any given length can be enormously reduced by the substitution of steel for cast-iron, other things being equal, there will be a great gain under this head in the use of the lighter pipes. And in addition to this direct saving in cost of carriage, there is also the indirect saving of labour in handling the pipes preparatory to, and in the actual work of, mainlaying.

(3) Pipes bendable.—Another great advantage is that steel mains in the smaller sizes may be bent to the very large curves frequently encountered in mainlaying which in the ordinary way could only be negotiated by either special castings and consequently largely increased cost, or by breaking joint and thus risking subsequent unsoundness.

(4) No fracture.—Last, but by no means least, the unbreakable character of a steel pipe must be taken into account. One of the great disadvantages in the use of cast-iron mains in our public

thoroughfares is their liability to fracture owing to heavy road traffic. Steam rollers and traction engines, the latter often conveying very heavy loads through our streets, are the principal sources of this danger. And when this surface traffic is coincident with slight subsidence in the subsoil, the danger of fracture, leading sometimes to explosion and destruction of property, becomes very acute. These risks are entirely obviated by the use of steel mains. The worst that could happen to them would be a deflection, or partial flattening of the main, possibly accompanied by the drawing of one or more joints, quite minor matters compared with complete fracture.

It is interesting, in this connection, to remember that of sixty-

Fig. 53.—Elevation of 36-inch Steel Main over River Aire, at New Wortley, Leeds.

five miles of high-pressure steel mains in San Francisco, it has been reported that not one joint was found broken after the earthquake. The flexibility of the pipes had saved them. In the Palo Alto district, which was considerably nearer the centre of the earthquake disturbance than San Francisco, out of 12 miles of 3-inch steel mains and over 500 services, no leaks were found after the earthquake shock had passed. The resilience of the steel mains had proved their salvation.

Steel mains may be conveniently classified under four headings, viz., riveted, lap-welded, seamless, and lock-bar.

Riveted steel mains.—Two very good examples of this type of steel main are those made by Messrs Clayton, Son and Co., Limited, of Leeds, and carried upon the bridge spanning the river Aire and the Leeds and Liverpool Canal at New Wortley, as shown in elevation in Figs. 53 and 54. For convenience in handling and fixing, these pipes were made in 15-feet lengths only. The mains are of 36 inches internal diameter, the material being mild steel plates of $\frac{3}{8}$-inch in thickness. The longitudinal and transverse seams are of the ordinary lap kind, single riveted, with $\frac{3}{4}$-inch diameter rivets to 2-inch pitch, as shown in plan in Fig. 55. Both ends of the pipe have a solid welded

FIG. 54.—Elevation of 36-inch Steel Main over Leeds and Liverpool Canal, New Wortley, Leeds.

ring of steel angle 3-inch by 3-inch by $\frac{1}{2}$-inch riveted on to the pipe with $\frac{3}{4}$-inch rivets set to 2-inch pitch. All the flanges were machined true in the lathe and had 28 bolt holes drilled in them for $\frac{3}{4}$-inch bolts. The joints are made with lead rings bedded in red lead.

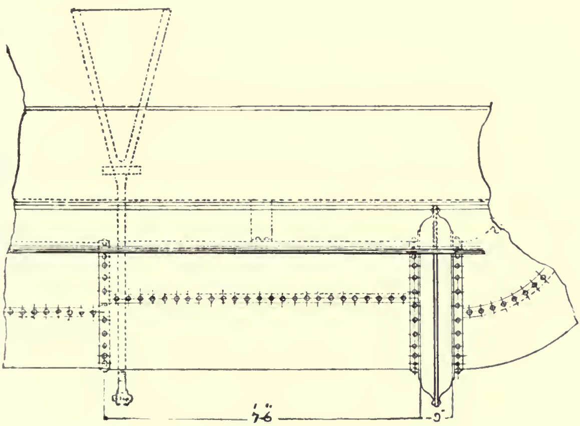


FIG. 55.—Plan of 36-inch Steel Main.

The main is carried by six wrought-iron brackets made of 4-inch by 2-inch flat iron, one end of which passing through the stone parapet has a fork bolted on, as shown in Figs. 55 and 56, and is bedded in concrete under the adjoining footpath. To give additional stability, suspenders are attached to end of bracket and let into the stonework at the upper end, as shown in elevation in Fig. 56.

The expansion joint is of the "concertina" type, shown in Fig. 57, formed of steel disc plates $\frac{3}{16}$ inch thick and 4 feet 10 inches diameter, outside measurement. The outer flanges of the expansion

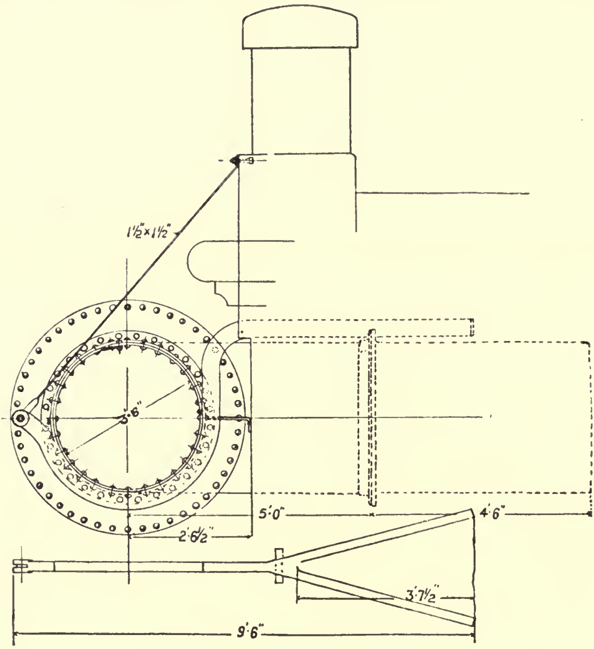


Fig. 56.—Parapet of Bridge.

joint are stiffened with 3-inch by ½-inch steel rings, the inner flange being attached to the pipe in the same manner as the joint flanges.

The total weight of the 90 feet of main, exclusive of the bends at either end, is under 7 tons, whilst the weight of a cast-iron main of the same diameter and length would be about 16½ tons.

Fuller details of this and other similar work were embodied in a paper read by the author at the Southampton meeting of the Gas Institute in 1902, to which reference may be made by those wishing to pursue the matter further.*

An extremely interesting piece of riveted steel main pipe line of very large diameter was laid in the year 1907, in connection with the waterworks of St Louis, U.S.A. This was of 7 feet internal

* Transactions of the Gas Institute, 1902. Also, *The Gas World*, 14th June 1902, pp. 1080-85.

diameter and nearly 20,000 feet in length. It was made up of soft open-hearth steel plates of ½ inch thickness and 7 feet in width, the tensile strength specified being 52,000 to 60,000 lbs. per square inch. Each plate was of sufficient length to give, when bent to a true circle, an internal diameter of the size mentioned, only one longtitudinal joint being allowed to each plate. The pipes were made up in lengths of 28 feet, each composed of four rings of the size specified.

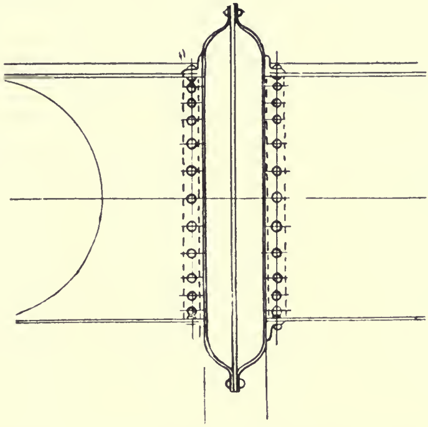


Fig. 57.—Section through Expansion Joint.

Lap-welded steel main.—For pipes of the smaller sizes, up to, say, 16 inches or 18 inches diameter, the lap-welded mild steel main has for long held a deservedly high place in the estimation of gas engineers. Fig. 58 shows an 18-inch lap-welded mild steel main made by Messrs Thomas Piggott & Co., Limited, of Birmingham, for the Rochester, Chatham, and Strood Gas Light Company, and carried upon the parapet of Rochester Bridge. The main was made in 15-feet lengths, exclusive of the sockets, and of ¼ inch in thickness. The solid welded sockets of ⅜ inch in thickness are of the section shown in Fig. 59, and are firmly riveted to the pipes in the manner shown.

Expansion and contraction are provided for in the special collar shown in Fig. 60, one of which is fixed over the centre of the span of each of the three arches of the bridge. These have acted most satisfactorily during the sixteen years the main has been laid.

The main is supported upon the parapet by cast-iron cradles, as shown in Fig. 61, which are firmly bolted to the parapet with four set screws, to prevent possible sliding.

Cast-iron one-eighth bends of special character were used for carrying the main round the abutments of the bridge, and jointed up to the steel main at either end of the span.

The lap-welded mild steel main manufactured by Messrs Stewarts & Lloyds, Limited, is another very good example of this class of pipe. In this the socket is pressed out of the solid metal and forms one continuous piece with the pipe of which it forms a part. There is, therefore, an avoidance of the unsightliness incidental to the riveted-on socket, the strength of the metal is maintained intact owing to the absence of punching or drilling, and the potential sources of leakage are materially reduced.

Fig. 58.—Lap-Welded Steel Main on Rochester Bridge.

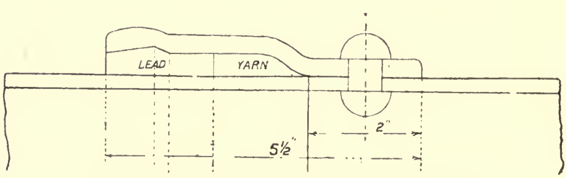


Fig. 59.—Section through Joint of Main.

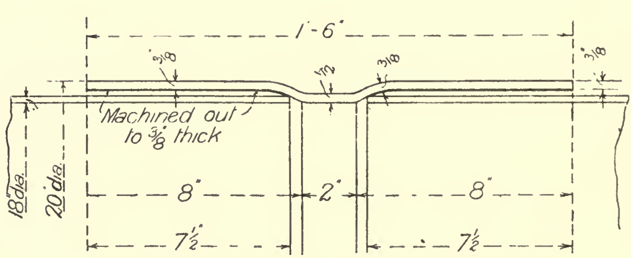


Fig. 60.—Section through Special Collar.

It is claimed that the weld is of not less than 0.8 of the strength of the plate, and that it has a tensile strength equal to about 24 tons

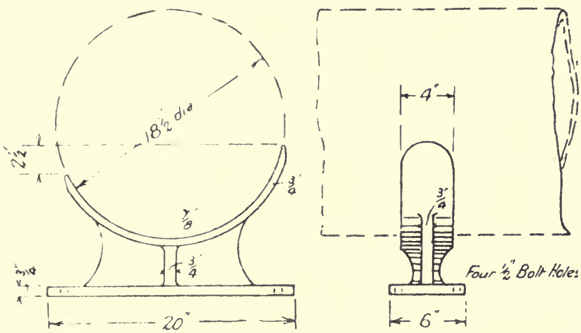


FIG. 61.—Cast-Iron Cradles.

per square inch section of metal. The finished pipes may be tested to half this strain.

The particular form of socket joints adopted is shown in section

FIG. 62.—Stewarts & Lloyds' New Patent Joint.

in Fig. 62, from which it will be seen that the socket is materially strengthened by being made somewhat longer than usual, the extra length being folded back inwardly upon the socket so as to give a

FIG. 63.—Stewarts & Lloyds' New Patent "Rigid" Joint.

double thickness round the rim. The conical form given to the interior front of the socket also prevents "drawing" of the jointing material. Fig. 63 shows the same principle applied to this firm's "rigid" joint, and Fig. 64 shows the "Kimberley" collar as used for steel mains.

The pipes are made in all sizes, from $1\frac{1}{2}$ inches to 48 inches diameter; in lengths of 18 to 40 feet; and of standard

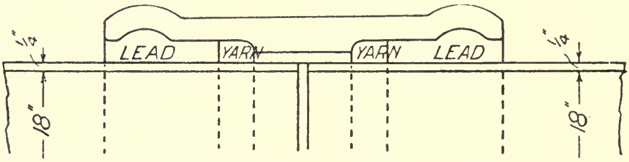


FIG. 64.—Section through Stewarts & Lloyds' "Kimberley" Collar.

thicknesses varying from No. 12 I.W.G. for pipes of 3 inches diameter; No. 11 I.W.G. for those of 4 inches diameter; $\frac{1}{8}$ inch for 6 inch pipes; $\frac{3}{16}$ inch for 12 inch pipes; to $\frac{1}{4}$ inch for pipes of 24 inches in diameter.

Particulars as to the approximate weight per foot run of the various thicknesses of metal of the standard sizes in which these pipes are made are tabulated on the next page.

Weldless steel tubes.—A very remarkable development along these lines has been made in recent years in the use of weldless steel

FIG. 65.—Mannesmann Tubes.

tubes for gas mains up to 10 inches in diameter. These pipes, patented by Mr Mannesmann, a continental engineer, have been used extensively upon the Continent, and in this country, at Cardiff, Newport, Stockport, Leeds, and Nuneaton, amongst other places. At the three former towns they have been in use for about eleven years.

The tubes are rolled out, to the diameter and thickness required, from the solid block of mild steel. There is therefore no seam or joint in the material throughout the entire length of any pipe, which,

WEIGHT OF LAP-WELDED STEEL PIPES IN LBS. PER FOOT RUN.

Thickness of Pipe.	Diameter of Pipe in Inches.																			
	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	27	30	33	36
12 W.G.	3.53	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
11 ,,	3.923	5.178	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
10 ,,	4.313	5.697	7.084	8.476	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
9 ,,	...	6.385	7.944	9.511	11.075	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8 ,,	...	...	8.798	10.540	12.277	14.046	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\frac{3}{16}$-inch	...	...	...	12.296	14.332	16.623	18.676	20.722	22.756	24.804	28.908	33.001	...	...	...	...	...	...	...	...
$\frac{1}{4}$,,	...	...	...	...	19.615	22.331	25.071	27.798	30.511	33.241	38.712	44.172	49.637	55 138	...	...	...	...	...	...
$\frac{5}{16}$,,	...	...	...	...	...	27.880	32.024	34.960	38.350	41.764	48.604	55.427	62.258	69.136	75.987	86.250	...	...	...	...
$\frac{3}{8}$,,	...	...	...	...	...	...	38.117	42.209	46.273	50.371	58.578	66.766	74.963	83.217	91.437	103.753	...	...	...	...
$\frac{7}{16}$,,	...	...	...	...	...	...	...	...	...	...	68.639	78.191	87.754	97.385	106.976	116.574	131.110	...	...	...
$\frac{1}{2}$,,	...	...	...	...	...	...	...	...	...	...	...	...	...	111.638	122.599	133.568	150.183	166.850	...	...
$\frac{9}{16}$,,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	160.339	188.090	206.895	...
$\frac{5}{8}$,,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	209.418	230.313	251.277
$\frac{11}{16}$,,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	253.815	276.876
$\frac{3}{4}$,,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	302.563

with the socket, forms one homogeneous whole. The other characteristic features of these tubes are their great flexibility and elasticity, which give them an enormous advantage over cast-iron in coal and iron districts which are undermined, and in which settlement to a greater or less extent is continually taking place. The extraordinary ductility of these tubes is admirably shown in Fig. 65, which is a copy of a photograph of six pieces of Mannesmann tube, three of which have been rolled open to a considerable extent, whilst the other three have been hammered quite flat with an 80-ton steam hammer, without the slightest fracture of material or flaw being shown in either case.

The standard dimensions to which these tubes are made are as follows :—

STANDARD DIMENSIONS OF MANNESMANN TUBES.

A	B		C	D	E	Remarks.
	I.W.G.	Equiv. Inches.				
Inches.			Ins.	Ins	Ins.	
2	11	0.116	$2\frac{51}{64}$	$3\frac{11}{32}$	$\frac{19}{64}$	
$2\frac{1}{2}$	11	0.116	$3\frac{3}{16}$	$3\frac{15}{32}$	$\frac{19}{64}$	
3	9—10	{ 0.128 / 0.144 }	$3\frac{13}{16}$	$3\frac{37}{64}$	$\frac{19}{64}$	The sockets in all cases are made considerably thicker than the body of the tube, and in the larger sizes, additional strength is obtained by means of an overcollar shrunk on the socket hot.
$3\frac{1}{2}$	9	0.144	$4\frac{43}{100}$	$3\frac{11}{16}$	$\frac{19}{64}$	
4	8	0.160	$4\frac{27}{32}$	$3\frac{13}{16}$	$\frac{19}{64}$	
5	8	0.160	$5\frac{13}{16}$	$3\frac{15}{16}$	$\frac{19}{64}$	
6	7	0.176	$6\frac{27}{32}$	$4\frac{1}{16}$	$\frac{19}{64}$	
7	6	0.192	$7\frac{7}{8}$	$4\frac{11}{64}$	$\frac{19}{64}$	
8	5	0.212	$8\frac{15}{16}$	$4\frac{21}{64}$	$\frac{5}{16}$	
9	3	0.252	10	$4\frac{21}{24}$	$\frac{5}{16}$	
10	1	0.300	$11\frac{3}{32}$	$4\frac{7}{16}$	$\frac{11}{32}$	

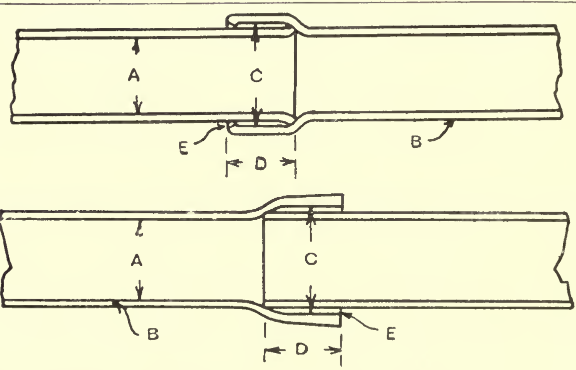


FIG. 66.—Section through and Dimensions of Mannesmann Tubes.

The Mannesmann tubes are made in various lengths up to 35 and 40 feet, and thus not only save materials and labour in jointing, but greatly facilitate the rapidity of mainlaying operations. In addition to this, where necessary the pipes may be bent upon the spot, by means of a " crow," to suit the turns and curves of a winding road, thus obviating the necessity, always objectionable, but frequently unavoidable with cast-iron pipes, of " breaking the joint."

Another great advantage of these tubes is that, where " cover " is very shallow, in such cases as passing over arches of bridges, or where the pipe has to be built in or accommodated between the girders of bridges, or where from any other cause the local circumstances demand it, these pipes may be rolled to oval section, thus allowing a main of larger section and capacity to be laid than would be possible with circular pipes.

The weight per yard run, as compared with cast-iron pipes of equal internal diameter, is given on page 113.

In order to minimize risk of corrosion as much as possible, the tubes are protected by the application, hot, of a special preservative solution applied to both inside and outside of the pipe. The outside is then still further protected by being wrapped round with a special jute cloth. It is claimed that the tubes are thus rendered quite

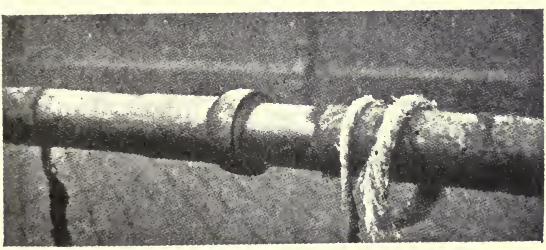


FIG. 67.—Parkinson " Rigid " Joint.

impervious to corrosion in any kind of ground whatsoever, whether of an alkaline or acid character. The coating should, however, be burnt off with a powerful lamp both from spigot end and interior of the socket before the joint is made, and then the exposed parts recoated and wrapped. The final wrapping should, of course, include the socket.

For the purpose of connecting up to cast-iron mains, the spigot or socket end of the Mannesmann tube may be rolled out sufficiently to make a perfectly good and sound joint with either socket or spigot end of cast-iron main, as may be required.

Parkinson " rigid " joint.—A later development in the jointing of Mannesmann tubes is by means of the Parkinson " rigid " joint, as shown in Fig. 67, which was the precursor of that shown in Fig.

63. In this the socket is elongated at the back of the jointing space proper, and rolled out to exactly fit the spigot end of the succeeding

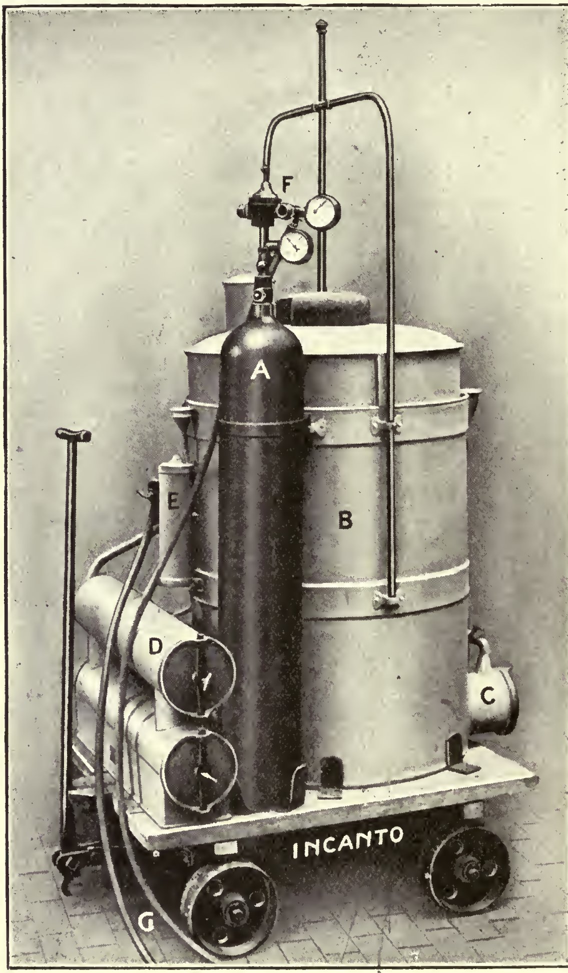


Fig. 68.—The "Incanto" Portable Welding Set.

pipe to a depth of one and a half times to twice the diameter of the pipe. The latter is driven home with wooden mallets, and telescopes tightly into the back socket extension, the front of the joint being then made in the usual way, with lead and yarn.

The advantage of this type of joint is that, whatever vibration or deflection the pipe is called upon to sustain, the strain does not come directly upon the jointing material, but is carried largely by the resilience of the body of the pipe itself, and is conveyed from one pipe to another by means of the tight-fitting telescopic portion of the joint. The lead ring, being relieved of a large proportion of these strains, remains a sound joint under circumstances which would be destructive of the tightness of a joint of the usual type.

	Internal Diameter of Pipe—Inches.										
	2	2½	3	3½	4	5	6	7	8	9	10
Approximate weight per yard run in lbs., cast iron	28	. .	42	. .	59	74.6	95	126	152.7	180	212.5
Approximate weight per yard run in lbs., Mannesmann tube . . .	9.9	11.1	15.6	21.0	23.4	28.2	38.4	52.2	60.6	80.7	106.8

Before the spigot is driven home into the socket extension it should be well smeared with graphite. This not only ensures an easy drive, but also very materially adds to the gas tightness of the joint.

The welded joint.—Following in logical sequence the development of the "rigid" joint comes the endeavour to eliminate the joint altogether by means of welding. In this respect Mr George Helps, of Nuneaton, is doing splendid pioneer work in utilizing the high temperatures developed by the oxy-acetylene blowpipe for the purpose of welding successive lengths of steel or wrought-iron main. By the courtesy of Mr Helps the author has seen the process in actual operation, and there can be no doubt that a simple, cheap, and easily manipulated joint may be made in this way. The cost of welding a 4-inch joint is not more than 1s., and smaller sizes proportionately less. Services may be welded into mains, and of course the successive lengths of services themselves also welded. We are, therefore, brought within measurable distance of a distributory system, at any rate as far as the smaller sizes of main are concerned, without a joint at all as hitherto understood. Assuming that fuller experience confirms the present favourable impressions, a prospect is thus opened up of the elimination of leakage proper and the distribution of gas safely at far higher pressures than have been hitherto generally contemplated.

The gas apparatus necessary for the oxy-acetylene welding process is shown, mounted upon a low trolley for convenience of movement along the side of the trench, in Fig. 68. In the illustration, A is the oxygen cylinder; B is the acetylene generating plant; C, the carbide container; D, the purifier; E, the hydraulic back-pressure valve; F, the oxygen regulator; and G, the rubber tubes conveying oxygen and acetylene to the blowpipe, as arranged by the British Oxygen Company, Limited, of Glasgow.

Mr Helps describes the process as follows:—"The process of

FIG. 69.—Welding Joint in Trench.

welding one pipe to another is very simple. Acetylene is generated and passed into a holder at about 9 inches pressure, and a connection made to the blowpipe. Another connection is made to the blowpipe from a cylinder of compressed oxygen at about 15 lbs. The size of the blowpipe used depends on the work to be done, and whether a small or a large flame is required. The flame produced has in its centre a small white cone, at the apex of which the temperature is about 6300° Fahr. In welding, this part of the flame is applied to the ends of the two pipes, the blowpipe being held in the right hand. The point of the flame is projected on to the metal first on one end and then on the other, always moving the flame from left to right, until the steel or iron is fluxed. In the left hand, iron wire is held and brought into contact with the flame, so that just at the moment that the pipes flux the wire fluxes also, and the result is just one wave, as it were, of molten metal to cover about $\frac{1}{8}$ or $\frac{1}{4}$ of an inch of the circumference of the pipe. In a welded 4-inch joint the metal would be found to be fluxed for about $\frac{5}{8}$ to $\frac{3}{4}$ of an inch in width, and to have just wave lines in it equidistant.

FIG. 70.—Welding Joint in Trench.

From the form these wave lines take, a good job can be at once detected. When the wave lines are irregular or lumpy, the joint is badly made and must not be trusted."

Figs. 69 and 70 show the welding process applied to a 3-inch Mannesmann main, in the trench, at Nuneaton.

The welding process is now being taken up very strongly by Messrs Stewarts and Lloyds, whose welded joint is shown in Fig. 71. This is a combination of their long sleeve joint and a weld, the latter being made on the face of the socket, as shown in Fig. 72. Either the "butt" or the "socket" weld may be made in the trench, but it is usually far more convenient to make the joint above ground. In that case the pipe is supported on low trestles, and, as each successive length is added and the trestles are moved forward, the pipes are allowed to sink to their berth in the trench by their own weight, a method for which the flexibility of steel mains renders them particularly adaptable. It is obvious, however, that this method can only be applied in those cases where it is possible to have a fairly long stretch of trench open at one time. Otherwise the weld must be made in the trench, a slight addition to the ordinary excavation being made to enable the jointer to work. In order to lessen the extent of this extra excavation it is, of course, possible and advisable to weld two, three or any convenient number of successive pipes together by the side of the trench, above ground, and then lower the combined stretch of jointed pipes to the length of, say, 100 feet or more into position in the trench at one time, and thus reduce the number of "joint holes" to an absolute minimum.

FIG. 71.—Stewarts & Lloyds' Welded Joint.

FIG. 72.—Welding Gas Main without turning pipe as done in Trench.

Considerable doubt has been expressed from time to time as to the value of welding in a distributing system from several points of view.

In the first place the question as to the permanency of the joints under the expansion and contraction, due to changes of temperature, which is continually going on, has been raised. The following experiment which has been carried out by Mr F. Herbert, of Messrs Stewarts and Lloyds, would appear to set all such doubts at rest. He says :—“ We laid a length of 350 feet of 4-inch pipe, welded into a continuous main, embedding it in a trench and filling in in the ordinary way. The pipe was laid on a somewhat heavy gradient, and two pits were dug—one near the lower end, and the other near the centre—in which fire was applied to the pipe so as to vary the temperature of the air within it. The main was sealed at each end by solid welded plugs, into one of which was introduced a pipe

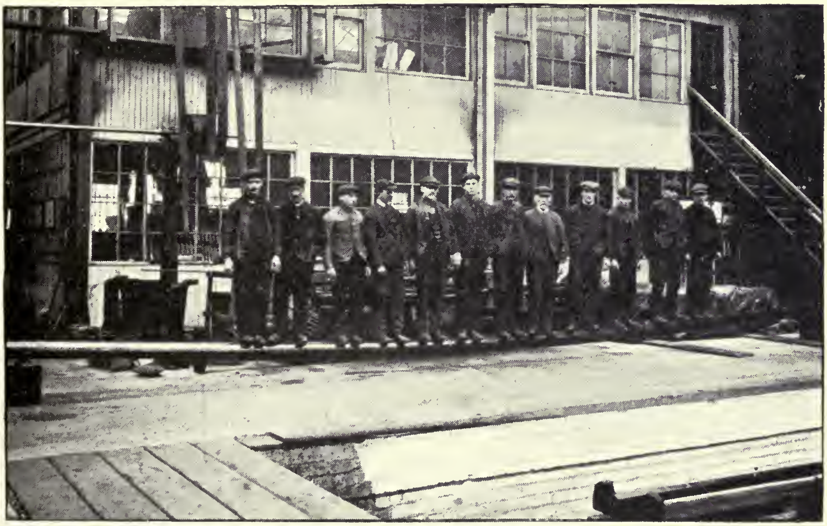


FIG. 73.—Test of Welded Joint for vibration.

connection with pressure gauge and valve, admitting air at 100 pounds per square-inch pressure. After charging the main at this pressure, it was found that under constant temperature the pressure dropped one pound in 24 hours, so that the main for practical purposes was absolutely tight. A heavy concrete block was laid within a few inches of each end of the main, while gauges were set to ensure that no movement of these concrete blocks occurred unrecorded. Heat was applied in the two pits, the gradient causing the air to circulate and so heat, practically uniformly, the entire length of pipe from 30° Fahr. to about 110° Fahr., this rise in temperature being confirmed by the increased length of the pipe, which showed a movement relative to the concrete blocks, of 1 inch at each end. The fires were then withdrawn, and, after the former temperatures (frost prevailed at the time) had been attained, closely-fitting iron wedges were accurately driven between the ends of the pipe and the concrete block. Heat, as before, was applied—one day on and one day off—for a period of one month, but without failure of any of the joints as,

No. of Test.	Size of Tube.		Breaking Load.		Elongation on Ten Inches.	Position of Fracture.
	o/d	Thickness	Total.	Per Sq. Inch of Section.		
			Tons.	Tons.	Inches.	
4587	4½	0.116	30.000	20.000	0.39	At Weld
4588	4½	0.116	30.625	20.400	0.30	,, ,,
4589	4½	0.116	34.200	22.800	0.48	Off ,,
4590	4½	0.125	32.250	20.000	0.25	At ,,
4591	4½	0.125	33.000	20.500	0.23	,, ,,
4592	4½	0.125	29.700	18.400	0.10	,, ,,
4596	4½	0.25	80.700	25.700	3.45	Off ,,
4597	4½	0.25	81.900	26.000	3.47	,, ,,
4598	4½	0.25	81.800	26.000	3.50	,, ,,

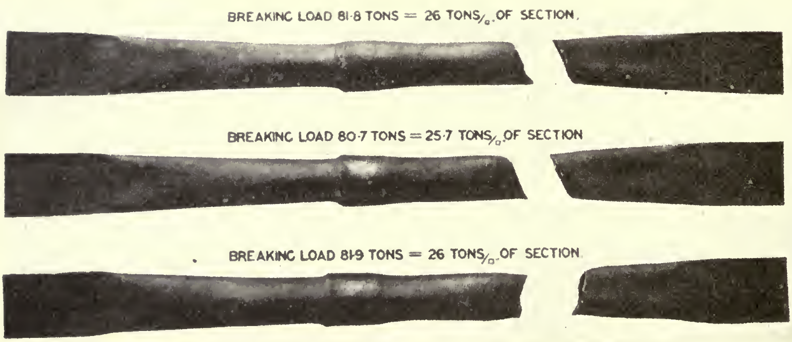


FIG. 73A.—Tests for tensile strength of Welded Pipe.

witnessed by the pressure gauge, which, at the end of the test, was found to recede as before, one pound in 24 hours from the 100 pounds maximum pressure. The gauges above referred to showed that no movement whatever of the concrete blocks took place, so that the natural expansion of 2 inches on this 350 feet length was taken up by the elasticity of the pipe itself, without injury to the joint."

Another objection which has been raised is as to the stability of the joint itself under rough usage. Fig. 73 shows an experiment made to determine this point. The pipe is a length of 6-inch lap-welded steel tube ⅛-inch thick with a Stewarts & Lloyds' long sleeve patent welded joint in the centre, supported at points 40 feet apart. Under the loading shown the centre was deflected to the extent of 5½ inches without disturbing the joint.

In this connection it is interesting to note that in the report on the work of the National Physical Laboratory for 1909 the two following conclusions, which are described as "preliminary," are made in respect of welded joints:—(1) That the material at a welded joint is very often in a dangerously brittle state. (2) That it is only by making a long weld, so as to secure a considerable surface of contact between the two halves of the joint, that a moderately good result can be produced. The author having drawn their attention to this criticism of the process, the series of tests shown on p. 118 were instituted to ascertain the tensile strength of pipes so welded. The tests were made at Lloyds' Proving House on 19th June 1912 on steel tubes fitted with Stewarts & Lloyds' long-sleeve welded joint. Each sample was 5 feet long and consisted of two pieces of tube, telescoped and welded together, and flattened close at either end for a distance of 10 inches up the pipe; with three 10-inch sections marked for measurement of elongation—the section recorded being in each case that in which the fracture occurred.

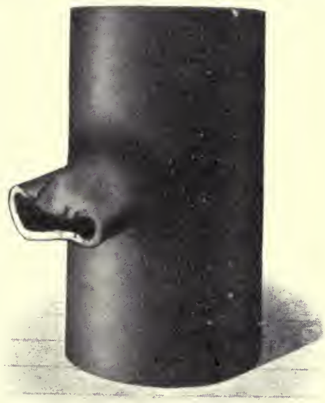


FIG. 74.—Hammered Welded Tee Joint.

As a further test a 40-feet length of 4-inch steel tube with a long sleeve-welded joint in the centre were fixed and vibrated by means of an eccentric with 3-inch travel and sixty strokes per minute. After 10 hours of such treatment, the joint was absolutely unaffected under pressure of 100 pounds per square inch. In a subsequent test the lift was increased to six inches, the strokes remaining at 60 per minute as before. After 120 hours' continuous vibration of this severe kind the welded joint remains absolutely intact and sound at 100 pounds pressure.

Fig. 74 shows the results of a further test for permanency. In this case a welded tee-piece was hammered to destruction but without disturbing the weld.

There will undoubtedly be general agreement that a joint capable of withstanding such violent vibratory tests, and a tube which after welding is capable of being elongated by 3½ inches on a 10-inch length, is also capable of withstanding the various strains to which they may be subjected as part of an underground main pipe system.

Methods of connecting services.—The means adopted for connecting services and branch pipes to the steel main is necessarily of a somewhat different character from that used in the case of cast-iron pipes. It is obvious that the thickness of metal in the steel main is altogether insufficient to allow of the tube being drilled and tapped for services in the usual way. A clamp is therefore used of the type shown in Chapter XXXIV. for the smaller sizes of services, while for the larger a socket saddle piece for open lead joint may provide an attachment where it is not convenient to use an ordinary type of tee.

These band and saddle attachments have, however, been found rather clumsy, and with a view to eliminate them altogether the Mannesmann Company are now rolling the tubes with a modified section, as shown in Fig. 75. This takes the form of a double thickness of the wall of the pipe, on opposite sides throughout the whole length of the pipe, and of a width of 2½ inches or more, according to the diameter.

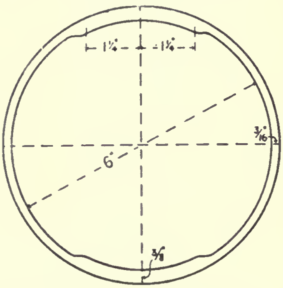


Fig. 75.—Thickened section of Mannesmann Tube.

The thickened section is laid towards the side where services are expected to be required, and gives a sufficient depth of thread to enable a perfectly sound joint to be made without the aid of any extraneous saddle or other device.

Another and more recent service attachment is the Parkinson expansible nipple, an arrangement which is shown in Figs. 76 to 78.

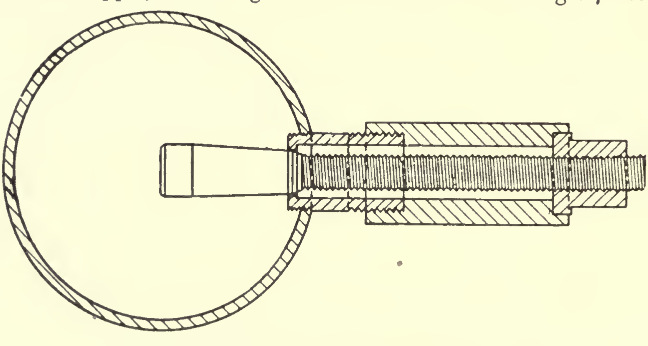


Fig. 76.—Parkinson Nipple before Expansion.

The soft steel nipple shown is rolled with a slight internal bead of about $\frac{1}{16}$ inch in thickness at the end which is screwed into the main.

By means of a sleeve, collar and long screw a solid mandril is then drawn through the nipple, as shown in Fig. 77. In its passage this expands the nipple and rivets it firmly upon the interior surface of the pipe. It is claimed that this gives a thoroughly sound attach-

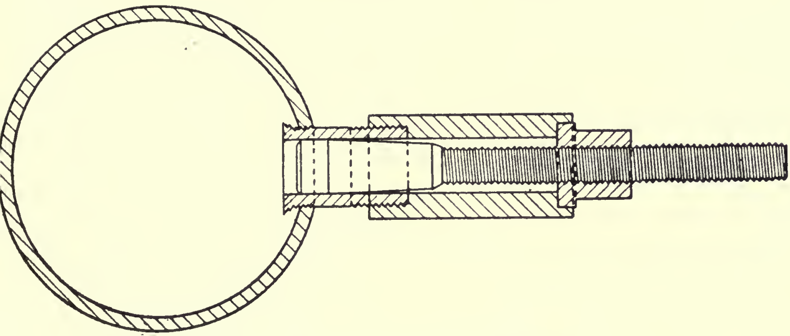


FIG. 77.—Parkinson Nipple after Expansion.

ment, even with a pipe of light make, and it is obvious that the service could not by any means be withdrawn from the main without serious rupture of the pipe. Fig. 76 shows the nipple, sleeve and

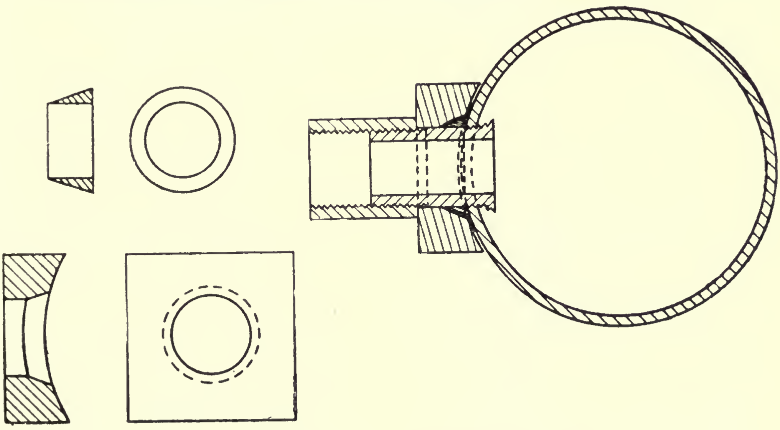


FIG. 78.—Parkinson Nipple with Saddle.

mandril all in position before, and Fig. 77 shows the same after the riveting operation has taken place. For joints which are intended to withstand heavier pressures, a cast-iron saddle, bedded upon a gutta-percha conical jointing piece, is used. This is forced home to a firm bed by means of the socket intended to take the first length of the service proper, as shown in Fig. 78.

Messrs Stewarts & Lloyds, Limited, have also a very handy form of service attachment for steel mains. This consists of a wrought-iron or steel nipple, curved, opened, and shaped at one end to fit the main and having a male thread upon the other to take the jam nut and socket, as shown in Fig. 79. The method of attachment is as follows :—A hole is drilled in the main sufficiently large to admit the special end of the nipple to slip through. The lead washer is then slipped over the nipple, followed by the distance piece and the jam nut screwed tight home. Grooves are cut in the end of the nipple and two jam nuts are used to keep the nipple in position.

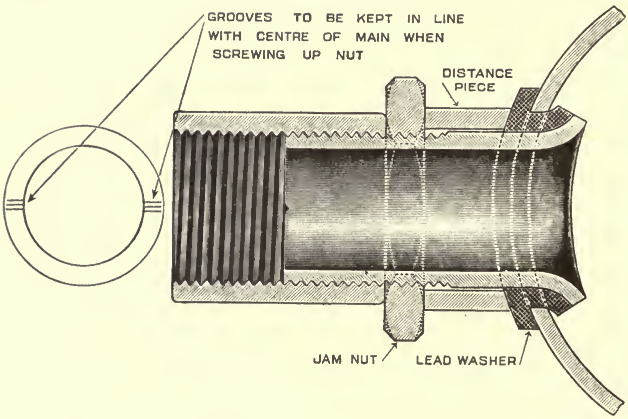


FIG. 79.—Stewarts and Lloyds' Service Attachment.

The special end is curved to fit the main, and the whole attachment is neat, simple, and cheap. A modification of this device is also made in which a malleable iron saddle is used between the washer and the tightening-up screw.

Lock-bar pipe—How made.—The Ferguson patent steel lock-bar pipes, manufactured by Messrs Stewarts & Lloyds, Limited, are of such a novel construction as to merit detailed description. The pipe consists of two sheets of steel of the length of the finished pipe and of width equal to nearly half of the circumference of the finished pipe. The longitudinal edges of the sheets are widened out to about twice the thickness of the body of the pipe. The sheets are bent to semi-circular form and the widened edges brought together. Over these edges a locking bar is passed, the lips of which are then forced home by means of hydraulic pressure.

A reference to Fig. 80 will make this perfectly clear. A and B are the two sheets bent to the half circle, with the edges widened out as described above. C is the locking bar, the lips of which are made sufficiently open to slide easily over the edges of A and B. The bar having been placed in position, the lips of the bar are then tightened home on the sheeting, the joint being made cold. It is claimed that the joint thus made is quite as strong as the plates it unites and shows an ultimate strength of considerably over 20 tons per square inch of plate section.

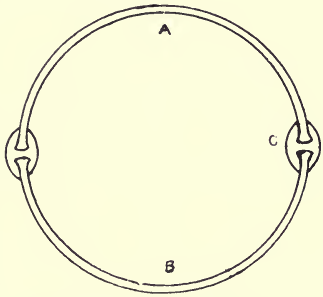


FIG. 80.—Section through Lock-Bar Pipe.

In 1897 Professor Unwin and Messrs Deacon and Carruthers carried out a series of tests upon the lock-bar joint with the object of proving its tensile strength. Three strips about 3 inches wide were sawn off a 12-inch pipe of $\frac{1}{8}$-inch thickness of plate. Each strip was cut in two and prepared as test pieces 3 inches wide. Gauge points 8 inches apart were placed upon each specimen. The following results were obtained :—

Test.	Width of Strip in Inches.	Thickness of Plate in Inches.	Area through Solid Plate in Square Inches.	Amount of Stretch in 8 Inches at Load of 9 Tons.	Breaking Point in Tons.	Breaking Point in Tons per Sq. Inch of Solid Plate.
A	2.99	0.140	0.4186	0.20	10.245	24.47
B	3.00	0.136	0.4080	0.45	9.52	23.33
C	2.99	0.132	0.3947	0.29	10.16	25.74
D	2.99	0.137	0.4096	0.27	10.30	25.14
E	2.99	0.139	0.4156	one dovetail drew out	..	21.66
F	2.99	0.132	0.3947	0.37	9.95	25.23

It will be noticed that in test E one side of the joint broke at 9 tons load. The amount of stretch in this case at load of 8 tons equalled 0.19. With this exception, the fracture took place in the sheeting in all the tests. A better testimony to the strength of the lock-bar seam could hardly be desired.

A further and more recent test, made in January 1905, gave even more favourable results, as follows :—

Test.	Width of Strip in Inches.	Thickness of Plate in Inches.	Area through Plate in Square Inches.	Breaking Point in Tons.	Breaking Point per Square Inch of Solid Plate in Tons.
1	2.02	0.27	0.5454	14.587	26.745
2	2.02	0.27	0.5454	15.000	27.502
3	2.015	0.27	0.5440	14.625	26.884
4	2.02	0.27	0.5454	14.837	27.204
5	2.02	0.27	0.5454	14.387	26.378
6	2.02	0.27	0.5454	14.462	26.514
7	2.02	0.27	0.5454	15.375	28.190
8	2.02	0.27	0.5454	15.475	28.373
9	1.97	0.27	0.5319	15.262	28.693

The average breaking point per square inch of solid plate section is therefore 27.387 tons.

The following additional particulars of the tests are very interesting :—

No. 1. One side drew out of joint without fracturing.
,, 2. ,, ,, ,, breaking one ear off.
,, 3. ,, ,, ,, ,, ,,
,, 4. ,, ,, ,, ,, ,,
,, 5. ,, ,, ,, without fracturing.
,, 6. ,, ,, ,, ,, ,,
,, 7. ,, ,, ,, ,, ,,
,, 8. ,, ,, ,, breaking one ear off.
,, 9. ,, ,, ,, ,, ,,

Any doubt that might have been felt as to the capacity of this form of joint to withstand any legitimate stress to which it may be subject, under actual working conditions, is therefore shown to be without any real foundation.

As a practical working test, it may be mentioned that 350 miles of 30-inch water mains have been working for years at Coolgardie, in West Australia, at 3000 feet head of water, with very satisfactory results.

Brooklyn 72--inch lock-bar main.—A 72-inch lock-bar steel main has also recently been laid in connection with the water supply of Brooklyn (New York). The plate is $\frac{7}{16}$ inch thick, made of steel, with an ultimate tensile strength of between 52,000 and 62,000 lbs. per square inch and an elastic limit of 30,000 lbs. The main is designed for an internal working pressure of 125 lbs. per square inch, with a factor of safety of 5 lbs. The edges of the lock-bar are pressed home by a hydraulic press working at a minimum pressure of 500 tons, the joint giving an efficiency of 95 per cent. of the solid material.

Each pipe is made of two plates 30 feet long of a width equal to half the circumference, so that there are only two longitudinal seams. The successive pipes are riveted together by a single row of 1-inch rivets to a $2\frac{1}{4}$-inch pitch.

The advantages of the lock-bar pipe over the riveted steel main are :—

(1) The preservation of the full strength of the material.

(2) The lessened resistance to flow. The presence of rivet heads upon the interior surface of the pipe, and the rough edges of the overlapping plates, offer considerable resistance to the flow, and materially increase the coefficient of friction.

As compared with the lap-welded pipes, it is claimed that the lock-bar pipes, while equally strong, are much cheaper in the large sizes.

The coating employed to protect these mains in the ground is composed of a good mixture of Trinidad asphaltum and tar, applied at a temperature of about 300° Fahr., after the pipes themselves have been heated to the same temperature in a furnace. The pipes are then still further protected by the addition of a wrapping of Hessian canvas or jute cloth. The method of coating employed in connection with the South Staffordshire Mond Gas Company's mains was described by Mr H. A. Humphrey at the London meeting of the Institution of Gas Engineers in 1904, as follows :—" They had tried all kinds of coating, and came at last to something which was cheap and simple. The pipes were taken hot, and covered with a bituminous coating which did not differ much from certain compositions in general use, but was put on rather thicker. While still hot they took a roll of cloth (say 18 inches wide, and very open in texture—in fact, a kind of string cloth), and this was attached to the sticky pipe at one end, and wound spirally around it all along ; while the pipe was rotated in headstocks. Then, while the pipe was still hot, it received another layer of the same coating composition, which went through the pores of the cloth, and fastened the two layers together. They thus obtained an absolutely secure protection from rust and access of water ; and it was made mechanically strong by means of the cloth. The pipes had been knocked about in all sorts of ways—rolled over the yard, and so on—and this particular kind of covering seemed to meet all the requirements. The cost was 9d. per square yard covered. With the pipe thus protected they had no fear."

The lock-bar pipes are made in sizes varying from 18 inches to 6 feet in diameter, in 28-feet lengths, and thicknesses ranging from $\frac{3}{16}$ to $\frac{3}{8}$ inch for gas mains and up to $\frac{3}{4}$ inch in larger sizes for water mains. The sizes up to 48 inches in diameter have two locking-bar seams, those over 48 inches in diameter have four.

The weight in lbs. per foot run of pipes of different diameters and various thicknesses is given on page 126.

WEIGHT OF LOCK-BAR PIPES IN LBS. PER FOOT RUN.

Thickness of Pipe in Inches.	Diameter of Pipe in Inches.														
	18	21	24	27	30	33	36	39	42	45	48	54	60	66	72
$\frac{3}{16}$	52.035	58.500	64.857	71.571	78.000	..	..	..	..	..	..	..	..	..	..
$\frac{1}{4}$	66.214	74.607	83.035	91.428	99.857	108.250	116.642	..	..	..	..	..	..	..	..
$\frac{5}{16}$	81.642	92.107	102.535	113.000	123.892	134.392	144.785	155.285	156.678	..	..	..	..	..	..
$\frac{3}{8}$	98.178	110.607	123.035	135.428	147.857	160.285	172.678	185.107	197.500	209.928	222.357	..	..	..	..
$\frac{7}{16}$	..	129.428	143.821	158.250	172.678	187.107	202.142	216.571	230.964	245.357	259.785	288.642	..	..	..
$\frac{1}{2}$	..	..	165.857	182.285	198.678	215.107	231.535	247.964	264.750	280.821	297.214	330.071	362.928	..	..
$\frac{9}{16}$	..	..	..	206.178	224.607	243.035	261.464	279.857	298.321	316.714	335.964	372.785	409.642	446.500	..
$\frac{5}{8}$	..	..	..	..	251.928	272.357	292.785	313.214	333.642	354.071	374.535	415.357	456.250	497.107	537.964
$\frac{11}{16}$	..	..	..	..	..	301.357	323.821	346.250	368.678	391.107	413.535	458.392	504.285	549.107	593.964
$\frac{3}{4}$	..	..	..	..	..	..	356.392	380.821	405.250	429.678	454.107	503.000	551.857	600.750	649.642

Connecting branch mains.—Branch and small mains are usually connected by means of special castings, or by means of steel saddle pieces, either riveted or bolted upon the main, as shown in Fig. 81. For small services up to 1 inch in diameter the locking bar may be drilled through, which gives ample thickness and width for the screwed connection without materially interfering with the soundness and strength of the joint.

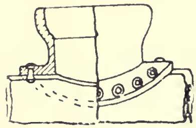


Fig. 81.—Riveted Saddle Piece for Steel Main.

Successive lengths of the main are jointed by means of collars for open lead joints. These collars are made somewhat longer than those used for water mains, thus giving a larger jointing surface for the lead, and are cast to

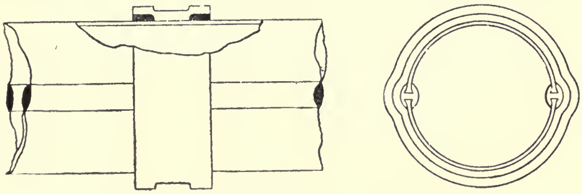


Fig. 82.—Special Ferguson Collar.

set out over the locking bar, as shown in Fig. 82, thus giving an equal lead joint round the whole circumference of the pipe.

The form of collar adopted by the Mond Gas Company in South Staffs., for use with the lock-bar pipe, as described by Mr H. A. Humphrey, is shown in Fig. 83. The collar is made 12 inches long

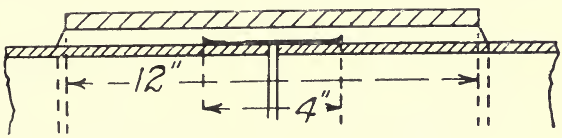


Fig. 83.—Mond Gas Company's Collar.

and ½ inch thick. The ends of the pipes are kept true by an alignment hoop of iron of No. 14 gauge, slightly turned up at the edges and fitting closely over the ends of the pipes. The intervening space is then run in with lead in the usual way.

Steel pipe cutting.—The difficulty of cutting steel mains without removal to the workshop has been solved by the introduction of a new pipe-cutting machine by Messrs Ruscoe & Co., of Westminster. This is quite different from that of the old-fashioned chain cutter which cuts a pipe by squeezing a groove in the pipe by the action of the cutter wheels. The new machine is shown in Fig. 84, and consists of a strong steel disc, A, to which are attached four "parting" tools such as might be used in a lathe. These are divided into two pairs, consisting of (*a*) a pointed tool, thus ; and (*b*) a flat-edged tool . The pointed tool is always a little in advance of the flat tool, and by this means the cutting is made much easier by the elimination of a great amount of friction.

The steel disc, A, is arranged to revolve around the circumference

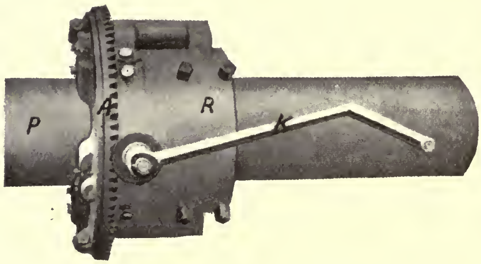


Fig. 84.—Ruscoe's Steel Pipe Cutter.

of the pipe, P, to be cut. Upon one side the disc is provided with a series of cogs which register with a small cog wheel, mounted on a spindle, and actuated by the handle, K.

After the body, R, of the machine has been firmly secured to the main, the turning of the handle, K, causes the cog wheel, and consequently the disc, A, to revolve, carrying with it the cutters. The cut or feed is put on automatically, and it only takes ten to fifteen minutes to cut through a 6 or 8 inch steel pipe.

CHAPTER X

JOINTS AND JOINTING

After a very considerable period during which it was impossible to chronicle much improvement in the methods adopted for the jointing of pipes, a great advance has been made of recent years. The introduction of lead wool and cold jointing, the invention of the "rigid" joint, and the application of welding to steel and wrought-iron mains constitute a tremendous forward move, not only in methods but also in efficiency.

The open lead joint.—For cast-iron main pipes the open lead joint is that most commonly used, and is shown in Fig. 85. The inner

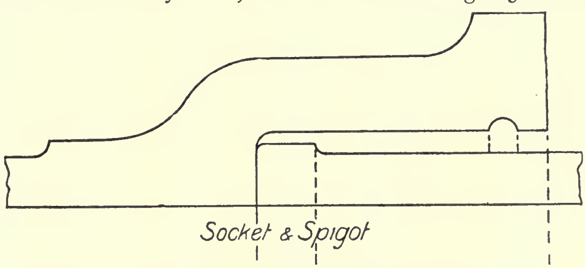
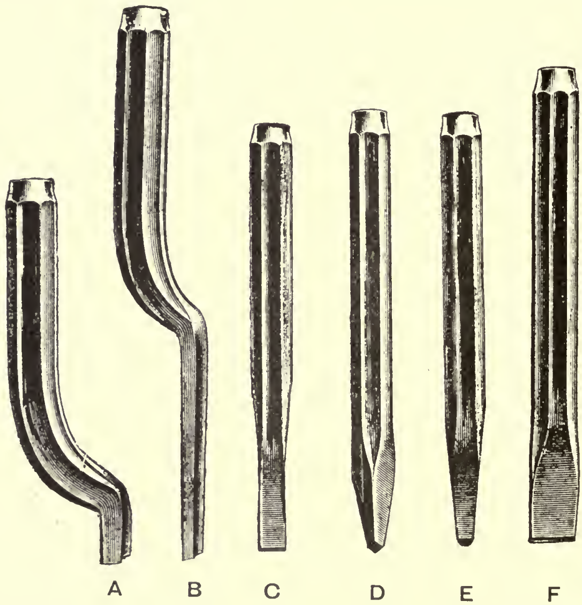


Fig. 85.—Socket and Spigot for Open Lead Joint.

diameter of the socket is cast larger than the exterior diameter of the spigot, the difference varying in amount somewhat with the size of pipe, as shown in the table on p. 89. The spigot end may be quite plain, but it is usual to cast a bead or narrow belt upon it, to facilitate jointing and to prevent the yarn passing by the end into the interior of the pipe. If the pipes have been coated the coating should be burnt off from the spigot end of the pipe and the interior of the socket before the joint is made. The back portion of the joint is made by several rings of yarn being well driven home with a yarning iron to rather more than half the depth of the socket. A yarn of good hemp tow is cheap and good for the purpose, and is much better than the jute yarn so often used. The purpose of the yarn is to give flexibility and play to the joint under the strains set up by subsidences of the ground or heavy traffic.

Tarred and untarred yarn.—The question as to whether the yarn should be tarred or not is variously answered. A tarred yarn undoubtedly offers greater resistance to the action of the products of condensation and of the gas, but does not make so strong a joint. The reason, of course, is that in winter time a tarred yarn becomes more or less brittle and cuts or breaks in the yarning; while in the summer it is rather sticky, adheres to the tool, and tends to pull out or become loose. On the other hand, the white yarn may be protected from contact with gas and condensation by putting a ring of tarred yarn before the white, or by caulking in a couple of coils of lead wool before yarning. The results of a series of experiments the author has made on the strength of the yarned portion of the joint is given on p. 138.



A, Sett; B, Yarning iron; C, Cross cut; D, Diamond point; E, Gouge; F, Chisel.

FIG. 86.—Jointer's Tools.

After the joint has been well yarned, the face of the socket is stopped by a collar of soft clay, in which a suitable port or lip is formed at the upper part, and the intervening space run in solid with molten lead.

Iron clips.—In the case of pipes of over 6 inches in diameter, in order to prevent the clay facing being burst off by the weight of lead run into the joint, before it has time to solidify, it is usual to strengthen it by means of a clip. This consists of two pieces of square iron (Fig. 88), bent to the circumference of the pipe they are intended to fit and bevelled on the inside edge. The two halves

Fig. 87.—Molten Lead being poured into Joint.

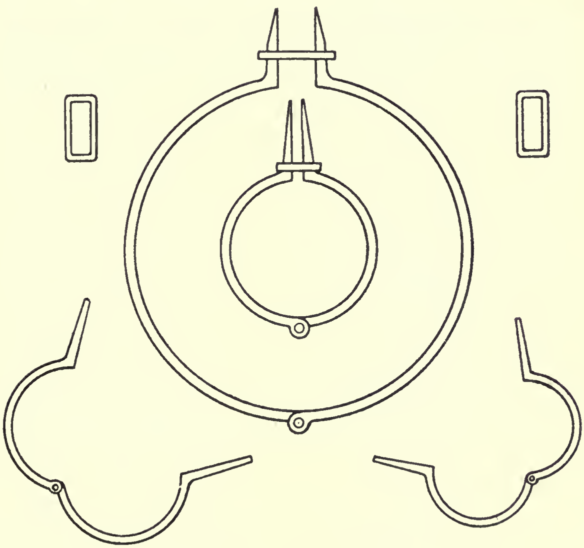


Fig. 88.—Pipe Clips.

are hinged together, and upon the side furthest from the hinge the iron is set back at right angles for a few inches, and worked to wedge shape to accommodate the ring, which holds the whole tightly together, and in place, on the face of the joint, as shown in Figs. 87 and 89. The set-back is so arranged as to leave a few inches of the face of the joint uncovered when the clip is placed in position, the opening thus left forming the port through which the molten lead is run.

An excellent pipe clip, which combines the rigidity of that shown in Fig. 88, with the flexibility of the yarn grummet, has been patented

FIG. 89.—Clips Fixed on Pipe.

by Messrs J. Tylor and Sons, Limited, and is shown in Fig. 90. This consists of a flexible metallic band enclosing a broad fabric of special construction, into the composition of which asbestos and linen enter largely. This fits closely against the face of the joint and is fixed in position by the thumb-screw, as shown. This clip does away entirely with the need for the stopping of clay necessary with either iron clips or hempen grummet, except for forming the port of the joint. When being used, the clip should be occasionally damped in water; and should the fabric become charred somewhat by repeated use, it may be pared down to a true surface again. The interior edge is bevelled, and thus allows a sufficient fillet for setting up. In common with the iron clip shown in Fig. 88, it is quite impossible for this clip to be blown off through the generation of steam in the socket by the hot lead, when the joint is being run.

After being run with lead, the clip is taken off, and the clay adhering to the pipe or socket is removed. Allowing a little time for the joint to cool down, it is then ready for setting up. This is done by means of a chisel and a number of setts (see Fig. 86, F and A), the latter increasing in width until the full thickness of the joint has been reached, the object being to render the joint gas-tight by hammering up the soft lead on the face of the joint into close contact with the exterior of the pipe and interior of the socket. Whatever the depth of lead in the socket, however, it is probable that the setting-up process does not affect the lead for more than about 1 inch of its depth.

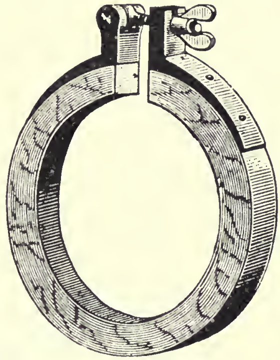


Fig. 90.—Tylor's Patent Pipe Clip.

Whole joint to be run at one pouring.—In the making of large joints it is well to remember the importance of running the whole joint at a single pouring. If one ladle does not hold sufficient lead for the purpose, two should be used, each simultaneously pouring lead through the port into the joint, or, if the conditions render this impossible, the ladle used for pouring the lead into the joint should itself be fed from a second ladle, as shown in Fig. 91. When the joint is made, the lead packing forming it should consist of one homo-

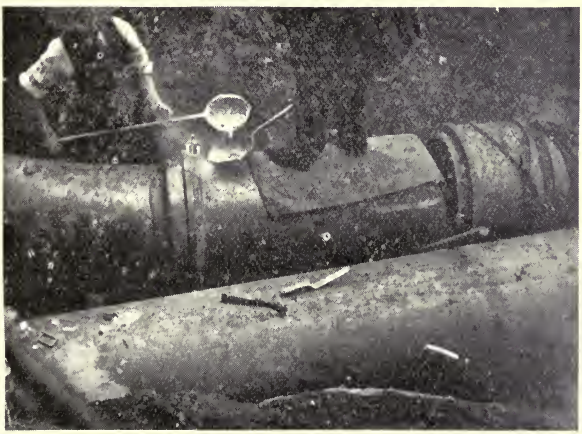


Fig. 91.—Running Large Joint from two Ladles

geneous ring, and not a series of two or more segments formed by as many different pourings.

Spigot and socket to be concentric.—Care must also be exercised to ensure that the socket and spigot are concentric each with the other, so that the ring of lead may be of equal thickness throughout. If this is not done, and in consequence the joint is much thicker upon one side than the other, it may easily happen that upon the thin side the molten lead is cooled before the space is run full, and a faulty joint, leading to considerable trouble, may result.

Precautions in yarning.—It is important that the spigot end of the pipe be pressed quite home to the back of the socket. Failing this, not only is the joint reduced in depth, but there is greater danger of some of the yarn passing into the interior of the pipe and correspondingly obstructing the passage. Fig. 92 shows a copy of photograph of a particularly bad specimen of this, which came under the author's notice some time ago. As will be seen, a very considerable

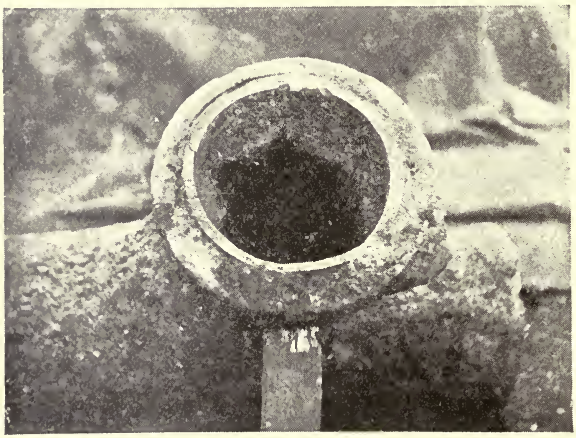


FIG. 92.—Tee Piece, showing Yarn having passed through from Joint to Interior of Pipe.

portion of the gas-way was obstructed by the fringe of yarn to be seen inside the pipe, which had got through, partly because of the spigot not being home, and partly in consequence of careless yarning. Another incidental disadvantage pertaining to this is that such a fringe forms a most convenient screen for a deposition of naphthalene, if there is any present in the gas.

Quality of lead used.—The quality of the lead provided is a most important factor in the making of a satisfactory joint. Only the best Spanish virgin pig lead should be used for this purpose. Any admixture of antimony, tin or zinc with the pure lead is highly objectionable, and such an admixture should not be used on any account. These metals are both granular in texture and brittle in working, and entirely unsuitable for jointing purposes.

It is also important that there should not be too much lead left upon the outside of the joint, when it is run. If this is done, and the joint be set up by a clumsy or unskilful workman, the socket may easily be fractured in the process.

Precaution in wet weather.—In wet weather great care must be exercised in running an open lead joint. Spitting and blowing are most likely to take place, owing to the hot lead converting the moisture in the socket into steam, which escapes, sometimes through the molten metal, and often with force sufficient to carry the hot lead with it, to the danger of the workmen around. A little tallow, oil or resin placed in the port of the joint, before the lead is run in, will greatly minimize the risk of mishap from this cause. The vapour arising from the use of a piece of tallow in the port comes out very clearly in Fig. 87 (p. 131).

Advantages of open lead joint.—The advantages of this form of joint are :—

(*a*) Its general ease of manipulation.

(*b*) Its flexibility. If a sufficiently deep ring of lead of the best quality is used, a well-made joint will take up a considerable amount of vibration, and even deflection, without much weakening.

(*c*) It allows of pipes being laid with a reasonable amount of deviation from the straight line. All are agreed that the breaking of joints is objectionable, and should be avoided wherever possible. But under the conditions governing mainlaying in large towns to-day, it is often impracticable to maintain a straight line for pipes for any great distance. It is therefore absolutely necessary that the joints used should allow of deflection within reasonable limits.

(*d*) As there is no special feature in either spigot or socket end, the pipes may be cut to any length to suit the requirements of the moment.

Disadvantage.—The disadvantage attaching to the open lead joint consists in the unequal coefficients of expansion of lead and cast-iron, the cubical coefficient of the former being 0.000087 and of the latter 0.000037, or approximately a proportion of 17 to 7. The influence this has upon the joint, especially where mains are laid near the surface of the ground, and so subjected to great variations of temperature, is easily seen. Mainlaying operations are usually carried out in the summer. The joints are then set up in a proper manner, and are perfectly sound. With the winter cold comes contraction of the socket, and the lead ring of the joint becomes still more compressed. But when summer comes round again, with its accompanying expansion of the pipes, the lead does not expand so much ; the lead ring having taken a permanent set, the first bulk is not recovered. There is therefore a possibility of leakage of gas between the surface of the pipes and the lead ring. Fortunately the coefficient of expansion is very low in each case, and when the pipes are buried in the ground at a sufficient depth, the inconvenience caused may not be very great. In those cases, however, where the pipes lie rather shallow, and in positions where they are affected much by the direct action of the sun, the trouble may be very considerable.

* **Average weight of lead and yarn required per joint.**—The average weight of yarn and lead used in making an open lead joint for each size of pipe up to 24 inch is as follows :—

Size of Pipe.	Weight of Lead required in Lbs.	Weight of Yarn required.
3 inches.	3	2 ozs.
4 ,,	4½	3 ,,
6 ,,	7	5 ,,
8 ,,	10	7 ,,
10 ,,	15½	8 ,,
12 ,,	19	9 ,,
14 ,,	22½	11 ,,
16 ,,	27	13 ,,
18 ,,	31	1 lb.
20 ,,	38	1¼ ,,
24 ,,	54	2½ ,,

Lead wool for jointing.—As an alternative to the run lead ring just described, a new departure has been recently made in the introduction of so-called "lead wool." This consists of very fine threads of pure virgin lead, combed off the solid block and twisted together to form a lead rope, a hank of which is shown in Fig. 93.

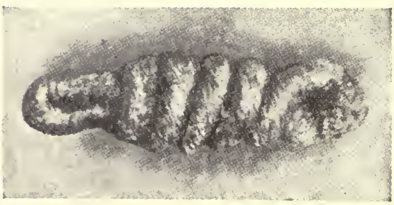


Fig. 93.—Hank of Lead Wool.

In place of the usual tarred gaskin, a white hemp yarn is used for the back of the joint. After this has been inserted, in the usual way, to such a depth as will leave about 1½ inches from the face of the joint, the lead wool is placed in the remaining space and thoroughly caulked up, one coil at a time. In the hammering-up process the strands of lead wool are welded together to form a solid jointing ring, as shown in Fig. 94. If desired, further strength and rigidity may be obtained by caulking into the joint a coil or two of the lead wool before yarning, then yarning and facing up with lead wool in the usual way, as shown in Fig. 95. The author has also found it advisable to protect the white yarn from the injurious effects of the condensation in the mains by using a ring of tarred hemp tow yarn at the head of the joint.

* For total cost of lead joints, see pp. 160.

At first sight it appears improbable that a joint made with lead wool could prove as strong as one made with a solid run lead ring, or that the strands of lead wool would caulk up into a perfectly solid and homogeneous packing. The results of the author's experiments, however, lead irresistibly to the conclusion that a well-made joint with this material is stronger, will resist greater loading strains and

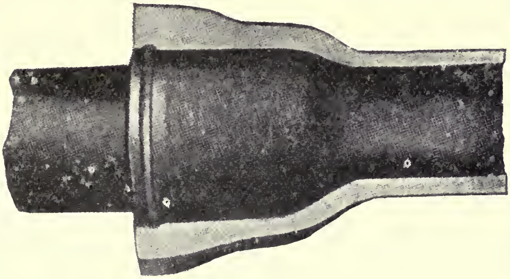


FIG. 94.—Lead Wool Joint.

higher pressures, and will also take up a greater amount of vibration without sensibly weakening, than a joint made in the usual manner. The reason is at once apparent from the fact that, whereas the cast lead ring in the ordinary joint is compressed by setting up for only, say, $\frac{3}{4}$ inch from the face, the lead wool packing is wedged tightly home throughout the whole depth of the material. In the process,

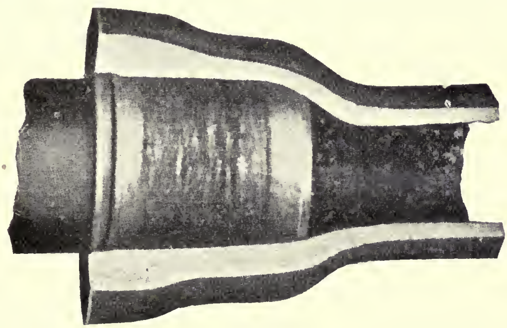


FIG. 95.—Lead Wool Joint: Lead Wool at Back and Face.

the yarn at the back of the joint is compressed much more than is the case with a run lead joint, and so both yarn and lead contribute to give a greater strength with lead wool from an equal depth of lead, or, conversely, an equal strength with a less weight of lead wool.

Objection is often made to the use of lead wool that a "shirker" may leave a badly made joint and be undetected. This is the very reverse of the truth, however. A smart blow or two on the face of the joint shows at once whether the lead wool has been properly hammered home. With the cast-lead joint it is far more difficult to detect the lazy worker. In joints made with either material, however, the personal factor (the workman) and the degree of skill and care exercised in making the joints enter very largely. With a view to testing the comparative value, under a loading test, of the two forms of joint, the author some few years ago carried out a large number of experiments. The result was to thoroughly convince a somewhat unwilling person that the lead wool joint is by far the better and stronger type of joint.

It is obvious from the method of jointing necessitated by the use

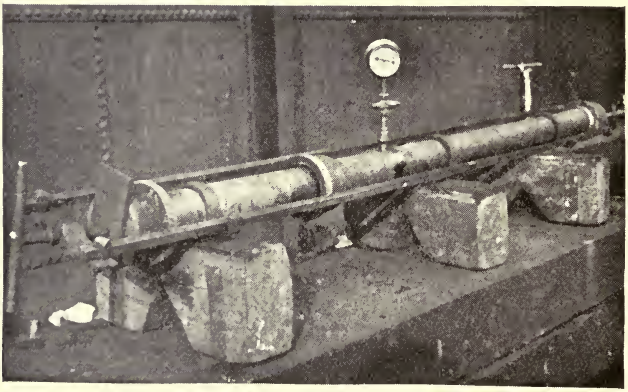


FIG. 96.—Yarn Joint under Test.

of lead wool, that the backing of yarn is hammered up into a much more compact and hard series of rings than was possible under the older system of run lead joint. But apart from this, there is no doubt that the use of untarred yarn makes a much firmer packing than tarred gaskin, other things being equal. The author's tests show that whilst a 4-inch joint made up with tarred yarn to within 1½ inches of the front of the joint, and without any facing of lead, will withstand a pressure of 48 lbs. per square inch, a similar joint made simply with hemp tow yarn, untarred, will stand a pressure of over 100 lbs. per square inch before leaking. Fig. 96 shows one such joint under test, the gauge standing steadily at 110 lbs.

Lead wire for jointing.—A further development along the line of cold lead jointing has been made by the use of lead wire for this purpose. Some experiments made by the author, and described in *The Gas World* for 27th February 1909, show conclusively that a very strong and flexible joint may be made in this way. Some 4-inch joints subjected to particularly rough usage and violent vibration remained perfectly tight at a pressure of 50 lbs. per square inch. The wire, a coil of which is shown in Fig. 97, is used in precisely the same way as lead wool, and welds up in the socket, if properly worked, into a perfectly solid and homogeneous lead ring capable of withstanding very high pressures. In one experiment the joints on three 4-inch pipes were subjected to a pressure of 850 lbs. per square inch for upwards of an hour, without showing any signs of leakage.

Pneumatic caulking.—It is obvious from what has gone before that one of the main factors in determining the cost of lead jointing is that of the skilled labour involved. From time to time many efforts have been made to considerably reduce this element in main-laying costs. Attention has been given to the production of a

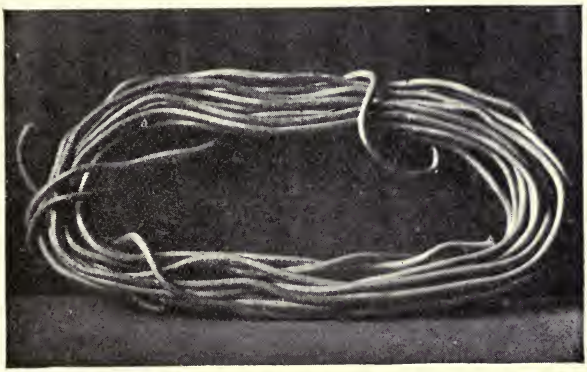


Fig. 97.—Coil of Lead Wire.

mechanical jointer which should go far to supersede manual labour, but, until recently, without conspicuous success. The problem appears to have been solved by the application of compressed air, a " pnuematic caulker " having been used with conspicuous success in the laying of large mains in New York, as described by Mr Colin C. Simpson, Junr., in his paper on " Pneumatic Caulking with Lead Wool," read before the American Gas Institute in 1910.

The two compressors adopted were the (*a*) Abenaque-Ingersoll Rand type, and (*b*) the National Brake and Electric Company's outfit. The former, which is shown in Fig. 98, is the 8 × 8 Ingersoll-Rand NE-I single stage water jacketed compressor, driven by a 15 H.P. Abenaque gasoline engine, rated to compress 78 cubic feet of air to 100 lbs. per square inch per minute. The hammer adopted was the Ingersoll-Rand " Crown " chipping-hammer, having a piston stroke of 3 inches, which together with the setts finally adopted (the three on the right) is shown in Fig. 99.

The engine and compressor were moved along the side of the trench as the work progressed, and the hammers were connected

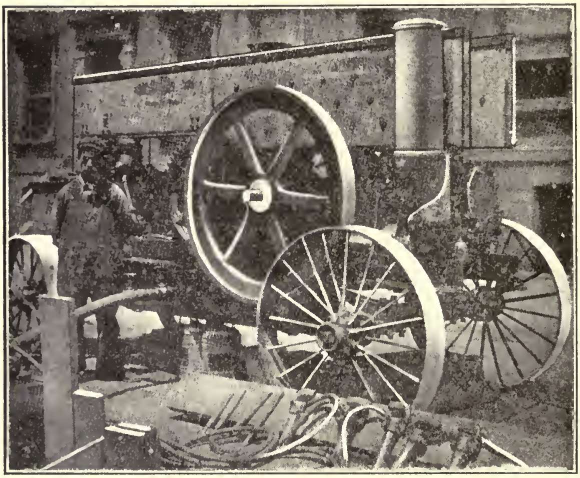


FIG. 98.—Abenaque-Ingersoll Engine and Compressor.

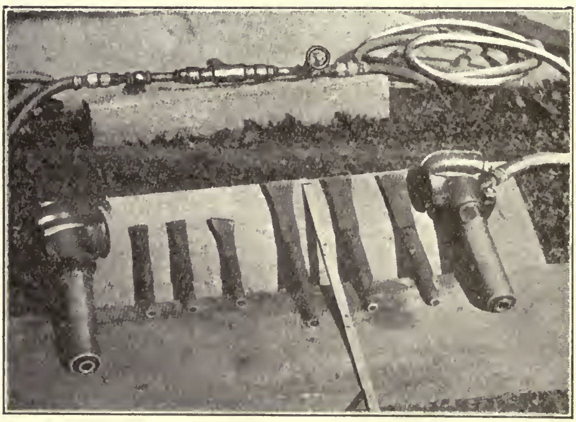


FIG. 99.—I.-R. Chipping-Hammer and Setts.

up to a manifold tee which in turn was connected up to the air receiver by means of a 3-inch flexible tube. "The average air pressure carried on the receiver gauge was about 70 lbs. This gave from 50 to 65 lbs. pressure at the tool, and was found quite sufficient."

Pneumatic caulking was found to be much quicker and easier than hand work, and was especially valuable in special cases where, as at street intersections, it was necessary to get the work completed in the quickest possible time. After allowing for depreciation on plant, the saving of air over hand caulking worked out at upwards

FIG. 100.—Caulker working on 48-inch main.

of 30 per cent. It is interesting to note that by means of the pneumatic caulker from 10 to 15 per cent. more lead wool was forced into the joints than with hand labour, and consequently a more compact and fully welded joint obtained. Fig. 100 shows the pneumatic caulker at work on a 48-inch main.

Possible modification of form.—It is likely that the development of high-pressure distribution, now in its infancy in this country, but which will almost inevitably make rapid strides during the next few years, will lead to some modification in the section of the socket, if the open lead joint is to be applied generally to this class of work.

On reference to Fig. 85 (p. 129) it will be noticed that the socket has a slight depression running round the interior about an inch from the face of the joint, and about $\frac{1}{4}$-inch in depth. The object of this groove is to prevent the lead ring being drawn in the event of any movement of the pipes due to expansion, or other cause, and by thus holding the lead firm tend to neutralize any possible ill-effects. Except for this groove and the bead on the spigot end, the exterior of the spigot end and the interior of the socket are parallel throughout their depth.

Form of socket used in Thirlmere aqueduct.—Sections through the sockets of the 44-inch water mains laid for the Manchester Corporation waterworks, in their Thirlmere aqueduct, show very considerable variation from that usual in gas mains. Fig. 101 shows sectional details through the socket of these pipes, and is reproduced by permission of the engineers, Messrs G. H. Hill and Sons, of Manchester.

The outstanding feature of the joint is the shortness of the socket. Where a gas main pipe would have a socket 5 inches deep, these sockets range only from 3 to 4 inches in depth.

A reference to Fig. 101 will show that the interior of the socket is

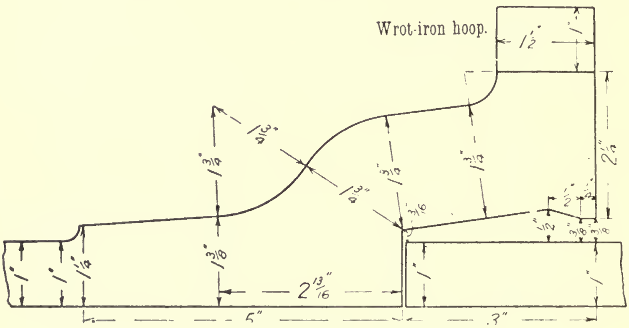


FIG. 101.—Thirlmere pipe, 1 inch thick.

not parallel with the exterior of the spigot end, the face of the joint having a thickness of lead equal to $\frac{3}{8}$-inch, which tapers down to $\frac{1}{4}$-inch thickness at the back of the joint. This general taper, however, is not uniform throughout the depth of the socket. At a depth of $\frac{1}{4}$-inch from the face, the interior of the socket turns outward from the spigot of the pipe until at a depth of $\frac{3}{4}$-inch from the face the joint attains its maximum of $\frac{1}{2}$-inch in width, and from this point tapers down to the back of the joint. The lead ring composing the joint will, therefore, be of double wedge shape in section, the wedges being long and short respectively, and set back to back. The object of adopting a joint of this section in the case of water mains is to prevent any movement or forcing out of the lead ring by reason of the pressure of the water behind it.

But it also has advantages as a joint for gas mains, especially for those which, from their position, are susceptible to more than ordinary changes of temperature, and consequently to more than the average of expansion and contraction. It is obvious that any

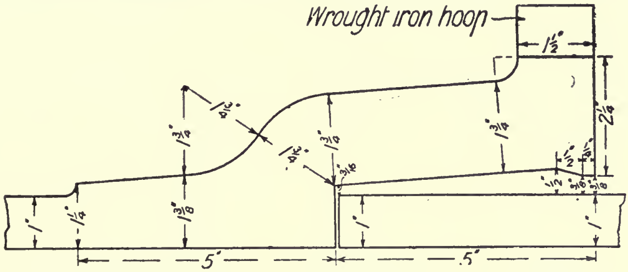


FIG. 102.—Thirlmere pipes, 1 inch thick, with longer sockets.

lateral movement of the pipes, due to contraction, would tend to draw the lead firmly against the face of the first short wedge surface

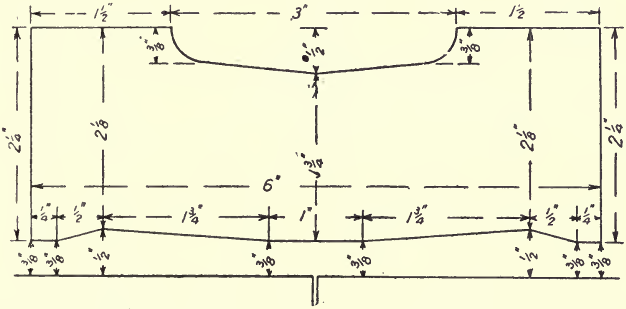


FIG. 103.—Section through Short Collar used on Thirlmere Aqueduct.

of the interior of the socket, whilst in any movement of the pipe, due to expansion, the effect would be to press home more tightly the

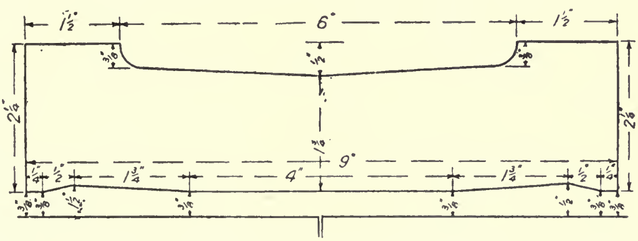


FIG. 104.—Section through Long Collar used on Thirlmere Aqueduct.

lead ring against the long taper face of the back of the socket, and in both these ways to minimize risk of leakage consequent on the movement. Fig. 102 shows a section through the socket of a 40-inch pipe used on another section of the same aqueduct. In this case, while the construction of the socket is similar to that of Fig. 101, the depth of the joint approximates more closely to that usual in gas mains.

It will be observed that the collars used upon these two sections, and shown in Figs. 103 and 104, correspond in section to the form adopted in the socket shown in Figs. 101 and 102.

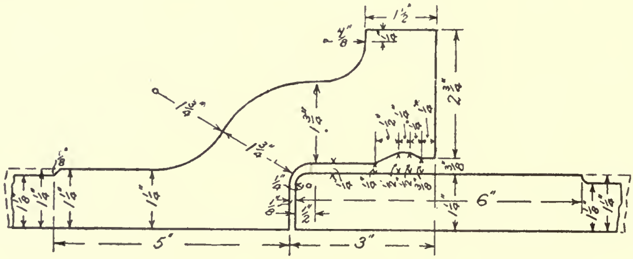


FIG. 105.—Section through Socket of Derwent Valley Pipe, $1\frac{1}{8}$ inches thick.

Derwent Valley pipes.—A section through the sockets of one size of the pipes used in the Derwent Valley water scheme, reproduced by permission of Mr E. Sandeman, engineer to the Derwent Valley Water Board, is shown in Fig. 105. On reference to the illustration it will be noticed that this again varies considerably from the Manchester type, and approaches more nearly to the usual form of socket, inasmuch as for approximately two-thirds of the depth of the joint the interior face of the socket is parallel with the spigot end. No yarn at all is used in making the joint, the whole of the joint space being run in solid with lead, which is prevented from flowing past the spigot end to the interior of the pipe by a flexible steel ring, fixed inside the pipe and keyed at the edges. The ring, shown in Fig. 106, is usually made about 2 inches or $2\frac{1}{2}$ inches broad and $\frac{1}{4}$-inch thick, a bolt and thumb screw being used to fix the band sufficiently firm against the interior of the back of the joint. The method of using the ring will be readily understood from the section given.

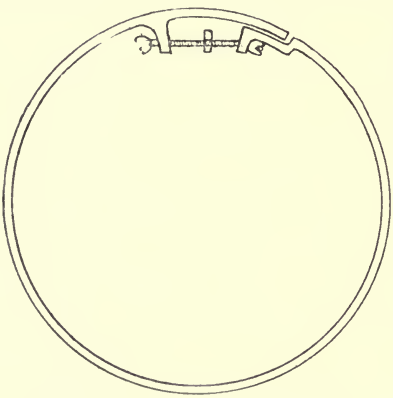


FIG. 106.—Flexible Steel Ring.

Nicholson's pipe extractor.—Unfortunately, pipes not only need jointing, but sometimes the opposite process has to be undertaken, and the pipes disjointed. Particularly is this the case when small mains are being replaced with others of larger diameter. The old method of cutting each pipe was both wasteful and clumsy. Of the many pipe extractors in use to-day, probably the best is the hydraulic-jack, made by Messrs Nicholson & West, of Halifax, shown in Fig. 107. As will be seen, a fulcrum is provided by a pair of strong steel clips, A, firmly bolted to the pipe. Between this and the socket the jack is placed, and on the ram being pressed out by the plunger in P, actuated by the handle H, the socket is forced off the spigot end. The loose end must be supported free of the ground to avoid friction, and the clips must be fixed absolutely rigid. Any slight twist in the latter may fracture the pipe upon which they are placed.

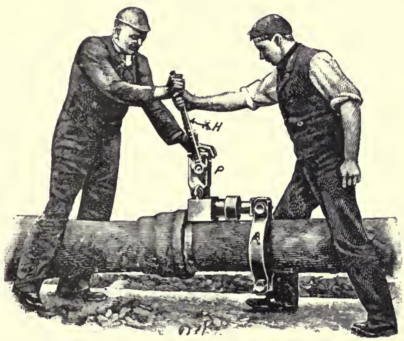


Fig. 107.—Hydraulic-Jack Pipe Extractor

Turned and bored joints.—The only other kind of joint which has proved a serious competitor with the open lead variety, is that known as the turned and bored joint, a section through which is shown in Fig. 108. In many respects this joint is a most excellent one. As will be seen on reference to the illustration, the spigot end of the pipe is first cast full and then machined true to a definite

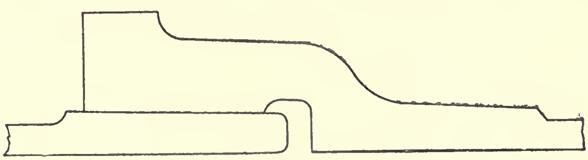


Fig. 108.—Section through original form of Turned and Bored Joint.

bevel, usually about one in thirty-two. The socket is cast of such section as to allow of its being bored out to exactly the same size and bevel as the spigot end.

When the joint is to be made, the faced surfaces are cleaned from all rust or dirt and then smeared with red lead, and the pipe well driven home with a heavy mallet, or mell, or swinging block, according to the size of the pipe being used.

It is obvious that this form constitutes a rigid joint of very considerable surface, and one which is very easy and cheap to make.

If pipes could always be laid and kept perfectly straight, and free from vibration or liability to movement in any direction whatever, the value of this form of joint would be correspondingly great. But, unfortunately, its very excellence in one direction constitutes a serious disadvantage in others, in practical working. Its excessive rigidity makes it impossible to deflect the line of pipes in the course of mainlaying without impairing the efficiency of the joint. For reasons previously stated, it is now almost impossible to lay a main absolutely straight in many of our crowded streets and roads. A joint must therefore be used which is capable of adaptation to actual, rather than ideal conditions.

The objection holds equally true in the event of deflection downwards through subsidence. In this case one of two things must happen — either the spigot must be withdrawn to some extent from the socket, or the main must fracture. This has been claimed as a positive advantage, inasmuch as it tends to concentrate possible leakage at one or two points. Plausible as this appears on the surface, it is hardly probable, even if the claim could be substantiated, that many engineers, actually responsible for gas distribution, would be found to assent to the principle that it is much better to have a broken main than a few joints leaking slightly. But, as a matter of fact, the disturbance due to subsidence is as likely to be spread over a number of joints with the turned and bored pipes as

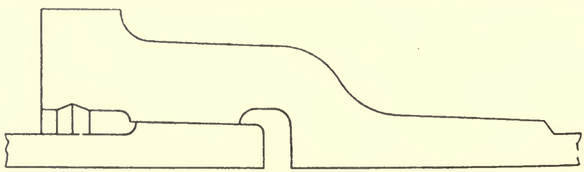


FIG. 109.—Improved form of Turned and Bored Joint.

with the usual open lead sockets. In the latter case, however, the joint can be made as good as ever it was in a few minutes by setting it up again, while in the former, any remedy short of relaying the main is at best a makeshift. In addition to this, it must be remembered that for a given amount of movement the leakage from the former will always be more than that from the latter, other things being equal, because in case of movement in an open lead joint, while the pipe may slide to a slight extent through the lead ring, the two surfaces always remain in contact; but in the case of a turned and bored joint, the surfaces of the joint are separated.

An improved form of turned and bored joint shown in Fig. 109 has found very considerable favour with gas engineers in various parts of the country. This consists really of a combination of the turned and bored and of the open lead joint. As will be seen, out of the 4 inches depth of socket the turned and bored section takes up nearly two-thirds of the back part of the joint, leaving about 1½ inches at the face to be run in with lead in the usual way. Whilst this is a very great improvement upon the older form of turned and bored joint, it is still open to the objection that in any movement due to contraction, instead of the pipe sliding slightly through

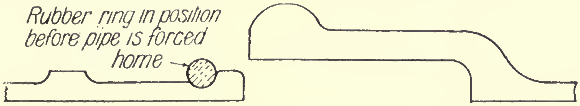


Fig. 110.—Forster Joint preparatory to making.

the lead facing ring, the shoulder of the turned spigot end acting upon the back of the ring tends to force it outward, and thus to imperil the soundness of the joint.

The Forster joint.—Another and very different kind of joint which has given great satisfaction to engineers in various parts of the country is that associated with the name of Forster, which is shown in Figs. 110 and 111.

The joint in this case is made by a circular vulcanized indiarubber ring. The socket is of the usual kind, but without any interior

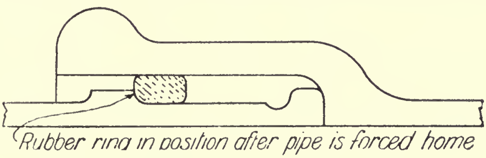


Fig. 111.—Forster Joint after being made.

groove; and as it has not to withstand the tensile strain involved in setting up it may be made considerably lighter than in the case of pipes jointed with lead. Upon the spigot end of the pipe a bead is cast, behind which there is a groove or depression running round the pipe; and about 3 inches from the end a shoulder is cast upon it. As the indiarubber rings are made larger in external diameter than the internal diameter of the socket, and as the internal diameter of the ring is smaller than the external diameter of the spigot end, two things will be necessary for making the joint—namely, a plug for getting the ring into position on the spigot end, and a cramp to force the ring with the spigot into the socket.

It is very necessary that the ring should not be twisted in any way, but should lie in the groove in a perfectly natural position, free from any torsion whatever. To ensure this, a wood plug (Fig. 112), tapering from the size of the interior of the ring to the size of the bead, is used, up the taper part of which the rubber ring is rolled to its place in the groove.

To force the spigot and ring into the socket, a cramp, similar to that shown in Fig. 113, for which the author was indebted, in the first instance, to Mr A. Grafton, of Southampton, is necessary. This consists of a back clip, C, tension rods, D and E, cross-head, A, saddle, B, and screw, S. For the purpose of jointing shorter lengths than 9 feet, cotter pin slots are made in the tension rods at 8, 7, 6, and 5 feet or other distances from the end, intermediate lengths being blocked out for. The saddle, B, is merely used for convenience of working, to carry weight of tension rods whilst the cramp is being adjusted.

To make the joint, it is necessary, first of all, to remove any possible burrs or roughness from either the spigot end of the pipe or the interior of the socket. The wood plug is then placed within the spigot end and the rubber ring carefully rolled into its proper

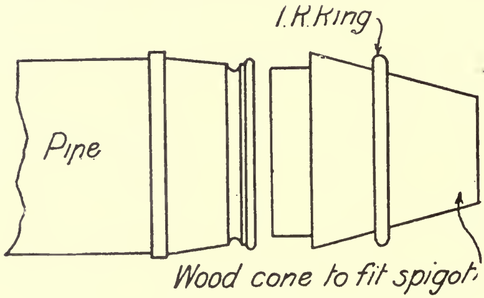


FIG. 112.—Wood Plug.

place in the groove, care being taken to avoid any torsion of the ring. The pipe may then be lowered to its place in the trench, and the cramp adjusted. It is important that the spigot end be set truly concentric with the socket before any pressure is applied. When this has been done, the screw is tightened up and the pipe gradually forced home. As the pipe is pressed forward the pressure of the interior of the socket causes the ring to roll out of the groove along the pipe to the shoulder, as shown in Fig. 111. When the screw is slackened there is a tendency for the pipe to roll back slightly. To overcome this, the author uses rods, capable of spanning three pipes, and after every third joint has been made, the three together are forced well home, and prevented from rebounding by partial filling in of the trench while the pipes are under pressure. After the joint has been made, it is usual to drive a ring of tarred yarn into the face of the socket, to prevent the entrance of sharp grit or stone.

In course of time the rings settle in their new position, from round to oval in section, and adhere, to some extent, to the two surfaces with which contact is made. A flexible gas-tight joint is thus formed,

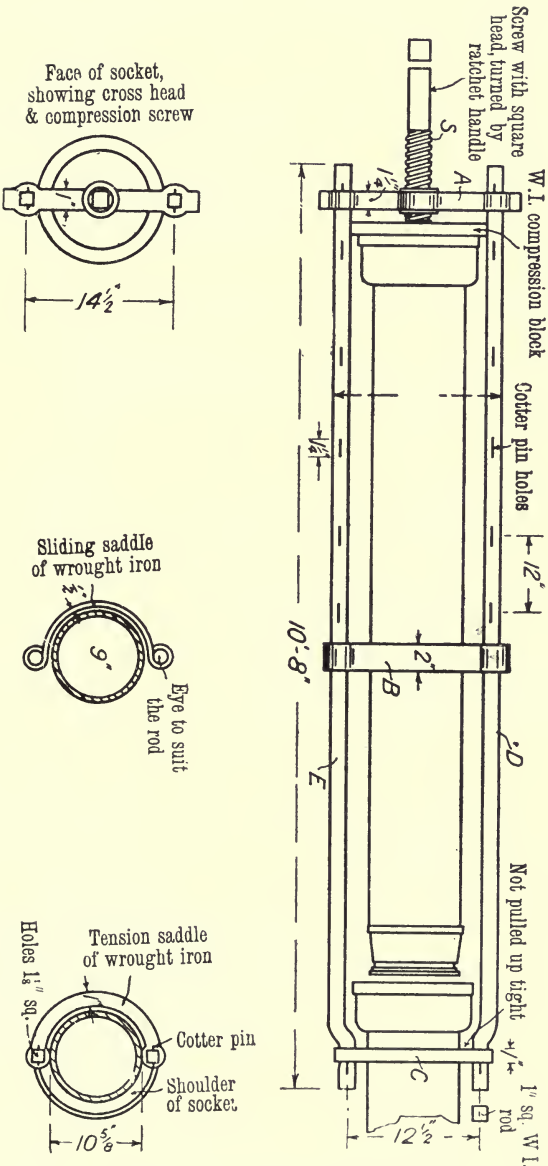


FIG. 113.—Forster Pipe Cramp.

capable of considerable deflection and movement without impairing the soundness of the joint.

In an undermined portion of the author's own district in which the ground is continually subsiding, a main which was a source of almost daily trouble through leakage was, some eight or nine years ago, replaced with Forster jointed pipes. In all the intervening years there has not been a single case of leakage on this main, and the same remedy is being applied to other mains in the same district.

The pipes may be easily disjointed by means of the hydraulic jack shown in Fig. 107.

The advantages attaching to a joint of this character will be readily appreciated. It is cheap, easy to make, requires no yarn

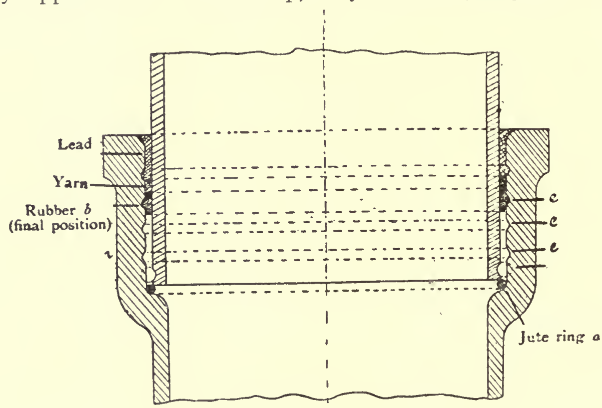


FIG. 114.—Zimmerman Joint.

(except as stated) or lead, no setting up, no extra excavation for joint holes, and can be readily made by any unskilled workman. It lends itself to great rapidity in mainlaying, and the facility with which pipes may be taken apart again, in case of necessity, gives it a great advantage over joints made in the usual manner with yarn and lead.

German rubber joint.—An interesting development of the Forster joint is that designed by Herr Zimmerman, of Recklinghausen, described in *The Gas World* for 6th May 1911 (p. 559).

As seen in Fig. 114 the spigot end of the pipe is provided with a circular groove in the same way as the Forster pipe. In this case, however, a series of grooves are also cast upon the internal surface of the socket. The joint is made by placing a rubber ring in the circular groove on the spigot end of the pipe, placing in front of it a ring of jute about half an inch in thickness, and forcing the spigot home into the socket. In this process the rubber ring rolls forward to the advanced grooves, where it assumes a flattened form The jute ring supplies not only a protective shield to the rubber

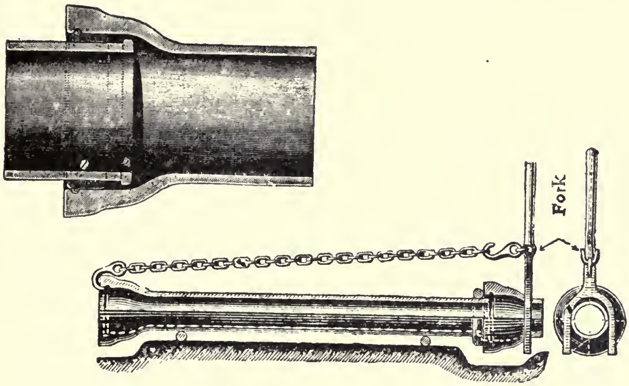


FIG. 115.—Somzees Joint.

against possible deleterious action by the condensation passing along the floor of the main, but also in the event of subsidence allows for a certain amount of compression in the pipe line. The face of the joint is then completed with lead and yarn in the usual way. The joint has been applied with great success to the destructive conditions usual in a colliery district.

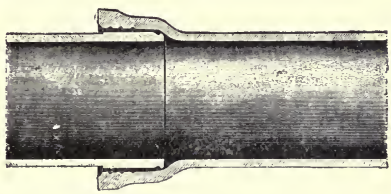


FIG. 116.—Trifet Joint.

French rubber joints, Somzees and Trifet patents.—Two French joints of the rubber ring open socket type are shown in Figs. 115 and 116. The first, which is Somzees' patent joint, is of quite the same character as the Forster joint just described, except that a larger ring is used, giving rather broader jointing surface and, of course, greater compression of the ring. The Trifet joint is similar in form, except that the socket contains three annular grooves into which the rubber ring beds. This tends to prevent lateral movement of the ring and the spring-back action in jointing which has been referred to in connection with the Forster joint.

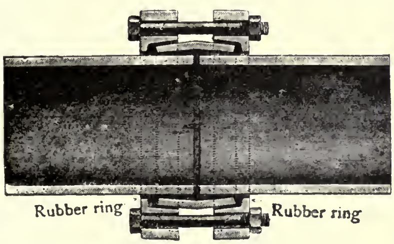


FIG. 117.—Gibault Joint.

The Gibault patent joint, shown in Fig. 117, is of the vulcanized rubber ring variety. The form of the joint allows of very considerable deviation from the straight line in mainlaying, and also, of course, accommodates itself readily to depression due to subsidences of the subsoil. The joint consists of a central cast-iron band, which overlaps on each side equally the spigot ends of the pipes to be jointed. This is of a double wedge shape in section, with the thick end of the wedges set back to back. Outside these, again, are two cast iron-clamps, one on either side of the band, provided with a sufficient number of tightening up bolts. Two properly vulcanized rubber rings, square in section, which fit the recess in the clamps, are forced into close contact with the surface of the pipe, on the one part, and against the slightly bevelled edge of the iron band, by the pressure exerted in tightening up the bolts. There is, therefore, a double and mutually independent flexible joint in each collar. This joint is especially designed to meet such cases as crossing of railway bridges or other positions in which an extraordinary amount of vibration may be anticipated. In exposed positions, too, the form of joint readily takes up the expansion and contraction incidental to mains in such places, and may thus be used as an expansion joint. And thirdly, the joint lends itself to the testing of mains either as they are being laid or after having been used, as the joint may be easily taken to pieces and blank flanges inserted for the purpose of isolating particular sections of the line of main.

"Patent true joint."—Perhaps the best joint of this character is that shown in Fig. 118, which is the patent "True" joint of the Pont à Mousson Foundries Company. This consists of a socket, A, and spigot, B, of which the latter is quite plain, and without the usual bead. The socket, A, is of particular section, as seen, the back fitting more or less closely the spigot end of the next pipe. In the socket, A, a recess is cast, rectangular in shape, except that the back tapers slightly towards the spigot pipe. This recess is intended to accommodate the vulcanized rubber ring, C, which is compressed into intimate contact with the surface of the spigot end, B, of the pipe and the bevelled back of the socket, A, by means of a suitable number of bolts acting through clamp D, and counterclamp, E. The features of this joint are (*a*) accurate centring, owing to the conical shape of the back of the socket; (*b*) the slight extent to which the rubber collar is in contact with the gas; and (*c*) a considerable power of deflection from the straight line, as shown in the

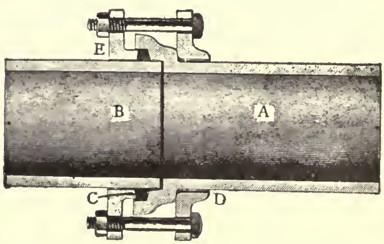


FIG. 118.—Patent "True" Joint.

photograph taken at Strasbourg in 1907, and reproduced in Fig. 119; (*d*) takes up readily vibration or depression due to road traffic or loading; (*e*) and finally, makes a very good expansion joint.

Durability of rubber rings.—Probably the question which will arise in most minds will be as to whether the gas, or products of condensation passing through the pipes will have any deleterious

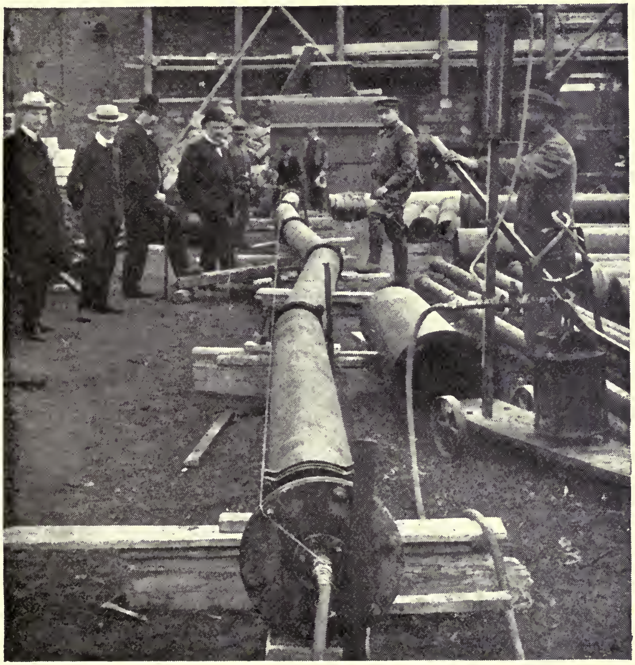


FIG. 119.—Strasbourg Photograph of "True" Joint.

effect upon the rubber ring. There is undoubtedly a great difference of opinion on this point. On the one hand, Mr Humphrey, at the 1904 meeting of the Institution of Gas Engineers, declared most emphatically, in another connection, that "experiments showed that indiarubber would not stand the attack of gas, and therefore its use in permanent systems was out of the question." Many other similar expressions of opinion might be cited. On the other hand, pipes jointed with these rubber rings have proved entirely satisfactory in several places where they have been used in this country. The author has in his possession a rubber ring which was used for twenty-five years in the joint of pipes conveying benzolized gas, and recently taken out of the ground, which shows no sign of solvent action, and, except for the permanent oval set it has taken, is to all appearances almost as good as when it was first used.

Herr Burgomeister, in a paper read before the Association of Gas and Water Engineers of Lower Saxony, states " that he had never discovered a rubber jointed socket joint to become leaky in all his thirty years' experience." In a communication to the *Journal of Gas Lighting* of 26th February 1907, particulars were given of experiences with rubber ring joints in two of the American Pacific Coast towns, which were of an entirely satisfactory character. In one case it was stated that, although the mains themselves were very much corroded, " the rubber in the joints was as soft and elastic as when new." In another town, " 70 to 80 per cent. are jointed with rubber rings. After an experience extending over nearly twenty years they had been found to be far preferable to, and much cheaper than, lead joints, and lasted practically as long as the mains themselves, especially when these were laid in damp or wet ground. Mains which had been in use for over thirty years had been taken up, and the rings found in perfect preservation." The rings do not, however, appear to have been so satisfactory where they were used in very dry ground, or so near the surface that the atmosphere could exert a marked drying effect upon them.

In further confirmation of these favourable practical experiences is the condition of some Lavril rubber rings used upon a main at Montreuil-sans-Bois (one of the Parisian suburbs). This was of 175 mm. diameter, and was laid in 1867. Owing to the demand for gas having outgrown its capacity the main was taken up in 1906. The rings taken out were tested, and, after having been in the ground for thirty-nine years, they were still capable of being stretched to half as much again as their normal length, and without the slightest cracking. They had, of course, taken on as a permanent set the oval shape to which they had been compressed for so many years, but could still be used as pencil erasers. In another case in connection with a water main taken up at the Pont à Mousson works, the Lavril rings were found to be absolutely sound after having been in the ground thirty-eight years.

Possibly the explanation of some of these discrepancies may be found in the fact that while naphthas and hydrocarbons will dissolve pure rubber, they have little, if any, solvent effect upon properly vulcanized rubber. If, therefore, a sample of rubber were used in one case which had been but imperfectly vulcanized, whilst in the other a well vulcanized rubber was used, this would be quite sufficient to account for the discrepancy in the results obtained. To test the point, the author has immersed a vulcanized rubber ring in a sample of the crudest and rankest liquor he could get from the works' syphons. Persons in the local rubber business predicted destruction within three days. At the end of six weeks the rings showed no signs whatever of solvent action, although they were slightly distended. At the end of three months they just began to show signs of pitting. If these rings can be made to stand complete immersion for three months in such a liquid, they may confidently be expected to withstand, for a great number of years, the attacks to which they would be subjected under ordinary working conditions.

The rings, which should be made of the best Para rubber, must be sufficiently large to allow of their being compressed to one-half their usual size when in position. This amount of compression undoubtedly tends to preserve them from any possible deleterious action, either of the gas or products of condensation.

The ordinary flange joint.—The flange joint is so generally used for air, steam, water and gas mains, and, indeed, on pipes used for almost any purpose whatever, that it is quite unnecessary to enlarge at any length upon it. As it is one of the oldest forms of joint, so for many purposes it is the best. It is simple, cheap, easily manipulated, may be taken apart with facility, and has a large joint surface.

In castings it is formed by a body of the material being continued round the end of the pipe at right angles to its axis, of about the same thickness as the body of the pipe, and of width varying with the diameter of the latter. The flange thus made has a suitable number of holes, either cast in or drilled through it, of the requisite size, and at equal distances apart. To ensure neatness and perfection of jointing, the flanges should be turned in the lathe to give true bearing surfaces.

In wrought-iron or steel pipes the flange may be formed by the metal at the ends being rolled out at right angles to the axis of the pipe or by angle iron being riveted on, or, in the smaller sizes, by loose flanges screwed on to the ends of the pipe.

The joint is made by the two flanged ends being brought together, with some form of bedding material between, the four surfaces then being drawn into close and gas-tight contact by means of the pressure exerted by the screwing up of bolts and nuts passed through the holes in the flanges. The bedding material may be of millboard, lead rings, sheet lead washers, asbestos sheeting, soft copper, or vulcanized rubber, according to the purpose for which the pipe is to be used. If millboard is adopted, it should be thoroughly well soaked in water to make it quite flexible and adaptable to any irregularities on the face of the flange, and then, after the moisture on its surface has evaporated, should be well smeared with red lead, mixture of red and white lead, or red oxide paste, before being used. The bolts, too, should be bedded, both under the head and the nut, with a small grummet of yarn well smeared with red lead, so as to keep the bolt holes perfectly gas-tight.

A joint made in this way is an extremely rigid one, and is therefore quite unsuited for the ordinary street mains of a distributory system. But for gasworks purposes and many kinds of interior fittings it is very valuable. It has a considerable jointing surface; it may be made in very confined spaces; it takes up but little room itself; and is therefore much used for connecting pipes to purifiers, exhausters, governors, and such classes of work, where there are frequently many branch pipes and valves to be connected within a very limited space, and, consequently, where other forms of joints would be absolutely inapplicable.

A very good illustration of such a use of the joint is shown in Fig. 120, which is an elevation and plan of the connections to a 36-inch and two 20-inch governors at the New Wortley gasworks at Leeds. Here the space available was extremely limited, and the number of connections to be made so many, that no other form of joint could be used.

Cement joints.—A very good joint may be made in the ordinary form of open socket and spigot by the substitution of Portland cement for the usual run of lead. For this purpose only the best quality of cements should be used.

Chemical composition.—The following is the chemical composition of a good cement suitable for this purpose :—

	Per Cent.
Water and carbonic acid	1.00
Insoluble residue	0.69
Silica	21.78
Alumina	7.97
Oxide of iron	4.07
Lime	61.75
Magnesia	1.15
Sulphuric anhydride	1.59
	100.00

The cement should be so finely ground as to leave not more than 3 per cent. of residue on a No. 180 sieve containing 32,400 holes to the square inch. A cement mortar consisting of 3 parts standard sand and 1 of cement should be able to resist a tensile strain of 300 lbs. per square inch six days after being made up, and upwards of 800 lbs. at the end of two years. A $2\frac{3}{4}$-inch cube of 3 standard sand and 1 cement should take a compression of 60 tons at the end of a year.

A very simple test which may be readily applied is that called the boiling test. To apply this, a circular knife edge pat of cement about $\frac{3}{8}$ inch thick in the centre and diminishing in thickness to $\frac{3}{16}$ inch at the circumference, and about 3 inches wide, is made up. This is kept for twenty-four hours in a damp box, having a flannel lid which is kept thoroughly moistened with water. The pat is then placed in cold water, which is raised to boiling point and kept boiling for six hours. A sample so treated should show no cracks

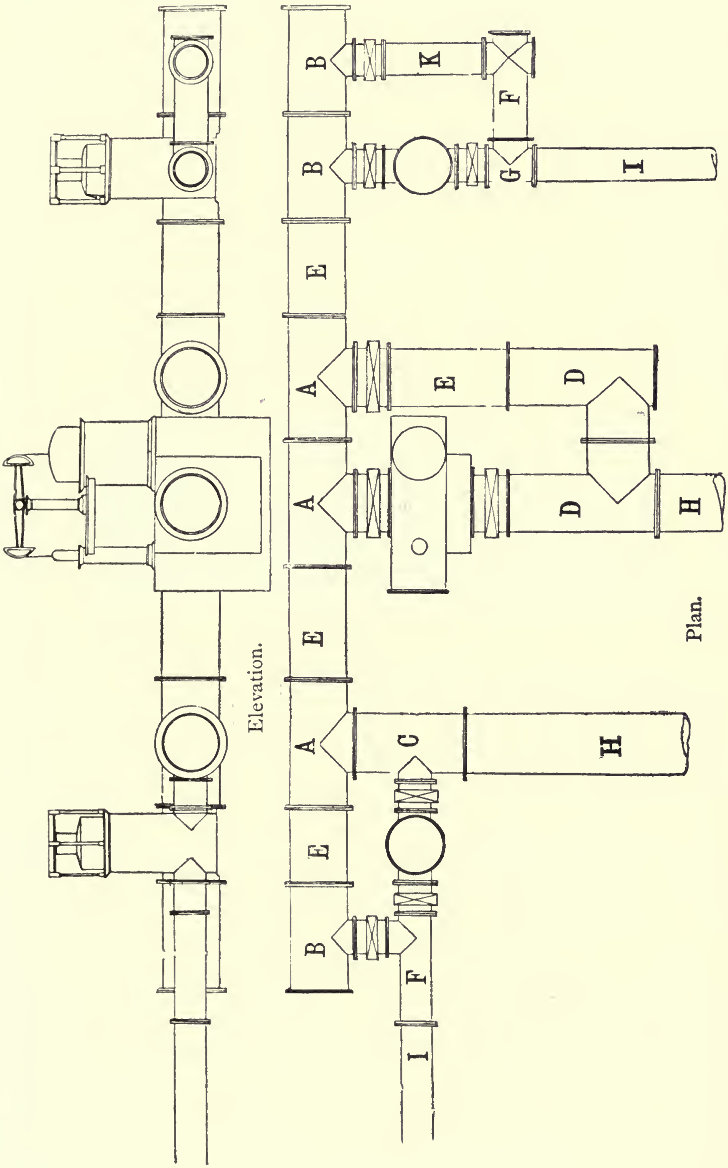


Fig. 120.—Elevation and Plan of Connections to 36-inch and 20-inch Governors at New Wortley Gasworks, Leeds.

when examined microscopically. No cement should be used for jointing which will not stand this simple test.

Chatelier expansion test.—Another easy and effective test is the Chatelier expansion test, which is carried out as follows :—Mix the cement with about 25 per cent. of water until plastic, and fill into the pronged moulds, placing a small piece of glass on the top and bottom of same. Then weight down with a 1 inch nut or similar weight to prevent the paste running from the moulds, and immerse in cold water for twenty-four hours. At the end of this time take out and measure across the end of the prongs, noting the measurements. Then put in a Faija's oven—or a small saucepan filled with cold water will do—and gradually boil for six hours at a temperature of 212° Fahr. Take out and measure again across the end of the prongs, and subtract the former measurement from the latter. The result gives the extent of the expansion.

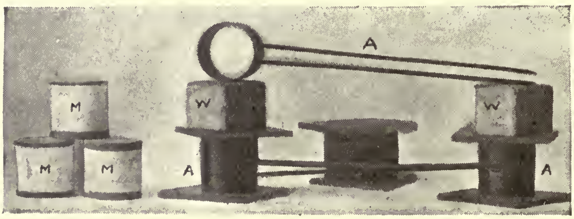


FIG. 121.—Chatelier Expansion Test for Cement.

If the expansion is under 4 mm. the cement is good, if it is only 2 mm. all the better ; but 4 mm. is quite safe to use. The essential outfit for this test is shown in Fig. 121, in which AA are the pronged moulds, WW are the weights, and MM are a few samples which have been tested.

Quick-setting cement only usable in winter.—For use in summer time, a comparatively slow setting and consequently much stronger cement may be used, but for work in the winter a little of the strength must be sacrificed to quickness of setting. A cement of not more than fifteen or twenty minutes final set should be used in cold weather.

Cement must be fresh.—It is important that all cement for jointing should be used quite fresh. It is a great mistake to use a cement which has been stocked for more than a few days. It should be obtained in, say, 20-feet bulks, to retain its strength. Immediately it is transferred from the bulk to the sack, and is, consequently, brought into more or less intimate contact with the atmosphere, a high-class, finely-ground cement begins to deteriorate in quality.

Action of constituents of gas on cement.—There is one point in connection with cement joints which does not appear to have received much attention, and upon which a little further information is clearly desirable. It is well known that paraffins have a somewhat deleterious action on cement, but the author has not been able to discover whether benzol, or any other constituent of gas, or the products of condensation, have any prejudicial effect upon it. Cement may be protected from the deleterious action suggested, when used for other purposes, by being well faced ; but it is obviously impossible to face the cement at the back of the joint, just where any such action must commence, except in the case of pipes large enough for a man to pass through.

Preparation of cement for jointing. — In preparing the cement for use, it may be gauged either neat, or a mixture of not more than three of sharp river sand to one of cement may be relied upon to yield a satisfactory joint, with a cement which has stood the boiling test as suggested. The cement mortar should be mixed to such a consistency that it will cohere when worked into the joint, but not wet enough to yield too readily by reason of its own weight.

Joint making.—In making the joint, after the pipes are placed in position, with the spigot end pressed home against the back of the socket, and the pipes have been properly bedded in the trench, one or two rings of untarred yarn are caulked into the joint in the same way as for the open lead variety. The cement is then prepared, in the proportions and manner described, and forced into the joint until all the air spaces are worked out and the socket is filled up quite solid. The cement is then faced up true to the front of the socket. In the case of pipes of over 8 or 10 inches in diameter it is usual, after pressing the socket full of the cement mortar, to drive a ring of yarn into the joint, for the double purpose of ensuring the solidity of the joint and as a reinforcement to prevent the cement yielding before it has time to set. The joint is then faced up with a coating of neat cement or of the cement mortar used for the body of the joint.

The cement joint may be safely adopted in cases where the pipes can be laid upon a good unyielding foundation, and where, consequently, there is no risk of subsidence, and where the main is not subject to vibrations caused by heavy traffic. It is especially useful in cases where the conditions are such that sufficient room for jointing in the usual way is not obtainable. Such special cases as the joints through the tank wall and under the tank floor, in laying larger inlet and outlet pipes to existing gasholders, and others of a similar character, will readily suggest themselves. In such confined spaces it is much easier to make a cement than a lead joint, inasmuch as the former can be made if a man can get his arm round the pipe, while much more room is required for the latter.

Comparison of costs.—Two great advantages of this class of joint are its extreme cheapness and the ease with which it may be made. This is shown in the following table of comparisons of costs per joint as between cement, lead wire, lead wool, and the ordinary run lead and yarn joint. These prices have been calculated from the practical results of actual work, with cement at £2, 1s. per ton.

	Size of Main.									
	4-inch.		6-inch.		8-inch.		18-inch.		24-inch.	
	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.
Cost of ordinary lead joint . . .	1	0.3	1	6.7	2	0.6	5	9.2	9	2.1
Cost of lead wire joint	0	9.3	1	2.1	1	6.45	4	3.9	6	10.5
Cost of lead wool joint	0	10.25	1	3.5	1	8.5	4	9.5	7	7.5
Cost of cement joint	0	4	0	5.25	0	7.25	1	0	1	6.5

It will be seen at a glance what an enormous saving might be effected if the cement joint could be used over the whole of a gas undertaking's distributing system. Probably the great hindrance to its more general adoption in this country has been the prevalence of the idea that not only would a cement joint not stand vibration, but that, because of its extreme inflexibility, it is quite unsuited to stand the other strains incidental to pipes laid under the roadways of our towns and cities. In this connection it must be remembered that cement loses with age the slight degree of elasticity it possesses when new.

Paper by J. D. von Maur.—In a remarkable paper on this subject by Mr J. D. von Maur, of St Louis, contributed to the Western (U.S.A.) Gas Association at their 1905 meeting, results of experiments and of actual work carried out are given, which quite set any such fears at rest. The favourable report which Mr von Maur there gives is also fully borne out in the experience of the author. For many years he has used cement for jointing main pipes in the streets of one of our large cities, and with uniform success. He has also put cement joints through some very severe tests, and in the results he obtained, three things stand out very clearly. First of all, at any rate for a few weeks after first being made, a cement joint is not quite so stiff and inflexible as it has commonly been supposed to be. Secondly, it will stand a good load before it begins either to crack or to draw. And thirdly, a cement joint may be deflected to a moderate extent before it cracks and becomes leaky. There appears, therefore, to be no reason why a cement joint should not be used, at any rate in those streets where it may be placed under the footpath, or where the subsoil is especially firm and solid, or where it will not be subjected to continual vibration due to heavy traffic or tramways passing either over it or in its immediate vicinity.

Iron cement joints.—A very good iron cement for joints on gasworks, and for other purposes, may be made up as follows, the proportions being those suggested by Mr Thomas Newbigging :—

For Quick Setting Cement.

98	parts of	fine cast-iron borings
1	,,	flower of sulphur
1	,,	sal ammoniac.
100		

For Slow Setting Cement.

197	parts of	fine cast-iron borings
1	,,	flower of sulphur
2	,,	sal ammoniac.
200		

The compounds must be thoroughly well mixed and kept very dry. When required for use, add hot water till the mixture is of

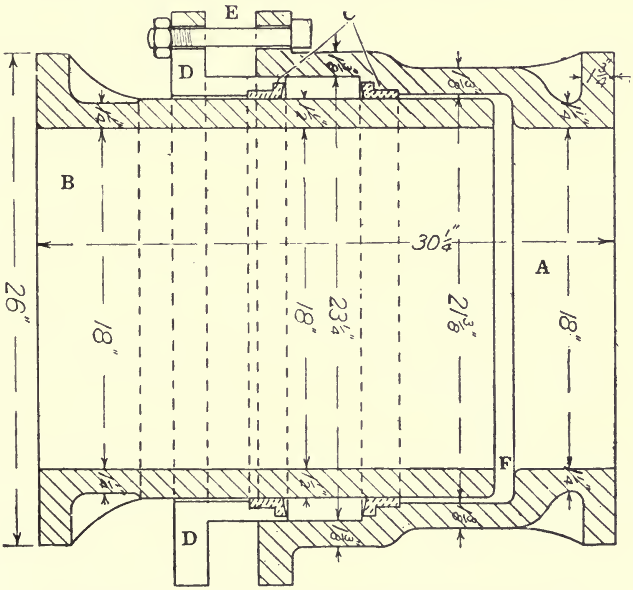


FIG. 122.—Piggott's Expansion Joint for 18-inch Main.

the consistency of stiff mortar. The borings used must be quite free from any grease.

Expansion joints.—It is not very often necessary, in connection with street mains, to consider and provide for the effect of expansion and contraction on a line of pipes. Occasionally, however, it happens that, owing to the exposed position of the main and its consequent subjection to great variation of temperature, or in districts where mining operations are carried on and there is more than ordinary risk of fracture through subsidence of the subsoil, it becomes necessary to insert an expansion joint. This, as its name implies, is a form of joint which allows for sufficient sliding movement to take up any variations in length due to expansion or contraction.

The construction of such a joint and the way it operates will be understood by reference to Fig. 122 which shows a section through

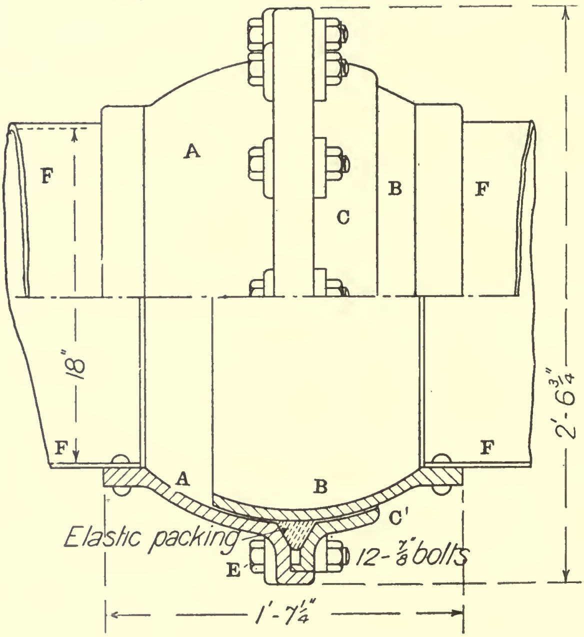


Fig. 123.—Piggott's Ball and Socket Joint for 18-inch Main.

an expansion joint made by Messrs Thos. Piggott and Co., Limited, of Birmingham, for an 18-inch main.

A is the flanged socket, in which the necessary movement may take place. B is the flanged spigot piece, which slides as required within the socket, A. C are the packing rings, properly woven and of a suitable mixture of greese asbestos. D is the angular collar, fitting loosely over and concentric with the spigot piece, B, and sliding easily into the socket piece, A, which keeps the former in position, and by means of the pressure applied through the series of bolts, E, keeping the packing rings firmly pressed against the exterior of B, and thus, whilst allowing of longitudinal movement, making a perfectly gas-tight joint.

It is obvious that in fixing this joint sufficient space must be left between the spigot end of B and the interior shoulder of A, at F, to allow for the maximum amount of expansion that is likely to occur.

Ball and socket joint.—The form of expansion joint shown in Fig. 122, while allowing of comparatively free motion along the line of main in the direction of its axis, does not provide for any deflection from that line. This is very ingeniously arranged for in the ball and socket joint shown in Fig. 123, which is also constructed by Messrs Piggott and Co. It is made up of two concentric and circular plates of metal, the outer of which is made to slide easily over the inner. The joint is intended to be used in connection with wrought-iron or steel mains, and the circular plates are attached to the main by means of rivets, as shown.

The outer plate is turned over at right angles to the periphery of the centre line of the joint, to accommodate the packing ring and to take the thrust of the complementary circular angular plate applied by bolts, as shown, and acting through the packing ring. The latter may be composed of vulcanized rubber, woven asbestos compound, or gutta-percha, either of which would make a thoroughly sound gas-tight joint. If necessary, arrangements might be made for drawing off any possible products of condensation.

When the joint has been fixed in position, the packing ring is laid against the shoulder of the outer plate, the loose complementary flange brought up to the packing ring, the whole being tightened up by the bolts, E, thus compressing the packing ring into gas-tight contact with the inner sliding plate.

A is the outer concentric sliding plate of cast-iron, ¾-inch thick. B is the inner sliding plate of cast-iron, ⅝-inch thick. C is the outer concentric angular plate, complementary to A and of the same thickness, and E the bolts by which the joint is made and kept gas-tight. F F are the opposite ends of the main pipes between which the joint is inserted.

The whole joint complete in this size weighs approximately 5¾ cwts.

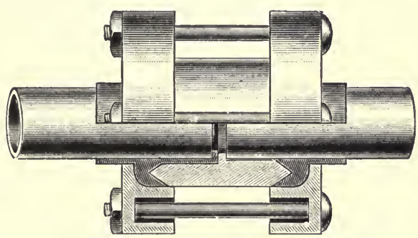


Fig. 124.—Dresser Coupling.

Dresser couplings. — An excellent series of pipe joints of the "Marini" type have been introduced into this country by Mr S. R. Dresser, of Bradford, U.S.A.

Fig. 124 shows a coupling designed for use upon wrought-iron or steel mains of all sizes from ¾-inch to 24 inches in diameter. It consists of two angular rings fitting loosely over the pipe, the recess in each ring facing the other, and each carrying a rubber ring with which the joint is made. Between the two rubber rings a plain circular iron band is inserted, having sharp bevelled edges. The two angular rings are drawn together by a series of bolts passing through them, and in the process considerable pressure is brought to bear upon the rubber rings, which are forced tightly against the surface of the pipe. Expansion and contraction are provided for by the pipe sliding in the rubber rings, when either occurs.

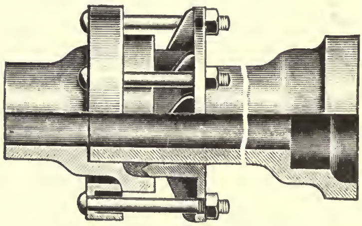


FIG. 125.—Dresser Coupling.

FIG. 125. shows the Dresser joint adapted to the usual form of cast-iron pipe. In this type the back circular ring fits over and works against the back shoulder of the socket, whilst the front angular ring slides loosely over the spigot end of the next pipe, the side of the ring carrying the bevelled edge sliding easily into the socket. The rubber ring is introduced into the latter, the joint being made by the tightening up of the bolts compressing the rubber ring against the back of the socket and between the exterior surface of the spigot end and the interior surface of the socket.

Fig. 126 represents a form of the coupling designed for stopping leaks on high-pressure mains without removing or disturbing the

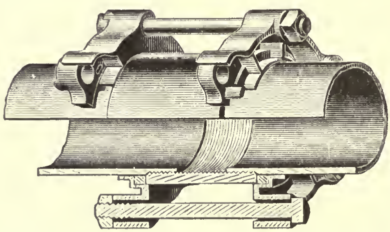


FIG. 126.—Dresser Coupling.

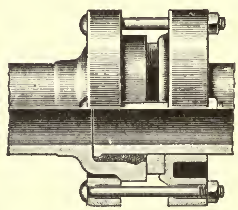


FIG. 127.—Dresser Coupling.

joint. It consists of a pair of clamping rings provided with an annular recess to receive the packing rings and clamping bolts which draw the rings toward each other, thus pressing the packing rings against the coupler and stopping the leak.

Fig. 127 shows another form of clamp, in this case designed to stop escapes from leaky spigot and socket joints made in the usual way with lead. The clamps are made in sections, and consequently may be used without breaking or interfering with the use of the pipe. The packing ring is placed against the face of the joint and pressed into gas-tight contact by means of the clamp and bolts, as previously described. In this case and others where the rubber ring may be subjected to deleterious action from the subsoil it is usual to protect it by means of a ring of yarn which is itself protected and held in position by a coating of elastic cement.

CHAPTER XI

MAINLAYING

Before commencing to lay any main, there are certain preliminaries to be carried out if the work is to be done expeditiously and well.

Preliminary survey.—First of all a survey of the suggested route should be made. The subsoil of most, if not all, of our large towns is now so crowded with pipes of one kind and another that it is necessary to ascertain, by consulting the various authorities, and if possible, their maps, whether the suggested route is clear, or whether it is already occupied by some other line of pipes or cables. Failing this, the necessary information must be obtained by means of trial excavations. Should the most convenient route be not available, then an alternative route will have to be found.

After the route has been finally decided upon it is essential that a complete survey of levels should be taken, so that all the necessary syphons may be provided for. It will be prudent to allow a little margin under this head, owing to the possibility of having to turn, twist, dip, or rise to avoid some obstacle which had neither been foreseen nor discovered during the survey.

Then the number and kind of the necessary irregulars, bends, tees, valves, tapers or other connecting pieces needed on the line for linking up to existing mains must be ascertained and provided for, so that, once begun, the work may go smoothly and quickly forward. The whole should then be reduced to plan and a copy given to the mainlayer in charge, so that he may be an intelligent worker, knowing exactly what he is expected to do and be able to prepare his work in advance.

Tools and implements required.—Before making the necessary arrangements for a continued daily supply of a sufficient number of pipes to be delivered at the place where the work is to be carried out, it is important to make quite sure that all the tools and implements likely to be required are available and in good working order. Many pounds are frequently wasted, work delayed, and much inconvenience caused by a lack of careful and proper foresight in this most elementary matter.

The tools and implements required will, of course, vary with the character and size of the work to be carried out. If only small mains are to be laid, then the provision of the necessary number of picks, shovels, and rammers, as shown in Fig. 128, for excavators, hammers, yarning, irons, setts and chisels for jointers (see Fig. 86, p. 130), together with the necessary yarn, lead and firepan, a straight-edge and spirit level, and a supply of soft clay, waste, and other small stores will be about all that is required.

Should the work involve the laying or relaying of service pipes, then, in addition, a handcart, with pipe vice, cutting and screwing

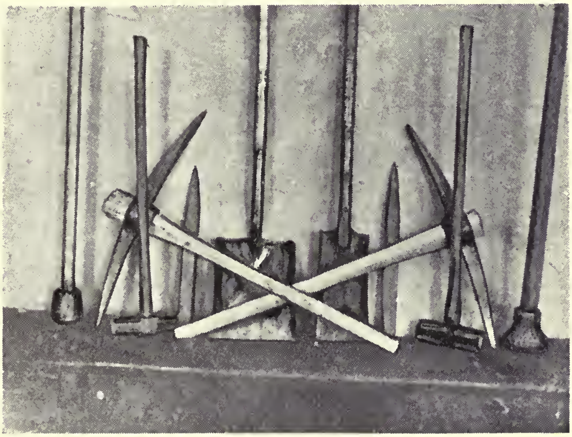


FIG 128.—Excavators' Tools.

tools, tongs, and drilling machine, as shown in Chapter XIV., and a supply of red or white lead, must be provided.

But if the work is of a heavy character, then many more of these tools and others of a different kind will be required. It will be necessary to provide a couple of pairs of shear legs (Fig. 129), each capable of bearing at least two of the pipes to be laid, with a sufficient margin of safety in addition. Then two sets of differential pulley blocks of the type shown in Fig. 130, fitted with chains long enough to allow of lowering the pipes into their position in the trench, with the necessary slings, must be available. With regard to the latter, the author has found that although they are more expensive, and need frequent renewals, hemp rope slings are much preferable to chain slings, owing to the tendency of the latter to slip on the smooth surface of the pipes, and the consequential risk of accident to the workmen employed. Wooden battens to lay across the trench to support the pipes previous to the latter being lowered into position will be necessary. The number and strength of these will be dependent upon the nature of the work, the kind of subsoil, and the method of mainlaying adopted. A proper supply of wood wedges to manipulate the pipes for jointing and to serve as packing pieces where necessary, and of wood plugs for stopping the ends of the pipes, will be needed. Other essential implements will include handspikes, crowbars, cold setts, planking, ropes, straight-edge long enough to reach from socket to socket, and spirit level. The supply of hammers, jointers' tools, lead pots, ladles, fire grates, etc., must be increased proportionately with the number of men employed. A sufficient number of picks, pick-shafts and shovels should also be

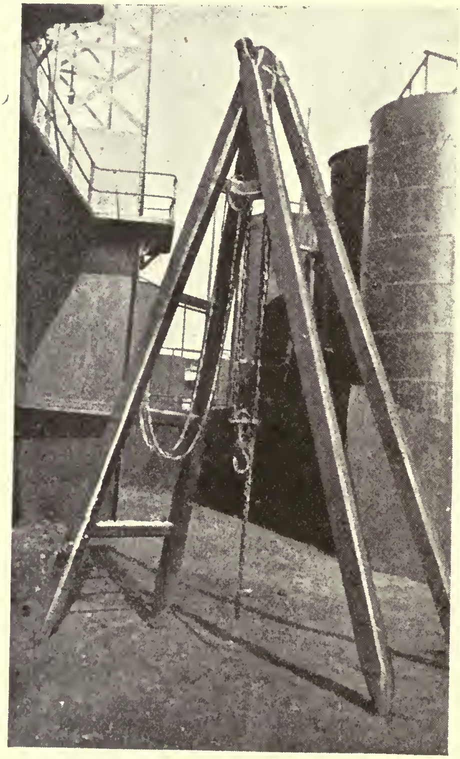


FIG. 129.—Shear Legs.

kept in reserve for emergencies. If the main is to be laid in hard, macadamized roads, or roads which are paved and concreted, or if such roads have to be crossed *en route*, a supply of striking hammers and steel wedges (see Fig. 128) will be required. As in the previous case, if services are to be dealt with, a handcart with the usual fitters' tools must be provided. It will also be necessary to make suitable provision for guarding the trench at night time, and for lighting the obstructed road by means of the usual red lamps. Fig 131 shows such a lamp and stand as constructed by Messrs Nicholson and West, Limited, of Halifax.

Number of men to be employed.—The number of men to be employed upon any given piece of work will necessarily vary with local conditions and requirements. In these days of crowded thoroughfares and heavy traffic, it is most desirable that any work involving disturbance of the roadways should be got out of hand as quickly as possible. Fortunately this is also the most economical method. It may almost be taken as an axiom that as large a number of men should be engaged as can be fully employed. There is a

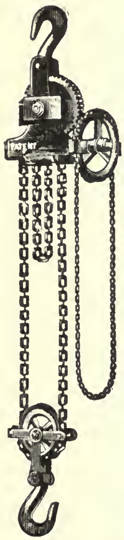


FIG. 130. Differential Pulley Blocks.

FIG. 131.—Danger Lamp.

point, however, varying in each case with the local conditions, beyond which every additional man will fail to do a full man's work, and by so much as they fall short of that there is a waste of labour.

It may frequently happen, in connection with mainlaying operations near the centre of our large towns and cities, and in congested thoroughfares, that the public convenience may necessitate the employment of double shifts of men. The work of excavation, at least, can thus be kept going from very early morning until late at night, even if not all night, and thus the rate of progress be considerably accelerated. This is rendered all the easier to arrange, inasmuch as work of this character is nearly always carried out during the long days of summer.

Depth of main.—With regard to the depth at which mains should be laid, the multiplication during the last quarter of a century of road rollers, traction engines, electric tram cars, motors, motor 'buses, and other forms of heavy road traffic, involving considerable road vibrations, has made it absolutely essential that mains should to-day be laid much deeper than was formerly considered necessary. Any main likely to be subjected to such strains as are involved in heavy traffic should be laid at a minimum depth of 30 inches from the surface of roadway to the upper side of the pipe. Should the

FIG. 132.—Gas Mains Covered over by Electric Cables.

main be subjected to exceptionally heavy traffic strains, the depth should be correspondingly increased. If, however, from any cause, such as obstacles in the subsoil, the necessary depth cannot be obtained, the same result may be arrived at by so protecting the main as to make it capable of offering very much greater resistance to shock. This may be done by filling the trench with concrete, under and around the pipe, and to a depth of 6 or 8 inches, or to the extent deemed desirable, above the top of the main.

If, on the other hand, it is merely a case of laying a distributing main under a footpath, a depth of 12 to 18 inches from the surface of the roadway to the upper side of the main will be quite sufficient, unless it is so placed as to experience exceptionally great variations of temperature, when it would be advisable to protect it from the effects of excessive expansion and contraction by carrying it a little deeper. The more moderate depth suggested incidentally ensures that the main will not be covered or rendered inaccessible, as has frequently happened, by the laying of electric cables or telephone or telegraph conduits, either immediately over or in very close proximity to a main. Figs. 132 and 133 show two particularly bad instances of this kind, in which A A are the gas mains and E E are lines of electric lighting cables.

Position of mains.—The question is frequently asked, what is the

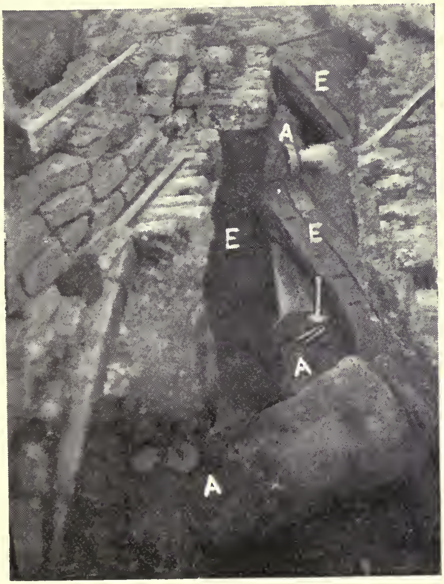


FIG. 133.—Gas Mains Covered over by Electric Cables.

best position in a roadway to lay a gas main? The practice varies so materially in different parts of the country that such a question can hardly be wondered at. The experience of the author leads him to the conclusion that all trunk mains should be laid in the roadway about 3 feet outside the kerb of the footpath. These mains being of large diameter are stronger to resist the vibration and weight of the traffic of the roadway than those of smaller size. It is not often necessary to bare them, as in the case of the distributing main. They may, therefore, be laid at a greater depth than would be advisable in the case of the latter. When, however, it is necessary to uncover them, if laid near the footpath the disturbance of the ordinary traffic is reduced to a minimum.

Similar reasoning leads one to the conclusion that distributing mains should be laid under the footpaths. They are comparatively weak, and less able to resist the strains due to traffic on the roadway. It is more often necessary to open them out for repairs or new connections, and if laid in the footpath there is no disturbance of road traffic, and such inconvenience as is caused to pedestrian traffic is very small, is soon over, and the footpath may be quickly reinstated, so that in the course of a few hours all traces of the excavation will have completely disappeared.

In thoroughfares where services are needed on both sides of the roadway, it is usual in our large towns to lay a main under both footpaths. Although this involves an extra initial expenditure, it is money well spent. The expense of laying long services across the roadway is saved, and the weakest part of the distributing system, and that in which the leakage is heaviest, is removed from the position of greatest danger, namely, the position where it would be subject to all the strains incidental to roadway traffic, to the comparative immunity of the side walk. The services are short, the attachments easy, and reinstatement cheap.

Influence of possible danger from electrolysis.—There is just one other point in this connection. The fell evil of electrolysis has begun to make its appearance in our distributing systems. There can be little doubt that the principal cause of the trouble is the stray current from our tramway lines. Now, if the mains are laid under the footpath they are removed as far as possible from the source of the danger. In the case of our trunk mains, laid in the roadway and parallel with the tramway lines, it is generally possible to keep some feet of more or less non-conducting soil between the main and the line. But in the event of services crossing the lines at right angles, and necessarily laid at a less depth than the main itself, this is obviously impossible. Services crossing roadways under tramway lines should, therefore, always be avoided where possible. Under certain conditions they are almost sure to become conductors for stray current to or from the mains.

This leads naturally to a further important question. The rapid growth of electric traction in our streets and the increase of electric lighting, to say nothing of telephone and telegraph lines, has naturally led to such a multiplication of cables that a very considerable amount of the subsoil of some of our streets is taken up by them. What, then, should be the minimum distance allowed between any of these and a gas main. It goes without saying that this distance should always be as great as it is possible to make it. But sometimes comparatively close quarters are unavoidable. If so, then no cable should be laid within 12 inches of a gas main. It must not, however, be assumed that this distance will give immunity from danger. It will not. But as the risk increases in inverse proportion to the square of the distance, it is obvious that they should be kept as far apart as possible, and that 12 inches should be the absolute minimum allowed.

In addition to the considerations of danger involved, it must also be remembered that the distance suggested is the least which will afford facility of access to the pipe in case of repairs or extensions becoming necessary.

Jointing above ground.—A very great economy in labour, combined with fuller assurance of good work on the part of jointers, may be obtained by jointing three pipes together, on bearers placed across the trench, before lowering them into position, as compared with the old-fashioned method of lowering them singly and making

FIG. 134.—Setting Joint Up from Trench.

every joint in the trench. The author has discussed this point in some detail elsewhere.[1] It is obvious that the particular place at which there is a temptation to a jointer to shirk his work is in setting up the under side of the joint. And the temptation increases with the size of the mains being laid. In the case of large mains which it is impossible to reach round, his work is often difficult, and his position when setting a joint up is very cramped at the best of times; and a slight shower of rain may make the condition of the trench very disagreeable for a man lying upon his back. Moreover, this part of the joint is out of sight, and any neglect is not so easy to detect as in other places. Anything, therefore, which will render the task easier and the position of the worker more natural, and

[1] See *Transactions of the Gas Institute*, 1902. Also *The Gas World*, 14th June 1902, pp. 1080-1086.

which facilitates thorough inspection of the work, is to be welcomed. It inevitably makes for better workmanship. This is admirably secured by jointing three pipes together, as suggested, above ground, before they are lowered into the trench. The bottom part of the joint can then be set up by a man standing in the trench below the pipes, whilst the whole of it is much easier to get at above the ground level than in the trench. Of course, this only applies to two joints out of three, but even so, it is well worth the additional tools required, and greatly facilitates the progress of the work. By reducing the number of joints made underground to one in three the great probability is that that one will be well made. In the case

FIG. 135.—Setting Joint Up from Trench.

of mains of small diameter, these may be jointed by the side of the trench on wooden blocks, and then lifted over into position with ropes. (See Fig. 136.)

Possible danger to the joints.—It has been thought by some that with this method of working there is a danger of the joints being strained in the process of lowering the pipes into position. This is extremely improbable, if proper care is exercised. If there is carelessness, then it is most likely that it will show itself in imperfect work, even although all the joints are made in the trench. When the pipes are properly balanced there will be as much weight upon one side of the sling as upon the other, and the strain on the joint is therefore reduced to a minimum. And just because it is easier to balance three pipes in the slings than two, it is better to lower three together than the smaller number. And in addition to all this, practical experience proves these fears to be groundless. The author has worked on this plan for nearly thirty years with the most satisfactory results.

Then there is the economy due to lessened need of excavation for jointing purposes. The cost of the additional excavation required for the men to work in necessarily varies with the character of the subsoil. If the cost for any size of main is x number of pence or shillings, then, assuming that on a mile run of main we avoid the necessity for this additional excavation for two-thirds of the total number of joints, it is obvious that a sum equal to $293x$ is saved.

To ensure that pipes have sustained no injury in transit and are quite sound, each pipe before being jointed should be smartly tapped

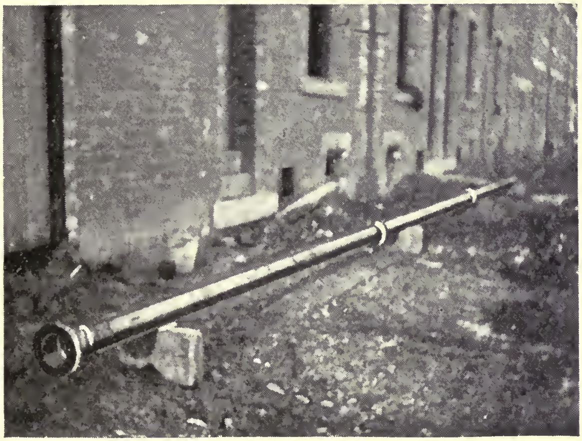


FIG. 136.—4-inch Pipes Jointed on Wooden Blocks.

with a hammer. If a full bell-like note is obtained the pipe may be accepted, but if the least jar is noticed careful examination should be made for the fault, which is usually either a cracked spigot end or split socket. Cracks are very seldom found in the body of the pipe, although sand holes and other faults may be. Although, owing mainly to the coating of the pipes, the test is not an infallible one, yet an observance of this precaution may often save very considerable delay and expense in cutting out faulty pipes.

Assuming that all preparations have been made, and the pipes delivered at the place where the work is to be done, we will now briefly describe the process of mainlaying.

Excavation.—First of all the trench must be excavated in which the pipes are to lie. It will have been previously ascertained which is the most convenient and available line for the pipe to take.

To avoid the crooked and irregular trench one sometimes sees, the two sides of the trench should be carefully marked out before excavation is commenced. Should the subsoil be composed of stiff clay, rock, chalk, firm sand, or other firm and unyielding materials, it will be sufficient, after excavating to the proper depth, to bottom out the trench to give the necessary and uniform fall to the main and make this the bed for the main to rest upon.

It frequently happens, however, that a pipe has to be laid through marshy or yielding ground, in which it is impossible to obtain a good natural foundation bed for the pipe line. In all such cases it will be found much better and more economical in the long run to prepare the bed specially than to run risk of serious subsidence. The inevitable result of the latter must be fracture of the pipe or drawn joints, with the main sagging and becoming waterlogged, and in the process causing great annoyance and inconvenience through oscillation of lights before final extinction of supply takes place.

A very good foundation in such circumstances may be formed by cutting up old battens or sleepers to the width of the trench, and

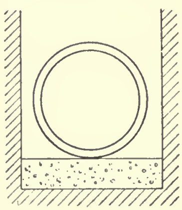


Fig. 137. — Main Lying on Concrete Bed.

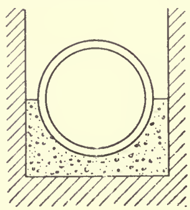


Fig. 138. — Main Bedded in Concrete.

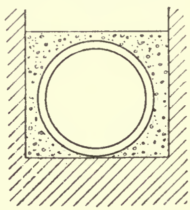


Fig. 139. — Main Bedded in and Covered by Concrete.

spacing them out a few feet apart. These should be well protected by dipping in a hot tar bath before being used. An excellent alternative is to excavate the trench to a depth of 6 or 8 inches below the necessary level and concrete the bottom, or lay the main on packing pieces of the requisite thickness, and then fill in under and around the pipe with coarse concrete, as shown in Figs. 137-139. Either of these make a very good bed, the two latter being exactly fitted to the shape of the pipe.

In the case of new roadways which have been raised to the proper levels by tipped-in soil and rubbish which has not yet become firm, it may be advisable to run a steam roller over the surface to consolidate it as much as possible before the mains are laid. In every case in which the subsoil is at all loose the bottom of the trench should be watered and then well rammed, so that there may be as little subsidence as possible.

The trench having been dug and fully prepared to receive the pipes, as much as necessary of the excavated soil is removed from the side of the trench so that the pipes may be easily moved into position. Battens of 9 inches by 3 inches or 9 inches by 4 inches section, varying with the size and weight of the pipes being used, are then placed across the trench to support the pipes whilst being jointed. If the side of the trench is of an unstable character it may be necessary to lay a series of planks of, say, 11 inches by 3 inches section and 12 to 15 feet in length, along the side of the trench, upon which the battens spanning the latter may rest, so as to distribute the load as much as possible.

Pipes brought into position.—Assuming that the pipes are to be jointed in threes before being lowered into the trench, the first pipe is rolled up on to the battens as nearly as possible over the position it will occupy in the trench, and scotched to prevent rolling. Numbers two and three are rolled up in succession and the pipes "rowed" home, spigot into socket, ready for jointing. The pipes are then lined up straight at the side by means of a line held taut against the further socket and against a sighting-board at the hither spigot end, the pipes being moved until each socket just touches the line. The pipes are then adjusted to a uniform level by chalking the top of the socket for a couple of inches, and sighting along the top of the pipes from the sighting-board placed upon the near spigot end. Taking the board as the first fixed point and the end socket as the last, the two intervening sockets should just, and only just, be visible, the pipes being raised or lowered as may be necessary by means of wood wedges driven under them on the supporting battens.

The sighting-board is simply a piece of $1\frac{1}{4}$-inch or $1\frac{1}{2}$-inch wood, as shown in Fig. 140, cut out to the exact curve of the exterior of

Fig 140.—Sighting-board.

the pipe, and of such depth at A that when the board is laid upon the pipe, the top of the board, B, exactly coincides with the outer edge of the socket.

Lowering the pipes.—The pipes having thus been adjusted straight and level, the jointing may now be proceeded with as described in Chapter X. After the joints have been set up and inspected, the pipes are ready for lowering into the trench. The two pairs of shear legs are brought into position over the pipes and straddling the trench, and the chain blocks hung from the shackle. The slings are passed round the pipes, the hook of the blocks is adjusted, and the pipes are ready for lowering into the trench, where they are jointed up to the pipes last laid.

It is very important that the slings should be placed in the exact position to balance the pipes. Failure to observe this precaution is no doubt the cause of trouble, where such has been experienced, through disturbance of joints in lowering the pipes. Assuming that a socket is equal in weight to one foot length of pipe, and neglecting the weight of lead and yarn in the two joints which have been

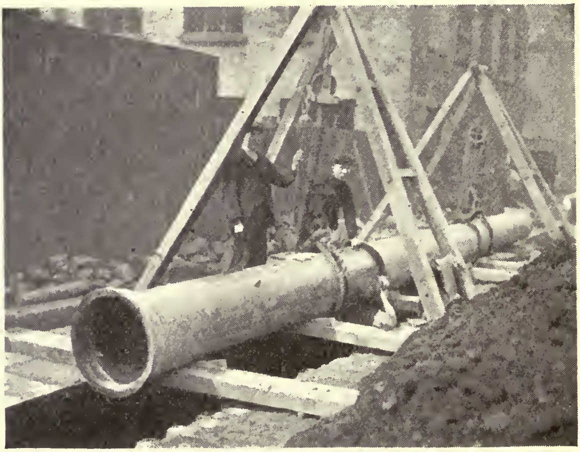


FIG. 141.—20-inch Pipes ready for lowering into Position.

made, and also that the pipes being used are 12 feet in length, exclusive of the socket, then, for our immediate purpose, we may imagine these three pipes to be 13 feet long each, or 39 feet in all. Dividing this by 4 we get 9 feet 9 inches from the spigot end as the place for our first sling. At the further end, however, inasmuch as the socket equals in weight one foot of pipe, we must deduct this length from 9 feet 9 inches, and thus measuring 8 feet 9 inches from the back of the socket we find the place for the second sling. The shear legs should be so placed that the slings are a few inches outside the true plumb line from the centre of the legs, so that the weight tends to draw the slings towards each other. If pipes are slung in this manner from the proper places the strain on the joints is reduced to vanishing point.

Should mains be laid " dead " or " alive ? "—A very considerable difference of opinion has existed on the point as to whether large mains should be laid " dead "—that is to say, without any gas being admitted to the main until the line is completed, or whether gas should be passed into the main from the very commencement of the work. In some parts of the country it is the custom to make a small connection of, say, 1-inch or 1½-inch tubing to some distributing main near, so as to give a supply of gas into the main being laid sufficient to try the joints for soundness, as the work proceeds This is, in the opinion of the author, a small advantage which is enormously outweighed by the disadvantages entailed. The danger of an explosive mixture forming in the more recently laid pipes, owing to a slight leakage past bag or disc, and becoming ignited by a spark struck from some stone by a workman's tool, or in any other way, is one to be avoided wherever possible. Again, if the main has to

FIG. 142.—Milne's Leak-Testing Machine.

be bagged off each day before work can commence there is consequential delay, much absolutely unproductive labour expended, and gas lost in the operation.

Testing work day by day.—It is, therefore, in the opinion of the author, much better, in all cases where it is possible to do so, to lay mains of large capacity without any admission of gas to them until the work is finished. Each day's work should be tested before the trench is filled in, and this may easily be done by means of a force pump, many suitable kinds of which are upon the market. The main can be charged to any desired pressure, and an examination made of each joint by painting round with soapy water or oil; air bubbles being, of course, noticed if the joint proves unsound. The detailed inspection of each joint may be avoided by fixing a pressure gauge on the main and taking observations as to possible drop of pressure, which, as the end has been previously blocked —and of course there is no consumption or other legitimate outlet— could only be due to leakage. Another ready means of locating a possible unsound joint is by means of a little ether used in a force pump, which, making its way through a leaky joint, may be easily detected by the sense of smell.

Fig. 142 shows a very good apparatus for the purpose of main testing, made by Messrs James Milne and Son, Limited, Edinburgh. As will be seen, the machine consists of a closed cylinder to which are attached two powerful pumps for filling the gasholder and the

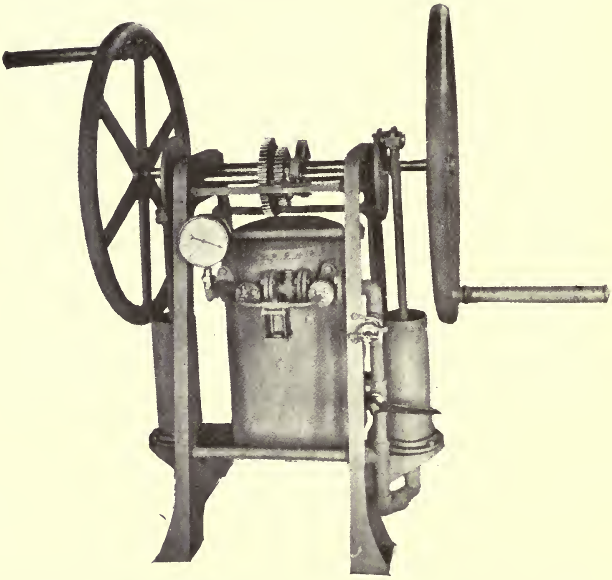


FIG. 143.—Milne's Main-Testing Machine for large capacities.

length of main to be tested, with air up to a pressure of 40 lbs per square inch. When the main and cylinder are filled, the by-pass cock is turned off, and should any leakage take place in the main the pressure therein will tend to fall. A quantity of air will then pass from the gasholder to the main through the indicator, which consists of a glass dish partially filled with water and having a tube leading from the holder, the tube being sealed slightly below the level of the water. Any air passing to take the place of leakage in the main has therefore to bubble through the water, and can be seen through the glass. A leakage of only $\frac{1}{300}$ th part of a cubic foot per hour, may by this means be detected.

For testing mains of large capacity, the same firm make an instrument, shown in Fig. 143, which is adapted for more rapidly inflating the main. This consists of a closed cylinder mounted on a cast-iron frame, and fitted with two 4-inch pumps worked by means of wheels and double crank shaft. This machine is capable of inflating a pipe with a capacity of 290 cubic feet in one hour.

The machine is fitted with small wheels on the bottom of the frame to facilitate movement along the side of the bench.

Blowing air out of mains.—When a main is laid "dead," it is obvious that before it can be brought into use some means must be adopted for expelling the air contained in the main. Where such a main runs direct from the works this may be done in a sort of back-handed fashion, by making the gas connection at the town end and blowing the air out through a blow-away on the works. If this is impossible, a 2-inch or 3-inch pipe, rising to a height of, say 20 feet, fitted with a cock for shutting off, and with an observation tap some 4 or 5 feet above ground level, may be connected at the most convenient end and the air expelled through it. For obvious reasons, it may be advisable to so arrange matters that the end of the blowing off process, and consequently the time of greatest danger, should take place in the early morning hours.

Cost of Labour per Yard Run of Main.

Size of Main.	Unpaved Footpath.	Flagged Footpath.	Tarred Paving.	9-inch Concrete and Tarred Paving.	Hard 12-inch Macadam.
	s. d.	s. d.	s. d.	s. d.	s. d.
3	0 11.52	1 2.22	..	..	..
4	1 0.02	1 4.40	..	..	..
6	1 2.72	1 6.73	..	..	..
8	1 6.52	1 9.29	..	..	..
10	2 3	2 6	..	..	..
12	3 0	3 3.33	3 7.10	..	4 6
14	3 6	3 9.18	4 0.58	..	5 2.1
18	..	4 0.62	4 3.07	..	5 7.5
20	..	6 1.6	6 6.53	..	8 1.63
24	..	..	7 3.41	10 1.81	9 9.7
30	..	..	8 5.73	12 1	11 5.5
36	..	..	..	18 2.94	15 7

Cost of labour in mainlaying.—The nature of the subsoil, and the depth at which mains have to be laid, varies so widely in different places that the cost of excavation for one piece of work as compared with another is bound to reflect these variations. The experience of the author in this respect, as shown in the foregoing table, is therefore given with considerable reserve. The figures are the actual results of practical work in laying upwards of 220 miles of mains during the past twelve years, ranging from 3 inches to 36 inches in diameter, under the actual conditions obtaining in a large town. The depths at which the mains were laid ranged from a cover of 1 foot 6 inches to 9 feet. The cost per yard run of main includes all labour both for excavation and jointing, and also cost of reinstatement in the case of flagged footpath. It is, however, exclusive of cost of all materials, pipes and cartage, and the relaying of concrete and tarred paving.

Amount of fall required.—As there is always a considerable amount of condensation taking place in the mains, it is necessary to arrange that they shall have a definite inclination to certain points. At these places catch boxes (see Fig. 45, p. 95), or syphons as they are improperly called, are connected, into which the products of condensation may flow. These are, of course, always placed at the lowest point of the particular section which they are intended to serve. The amount of fall necessary in the main for the effectual removal of the products of condensation to the syphon has been variously estimated. In some cases the gradient given is absurdly low. The pipes should seldom be laid with a smaller amount of fall than 1 inch in 10 feet. If the declination of the main is in the direction of the flow of gas—that is to say, if the gas is flowing down hill, the amount of fall may safely be reduced to 1 in 150 to 1 in 200.

Usually the surface of the roadway under which a main is to be laid has a definite fall in one direction or the other, and as the main is laid at a moderate depth, it is sufficient to follow the general inclination of the surface. That is to say, if the road rises in the direction in which the work is going forward the condensation must inevitably travel back to the preceding syphon box, while if it falls as the work progresses, the main is laid too near the surface to enable the fall of the pipe to run counter to the fall of the surface of the road for any great distance. But it frequently happens that a roadway is so flat that in order to avoid an unnecessary multiplication of syphon boxes, and yet to preserve a general inclination in a definite direction, great care has to be exercised. In these level districts an instrument for truly grading the trench bottom to any definite amount of "fall" comes as a great boon. Such an instrument is found in the Gradiograph, illustrated in Fig. 144. This consists of an accurately graduated steelyard, A, accommodated in a metal casing of rectangular section made of nickel-aluminium, C.

The steelyard is pivoted at one end, D, at a point which coincides with zero, and from this point is graduated in units and half-units from 30 to 305. Above the pivots and attached to the steelyard is mounted a sensitive, graduated, and accurately ground bubble, B, such as is used upon a theodolite.

Travelling along the steelyard is a graduated cursor, E, made of gun-metal with a hardened steel runner inserted, which enables adjustments to be made to any intermediate gradient as 196.5 or 225.8. At the extreme end of the steelyard is a notch, and when the cursor is placed in this position, the Gradiograph is converted into a very accurate level. The reading by means of the graduation on the cursor gives a unit of 0.1. When the desired gradient has been determined, all that is necessary is to place the zero line of the cursor, E, opposite the gradient required. The sliding cover, F, may then be replaced and locked to prevent tampering with the mechanism and to secure the exclusion of dust. The bubble may be inspected through the glass cover provided for the purpose. For bottoming out a trench to receive pipes the Gradiograph may be mounted upon a straightedge of convenient and suitable length, and the trench graded to any requisite inclination.

Should the main, through any carelessness on the part of workmen, or lack of efficient oversight, be laid with a fall in the wrong direction,—that is to say, away from and not towards the syphon, the main will in course of time, as condensation collects, become waterlogged. The supply will become increasingly impeded until, if the amount of fall in the wrong direction exceeds the diameter of the pipes, the flow of gas through them is at last stopped altogether. In such a case the alternative lies between finding the

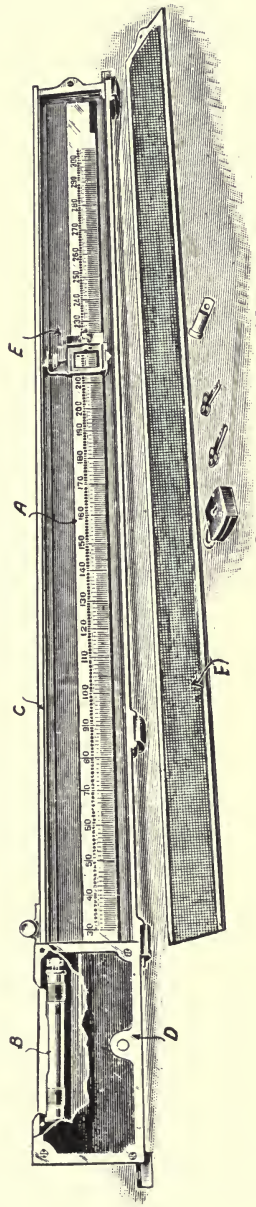


Fig. 144.—The Gradiograph.

point where the collection has taken place and inserting the necessary syphon, or relaying the main with a proper fall. It may occasionally be necessary to lay a main dead level for a short distance. But this should never be done unless there is an absolute necessity, and then the length of main so laid should be kept as short as it is possible to make it. In the event of settlement or subsidence, such a main may be the source of very considerable trouble, through condensation collecting and causing oscillation in the supply.

Regular and systematic attention to syphons necessary. — The importance of the regular and systematic examination, and periodical clearing of, all syphons in a district cannot be overestimated. If any are missed or forgotten, trouble and inconvenience and loss may ensue through stoppage of supply. A list of all syphons should

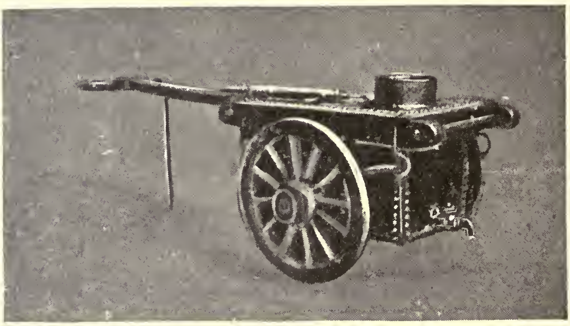


FIG. 145.—Handcart Syphon Tank.

therefore be kept, with particulars of their exact positions, so that in the event of the regular syphon pumper being taken ill another man may be promptly put in his place. Or in the event of the syphon box being covered up when a roadway is new metalled, or snow is upon the ground, it should be possible to locate the exact spot where the syphon is to be found.

For the purpose of conveying the liquor pumped from the syphons in the vicinity of the works to the works' tank, a handcart tank, as shown in Fig. 145, is provided. In the case of those syphons lying farther afield, and where such an arrangement would be much too heavy, slow and costly, a tank mounted upon wherry wheels for horse traction is used to collect the condensation found in the syphons for conveyance to the works.

Undesirable subsoil.—It frequently occurs that a main has to be laid through ground which has been filled in to new levels with most undesirable materials from the point of view of the durability of the pipes. Ashes, clinker, and such refuse of a porous and friable character, frequently containing acid compounds and other deleterious matter, which are often used for this purpose, exercise a

FIG. 146.—2-Inch Syphon Taken Out of Acidiferous Subsoil.

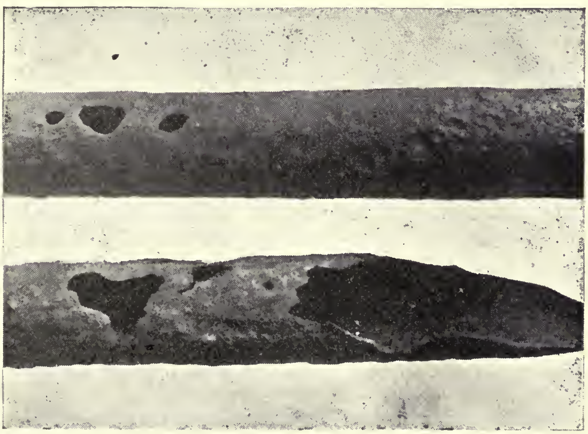


FIG. 147.—Corroded 3-inch Pipe taken from Acidiferous Subsoil.

most adverse influence upon the life of the main. Fig. 146 shows a syphon and Fig. 147 a 3-inch pipe taken out of such a subsoil. In every case, all such material excavated from the pipe trench should be carted away and fresh clay or clayey loam, or other harmless material, substituted for it. The additional initial expense thus incurred will be much more than recouped, in the addition to the life of the main which is thus secured.

Bacterial action on pipes.—It is a familiar enough thought with us to connect ravages upon living organisms with bacteria, but it may be new to many to associate these with attacks upon such inanimate bodies as cast-iron pipes. We are, however, told that certain species of bacteria may attack such pipes unless protected by a coating of tar. These attack the iron directly, by the excretion of an acid

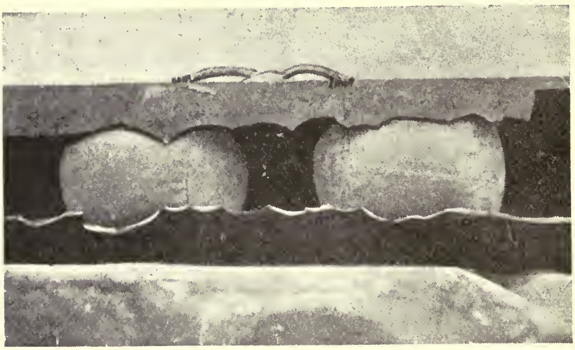


FIG. 148.—Gas Bags in Main.

product, which gradually dissolves the metal, forming a series of pittings. In other cases the action is indirect, and is due to the product excreted by the bacteria rendering the soil acid. Sulphur compounds, produced by their actions upon compounds such as sulphates in the soil, may also play a part in the corrosive process. As a remedy, Mr Gaine suggests that the soil in the vicinity of iron pipes should be drained in such a way as to carry off the acid bacterial products rapidly. In point of fact, the numerous cuttings in the roadways of our towns for sewer and other connections practically serve the purpose of draining the subsoil in the neighbourhood of gas mains and so carry the suggestion into effect.

Gas bags.—It is very important, indeed, that in making connections the gas bags used for stopping the flow of gas should be absolutely reliable. Owing to its liability to burst, the rubber bag should never be used. A canvas bag, with each seam taped and sewed similar to those manufactured by Mr Thomas Bugden, London, are undoubtedly the best in the market for this purpose. For large mains, the bags which are nearly rectangular in section are preferable to the round. Those bags which rely upon rubber solutions for cementing the various parts of the bag together should be avoided at all costs, as the solution is frequently so acted upon by the moisture in the main as to cause the seam to give way and the bag to burst open. If this should happen whilst a joint is being run with lead, the consequences might be very serious. Large mains have sometimes got alight from this simple cause.

Rubber discs.—When laying long distances of mains along a straight roadway the rubber disc is a most handy contrivance. It is used as shown in Fig. 149. A is a bobbin of wood large enough to slide easily through the pipe to be laid, and 4 to 6 inches thick. This is fixed on rod, D, and serves as a guide, and also keeps the disc itself in the true vertical plane. B is a disc of rubber slightly larger than the interior of the pipe, and varying in thickness with its diameter. It is held vertically by two plates of ⅛-inch iron, C,

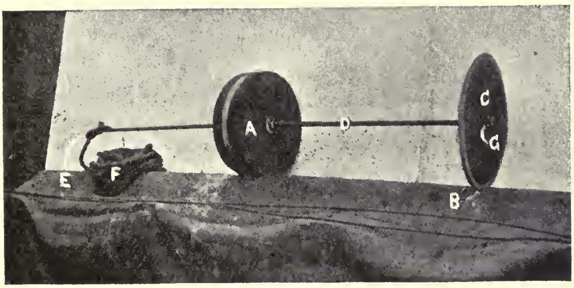


FIG. 149.—Rubber Disc.

which are placed one on either side of it, the whole being firmly bolted to the rod, D, by the nuts, G. At the end, E, the rod terminates in an eye through which a rope is passed, and by which the whole arrangement is pulled forward as the work proceeds. Light iron rods are supplied, each linked to the other, which may be threaded through the pipes for the purpose of taking the end of the necessary rope, F, through. This implement serves two excellent purposes. First of all, the mere fact of its use ensures that the main is left perfectly clear and unobstructed. It is impossible for the proverbial bag of waste, handspike, or other tool, of which the pipes being laid are so often the depository, to be left in the pipes after the disc has been pulled through. And secondly, if the main has gas in it, the disc is an excellent means of keeping the gas back. The trouble and expense of cutting holes in the mains for the insertion of bags is avoided, as is also the loss of gas in bagging off, and the wear and tear of the bags themselves. Of course, in turning corners or curves the main must be bagged off in the usual way and the disc taken out, to be reinserted in the first straight length.

Goodman main stopper.—The Goodman patent stopper is an ingenious and very reliable device for stopping gas mains during cutting out operations or repairs, and is shown in pipe, M (Fig. 150). The stopper consists of two strips of flexible steel encased within a padded leather sheath, H, the strips being hinged at top and bottom. As these steel bands at rest tend to straighten themselves as much as possible, the two together, when out of use, take the form of a

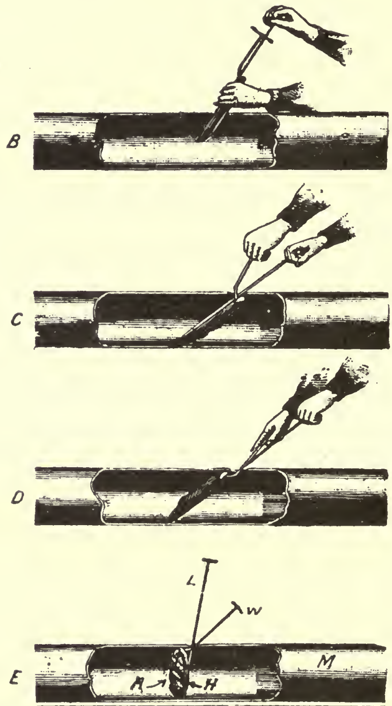


FIG. 150.—Goodman Main Stopper.

very flat ellipse. Around the interior of the rim a diaphragm of very strong oiled canvas, A, is firmly sewn to the leather. This canvas is of such size as to completely stretch across the main to be stopped without becoming tight, as shown at A.

At each end of the ellipse, and passing over the canvas, two guide rods are fixed, each rather longer than half the length of the ellipse, and the lower sliding easily over the upper. These guides are not seen in Fig. 150, being on the opposite side of the diaphragm to that shown. The ends of the sheathed flexible strips are attached at top and bottom to the two rods, L and W, which are slightly bent, and terminate in handles by which the stopper is worked.

When the stopper is to be used, the main must be drilled in the same way as for the ordinary bag. The canvas is then carefully and tightly wrapped round the rim as shewn at B, to prevent cutting and to facilitate entrance into the main, and the stopper inserted in the latter with the face down and handles on the top as seen at C. When placed in the main the rims are, of course, considerably longer and narrower than the diameter of the main. When the stopper is in the main the handles are given a half turn (see D), thus facing the stopper to the pressure. The handle, W, attached to the upper end of the rim, is then held firmly with the stopper close to the hole through which it was inserted, whilst the lower one, L, is drawn upward, the lower guide at the same time sliding over the upper one. This, of course, shortens the ellipse until the rim takes the circular form, the stopper being at the same time brought into an upright position. The short handle, W, should then be pushed or tapped slightly until the gas is completely stopped. The padded rim is thus pressed into intimate and gas-tight contact with the interior surface of the main, and the passage is completely blocked by the diaphragm of canvas being stretched across the pipe as shown at E.

It is the great advantage of this arrangement that the stopper can be very quickly inserted and adjusted in the main, and the necessity for a long and more or less tedious preliminary, such as is experienced in inflating the bags, entirely obviated. The stopper will also remain perfectly tight under the considerable amount of vibration and shock necessitated in cutting-out operations, whereas under the same conditions the bags need constant attention.

Cutting out.—Cutting out a piece of old main for the insertion of branches, or making new connections, is always a rather ticklish operation, and particularly is this the case if the main is of large diameter.

To begin with, the main itself, having probably been laid a number of years, and the pipes cast at a time when there was not so much care bestowed upon their manufacture, may be difficult to cut without fracturing or splintering.

Then, if the interior of the pipe is badly corroded, it is frequently very difficult to make the bags or stopper hold absolutely tight. Should any small quantity of gas, finding its way past the bag, become ignited by a spark struck by some unfortunate or careless workman, the consequences may easily be very serious. To minimize these and other risks as much as possible, every precaution which experience has proved necessary, or foresight can suggest, must be taken.

At the place where the connection is to be made, the accretions of rust upon the exterior of the pipe must be removed. We will assume that, say, a 14-inch main is to be cut for the purpose of inserting a tee-piece. The position of the outlet of the tee will be fixed by the local circumstances. The length of the tee both ways from centre of outlet to back of socket, and centre to end of spigot, should be marked upon the existing main from the centre line which the outlet of the tee is to occupy. It will be necessary to allow, say, 1¼ inches at each end, so that the tee may easily be moved into position. In other words, the piece cut out will be, say, 2½ or 3 inches longer than the dead length of the tee itself.

The point where the main is to be cut having thus been ascertained, a narrow groove should be cut into the main with gouges or diamond points at each place. Care must be taken to make this groove at

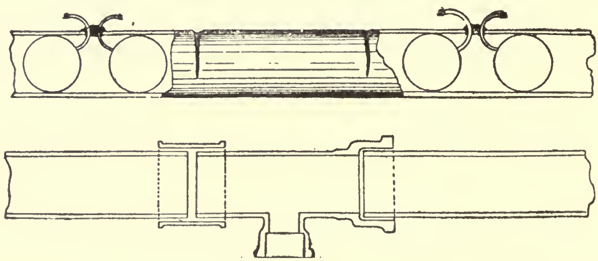


FIG. 151.—Main Bagged Off and Gouged.

right angles to the axis of the main, and it should be cut to the depth of about half the thickness of the pipe, and round quite two-thirds of its circumference, as shown in Fig. 151. The reason for cutting the groove is to facilitate the cutting out process, and especially to ensure as far as possible a clean and vertical break.

Drilling holes for bagging off.—Simultaneously with the above preparations, the work of drilling holes through the main for the insertion of the gas bags should be proceeded with. These may be placed at any convenient distance from the cut, but not less than 3 feet away. The bags should be far enough inside the pipe to be out of harm's way when the break is made and during the subsequent jointing, but not far enough from the severed end to afford opportunity for an explosive mixture to form in the main should any small quantity of gas succeed in getting past the bag or bags. Any corrosion lying in the main, which would prevent the bags fitting tightly to the interior surface, may be removed by a mop made of waste or yarn fastened to the end of a cane or thin stick.

If the main is usually under pressure of more than about 18-tenths, it is advisable to make temporary arrangements to have this pressure reduced as much as possible during the cutting out process. It is also advisable that any considerable operation of this kind should be undertaken in the early hours of the morning. At that time there are fewer people about to impede the work by looking on and obstructing the workmen. There is also less risk of some careless passer-by, after lighting his pipe or cigarette, flinging his match into the proximity of the severed ends of the main. Then, too, the workmen are fresh and less likely to become "gassed," in the event of gas leaking past the bags, than after the fatigue of working part of the day. And, in the last place, if after all the foresight and care exercised things should go wrong, as sometimes they will, there is the whole of the remainder of the day to make any temporary provision that may be necessary for a due continuance of the gas supply at nightfall.

To make assurance doubly sure, it is usual to insert two bags, instead of one, at either side of the "cut out," as shown in Fig. 151. One bag is inserted first, and turned away from the cut and inflated. Number two is then inserted and turned towards the cut, to act as an auxiliary and stop any small quantities of gas succeeding in passing number one. A difficulty in making the bags fit tightly in the main may often be obviated by thoroughly soaking them in water before insertion. In addition to this, if the space in the main between the bags is filled with water, an absolutely gas-tight stop is ensured.

Having got the gas securely bagged off on either side of the piece to be broken out, we are now ready for the final operation of cutting

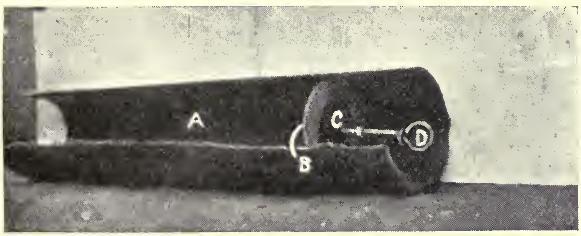


Fig. 152.—Hand Disc in Main.

out. This is done by means of cold setts and chisels. The pipe is chiselled at the most convenient point in the groove previously referred to, and as soon as an opening has been made through the thickness of the pipe, a soft steel or iron wedge is driven hard home, the result being a fracture through the weakest part (the groove), carried right round the circumference of the pipe in a line which is a continuation of the groove. As it is impossible, even if we are successful in obtaining a clean cut, to remove the severed piece whole, it must be broken up at least partially; but care must be exercised not to damage the severed ends of the pipe which remain.

Immediately on the removal of the broken piece of pipe, wood plugs, or better still, hand discs, should be placed in the open ends of the main, while any further excavation which may be necessary is proceeded with. The hand disc is simply a disc of rubber supported by two plates of iron, as shown in Fig. 152, in which A is the main, B the rubber disc, C the supporting plate, and D the handle. Fig. 153 shows a similar disc for use in a larger main, in which case it is necessary to have the support, H. The other letters are common to both. It will also be well, throughout the whole period, from the time of commencing to break out until the time the last joint is run, to tell off a man, or couple of men, whose duty should be to prevent any one coming near the work either with lighted pipe or cigarette, or striking a match in its immediate vicinity. English people are most reasonable in this respect, and do not at all resent

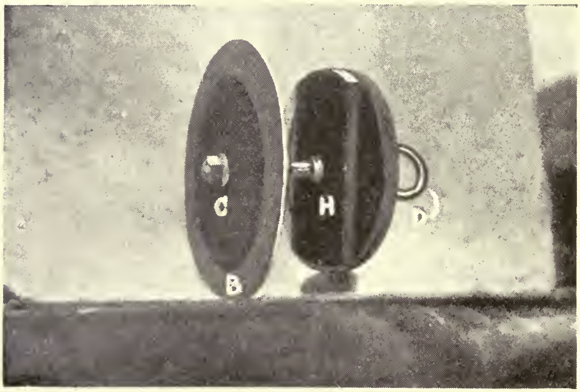


FIG. 153.—Hand Disc with Support.

being requested not to approach with lighted pipe when they understand that by so doing they may become a source of danger to their fellows.

Jointing up main again.—All necessary excavation having now been carried out, the shear legs are placed across the trench (if they have not already been used for removing the piece cut out), the collar is lowered and slipped over the end of the existing main, towards which the spigot end of the tee will be placed, and the tee is then lowered into position. To make sure that the centre of the collar is exactly over the centre of the space between the spigot end of the tee and the cut end of the pipe (the $2\frac{1}{2}$ inches which the tee is shorter than the piece removed), measure off and mark upon either the tee or original main, or both, the exact place for the face of the collar. It will also be necessary to make sure that at the socket end the tee is not driven off the cut main during the process of jointing. Care should also be exercised in bringing the ladles of lead for running the joints, that no spark or particle of burning tinder adheres to the bottom of the ladle. Such a spark or particle has frequently been the cause of very serious accidents, when it has been brought into close proximity to a main in which a little gas has been leaking past the bags.

Ruscoe's drilling apparatus.—During the last few years there has been placed upon the market a combination of split-tee and drilling apparatus, which will undoubtedly supersede altogether this dangerous business of cutting out. The split-tee, as will be seen from Fig. 154, is a combination of the old split-collar and the old saddle, cast with flanges, which are faced and bolted together with

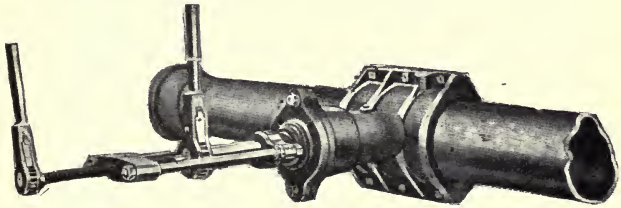


FIG. 154.—Ruscoe's Drilling Apparatus.

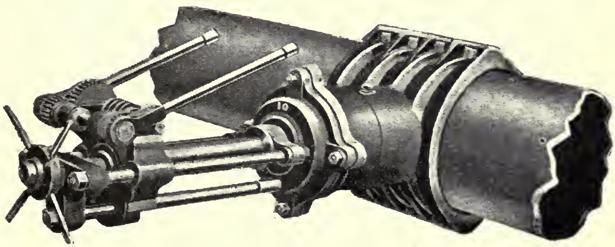


FIG. 155.—Ruscoe's Drilling Apparatus, large size.

a thin strip of sheet-lead between. Upon the socket or outlet two lugs are cast to receive the base of the drilling apparatus shown in Figs. 154 and 155. The former is intended for the smaller sizes, whilst the latter, with its double ratchet handle arrangement, is designed for the larger attachments. Machines are now being made by Messrs Ruscoe & Co., of Westminster, capable of drilling holes up to 48 inches in diameter.

The method of using the apparatus is as follows :—The two halves of the split-tee are placed into position where the branch is required, and firmly bolted together, the strip of sheet-lead between the flanges making a perfectly sound joint. When the two halves are bolted together the internal diameter of the split-tee is the same as that of an ordinary socket for that size of pipe. This leaves a space for open lead joints at either end of the tee, which are then made in the usual way, with yarn and lead. After these joints have been finished, the drilling apparatus is bolted to the face of the outlet of the tee by means of the two lugs. The drill is made to fit tightly into the socket of the base of the apparatus and also into the neck of the outlet of the tee when well greased. The

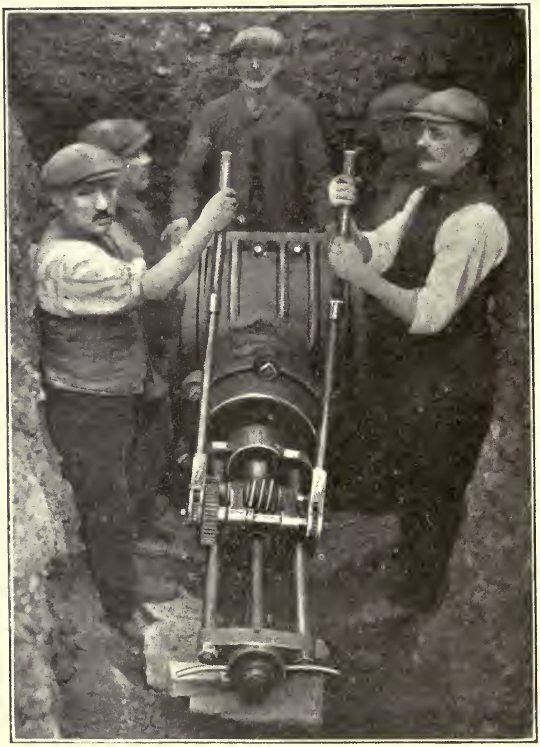


FIG. 156.—Drilling out 24-inch main for 14-inch branch at Leeds Gasworks.

centre of the main corresponding to the outlet of the tee is then drilled out by means of the specially-constructed cup drill worked by means of a long ratchet, as shown. The cup drill is filled with tallow before commencing operations, and the loss of gas is remarkably small. Before the drill is fully withdrawn a bladder is inserted in the neck of the tee, thus keeping gas back whilst the drilling apparatus is withdrawn and the first length of pipe laid. It will be seen, therefore, that this arrangement saves the breaking of the main and so weakening it, saves cutting the holes for the bags, saves the necessity of bagging off, or of interfering with the supply in the slightest degree, prevents loss of gas, and incidentally minimizes risk of accident or gassing of workmen, and, in a word, reduces a risky operation to one of almost complete immunity.

" Gassing " of workmen.—But notwithstanding all the care which may be exercised, and the use of the most modern tools and methods, the "gassing" of workmen, although much less frequent than formerly, does occasionally take place. It is very necessary, therefore, to be able to apply first aid remedies at a moment's notice.

To do this intelligently, we should understand one or two simple physiological facts. It is well known that the red corpuscles are the oxygen carriers of the blood. This oxygen they obtain from the air which is taken into the lungs at every inspiration. Simultaneously with the taking up of the oxygen, they give up the carbonic acid which they have collected on their journey through the body, and which is expelled in the act of respiration. When, however, a person breathes an atmosphere charged with CO or H_2S, these gases are taken up by the blood in the lungs, to the exclusion of the necessary oxygen. The provision of oxygen for the various functions of the body therefore fails. Neglecting all intermediary processes, the result of this is seen in the dizziness, faintness and loss of muscular control which supervenes.

The evils of "gassing" are greatly accentuated where a considerable proportion of water gas is present. This is not only because the action is more severe in degree because of the larger quantity of CO present, but also because of the suddenness with which a workman may be attacked. With coal gas there is a certain amount of warning from premonitory symptoms realized by the workman, and also apparent to any one who may be watching him. In the case of "gassing" by carburetted water gas, however, the collapse is quite sudden, without warning either to the man affected or to any onlooker. It must be also remembered that water gas is not so odorous as coal gas, and that therefore any possible leakage past bags or stoppers is not so noticeable in the former as in the latter case.

It is obvious from what has been said above, that the point to be aimed at in any remedies which may be applied is to stimulate into the fullest activity the twin functions (in this connection) of respiration and circulation. By vigorous circulation, the blood is brought to the lungs as rapidly as possible, and while there, by means of respiration, it discharges the CO and takes up the oxygen from the air, which, in turn, is carried through the body, and so restores the physiological processes to their normal course.

Seeing now clearly the point to aim at, the first thing to do, naturally, is to remove the affected workman to a pure atmosphere. Any collar, scarf, or other neck covering which might interfere with free respiration should be loosened or removed.

In slight cases, where some degree of control of the limbs remains, it is obvious that physical exercise may be used to stimulate respiration and blood circulation. The distressed workman should, therefore, be encouraged to walk to and fro, in a pure atmosphere, supported, as far as is necessary, by a fellow-workman on each side.

Hot drinks, such as tea, coffee, or spirits, may be given as a stimulant to give a fillip to heart action, where this may be deemed necessary. In every case the distressed workman should be kept as warm as possible.

First steps in severe cases.—In more severe cases, where the workman is quite unconscious and helpless, a doctor should be immedi-

FIG. 157.—Dr Sylvester's Method of Performing Artificial Respiration—*Inspiration.*

ately sent for. Pending his arrival, the man should be laid flat on the ground, the head kept low, neck coverings loosened, and artificial respiration resorted to. The patient should be placed where he will receive the fullest benefit from air currents; and on no account should he be surrounded by a crowd of onlookers, whose misplaced sympathy has only the effect of preventing the necessary free access of air. It follows also, from what has been said before, that in winter time the patient should be protected from cold winds or sudden chills. These, by constricting the blood vessels, prevent the vigorous circulation of the blood, which is so desirable, and may nduce sudden and dangerous fainting.

The Sylvester method of restoring natural breathing, as far as it is applicable to our immediate subject, is as follows:—

Rule 1. Place the patient on his back on a flat surface, or one inclined a little from the feet upward; raise and support the head and shoulders on a small firm cushion or folded article of dress placed under the shoulder blades. Remove all tight clothing about the neck and chest, such as necktie, collar, scarf, braces, belt, etc.

Rule 2. *To maintain a free entrance of air into the windpipe.*—Open the mouth; draw forward the patient's tongue, and keep it forward. An elastic band over the tongue and under the chin will answer this purpose.

Rule 3. *To imitate the movements of breathing.—First,* induce inspiration. Place yourself at the head of the patient, grasp his arms, raise them upwards by the sides of his head, stretch them steadily but gently upwards for two seconds. (By this means fresh air is drawn into the lungs by raising the ribs; see Fig. 157.)

Secondly, induce expiration. Immediately turn down the patient's arms, and press them firmly but gently downwards against the sides

FIG. 158.—Dr Sylvester's Method of Performing Artificial Respiration—*Expiration.*

of his chest for two seconds. (By this means foul air is expelled from the lungs by depressing the ribs; see Fig. 158.)

Thirdly, continue these movements. Repeat these movements alternately, deliberately, and perseveringly fifteen times in a minute, until a spontaneous effort to respire is perceived. (By these means an exchange of air is produced in the lungs similar to that effected by natural respiration.)

Rule 4. *To excite respiration.*—While you are busy performing artificial respiration, some one else should excite the nostrils with snuff or smelling salts; tickle the throat with a feather; rub the chest and face briskly, and dash cold and hot water alternately on them, or flap the chest with a wet towel; and rub the body and lower limbs with dry flannel or cloths.

TREATMENT AFTER NATURAL BREATHING HAS BEEN RESTORED

To induce circulation and warmth.—Wrap the patient in dry blankets or warm clothing, and rub the limbs upwards energetically, thus pressing the blood along the veins towards the heart. Promote the warmth of the body by hot flannels, bottles or bladders of hot water, or heated bricks applied to the pit of the stomach, the armpits, and to the soles of the feet.

On the restoration of consciousness, when the power of swallowing has returned, a teaspoonful of warm water, small quantities of wine, warm brandy and water, or coffee, should be given. The patient should be kept in bed, and a disposition to sleep encouraged. During reaction, large mustard plasters to the chest and below the shoulders will greatly relieve the distressed breathing.

Even in the worst cases, it should never be assumed that death has already taken place or that recovery is hopeless. It is pointed out by Dr Haldane that, "as a general rule, breathing stops a considerable time before the heart entirely ceases to beat, and until the latter has occurred the unconscious man can be resuscitated by artifical respiration."

CHAPTER XII

VALVES AND MAIN COCKS

VALVES for gas purposes may be classified into two main types, namely (*a*) those which are complete in themselves, or dry valves; and (*b*) those which are dependent upon a fluid seal for their operation, or hydraulic valves.

The hydraulic valve.—The hydraulic valve is a very cheap, simple, durable piece of apparatus, and extremely effective so long as the seal is kept full, or sufficiently so to more than balance any pressure of gas which it is likely to be called upon to withstand. It has been chiefly used for gasworks purposes, the constant attention which the fluid seal necessitates rendering it a most inconvenient type for use upon the distributory mains in our public thoroughfares.

The hydraulic valve, one form of which is shown in Fig. 159, consists of a circular cast-iron case, A, flanged at top and bottom, containing within and concentric with itself a dip pipe, B, of the same diameter as the main to which it is applied. The pipe, B, is supported by a circular plate, C, bolted to the upper flange of the valve case, and is in connection at the side with the inlet or outlet of the valve case. As B is perfectly open at its lower end, there is full gas-way from D, down the tube, B, to E, or *vice versâ*. The upper part of the dip pipe, B, is closed by a stuffing-box gland, F, through which is passed the long screwed rod, G, the lower end of which, after passing through the guide, I, is fastened to the bucket, H. The fluid which is to serve as the seal is inserted through the tube, J. The level of the liquid must be kept above the upper edge of the bucket, H, and sufficiently below the lower edge of the pipe, B, to allow of a free gas-way from D to E when the valve is open. The upper and threaded part of the bucket rod, G, passes through an an internally screwed boss forming part of the actuating wheel, K, the wheel being supported by, and working through, the yoke formed by the T-iron castings, L and M.

The operation of the valve is simple in the extreme. If the valve is open, as shown in the illustration, the sealing liquid being also as shown, and being sufficient to more than cover the bucket, and it is desired to close the valve, the wheel, K, is rotated from left to right. The rod, G, being incapable of rotation is, by means of the screw and resistance of the yoke, L M, caused to rise through the boss of the wheel, K. As it rises, the rod lifts the bucket, H, until the bottom of the latter is brought to rest against the bottom of the dip pipe, B, the sides of B and H being concentric with each other. The fluid contained in H thus forms a perfect hydraulic seal between D and E, so long as the depth of the bucket is greater than the

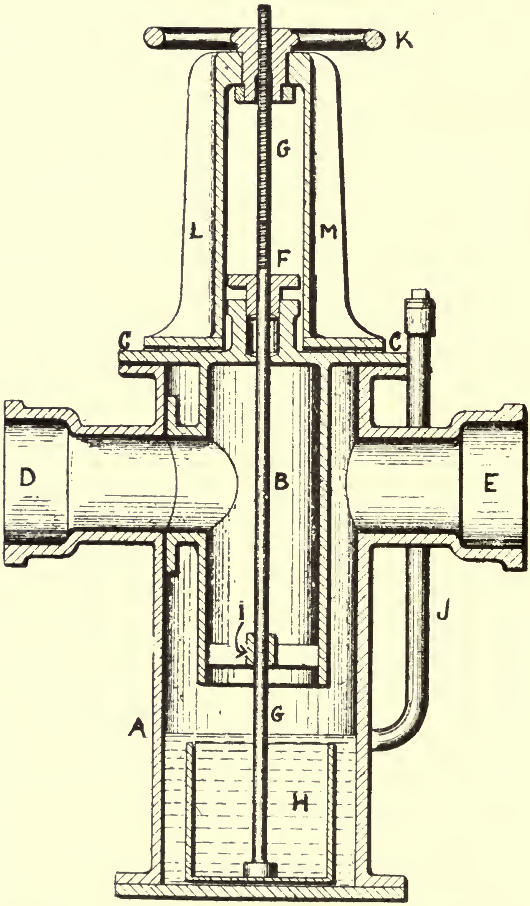


FIG. 159.—Section through Hydraulic Gas Valve.

pressure which the seal may have to withstand. To open the valve, of course, the operation is reversed.

Another form of hydraulic valve is shown in section in Chapter XV., in connection with Braddock's station meter. In this the bucket is inverted, and caused to dip into or rise from the annular seal provided on the exterior of the upper portion of M, and is actuated by means of the screw and wheel, N.

The slide valve.—It is obvious, from the preceding description of the hydraulic valve, that although, as has been pointed out, it is of a simple, cheap, and durable type, it still leaves something to be desired when considered as a piece of mechanism upon the reliability and effectiveness of which, under greatly varying conditions, so much may depend. It is not at all to be wondered at, then, that the high degree of excellence, both of design and workmanship, which has been attained in the manufacture of the slide valve, resulting in the production by many first-class firms of a valve which may be thoroughly relied upon, has led to the gradual displacement, to a very large extent, of the hydraulic by the dry valve.

The many different types of slide valve may be conveniently classified under three heads, viz :—

(*a*) Those actuated by a rack and pinion.
(*b*) ,, ,, ,, ,, worm.
(*c*) ,, ,, a screw.

Each of these, again, is made in two patterns—namely, those which have the actuating arrangement external to the valve itself, and those in which it is contained within the valve case.

Of these, the internal rack and pinion valve is the one most used upon the distributory system of a gas undertaking. It is quick in action, less than two complete revolutions of the pinion being sufficient to fully open or close the valve. It is strong, not easily jammed, does not readily stick fast, and is both durable and reliable. The worm and rack valve is more generally used upon the gasworks in positions where a slower acting valve is necessary, as, for instance, for gasholders and station governors. The internal screw operated valve is now largely discredited because of its many faults, principal among which are

(*a*) The wear and tear of the screw leading to imperfect working and ultimately to stripping of the thread.
(*b*) The liability of the comparatively slender spindle to break or bend when subjected to undue strain.
(*c*) Its liability to set hard if unmoved for any considerable time.

This type is, therefore, now generally displaced by the internal worm and rack valve, where a slow acting valve is needed.

The actual construction and arrangement of the slide valve may best be understood from a detailed description of one of the best patterns upon the market. Fig. 160 shows a sectional elevation of the new patent valve manufactured by the Bryan Donkin Company, Limited, and represents the latest development in valve construction by that firm, whose reputation for this class of goods is deservedly of the highest.

The valve is contained within a cast-iron case terminating in the flanges, A and B, to which the main connections are made. The internal faces of the outer case, over which the doors slide, are machined perfectly true, the upper edge being left sharp for the purpose of clearing any tarry matter or grit, which would interfere with the effectiveness of the valve, from the face of the door each time the valve is closed. This scraping action has been devised to obviate the difficulty experienced with earlier types of slide valves, which were frequently rendered unsound by these foreign substances upon the valve seat.

The door, or slide, is duplicated, the two faces, C and D, being forced apart, and caused to undergo the scraping process described, by means of springs placed between the backs of the slides and

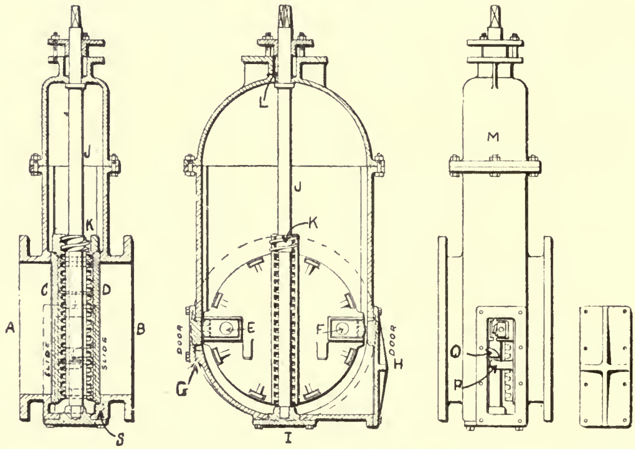


FIG. 160.—Section through the Bryan Donkin Company's Valve.

within the spring chambers, E and F. One great advantage of the double slide is that when the gas is shut off the whole of the interior of the valve is readily accessible for inspection, repairs, and cleaning. The spring chambers are covered by the two movable doors, G, H, by means of which not only is the spring get-at-able for inspection, but the whole spring box may be removed and renewed without disturbance of any other portion of the valve. The door, H, extends to the base of the valve for the purpose of giving access and enabling the bottom of the valve to be cleared of naphthalene or other deposits ; a process which is greatly facilitated in the case of this valve, as the footstep, I, in which the valve spindle works, is also removable from the base of the valve.

The valve spindle, J, carrying the worm, K, passes right through the valve from the stuffing-box gland, L, to the footstep, I, an arrangement which gives it a considerable rigidity, as well as directness of thrust in the opening and closing operations. By taking off the bonnet, M, the valve spindle may be entirely removed from the valve, leaving the whole of the upper part of the latter accessible for inspection and cleaning. The stuffing-box gland, L, is of the usual kind.

In order to provide for a due wedging action in closing the valve, a very ingenious method of operating the slides has been devised. The slide, D, when closed, is brought to rest by the step, S, while at the same time the rack of this slide falls out of engagement with the worm, K. The slide, C, however, has no step to rest upon, and the rack upon it is never out of engagement with the worm, K. The result is that after the door, D, is fully closed, the downward motion of door, C, is continued slightly, thus bringing the wedges, described later, into action, and forcing the doors tightly home to their seating. When, on the other hand, the valve is to be opened, the door, C, is first acted upon, and when it has been lifted sufficiently to bring the projection, P, into engagement with projection, O, upon door, D, the two racks are brought into line again, and act together as one rack. This action will possibly be better understood on reference to the internal rack and pinion valve now to be described.

The application of the double-door principle by the Bryan Donkin Company to the internal rack and pinion valve is a very interesting and ingenious piece of mechanism, which is shown in Figs. 161 to 167.

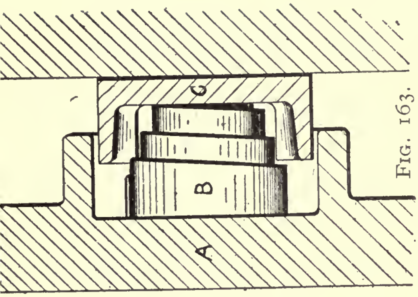
In this valve the two doors are entirely independent of each other; but by the adoption of the device of making the rack cast upon the back of door, C, fit within a corresponding slot in the rack cast upon the back of door, B, the racks of both doors are brought to one side and into line and are operated simultaneously as a single rack, with an exception to be presently noted, and thus the two doors are lifted together.

Upon the back of both doors the usual wedge strips are cast, but these are supplemented by the loose circular wedge, D (Fig. 166), which is of equal internal diameter with the valve, thus allowing an unimpeded gas-way through the latter. This wedge is fixed in position by means of pins cast upon the two side doors, F F, and the recess in the end door, G.

The pinion and spindle, E, are formed of one solid steel forging, the cogs in the pinion being cut out of the solid metal. The spindle passes right across the valve case and engages in the footing, K, provided in the valve body, A. The maximum of strength with the minimum of weight is thus ensured. The gland stuffing-box, J, is of the usual kind.

The scraping action of the valve door upon the seating of the valve body, characteristic of the Bryan Donkin Company's valves, is caused by the pressure of springs fixed in two projections cast upon the back of door, B.

The action of the valve is as follows:—Assume the valve to be



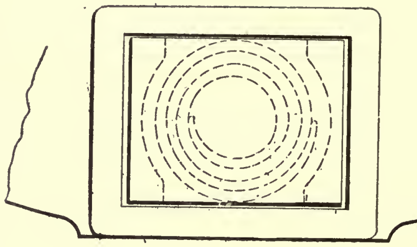


Fig. 163. Section through Spring Box.

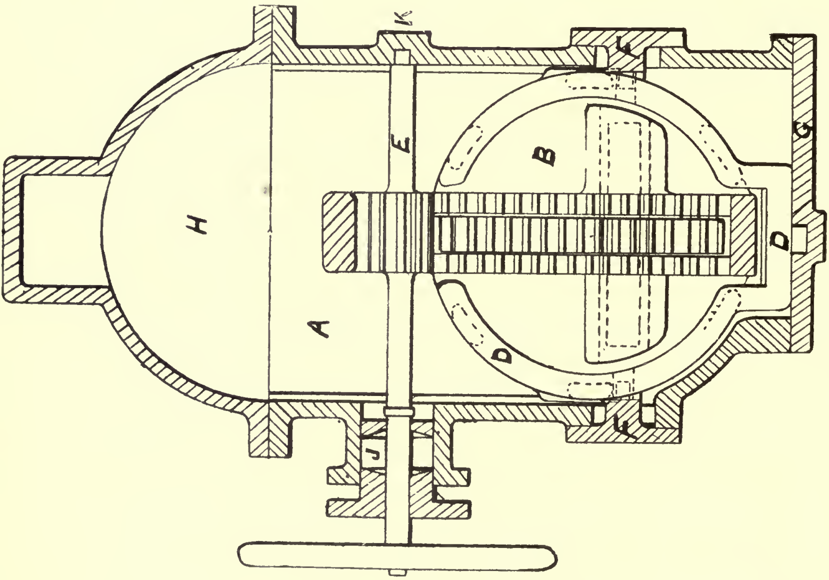


Fig 162.—Cross Section.

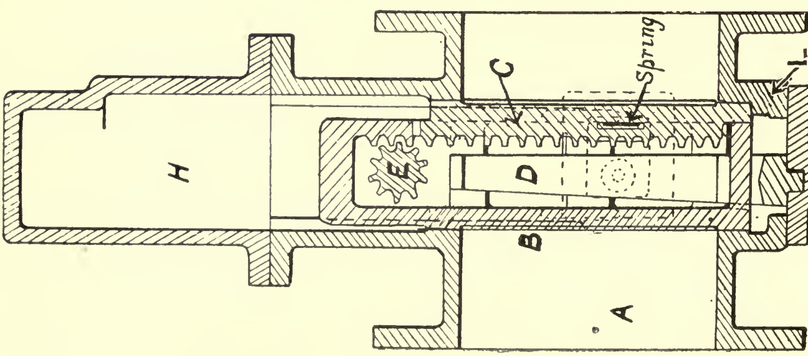


Fig. 161.—Longitudinal Section.

fully open, and it is desired to close it. The pinion is operated until the door, C, is brought to rest upon the lug, L, cast upon the interior bottom of the valve body. As the door, C, is brought into this position the pinion becomes disengaged from the rack cast upon this door, while remaining in engagement with the rack cast upon door, B, in the position shown in Fig. 161. From this point, there-

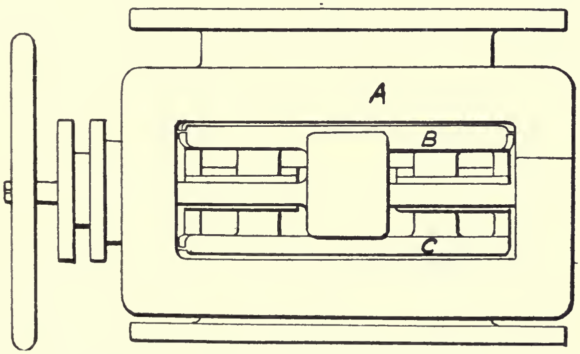
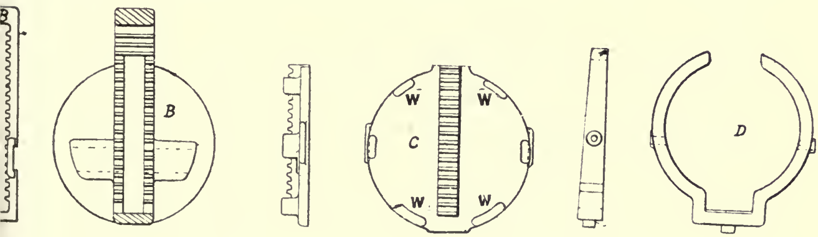


FIG. 165.—Plan, with Bonnet Removed.



DOOR, B. DOOR, C. WEDGE, D.

FIG. 166.—Details of Door and Wedges.

The Bryan Donkin Company's Double-Door Internal Rack and Pinion Valve.

fore, the door, B, alone is actuated by the further movement of the pinion. In its motion it slides down the face of the wedge, D, and thus presses both doors very tightly home to their seating as a result of the wedge forcing the doors apart.

If, now, it is desired to open the valve, the action of the pinion upon the rack of door, B, causes this to lift slightly in advance of the other door, correspondingly to the depth of the wedge-thrust in the closing operation. This relieves the pressure due to the wedging action. By this time the bottom of the slot in the rack of door, B, is brought into contact with the bottom of the rack of door, C, the two racks are brought into line, and are together moved upwards by the pinion engaging in both racks, as previously described. The doors pass on each side of the pinion, the wedge D being so designed that when the doors come up together they are sufficiently far apart for the pinion to pass between.

The advantages claimed for the two-faced valves are :—

(*a*) There are two faces to withstand the pressure brought to bear against them, in place of one as in the ordinary type.

(*b*) When the valve is closed all the three covers and bonnet may be removed, and the whole interior of the valve opened to inspection, for cleaning or repairs.

(*c*) An old or worn pinion may be replaced by a new one by simply removing the gland, J, and taking spindle and pinion out through the stuffing-box.

The volute spring by which the two faces of the valve are pressed apart is a speciality with this firm, and is shown in detail in Figs. 163 and 164, in which A is the slide of the valve, B is the volute spring, and C the cap of the spring box. These springs are manufactured from the best spring steel, and vary in number in accordance with the size of the valve. They are applied to all sizes of valves of over 5 inches in diameter ; a flat spring being used for the smaller sizes.

The action of these springs is, of course, limited to ensuring a perfect scraping and cleansing action as the valve door passes over the valve seat. The tightness or otherwise of the valve when shut is not dependent upon the springs at all. The absolute tightness of the valve when closed is ensured by the action of a series of wedge-shaped projections, see W (Fig. 166), cast upon the back of the valve slides, and working in pairs in the single door valve, and against the circular wedge in the double-door valve as shown in Fig. 161. In closing the valve, just as the doors are in the final position against the valve seat, these wedges are caused to slide one over the other, thus wedging the valve door tightly against the body of the valve and ensuring a perfectly gas-tight valve.

One great advantage of these small wedge-shaped surfaces is that any tarry matter which may be deposited upon their faces is pressed out, and thus neither causes leakage of the valve nor the surfaces to stick, a tendency which was very pronounced with the older type of slide, with its wedge shaped back of large surface.

Fig. 167. shows the ordinary single door internal rack and pinion valve of the Bryan Donkin Company as made in the smaller sizes. In this type the rack is hinged to the centre of the door by means of a pin and lugs, and is engaged by the solid steel pinion, B. The door is guided in the slide channel by the body of the valve, and the movement of the rack on the door is limited by blocks upon the latter.

When the door is nearly shut the front end of the rack makes contact with a wedging slope, and, lifting it, brings the afterpart down on to elevations on the jacket of the valve. The movement of closing being continued, the rack is forced toward the door, and the latter closed by pressure on the centre. The scraping of the slide face is ensured by means of the pressure exerted by a flat spring working on the back of the slide, and a thoroughly sound valve is secured.

Woodward's Valve.—Another excellent type of valve is that associated with the name of Mr J. Woodward, of Manchester, and

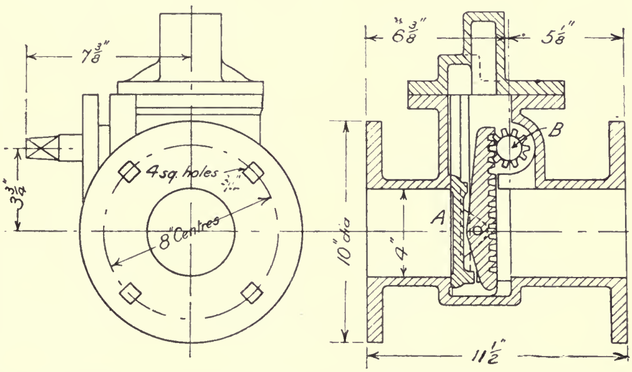


FIG. 167.—Elevation and section through the Bryan Donkin Company's Single Slide Self-Adjusting Internal Rack and Pinion Valve.

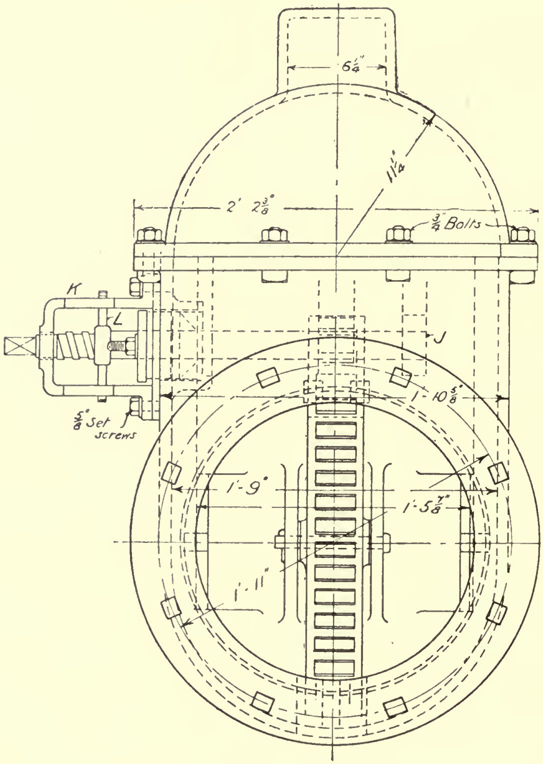
manufactured by Messrs Newton, Chambers and Co., Limited, of Sheffield, which is shown in front elevation and plan in Fig. 168, and in sectional and side elevation in Fig. 169. The valve, as shown, is of the internal rack and pinion single slide pattern.

The valve plate, C, is cast with a rack channel, D, shown in plan (Fig. 168), within which the rack, E, manufactured of cast steel, is held in place by the pin, F, of Bessemer steel. Upon the rear of the valve plate are cast the lugs, G G, which slide easily over the guides, H H, and thus maintain the valve plate in a true vertical position.

The pinion, A, and spindle, I, are formed of one solid steel forging, the cogs in the pinion being cut out of the solid metal by special machinery. The foot of the spindle, I, being let into the step, J, keeps the spindle firm and inflexible. The upper part of the spindle works through the bridge piece, K, within which an indicator, L, travels proportionately to the movement of the valve plate, being actuated by a coarse thread cut upon the upper end of the spindle, and showing the extent to which the valve is open.

One special characteristic of the valve consists in the peculiar wedging action brought into operation when the valve is closed.

This is accomplished by means of the wedge shaped footing, M



Front Elevation

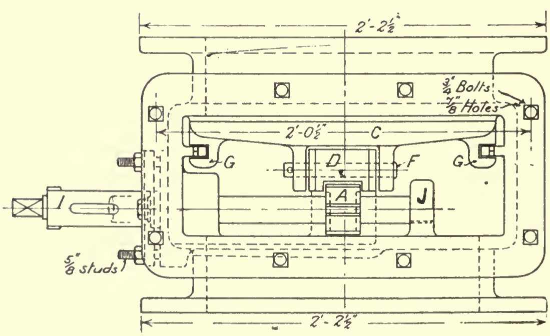
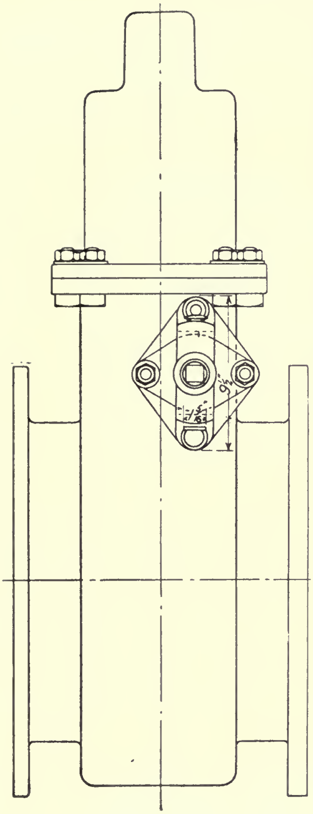


Fig. 168.—Woodward's Valve: Plan.



(Fig. 169) four inches wide, against which a similarly bevelled wedge surface upon the back of the rack is caused to slide when the valve door is fully closed, thus wedging the latter very tightly against the seating upon the body of the valve.

Westwood and Wrights' Valve.—Figs. 170 and 171 show elevation and details of the effective and durable gas valve manufactured by Messrs Westwood and Wrights, of Brierley Hill.

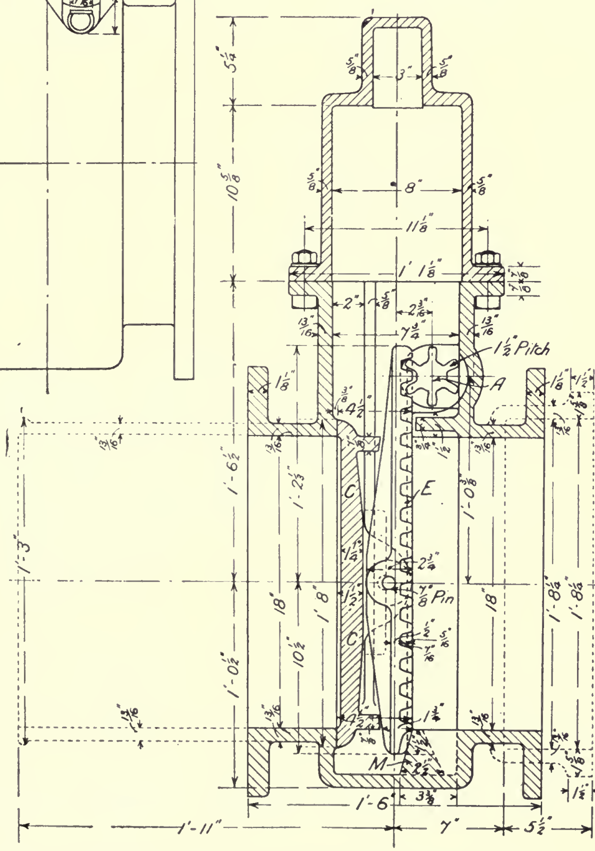


Fig. 169.—Woodward's Valve: Sectional and Side Elevation.

This type varies very considerably in construction from those previously described. Instead of the valve doors being constructed of one sliding casting, which is caused to pass right across the gas-way through the valve, as is the case in both Bryan Donkin and

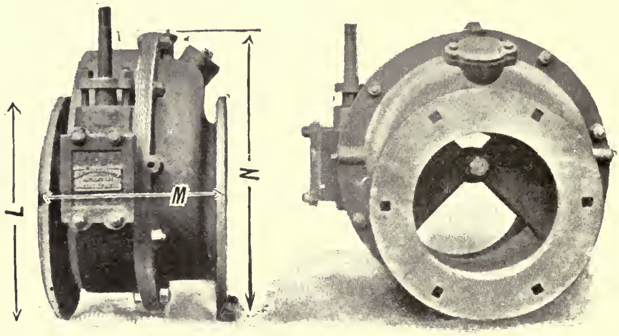


FIG. 170.—Westwood and Wrights' Valve: Elevation.

Woodward valves, in Westwood and Wrights they are constructed of segments of a circle, working upon a centre, two of which segments are made to slide over the remaining two. This necessitates an enlargement of the body of the valve in the segment chamber, to give corresponding area of gas-way to the valve connections and compensate for the blocking operation of the fixed segments.

The general arrangement of the valve will be seen from the details in Fig. 171. In the body of the valve, A, E is the screw and F the

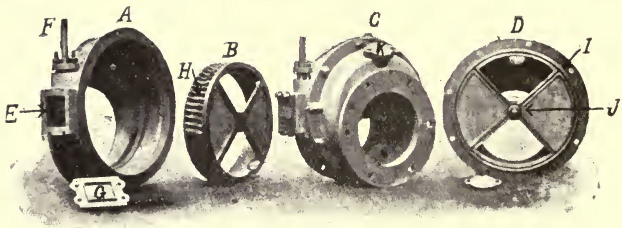


FIG. 171.—Westwood and Wrights' Valve: Details.

spindle which operate the valve. H is a set of tangent teeth upon the movable disc, B. D is the body of the valve, showing the valve face, J being the centre pin upon which the movable disc rotates, while I is the groove cut in the valve face by means of which the faced surfaces are lubricated, if and when desired, by means of the lubricator, K, shown in the complete valve, C.

Perhaps a brief description of the way the valve is put together will assist the reader to understand the working of it better than any other description. The movable disc, B, is first placed upon the centre pin, J, of the body of the valve, D, upon which it is capable of rotating. The second half of valve, A, is then bolted on to the body of the valve, D, and makes the complete valve, C.

When the valve is being operated, the movable disc, B, is kept

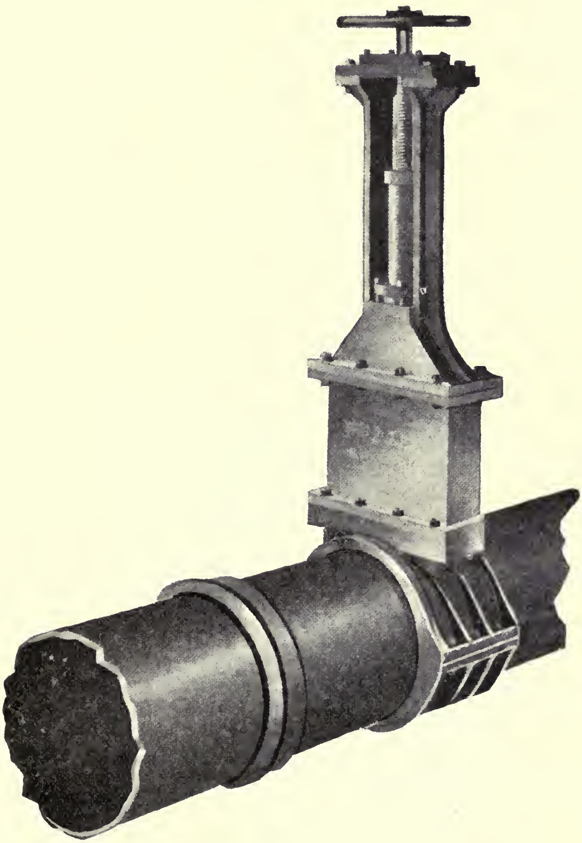


FIG. 172.—Valve Fixed on 18-inch main.

pressed to the face by means of a coil spring, but when closed it is wedged up to the face by three wedges in contact with the outside rim of the movable disc, B. When thus closed the valve is gas-tight up to a pressure of 20 lbs. per square inch. If required to withstand high pressures, the parts are made rather stronger than is necessary for more ordinary purposes.

In opening and closing the valve the movable disc, B, is moved through a quadrant of a circle by the screw, E, working in the bevel teeth cast upon the rim of the former ; the valve spindle, F, being turned to the right in opening and the reverse in closing.

When it is desired to lubricate the valve, the cone pin, K, is removed, the recess forming an oil cup, which is connected to the grooves, I, in the face of the body of the valve. Incidentally, the oil cup furnishes an excellent test as to the absolute tightness of the valve. If the oil should leak away it would, of course, be proof that the valve was not tight.

One great advantage of this valve consists in the fact that the machined faces are always protected against any corrosive action, the settlement of any grit, or deposition of tarry vesicles or other foreign matter, in whatever position the movable disc may be, whether open or closed, or at any point between the two.

Other advantages claimed for the valve are that the faces may be lubricated from the outside, as desired ; that there is no liability of the parts to stick or become unworkable ; and that it is always reliable, in all positions and for all kinds of gases.

Fixing valves *in situ*.—A most ingenious type of valve, which in combination with a special form of split tee may be fixed to mains

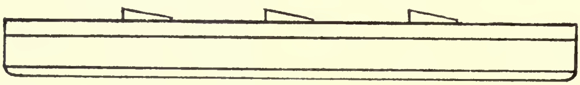


FIG. 173.—Side View of Gate and Temporary Slot Valve.

in situ without throwing the main out of use, and under pressure, has recently been put upon the market by Messrs Ruscoe & Co., of Westminster. In this device a temporary slot valve shown in Fig. 175 is attached to the flange, which forms the upper portion of the top of the tee shown in the illustration. Upon this valve gate the drilling machine shown in Fig. 175 is fixed. The object is to cut a series of holes, varying in size according to the diameter of the main operated upon—for an 18-inch main they would be 3.6 inches in diameter—in a perfectly vertical direction, right across from side to side of the main as shewn in Fig. 176. A perfectly parallel rimer which exactly fits the holes which have been drilled is then placed in the end hole, and whilst being rotated in the same way as a drill the cutting edges are pressed horizontally by the rimering machine upon the projection left between the holes until the whole have been successively removed and a clean-faced parallel slot is left across the pipe as shown in Fig. 177. When the cutting of the slot has been completed, the temporary slot valve (Fig. 173) is inserted in the valve

FIG. 174.—End View of Slot Valve Gate Slide.

gate thus completely shutting off the gas, whilst the permanent valve is being fixed.

The permanent valve gate is an unique feature of the arrangement.

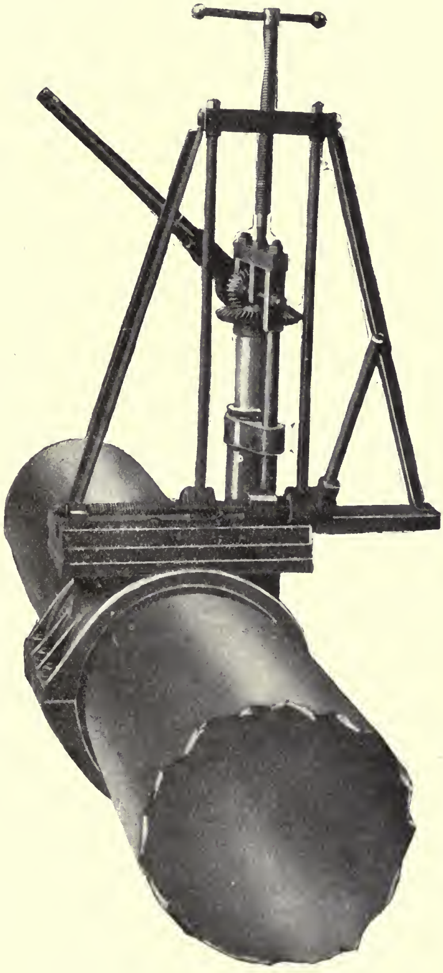


FIG. 175.—Pipe-Cutting Machine.

Around the edge of the lower portion of the gate a slot is formed to accommodate a stout hollow rubber packing of about $1\frac{1}{4}$ inches diameter, and of a section somewhat similar to the cushion tyre of an old-fashioned bicycle. This rubber pad has a leather covering, kept in position by light iron clips which are fastened to the valve gate on either side of the rubber by a series of set screws. The leather bound rubber pad projects beyond the surface of the edge of the gate sufficiently to give a compression at the final turn of the screws of about ¼ inch. The compression is, of course, very materially assisted by the hollow character of the rubber. The pad is

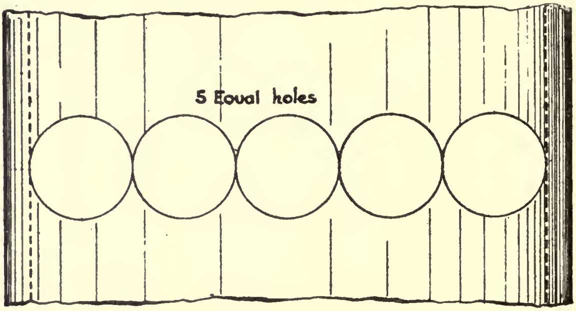


FIG. 176.—Plan of 18-inch pipe after being drilled

finally pressed into such intimate contact with the interior surface of the lower portion of the pipe as to make a joint capable of withstanding a very considerable pressure.

In a very similar way a joint gas-tight at high pressure is made

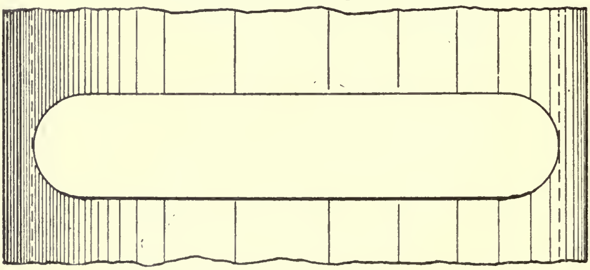


FIG. 177.—Plan of 18-inch pipe after being rimered.

between the valve gate and the newly cut slot faces. In the side of the valve gate and round the arc corresponding to the cut in the pipe, a slot is formed, in which a leather covered rubber pad is clipped in position in the way above described. When, therefore, the valve is on the point of being closed, and the pad upon the bottom edge of the valve gate is pressed home to the interior surface of the pipe, the pads upon the side of the valve gate are also forced into contact with the surface of the cut in the pipe, the whole together forming a satisfactory valve attachment.

It is not, of course, suggested that such an arrangement as above described can be as strong and capable of withstanding wear and tear as a valve of the usual kind. It is not intended as a substitute for the ordinary valve, but for attachment in those comparatively rare cases where it is necessary to affix a valve upon a main without throwing the latter out of use. It is obvious that by the insertion

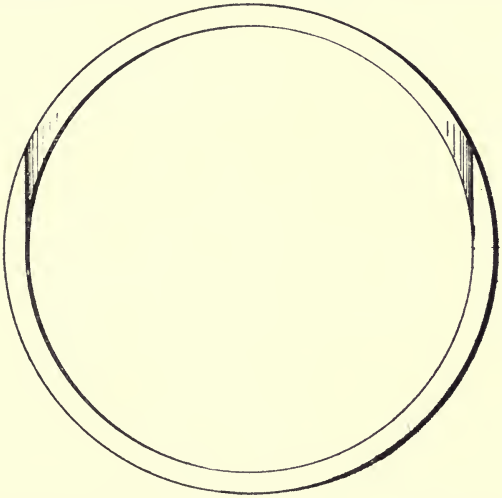


FIG. 178.—18-inch pipe showing section through cut.

of the temporary valve slide the permanent gate may be removed and worn leathers replaced at a very slight cost whilst still keeping the main at work.

Importance of good quality main cock.—The main cocks used upon the services for controlling the supply to the consumers' meters are a very important part of the distributory system. The soundness and efficiency of these concern the undertaking and consumer alike. If unsound, they are an annoyance to the consumer, because of the leakage of gas into the premises, and of danger, because they fail to fully shut off the gas when alterations and extensions of fittings are being carried out. The cheap and nasty types of main cocks are also a continual source of trouble and expense to the undertaking whilst they are in use, and, owing to their short life, prove much more costly in the end than if a good, serviceable article had been originally obtained.

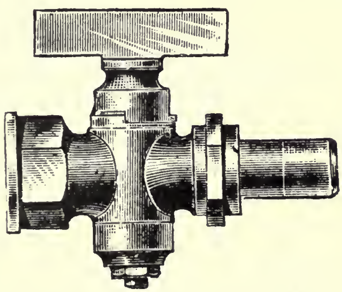


FIG. 179.—Tee-Head, Gun-Metal Main Cock.

The gas main cocks should be manufactured of good quality gun-metal, likely to withstand the corrosive action incidental to their use. The bearing surfaces must be deep, well fitted and ground in, and the body so shaped as to give a sufficiency of lap after shutting off. Each tap should be capable of withstanding a hydraulic pressure up to 50 lbs. per square inch.

Gas-way.—The gas-way should be of adequate area, and in section may be either oval or round, the latter being again divided into those in which the gas-way is "full," similar to that shown in Fig. 180, and those which fall short of the complete full-way type.

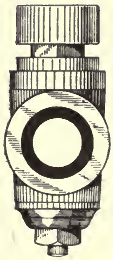


Fig. 180.—Biggs, Wall & Co.'s Round Bore Gas Main Cock.

Heads and threads.—The plugs may be finished with tee heads, as shown in Fig. 179, or with square heads for use with spanner. The threads may be either male and female, or both ends female. The former is the most usual kind of fitting, especially in the smaller sizes, as it is more convenient for attachment of the cap and lining, or union, necessary for the compo. connection to the meter. Whilst it is not usual now to lay smaller services than ¾-inch tube, it is needless to carry the ¾-inch bore right through to the meter in the case of very small consumers. A slight saving is therefore frequently secured in the cost of cocks by reducing the outlet end of the cock to ½-inch bore. Where lead services are in use, the tap must be of the type shown in Fig 181, for convenient attachment to both service and meter connection.

Locking arrangements—In cases where it is necessary to shut off the gas to any premises at the main cock, for any reason whatever,

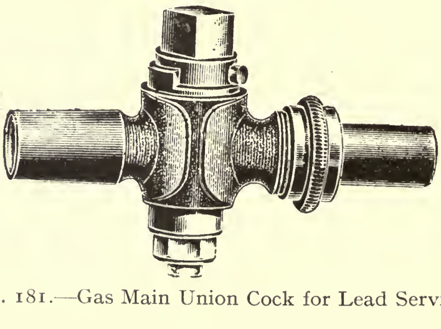


Fig. 181.—Gas Main Union Cock for Lead Services.

and it is equally necessary to ensure that the cock shall not be turned on again without the knowledge of the authorities, special forms of main cock, shown in Figs. 182 and 183, are frequently adopted. One has a perforated lug cast upon the body of the cock, and another similar lug formed upon the plug, the two being so arranged that when the cock is closed the holes in the two lugs are brought into line. The cock is then locked by means of a padlock, or by a pin being passed through the two lugs and sealed. It is then, of course, impossible to turn the cock without either removing the padlock or

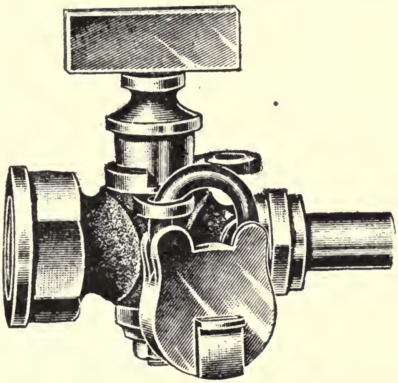


FIG. 182.—Jas. Milne and Son's Lock Main Cock.

breaking the seal. Fig. 182 shows the padlock attached to the lug on the body of the cock, the latter being full open.

A further type of locking main cock, which dispenses with either padlock or lead seal is the "Solari," manufactured by Messrs Willey & Co., Limited, of Exeter. This cock has two distinctive features.

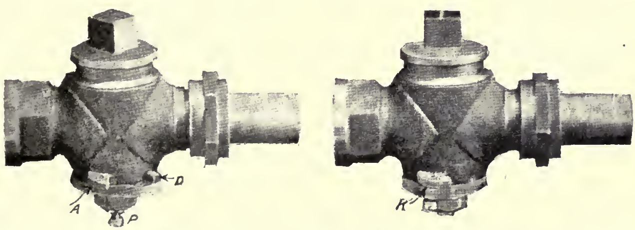


FIG 183.—"Solari" Main Cock.

The old method of cut down barrel and pin in the plug is entirely superseded by two stops, cast one on each side of the bottom of the barrel, one, A, of which only is seen, which engage with a stop, D, cast upon the bottom washer. One common source of leakage due to the stop pin is therefore completely eliminated, while the whole arrangement is far stronger and better than that of the old type. In addition, the stops are made large enough to take a small screw, by means of which the cock can be secured in the shut off position as shewn at K. The screw when not required for this purpose is screwed into the bottom of the plug as shewn at P to prevent its being lost.

Another form of gas main cock of an excellent type is that shown in Figs. 184 and 185, and known as the inverted plug gas main cock, one of the specialities of Messrs Biggs, Wall & Co., of London.

In this tap the position of the plug is entirely reversed from that of the ordinary type, inasmuch as the larger diameter of the plug is placed downwards and the small end at the top. The upper portion of the plug is extended and squared to accommodate the key, which, in this case, is placed immediately over the washer, the whole being screwed up tightly by the nut, C, in the usual way.

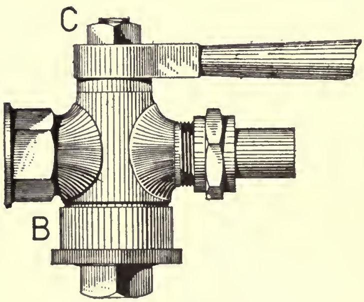


Fig. 184.—Elevation.

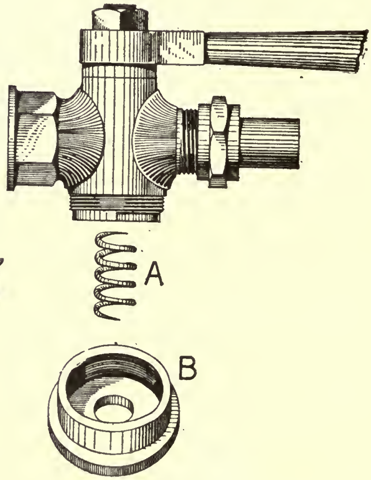


Fig. 185.
Showing Spring and Cap.

Biggs, Wall & Co.'s Inverted Plug Gas Main Cock.

An essential feature of the cock is the use of the spring, A (Fig. 185). This is placed within the cap, B, and when the latter has been screwed into position, as shown in Fig. 184, the spring is enclosed between the cap and the base of the plug. A constant pressure is therefore exerted upon the latter in an upward direction. This pressure forces the plug into close and intimate contact with its seating and effectually prevents the former from becoming loose and leaky, as so frequently occurs with the usual form of tap, owing to the screw and washer working slack, or even coming off altogether.

For the larger sizes of services, or where a main cock is subjected to especially rough usage, or for use underground, and for many

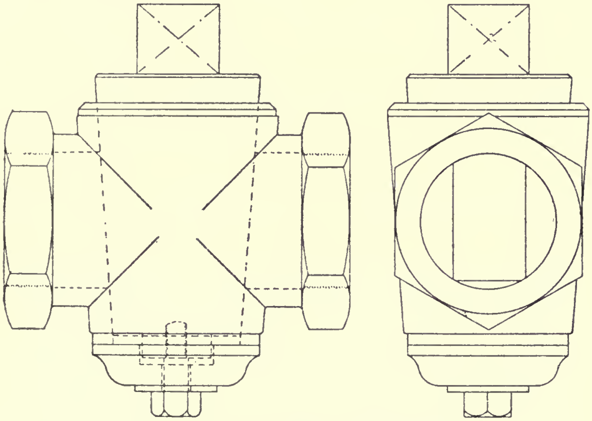


FIG. 186.—Cast-Iron Main Cock.

gasworks purposes, a cast-iron main cock, shown in Fig. 186, either with iron or brass plugs, is frequently used.

CHAPTER XIII

SUBWAYS

THE problem of the regulation of the traffic in our streets and the preservation of the road surfaces would appear to the casual observer to have little connection with the subject of gas distribution. But a little consideration will soon convince anyone that the relation is real.

The traffic problem tends to become more acute each year, and as far as can be foreseen will continue to do so. The great growth of our city populations and the influx of people from the country into our large towns, producing that congestion which is so much deplored on all hands, involves a traffic which has to be accommodated within thoroughfares which cannot be expanded as the volume of traffic grows.

Simultaneously with the growth of population in our large cities, there has, during the last generation, been a remarkable development in the improvement of the surface of the roadways. The rough, irregular, and uneven surfaces which were at one time so common are not now to be found, at any rate in the principal thoroughfares, of any self-respecting community. Vast sums have been, and are being, spent upon the preparation and maintenance of our roadways in such a perfect condition as alone makes the present-day means of rapid transit safe and agreeable.

The rapid development of light railways and electric and other tramcar systems has brought another serious factor into the problem, and, in conjunction with the conditions just suggested, make the opening of the roadways increasingly difficult and inconvenient.

Gas mains, it must be remembered, form only one system out of many underground conduits. To enumerate just a few. There are the sewers, gas and water mains, telephone, telegraph and electric lighting cables, and pneumatic power mains, amongst others. The repairs, extensions and attachments of each of these undertakings involve a very considerable amount of disturbance in the streets ; and the cumulative effect of the whole constitutes a very serious interference with and danger to the ordinary traffic, in addition to the inconvenience caused to the community.

These evils have directed, and must increasingly concentrate, attention on the problem of the streets. They inevitably point to the conclusion that some remedy must be found. One of the remedies suggested, as, at any rate, a partial solution of the problem, is the provision of suitable subways.

With the larger subject we, of course, have no concern here. The question we have to consider is how the provision of subways would affect the general problem of gas distribution.

Past opposition to subways.—It is a matter of history that when, nearly half a century ago, the Metropolitan Board of Works first took action in London in this matter, and when in 1868 the Metropolitan Subways Act was passed, there was a very decided disinclination on the part of the gas undertakings concerned to use the subways for their mains. How far the disinclination was due to

FIG. 187.—Perspective View of Holborn Subway.

subways as such, apart from the conditions under which they were to be used and the expense of the removal of the mains, hardly comes within the author's purview.

Present-day experience.—To-day, however, we are in a very different position, in respect to the general subject, from that of forty years ago. We have had considerably over thirty years of actual experience of the matter. In that time many of the fears and forebodings so freely expressed as to the safety and suitability of subways for the housing of gas mains have proved to be groundless. It was stated, in evidence before the Royal Commission on London Traffic (1905), by Mr G. F. L. Foulger, then chief distributing engineer to the Gas Light and Coke Company, who had thirty-five subways in his district, containing an aggregate of over eleven miles of mains, that in an experience extending over thirty years his Company had suffered no inconvenience; there had been no accident, and no serious difficulty had presented itself in consequence of those mains being contained in subways. Probably most people will consider that such emphatic testimony, after so long an experience, should remove all such doubts as those just suggested. The author entirely

FIG. 188.—Holborn Subway, showing Alteration of Levels.

fails to understand how any one having practical experience of distribution, who has investigated the subject for himself, and who has seen the snug berthing of the various mains in such subways as those at Holdorn Viaduct, Mansion House, Shaftesbury Avenue, or the Embankment, in London, some of which are shown in the accompanying illustrations, or such typical instances in the provinces as those at St Helens and Leeds, could come to any other than a favourable conclusion as to the value of subways for the purpose.

Holborn Viaduct Subway.—Fig. 187 is a perspective view of the subway under Holborn Viaduct, which is about 12 feet 6 inches high and 7 feet wide, showing the gas mains of the Gas Light and Coke Company berthed on cast-iron brackets built into the wall. It is a significant commentary on much that has been said and written upon the dangers incidental to subways that this, which has been in use for about forty years, is lighted by naked gas jets. The gas service attachment for one of the adjoining premises is seen in the centre of the illustration, and also the water service from the lower of the two mains passing away through the wall of the subway. The subway is remarkably dry and clean, any splashing of rain or surface water through the various ventilating shafts being received by pans set upon tripods, one of which is shown in the foreground.

FIG. 189.—End of Holborn Viaduct Subway, showing turning into Charterhouse Street.

Fig. 188 is another view of the Holborn subway, showing an alteration of level of the mains and floor of the subway. The ease with which the mains may be inspected, and any joint showing the least signs of weakness at once detected and set up, will be realized from the appearance of the figures in the illustration.

Fig. 189 is yet another view of the Holborn subway, taken under Holborn Circus, and showing the lateral subway under Charterhouse Street. This is the end of the subway under Holborn Viaduct, and the main pipes are seen rising in the distance to their level under the roadway. The three photographs were taken, and are here reproduced, by the courtesy of Mr Frank Sumner, M.Inst.C.E., City Engineer to the Corporation of London.

Mansion House Subway.—Fig. 190 is a perspective view of the

Mansion House pipe subway, which, again, lies under the passenger subway of the Central London Railway. In this subway there is

FIG. 190.—Mansion House Subway.

accommodated a 30-inch gas distributing main and a 24-inch high-pressure main of the Gas Light and Coke Company, and two 24-inch

FIG. 191.—Mansion House Subway.

water mains. A very neat piece of engineering, as applied to large pipes, may be seen in this subway. The subway is more or less circular in plan, and the large pipes referred to were cast to the shape of the subway, the work being so carefully done that each joint is as concentric as though the pipes were laid perfectly straight. This subway is lighted throughout by electricity.

Fig. 191 is another view of the Mansion House subway, showing a sharper curvature of the main pipes and the connection of distributing gas and water mains to the trunk mains lying in the subway. The two Mansion House subway photographs were taken and are here reproduced by permission of Mr C. C. Cunningham, M.Inst.C.E., general manager of the Central London Railway.

Essentials of a good subway.—If, now, we turn to the experience of those who have adopted subways, and ask what are the essentials of a good subway from the point of view of gas distribution, we find that the following conditions, amongst others, must obtain.

(*a*) *The subway must be roomy.* It should be at least high enough inside to allow a tall man to pass comfortably through it. It should be wide enough to accommodate all the necessary mains, leaving a minimum of twelve inches clear round the pipes for purposes of jointing or repairs, and yet permit the free passage of workmen and the haulage of the largest pipes likely to be required. As a good example of how not to do it, the author would instance a subway he inspected recently, which is only 5 feet in height and about 2 feet 6 inches wide, and which was built to accommodate gas and water mains and electric cables. The cramped position of the workmen, the difficulty of carrying out the work, and the utter inadequacy of the whole arrangement may be imagined.

(*b*) *The subway must be well ventilated.* The need for this is sufficiently obvious. Safety and cleanliness equally demand it. Free currents of air imply a dry, or comparatively dry, subway, with all its attendant advantages. If at any time there should happen to be a small escape of gas, in a well-ventilated subway it would be dissipated before an explosive mixture could be formed.

(*c*) *It must also have a sufficient number of convenient entrances,* large enough to lower the longest pipes likely to be required in the subway.

(*d*) *It should also be easy of approach,* and access readily obtainable for frequent inspection of the contained mains.

(*e*) In very wide thoroughfares it may be advisable, where possible, to build a subway upon each side of the roadway, and thus avoid long services from subway to consumer.

(*f*) Provision should be made for easy transit of pipes and materials through the subway, by the provision of a light tramway in the floor, as shown in Figs. 192 and 194.

As far as the internal arrangements are concerned, all service mains should be so placed as to facilitate the attachment and repair of services, as may be required. Trunk mains to which no services are connected may be less advantageously placed. But these should

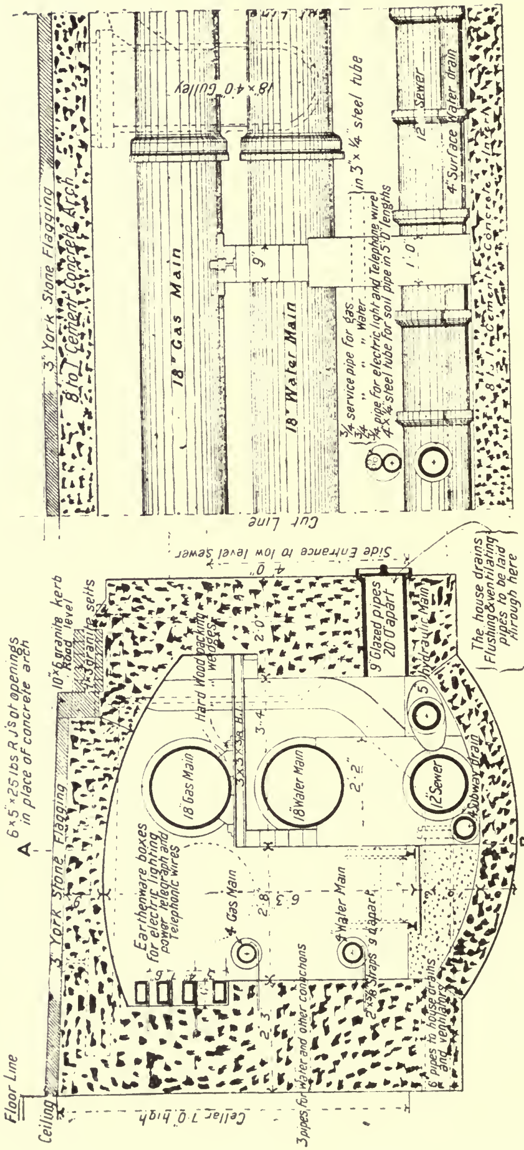


FIG. 192.—Elevation and Section of Deep Subway Under Footpath.

always be laid in such positions that the joints may be readily got at.

The electric lighting, tramway and other cables should always be placed as far away as possible from the gas mains, so that, in the event of accident to or fault in the cables, all risk of contact and consequent fusion may be reduced to a minimum. In Fig. 192 these are shown on the opposite side of the subway to the gas and water mains.

There should also be a sufficient number of earthenware or other channels built into the side walls at regular intervals, through which services may pass to adjoining properties.

Mr R. M. Parkinson's schemes.—The method in which these and other similar conditions are complied with on the most modern types of subways is shown in Figs. 192 to 195, reproduced here by courtesy of the editor of *The Surveyor and Municipal and County Engineer.* These plans were designed by Mr R. M. Parkinson, of Peterborough, and accompanied his prize essay on "Subway Systems for Municipal Conduits," published in 1903.

Fig. 192 shows elevation and section of a deep subway under a footpath. "The small pipes are carried on straps let into the walls, the large water main on concrete supports 12 feet apart, and the large gas mains on rolled joists supported by brickwork. Small angle irons are riveted to the rolled joists to take the thrust of the wedges which tighten up the packing blocks provided to hold the pipe secure. A width of 16 inches is given between these pipes and the wall to enable the pipe jointer to work. 9-inch glazed pipes are put in at intervals in the right-hand wall for the house connections on the other side of the street.

"It is evident from the figure that so long as plenty of these glazed pipes are built into the wall, the making of the connections on the left is a simple matter. It is almost as easy to make them on the right without disturbing the surface. A 4-inch steel tube for the soil pipe and a 3-inch tube for the electric mains, and the gas and water pipes can be driven across the road in practically the same way as a boring is made for the purposes of a water supply, a special plant, with short tubes and boring tools, being provided, together with a powerful hydraulic jack. The stop to the 9-inch pipe would first be broken and then a 6-foot tube and boring tool inserted, the left wall being used as a base to work from.

"Access should be provided by means of locked iron doors placed over the tramway near the supports to the large pipes, which could be utilized as steps. At intervals, spaces 13 feet long and 2 feet 3 inches wide should be left in the roof to admit of the introduction or removal of the pipes, iron girders being used instead of the concrete arch for the purpose, the flags being laid on the girders in this case."

Fig. 193 shows an arrangement for a shallow subway in roadway.

In this case "the electric mains are carried on ledges in the channels on either side, iron pins being placed at 3 feet intervals to keep them from falling on to the ledge below.

"The small pipes are hung up from above, and the straps being keyed up to a true line do not require any adjusting." The 24-inch gas and water mains are supported by 3-inch by 3-inch by $\frac{3}{8}$-inch rolled joists supported by brickwork.

The subway shown in Fig. 194 is of an altogether different construction. It is of a type suitable for placing deep down in a road-

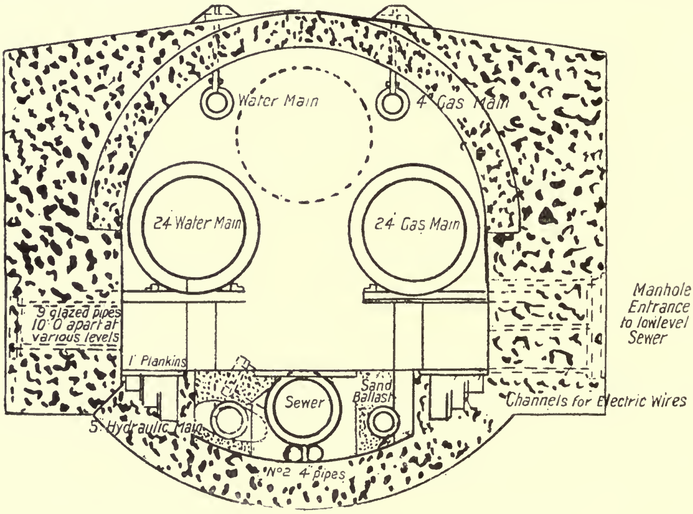


FIG. 193.—Shallow Subway in Roadway.

way or in a subsoil where water may have to be contended with. It is formed of $\frac{3}{4}$-inch cast-iron segmental plates fastened together with bolts and nuts, and forming a circular tube 7 feet in diameter. It contains two sewers 9 inches and 12 inches in diameter respectively; an 18-inch trunk water main and an attendant 4-inch distributing main; a 21-inch trunk gas main, with its auxiliary 4-inch distributing main; the electric lighting and telephone cables being carried upon tile slabs. "The large pipes are hung up from the flanges by straps, and adjustable bolts, and the smaller are supported by straps resting on these as cantilevers. The wires are carried on 8-inch tiles set in concrete, with which the lower parts of the segments are covered.

"In the middle plate on each side, holes are left for the house connections; these are nearer the top or bottom of the plate according to the way this is placed, to enable the tubes to be driven in various directions. The holes are covered by plates which can be removed when it is desired to make a connection. They can be replaced by plates with stuffing-boxes in water-bearing strata, and the work done under pressure, power for the operation being obtained from the hydraulic or electric mains in the subway and a special tube."

Fig. 195 shows another type of subway, in this case a shallow one, running under the centre of a roadway over which a double tramway line passes. This is arranged for occupation by a 36-inch gas main, a 36-inch water main, two 4-inch gas distributing mains, and a 4-inch water main, in addition to provision for electric cables of different

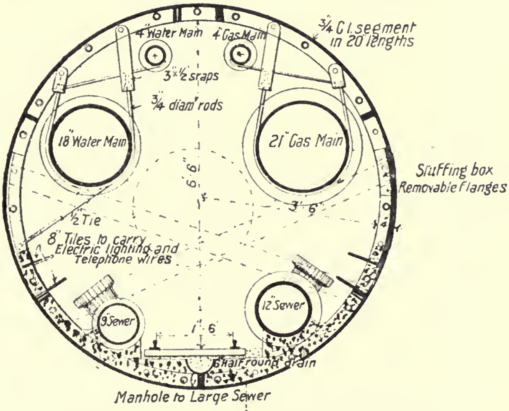


FIG. 194.—Deep Subway in Roadway.

kinds upon the channel shown. "The centre rails of the surface tramway are carried on concrete arches of 10 feet 6 inches span, with a 2-foot rise, 15 inches deep by 12 inches wide, supported by piers 18 inches long by 12 inches wide, and so 12 feet centre to centre." The arrangement as shown would, however, be a rather inconvenient one, inasmuch as the 36-inch pipes would have to be lowered into position from the surface, the space between the piers being insufficient to allow of their being moved through the subway by means of the tramway running over the sewer.

Subways impossible of immediate general adoption.—It is, of course, impossible that subways can be provided to any very great extent in the crowded central thoroughfares of our large towns, the very places where they are most needed. The cost of construction in established thoroughfares would be enormous. The engineering difficulties would also be very considerable; and even if these obstacles were surmounted the cost of removing all existing mains would be almost, if not quite, prohibitive. Moreover, the interference with the regular services performed by the various mains would be so great as to render the removal almost impracticable.

What can be done, however, is to take advantage of street widenings and other roadway improvements, and especially the opening out of new thoroughfares, to make provision of suitable subways. A commencement having been once made it would be sure to be followed up, possibly at widely separated points. Each of these

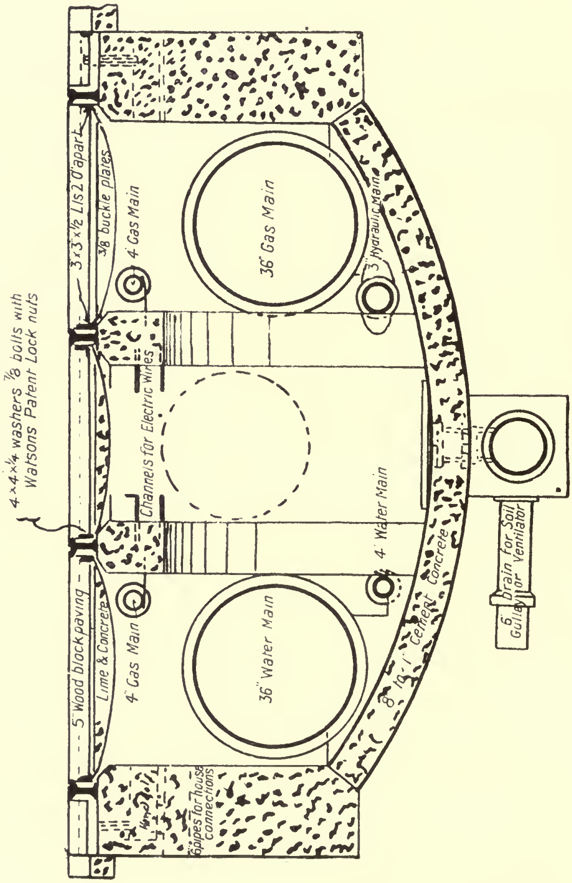


Fig. 195.—Subway under Tramway.

subways, in turn, would serve as a fresh starting-point, to be added to as opportunity arose, until, in course of time, a considerable system would be evolved. It may be said that this would take a very long time. Quite so! But, after all, half a century is not long in the life of a town, and a great deal might be done in that time if every opportunity were seized. Meanwhile, at any rate the principal new thoroughfares would be redeemed from the possibility of continual disturbance.

Conditions under which subways should be used.—The question then arises, under what conditions might gas undertakings be fairly asked to lay their mains in subways? These appear to resolve themselves into two or three very simple propositions.

(*a*) Where mains are already laid, and removal to subways constructed as part of a plan of street improvements is desired, the cost of the removal should, clearly, be borne by the local authority. Such a charge could not be placed to the capital account of the gas undertaking, and if it could it ought not. And it would be manifestly unfair that revenue account, or, in other words, the consumers, should be burdened with the cost. It is clearly a part of the general improvement, and should be included in the improvement account.

(*b*) The provision of the subways should not be used to prejudice the general position of gas undertakings. The latter have now the right, within their own areas, to open the ground and lay their mains and services, a privilege conferred in return for the service they render to the community. Provision should, therefore, be made in the subway free of cost. The cost of laying a main in a subway is approximately as great as that for laying a main in the ground in the ordinary way; the saving on account of excavation being fully balanced by the increased cost of haulage and of placing the pipes in their berths under the special conditions.

(*c*) There must be perfect freedom of access at all hours, without previous notice necessarily being required. This is absolutely essential, in cases of emergency, escapes, stoppages, etc. The unreasonableness and danger of having to wait for formal notification in emergency cases is apparent at once.

(*d*) A separate channel from subway to consumers' premises should be provided for gas service pipes. The suggestion which has been made that gas pipe, water pipe, and electric cable should be accommodated in one channel should not be entertained. It would be not only inconvenient but positively dangerous, in the event of accident to the cables.

Some advantages.—The advantages of placing main pipes in subways, from the point of view of the gas undertaking, appear to be mainly as follows:—

The mains are kept dry, and are, therefore, correspondingly protected from corrosion.

The mains are bare and get-at-able, and can, consequently, be further protected by painting.

The mains are always open to inspection, and any fault can be immediately rectified without previous excavation.

The mains are relieved of the strains due to the weight of the superincumbent earth.

The mains are relieved of all strains due to subsidence of the subsoil.

The mains are relieved, to a large extent, of the strains due to vibration of the roadway.

The mains are free from the strains of suddenly applied loads due to heavy vehicular traffic.

In consequence of the more equable temperature of a subway, the joints are relieved of the strains due to expansion and contraction.

There is less liability to attract wandering electric currents, and consequently lessened likelihood of electrolysis.

The service pipes, which are the most perishable part of any distributing system, are much better protected, last longer, and, when necessary, are much more easily renewed.

The leakage account is, therefore, correspondingly reduced.

Each line of pipe, having its own position, and in the very nature of the case being restricted to its own track, proper and suitable distances can always be maintained between the mains and cables.

Precautions to be observed.—There are, however, certain precautions in connection with gas mains in subways which must be observed.

(*a*) First of all, it is obvious that the circumstances demand that only the very best materials and workmanship should be employed.

(*b*) All new work should be subjected to the most severe tests for soundness before gas is turned into the mains.

(*c*) Provision should be made of valves at each end of, and exterior to, the subway, so that in case of necessity the gas may be cut off without entering the subway. It follows, of course, that all lateral mains should also be fitted with valves for the same purpose.

(*d*) And just as it is advisable that it should be made possible to turn off the gas in the main as a whole, so, in a less degree, it is advisable that provision be made to shut off each separate service when necessary. A tap should, therefore, be provided for each service, and fixed as near to the main as possible.

(*e*) It is also advisable that periodical inspection should be arranged at such suitable intervals as may be deemed best.

(*f*) In cases where there is the least danger of the subway becoming flooded, all large gas mains, those that would be buoyant in water, should be securely bolted down upon their seatings or cradles. The author has heard of mains being floated right out of position when not so secured.

(*g*) Where mains pass immediately under the manhole covers or entrances they should be bridged over with stout timbering. The author has had a large main splintered through the cast-iron entrance cover being dropped through on to the main below.

CHAPTER XIV

SERVICES

A SERVICE may be defined as the length of piping which connects any premises to be supplied with gas with the gas mains in the locality. Services may vary in size from $\frac{3}{4}$-inch in diameter for the cottage to the 8-inch, 10-inch, or 12-inch pipe for the large manufacturer. The $\frac{1}{2}$-inch service, so freely laid at one time, has been completely discarded, nothing smaller than $\frac{3}{4}$-inch being now used.

In the larger sizes, say of more than 3 or 4 inches diameter, these services are of cast-iron, and much of what has already been said in connection with mains applies to them also. Services of the smaller sizes may be either of wrought-iron or lead-tubing, and the former may be again divided into gas tube, water tube, and steam tube. Gas tube is the cheapest of the four; but because of its lightness, its comparatively short life when buried in the ground, and its incapacity to withstand the rough wear of underground work, it is generally rejected in favour of the heavier tubes.

Heavy tubes most economical.—It is becoming increasingly recognized that although the initial cost is somewhat more, the truest economy is realized by the use of the heavier water or steam tube services. Such tubes may be expected to have a life of twelve to fifteen years in good ground, as against eight to ten years with the lighter pipes. The cost for labour is the same for them as for the lighter tubes, and the increased cost for piping is much more than recouped in the greater durability, lessened leakage, stronger joints, and greater resistance to breaking strains of the thicker and stronger tubes. With a view to reducing the number of joints to a minimum, all tube should be used in as long lengths as possible.

Qualities of good steam tube.—The table on page 235 gives the thickness in B.W.G. and weight per foot run, approximately, and other particulars, of a good sample of steam tube of the commoner sizes as used for service pipes.

Besides being of good quality of iron and sufficient thickness of material, wrought-iron tubes should be perfectly round in section, as smooth as possible internally, and quite free from burrs. The weld should be indistinguishable, and the pipe should be capable of standing a bending test, hot, without kinking.

Sizes used for given number of lights.—The following table shows the size of service pipe usually laid for the number of lights specified, the length of service being assumed not to exceed 100 feet :—

$\frac{3}{4}$-inch	service	up to	10 lights.
1	,,	for	10 ,,
$1\frac{1}{4}$	,,	,,	20 ,,
$1\frac{1}{2}$	,,	,,	50 ,,
2	,,	,,	80 ,,
3	,,	,,	150 ,,
4	,,	,,	200 to 300 lights.
5	,,	,,	400 ,,
6	,,	,,	500 to 600 ,,
7	,,	,,	800 ,,
8	,,	,,	1000 ,,

Lamp services.—It has already been pointed out that no tubing of less than $\frac{3}{4}$-inch diameter should be used for service pipes. For the rising pipe of ordinary public lamps, owing to the strong corrosive action continually going on inside the lamp column, it is usual to adopt galvanized tubing of $\frac{1}{2}$-inch diameter. In many places, too, it is the custom to leave a 1-inch by $\frac{3}{4}$-inch by $\frac{1}{2}$-inch tee on the service at the base of the column, so that in the event of slight condensation taking place it may collect in the end of the tee, and thus prevent interruption of the gas supply (Fig. 196).

Lead services.—In places where the subsoil is more than ordinarily deleterious to the pipe, owing to the presence of ashes, clinker, and acidiferous compounds, which would quickly corrode wrought-iron tube, it becomes necessary to adopt lead tubes, in the place of iron. These services are usually connected to the main by means of brass bend-unions. (See Figs. 197 and 198, which show the unions on opposite sides of the bend.)

In the case of lead-tube services, it is necessary to afford them support throughout their entire length, to prevent sagging and consequential accumulation of condensation and interruption of supply. This is usually done by means of troughing of either V or ⊔ section, formed of rough wood strips nailed together.

Over-weakening of mains to be avoided.—It is obvious that the drilling of holes in mains must inevitably weaken the pipe considerably in the section through which the hole is cut. The extent of the weakening is, of course, proportional to the size of the hole, as compared with the diameter of the main. If too large a hole is cut, the main may be weakened to a dangerous degree, and fracture ensue, either in tapping or afterwards, by reason of road vibration, or through the expansion and contraction due to changes of temperature. In order to avoid these dangers, the following limits should, on no account, be exceeded :—

3-inch main	—hole not to	exceed	1 inch.
4 ,,	,,	,,	$1\frac{1}{2}$,,
5 ,,	,,	,,	2 ,,
6 ,,	,,	,,	2 ,,
8 ,,	,,	,,	3 ,,

Internal diameter in inches	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	4	5	6
External diameter in inches	$1\frac{1}{16}$	$1\frac{11}{32}$	$1\frac{11}{16}$	$1\frac{29}{32}$	$2\frac{3}{8}$	3	$3\frac{1}{2}$	$4\frac{1}{2}$	$5\frac{1}{2}$	$6\frac{1}{2}$
Thickness of tube, B.W.G.	9	8	7	6	5	5	5	5	5	5
Decimal equivalent in inches	0.148	0.165	0.180	0.203	0.220	0.220	0.220	0.220	0.220	0.220
Approximate weight per foot run, in lbs.	1.422	2.038	2.863	3.539	4.931	6.364	7.535	9.843	12.325	14.725
No. of threads per inch	14	11	11	11	11	11	11	11	11	11
Gauge diameter at top of thread	1.041	1.309	1.650	1.882	2.347	2.960	3.460	4.450	5.450	6.450
Depth of thread	0.0455	0.0580	0.0580	0.0580	0.0580	0.0580	0.0580	0.0580	0.0580	0.0580
Length of screw on tube, in inches	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{5}{8}$	$1\frac{3}{4}$	2

For water quality of tubes the gauge is one weaker, and for gas quality the gauge is two weaker than for steam.

The threads are of Whitworth form; the angle between the slopes, measured in the axial plane, is 55°; the threads are rounded equally at crests and roots, leaving a depth of thread equal, approximately, to 0.64 times the pitch.

Should a larger service be required than the main will allow of being safely cut, the quantity of gas passed through a long service will not be materially reduced if a connection to the main one size less than the service is made and immediately enlarged to the desired size. For example, a ¾-inch service may be connected to 2-inch main by means of a ½-inch bend, or a 1¼-inch service connected to a 3-inch main by a 1-inch bend. But this is a device which should not be used if it can possibly be avoided. Full-way connections ought always to be insisted upon.

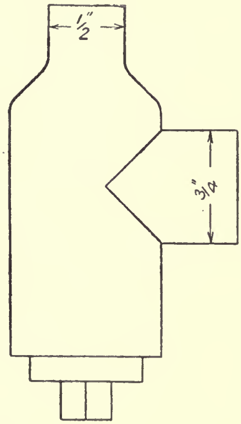


FIG. 196. — 1-inch by ¾-inch by ½-inch Tee for Lamp Service.

Gouging *versus* drilling.—It is not difficult to understand how the old, pernicious, and discredited system of cutting holes in mains by means of hammer and gouge, instead of drilling them, still lingers on in some parts of the country. The hammer and gouge are light, portable tools, while the drill stand is heavier and more cumbersome. More excavation is also necessary to fix the latter, and more labour is expended in drilling than in gouging. It must be conceded, too, that many workmen can be depended upon, in the vast majority of cases, to cut a good round hole. But when full allowance is made

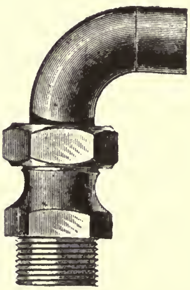


FIG. 197.—Union Bend for Lead Service Pipes.

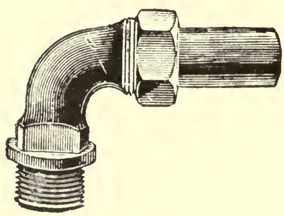


FIG. 198.—Main Union Bend for Lead.

for all this, the solid advantages of drilling are still very great by comparison. If a hole is properly drilled it must, in every case, be perfectly round. In drilling, the edges of the hole are not broken or chipped away, and consequently the full thickness of the pipe is available for cutting the thread upon. If the drill is a proper one, the hole must always be of exactly the correct size to take the tap, and a full thread may be depended upon. Although, therefore, it may take a little longer, and involve a rather greater expenditure of labour, there can be no doubt that, in the truest sense of the terms, economical and efficient working require that all holes should be drilled.

Services connected to top of main.—Wherever the gas main is deep enough to allow of its being done, the service pipe, either of iron or lead, should be connected to the top of the main. The main is easier to drill in this position, and the service connection is more accessible for repairs and renewal. In order not to impede the flow of gas more than necessary, the connection to the main should be made by means of a bend, rather than by a sharp elbow or tee-piece. It is also advisable, especially in districts troubled with naphthalene, that a connecting bend should be used in the main, or a connecting piece placed near the main, to facilitate repairs and renewals and the clearance of the service, in the event of stoppages which will not yield to other treatment.

Services connected to side of main.—In those cases where the main lies too shallow to admit of the service being connected at the top of the main, it is necessary to take it out of the side. In this event care must be exercised to secure that the hole shall be so drilled that the service may have a fall to the main, that the hole shall be truly round, and the thread a full one. As it is less easy to tap a hole in the side than upon the top of a main, bungling workmanship may easily tear the threads to a large extent, with the result that, although easily hidden at the time, the connection becomes the cause of much trouble and loss, through leakage afterwards.

Before being screwed together, the threads of the tubing should be well smeared with either red or white lead, or red oxide paste, mixed to the consistency of very thick paint. Also all sockets upon pipes received from the makers should be removed, reversed, and leaded on, before the tube is used for gas purposes. A graphite paste has recently been introduced which serves as an excellent substitute for the usual red or white lead, and in some respects, notably in the ease with which pipes may be taken apart after having been jointed with this material, has considerable advantages.

Amount of " fall " required.—Owing to the greater internal surface in proportion to the quantity of gas passing, and its comparative roughness, which proportionately impedes the flow of possible condensation, especially as the latter has usually to take place in opposition to the direction of the flow of gas, it is advisable that services should have, if possible, a greater fall than is necessary in the main itself. Should the local conditions render this impossible, then, rather than lay the service too flat, it is preferable to turn the fall definitely in the opposite direction, and at the lowest point place a bottle syphon (see Fig. 48, p. 96). The syphon should always be fixed in an easily accessible situation, and outside the premises to be supplied, so that it may be regularly emptied by the syphon man when in the district, and the inconvenience caused by the escaping odours in confined spaces be avoided.

Examination and testing of pipes before being used.—Before being laid as a service, every piece of piping should be thoroughly examined to ensure its being quite free from flaws, and clear of the soil, chips, or waste which seem to find such a ready lodging in it. It sometimes happens, even with the tubes of the best firms, that pipes get through with a considerable burr in the interior, due to faults in manufacture, in some cases sufficient to practically stop the gas-way. Every pipe with a burr should be discarded, even if the gas-way is not materially obstructed, as the roughness forms a convenient point for the deposition of naphthalene or the collection of condensation. It is very difficult to clear such a pipe of these obstructions, which are bound to cause trouble sooner or later.

If a service pipe is being carried to such a position that at any part of its length it cannot be got at for testing after being laid in position, and especially if it has been necessary to bend the tube at all, it should be fully ascertained before the pipe is fixed that there has been no opening of the seam or other fault developed during the process of bending. This may be easily done by stopping one end and sucking the air out of the pipe, just as a school-boy would treat a key to make it hang from his lip. In the case of the piping, the pressure upon the lips will be at once reduced, or released altogether, if the pipe admits air to take the place of that exhausted. No piece of pipe should be used which will not stand this simple test.

Services to be left square with building.—Services should always be left perfectly square with the interior of the place which is intended to accommodate the meter. A pipe entering a building at an oblique angle is always unsightly. In addition to this, very great inconvenience is frequently experienced in making shapely connections, especially in the case of meters of large size, through failure to observe this rule.

Valve used with large services.—It is always desirable, in the case of services of large diameter, that a valve should be fixed upon the service upon the outside of the premises supplied, in some convenient position, so that in case of serious accident, fire, or other emergency, the supply may be completely under control, and, should it be deemed necessary, may be shut off from outside.

Gauge cocks.—In the case of large services it is desirable, in many cases, that gauge cocks should be fixed on both inlet and outlet of the meter, so that in the event of interruption of supply the cause of the failure may be located, to some extent, without necessitating the shutting off of the supply altogether.

Protective Coatings.—It is always expedient to give wrought-iron pipes which are to be used as services a good protective coating of either red oxide paint, or of tar and pitch applied hot. To avoid the cost of treating each pipe separately, a bath is generally adopted for the latter purpose, as shown in Fig. 199. This is a chamber, 12 inches by 12 inches, in cross section, and long enough to accommodate the longest tubes to be treated, and capable of being heated by

Fig. 199.—Pipe-Dipping Tank.

either steam or gas jets. Before being placed in the bath, the pipes should be heated to the temperature of the hot composition, either by being placed in a second chamber, which can be heated and used as an oven, or by other similar means.

The author has found the following a very good composition for the purpose of coating service pipes :—

3 gallons tar.
1 lb. medium stearine pitch.
2 lbs. common pitch.

Of course the ends must be plugged and the threads protected by sockets before the pipe is placed in the bath, to prevent either the mixture getting to the interior of the pipe or the threads being filled with the composition. If this precaution is not taken, when the pipe is in use the interior coating will become partially dissolved by the passing gas, and, collecting as a viscous mass at some point, may lead to stopped services. After immersion for a few minutes, the pipes should be taken out of the bath and set on end to drain. Should the composition give too brittle a coating, the proportion of tar must be increased.

As the result of a great number of experiments, the late General Hickenlooper suggested the following composition as a very efficient one for the protective coating of services. The recipe was given by Mr A. C. Humphreys in a paper read by him before the American Gas Light Association in 1896.

"Bring a kettle of tar (20 gallons) to a low boiling point, and add 20 lbs. of fresh slacked lime, sifted over the top and worked down. Boil down to a paste or a consistency about midway between tar and pitch. Let it settle for a few minutes, then add 4 lbs. of tallow and 1 lb. of powdered resin. Stir until they are thoroughly dissolved and incorporated with the tar. Then let it cool and settle. Ladle off into barrels. When ready for use, to each barrel of 45 gallons of the above mixture add 4 lbs. of crude rubber dissolved in turpentine to the consistency of thick cream. Heat the mixture to about 100° Fahr., and immerse the service pipe, which should have been previously heated to about the same temperature." This composition has been extensively used in the United States, and with great success.

Exceptional protection sometimes necessary.—In the event of the subsoil which is to receive the pipe being of an especially deleterious character, it may be necessary to give the piping still further protection. This may be done by laying the pipe in a rough wooden trough of  or  section, which is then run full of pitch. In this case the pipe should be raised from the bottom of the trough to allow the pitch to run freely under the bottom of the tube, so that the latter may be completely encased. This may easily be done by means of bridge wires placed at intervals along the trough, as shown by the dotted lines. A very good substitute for the pitch mentioned

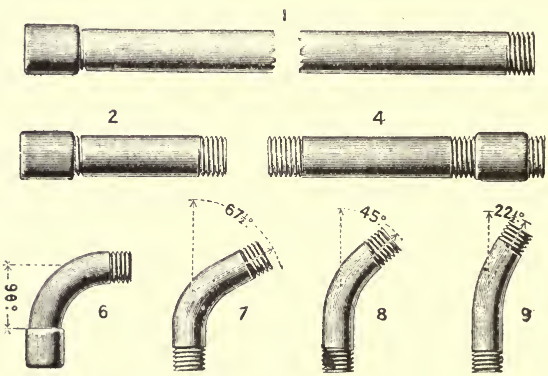


FIG 200.—Wrought-Iron-Fittings.

1. Tube.
2. Short piece.
4. Connector.
6. Bend $\frac{1}{4}$.
7. ,, $\frac{3}{16}$.
8. ,, $\frac{1}{8}$.
9. Bend $\frac{1}{16}$.

may be found in a mixture of fine sand and gas tar, or sawdust and gas tar.

A few of the commoner kinds of fittings used with wrought-iron tubes are shown in Figs. 200 and 201.

Malleable iron fittings.—A very great improvement in the manu-

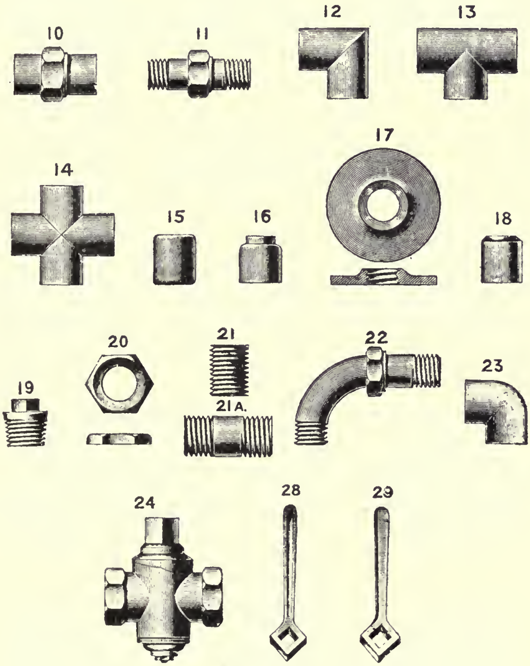


FIG. 201.—Wrought-Iron Fittings.

10. Socket union.
11. Pipe union.
12. Square elbow.
13. Tee.
14 Cross tee.
15. Socket.
16. Diminisher.
17. Flange.
18. Cap.
19. Plug.
20. Lock nut.
21. Nipple.
21A. Space nipple.
22. Union bend
23. Round elbow.
24. Iron main cock.
28. Wrought-iron spanner.
29 Malleable-iron spanner.

facture of malleable iron fittings has taken place during recent years. In place of the clumsily made, unshapely, and imperfectly threaded malleable fittings of two or three decades back, these are now placed upon the market as good and perfect in every way as the best wrought-iron fittings. The cost is very considerably less than that of the latter, and there has, during the past few years, been a very great development in their use. The bends shown in Fig. 203 bid fair to

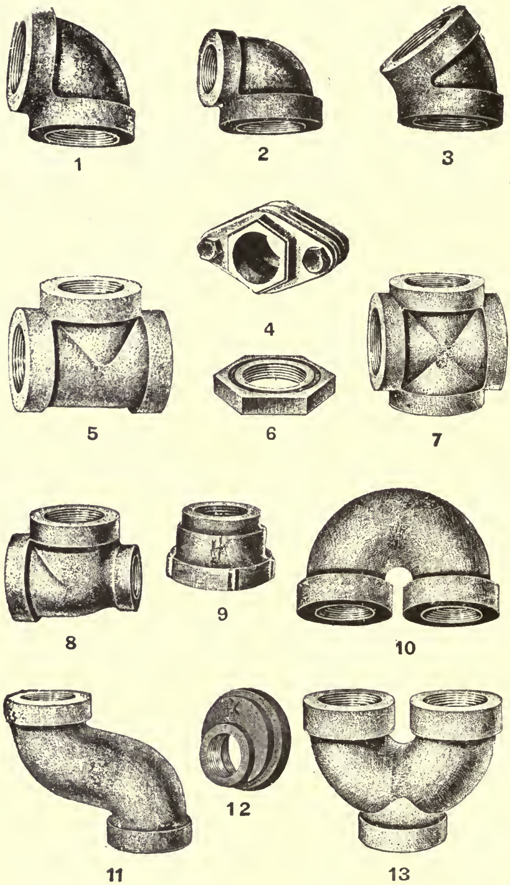


FIG. 202.—Malleable Iron Fittings

1. Elbow.
2. Diminishing elbow.
3. One-eighth elbow.
4. Flange union.
5. Tee.
6. Lock nut.
7. Cross tee.
8. Diminishing tee.
9. Diminisher.
10. Return bend.
11. Set-off.
12. Eccentric diminisher.
13. Return bend with back outlet.

completely displace the wrought-iron bend for the purpose of service attachment to gas mains, owing to their greater thickness and consequent durability. Although, perhaps, in some other instances, these fittings are not quite so well adapted for use in the ground as the wrought-iron variety, they have come into very general use for

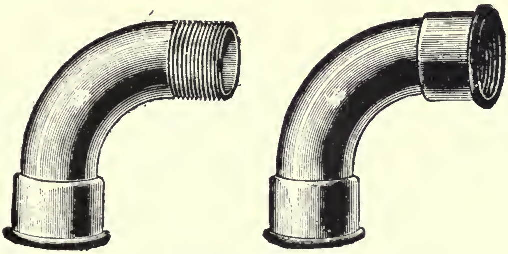


FIG. 203.—Malleable Iron Bends.

all kinds of internal work for water and steam, as well as for gas. Some of the ordinary stock patterns are shown in Fig. 202.

A few of the most useful union fittings are shown in Fig. 204.

Equipment for service layer.—In view of the fact that services are responsible for a great deal of the leakage of gas undertakings, it is becoming increasingly recognized that not only must the pipes

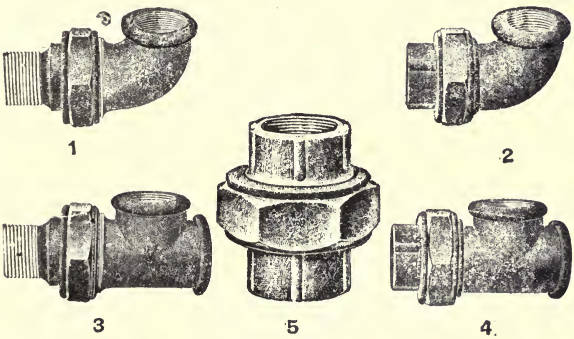


FIG. 204.—Malleable Iron Union Fittings.

1. Male elbow union.
2. Female „
3. Male tee union.
4. Female „
5. Female union.

themselves be of the very best quality obtainable, but that the tools and general equipment also of the service layer must be of the best of the kind and of the most up-to-date type.

Handcart.—The first thing necessary in the equipment of a service layer is a good lock-up handcart such as is shown in Fig. 205. Upon one side of the roof of this, the necessary pipe vice, shown in Fig. 206, for holding the pipe whilst it is being cut and screwed, is fixed. In the lock-up part, which is specially arranged for the purpose, the more

FIG. 205.—Service Layer's Handcart.

expensive tools may be kept. These should each be fitted to its own particular place, so as to avoid injury, one from the other, from

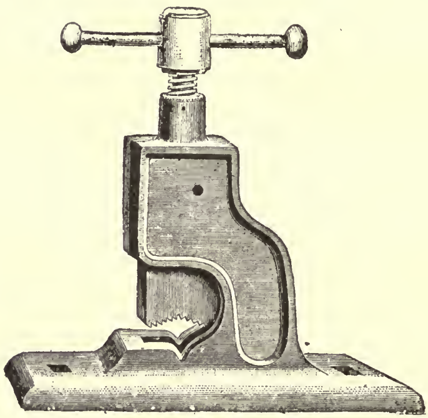


FIG. 206.—Flanged Pipe Vice.

the vibration incidental to moving the cart from one place to another.

Drilling Apparatus.—One of the service layer's important tools is his drilling apparatus. The drill stand should be made as light as is compatible with durability. Fig 207 shows one type which is in very general use. The great disadvantage of this pattern is that in use the stand is apt to tilt a little, and thus throw the drill out of the true

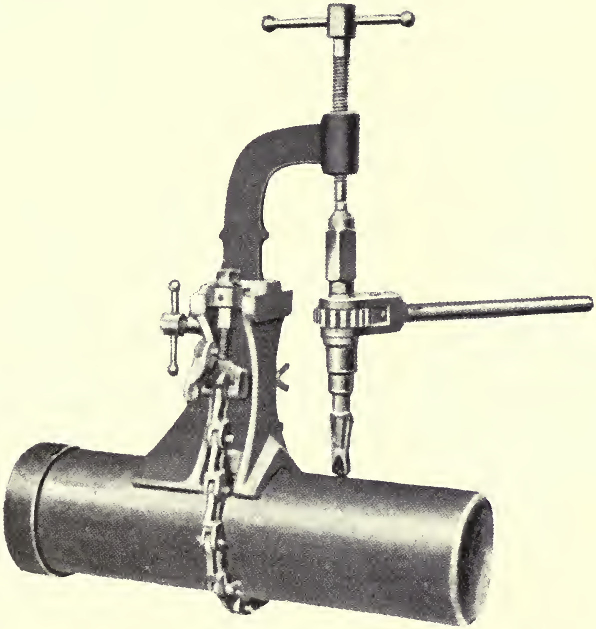


FIG. 207.—Drill Stand, Fixed.

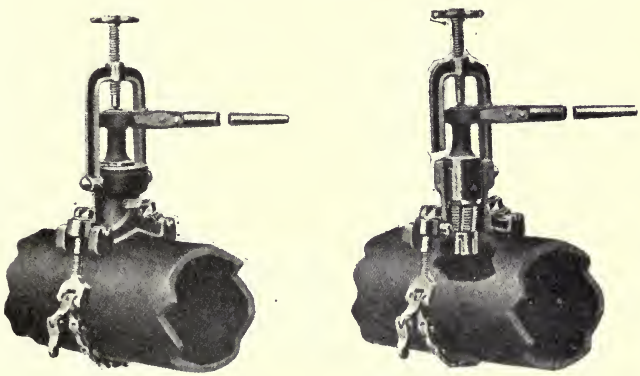


Fig. 208 —Ruscoe's Patent Drill Stand.

vertical line. With a view to surmounting this difficulty, a very handy and ingenious drill stand has been patented by Messrs Ruscoe and

Co., which is shown in Fig. 208. In this apparatus the thrust of the drill is absolutely central and direct, the disadvantage ordinarily attendant upon the double stay being avoided by making the bridge capable of turning freely by means of the collar joint. One great advantage of this arrangement is that, owing to the long, true socket into which the drill holder is made to work tightly, holes may be drilled without appreciable loss of gas. The arrangement of spindle, socket and drill is seen very clearly in the sectional view (Fig. 208).

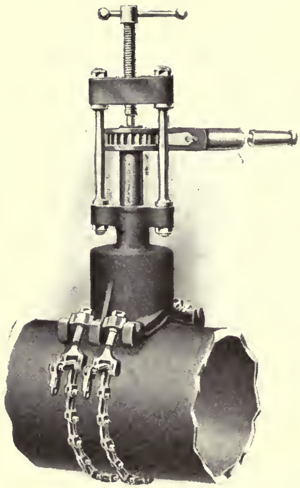


Fig. 209.—Pass and Co.'s Patent Drill Stand.

Fig. 209 shows the stronger type of machine of somewhat similar type made by Messrs E. Pass and Co., Limited, Denton, which is capable of drilling and tapping holes up to 4 inches in size.

In the matter of drills, too, there have been great improvements of late years. The use of the old flat drill, with its accompanying loss of gas and poisoning of workmen, has been completely superseded by the types shown in Figs. 210 and 211. These drills with the fluted or twisted portion properly filled up with tallow, and used in the drill stand

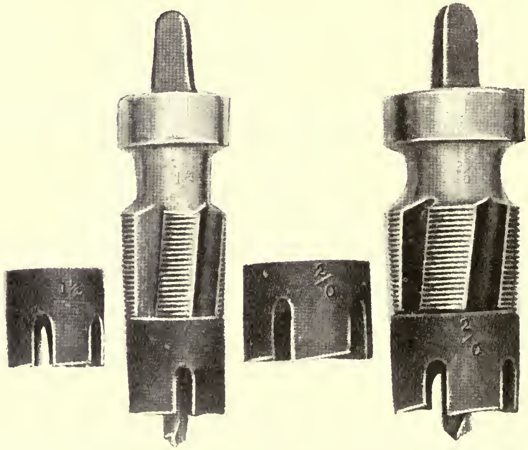


Fig. 210.—Ruscoe's Cup Drills.

shown in Fig. 208, with its spindle well greased in its socket, may be safely used even in confined spaces, or for mains under a pressure of 6 or 7 inches head of water. The combination of tap and drill, making it possible to drill and tap a hole at one operation, is therefore seen to be one of the most useful tools in the service layer's kit. The drills may be separated from the taps, and may be re-cut when necessary.

Stocks and dies are another type of tool which have undergone

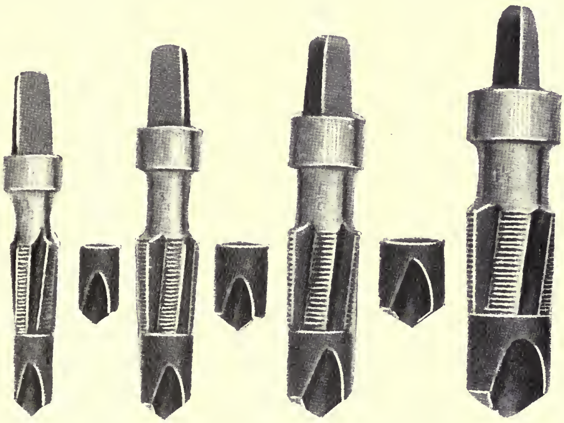


FIG. 211.—Ruscoe's Twist Drills.

very great improvements in recent years. The fact that "time is money," and the necessity for keeping down expenses of all kinds, in addition to the intrinsic utility of the newer forms, have caused the old slow-acting pattern of stocks and dies shown in Fig. 212 to be almost entirely superseded, except for special work, by the solid die stocks shown in Fig. 213, which cut the whole thread at one travel. The latter are now made adjustable by the simple device of making the die in two halves (see Fig. 214), which may be manipulated by special set screws arranged for the purpose and still cut the whole thread at one travel.

Probably one of the handiest tools for the service layer ever invented is the ratchet stocks and dies shown in Fig. 215. Not only is this a most useful tool for general work, but it is especially so in connection with repairs to, and relaying of, mains and services. The use of this tool makes it quite unnecessary to follow a service pipe from socket to socket in order to repair an injury which may only extend over a few inches of the tube. The damaged part may be cut out, and the severed end screwed *in situ* by means of the ratchet stocks. Or in relaying mains and connecting up previously laid services again, it frequently happens that these services are in very good condition,

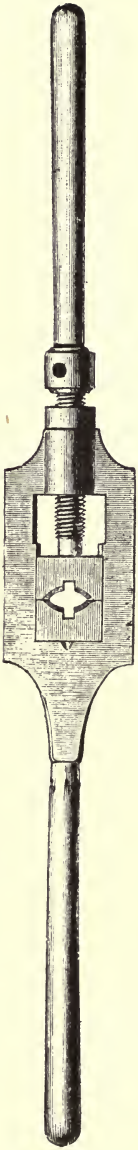


FIG. 212.—Slow-acting Stock and Dies.

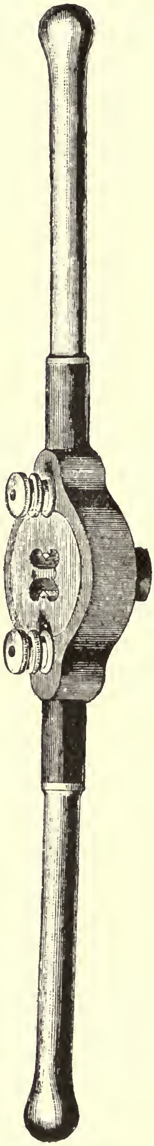


FIG. 213.—Solid Die Stocks.

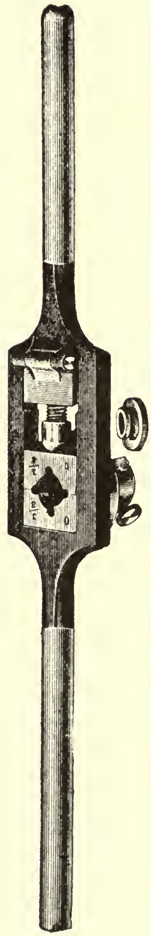


FIG. 214.—Adjustable Die Stocks.

and much time, trouble, and expense may be avoided by tapping the end which has been cut, without removing it from the ground. Ratchet stocks make this a very simple operation. The end of the pipe to be screwed is first filed down to permit the dies to bite, and then the pipe *in situ* is firmly held by means of pipe tongs whilst

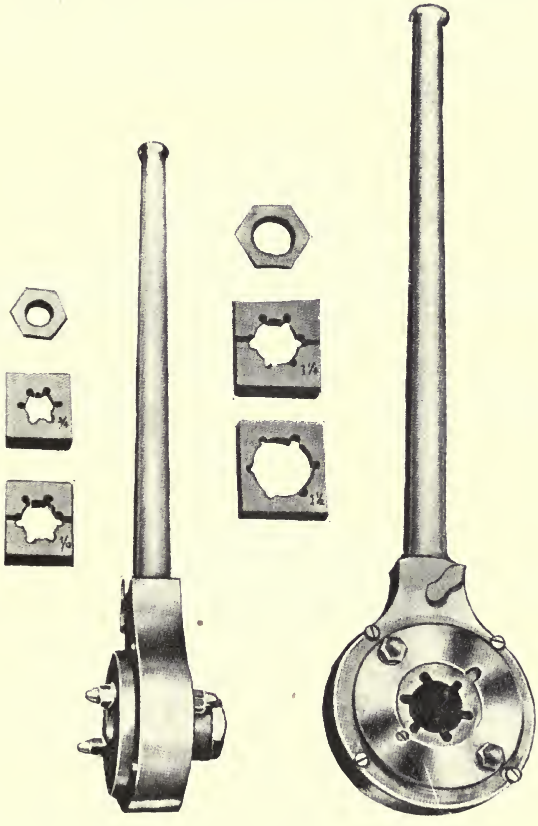


Fig. 215.—Ratchet Stocks and Dies.

the thread is being cut. The recent addition of a self starter to both these and the solid die stock has proved very beneficial.

The "Buckeye" die stock.—The latest type of die stock which has been introduced is that having dies of the chaser pattern, of which we may take Hart's "Buckeye" stock as an example. These are shown in Fig. 216.

The dies having a short cutting edge cut very easily, and by means of an automatic expanding movement cut a taper thread. The dies may be kept sharp by simple removal and grinding of the flat surface, and considerably less power is required to cut a thread than in the case of stocks of an older pattern. As soon as a sufficient length of thread has been made the dies stop cutting and release themselves from their work. By means of a controlling cam-plate the dies are withdrawn after cutting so as to avoid turning them backwards again over the new cut thread.

The operation of starting, always a more or less difficult one with dies of other types, is made quite easy in the "Buckeye" by the

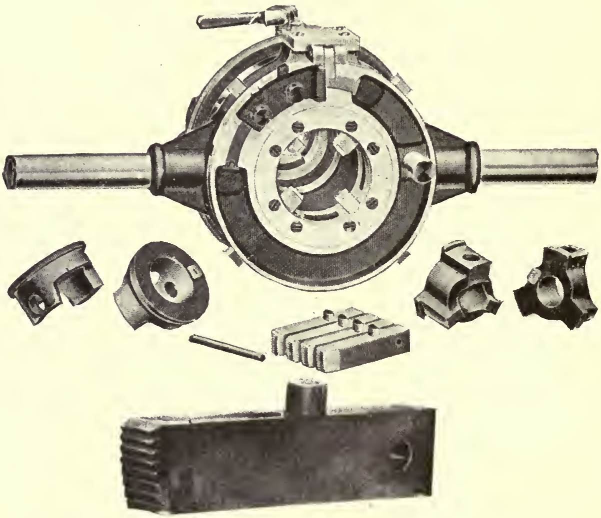


FIG. 216.—Hart's Patent "Buckeye" Die Stocks.

adoption of a leader ring which starts the die automatically without pressure or exertion. Unlike the case of the ordinary screw leader, the employment of the ring enables threads of any pitch, or even right and left handed threads, to be cut.

Want of oil in lubrication is prevented by the provision of a series of pockets in the stock in which the oil is caught as it drips from the die, and from which it is repeatedly returned to the cutting edge, instead of being allowed to run to waste.

Pipe Tongs.—The convenience of having one tool capable of adjustment to take several sizes of pipe has led, to a large extent, to the displacement of the old-fashioned pipe tongs shown in Fig. 217. With this type it was, of course, necessary to have a separate tool for each size of pipe and socket. In this department of tool manufacture, the inventive brain of our American cousins has been particularly active. The chain tongs shown in Fig. 218, each capable of taking various sizes of pipe, up to the limit of the length of the chain, and requiring little space behind the piping, forms a light, handy, and serviceable tool. The jaw may be either re-cut when worn or replaced by new. Another excellent type of tongs is the

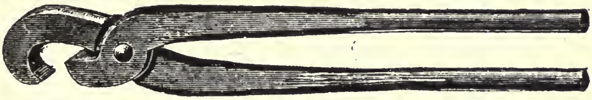


FIG. 217.—Pipe Tongs, Old Pattern.

"Adjustable," shown in Fig. 219, in which the grip may be extended or reduced by means of the thumb screw, A, working against the pin of the tongs. Although not giving such a range of usefulness in the various sizes of pipes manipulated with one pair of tongs, it is

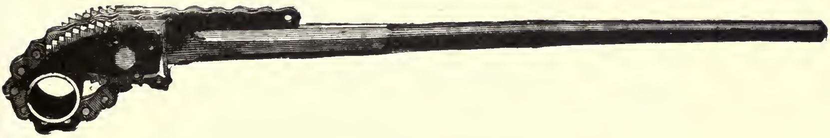


FIG. 218.—"Vulcan" Chain Tongs.

yet a favourite tool with workmen. Another first rate pipe wrench is the "Clarke reversible," shown in Fig. 220, in which each pair of tongs is fitted with three-sided reversible grips, which may be re-cut when worn, and consequently have a very long life. Of the

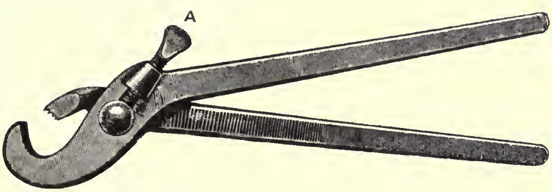


FIG 219.—"Adjustable" Pipe Tongs.

smaller variety, probably the "Footprint" (Fig. 221) is as useful a tool as can be found for general purposes, adapted as it is for both meter unions and nuts, as well as for pipes.

One of the latest of many such importations from America is the "Ideal" wrench, shown in Fig. 222 and in sections in Fig. 223. The unique feature of this wrench consists in the bevelled grip inside the ordinary flat grip for pipes, which gives it a double biting surface, and enables it to be used to splendid advantage with malleable beaded fittings, or flanges, and other work where the available grip is comparatively narrow. This will be seen at a glance from Fig. 224. The wrench is very simple in design and exceedingly

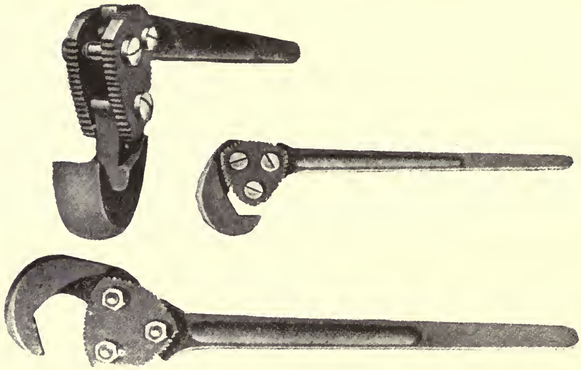


FIG. 220.—"Clarke Reversible" Tongs.

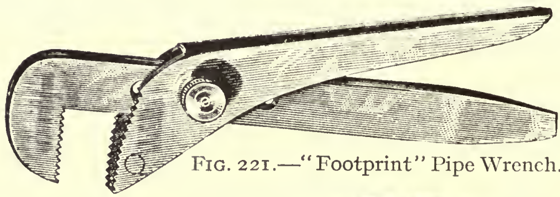


FIG. 221.—"Footprint" Pipe Wrench.

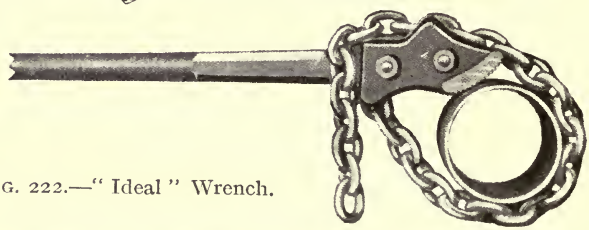


FIG. 222.—" Ideal " Wrench.

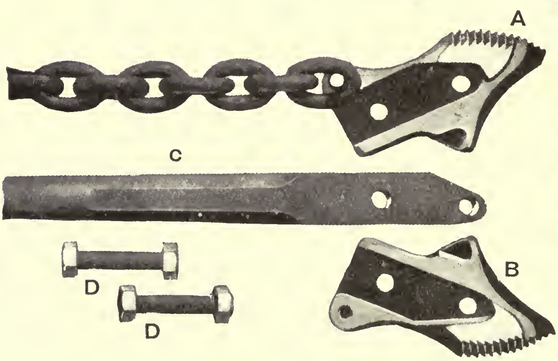


FIG. 223.—Details of " Ideal " Wrench.

FIG. 224.—" Ideal " Wrench.

strong. The various parts are shown in Fig. 223, in which A and B are the dropped forged jaws of tool steel. The handle, C, is of spring steel, and D D are the bolts required to hold the parts together.

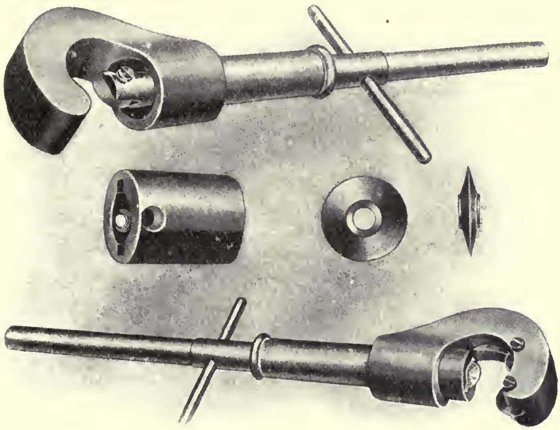


Fig. 225.—Improved Pipe Cutters.

The pipe cutters shown in Fig. 225 contrast the old and new type. In the older form, the spindle end carrying the cutter wheel has always been a very weak point, as the side strain sooner or later caused the end to open out. In the new type a thimble has been added to the spindle end, which enormously strengthens it and converts the weakest into the strongest part of the tool.

One great disadvantage of this type of cutter is that it must inevitably leave a burr upon the interior of the pipe at the point of the cut. This has then to be removed by either filing or rimering, if the pipe is to be of full bore. The objection to this, particularly in the smaller size of pipe, is obvious. The "Beaver" pipe cutter (Fig. 226) obviates the difficulty by giving an absolutely clear cut, just as clear and clean and free from burr as though the pipe had been cut with a saw. It is self-centring and self-feeding, and operates in the same manner as a die stock.

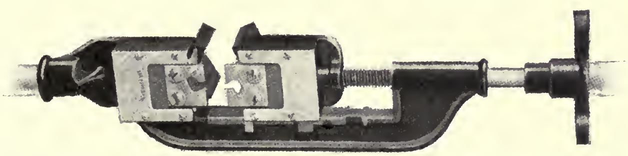


Fig. 226.—The "Beaver" Pipe Cutter.

CHAPTER XV

WET METERS

It is of the utmost importance to the success and prosperity of any gas undertaking that the meters used should work as perfectly and as accurately as possible. The results of good carbonization in the retort house, and careful distribution, may easily be altogether neutralised by defective measuring instruments on the consumers' premises.

It is, therefore, not without sufficient reason that the scientific knowledge and mechanical ingenuity of gas engineers have been directed towards the production of a perfectly accurate meter, which should be absolutely reliable under all normal working conditions, ever since the day when Clegg patented and placed his first gas meter upon the market. The result of the skill and application which have been brought to bear upon the problem is shown to-day in the production of meters of various types, of the best of which it is not perhaps too much to say that, whilst not absolutely perfect, they still approximate very closely to the ideal just suggested.

Gas meters may be divided into two classes :—(*a*) Those that are complete in themselves and are called dry meters, and (*b*) those which rely for their action upon the presence of fluids, or wet meters.

The principle and working of the wet meter.—In its simplest form, the wet meter consists of a hollow drum capable of revolving freely upon its axis in an outer case. The drum is divided into a number of equal compartments by as many partitions, set obliquely to both the horizontal and vertical planes, for the purpose of diminishing and equalising resistance. If they were placed square with the shaft, there would not only be greater friction, but oscillation in the flow of gas. With the same object of diminishing friction, the drum is cut away in the centre, near the shaft, to allow of a free passage of water from one chamber to another.

Water is introduced into the outer case, thus displacing the air in both drum and case, to the necessary level above the axis of the drum. Consequently, when that has been done, more than half the drum will be always under water as it rotates, no matter what position it may be in at any given moment.

In front of the drum case and divided off altogether from it by a partition is the front box, which forms the inlet chamber to the meter, and upon which is placed the dial plate and train of cog wheels which constitute the recording apparatus.

The only gas communication between the front case and the measuring drum, when the meter is properly water-lined, is by means of a bent pipe, called the spout, which conveys gas from the inlet, and which is sealed from the outlet side of the drum by the hood or hollow cover. The oblique position of the partition ensures that the outlet of any one compartment remains sealed as long as the inlet side is above water, and *vice versâ*. There is never, therefore, at any instant, a clear passage through the chamber. No gas can enter the chamber unless the outlet is sealed, and none can leave it until the inlet is sealed. The inlet is at the front and the outlet at the back of the drum.

We have here, then, the essential parts of a wet meter in their crudest form—namely, (*a*) an inlet chamber; (*b*) a drum divided into partitions; (*c*) an outer case in which the drum may revolve; and (*d*) the apparatus for recording measurement.

If, now, after the meter has been supplied with water to the proper level, the gas is turned into it, the pressure of the gas from the main, entering the compartment available, is brought to bear in two opposite directions. There is an upward thrust against the inclined partition wall and a downward thrust upon the surface of the water. The drum only, however, has the power of motion. The action, therefore, of the gas pressure upon the surface of the water is one of depression to the extent necessary to overcome the inertia and friction of the drum. The amount of depression varies, of course, with the freedom of action of the drum, and may range from less than one-tenth of an inch to as high as two or three-tenths, if the meter is working heavily. When the extent of the water depression equals the back pressure due to friction thrown by the drum, the pressure of the gas thrusts the partition wall upwards, and, the latter being capable of circular movement only, a rotary motion is imparted to the drum. In other words, the drum commences to revolve. The gas, therefore, in entering a compartment of the drum acts as a fluid wedge driven by the pressure behind it and continually forcing the partition and the surface of the water farther and farther apart. And this operation is continued with successive chambers so long as, on the one hand, the inlet pressure is sufficient to overcome the drum friction, and, on the other, there is an outlet for the gas.

By the time the measuring chamber first supplied is perfectly full the rotation of the drum has caused the second to commence to appear above the water-line. This, in turn, is filled in the same way, the rotary motion of the drum being still maintained by the wedge-like action of the incoming gas. And so the action goes on through the full cycle of the revolution. Each chamber is filled in succession as the drum rotates and brings it above the water-line, until the partition first filled arrives at the position in which it stood when the rotation of the drum commenced, and one revolution of the drum has been completed.

So far, we have only concerned ourselves with the gas entering the measuring chamber. It is obvious that when the chamber has been filled and the rotation of the drum causes it to begin to dip below the water-line the opposite process to that described above is set up. As the chamber enters the water, the gas becoming compressed between the surface of the water and the partition of the drum seeks an outlet; this it finds at the back of the measuring chamber, and so passes into the outer case. Therefore, when the drum has rotated sufficiently the whole of the gas contained in the chamber as it commenced to enter the water will have become displaced by water. Thus, as each chamber in succession dips into the water the same process is continued, each full compartment having the gas displaced by the water in turn.

Putting, therefore, the two actions together, we have a succession of chambers, first completely filled with gas and then as completely emptied again, the rotation of the drum providing for both actions to be proceeding continuously and simultaneously. Thus, so long as gas is supplied and there is an outlet, or, in other words, any consumption of gas, a continuous stream of gas will be passed through the meter.

It is apparent, therefore, that if we know the cubical capacity of each chamber above the water-line, and the number of chambers, we shall also know the exact quantity of gas passing through at each revolution of the drum. And if the drum is properly geared up to an index which will record the number of its revolutions, we have only to multiply the number of complete revolutions of the drum by the cubical contents of the sum of the measuring chambers to ascertain the quantity of gas passed through the meter in any given period.

The cubical capacity of the measuring chambers of the drum is usually arranged on the basis of each light consuming 6 cubic feet of gas per hour, and that when supplying the maximum number of lights the drum should make 120 complete revolutions per hour. Thus a 20-light meter is made to pass 120 (20 × 6) cubic feet per hour; and if the drum is to revolve 120 times per hour it follows that the cubical capacity of the sum of the measuring chambers must be 1 cubic foot, or, if there are four such chambers, that they must be of the cubical capacity of ¼ cubic foot each.

Reverting now to what has been said as to recording the number of revolutions of the drum and finding the quantity of gas passed by multiplication, it is obviously better to arrange for the wheelwork to make the calculation for us. Therefore, instead of the index showing the number of revolutions of the drum simply, it is so geared up as to show, not the number of revolutions, but the actual quantity of gas which has passed through. Thus, in the case of the 20-light meter referred to, the shaft of the drum is geared by worm and screw into an up-shaft, which imparts motion to a series of wheels, which, in turn, actuate the pointers. The up-shaft in this particular case must work into the first wheel in such a way that one hundred revolutions of the drum will turn the first dial one-tenth of a revolution, thus moving the index pointer from one figure to the next on the dial registering hundreds of cubic feet. The first pinion then works into a wheel containing ten times as many teeth as itself. Number two, in turn, in the same way, works into a third, and so on through the series. The dials, therefore, in sequence, register hundreds, thousands, tens of thousands, and so on, each succeeding dial registering ten times the quantity of the one immediately preceding it.

It is obvious, however, that the meter, so far as has been described, whilst containing all the essentials of a measuring machine, is yet but a very crude and imperfect instrument. The correctness of the measurement is seen at once to be absolutely dependent upon the water level. But evaporation is continually taking place to a greater or less extent. If, therefore, the meter is started with a true water-line, and absolutely correct as to measurement, as evaporation proceeds the capacity of the chamber will be increased, and thus more gas allowed to pass through than is registered, to the serious loss of the undertaking when multiplied out over the thousands of meters which may be in use.

In addition to this, nothing could be easier with the simple form of meter described than to very largely increase the capacity of the drum by either tilting the meter forward or by abstracting a quantity of the water. This had a double effect in the early forms of meter. Not only was the capacity of the chamber enlarged by the low water-line, but if the water-line fell below a certain point, and the consumption was low in comparison with the size of the meter, small quantities of gas might pass clear through the centre of the drum without rotating it, and consequently go unregistered.

In the evolution of the meter as we know it to-day very many devices have, from time to time, been introduced, with the desire to make it as accurate an instrument of measurement as possible. One of the first of these, and one which has stood the test of time, was the float placed in the front box, as shown in Fig. 228 (p. 260). The purpose of this was two-fold :—(*a*) To close the gas-way when the water-line fell below a certain level ; and (*b*), as a consequence, to prevent the possibility of gas passing through the drum without rotating it.

It has also been sought to lessen the effect of a varying water-line by altering the shape of the drum itself. By increasing the diameter of the drum and decreasing its depth, the variation of drum capacity proportionately to a given alteration of water-level is considerably lessened. The same object was aimed at by another rather similar expedient, namely, that of contracting the depth of the drum near its axis and increasing it at the periphery. In the "Equitable" drum, invented by Mr Wm. Cowan in 1844, the central portion of the drum is blocked altogether. These and many other methods which aimed at neutralizing the effect of a variable water-line were

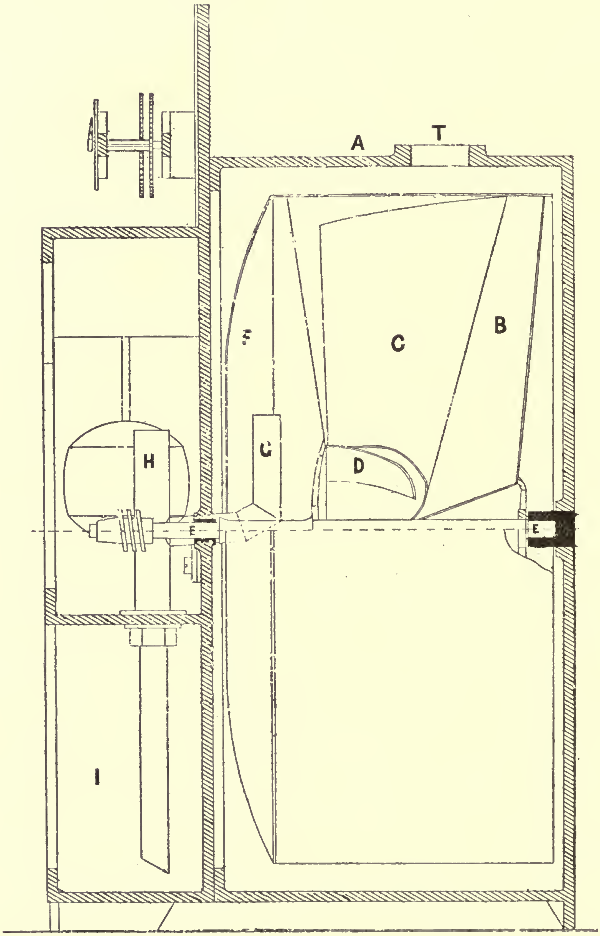


Fig. 227.—Braddock's Wet Meter. Cross-section through Drum and Front Box.

soon discarded in favour of the maintenance of a constant water-line by means of one or other of the various compensating devices which were introduced. Some of the best known of these are subsequently described.

Braddock's wet meter.—Fig. 227 shows a sectional elevation taken through the drum and front box of the excellent iron-cased consumer's wet meter manufactured by Messrs J. and J. Braddock, of Oldham. A is the outer case and B the measuring drum, only the portion above the axis being shown in section. C is one of the partitions carrying at the centre the peculiar dished arrangement, D, which, in conjunction with the "Equitable" drum, contains the germ of the idea afterwards developed so splendidly in the Warner and Cowan double drum, and intended to neutralize, to a great extent, the difficulty of a variable water-line. As will be seen, the drum is capable of revolving very freely in the bearings carrying the spindle, E, to which the drum is fixed. F is the cover plate, which, with the side of the drum, forms an inlet chamber for the gas passing into the drum. G is the spout which conveys the gas from the front box to the measuring chambers, and H is the overflow, the top of which is level with the high water-line of the meter, and which conveys any excess of water, which may be introduced, into the box, I.

Fig. 228 shows the arrangement of the front box. J is the float controlling the passage of the gas through the inlet valve, K, which, in the illustration, is shown closed; and L is the inlet pipe. The spindle, E, which forms the axis of the drum, is terminated by the screw, M, which is geared into the toothed wheel, N. The latter, by means of the up-shaft, O, is, in turn, geared at its upper end into the series of wheels actuating the index pointers. The lower part of the front box, I, is divided by a vertical partition into two chambers, P and Q, which communicate only at the top. R is the tube through which excess of water may be drawn off, and S the pipe through which water is supplied.

If, now, the meter be fixed ready for use, water is introduced by the pipe, S, until the proper water-line is reached. As the water rises in the meter, the float, J, is lifted and the valve, K, opened. Any excess of water passes away by the overflow pipe, H, into the chamber, P, which, when full, overflows into the chamber, Q, and it is only when the latter becomes full that water will flow away througg the tube, R. This arrangement effectually prevents water being extracted from the waste water box and, by unsealing pipe, H, affording the opportunity of a supply of unmeasured gas being obtained from the meter.

Having properly water-lined the meter, if the gas be turned on, it passes through inlet pipe, L, through valve, K, and through spout, G, into interior of cover plate, F, whence it enters the compartment of the drum which is available, and in the way previously described causes the drum to revolve. Whilst one measuring chamber is being filled from the front, the one immediately before it, in the direction of the rotation of the drum, is being emptied at the back, the issuing gas passing away by outlet pipe, T, to the consumer's fittings.

As has been previously shown, the number of revolutions of the drum, and consequently the quantity of gas passed, is communicated to the pointers, moving over the index dials, by means of the wheel, N, and up-shaft, O.

If from any cause the water-line of the meter is permitted to fall below a certain point, the accompanying descent of the float brings

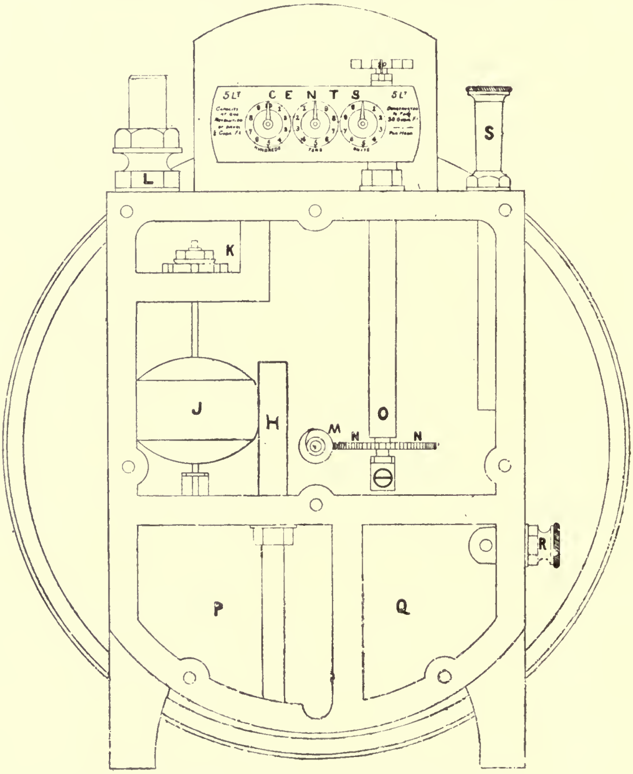


Fig. 228.—Braddock's Wet Meter, Front Box.

the valve, K, down upon its seat, effectually shutting off the gas, and the meter is thrown out of action. The latter is thus prevented from working under conditions in which the limit of error allowed by the Sale of Gas Act would be exceeded. This range of error, as has been pointed out in a previous chapter, is between 2 per cent. fast and 3 per cent slow. The high water-line is, of course, the top of the overflow pipe, H (Fig. 227). This line is so fixed by experiment that it cannot give a registration of more than 2 per cent. fast. It is impossible to raise the water-line above this point and work the meter, as the elbow pipe would be sealed by the excess water.

On the other hand, the low water-line is adjusted by means of the float so as to stop the supply when the water-line has fallen so low as to register 3 per cent. slow. The whole range of variation, however, in a Braddock's 20-light wet meter is only $\frac{5}{8}$ inch. In such a meter a depression of the water-line through $\frac{1}{4}$ inch below the true line represents an increase of capacity of the drum equal to 51.84 cubic inches per revolution, or a registration of 3 per cent. slow. If the water-line could be raised $\frac{1}{4}$ inch above the true level the decrease of capacity per revolution of the drum would be 53.568 cubic inches, representing a registration of 3.1 per cent. fast.

As an experiment, the water level of a 20-light Braddock's meter was artificially raised $\frac{1}{4}$ inch above the true water-line, and it was found necessary to add 87 cubic inches of water to the meter, while to lower the water-line $\frac{1}{4}$ inch below the true registration level it was necessary to abstract 90 cubic inches of water, the difference in the two quantities being due to the approach to the full diameter of the meter case and drum.

Glover's compensating device.—A scrutiny of Fig. 228 will reveal the fact that a sudden increase of pressure on the inlet of the meter may, both by its action upon the valve, K, and also by depressing the water level in the front-box, and so causing the float to fall, tend to close the valve and stop the flow of gas. To obviate this possibility, a simple device has been patented by Mr W. T. Glover and Meters Limited, Manchester. This consists of the provision of a double valve of equal areas, with the gas supply entering between the two. Any variation of pressure, therefore, acts equally but in opposite directions upon the two valves and consequently preserves equilibrium. The depression of the water level in the front box is prevented by arranging for a diaphragm as the base of the above-mentioned valve chamber, through which the float-rod passes at a sufficiently tight fit to just allow. and only allow. of free movement. In the base of the valve chamber a small hole communicates with the back chamber of the meter. The effect of this provision is that any sudden increase of pressure cannot act as quickly upon the water in the front box as it does in the measuring drum, and consequently a small quantity of water is forced from the back to the front of the meter, thus lifting the valve. But by means of the passage around the float-rod the pressure both in the back and front of the meter quickly becomes practically uniform, and the water level is equalized again.

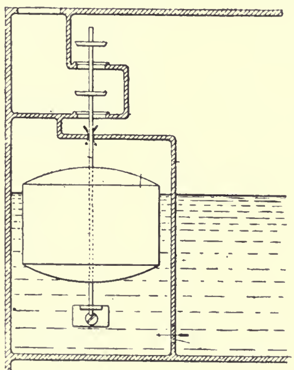


Fig. 229.—Glover's Compensating Device

The following table shows the relation of high and low water-line to the cubical capacity of the measuring chambers of a few common sizes of meters as manufactured by Messrs J. and J. Braddock.

RELATION OF CAPACITY OF DRUM TO WATER-LINE.

(Water-Line taken with Open Inlet and Outlet.)

Size of Meter.	Drum Capacity per Revolution in Cubic Feet.	Distance of True Line to		Evaporation for Variation of 1 per Cent.		Number of Cubic Inches over the whole Range.	Distance from High to Low Water-Line.
		High Water-Line.	Low Water-Line.	Linear Inches.	Cubical Inches.		
		Inch.	Inch.				Inch.
3 lights	0.125	$\frac{3}{16}$	$\frac{1}{4}$	0.087	7	35	$\frac{7}{16}$
5 ,,	0.25	$\frac{7}{32}$	$\frac{7}{32}$	0.087	9.6	48	$\frac{7}{16}$
20 ,,	1.0	$\frac{1}{4}$	$\frac{3}{8}$	0.125	31.74	158.73	$\frac{5}{8}$
50 ,,	2.5	$\frac{1}{4}$	$\frac{3}{8}$	0.125	55.49	277.46	$\frac{5}{8}$

The importance of regular and systematic attention to the water-lining of meters cannot be too strongly emphasized. It affects both buyer and seller. It is of the utmost importance that consumers should not be put to unnecessary trouble and inconvenience through the gas supply failing owing to the meter being short of water. On the other hand, it is most essential to the gas undertaking that the margin of error allowed by the Act should not be trenched upon more than is absolutely unavoidable. Even an average slow registration of 1 per cent. is a very serious matter in these days, when large undertakings number their customers by scores of thousands.

Compensating meters.—Descriptions of a few of the best-known of the various devices which have been adopted for the purpose of automatically ensuring a constant and unvarying water-line follow.

The scoop expedient was introduced by Mr C. R. Mead in 1851, and consists of a scoop or spoon, which is dipped at regular intervals, by the rotation of the measuring drum, into the water reservoir, lifting from thence a small quantity of water, which flows down the scoop into the measuring chamber. The water in the drum is thus maintained at a constant level, and any excess of water supplied finds its way back again, through the channel provided, into the reservoir.

In the first meters in which the scoop principle was introduced, the latter dipped and emptied itself at each revolution. This was found to throw so much work on the meter, and, consequently, caused so much back pressure, and, in addition, was found so unnecessary to attain the object in view, that the dipping of the scoop was reduced to once in several revolutions of the drum.

Parkinson and Cowan's compensating meter.—The arrangement as applied to meters to-day is shown very clearly in Fig. 230, which is an illustration of the iron-case compensating meter made by Messrs Parkinson and W. & B. Cowan. As will be seen, the scoop is actuated by cam action in connection with the spindle and wheel.

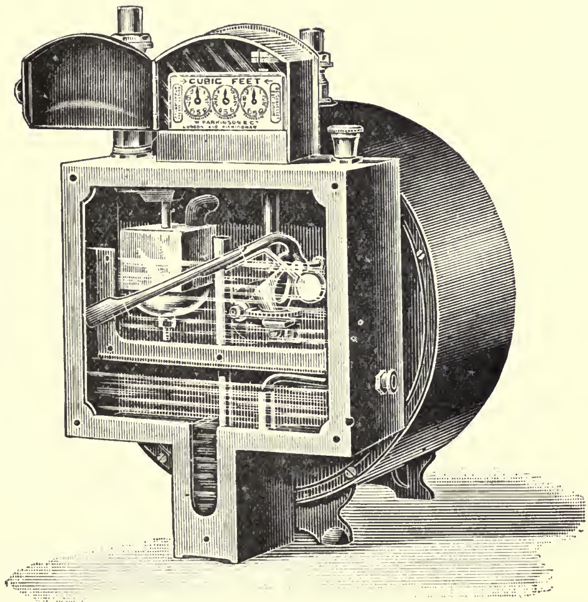


FIG. 230.—Parkinson's Iron-cased Slow Spoon Compensating Meter.

In the 3-light size of meter there are forty revolutions of the drum to one lift of the spoon, thus minimizing the additional friction to practically vanishing point.

Danubia Company's spoon device.—Another very simple spoon device for maintaining a constant water level is that described by Herr Vieweg, of Kiel, in an article in the *Journal für Gasbeleuchtung* in 1911. This is the arrangement of the Danubia Company, of Strassburg, and is shown in Figs 231 and 232.

It consists of a number of metal spoons, A, and lead tubes connected to the drum, which in revolving with the drum carry gas down with them. When at the bottom of the revolution this gas leaves the spoon, A, and passes under the cap, B, and through the tube, C, into the anterior water chamber containing the water reserve.

Here it is collected in the holder, A, and when its pressure becomes great enough to overcome the column of water in F it rises, lifting the water in F, which passes into the drum, any excess being, of course, carried away by the overflow, G, back again into the reserve.

Sanders and Donovan's meter.—Another very interesting and effective arrangement for obtaining an unvarying water-line is that

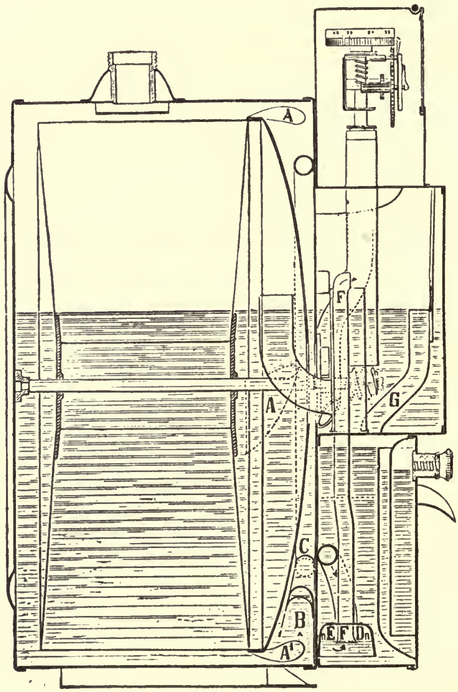


FIG. 231.—Danubia Company's Device.

patented by Messrs Sanders and Donovan. Although originally introduced so far back as 1855, this apparatus is still being used in large numbers. Fig. 233 shows the arrangement adapted to the meter manufactured by Messrs Parkinson and W. & B. Cowan, and is seen to consist of a compensating float, A, of half-moon shape, made of tin plates and carrying a stop-valve, B. The float is entirely independent of the ordinary action of the meter, is placed in the front case, and is capable of moving freely on its axis by means of pivots, C. When, therefore, water is introduced into the meter the float commences to rotate on its pivots, rising progressively as the water level is raised, until the proper water-line is reached, by which time the float has assumed the position shown in Fig. 233.

Should more water be added than is necessary, the float rests upon the inlet valve base, whilst the superfluous water flowing into the spout stops the gas-way until it is drawn off at the overflow.

As evaporation takes place, or from any other cause the water-line tends to become lower, the float, rotating on its axis, falls in exact proportion. The descending float progressively displaces a corresponding quantity of water, and thus maintains an unvarying water-

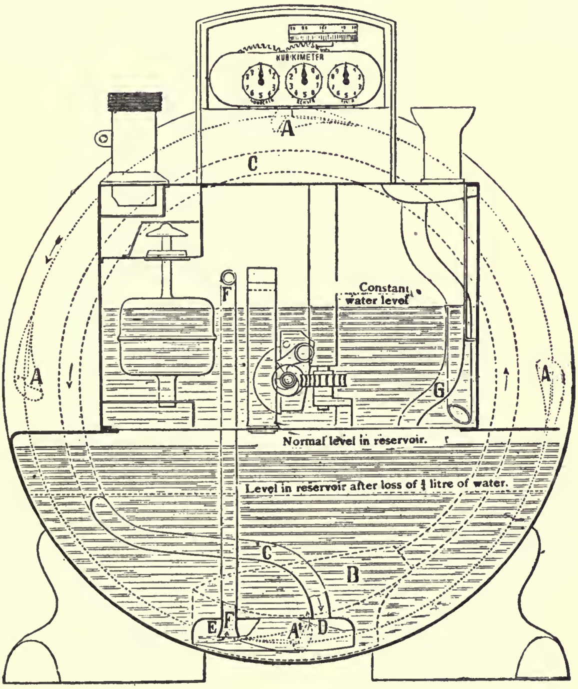


FIG. 232.—Danubia Company's Device.

line in the measuring chamber. When the water falls so short as to make this impossible, the float rotates to such a position as that the flat valve, B, is pressed against its seating, D, and stops the flow of gas at the inlet until the water-line is restored.

The Gas Meter Company's "Reliance" meter.—The "Reliance" meter, invented by the late Mr James Urquhart, and manufactured by the Gas Meter Company, has some distinctive features of its own. The practical effect, in the ordinary meter, of the partition between the front box and drum case is to divide the meter into two sections having waterway connection only, except by means of the spout. The pressure of the incoming gas, therefore, exerts a downward thrust upon the water-line in the inlet section and in the measuring chamber open to the inflowing gas, which is attended by a corresponding rise of the surface in the outlet. In other words, as meters are at present ordinarily constructed, there is bound to be a difference of water level between the front box and the compartment of the drum which is being filled and the outer case equal to the back pressure thrown by the drum due to friction in working. To surmount this difficulty, Mr Urquhart adopted the novel expedient of removing the partition altogether and taking the hood from the front to the rear side of the drum. The hood, therefore, in this

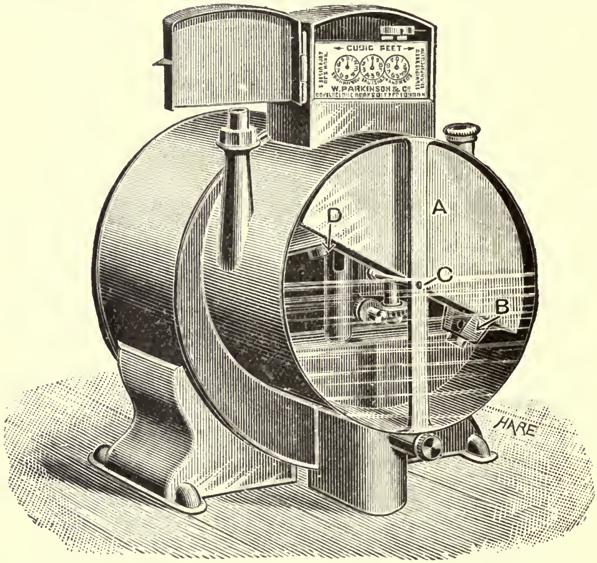


FIG. 233.—Tin-Cased Meter with Sanders and Donovan's Float.

meter, becomes the outlet from instead of the inlet to the measuring chambers, and the whole water surface is equally open to the influence of the pressure of the incoming gas. The arrangement will be readily understood by reference to Figs. 234 and 235, which show a front and back view of the meter respectively, the former with the compensation float, already described, removed. In the illustrations, A is the drum divided into four measuring compartments by the partitions, A A A A. B is the inlet valve box, containing the valve seating for the Sanders and Donovan float. C is the overflow pipe from the waste water box, and F is the plug for emptying the meter. D is the water-line pipe to carry the excess water to waste water box, and E is the pipe for supplying the meter with water. I is the waste water box with the chamber for the registered gas.

K is the hydraulic seal in waste water box, and L is the outlet for the registered gas from under the hood, as shown by the arrows. The " Reliance " meter may be, and usually is, fitted with the Sanders and Donovan compensation float.

Parkinson and Cowan's three-partition drum.—From the preceding description of various meters it will have been gathered that the usual form of drum is divided by partitions into four measuring compartments. Messrs Parkinson and W. & B. Cowan have, however, introduced a new feature in this respect, in the three-partition drum, which, for many years, has been fitted to all the wet meters

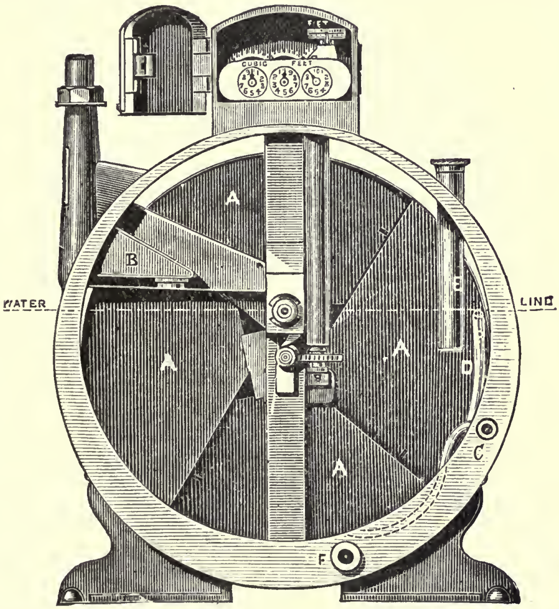


FIG. 234.—" Reliance " Meter, manufactured by the Gas Meter Company. Front view, with Sanders and Donovan's Float Removed.

manufactured at their works, including all their station meters. This form of drum has also been adopted for a large number of station meters erected in America by the American Meter Company.

The advantages claimed for this type of drum are as follows. The construction is more simple, and for purposes of cleaning and repair the arrangement is much more convenient. The fewer angles and larger chambers render them much less liable to accumulate deposits. If and when deposits have been formed, the large area of space between the hoods affords great facility for cleaning the plates.

The number of hoods is reduced from eight to six, and consequently the weight of the drum is lessened to approximately four-fifths of that of the usual four-partition drum. This, together with the wider waterway, allows the drum to revolve very freely and tends to decrease the friction due to rotation.

It is also claimed that while the three-partition drum is a great improvement on the older form for small consumer's meters it is especially valuable for station meters, owing to the lessened friction

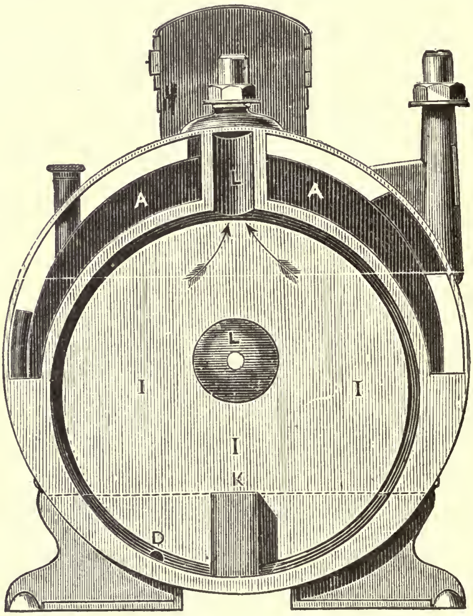


FIG. 235.—" Reliance " Meter. Back View with Hood Removed.

and greater convenience with which examination and repairs may be carried out.

If the size of the hoods and partitions are kept similar in the case of a three and four-partition drum of the same size, the cubical capacity of each would be practically the same. In a meter of the same external size it is not, however, necessary with the three-partition drum to make the hoods so deep as in a drum of the usual type, and consequently the partition can be made wider, and in this way it is possible to obtain a considerably larger capacity than with the four-partition drum. In other words, a meter fitted with a Parkinson drum can be made smaller for the same capacity.

A variation of water level of equal amounts in the same size of meter fitted with three and four-partition drums introduces approximately the same degree of error in both cases. The extent of the error for the usual form of meter has already been spoken of. With the three-partition drum, in the 20-light size of meter, if the water level be raised $\frac{1}{2}$-inch above the normal water-line the meter will register about 7 per cent. fast. If the water level falls for an equal distance below the normal water-line then the registration would be about 4 per cent. slow.

The three-partition drum is admitted by the Board of Trade as a standard instrument for official test meters.

The importance of the drum working as easily as possible cannot be over-estimated. It has already been pointed out that the first effect of turning gas into the measuring chamber of a wet meter is

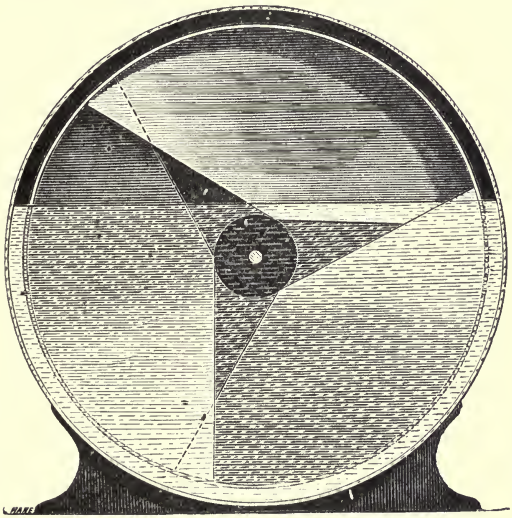


FIG. 236.—Parkinson's Three-Partition Drum

to depress the water level in the chamber. This depression, as has already been explained in connection with the "Reliance" meter, is strictly proportionate to the friction which has to be overcome in the rotation of the drum. Consequently, the greater the friction the greater the depression. This depression, of course, correspondingly increases the cubical capacity of the measuring chamber, and causes the meter to register incorrectly, by passing more gas than is represented on the meter dial.

For this reason no wet meter should be allowed to work at much more than its maximum load. If this is permitted the drum must revolve more quickly than it should, to allow sufficient gas to pass. But faster rotary motion involves greater friction, and that involves, as has been shown, a corresponding disturbance of the water-line and interference with the accuracy of registration.

Warner and Cowan drum.—Probably one of the most valuable, as well as ingenious, compensating arrangements introduced in connection with wet meters is the Warner and Cowan patent drum, shown in Figs. 237 and 238. In the compensating devices already described, the endeavour has been made to secure an unvarying water-line, and, consequently, accuracy of registration, by making good the loss due to evaporation in the measuring chamber by means of a fresh supply obtained from a reservoir in the meter. But the Warner and Cowan drum sets up a give and take operation in the

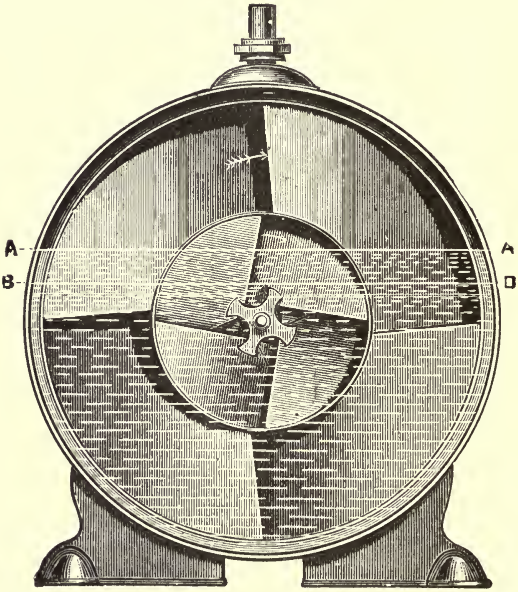


FIG. 237.—Warner and Cowan's Drum in Case, with Hollow Cover Removed.

drum itself. It obtains compensation in a perfectly automatic manner, by means of a process of subtraction which is strictly proportional to the first error, and so attains the ideal of accurate registration with a varying water-line.

The way in which this object is attained is as follows:—Within the ordinary form of four-chamber drum, a second drum is placed, concentric with the first and about half its depth, and which itself is divided into four chambers corresponding with the four in the outer part of the drum. The partitions in the inner drum are in a similar manner placed obliquely to horizontal and vertical planes, but in an exactly opposite direction to those in the outer drum. The effect of this reversal of position of the partition blades is that whilst the gas in the outer drum is passed from front to back, any gas in the inner drum is passed in the opposite direction, from back to front.

The periphery of the inner drum rises a little above the high water-line A A, and its capacity is such that it exactly divides, with the outer drum, the variable portion between highand low water-line level, B B. The inner drum, owing to the position of the partitions, must take its supply from the back. If, therefore, the water level falls below the true water-line, the capacity of the measuring chamber

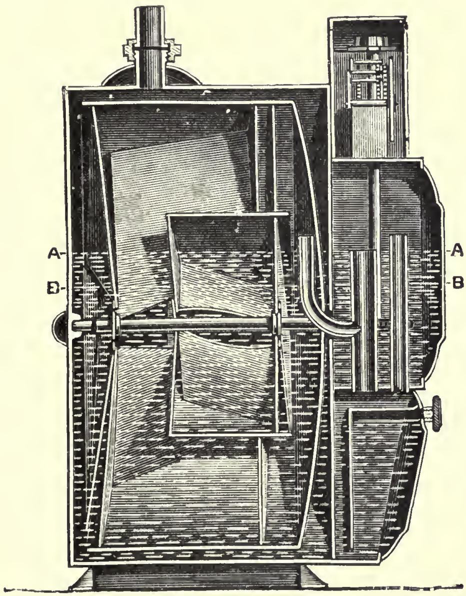


FIG. 238.—Cowan's Wet Meter, showing Section through Warner and Cowan's Drum.

of the drum is augmented correspondingly, and more gas is passed through than is registered. But this increase of capacity is equalled by the increased capacity of the corresponding chamber in the inner drum, and, consequently, an exactly similar quantity of gas is passed back again through it to the interior of the cover, there to be passed through the meter once more, as shown by the arrow in Fig. 237. The overplus, therefore, measured in the first instance, is abstracted from the back of the meter, and returned to the inlet side of the drum, and as this takes place proportionately, whatever the water-line, within definite limits, it follows that any error in the first measurement due to variable water-line is always automatically corrected by the operation of the drum.

Tin *v.* iron cases.—Wet meters are manufactured by all the makers with either tin or cast-iron cases. The advantages of the former consist in their comparative lightness, the ease with which they may be handled, and the lessened work involved in removing the meters from place to place. On the other hand, the case is not so durable, and when fixed in damp situations pitting and corrosion soon set in. The cost for maintenance and repair is relatively high, and these repairs necessitate the employment of skilled tinmen to execute them.

With the cast-iron case, the life of the meter is undoubtedly prolonged. The case is heavy and more or less cumbersome, but it is durable. In fact, with fair usage and ordinarily decent conditions, the case is practically indestructible. Being put together with set screws, it is easily taken apart for cleaning and repair, and does not need the skilled labour of the trained artizan. It will be readily understood that for damp situations, or places where corrosion may be anticipated, the use of the iron case is imperative, if economy is to be considered.

The different dimensions of each size of meter vary somewhat with each maker. The following list shows the various measurements of the Braddock wet meter with cast-iron case :—

Dimensions of Braddock's Iron-Case Meters.

Size of Meter.	Diameter of Connections.	Measuring Capacity in Cubic Feet.		Measurements.		
		Per Revolution.	Per Hour.	Height.	Width.	Depth.
Lights.	Inches.			Ft. Ins.	Ft. Ins.	Ft. Ins.
2	½	0.084	12	1 2¾	0 10	0 8
3	⅝	0.125	18	1 3¾	1 0	0 8¼
5	¾	0.25	30	1 4¾	1 1¾	0 10¼
10	1	0.5	60	1 9	1 4½	1 0½
15	1	0.75	90	1 11¼	1 6½	1 2¼
20	1¼	1	120	2 1¾	1 9	1 3¼
30	1⅜	1.5	180	2 4½	1 11¼	1 5¼
50	1½	2.5	300	2 9¼	2 3½	1 8¼
60	1½	3	360	2 11¾	2 5½	1 11¼
80	1¾	4	480	2 11¼	2 6¾	2 0¼
100	2	5	600	3 2	2 9¼	2 2½
150	3	7.5	900	3 8¼	3 2¾	2 9½
200	3	10	1200	3 10½	3 5	3 2½
250	4	12.5	1500	4 5½	3 10	3 3
300	4	15	1800	4 5½	3 10	3 8
400	4	20	2400	4 7	4 0	4 2
500	5	25	3000	5 4½	4 6	5 1½
600	6	30	3600	5 4½	4 6	5 6½

Large consumer's wet meter.—The larger sizes of consumer's wet meters, say from 150 lights and upwards, are made either after the pattern of those of small capacity, as shown in Fig. 239, or with cylindrical iron cases, with or without loose cradles, as illustrated in Fig. 240.

The former type offers considerable advantages where the meter has to be fixed in confined spaces, as often occurs in mills and workshops, and where, for this or other reasons, it is more convenient to place the inlet and outlet upon the top of the meter.

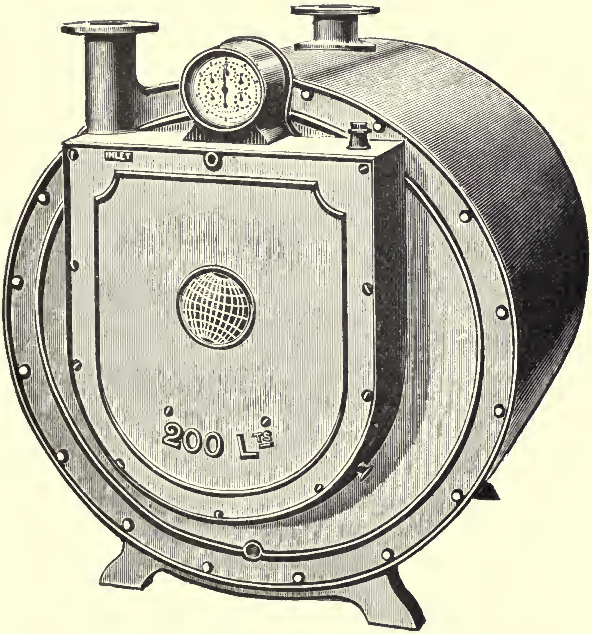


FIG. 239.—Braddock's Large Consumer's Wet Meter.

In this class of meter, which may be made either with or without float, the front box is made of much smaller capacity in relation to the drum case than in the small sizes, and is occupied by the elbow pipe, dip pipe, up-pipe, and up-shaft, as well as the syphon overflow in the waste box, and contains the funnel for filling the meter with water. If constructed to work without float, then a water-line gauge must be fixed on the side of the front box to indicate the line of true measurement, or what is commonly called "par," *i.e.* neither fast nor slow in registration. When the float is dispensed with, the fact must be clearly stated by a badge attached to the meter case bearing the words "Without Float," as prescribed by section 12 of the Sale of Gas Act of 1859. In these meters the inlet and outlet are flanged to receive the necessary connections.

It is, however, more usual to construct large consumer's wet meters in station meter form, with cylindrical cast-iron cases, with feet cast upon the case, or with loose cradles upon which they may be supported. This type of meter is shown in Fig. 240. No float is used, but a good water-line gauge is fixed to the outer case, giving facility for periodical inspection of water level. The syphon overflow pipe and box are also fixed in a most convenient position for water-line adjustment. The inlet and outlet connections are placed at the back of the meter, and are flanged to receive the necessary valves and connecting pipes.

The following table gives the various dimensions of this type of meter, as manufactured by Messrs Parkinson and W. & B. Cowan :—

Dimensions of Large Consumer's Wet Meters in Cylindrical Cast-Iron Cases.

Lights.	Measuring Capacity.		Dimensions.		Size of Connections.		Distance between Centres of Inlet and Outlet.	
	Per Revolution.	Per Hour.	Diameter over Flanges.	Length, including Connections.	Size of Bore.	Diameter of Flanges.	Horizontally.	Vertically.
	Cub. Ft.	Cub. Ft.	Ft. Ins.	Ft. Ins.	Ins.	Ins.	Ins.	Ins.
100	5	600	3 0	2 8½	3	8½	7½	8½
150	7.5	900	3 5	2 10½	3	8½	7¾	8½
200	10	1200	3 5	3 5	4	10	7¾	8½
250	12.5	1500	3 5	3 8	4	10	7¾	8½
300	15	1800	4 0	3 8	4	10	9¾	9½
400	20	2400	4 3	3 11½	5	10½	9¾	10⅝
500	25	3000	4 3	4 7	5	10½	9¾	10⅝
600	30	3600	5 0	4 7	6	12	13¾	12
800	40	4000	5 0	5 5	6	12	13½	12¼
1000	50	5000	5 7	5 5	8	15½	11¾	16¾

If specially required, the cylindrical form of large wet meter, up to and including the 1000 light size, is manufactured by Messrs J. and J. Braddock with float. But it is an unusual fitting for this kind of meter, and is only adopted in special cases.

The whole of the meters hitherto described have been essentially modifications and improvements of the original wet meter, introduced by Clegg as far back as the year 1815, which consisted of a hollow drum, divided into compartments, rotating in a case, actuated by the pressure of the gas and recording the consumption by means of wheelwork. Although many other forms have been tried, the experience of nearly a century has concentrated on this as the best working principle for a wet meter.

The station meter.—Although station meters are properly outside the scope of this work, being used for the registration of gas made upon the works, and not in the process of distribution, yet a chapter

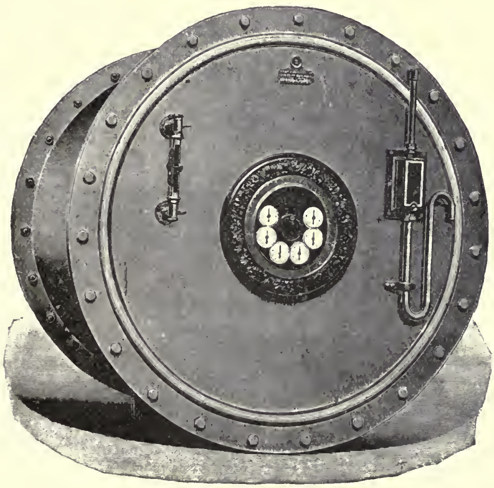


FIG. 240.—Parkinson's Large Consumer's Cylindrical Meter.

dealing with gas meters generally would be incomplete without a brief description of a station meter.

Fig. 241 is a copy of a photograph of a station meter manufactured by Messrs J. and J. Braddock, of Oldham. This type of meter is always a wet one, and is usually enclosed in a case of a much more elaborate and artistic character than those previously described. They vary considerably in design, and usually, with the meter house and the governor house, constitute the most ornamental portion of a gasworks. They are generally rectangular in plan and covered with a pitched roof. The latter is formed of strong tee-iron ridge and rafters, covered with wrought-iron plates, which may be taken off separately for the purpose of examination or repair of drum when necessary. The front of the meter contains, besides the dial, a water-line gauge showing the water level in the meter at a glance, and a pressure gauge. In addition, most of the larger sizes of station meter are fitted with a clock and tell-tale, the latter making a complete and continuous record upon specially prepared charts of the gas manufactured throughout twenty-four hours.

The overflow is fixed at the back of the meter and may be either quite open or enclosed in a water-level box, with glass front and sealed lid, to prevent its being tampered with. As in the cylindrical type of large consumer's meters, the inlet and outlet are both at the back, the inlet being in the centre and the outlet either at the right or left hand side, and higher up. In fixing, the inlet and outlet of

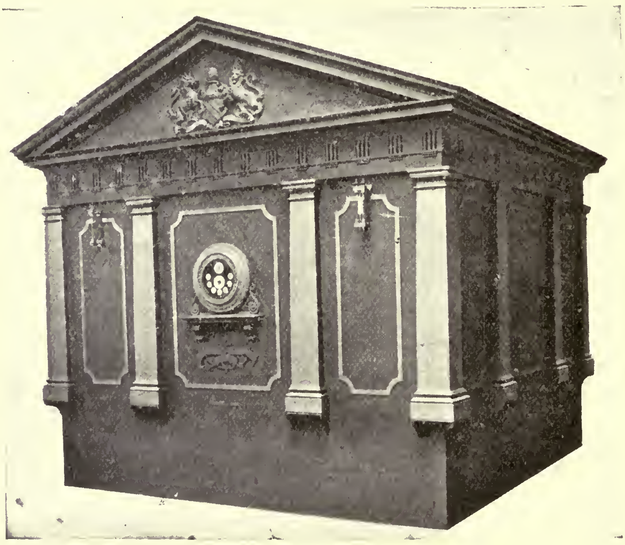


FIG. 241.—Braddock's Station Meter.

the station meter are always connected together by means of a by-pass, on opening which, in the event of repairs being necessary, the meter can be completely thrown out of action without being disconnected.

Fig. 242 shows a sectional elevation taken through the case and drum of a station meter, as manufactured by Messrs J. and J. Braddock. A is the front, B is the back, and C the roof of the case. D D are the tee-iron rafters supporting the roof. E is the drum, F one of the partitions, and P P the wrought-iron stays. G G is the shaft which carries the drum and works in the bearings, H H. An extension of this shaft passing into the index box actuates the train of wheelwork which constitutes the recording apparatus. J is the cover plate, and K the spout. L is the inlet pipe, M the hydraulic valve on the inlet, N the wheel for actuating the valve, and O the by-pass.

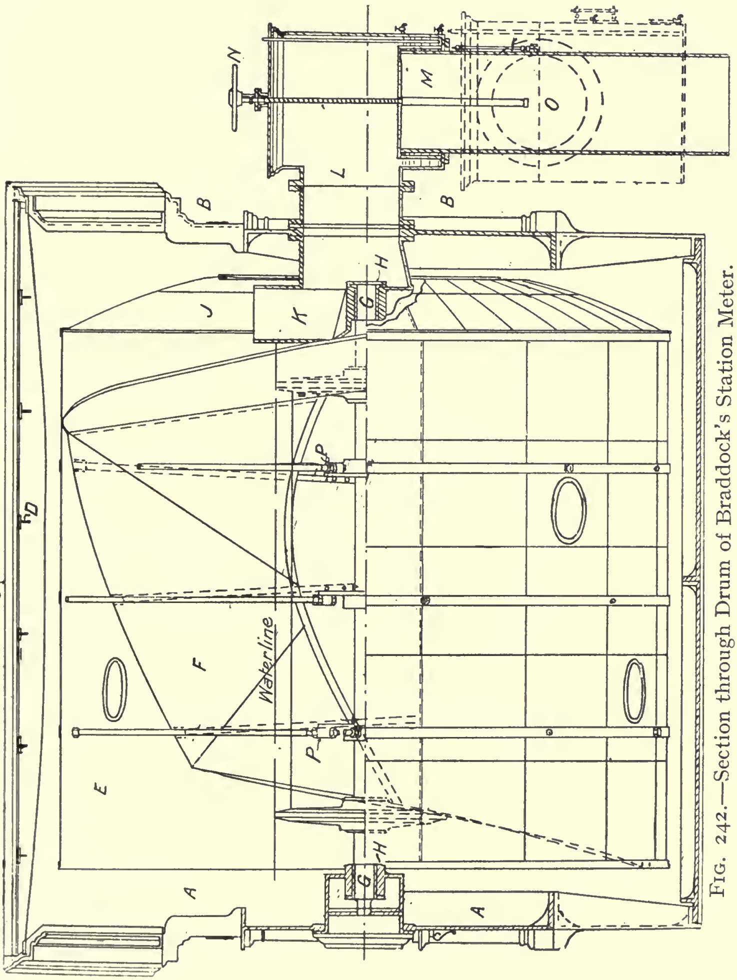


FIG. 242.—Section through Drum of Braddock's Station Meter.

The water-line in a station meter is maintained by allowing a small stream of water to flow into the meter and out again by means of the overflow. Experiment will soon show the quantity sufficient to maintain a slight trickle of water through the overflow, and the taps should be set to pass this quantity and no more. If too much water is allowed to flow in, the water-line may become raised, with the result that the meter will register fast and simultaneously inflate the "make of gas" and the so-called leakage account. The water-line, therefore, should be kept invariable and correct; for upon the accuracy of registration of the meter depends the check upon the

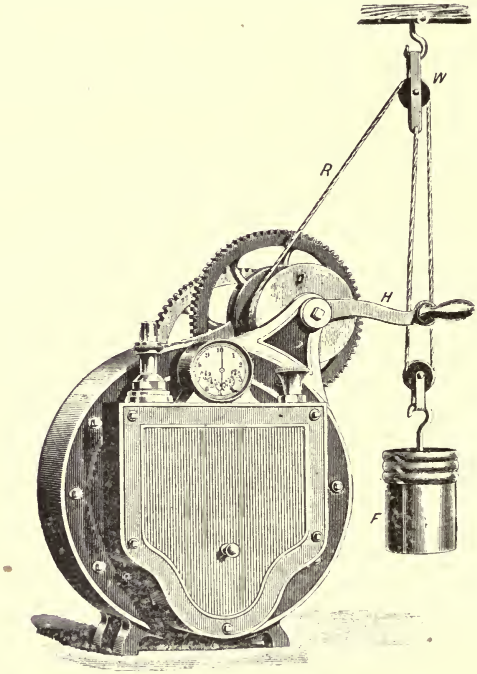


Fig. 243.—Motive Power Meter.

results of the retort-house work and also, to some extent, upon the unaccounted-for gas.

The motive power meter.—For use in those situations where from any cause the pressure on the supply falls too low, a meter is manufactured by the Gas Meter Company, through which, by means of a train of cog-wheels and the action of a weight similar to that of an old-fashioned clock, the pressure may be increased.

Figs. 243 and 244 show this additional apparatus, which originally was used in connection with a separate meter drum. The separate meter drum has now been eliminated, the one meter registering the gas and raising the pressure. The arrangement is a very simple one. As shown in Fig. 244 a small pinion, P, is fixed upon the drum shaft, which is connected through the train of wheelwork, A B, to the wire rope drum, D. From D a rope, R, is carried over the wheel, W, from which there is suspended the weight, F. The weight may be wound up as often as is necessary, by means of the handle, H.

The drum of the motive power meter works in an exactly similar

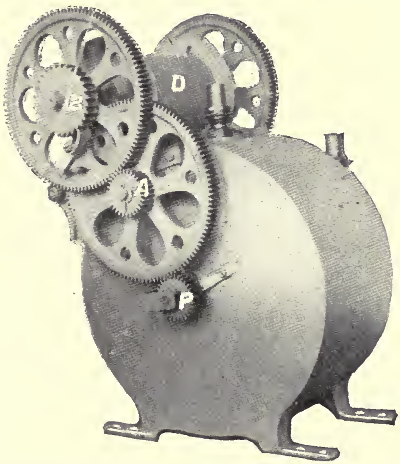


FIG. 244.—Motive Power Meter. Back View, showing Meter Spindle Attachment.

manner to that of an ordinary meter, except that in the case of the latter the motive power causing the drum to revolve is the gas pressure, whereas in the power meter the drum is caused to revolve by the weight acting through the wheel gearing, which draws the gas through the meter by suction. These meters are capable of increasing the pressure by from eight-tenths to one inch head of water.

CHAPTER XVI

DRY METERS

It seems rather strange, in view of the tremendous development in the manufacture and use of dry meters, to recall the intense prejudice which was felt against their use even up to comparatively recent years. They were considered to be delicate pieces of mechanism, which could not stand the wear and tear of the usual conditions of working. They were not to be depended upon for accurate registration. The flexible diaphragms could not prove durable when subjected to the continuous chemical action of the gas, and often products of condensation, which they must sustain. These and many other objections to the common use of the dry meter were most strenuously urged from time to time by many gas engineers.

Experience has, however, proved these fears to be groundless, and not only is every wet meter manufacturer also a maker of the dry meter, but the latter has for years been gradually displacing the wet meter in the estimation of the gas engineer. And the reasons for this are not difficult to find. They lie almost upon the surface. The dry meter is light and portable. It is self-contained, requiring no addition of anything outside itself to render it ready for work. There is no trouble of water-lining in connection with it, nor of the frequent spilling of portions of the waste water from the over-flow, leaving a disagreeable odour behind for some time. There is no trouble with freezing, nor so much trouble with condensation in consumer's faulty fittings. These, and other advantages of a similar practical character, together with the considerable amount of wear and tear which these meters have proved capable of withstanding in actual practice, have won for the dry meter a slow but none the less sure recognition, and placed it in the foremost position as a convenient and reliable measuring instrument in connection with the sale of gas.

Alder and Mackay's meter.—The dry meter as manufactured to-day consists of a rectangular chamber divided into three main compartments, as shown in Fig. 245, which is a cross section through a dry meter as manufactured by Messrs Alder and Mackay, of Edinburgh. First of all the horizontal partition, A, divides off the valve box and recording apparatus from the measuring chambers. The lower portion of the meter is again divided by the vertical partition, B, into two distinct compartments. To this vertical partition, B, and upon either side of it, is fixed a circular metallic band, called the diaphragm rim, to which one edge of the flexible diaphragm, C, is firmly attached. The remaining edge of the diaphragm is fixed to the metal disc, D, which, together with diaphragm and partition,

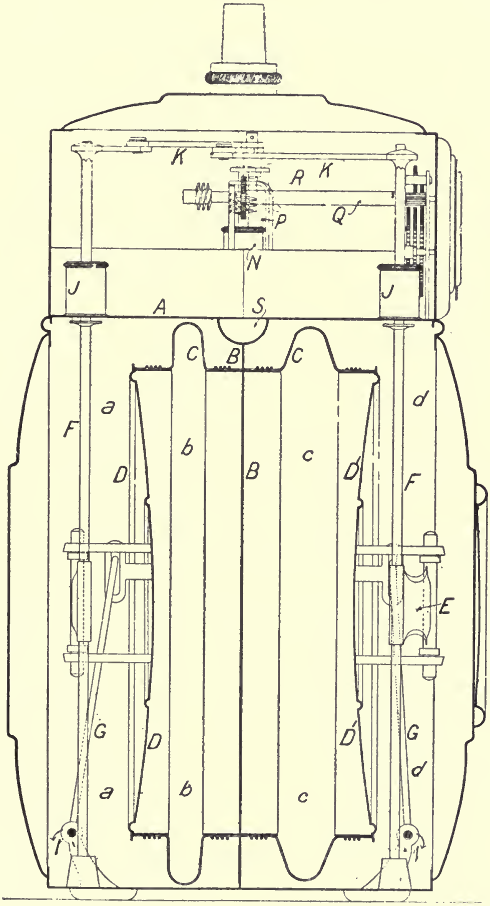


FIG. 245.—Section Through Alder and Mackay's Meter.

B, encloses one of the measuring chambers. The metal disc, D, is kept in position and working in a true vertical plane by the motion wires, G, supported from the motion wire step, I, and the flag attachment, E, to flag rod, F. The arrangement thus briefly sketched is duplicated upon the other side of the vertical partition, B. The result, therefore, is that each of the lower compartments is still further subdivided into two distinct chambers, making four in all, *i.e.* those enclosed by the disc, diaphragm, and partition, and the portions of the compartments exterior to these, the series being lettered in the illustrations, *a*, *b*, *c*, *d*.

The horizontal movement of the disc due to distension and collapse of the flexible chamber is conveyed to flag rod, F, by means of the flag piece, E, which converts the horizontal movement to a partly circular one, and turns the flag rod F, partially round upon its axis. The rod, F, passes up through the flag rod stuffing box, J, which is

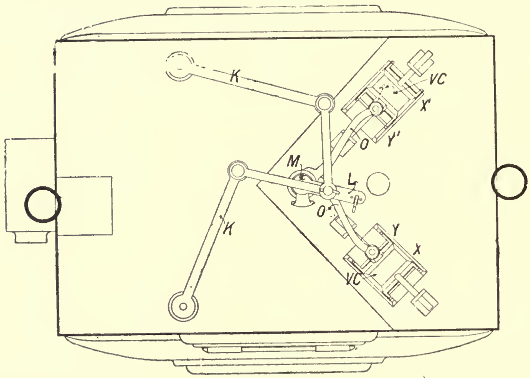


FIG. 246.—Alder and Mackay's Meter : Plan of Valves.

fixed upon the partition, A, to the upper compartment of the meter. The upper ends of these rods are connected by the top arms, K, by means of the tangent, L, to the crank shaft, M, which, working through stuffing box, N, by means of the valve arms, O, actuate the valve covers, V C, as shown in plan in Fig. 246. The turning motion of the flag rod, F, is, by means of the top arms, K, converted into a rotary one in the crank shaft, M. The upper end of the latter carries a worm, P, which is geared into a toothed wheel on the index shaft, Q, which communicates the rotary movement of the crank shaft, M, to the series of wheels forming the recording apparatus.

Thomas Glover and Co.'s dry meter.—Fig. 247 is a front elevation of one of Messrs Thomas Glover and Co.'s dry meters, with the front removed and partly in section, in which corresponding parts are lettered as in Fig. 245, showing clearly the flag and flag rod attachment, F and E, to the metal disc, D, and the method of guiding by means of the motion wires, G. The travel of the gas is also shown from inlet A^1, through tube, S, and the inlet port, V, to the valve chamber, W, where it is dealt with in the manner described below. The outlet passages, T, U, for the measured gas, are also shown leading to the common outlet of the meter, Z.

Fig. 248 is an under plan showing the arrangement of the valve plate, in which S is the inlet passage, V the inlet port to valve cham-

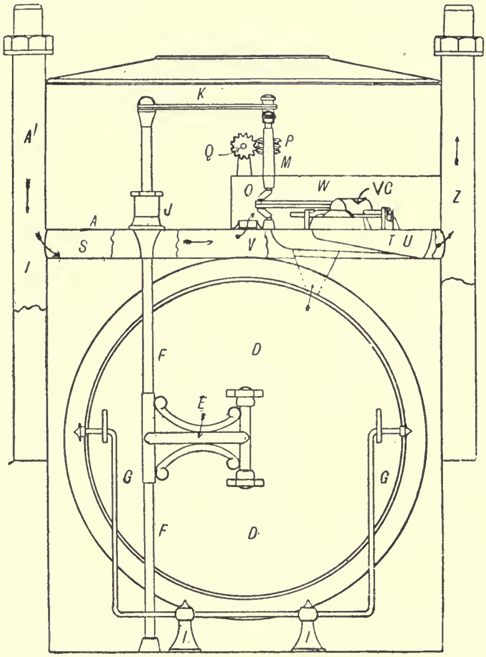


FIG. 247.—Front Elevation of Thos. Glover and Co.'s Dry Meter.

ber, X, X¹, Y, Y¹ are the inlet ports of the valve grid, and T, U, the outlet passages from valve chamber to the outlet, Z, of the meter.

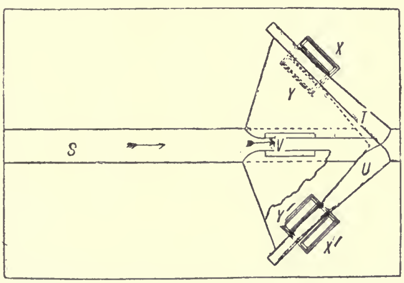


FIG. 248.—Under Plan Showing Arrangement of Valve Plate.

As will be seen from Fig. 248, the valve grids have each three distinct ports, of which the two outer are the channels by which gas enters in turn the collapsible and the outer chambers, the centre being the outlet port for the measured gas.

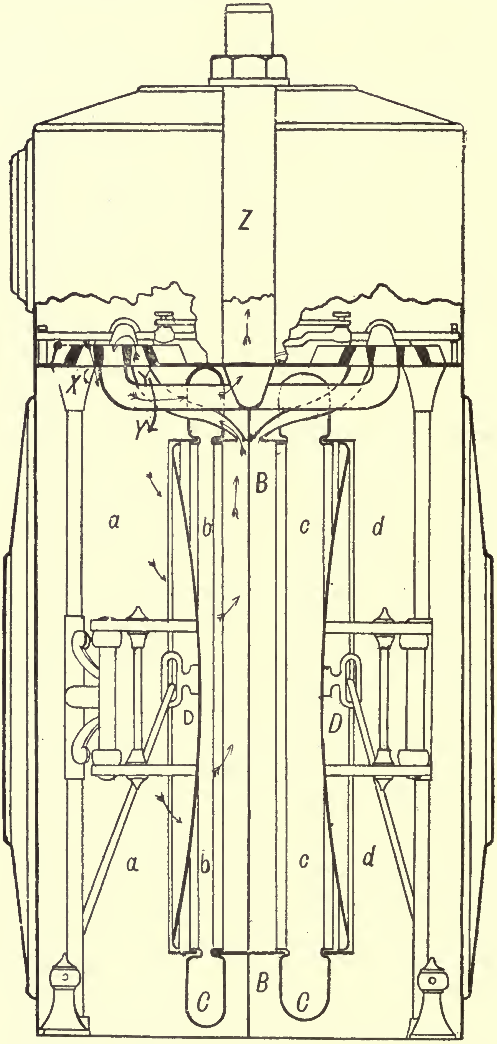


FIG. 249.—Thos. Glover and Co.'s Dry Meter : First Phase of Cycle.

The detailed working of the dry meter has been admirably described and illustrated in a booklet published by Messrs Thomas

Glover and Co., Limited, which should be in the hands of everyone having to do with dry meters, and to which the author is indebted for the excellent series of plates, reproduced here by permission of that firm, the lettering being altered to harmonize with the other illustrations.

"The gas passing down the inlet pipe, A^1, enters the channel, S,

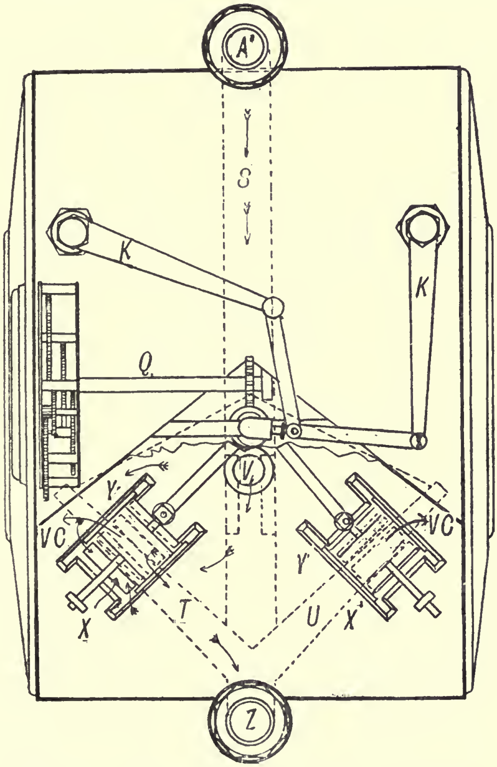


FIG. 250.—Thos. Glover and Co.'s Dry Meter : First Phase of Cycle.

passes through the orifice, V, into the chamber, W, the valves at this juncture being in the position shown in Figs. 249 and 250—that is to say, the port, X, of the valve is fully open to allow the gas to pass through in the direction indicated by the arrows, to fill the chamber, *a*, and by its pressure upon the disc, D, cause it to close in and expel the gas through the passage and port, Y, and under the valve, through the exhaust, into the channel, T, to the outlet, Z, and thence into the consumer's pipes.

The movement of the disc, D, acting through the flag rod, F, in the way previously described, causes the movement of crank shaft,

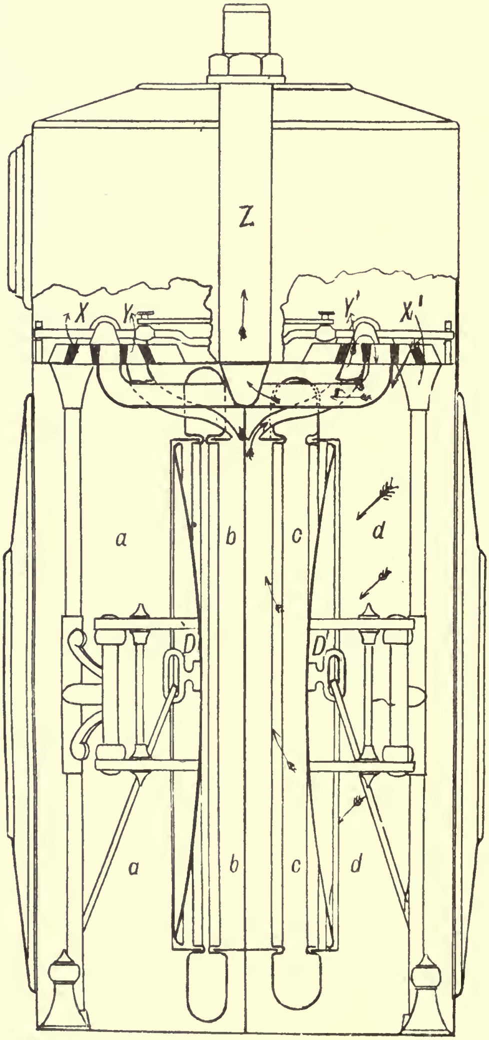


Fig. 251.—Thos. Glover and Co.'s Dry Meter : Second Phase of Cycle.

M, through one quarter turn and brings the valves into the position shown in Figs, 251 and 252, in which the corresponding valve port, X[1], is now fully open to admit gas to the chamber, *d*, which, pressing on the disc, D[1], expels the gas in *c* through the port, Y[1], under the valve, through the exhaust, into the channel, U, to the outlet, Z, as before described with reference to the chamber, *a*.

"The disc, D[1], in its movement inwards has communicated motion to the crank shaft in the same manner as in the previous phase, and

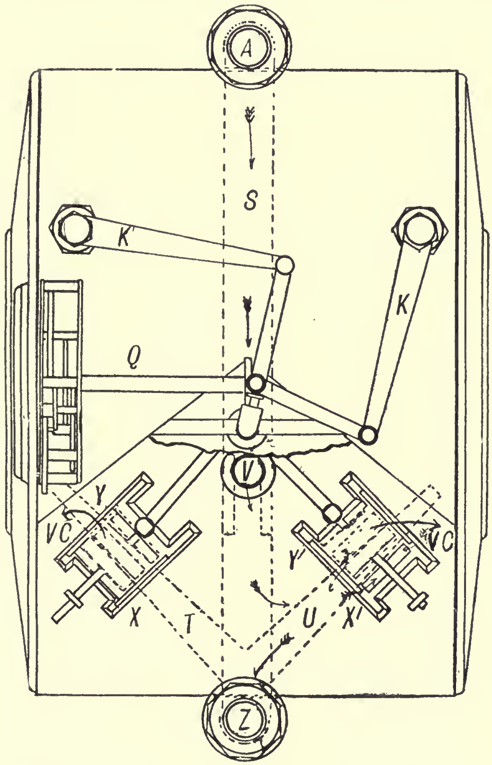


FIG. 252.—Thos. Glover and Co.'s Dry Meter: Second Phase of Cycle.

has gradually moved the valves to the position shown in Figs. 253 and 254, in which it will be noticed that the port, Y, is fully opened for the gas to enter by the corresponding channel and fill the bellows to the utmost extent of its movement, and expel the gas previously fed into the chamber, *a*, back through the port, X, under the valve, through the exhaust port, to the channel, T, and thence by pipe, Z, to outlet, by which time a further movement has been communicated to the crank shaft, M, in the manner now well known, bringing the valves into the position shown in Figs. 255 and 256, for the gas to enter the port, Y^1, and expand the bellows of chamber, *c*, forcing

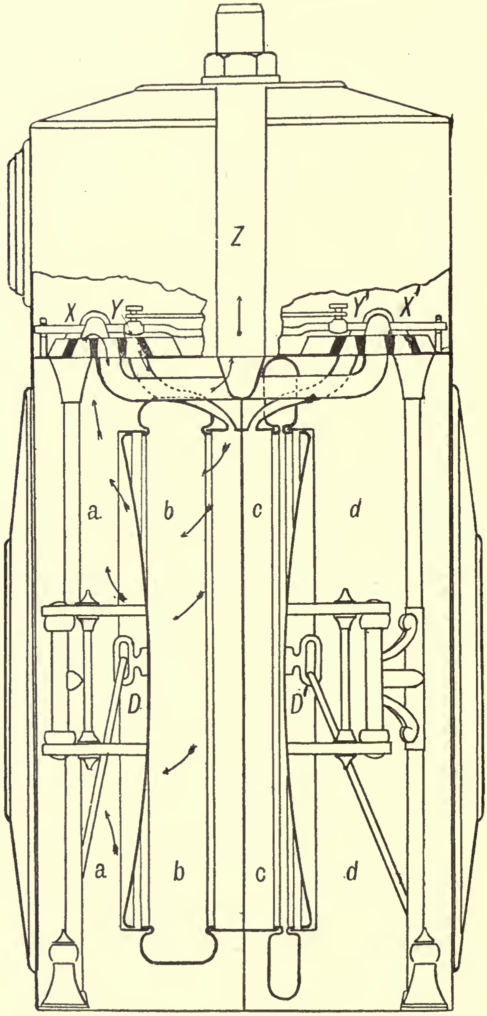


FIG. 253.—Thos. Glover and Co.'s Dry Meter : Third Phase of Cycle.

out the gas in chamber, *d*, through the port, X^1, under the valve, by way of exhaust channel, U, to the outlet, Z, under the valve, by way of exhaust channel, U, to the outlet, Z, and, by means of the flag rod, brings the valves into position" for the operation shown in process in Figs. 249 and 250, thus completing the cycle.

It is perfectly clear that if the cubical capacity of each diaphragm chamber or the area of the metallic disc, D, is known, together with the number of times the chambers have been inflated in a given period, and the distance through which the disc has travelled, the quantity

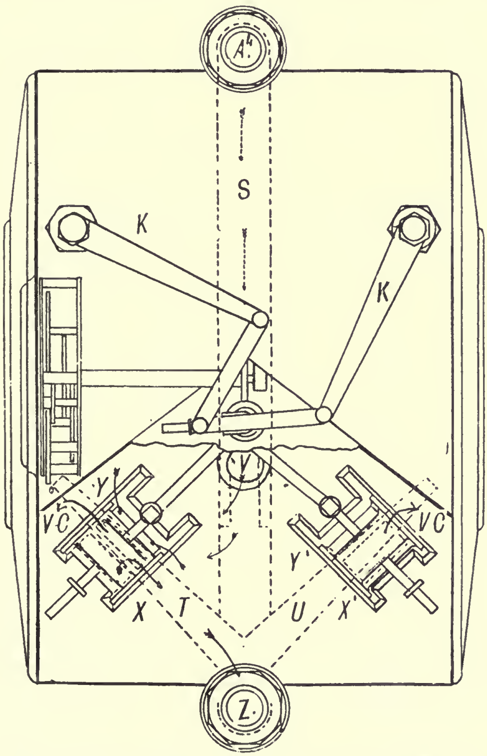


FIG. 254.—Thos. Glover and Co.'s Dry Meter : Third Phase of Cycle.

of gas passed in that time may easily be ascertained. If, for example, the area of each disc be exactly one superficial foot, and each disc has a travel of 3 inches maximum, it is evident that the quantity of gas received, measured, and expelled through one complete cycle of the operation would exactly equal one cubic foot.

The wheelwork communicating the rotary motion of the crank, M, to the index is so adjusted that whatever the area and travel of the metal disc, the dials record the exact quantity of gas which has been passed through the meter. Any risk of the meter being connected up the reverse way, inlet for outlet and *vice versâ,* either by accident or fraud, is effectually prevented by the kill post, R (Fig. 245, p.

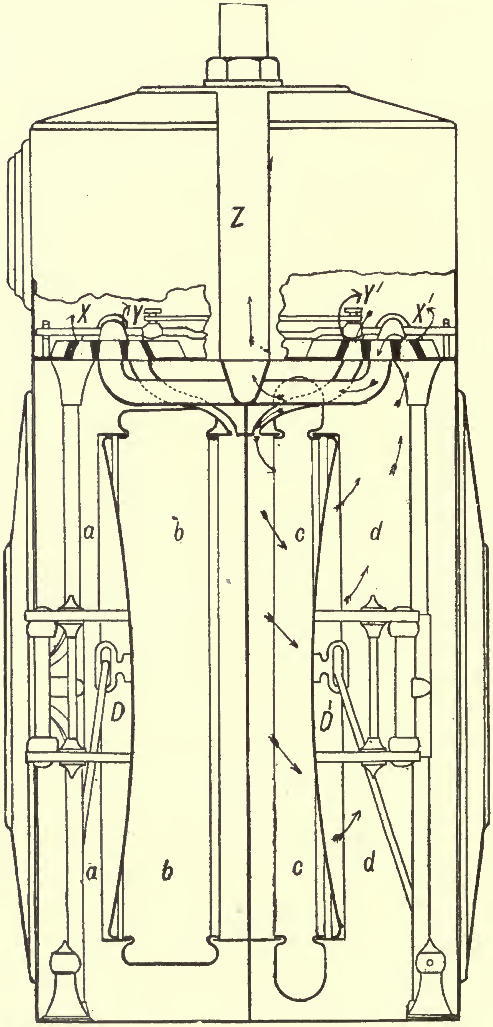


FIG. 255.—Thos. Glover and Co.'s Dry Meter : Fourth Phase of Cycle.

281), which prevents the tangent moving in the wrong direction and so stops the working of the meter.

Importance of good workmanship and materials.—It is obvious from the description given that the accuracy of the dry meter as a measuring instrument depends to a very large extent upon the quality and condition of the flexible diaphragm and upon the fit and correct working of the valves. The valve is one of those parts of a meter in which excellence of workmanship is most important. The

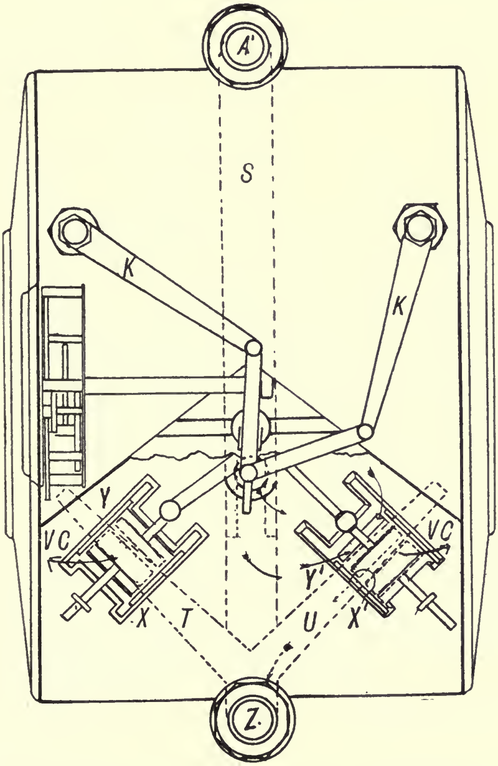


Fig. 256.—Thos. Glover and Co.'s Dry Meter: Fourth Phase of Cycle.

slightest deviation of the valve cover or seat from its perfectly true alignment may cause the valve to tilt or leak slightly, and allow gas to pass unregistered. Again, any irregularity in the action of the valve throws an unnecessary strain upon the connecting shaft, and in time wears the various bearing surfaces into an irregular shape, and thus causes an interference with proper opening and closing of the ports. In this way one fault breeds another, and causes grave disturbance of the correct action of the meter. The grease cup now adopted by most manufacturers is especially valuable in neutralizing any action of this kind.

And just as the best of workmanship only should be employed in the manufacture of meters, so it is essential that the very best of materials should be used exclusively. The life of a meter depends largely upon the material of which the case is made. This should be of the best charcoal annealed tinned-iron plates which can be obtained. Experience has proved that these plates resist the corrosive action of moisture to a greater extent than others, and conse-

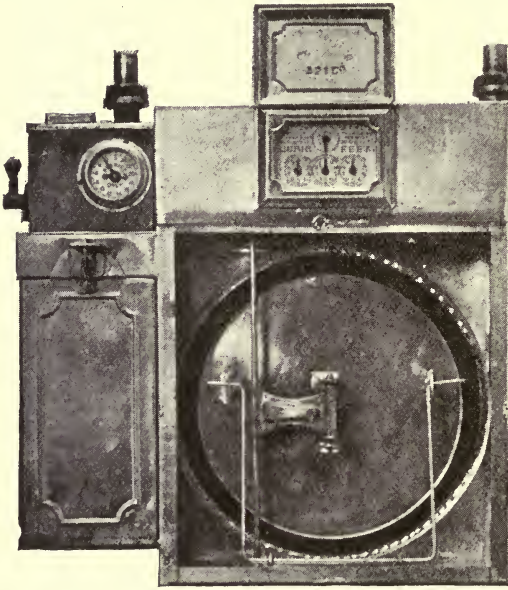


Fig. 257.—Messrs J. and J. Braddock's Diaphragm Attachment.

quently prolong the life of the meter to a corresponding extent. A misplaced economy here must react disastrously in a swollen repair and maintenance account.

The diaphragms are made of the best quality of Persian sheepskins, specially dressed for the purpose. After treatment with almond oil they should be laid aside for a considerable time to ensure thorough curing. So far there is a general consensus of opinion. There is, however, a considerable divergence of practice as to the best way in which to use the skins and the method of attachment to the disc and rim. Messrs J. and J. Braddock, of Oldham, whose meters deservedly rank high in the estimation of gas engineers, claim that if the diaphragm is in one piece it must necessarily be sounder, and will last longer and bear the strain of its work better than a stitched diaphragm, however carefully the seam is made. In all meters up to the 100-light size they therefore face the waste and additional cost involved in cutting the diaphragms whole out of the skins. Fig. 257 shows copy of photograph of Braddock's diaphragm and disc, as seen on the removal of the front plate of the meter. Other makers of equal eminence make their meter diaphragms of strips of the skins carefully stitched through the seam and stretched over moulded wood blocks or tin moulds to take the convex shape, as shown in Fig. 258.

Methods of attaching diaphragm.—There is also considerable difference in the methods adopted for attaching the diaphragm to the rim and disc. In the Braddock meter the diaphragm is securely attached by means of a circular tin clip, bent over and pressed home

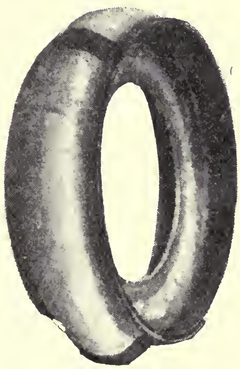


FIG. 258.—Persian Skin Stitched Diaphragm stretched on Tin Mould.

by suitable machinery. It is claimed that this method of fastening is an improvement on tying, and makes leakage at the joint practically impossible. Other manufacturers prefer to tie the skins on with a specially prepared cord, between which and the skin a tape cushion is inserted to prevent injury to the skin, the whole being then secured and protected by a coating of specially prepared glue, to prevent any chemical action of the gas upon the cord. In other cases tinned steel or iron wire is used for binding the diaphragm to rim and disc. In this case the leather is protected from injury from the binding wire by means of a band of flax webbing, strip of leather, or other packing material inserted between the diaphragm and the wire. Another manufacturer of world-wide reputation uses a flat metallic band, with adjusting screw, for binding. By each of these methods a good sound attachment can undoubtedly be made, but there is some difference of opinion as to which mode of attachment tends to give the longest life to the diaphragm.

DIMENSIONS OF THE VARIOUS SIZES OF DRY METERS FROM 2 LIGHTS TO 120 LIGHTS AS MADE BY MESSRS GEO. GLOVER & CO., LIMITED.

Sizes.	Capacity per Hour.	Outside Dimensions.			Diameter of Inlet and Outlet.	Distance from Centre to Centre of Inlet and Outlet.
		Height, including Unions.	Breadth.	Depth (Back to Front).		
Lights.	Cub. Ft.	Inches.	Inches.	Inches.	Inches.	Inches.
2	12	$13\frac{7}{8}$	$9\frac{7}{8}$	$7\frac{1}{2}$	$\frac{1}{2}$	$8\frac{3}{4}$
3	18	$15\frac{1}{2}$	$11\frac{1}{8}$	$8\frac{1}{2}$	$\frac{5}{8}$	$9\frac{3}{4}$
5	30	$16\frac{7}{8}$	$12\frac{5}{8}$	9	$\frac{3}{4}$	$11\frac{1}{4}$
10	60	$19\frac{1}{8}$	$14\frac{5}{8}$	$10\frac{1}{2}$	1	$12\frac{7}{8}$
15	90	$20\frac{1}{2}$	17	13	$1\frac{1}{4}$	$14\frac{3}{4}$
20	120	$23\frac{1}{4}$	19	$13\frac{1}{2}$	$1\frac{1}{4}$	$16\frac{1}{2}$
30	180	26	$21\frac{1}{4}$	$15\frac{1}{2}$	$1\frac{3}{8}$	19
40	240	29	$23\frac{3}{4}$	18	$1\frac{1}{2}$	$20\frac{3}{4}$
50	300	$31\frac{1}{4}$	25	19	$1\frac{1}{2}$	$22\frac{1}{2}$
60	360	35	$27\frac{1}{2}$	$20\frac{3}{4}$	$1\frac{3}{4}$	$24\frac{1}{2}$
80	480	$38\frac{1}{4}$	31	$22\frac{1}{2}$	2	$27\frac{3}{4}$
100	600	41	$32\frac{1}{4}$	$23\frac{1}{2}$	2	$28\frac{1}{2}$
120	720	$42\frac{1}{2}$	$33\frac{1}{2}$	$23\frac{3}{4}$	2	$29\frac{3}{4}$

DIMENSIONS OF THE VARIOUS SIZES OF DRY METERS FROM 150 LIGHTS TO 1000 LIGHTS AS MADE BY MESSRS GEO. GLOVER & CO., LIMITED.

Sizes.	Capacity per Hour.	Outside Dimensions.			Diameter of Inlet and Outlet.	Flanges at Side. Distance from Centre of Inlet to Ground.
		Height.	Breadth.	Depth (Back to Front).		
Lights.	Cub. Ft.	Inches.	Inches.	Inches.	Inches.	Inches.
150[1]	900	50	37	$29\frac{1}{2}$	3	33
200	1200	$55\frac{1}{2}$	$42\frac{1}{2}$	$32\frac{1}{2}$	$3\frac{1}{2}$	$38\frac{1}{2}$
250	1500	56	45	33	$3\frac{1}{2}$	39
300	1800	62	48	37	4	44
400	2400	70	52	40	4	49
500	3000	73	58	46	5	$50\frac{1}{2}$
600	3600	74	61	47	5	53
800	4800	83	63	49	6	57
1000	6000	86	66	51	8	$58\frac{1}{2}$

[1] This size is also supplied with union at the side. The breadth is then 40 inches.

Iron-cased dry meter.—With a view to prolonging the life of a dry meter, where it is exposed to special danger of corrosion from moisture or other causes, the meter is also made with cast-iron cases in lieu of the usual tin case. Whilst the additional weight thus added to the meter is a decided inconvenience, it is amply compensated for in the reduction of maintenance charges, owing to the greater resistance to dampness, and in the greater facility with which cleaning and repairs may be carried out.

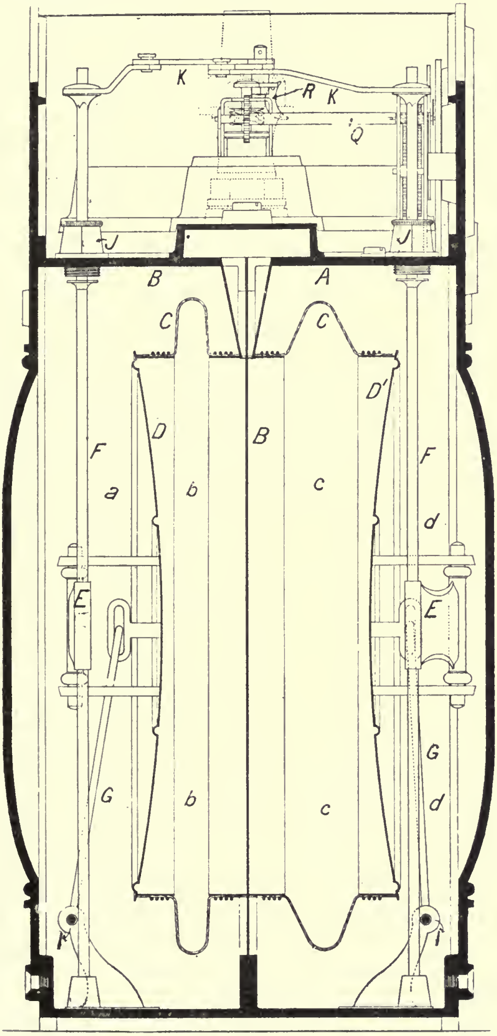


Fig. 259.—Alder and Mackay's Iron-Cased Dry Meter: Sectional Elevation.

Figs. 259 to 261 show elevation and plan of the working parts of an iron-cased dry meter as manufactured by Messrs Alder and

Mackay, of Edinburgh, the original makers of this class of meter. Fig. 259 shows a sectional elevation taken on a line running through the measuring chambers and attic from front to back.

Fig. 260 shows plan of attic with the top cover removed, and

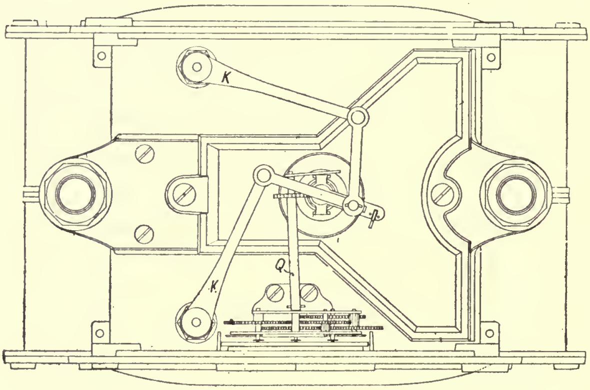


Fig. 260.—Alder and Mackay's Iron-Cased Dry Meter: Plan of Attic Arrangements.

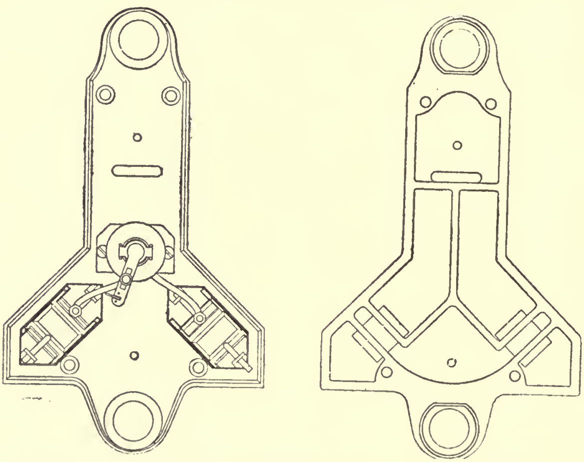


Fig. 261.—Details of Gas-Way from Above and Below.

Fig. 261 shows details of the gas-way from above and from below. The various parts are lettered to correspond with Figs. 245, *et seq.*, and the working of the meter will be readily understood from the description relating to the tin-cased dry meter.

In the dry meter illustrated in Figs. 259 to 261 one advantage claimed is that the number of separate parts is reduced to a minimum. Six light and simple castings take the place of twenty-two distinct parts in the tin-cased dry meter. The unique gas plate shown in Fig. 261 combines in a single casting the functions of as many as ten separate parts of a tin-cased dry meter.

Not only are the parts few in number but they are simple in character, easily taken apart and put together again, and are interchangeable. The bearing of this upon labour charges is obvious.

Thorp's rotary meter.—The "Rotary" inferential meter invented by Mr Thos. Thorp, and described by Mr T. G. Marsh at the Southampton meeting of the Gas Institute in 1902, is an application of the familiar principle of the anemometer to the registration of gas.

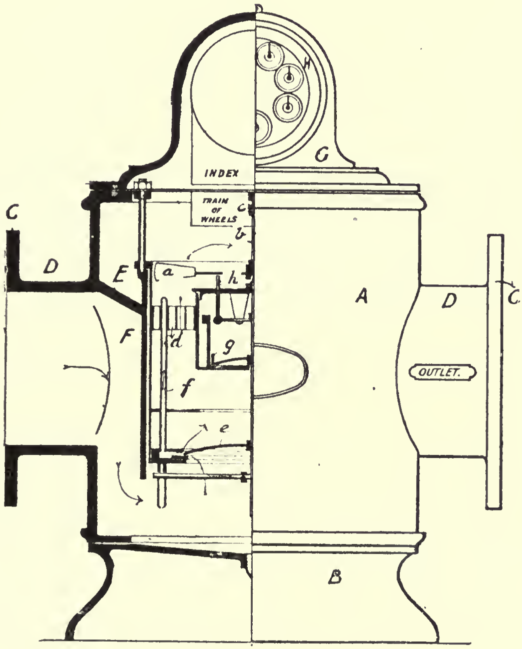


FIG. 262—Thorp's Rotary Station Meter.

A. Cast-iron case.
B. Base.
C.C. Flanges.
D.D. Connections.
E. Partition.
F. Vertical tube.
G. Cast-iron hood.
H. Bezel.
a. Fan wheel.
b. Centre shaft.
c. Pinion.
d. Vertical guides.
e. Valve.
f. Auxiliary tubes.
g. Dash pot.
h. Brake.

The apparatus consists essentially of a series of vanes, set at an angle of about 45°, fixed upon a fan wheel. This is carried by a vertical shaft, jewelled at the top and bottom to reduce friction, secure freedom of action, and prevent wear and tear. The stream of gas passing through the instrument is broken up by a series of vertical guides and auxiliary tubes so as to be distributed equally over the vanes, and thus render them sensitive to the passage of small quantities of gas. The revolutions of the fan are communicated by the centre shaft, through the medium of a worm wheel, to the train of wheels which form the recording apparatus.

Fig. 262 shows the arrangement in partial sectional elevation. A is the cast-iron outer case of the meter, which is supported by the base box, B, and surmounted by the hood, G, which contains the index. C and D are the flanged connections to the meter, and E the partition dividing the inlet chamber from the outlet. In the lower part of the measuring apparatus is fixed a diaphragm valve, *e*, which is intended to prevent any backward flow taking place; and, when small quantities of gas are flowing through the meter, it acts as a "spreader," directing part of the current through the auxiliary tubes, *f*, to the vanes and rendering them exceedingly sensitive to the main body of gas. In the small centre tube is fixed a dash pot, *g*, which is inserted to prevent any possible dancing of the valves.

It is obvious that with such an arrangement, necessarily almost frictionless in its working, the momentum acquired by the fan wheel tends to continue the latter in motion after the gas is shut off, and consequently impair the correctness of the registration. To provide against this, the brake, *h*, has been inserted, which is brought into play as soon as the meter ceases to pass gas, and by acting upon the fan wheel brings the wheel to rest—a provision which is especially necessary where a meter is being constantly stopped and started.

This meter may be used not only as a station meter but also for measuring crude gas; testing results obtained on the works; sectionalizing the retort houses; in connection with water-gas plant; and other such purposes, for which it is admirably adapted. Various detailed alterations are, of course, necessary when the meter is used for unpurified gas, or for gas that is highly saturated with oil (not of a fixed nature). There are certain other modifications of detail necessary in the case of meters used where the fluctuations of pressure are considerable at different times. Unlike the ordinary type of meter, the interior of the rotary meter may be readily removed for inspection and cleaning; and as all parts are interchangeable, a duplicate interior may be kept, for alternate use, where cleaning is likely to be frequently necessary.

In addition to the uses suggested above, these meters may be used in distribution as subsidiary meters for large establishments in connection with differential prices for gas used for power purposes.

A further important point in connection with this meter is its adaptability for high-pressure distribution, as it is equally accurate at any pressure up to 50 lbs. per square inch. When used for high pressures, corrections for variations of volume due to compression are made by means of a simple differential mechanism as the gas passes through the meter, the index showing the quantity corrected to atmospheric pressure.

The space occupied by the rotary meter is only about one-tenth

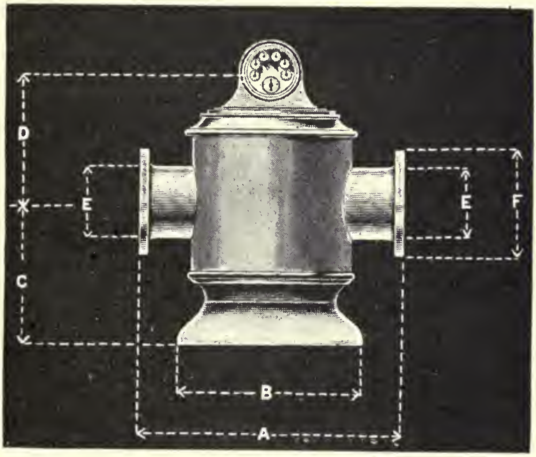


Fig. 263.—Thorp's Rotary Station Meter.

Capacity in Cubic Feet per Hour.	Dimensions in Inches.					
	A	B	C	D	E	F
2,000	$13\frac{1}{4}$	9	$4\frac{3}{4}$	$7\frac{1}{4}$	3	$5\frac{1}{2}$
3,500	22	21	$12\frac{1}{2}$	15	6	$11\frac{1}{2}$
5,000	24	21	$12\frac{1}{2}$	15	6	$11\frac{1}{2}$
7,500	28	21	16	$16\frac{1}{2}$	6 8	$11\frac{1}{2}$ $14\frac{1}{2}$
10,000	32	24	18	18	10	$17\frac{1}{4}$
15,000	$36\frac{1}{2}$	28	$20\frac{1}{2}$	21	10 12	$17\frac{1}{4}$ $19\frac{1}{4}$
30,000	49	37	25	25	15	$22\frac{1}{2}$
60,000	72	54	36	35	24	32
100,000	96	72	36	48	30	38

of that occupied by an ordinary meter of the same capacity, as will be seen from the table of dimensions.

The discount meter.—A small meter of the rotary type intended for use as a discount meter, for gas consumed for heating or other purposes for which special discounts are given, is shown in Fig. 264.

The operation of the meter will be readily followed from the description given of the station meter, the two being similar in character. The gas flowing in the direction of the arrows passes under valve, V, through gauze, L, to guides, K, which cause the current to impinge directly on fan, F. At the same time another and smaller stream of gas flowing through the auxiliary tube, N, is also directed upon F. The rotary movement of the fan wheel is communicated by centre shaft, H, working through sleeve, I, to the index wheels.

Probably the question that will arise in many minds on con-

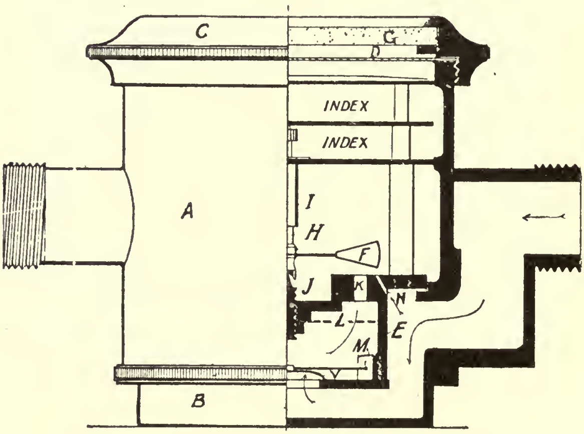


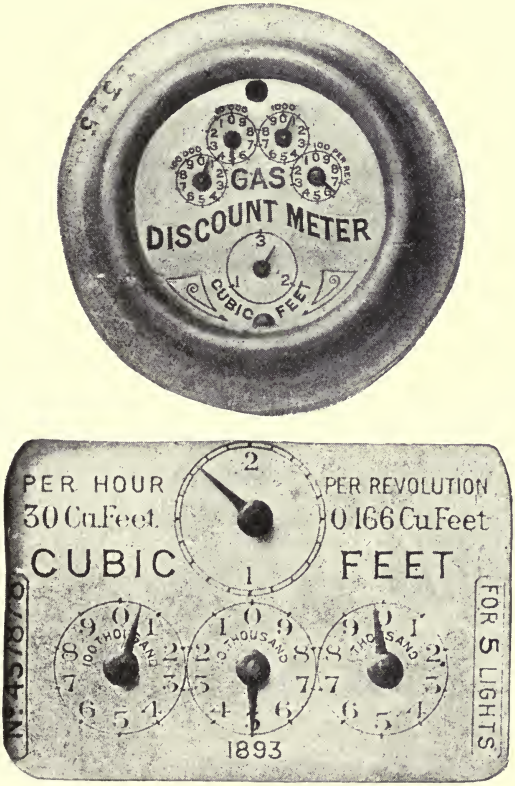
FIG. 264.—Thorp's Discount Rotary Meter.

A. Body.
B. Base.
C. Cap.
D. Disc of celluloid.
E. Inner casing.
F. Fan wheel.
G. Glass disc
H. Centre shaft.
I. Tube round H.
J. Bottom bearing.
K. Vertical guides.
L. Gauze.
M. Hinge.
N. Auxiliary pipe.
V. Valve.

sideration of a meter constructed on such novel lines for the measurement of gas will be as to the accuracy of its registration. It is not claimed that the meter is correct when passing small quantities, say less than 4 to 5 per cent. of its full capacity. The meter is, therefore, unsuited for general purposes, and until this drawback has been remedied could not be accepted by the Board of Trade and stamped for use under the provisions of the Sale of Gas Act. But as no one would think of giving special discounts for such small quantities, the fact of its inaccuracy under these conditions is of little moment.

As a matter of fact, however, the meter proves remarkably accurate in actual practice. For the purpose of testing the matter, the author had a couple of these meters connected up to his house and stove meters, respectively, each pair working together under identical conditions. The ordinary dry meters were tested before the experi-

Discount Meter.



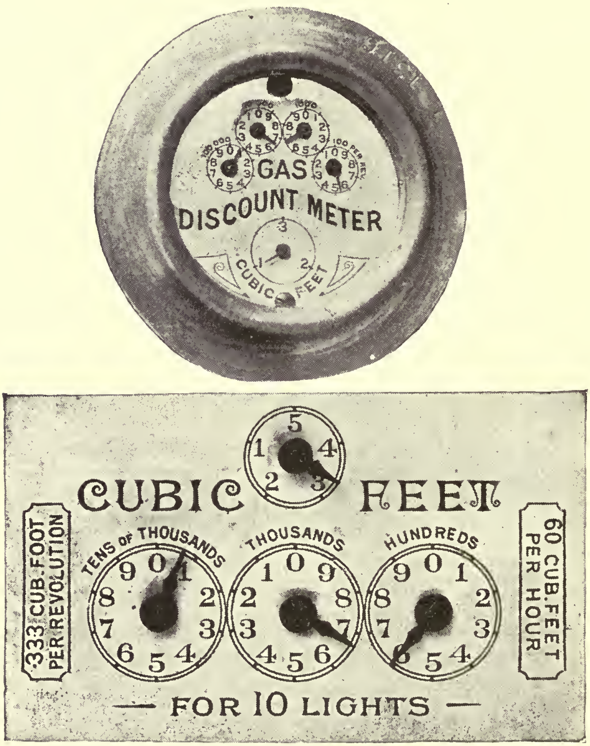
Stove Meter.

Fig. 265.—Comparison of Registration of Discount Meter against Stove Meter. The latter tested 1 per cent. slow previous to experiment.

ment and proved 1 per cent. slow. The stove meters started together exactly at zero, but the house meter index was 001 while the corresponding discount meter commenced at zero. The results of 103 days' working are shown in Figs. 265 and 266. These tests were taken under the very worst conditions for the rotary meter, the time being the middle of summer, when, of course, the percentage consumption of small quantities to the whole would be much higher than in the winter.

Besides its use as a discount meter, the small amount of space occupied makes this a very suitable meter for use in connection with gas fires in hotels, cookers and geysers in public establishments, and

Discount Meter.



House Meter.

FIG. 266.—Comparison of Registration of Discount Meter against House Meter. The latter tested 1 per cent. slow previous to experiment.

for many other similar purposes where a subsidiary meter is generally necessary.

The taxi-meter.—The taxi-meter is a very interesting development of the discount meter. In this an index showing the value of the gas consumed in shillings and threepences is provided.

The taxi-meter is intended primarily for use in lodging or boarding houses in connection with gas fires. The landlady is provided with a key which moves the hand back to zero, and upon letting the room the lodger may avail himself of the use of the gas fire. Landlady and lodger read off at the end of the week the amount of gas used, the value of which is incorporated in the weekly bill, and so a great deal of bickering and discussion as to the use of the fire is eliminated. It may be added that the landlady's key can turn the pointer to zero but not forward.

The meter may also be used as a check upon wastefulness in cooking

FIG. 267.—Thorp's Gas Taxi-meter.

stoves, any extravagance being immediately detected by the mistress of the house.

The taxi-meter is strictly a subsidiary meter, but a dial is attached to each by which the gas officials may, when desirable, ascertain the total quantity of gas passed by the meter and therefore also the amount which has actually been received from lodgers. The use of this provision in cases of disputed accounts is obvious.

CHAPTER XVII

PREPAYMENT METERS

PERHAPS the most remarkable development which the last quarter of a century has witnessed in connection with the gas industry has been the inception and extraordinary growth of the system of selling gas in small quantities on the prepayment system. During that period gas undertakings have had to meet two very different kinds of competition, at the opposite extremes in the social scale. On the one hand, with the upper classes, to whom economy has been quite a secondary consideration, the pressure of competition from the electric light has been very severe. At the other end of the scale the competition of cheap lighting oils has had to be fought.

One great advantage which cheap oil had over gas until recent years arose from the fact that it could be bought in small quantities, from time to time, as it was required. There are doubtless hundreds of thousands of householders up and down the country who, either from necessity or choice, show a marked disinclination to incur the responsibility of quarterly or half-yearly accounts. This number includes very many of the most industrious and respectable of the artizan class, whose honesty and rectitude are probably the reason for avoiding debts which might be difficult to discharge when accounts become due. By all such, cheap oil, bought in small quantities for cash, was naturally turned to as the illuminant to be adopted.

It is this great field which is being gradually covered and claimed for gas by means of the prepayment meter. In this way gas may be bought by the pennyworth or in greater quantities, for which the price is prepaid, to the great convenience of the class above referred to, who are thus enabled to light their houses at a moment's notice, without any of the smell or preliminary trimming and attention inseparable from oil lighting by even the best kind of lamp.

The advantages arising from the prepayment system have not been all upon one side. Gas undertakings are reaping a great benefit from the system, which has now become general throughout the country. By including this business within their sphere of operations, the sales of gas have been enormously increased, and that in such a way as to entirely avoid the trouble of bad debts. The increased price charged for the gas has been sufficient in most cases to cover interest and sinking fund charges on the additional capital outlay, and probably those who have most vigorously pushed this class of business have reaped the greatest benefit.

Prepayment meters may be divided into two general classes. There are, first of all, those of which Valon's prepayment meter is a type, and which are used for residential flats, offices, lock-up shops, and other similar places, and intended to dispense with the odious, but previously necessary, system of requiring deposits. Where these meters are in use a periodical inspection, say weekly, fortnightly, or monthly, is instituted ; and the prepayment is made personally to the inspector, who sets the meter to pass the quantity

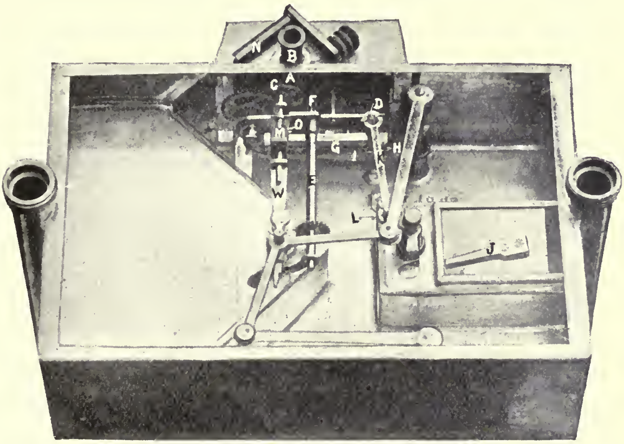


Fig. 268.—Valon's Patent Stop Meter : Prepayment Mechanism

of gas corresponding to the amount of the prepayment. When this quantity has been passed, the meter ceases to work until another payment has been made and the meter freshly adjusted by the inspector.

Of this first class of prepayment meters, or " stops " as they are colloquially termed, that of Mr Valon and the " Metropolitan " convertible stop meter may be taken as examples for detailed description.

Valon's stop meter.—In connection with his Ramsgate scheme for introducing and fostering the use of gas for dwelling-houses and other premises not previously supplied, by undertaking the provision of the necessary fittings and accessories at an inclusive charge for gas, the late Mr W. A. Valon found it desirable, for obvious reasons, to provide a ready means of prepayment for the supply afforded. The stop meter designed and patented by Mr Valon for this purpose is shown in Fig. 268.

The arrangement consists of additional mechanism attached to and geared into the index wheels of an ordinary meter, whereby a valve, J, controlling the gas inlet passage, is operated. When a quantity of gas has been prepaid the valve is opened, and as the supply so prepaid becomes exhausted the valve automatically closes, and remains closed until a further amount has been paid for and the meter adjusted by the inspector accordingly.

The prepayment part of the apparatus consists of a vertical shaft, A, the upper end of which is enclosed in the socket, B, and which is capable of being rotated by a suitable key, N. Upon the lower part

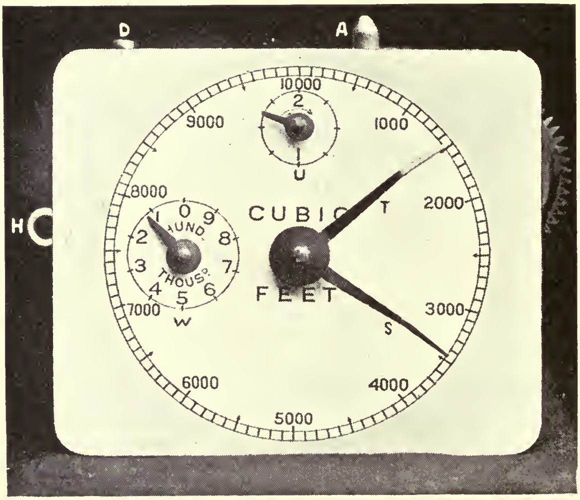


Fig. 269.—Valon's Patent Stop Meter Dial.

of the shaft a coarse thread is cut, which gears into a toothed wheel carried upon the main spindle. The bottom end of the shaft, A, is extended through a bracket and plate and carries a toothed wheel with which a clutch engages, and prevents the shaft being turned in the wrong direction.

Upon the back of this toothed wheel a boss is cast, into which a bevel-shaped notch and catch are cut, which at a certain point, determined by the amount of the prepayment, engages with a pin carried by the main spindle. The latter is capable of lateral as well as of rotary movement. The connecting piece, G, technically called the "Gate," acts as a lever, working upon the pin, H, as a fulcrum, the lower arm of the former being kept pressed against the end of the main spindle, by which it is operated by means of the strong spring, I. The upper arm of G is connected to the inlet valve, J, by means of the socket and eye at D and the connecting rod, K, and the crank, L. The guide rod, M, working through the slot in the second arm, O, of the upper end of lever, G, and support, W, serves to keep the lever in a true alignment and, with the tangent stop, serves to stop the meter in case the inlet valve becomes leaky.

The index dial is of a special kind, and consists of one large dial, capable of registering up to 10,000 cubic feet, and divided into hundreds. This dial has two pointers, one bright and the other dark. The bright one, S, is manipulated by the inspector and shows the amount of gas prepaid. The dark one, T, registers the gas as it is passed through the meter. Contained within the main dial are two smaller and subsidiary ones, U and W. The upper one, U, is for recording the passage of single feet of gas, and the other, W, takes up the registration from the point reached by a full revolution of the dark pointer, T, over the main dial, and carries it on to a record of 100,000 cubic feet. The index, as shown in the illustration, records that the quantity of gas prepaid is 3500 cubic feet, and of this amount 1500 cubic feet has already been consumed.

Upon the front of the toothed wheel a boss projects through the front plate of the index dial and carries the bright pointer, S. As, therefore, the wheel, F, is caused to revolve, the pointer travels over the dial and indicates the amount of gas prepaid.

The action of the apparatus is comparatively simple. When a supply of gas is to be prepaid, the shaft, A, is rotated by the inspector, by means of the key, N, to an extent corresponding to the sum paid. The amount of the rotation determines the position of the stop in the boss of the toothed wheel. As the wheel is rotated the bevelled side of the notch rides over the pin carried by the main spindle, and in doing so forces the latter backward, and with it the lower part of the lever, G. This action, converted by the lever, G, working upon the pin, H, into a forward movement in the upper arm, operates the valve, through the medium of the connecting rod, K, and crank, L, and opens it.

The measuring-off part of the apparatus consists of a suitable train of wheelwork, actuated by the index shaft, E, which revolves the main spindle by means of wheels, F and C, and with it the engaging pin. The latter passes round the edge of the boss upon the wheel, until the quantity of gas prepaid becomes exhausted, when the pin drops into the notch cut in the boss. The lower arm of G, being pressed against the end of the main spindle by the spring, I, follows it in its lateral movement. This gives a backward thrust to the connecting rod, K, which, acting through crank, L, closes the valve until the meter is adjusted to pass a fresh supply. Upon the front end of the spindle, which projects through the face of the dial plate, is fixed the second or black indicator, T. As the prepaid gas is consumed and the spindle is revolved, the black indicator is caused to pass over the dial, and it gradually approaches the prepaid indicator. When the position of the two pointers coincides, the quantity of gas prepaid has been consumed and the valve is closed. The registering indicator, T, therefore, gives ample warning of approaching exhaustion of supply ; and as the inspection may be made either weekly or monthly as may be found necessary, the danger of complete exhaustion and failure of supply before a fresh quantity can be paid for is reduced to a minimum.

The "Metropolitan" convertible stop meter.—In the "Metropolitan" meter the operating portion of the stop arrangement,

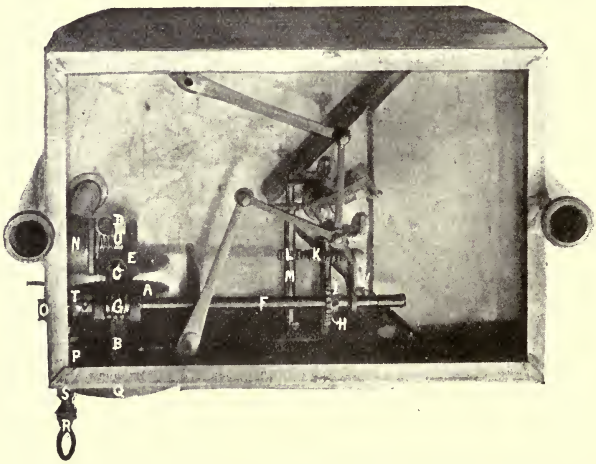


FIG. 270.—"Metropolitan" Convertible Stop Meter: Prepayment Mechanism.

shown in Fig. 270, consists of a toothed wheel, A, capable of revolving freely around its spindle, B, which is supported by pillar, C, fastened to the floor of the attic of the meter.

Upon the rear side of the wheel, A, and upon opposite sides of it, are fixed two studs. The spindle, B, also carries the bracket, E, which is capable of revolving freely around the spindle. The pillar, C, is extended sufficiently above the axis of wheel, A, to support the shaft, F, upon which is keyed the worm, G.

At the end farthest away from A, the shaft, F, carries the toothed wheel, H, which, through the worm, I, and toothed wheel, K, is geared into wheel, L, upon the meter index shaft, M.

The auxiliary valve, N, is fixed upon the side of the attic of the meter as shown, and access to the prepayment arrangement is obtained by means of a screwed key, R, which, when attached to end of bolt contained within the socket, S, enables the operator to withdraw the bolt and release the side door, O, previously held in position by the spring, P, acting upon the bolt.

The front end of the spindle, B, carries an index pointer which moves over dial, Q, contained in a glass fronted circular box at the side of the ordinary index, and indicates the quantity prepaid, and also, as the hand revolves back again to zero, indicating the quantity prepaid which is still to be consumed. This gives plenty of warning when the quantity still to be supplied is running short, so that another prepayment may be made before the gas is shut off entirely.

The operation of the meter is as follows. When a prepayment is to be made, the side door is opened by means of the key, R. The shaft, F, is then drawn towards the open door to throw the toothed wheel, H, out of engagement with the worm, I. The pinion being thus detached can be revolved by the knob, T, and in the process, acting through worm, G, the toothed wheel, A, is also caused to revolve. This carries with it the index hand in the dial box, Q, which indicates the quantity of gas corresponding to the value of the prepayment. The shaft is then pressed back into position and the toothed wheel, H, again engaged with worm, I.

As gas is passed through the meter the index shaft, M, acting through the medium of wheel, K, worm, I, and wheel, H, causes the shaft, F, to revolve. This movement is, by means of the worm, G, communicated to the toothed wheel, A. As the latter revolves the bracket, E, is carried round by one of the studs, and as the prepaid gas is gradually consumed the bracket approaches the valve spindle, U, and, as the last of the prepaid quantity is passed, presses the spindle home and closes the valve.

The meter illustrated is constructed for a prepayment up to 5000 cubic feet, the wheel, A, being prevented from moving further round in that direction by means of one of the studs, bracket, E, and a stop, D, fixed upon the floor of the attic.

When the side door of the attachment is closed, it is impossible for the shaft, F, to become disengaged from the worm, I, as all lateral movement is prevented. As the whole of the prepayment mechanism is entirely separate from the meter proper, the meter may be converted from "stop" to ordinary in a moment. By removing knob at the door end of the shaft, the shaft may be moved out of gear with the worm, I, and the meter becomes an ordinary one at once.

The second class of prepayment meters includes those that are perfectly automatic in their action and require no attention beyond putting the proper coin into a slot and passing it through the prepayment mechanism.

Important points to be kept in mind.—As the prepayment apparatus of different makers vary very considerably in their details, a few typical attachments will be described. Before this is done, however, it may be well to consider what should be looked for in the very best apparatus for this purpose. The most important points may be summarized as follows :—

(*a*) The mechanism should be simple in design.
(*b*) It should be strong in materials and excellent in workmanship.
(*c*) It should be accurate and efficient in working.
(*d*) It should be conveniently placed in connection with the meter to facilitate inspection and repair when necessary.
(*e*) It should be capable of easy detachment from the body of the meter.
(*f*) It should be so designed as to make fraud very difficult, if not impossible.
(*g*) The price-changing arrangement should be as simple as possible and capable of alteration *in situ.*
(*h*) It should be possible for both the consumer and the gas company's representative to see at a glance how much gas is being supplied for the coin inserted.
(*i*) The various parts should be interchangeable with similar parts of other meters.
(*j*) The action of the mechanism should be as silent as possible.
(*k*) All springs should be excluded. Springs are sure to be a source of trouble in course of time, and also throw additional work upon the meter to overcome their resistance.
(*l*) The auxiliary valve should be easily get-at-able, for cleaning the valve seat from possible deposit of dirt or of naphthalene.
(*m*) The measuring-off apparatus should close gradually enough to give warning of approaching exhaustion of the prepaid supply, but not so slowly as to inflict the nuisance of dwindling lights for an undue length of time before the prepaid quantity is fully consumed.
(*n*) The cash box should be so arranged as to make it as difficult as possible to tamper with.

As to the extent to which the various attachments come up to the standard here suggested, the reader will be able to judge from the detailed descriptions which follow.

Braddock's prepayment attachment.—The Braddock prepayment attachment is an arrangement of mechanism for accurately manipulating the valve controlling the gas supply. This mechanism is contained and supported in a rectangular frame, A B C D (Figs. 271 and 272), which may be readily attached to the body of the meter. Rotating within a bearing in this frame is the shank of a turn-screw, which can be turned from without by means of the handle, F. A second shaft, concentric with the turn-screw, called the receiver shaft, carries the coin receiver, G, and is borne at the end adjoining the turn-screw by a bracket, S, fixed to the frame, and at its inner end by a bearing in or fixed to the frame.

Fixed on the boss of the turn-screw is an arm, U, attached to, and forming part of, a carrier, H, which is curved so as partially to surround the coin receiver. One end of the carrier is formed with a toe, T, projecting inwardly towards the coin carrier, which is notched V at each end so as to allow the toe to pass freely. The other end of the carrier is normally below the end of the slot in the receiver, so that when a coin falls into the receiver it is sustained thereby in such a position that a part of the coin projects above the notch, thus preventing the carrier from being rotated unless it also

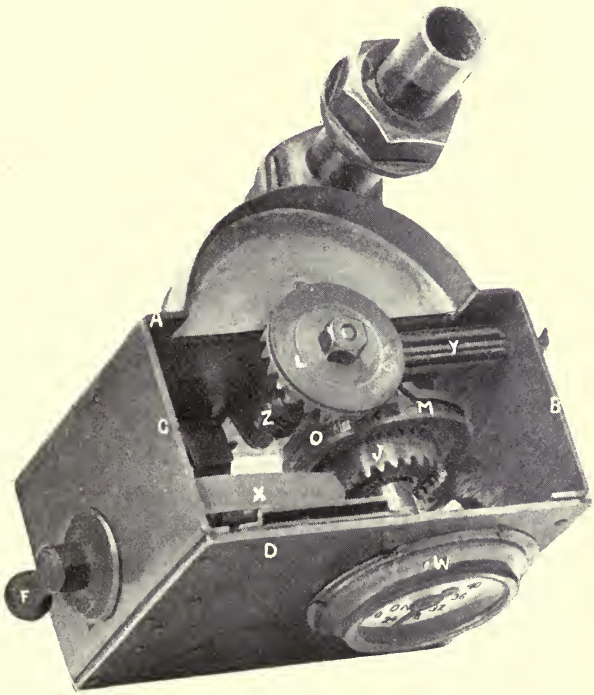


FIG. 271.—Braddock's Prepayment Attachment: Viewed from above.

rotates the coin receiver and its spindle. The receiver shaft, E, has upon it a worm, I, which engages with a toothed wheel, J, called the measuring wheel, which is loose on a transverse spindle, K, called the cam shaft.

The measuring wheel is compounded with a crown wheel, L, forming the first member of an epicyclic train, the last member of which is compounded with the return wheel, driven from a worm which is actuated by the meter on the passage of gas through it, by means of a long pinion, Y, and the crown wheel. The intermediate pinion of the epicyclic train is borne by a disc, O, mounted on the cam shaft.

The disc has formed upon its edge a groove or cam course, M, with which a pin, fixed in a suitably pivoted lever, N, engages. The cam course is so shaped that at one point it produces a rapid oscillating movement of lever, N, in a direction determined by the direction of rotation of the cam, while for the greater part of the rotation of this disc no effect is produced upon the lever.

The lever, N, is coupled to a valve spindle, P, by a pin, the spindle being borne by a long boss or a stuffing-box fixed to the framing. The

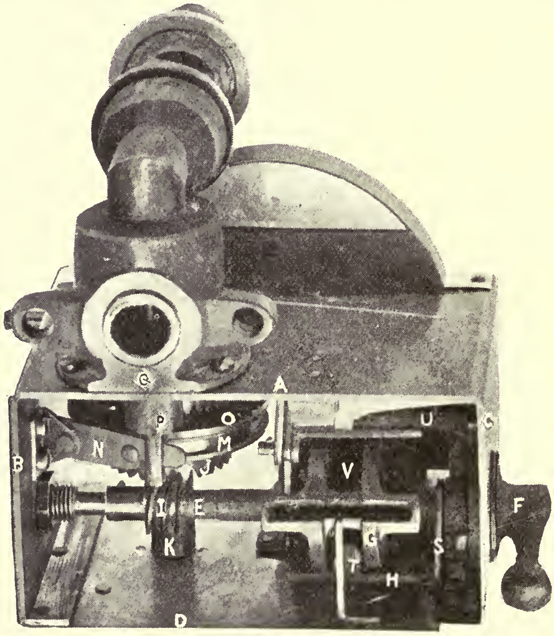


Fig. 272.—Braddock's Prepayment Attachment: Viewed from below.

valve spindle passes into an auxiliary valve box, Q, through which the gas flows on its way to or from the meter. A valve seat is formed within this valve box, and a disc valve fixed on the inner end of the valve spindle can be pressed on or withdrawn rapidly from the seat by the action of the cam, thus closing or opening the valve. The auxiliary valve chamber may be attached, by means of a screwed nipple, to either the inlet or the outlet of the meter.

The cash box is a light oblong tin box, fixed underneath the prepayment mechanism and at the side of the meter, with a passage into it large enough to receive the desired coin.

The operation of the meter will be readily followed from the preceding description of the mechanism. When a suitable coin is placed in the slot, X, it falls into the receiver, G, and is there supported by the carrier, H. When, now, the handle, F, is turned, the receiver shaft, E, is rotated by means of the locking action of the toe, T, and the coin. This rotary motion is conveyed to the wheel, M, by the worm, I, and teeth, J, the movement of M causing the pin in lever, N, to move along the cam course for a corresponding distance, and in doing so to open, or maintain open, the auxiliary valve.

As gas is being passed through the meter, the pinion, Y, is rotated by the index shaft, and acting through the crown wheel, L, and worm, Z, revolves the wheel, M, in the opposite direction. As the last quantity of prepaid gas is being passed through the meter the pin in the lever, N, engages in the cam course, shown in Fig. 271, and gradually closes the valve ; which, of course, remains closed until, by the insertion of a fresh coin and rotation of receiver shaft, the wheel, M, once more imparts motion to the valve spindle, P, and again opens the valve.

From the foregoing description of the apparatus and method of working, it will be seen that the attachment may be readily removed, in case of accident, and another substituted. The valve, too, is easily accessible for cleaning or re-facing, and the mechanism is so arranged that it closes very gradually, thus giving ample warning that the quantity of gas prepaid is becoming exhausted.

The crown wheel, for altering the quantity supplied per penny, is an exceedingly simple arrangement, and may be easily changed *in situ* by removing the top plate of the attachment box. The gearing of the wheel is generally arranged so that each tooth in the wheel represents 1 cubic foot per penny, so that a 30-toothed wheel would pass 30 cubic feet per penny, a wheel with 32 teeth would pass 32 cubic feet per penny, and so on.

It is obvious that, however easily the wheels may be changed, the labour involved in altering them, where thousands of meters are in use, must be very considerable. It is, therefore, now being found more convenient to allow an equivalent rebate when the price of gas is lowered rather than face the expense of changing the wheels.

The cover of the attachment box is secured by a bolt which passes through the base and is fastened by a nut in the cash box. The one lock, therefore, which secures the cash box protects the whole attachment from interference, and there are no fine wheels or other delicate mechanism to get out of repair, the whole arrangement being strong and durable.

George Glover and Co.'s change wheel prepayment meter.—Messrs George Glover and Co. are also manufacturers of a simply designed, strong, and substantial prepayment attachment of the "change wheel" type, which varies very considerably from that just described. The salient feature of this is a combination of a rotary pocket with a Geneva stop wheel, the interlocking of which effectually prevents any possibility of fraud. The change wheel is conveniently placed, and fresh ones may be easily adjusted for price-changing purposes. In this arrangement all springs have been excluded.

The action of the mechanism may be followed by the aid of Fig. 273, as follows :—

The rotary coin pocket A, and the Geneva stop wheel, B, interlock,

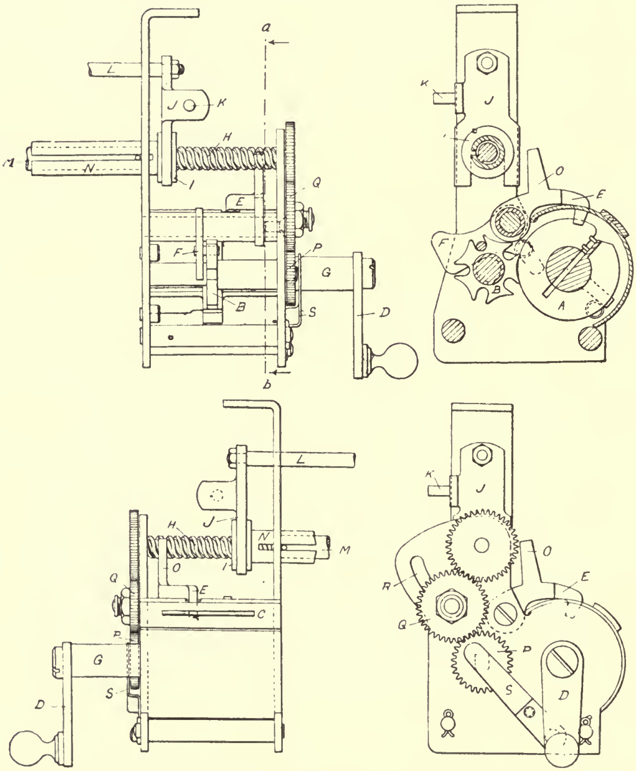


FIG. 273.—George Glover and Co.'s Change Wheel Prepayment Meter.

and the latter can only be turned when a coin of the proper size is inserted and acts as a tooth.

Insert the coin in the slot, C, and turn handle, D, half-way round. The coin in its progress actuates successively two levers, the first of which, E, falls behind the coin and prevents its being withdrawn, and also prevents a second coin entering until the first has been discharged. The second lever, F, as it is raised, unlocks the Geneva stop wheel, B, allowing it to move forward one division as the coin impels it, the lever, F, falling and again locking the wheel, B. The coin will then drop into the box, and the handle and pocket may be returned to their first position in readiness for another coin.

The spindle, G, carrying the wheel, B, being geared up to a suitable screw, H, this screw is rotated and causes the sleeve, N, with collar, I, to travel, carrying with it a saddle piece, J, which by a pin, K, and lever connection opens the valve and allows the gas to pass.

The saddle piece, J, has also attached to it a rod, L, extending sufficiently inside the meter to carry a pointer which moves over a scale engraved on the ordinary dial of the meter, showing the quantity of gas paid for in advance.

As the gas is consumed the quantity is registered by the meter, and the index spindle of the meter being geared to the automatic spindle, M, the latter is turned and causes the sleeve, N, with collar, I, to move in the reverse direction, closing the valve and bringing the pointer back to zero. This is done gradually so as to give warning of the approaching exhaustion of the quantity of gas paid for.

To prevent the mechanism being damaged or strained by the insertion of too many coins in advance, the lever, E, is provided with a projection, O, which impinges on the saddle piece, J, when more than a stipulated quantity of gas has been paid for. This effectually prevents any more coins being put in until sufficient gas has been consumed to cause the collar, I, to move out of the way of the projection, O.

The alteration of quantity delivered for each coin is made by the exchange of one small wheel, P (the next wheel, Q, being adjustable in the curved slot, R, so as to engage properly with the new wheel). The arm, S, holds the change wheel in position, and is moved aside to allow the change to be made. Each tooth in the change wheel, P, represents 1 cubic foot in the penny meter. Example: A 20-tooth wheel will give 20 feet in the penny meter, or 240 feet in the shilling meter.

The mechanism works smoothly and with a minimum of friction, which is very important, as any attachment which causes undue friction throws additional work on the meter and necessarily shortens its life. This mechanism has been adapted for pennies, shillings, half-crowns, and many foreign coins.

It is interesting to note that this prepayment attachment was in the year 1911 adopted by the South Metropolitan Gas Company as their standard prepayment mechanism, and is attached to all meters purchased by them.

George Glover and Co.'s price-changing prepayment attachment.—Messrs Geo. Glover and Co. are manufacturers also of an excellent prepayment attachment of the price-changing type in which the salient features are the employment of a lantern wheel, a rotary coin pocket, and an adjustable price-changing shield. The advantage of this type is felt in districts where different prices are charged in different areas, as a meter may be taken out of stock and adjusted to the particular price charged by simply altering the position of a shield.

"Metropolitan" prepayment apparatus.—One of the simplest prepayment arrangements produced as yet is the new type of the Metropolitan Gas Meter Company, shown in Figs. 274 and 275. In order to afford the fullest facility of access to the mechanism the inlet in this meter is placed at the back, thus allowing the covering

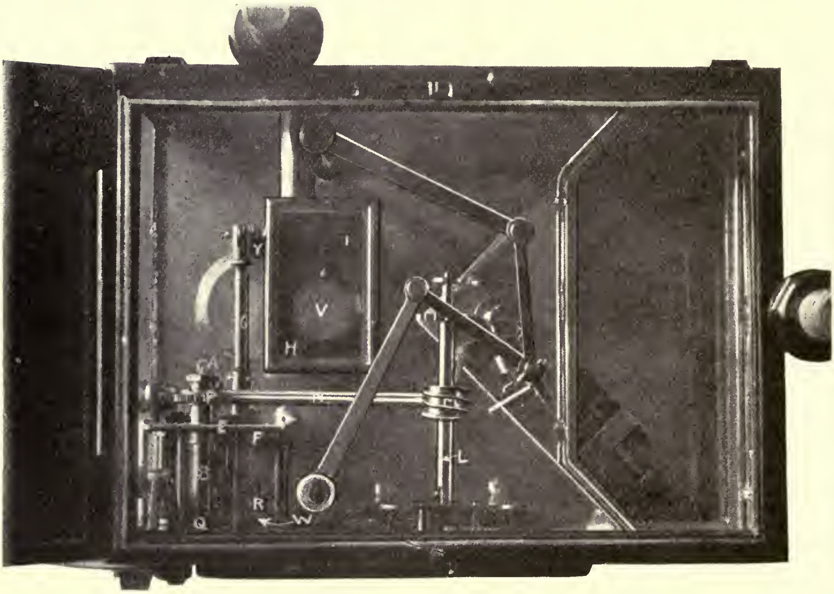


FIG. 274.—Metropolitan Prepayment Attachment: View from above.

flap of the attachment to be extended to the full depth of the side of the meter.

The coin is inserted through a slot in the front of the meter and falls into a lantern pinion, C, which is also the coin carrier, and in doing so passes into the slotted end, X, of the spindle of the handle, D, thus locking the handle and lantern pinion together. The handle, D, is then turned to the right, carrying with it the pinion, C, in consequence of the locking action of the coin, and causing the spindle of the pinion, C, to ride up the inclined slot, which forms its bearing on the end remote from the handle, and thus disengages the notch in the plate, E, at the end of the pinion from the locking pin. The lantern pinion, C, is now free to turn with the handle, D, and, in doing so, rotates the pinion, F, through a distance equal to the pitch of the teeth, thus turning the spindle, G, through the same distance, and with it carrying the stop screw away from the curved recess formed upon the boss of wheel, R. In order to reduce the friction of this travelling action of the pin over the edge of the boss, the stop screw has been fitted with a light sleeve roller. As soon as the turning movement is completed the coin is released and passes away to the coin box, which is fastened in a very simple manner to the side of the meter. The operation is, of course, repeated with the introduction of every additional coin.

Operating the valve.—The valve box, H, contains the weighted

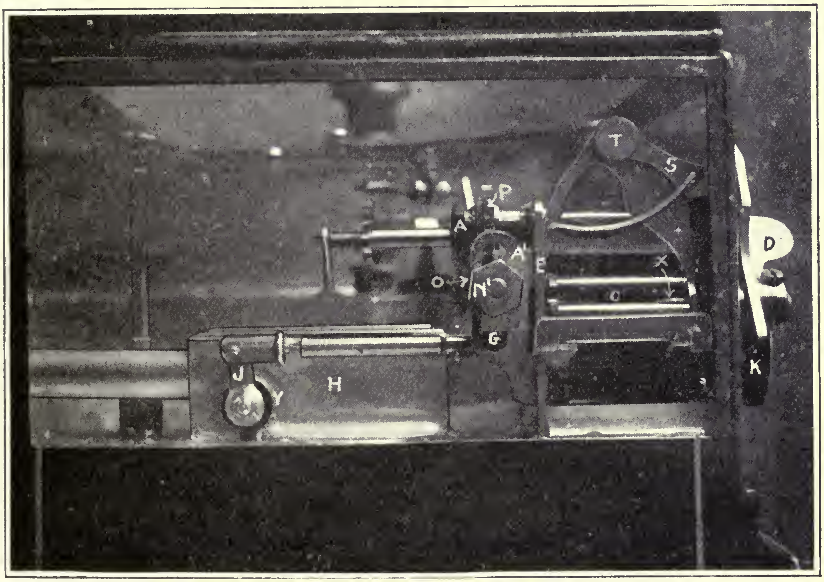


FIG. 275.—Metropolitan Gas Meter Company's Prepayment Meter Attachment.

flap valve, V, mounted upon the square spindle, I. The weight of V acting through stuffing box, Y, and lever, J, keeps the stop screw firmly pressed against the rim of the wheel, R, so that when the recess in the latter and the pin are brought into line, the necessary lateral movement is obtainable, the weight of V presses the pin into the recess, while at the same time V comes to rest upon its seating and closes the valve.

The force of gravitation is thus made, in a very simple manner, to take the place of the spring in the older form of attachment. With the valve as now made there is practically no friction in the mechanism, as, under normal conditions, the valve comes to its seating under its own weight; but should the face become slightly uneven from any cause, the valve is forced to its seating by the hook of the cam, R, engaging with the roller, thus renewing the bearing.

The sector, S, is an ingenious contrivance designed to prevent the insertion of a fresh coin until the first one has been released. The sector is pivoted at T, and when a coin is passed through the slot the front arm of the sector rides over the edge of the coin, which lifts it sufficiently to allow the coin to pass. When the coin has been received by the pinion, C, the upper edge of the coin projecting, above the pinion, prevents the rear arm of the sector turning forward sufficiently to remove the front arm from its position at rest in front of the coin slot, and, consequently, the insertion of a fresh coin is effectually prevented until the preceding one has passed from the pinion to the cash box.

At the front end of spindle, G, an index hand is fixed, which moves with the spindle and revolves over a dial contained within the small glass-fronted box, K, and indicates the number of coins which have been passed into the mechanism.

The passage of gas through the meter operates the meter index shaft, L, which, by means of the worm, M, actuates the spindle, N, which, through the medium of toothed wheels, O, P, Q, W, is ultimately geared into the teeth of the wheel, R. As the quantity of gas which has been prepaid is gradually consumed, the recess and stop upon the boss of wheel, R, approach and overtake the roller pin, and as the last quantity which has been prepaid is flowing through the meter, the weight of the valve forces the roller pin into the recess in rim of wheel, R, in the manner previously described, gradually closing the valve, which remains closed until a fresh coin has been introduced.

The price-changing arrangement consists of the single change wheel, P, which is fitted upon the shaft, B, by means of a loose slotted sleeve and set pin, and maintained in position by the nut, A. The change wheel works into the worm, O, upon spindle, N, as previously described. Change of price is effected by the substitution of change wheels having varying numbers of teeth to correspond with the price charged, the necessary accommodation in worm, O, being obtained by carrying the end of spindle, N, in a slotted bracket, A^1. By removing the nut, N^1, the spindle, N, may be moved either up or down, within limits, to afford proper engagement of worm, O, with the new change wheel.

Alder and Mackay's prepayment attachment : the slotted extension. —Another very simple and compact prepayment attachment is that shown in Figs. 276 and 277, manufactured by Messrs Alder and Mackay, of Edinburgh. The outstanding features of this piece of mechanism is the use made of a combination of parallel moving spindles, one of them being a slotted extension of the reciprocating screw, A, which passes within the coin chamber, B. Within the latter an internal sleeve secured to the handle boss, C, and having a projecting arm, is fixed. When, therefore, a suitable coin is inserted

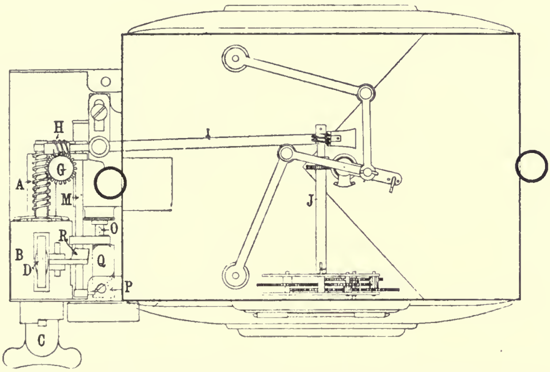
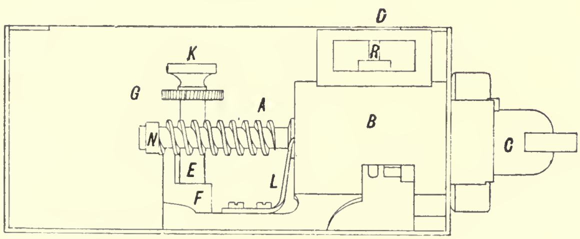
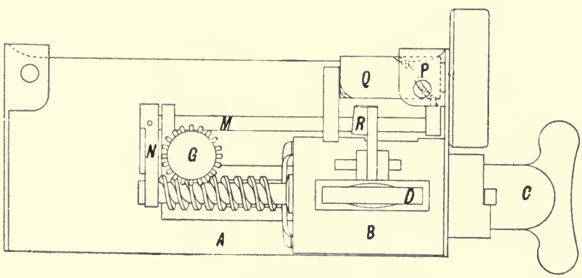


FIG. 276.—Alder and Mackay's Prepayment Attachment connected to Meter.



Side View.



Plan.

FIG. 277.—Details of Alder and Mackay's Prepayment Attachment.

at D, it passes behind the arm into the slot of the extension piece, thereby locking the reciprocating screw, A, to the handle boss, C.

The latter, being then turned, causes the simultaneous turning and the horizontal traversing movement of the extension piece.

The reciprocating screw gears into a toothed wheel, formed on a sleeve, E, turning on a vertical arbor fixed to the base block, F. The upper portion of sleeve, E, carries the toothed change wheel, G, by means of which the quantity of gas per coin is adjusted. The wheel, G, is geared directly by means of the worm, H, and the shaft, I, into the index shaft, J. By the simple operation of removing the head screw, K, the sleeve, E, together with the change wheel, may be easily lifted off the arbor and fitted with new change wheel as required to suit any alteration of price. It will be noticed that the reciprocating screw, A, acts as a screw only when being operated by the handle boss, C, through the medium of the locking action of the inserted coin ; the action of the gas passing through the meter serving to return it as a rack.

With a view to preventing any accidental movement of the mechanism, a very ingenious bushing piece has been devised for the end of the coin chamber. This takes the form of an annular disc, upon the internal face of which a projecting collar is formed, through which and the slot and the extension of the reciprocating screw a pin is passed, thus securing the simultaneous turning of the screw and disc while giving to the former freedom of longitudinal movement. The Y-shaped bracket, L, presses against the exterior face of the bushing piece and provides the necessary friction. The strain, therefore, thrown on the mechanism by the locking and turning of the coin is distributed between the bush and the slotted extension, instead of having to be borne solely by the latter.

The spindle, M, is mounted in bearings parallel to the reciprocating screw, the crosshead, N, connecting the two together, so that when the former is made to move forward or backward by the operation of the mechanism a corresponding longitudinal movement is imparted to the spindle, M. A forked arm at the opposite end of M to the crosshead, N, engages the spindle, O, of the gas controlling valve, so that the latter is actuated by the longitudinal motion of the spindle. A projecting pin from the forked arm traverses a spiral groove, P, formed on the barrel of a parallel spindle, Q, the front end of which carries a pointer, capable of moving over a dial in the front of the meter and indicating the amount of gas which has been prepaid. An upward extension from the spindle of the forked arm is made to tilt the bent lever, R, so as to obstruct the coin slot and prevent the entrance of additional coins when the maximum amount has been prepaid.

As prepaid gas is being consumed, the reciprocating screw is actuated as a rack by means of the shafts, J and I, and the sleeve, E, and in its travel carries with it the parallel shaft, M, so that when all the prepaid gas is consumed the gas valve is automatically closed through the agency of the forked arm.

The whole of the prepayment apparatus may be readily detached from the meter. By removing the two screws which keep down the the cover, and the screw which fastens the bottom plate of the mechanism to the cash box, the whole comes away from the meter. In the event, therefore, of anything going wrong—the mechanism becoming strained, bent coins being jammed, or examination proving necessary from any other cause—the attachment may be removed to a convenient position for inspection, leaving the meter working.

The Gas Meter Company's prepayment attachment.—The Gas Meter Company's prepayment device consists of a coin receiving mechanism, actuating a traversing screw, B, which gears into a worm wheel, *a*,

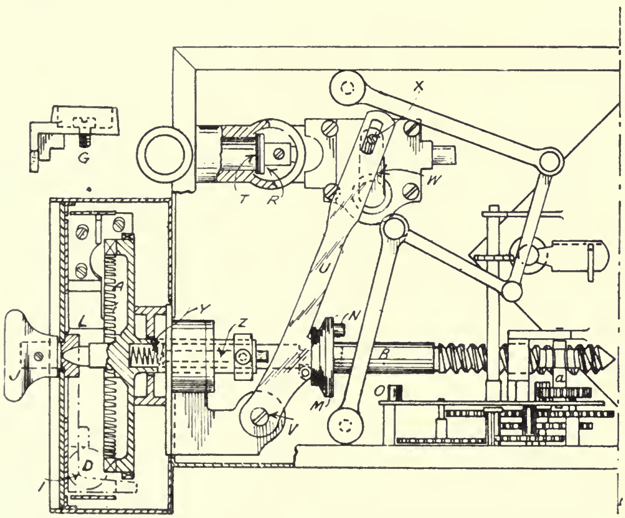


FIG. 278.—Sectional Plan of Prepayment Attachment.

actuated by the meter index, the gas valve, R, being opened and closed by a lever, U, actuated by the traversing screw, B. The latter is prevented from further rotating when at the end of its traverse by stops N and O.

The toothed coin wheel, A (Fig 280), is slidably fixed on one end of the traversing screw, B, and is adapted to engage directly by means of the teeth, C, with the coin, D. A notched indicating disc, E (Fig. 279), provided with a fixed coin slot, F, is arranged co-axially in front of the wheel, A, and is fixed in any desired position by means of the bracket, G, screwed to the body of the meter and engaging in one of the slots, H, in the disc, E. The coin pocket, I, is arranged on the inside of the disc, E, and can be turned by means of the handle, J, into a position in engagement with the stop, K, fixed on the disc, E, when it will register with the coin slot, its movement being limited when operating the meter mechanism by the fixed stop, L.

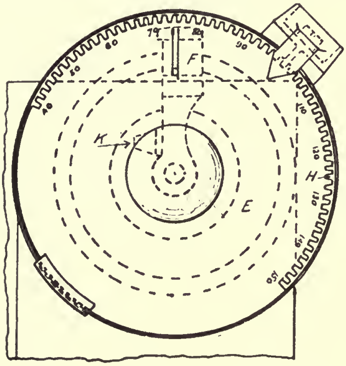


FIG. 279.—The Indicating Disc.

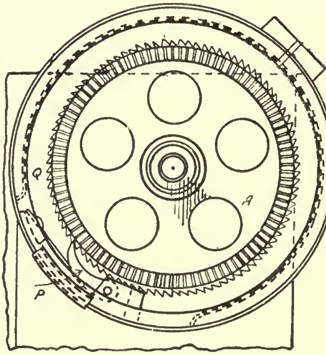


FIG. 280.—The Toothed Coin Wheel.

The traversing screw, B, carries a plate, M, on which a stop, N, is fixed which, when the traversing screw has been operated by the

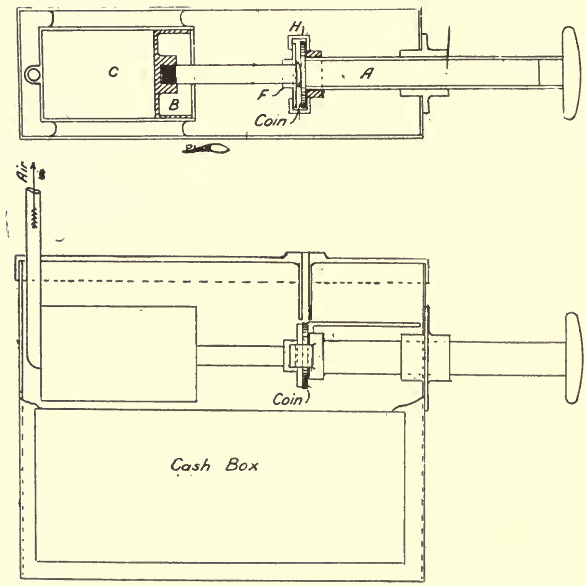


FIG. 281.—Peebles' Distance Control Meter: The Cash Box.

insertion of the maximum number of coins, comes into engagement with a pin, O, on the body of the meter and prevents its further rotation. Should a coin still be in the receiving mechanism when the traversing screw has been arrested in its movement, the coin will be locked in the mechanism till sufficient gas has been consumed to cause the disengagement of the stops, N and O, through the return of the traversing screw, the backward movement of the coin being prevented by means of a pawl, P, engaging in the teeth, Q, on the wheel, A.

The shut-off valve, R, pressing on a knife edge seat, T, is operated from the traversing screw, B, by means of the lever, U, fulcrumed at V by a slotted arm (not shown in the illustration) fixed on the same axis with the arm V V; the pin, X, on the arm, W, engaging in a slot in the end of the lever, U. The spring, Y, is arranged in the hollow sleeve, Z, of the wheel, A, and presses on the end of the traversing screw, thus assisting in opening the valve and taking up the back lash.

The rest of the operating mechanism will be readily understood by those who have followed preceding descriptions.

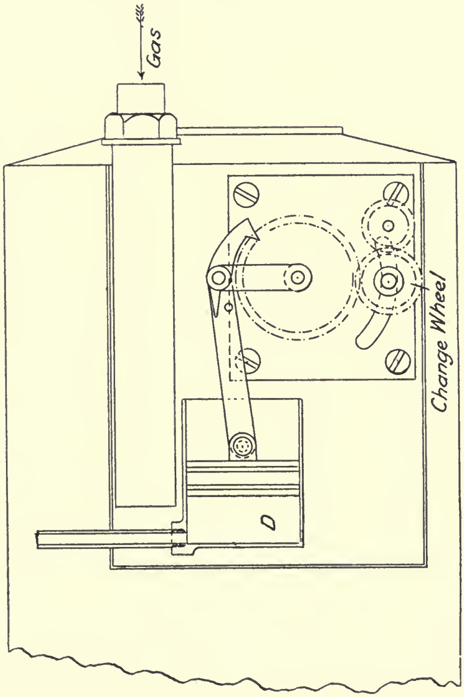


FIG. 282.—Peebles' Distance Control Meter: The Piston Lever.

Peebles' distance control meter.—One of the most interesting developments in the matter of prepayment meters is that shown in Figs. 281 to 283. This is an adaptation to the case of prepayment meters of the well-known pneumatic switch arrangement which has done so much to popularize the use of gas for lighting. By this device the cash box and the meter may be separated, and the former fixed in any safe and easily accessible position without regard to the limitations which determine the locality of the latter.

To actuate the valve the coin is dropped through the slot in the top of the box and engages between the push rod, A, and the spindle of air piston, B. On the rod, A, being pushed in, the air is transmitted from the cylinder, C, through small pneumatic tubing to the meter cylinder, D, which actuates the piston in that cylinder and rotates the meter mechanism to open the valves. On withdrawing the push rod, A, piston, B, is withdrawn by means of the disc plate, F, and hook, H. The suction caused by this piston being drawn out returns the piston on the meter to its original position, ready for the next operation.

The working of the push rod, A, without a coin has no effect upon the piston, B, as the push rod being hollow it passes over the end of the spindle on piston, B.

The action of the meter, which may be of any ordinary type of

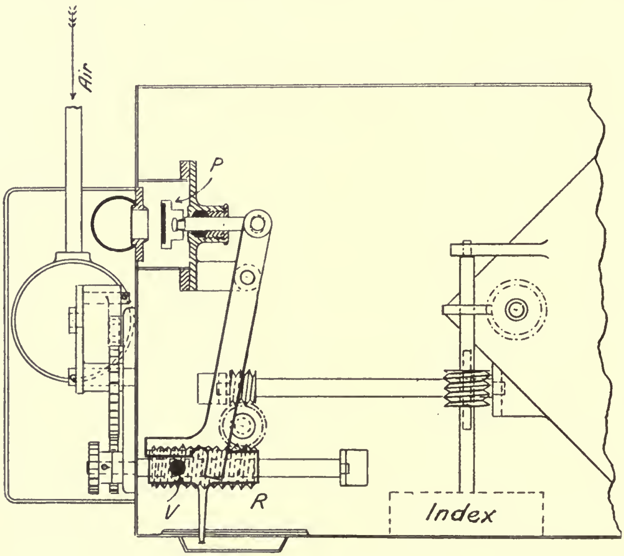


FIG. 283.—Peebles' Distance Control Meter: Plan of Prepayment Attachment.

valve mechanism, is clearly indicated on the drawing; P being the prepayment valve, R the sliding worm, and V the pin to operate the valve lever.

The chief advantages of the device are (1) that the coin box, now so liable to be pilfered, is in a much safer position in the house than can be possibly the case when attached to the meter and placed in cellars or other out-of-the-way places; (2) the great convenience to the consumers in the introduction of the coin to get gas, the cash box being fixed in an easily accessible position; (3) the money box can be made particularly strong, and permanently fixed or bolted to the wall of the building; (4) the meter will be practically of the same dimensions as the ordinary gas meter, and in the event of repairs being necessary to either the meter or the coin apparatus, it will only be necessary to send the one in need of repair. Should it only be the coin box that is out of order, all the trouble of disconnecting the meter will be done away with, another box being substituted; (5) apart from the pneumatic connection, these advantages are obtained without any increase of cost over the present prepayment meter. The trifling extra cost of running a small tube will probably be repaid by the saving in repairs alone, but a far greater saving should also be brought about by the prevention of thieving, due to the money box being more under control. Where the tenant or occupier leaves and another is expected, the meter may be left in place, while the coin box could be taken away.

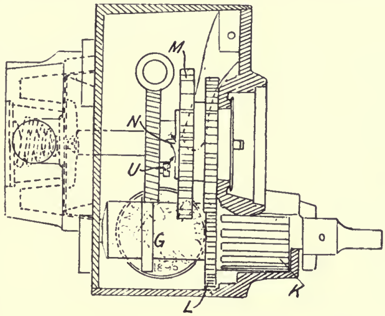


Fig. 284.—Section through Wilson's Double Coin Meter, showing Coin Carrier.

Wilson's two coin meter attachment.—Another very interesting and useful meter of the prepayment type is the two coin meter manufactured by Mr Geo. Wilson, of Coventry. The attachment is very simple and strong, and is made to take two coins of different values. These may be one penny and sixpence, one penny and a shilling, sixpences and shillings, or other various kinds. Fig. 284 to 288 shows the arrangement for pennies and sixpences.

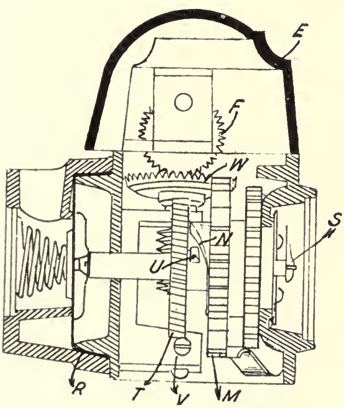


Fig. 285.—Section through Wilson's Double Coin Meter showing Diaphragm Valve.

The casing is made of special anti-corrosive metal in two halves neatly fitted together, and securely fastened by screws, which can only be removed upon taking the cap off. The casing is made so as to provide for an inspection of the mechanism without removing the meter from its position. In the casing, on the side, is formed two slots, one for the reception of pennies and the other for sixpences. Journaled below the slots and inside the casing is provided a coin carrier, G, which has two longitudinal slots extending diametrically through it, with inclined walls to prevent the pieces of money dropping through. The outer end projecting through the casing is provided with an operating handle. Loosely arranged on the one end of the coin carrier, and under the slot provided for sixpences, is a radially slotted drum K (Fig. 286) made with teeth, L (Fig. 284) on the one side. This drum is provided with fourteen slots and teeth.

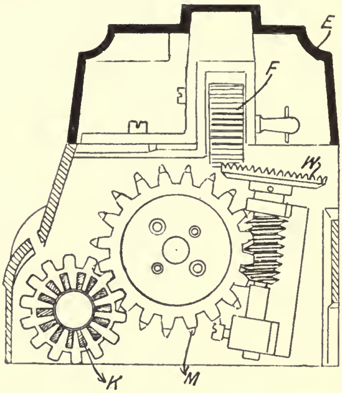


Fig. 286.—Section through Wilson's Double Coin Meter showing Measuring Wheel.

The measuring wheel is situated in the centre of the front wall of the casing, and is formed out of a double wheel, M (Fig. 286), with twenty teeth, which are accurately cut or divided to ensure each distance being the same ; on the one end is formed a cam or bridge, N (Fig. 285), which is used to open or close the valve, and on the other end is formed a shoulder which passes through the front wall and is made secure by a brass plate, to which is attached the small round pence dial, thus making the wheel fast to the casing, but allowing it to revolve freely. Through the centre of wheel, M, is a hole large enough to allow a shaft to pass freely through. This wheel is allowed to rotate in one direction only by the engagement of the coins, and is prevented from working in the opposite direction by a stout steel spring (Fig. 285), which forms in itself a ratchet, thereby only allowing the wheel to travel the exact distance according to the value of the coin. The teeth of this wheel engage with the teeth of the slotted drum, L.

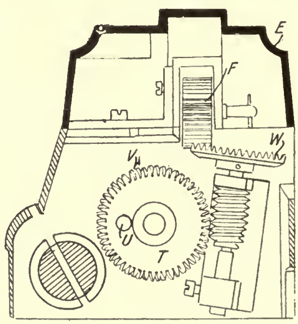
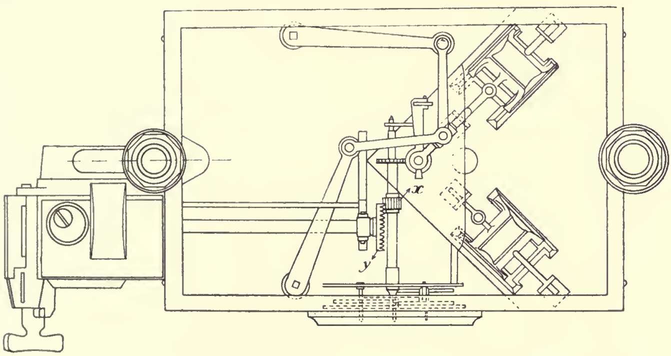


Fig. 287. — Section through Wilson's Double Coin Meter showing Fixture, Crown and Change Wheels.

The valve casing is formed out of a special white metal, and is securely fastened to the casing of the mechanism. The valve is of the diaphragm type, with a small plate in the centre, which has a diameter a little larger than the valve seating, so that when sent home against the seating it forms a perfectly sound valve. The diaphragm, R (Fig. 285), is made perfectly sound between the attachment casing and the valve casing by being clamped up between a taper ring on the wall of the former.

The closing of the valve is operated in the following manner :—Through the hole in the centre of the double wheel, M, carrying the cam, N, passes a shaft to a little distance outside the small pence dial, and to this shaft is attached a finger or pointer, S (Fig. 285), which travels with the shaft over the dial as the gas is consumed. The other end of the shaft passes through the back wall of the casing to the valve. On this shaft is made a fixture wheel, T (Fig. 287), which has a screw, U, on its face, set at the same radius as the cam, N, on the double tooth wheel. The cam, N, meeting the screw, U, and the wheel still revolving, the cam, N, climbs up the screw, U, and so tends to push back the wheel, T, with its shaft, and that, pressing on the valve, closes it. The wheel T, has teeth on its outside edge, which engage with a worm in a stool. On the top of



288.—Wilson's Double Coin Meter. Plan of Attic Arrangements.

this worm is fixed a crown wheel, W, with which engages the change wheel, F, which is driven by the meter. On the cross shaft which communicates with the ordinary registering index is a wheel, *x* (Fig. 288), which gears into another wheel, *y*, on a shaft at right angles, which is in connection with the change wheel, F. This shaft is free to rise and fall according to the gas price, and consequently the size of the change wheel, in the following manner. Close to the wheel, *y*, the shaft has a swivel joint which comprises a loose ring on the shaft, and a fork with two pins or screws at each side, entering this loose ring, allows the shaft to freely revolve and rise and fall as is necessary, through the attachment of a larger or smaller sized wheel.

The operation of the meter.—Upon the insertion of a penny piece into the larger of the two slots it falls into the coin carrier, G. Upon rotating the handle this coin engages with one set of the teeth on the double wheel, M, and by still rotating till the stop is met, the coin turns the wheel to the extent of one tooth, and so opens the valve for gas to flow into the meter. The coin is then free to fall into the cash box provided for it. Upon the insertion of a sixpence into the proper slot, there is a connection made between the coin carrier and the slotted drum, K. When the handle is rotated, it takes with it the slotted drum, and that being in gear with the double wheel, M, causes that to rotate to the extent of six teeth before it meets the stop, whereby the mechanism is actuated to the extent of six times the value of a penny. The mechanism is made to take up to the value of eighteen pennies. As the gas is being passed through the meter, the wheel, *x*, is rotated by the index shaft, and acting through the crown wheel, *y*, and the crown wheel, W, the worm rotates the wheel, T, in the opposite direction to the double wheel, M, and through that gradual rotation, the cam, N, comes into contact with the screw, U, and the double wheel being kept in a fast position, the wheel, T, is pushed back and, that being a fixture to the shaft by which it is carried, the valve is slowly closed, checking the gas supply to the meter until the insertion of another coin.

Returning coins to the outside of casing.—There is provided under the coin carrier, and below the slot for insertion of pennies, a small shoot for catching the sixpence if by accident it should be inserted in the wrong slot, and so returning it to the outside of the casing, where the consumer will find it laid on a small table provided for it, ready for re-inserting.

Change-wheel.—The change-wheel, F, is very easily changed by simply taking out a screw which secures it in position, after the removal of the cap, E.

CHAPTER XVIII

FIXING METERS

It is extremely important that the position chosen for the meter should be determined with due regard to several very practical considerations. Frequently the careless and haphazard method of fixing the gas meter in any out-of-the-way place that may happen to suit the immediate convenience of builder, landlord, or tenant leads to a considerable amount of future inconvenience and annoyance, which might easily have been avoided by a wise choice in the first instance.

Freedom of access.—In fixing the site of the meter, one of the first points to be considered is freedom of access. The main cock controlling the supply to the premises is usually placed upon the inlet, in close proximity to the meter. In view of many contingencies, it is important that this should be easily accessible. Then the periodical inspection of the meter will be much facilitated when the meter is placed in a position which is easily reached. And, in addition, such occasional work as repairs, examination of, or changing the meters, and attention to complaints of defective supply, will be rendered much more easy by a little forethought in choosing a sufficiently roomy and suitable place for the meter.

Equable temperature : Risk of freezing.—The meter should also be fixed in a position where the temperature is moderate and equable. If placed in a very cold situation, two evil results follow. In the first place, annoyance and inconvenience caused by a cessation of supply, in the case of wet meters, may occur in the depth of winter, when the need for an uninterrupted supply is greatest, by the freezing of the water in the meter. In all instances where a position involving this risk has, perforce, to be accepted, the risk should be guarded against and minimized as far as possible by loosely boxing the meter in, and surrounding it to a depth of several inches in sawdust or other non-conducting material.

Imperfect Registration.—The second result of placing a meter in a very cold situation is an imperfect and unfair registration of the gas passed, and a consequential inflation of the so-called leakage account of the undertaking. This aspect of the matter is more fully discussed in connection with unaccounted for gas (Chapter XXXVI). From the well-known law of expansion of gases under increase of temperature, we find that the increase of volume is in the proportion of $\frac{1}{490}$ for each 1° Fahr. above 32° Fahr. and $\frac{1}{273}$ for each degree Centigrade above 0° C. Now, at most gasworks, the gas made is corrected to 60° Fahr. If, therefore, to take an extreme case, gas sent out from the works at 60° Fahr. is measured to the consumer at 32° Fahr., it is obvious that a considerable shrinkage of volume will have occurred, to the great disadvantage of the supplier and to the equally great advantage of the buyer. For every 1000 cubic feet thus measured by the consumer's meter the works will have sent out 1057 cubic feet, and proportionately with other variations between these extremes.

Condensation of hydrocarbons.—In addition to the foregoing, there is also the danger of condensing out valuable hydrocarbons from the gas, with consequential impoverishment of its illuminating power, in such sudden cooling of the gas in the meter and connections. It is therefore seen to be of great importance that the consumer's meter should not be subjected to low temperatures.

And, conversely, it is equally unwise to fix the meter in a very warm place. The registration in this case is all against the consumer, owing to the increase of volume due to the higher temperature. Again, if the meter is a wet one, evaporation of the water will be rapid, necessitating frequent attention, if the water-line of the meter is to be maintained. If a dry meter is used, the leathers of the measuring chambers rapidly deteriorate, and the life of the meter is materially shortened. From each point of view, therefore, it is essential that the meter should be fixed in a position where the temperature will be moderate and fairly equable.

Relation of position to street mains and consumers' fittings.—A further point to be kept in mind in this matter is the accessibility from the street mains, on the one hand, and the relation any suggested position bears to the general arrangement of the premises to be supplied, on the other, It is, for many reasons, desirable that services should be kept as short as possible; in other words, that the meter should be fixed as near as may be to the street main. It is with a view to discouraging lengthened services that most gas undertakings charge the cost of fixing such portions of the services as may lie beyond, say, four or five feet upon private premises.

In the case of dwelling-houses, business premises, or other buildings of only a single room in width, the exact position of the meter may be a matter of indifference, as far as fitting up the house is concerned, so long as the condition suggested in the preceding paragraph is observed. But where house property is double fronted, or business premises, warehouses, or mills are concerned, it is obviously desirable, both from the point of economy in fitting and of efficiency of supply, that the meter should be as centrally placed as possible. The rising main, or main supply pipe, is then, also, in the best position for supplying the lateral pipes to the various rooms.

In order to preserve the life of the casing of the meter, the position chosen ought also to be perfectly dry. Wet positions should be avoided at all costs, and even damp situations should be shunned as far as possible.

And, lastly, just as the best position for a gasworks is at or below the lowest point of supply, so a gas meter should be fixed either at or below the level of the lowest lights to be supplied.

Small consumers' meters are usually fixed on shelves on the wall. Where these do not already exist a pair of stays or supports may be driven into the wall and a short board laid upon them to carry the meter. This method gives a considerable choice of vertical position to suit local circumstances. In those of larger capacity, to which this method is inapplicable, the meter should always be raised from the floor by means of a stool, cradle, or built foundation.

Size of meter required.—The very general adoption of incandescent burners in this country, with their lower rate of consumption, and the remarkable development of the use of gas for cooking, heating, and industrial purposes, renders the classification of gas meters by the number of burners they should supply, calculated upon a 6 cubic feet per hour basis, an absurd and antiquated one. The number of points of consumption may, obviously, give only a very imperfect indication of the quantity of gas required per hour. While, therefore, it may be convenient to retain the old names, in determining the size of meter requisite for the adequate supply of the premises, the mere number of lights should be ignored, and the probable consumption per hour estimated in accordance with the table on page 355, with a liberal allowance for contingencies. If no one of the stock sizes of meters exactly suit the requirements, the size next above should be taken. It is always better to have the meter rather too large than too small, in the interests of both the undertaking and of the consumer.

Method of fixing meter.—The method of fixing meters will obviously vary with the kind and size of meter. Take the simplest case first, which is that of a small dry meter. The meter, of course, must be fixed perfectly level, to ensure absolute regularity of working.

As will be seen on reference to Figs. 246-7, pp. 282-3, the inlet and outlet joints in this class of meter are placed upon the top left and right-hand side of the meter respectively, and at half the depth of the meter from front to back. The service may be brought near to the side of and at right angles to the meter, or it may be brought in a vertical direction either from below or above. Whatever the direction of approach, the service is brought to a convenient position in relation to the meter, and the main cock (see Fig. 179, p. 215) screwed upon it. The main cock is fitted upon the end nearest the meter, with a cap and lining corresponding with and similar to those upon the inlet and outlet of the meter. In the case of meters for more than ten lights, this cap and lining, which somewhat restricts the gas-way, should be replaced with a full-way barrel union, so as to give full bore right through from service to meter.

Compo. tubes.—The inlet and outlet pipes are, in the case of small meters, either wet or dry, usually made of thin lead tubes coated with tin, termed compo. (See page 343.) These tubes are

FIG. 289.—Tube Bender.

both economical and convenient for the connections of small meters. It will be noticed that the sizes given (page 344) refer to inside measurements. In cases where connections of over 1 inch diameter are necessary it is customary to use ordinary lead or iron tubes in place of compo. The connections of a meter, whether of large or small size, should never be less in diameter than that of the meter unions.

Having placed the meter in a perfectly level position, screwed the main cock upon the service, and obtained a sufficient length of compo. of the correct size, it is now necessary to join this at the one end to the meter union and at the other to the cap and lining to be attached to the main cock. This is done by means of a solder joint, as described later.

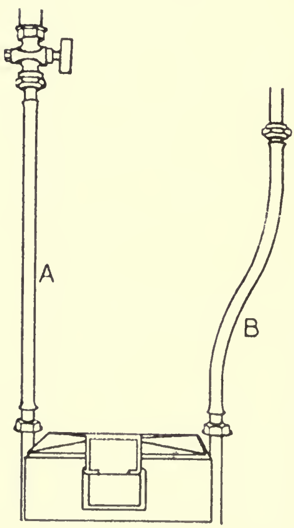


FIG. 290.—Rigid Inlet Pipe.

Bending the tube.—In bending the tube to the exact form required for the connection, care must be taken to obtain regular curves of as wide a sweep as the circumstances may allow, without, of course, becoming gawky or unsightly. The use of a pipe bender, such as that shown in Fig. 289, may prevent kinking of the pipe. Very short bends should be avoided, and kinking of the tube must be guarded against.

It occasionally happens, in the event of a service approaching the meter from above, that it is possible to fix the meter in such a position that the connection forms a straight prolongation of the service pipe, as shown at A (Fig. 290). In all such cases the meter should be moved out of the direct line, so that the connecting pipe is made to take the form shown at B. The straight, rigid pipe is most inconvenient for either connecting or disconnecting the meter.

Fixing the connection.—After the tubing has been bent and adjusted to the exact positions of the main cock and meter respectively, the seatings of the linings are fitted with well-greased leather washers, the pipe is placed in position, and secured by screwing the cap of the union hard down on to the shoulder of the lining.

The various forms which an inlet connection may assume are shown in Figs. 290 to 298.

In connecting up the outlet of dry meters, small as well as large, the common principle must be applied of never allowing the condensation from the consumer's fittings to fall back into the body of the meter. Exactly how this evil is to be avoided will depend upon whether the rising main from the meter is of compo. or of iron tubing.

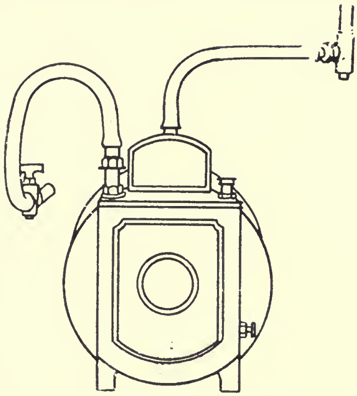


FIG. 291.—Connection to Wet Meter, showing further type of Inlet.

If of the former, the outlet pipe must be brought down below the level of the outlet of the meter, the lower portion of the pipe being intended to act as a syphon. This is stopped by a piece of brass tube being soldered into it, upon which a small cock is screwed, so that the products of condensation may be drawn off at will.

At a convenient height above the meter, a tee joint may be made to serve as the junction of the meter outlet and the consumer's fittings, as shown in Fig. 292, and as described in Chapter XIX., p. 347.

If the rising pipe is of iron tubing, the same general arrangement must be obtained as described in the preceding paragraph, but, in this case, with iron fittings. A tee piece is screwed upon the lower end of the rising pipe, and from that again a short piece of piping, to act as a syphon, as shown at Fig. 293. The position of the tee in that case is shown below the level of the meter, but obviously the same kind of connection must be made, whatever the position of the tee in relation to the meter. The syphon, of course, will be terminated by a small cock, to discharge the condensation.

In those cases where, from lack of foresight or bad arrangement, the lower end of the rising main has been left too low to allow of a simple bend outlet, such as that shown in Fig. 291, then a swan neck connection must be made, as shown in Fig. 293.

Upon the outlet of the tee a nipple or short piece of iron pipe is fitted, and to this, again, a cap and lining, or barrel union, to which the compo. outlet pipe from the meter may be attached, as described in the case of an inlet connection. The whole arrangement is shown in Fig. 293.

In the case of iron fittings the syphon upon the outlet serves two purposes. It not only prevents condensation from running back

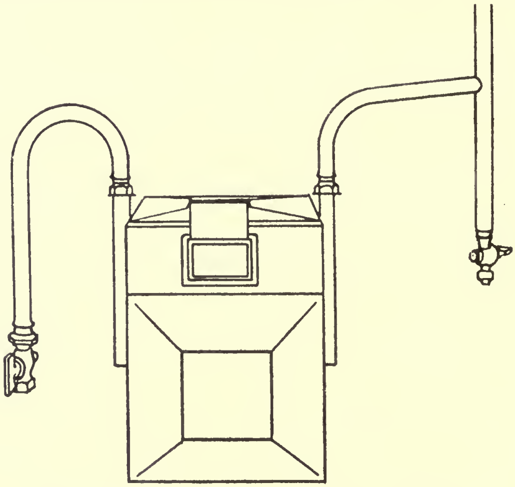


Fig. 292.—Tee Joint on Outlet (Compo).

into the meter, but also prevents particles of corrosion, which are continually forming on the interior surface of the pipes and dropping

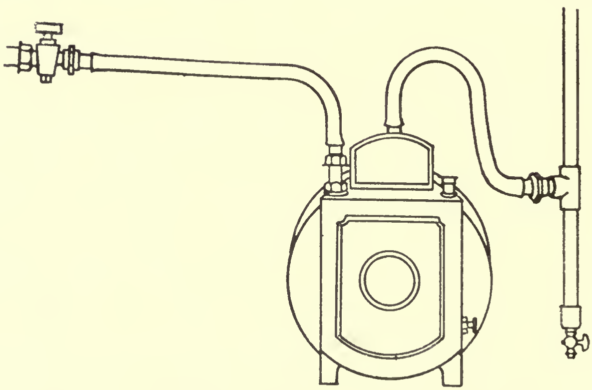


Fig. 293.—Outlet connecting into Iron Rising Main.

to the bottom of the rising pipe, from finding their way into the meter. The form of outlet shown in Fig. 296 should, therefore, always be avoided in the case of dry meters.

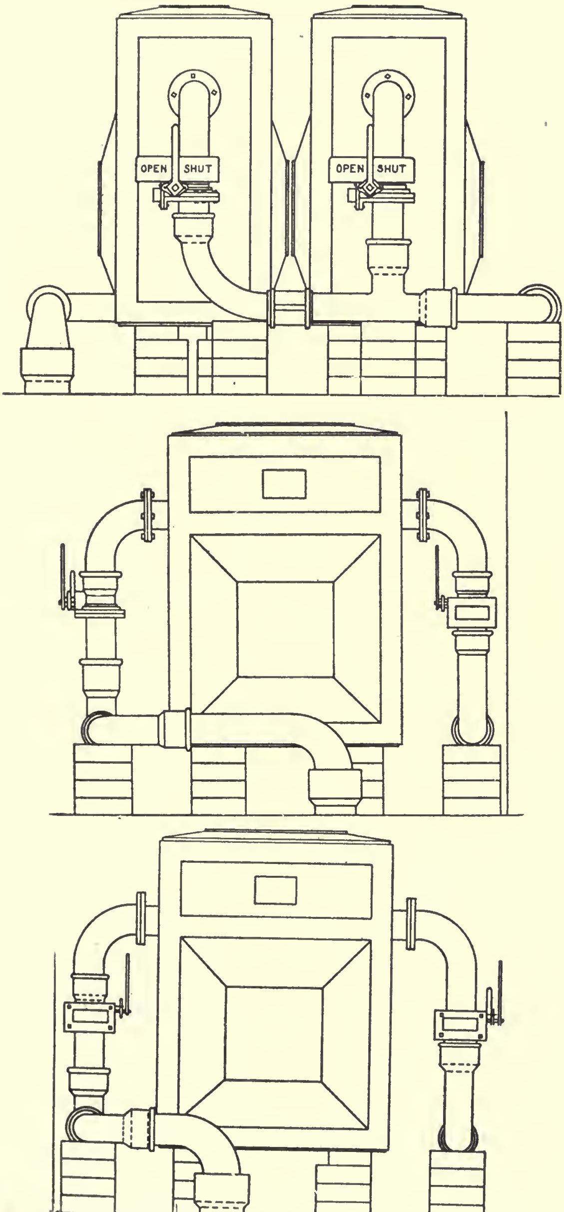


FIG. 294.—Fixing Meters Back to Back: Elevations.

Connections for large dry meters.—With larger dry meters, up to the 100-light size, the same general method of attachment is followed. Lead or iron piping takes the place of compo., and the connections are of a more substantial character generally.

The inlet and outlet of the dry meter of the 150-light size and over are usually placed at the side, and are connected up by means of iron tubing and wrought-iron flanges, or by cast-iron pipes and valves. This is necessarily a very rigid form of connection, and very accurate fitting is imperative. But even here it is possible, by a

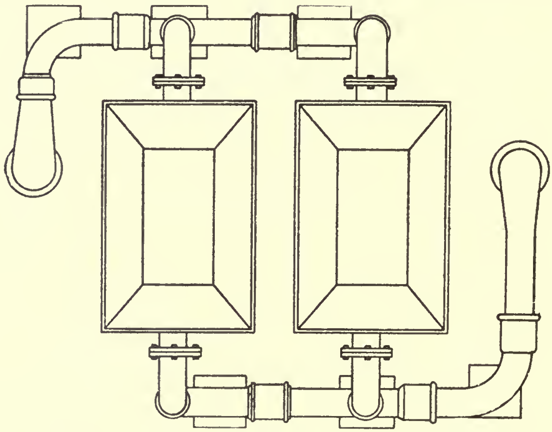


FIG. 295.—Fixing Meters Back to Back: Plan.

judicious arrangement of the inlet and outlet connections, to ensure a comparative facility for removing and changing the meter whenever repairs may be necessary.

The importance of preventing condensation or corrosion getting to either inlet or outlet, which has already been alluded to, in the case of small meters, becomes much more pronounced when dealing with meters of large dimensions. The oscillation of lights or partial cessation of supply, the wear and tear of the meter and rapid deterioration of leathers and working parts, and the ill effects of fine particles of corrosion upon the valve facings, when these precautions are not observed, are, of course, much more serious, both to consumer and supplier alike, and need only to be named to draw attention to their obvious character.

Fixing meters back to back.—In particular cases it may be advisable to duplicate meters of smaller size rather than to put down one meter of sufficient capacity in itself. Fig. 294 shows an arrangement by Messrs Geo. Glover and Co., Limited, of two 500-light dry meters fixed back to back, to take the place of one meter of 1000-light capacity. These meters are made with right and left-hand inlet and outlet, so that both inlets are brought to one side, and the same, of course, with the outlets upon the other. This obviously facilitates connecting up, and brings the inlet valves close together. The advantages of such an arrangement are that space is economized in the two directions of height and width, and also that in times of small consumption only one meter need be used. Then, again, repair and testing may be done upon one without interrupting the supply, or having to fix a by-pass.

Fixing wet meters.—As in the case of the dry meter, the wet meter must be fixed perfectly level. In both alike this is necessary to ensure the accurate working of the meter as a piece of mechanism. But in the case of the wet meter there is the additional reason that any tilting materially affects its accuracy as a measuring instrument, as shown in Chapter XV, and may, if carried far enough, throw the meter out of action altogether.

As far as the wet meter itself is concerned, there is no reason why any condensation which may occur in either the service or the consumer's fittings should not find its way into the meter. There is no need, therefore, from that point of view, for any syphon on either the service or outlet. Indeed, such condensation, by tending to restore the loss of water due to evaporation, is an advantage, as assisting to maintain the water-line constant.

It frequently happens, however, that the inlet to a small wet meter rises from the main cock to the meter. In such an event, it is obvious that if the service falls towards the meter, any condensation would collect at the upward bend, and ultimately obstruct the gas-way. Therefore, wherever there is a rise from service to meter, and the inclination of the service is toward the meter, a syphon should be fixed upon the service, as shown in Fig. 296.

The same principle holds true, of course, in the case of the outlet. As a rule the end of the rising pipe is at a higher level than the outlet of the meter. It is then possible to arrange the outlet connection so that the condensation going on in the fittings shall fall into the meter, as shown in Fig. 296. But when it happens that the fittings commence from a level below the meter outlet, and consequently the outlet connection falls from the meter to the fittings supply pipe, a syphon must be fitted upon the latter, to receive condensation and prevent waterlogging of the pipes, as shown in Fig. 293.

The connections to small and medium-sized wet meters are made of the same materials, similar joints are used, the same method of jointing is adopted, and the same general form taken as those previously described in connection with dry meters. The warning against a too direct and rigid connection is also equally applicable.

The outlet generally takes the form of a graceful double bend, as shown in Fig. 296. Where the main supply pipe is of compo. a sufficient length is generally left to reach to the outlet of the meter. In that case, it is only necessary to bend the pipe to the shape required, cut off to the proper length, and then turn the pipe upwards to make the joint with the meter union, as described later, see p. 351. Where the rising pipe is of iron tube, a cap and lining,

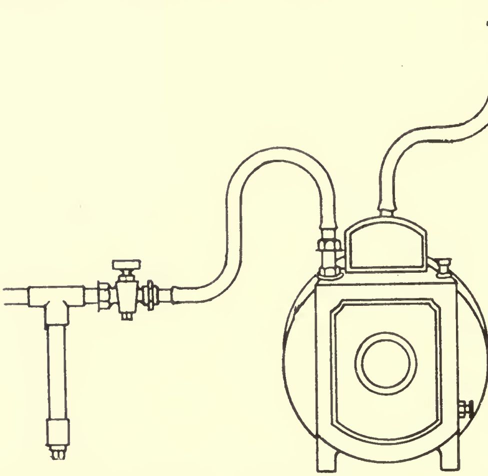


FIG. 296.—Outlet Connection to Iron Pipes and Syphon on Inlet.

or barrel union, similar to those used upon the main cock, must be attached, and the outlet connection fitted in the same way as the

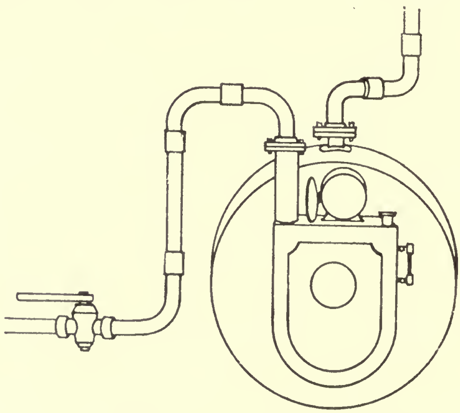


FIG. 297.—W.-I. Connection to Large Meter.

inlet (Fig. 296). In the event of its being necessary to have a syphon upon the outlet, the latter may take the form shown in Fig. 293, where iron tube is connected up to, or that shown in Fig. 292, where the fittings are of compo. pipe. In the latter case, of course, the tee joint may be below instead of above the level of the meter outlet, as shown in Fig. 293, rising in a graceful swan neck curve from the tee joint to the outlet of the meter.

Connections for large wet meter.—Consumers' meters of 150 lights capacity and upwards are connected by flanged joints, either upon the top, as shown in Fig. 297, or at the back, if the cylindrical

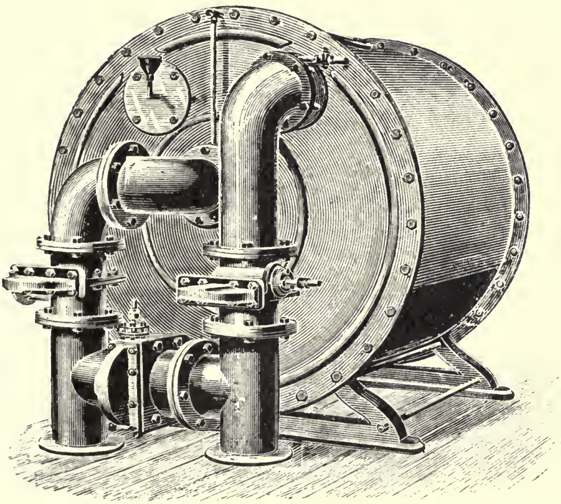


FIG. 298.—Connections to Cylindrical Wet Meter with Valved By-pass.

form of meter be adopted, as shown in Fig. 298. The same general principles apply here as in the case of small meters, and the same precautions are also necessary. As the connections are of either wrought or cast-iron they are exceedingly rigid, and must be fitted with great exactitude. Should the connections not fit correctly, they must be made to do so, and on no account should strain be put upon the joints in the endeavour to make gas-tight an ill-fitting flange. The connections shown in Fig. 297 are a good type, the bends used allowing them to be readily turned out of the way in the event of inspection, examination, or changing of the meter becoming necessary. In these cases, however, local conditions vary greatly, and will always determine the exact form such connections must take.

Connections for station meters.—The method of connecting up large cylindrical and station meters differs materially from those hitherto considered. These are usually supplied by, and supply, mains of large diameter lying underground. The particular form the connections will take may differ very widely, according to circumstances. Three forms are shown in Figs. 298 and 299. As, however, these involve the handling of pipes of considerable size such work may more properly be considered as mainlaying than as meter fixing. A perusal of the chapters devoted to that subject, and to jointing, will afford such information as is necessary.

By-pass connections.—It is usual in fixing large meters to also fix a by-pass connection, so that in the event of inspection or repairs being required the gas supply may be continuously maintained while the meter is out of use.

The by-pass takes the form of a direct connection between the service and the outlet from some convenient point behind the inlet valve or main cock. Two common forms are shown in Fig. 298-9. The use of a by-pass necessitates the employment of three valves, one each on the inlet, the outlet, and the by-pass, so arranged that the two former are nearer to the meter than the by-pass connection. Usually the by-pass valve is kept closed, but when the meter is to be thrown out of work the inlet and outlet valve are closed and the by-pass valve opened. The gas then passes direct from the inlet to the outlet without being measured. In such cases the consumption of gas must be estimated for the time the meter is off. To prevent any unauthorized interference with the by-pass valve when the meter is working, the latter is usually secured by a hinged strap passing round the valve and socketed on to the square of the valve spindle, locked, and sealed with wax. A simpler but less efficient method is to tie the valve round with tape in such a way as to prevent it being turned without the tape being broken, and then sealing the tape and valve with sealing wax.

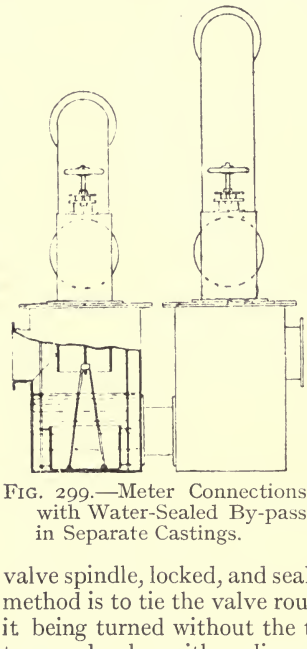


FIG. 299.—Meter Connections with Water-Sealed By-pass in Separate Castings.

Fixing meter to lead service.—In the case of lead services, the method of fixing corresponds generally with the examples previously given. Similar precautions as to fall must, obviously, be observed with these as with iron services, the service being well hooked to wall or otherwise supported, as may be necessary, to prevent sagging. The main cock and meter unions are soldered into the meter connections as previously described, care being taken not to heat the plug of the cock more than is absolutely necessary. The position for the cock should be so chosen as to throw the minimum of strain upon the soldered joints in the event of the plug becoming fixed or working stiffly.

CHAPTER XIX

PIPES AND JOINTS FOR INTERNAL FITTING

THE obvious first step precedent to a profitable discussion of the various matters connected with the internal fittings of premises is a consideration of the various kinds of tubes and joints generally used for this purpose. These may be cast-iron, wrought-iron, lead, composition, usually abbreviated to compo., block tin, copper or brass.

Cast-iron pipes and the various methods of jointing them have already received extended notice (Chapters VIII and X), and call for no further consideration here. This class of pipe is only used internally in the fitting up of very large premises, such as barracks, halls, mills, and factories.

In addition to the sizes of wrought-iron pipes commonly used for services, particulars of which are given on pages 233 and 235, these tubes are used for internal fittings as small as $\frac{1}{8}$-inch bore. The use of the latter cannot, however, be recommended. Nothing smaller than pipes of $\frac{1}{4}$-inch bore should be used, even for a single light. Not only is $\frac{1}{8}$-inch pipe, and especially any bends or elbows which may be used upon it, quickly stopped by corrosion, naphthalene or condensation, but the additional strength, and resistance to the torsionary strains involved in screwing, makes the use of tubes of $\frac{1}{4}$-inch bore both advisable and economical, notwithstanding the slightly heavier first cost. Labour costs are about the same in each case, so that only the difference in first cost of material has to be considered.

Standard dimensions and weights.—The standard dimensions and weights of these smaller tubes are shown on the next page.

The various joints used with these tubes will follow generally the lines of those shown on pp. 241 to 243, but for internal fitting a much wider range is necessary in each class. For instance, tees will be required which diminish through a large number of sizes at both ends and centres. An equally great variety will be needed in cross tees, elbows, and other fittings.

Tools.—In addition to the various tools usually included in a service layer's kit, a good portable bench and pipe vice will be necessary, if internal wrought-iron work is to be done economically. On premises of the larger kind, such as public schools, halls, etc., where a great deal of cutting and screwing of comparatively large sizes of

Standard Dimensions and Weights of Wrought-Iron Tubes.

Internal Diameter of Pipe.	¼-inch.			⅜-inch.			½-inch.		
	Quality.			Quality.			Quality.		
	Gas.	Water.	Steam.	Gas.	Water.	Steam.	Gas.	Water.	Steam.
Thickness of tube, B.W.G.	14	13	12	13	12	11	11	10	9
Decimal equivalent in inches	0.083	0.095	0.109	0.095	0.109	0.120	0.120	0.134	0.148
Approximate weight per foot run, lbs.	0.359	0.375	0.4375	0.515	0.5625	0.6875	0.8125	0.851	0.100
Number of threads per inch	19	19	19	19	19	19	14	14	14
Gauge diameter at top of thread	0.518	0.518	0.518	0.656	0.656	0.656	0.825	0.825	0.825
Depth of thread	0.0335	0.0335	0.0335	0.0335	0.0335	0.0335	0.0455	0.0455	0.0455
Length of screw on tube, in inches	⅜	⅜	⅜	½	½	½	⅝	⅝	⅝

pipes may be anticipated, it will also be necessary to provide a good screwing machine, such as that shown in Fig. 300.

Compo. pipes.—Composition pipes are tubes made of thin drawn lead, the walls of the pipes being much thinner than usual in lead pipe. In their manufacture, as the tubes are being drawn through the mould, they are washed and finely coated with block tin, both

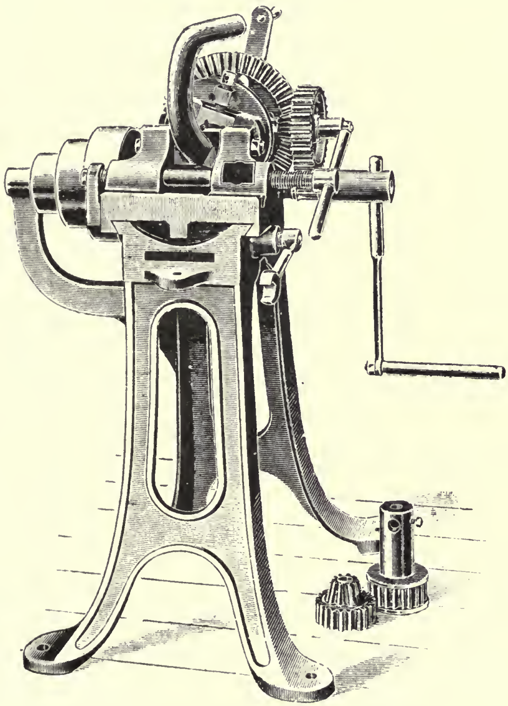


FIG. 300.—Screwing Machine.

internally and externally. This coating is necessary for several reasons. The lead piping of itself, drawn so thin, would be more or less porous. The tin washing fills the pores and makes a thoroughly sound and gas-tight tube. The hard tin sheath also tends to preserve the form of the pipe, which otherwise, in consequence of its softness, would undoubtedly become distorted in section. And, lastly, the coating assists to preserve the pipe during the sometimes unreasonably rough usage incidental to its being fixed; allows of comparatively short bends being made in it without kinking; and permits the pipe to be firmly hooked up in position without undue bruising.

STANDARD WEIGHT, IN POUNDS, OF TIN, COMPOSITION AND LEAD TUBES PER 100 FEET RUN.

Internal diameter in inches	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	4
Block tin	17.0	19.7	23.0	29.2	35.4	48.0	62.5	79.5	98.0	..	..	..	..	..	..
Composition	27.0	33.3	43.8	54.1	78.8	108.4	141.7	158.3	183.3	..	..	..	..	..	..
Lead	..	..	..	..	83.25	133.2	199.8	..	233.1	299.7	399.6	532.8	599.4	999.0	1531.8

Compo. piping is extremely useful and cheap for the purpose of fitting up premises requiring only a few lights. It may be used in long lengths, is easily bent round corners, adapts itself easily to all irregularities, and may be fitted into positions where iron piping would be clumsy and awkward. Junctions and fittings are reduced to a minimum, and joints may be easily, neatly, and soundly made by properly trained workmen. The pipes are perfectly smooth internally, in this respect having a great advantage over iron. As a result of this smoothness, friction is materially reduced, and consequently a compo. pipe of equal size will pass a correspondingly greater quantity of gas than will a wrought-iron tube. A still further advantage is that, whereas iron tubes corrode on their internal surface and the particles of rust so formed tend to obstruct the flow, especially if the tubes fall to some elbow or bend at the bottom of a section of rising pipe, the compo. tube is non-corrodible.

The table on this page gives the dimensions and weights of the common sizes of tin, composition, and lead pipe.

Both composition and lead tubes may be obtained either lighter or heavier than the weights given in the table. These are, however, fair average qualities. Compo. tubes are usually supplied in coils of $\frac{1}{2}$ cwt. to 1 cwt. each, and lead tubes in rolls containing from 10 feet, in the largest sizes, to 36 yards in the smallest.

Methods of jointing.—Successive straight lengths of compo. piping are joined together by the simple form of soldered joint shown in Fig. 301. The end of one of the pipes, A, is opened out by means of a conical boxwood wedge termed a tanpin, shown in Fig. 302, sufficiently to allow of the end of the other pipe, B, to enter and leave a cup-like cavity around it. The enlarged end of pipe, A, is then either filed or cut level, and the edge and cup thoroughly scraped, leaving a clear, clean, metallic surface.

The end of pipe, B, is then filed down to a chamfer, making an angle of about 45° with the line of the pipe, and for a distance of, approximately, twice the depth of the cup on A, the pipe, B, is scraped perfectly clean with a shaving hook, such as is shown in Fig. 303, or an ordinary pocket knife. The pipe, B, is then ready for placing in position in the previously cleaned cup on pipe A.

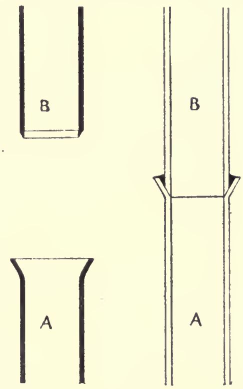


FIG. 301.—Simple form of Soldered Joint.

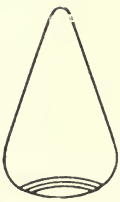


FIG. 302. Tanpin.

As an alternative to the method above described, Bailey's universal pipe jointer, shown in Fig. 304, is an excellent little tool. The long taper end, C, worked from right to left, is used to open out the end of the pipe. When sufficiently opened, the tool is twisted in the opposite direction, from left to right, and the cutting edge is brought into action

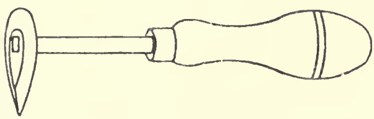


FIG. 303.—Plumber's Shave Hook.

to scrape the pipe perfectly clean. The pipe to form the spigot end of the joint is placed in the socket portion, B, of the tool, and

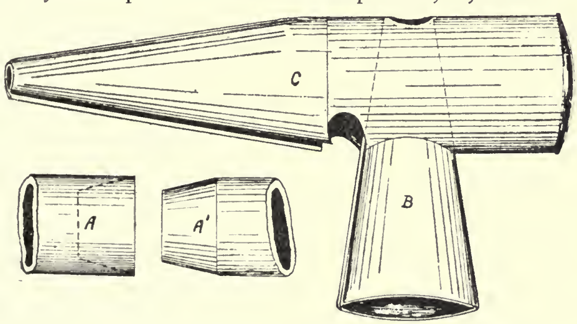


FIG. 304.—Bailey's Patent Universal Jointer.

the latter, in being rotated on the pipe, cuts it off, in spokeshave fashion, to the chamfer shown at A^1. The joint made in this way is exceedingly neat, the rather clumsy bulging, characteristic of the ordinarily made joint, being almost entirely avoided.

An excellent and ingenious tool for holding the two pipes perfectly rigid whilst the joint is being made is that shown in Fig. 305. The sliding arrangement of the two arms, coupled with the set screws at A, B, and C, admit of such a number of combinations as virtually cover the whole range of positions required for ordinary purposes. The combination set to suit a tee-joint is seen in Fig. 311.

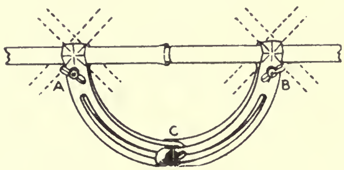


FIG. 305.—Pipe Holder.

The two pipes, being now in position, are gradually heated at the joint, by means of a blowpipe flame, to the melting point of a rich blowpipe solder made of two parts of block tin to one part of lead. The blowpipe flame may be obtained by either a mouth blowpipe, such as is shown in Fig. 306, in combination with a suitable gas, tallow candle, or spirit lamp flame, for the smaller sizes of joints ; or by an adjustable pressure lamp flame, such as is shown in Fig. 307, for joints of larger size. A little powdered resin is used as a flux, and the solder applied to the joint as required. It is important that the ends of both pipes to be joined should be uniformly and simultaneously heated to the melting point of the solder. If this is correctly done, and the pipes have been properly cleaned, the solder will readily run into the cup, and being followed round with the blowpipe flame, and reinforced from the solder strip to the extent necessary, will gradually fill the cup with molten metal. The latter, attaching itself to the cleaned surfaces of the two pipes, makes a thoroughly sound joint, which, when cold, is considerably stronger than the pipe upon which it is made. It is obvious that, for this kind of work, the solder should be prepared in comparatively thin strips or pencils.

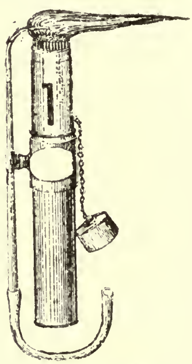


FIG 306.—Mouth Blowpipe, with Spirit Lamp.

It is important that, as the joint is being made, care should be exercised to ensure that any air bubbles which may be formed in the molten solder should be worked out. Unless this is done, pinholes may be left in the solder which will render the joint unsound. Should the solder not be rich enough in tin it will not run sufficiently easy, and trouble will be given in making a good joint, owing to the solder being too sluggish and inert. In that case, possibly the wall of the pipe may be melted away before the joint can be properly made. If either of the two pipes is not heated sufficiently, the cup may be filled with molten solder and yet the joint be a bad one. In that case the solder will not have attached itself to the cooler surface, and the two metals may be easily separated when cold. This, of course, seldom occurs round the whole surface of either pipe, except with worthless workmen, but may happen in places, through unequal heating. Again, if the pipes are heated too much, the solder may give trouble by running past the bottom of the cup into the interior of the pipe and reducing the clear gas-way ; or the edge of the cup on A may be melted down by over-heating ; or lastly, if the solder is not carefully applied, part of it may run down the exterior surface of the cup and form a most unsightly "wart" upon the pipe, which can only be neatly removed by melting it down still further by means of the blowpipe flame and wiping it off the pipe before it solidifies again.

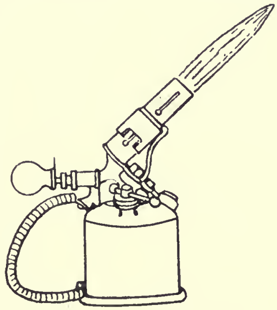


FIG. 307.—Blowpipe Lamp.

The tee joint shown in Fig. 308 is one of the commonest types of joint met with in compo. work, and is made in the following way. At the point in the main supply pipe, A, at which it is desired to take off a supply pipe, B, at right angles to A, a hole is bored in the latter with a plumber's gimlet, such as that shown in Fig. 309. The burr caused is filed down with the back of a half-round file to a sufficient extent and the hole worked out to the requisite size by means of round punches or other similar tools. The edges round the hole should then be either filed or pared to give a good jointing surface, and the surface thoroughly cleaned by scraping.

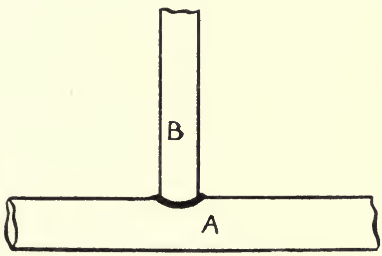


FIG. 308.—Compo. Tee Joint.

The end of pipe, B, which is to be inserted into A, is filed down to a short chamfer, and the surface of the pipe thoroughly scraped for a distance of $\frac{1}{2}$ inch to 1 inch from the end. This chamfered end should fit tightly into the hole in pipe, A, without intruding more than is absolutely inevitable into the clear gas-way of that pipe. Great attention must be given to this point, as, in the case of a too loose fit, the inserted pipe may, in jointing, be pressed so far in to the main supply pipe as to cause a serious obstruction to the flow of gas in the latter.

When the two pipes have been thoroughly prepared, they are placed in position, heated in a blowpipe flame, and the joint made with solder in a similar way to that already described in the case of the " end-on " joint.

It is obvious that these two joints are most easily and simply made when, as in the example shown in Fig. 301, the pipes, A and B, are in the same vertical plane, and in that shown in Fig. 308, the pipe, A, is in the horizontal and the pipe, B, is in the vertical, and rises from A. In that case the molten solder is caused to flow within and fill a horizontal cup in a natural position, and the force of gravity assists the workmen in making a perfect joint. But in actual practice these conditions do not always obtain. In the case of the tee joint, indeed, the position is frequently exactly reversed, the vertical pipe, B, being taken from the under side of the horizontal pipe, A, instead of the upper. And, in addition to this, the " tee " and " continuation " joint will often have to be made when both pipes are in the horizontal plane, and consequently, the joint itself is in the vertical. A very common form of tee joint also is that shown

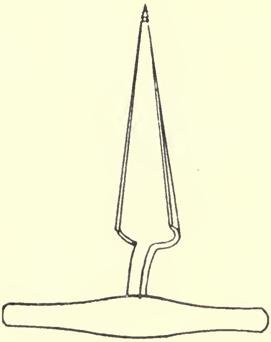


FIG. 309.—Plumber's Gimlet.

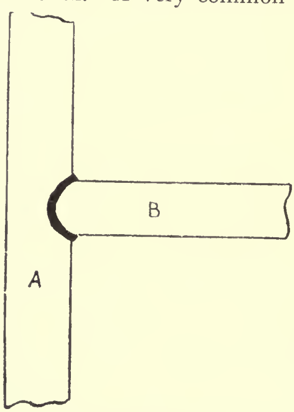


FIG. 310.—Vertical Compo. Tee Joint.

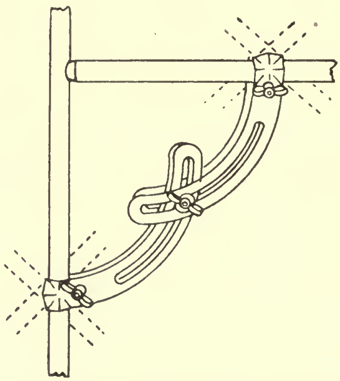


FIG. 311.—Patent Pipe Holder, arranged for Tee Joint.

in Fig. 310, where a horizontal branch is taken off a main running in a vertical direction.

It is easily seen, therefore, that in all such cases much greater care will have to be exercised in heating the pipe to the exact and uniform temperature required. If too much heat is applied, the solder, instead of lying in an even layer around the joint, will run to the bottom, forming a useless and ugly "wart" of metal, whilst the upper part of the joint is left very weak. To prevent this happening, the upper part of the joint is brought to the melting point of the solder slightly in advance of the remaining portion, and as the solder is applied there, it is followed round with the blowpipe flame until an even layer of the solder is deposited and attaches itself to both the jointing surfaces, and a sound and satisfactory joint is obtained.

Another form of tee joint, sometimes used in compo. work, is the saddle joint, shown in Fig. 312. In this the pipe, A, is bored out to the required size, and the pipe, B, instead of being chamfered off to fit within the hole made in the main supply pipe, A, is shaped at the end, with a round or half-round file, to fit over A in the form of a saddle. To make the joint, the surface of A, contiguous to the hole, and the shaped end of B are thoroughly scraped clean, and a soldered joint made with the blowpipe, in a somewhat similar way to that previously described.

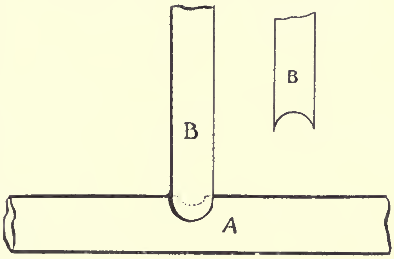


FIG. 312.—Compo. Saddle Tee Joint.

The saddle tee joint has one obvious advantage over the inserted joint, in the fact that no obstruction can be caused in pipe, A, by the projection into its clear gas-way of the end of pipe, B. On the other hand, the saddle is not so easily made as an insertion joint, and, when made, is not so sound and strong, and will not bear such rough usage as the latter.

Another method of making a tee connection to a compo. pipe is by using a brass union tee, as shown in Fig. 313. This, as will be seen, consists of a brass tee body fitted with caps and linings at the centre and one or both ends. These linings are soldered into the compo. in the way described later, and the attachment made to the body of the tee by means of the loose cap, as in the case of a meter connection.

These union tees have the advantage of keeping the gas-ways of the pipe free from obstruction and of making a very strong attachment. On the other hand, they are clumsy in appearance, and the use of them involves making three soldered joints, or six joints in all, for each tee. The inserted joint is much neater in appearance, is, of course, more quickly made, is strong enough for all practical purposes, and is, therefore, the one most generally adopted.

In common with brass and copper tubes, compo. pipes readily lend themselves to the making of elbow joints at any angle. This is a valuable advantage where pipes are carried in view round sharp corners, such as woodwork, and great neatness and accuracy of fit is required.

To make a mitred joint, a wedge-shaped piece is cut out of the pipe, as shown in Fig. 314. This will, of course, vary in size with

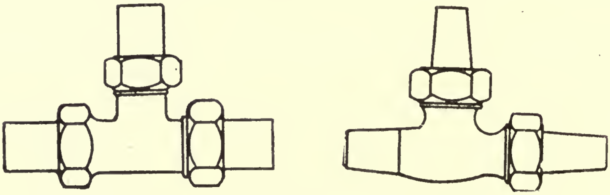


FIG. 313.—Brass Union Tee Joints.

the degree of obliquity or acuteness desired in the elbow. For a right angle the line of cut, A B, must obviously make an angle of 45° with an imaginary vertical line, C D, passing through the centre

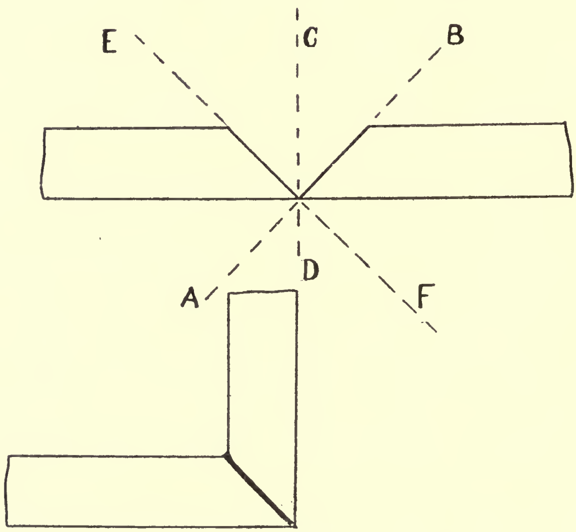


FIG 314.—Mitred Compo. Joint.

of the cut, and the same with the line of cut, E F. Whatever kind of elbow is required, the angle of cut must be equal upon either side of the vertical.

When the cut has been correctly made, and the burr resulting therefrom removed from the inside of the pipe, the cut surfaces are scraped quite clean, and the pipe bent over, surface true to surface.

The sharp edge of a half-round file should then be passed lightly round the cut edges of the joint, to form a slight channel for the solder, and the joint made by means of a blowpipe flame, as in the case of the tee joint.

Hitherto, in discussing the question of soldered joints, we have considered only the cases of jointing compo. to compo. But in the case of meter connections, and for the attachment of compo. tubes to the various brackets, pendants, and other fittings of a consumer, it is necessary to solder compo. and brass together, so as to admit of a screwed connection. As an example of this type of joint, we will take the simple case of a meter connection.

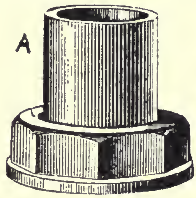


FIG. 315.—Brass Meter Union.

The first thing to be done is to thoroughly tin the lining, A (Fig. 315) of the meter union. This must be well cleaned, and roughened in the process by using a medium file, the roughness giving grip to the coating of solder, which is then applied with a soldering bit and a flux of resin. Fig. 316 shows a very good type of soldering bit, adjustable to any position, as may be needed, with handle protected to ensure comfort in working.

The end of the compo. pipe is then opened out by means of a tanpin, or Bailey's jointer, sufficiently to allow the lining of the union to enter to the depth of about ⅛ of an inch or more, according

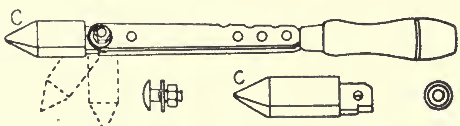


FIG. 316.—Soldering Bit.

to the size of the pipe. The compo. thus opened forms a wedge-shaped cup around the lower portion of the lining. This cup is filed or cut perfectly level at the end, and well scraped on the edge and in the opened portion, with a knife or scraper.

The lining is then pressed tightly home within the cup and held in position, either by a lad or a tool, whilst the joint is being made. By means of a blowpipe flame the brass union is heated to the melting point of the solder. A small quantity of resin is used as a flux, and the end of a thin strip of solder applied to the heated brass. As the solder liquefies it runs down and fills the cup, and firmly attaches itself to the compo., which during the process has become sufficiently heated to receive the solder. The latter, in its flow, is followed round with the blowpipe, any slight irregularity in the heating is rectified, any possible air bubbles worked out, and sufficient solder applied to fully fill the cup. The joint may then be allowed to cool, a little oil or tallow being applied to facilitate removal of the resin floating upon the surface of the solder.

The same method of jointing is employed for all brass or copper and compo. attachments, and the example just taken is sufficiently illustrative of the whole range of these operations, from the soldering together of $\frac{3}{8}$ copper and compo. tubes to the making of joints on large meter connections.

Block tin tubes.—Block tin tubes are made in a very similar manner to the compo. pipes, but from pure tin. They are extremely thin, light, and durable, but much more costly than the heavier classes of tubes. They share, equally with compo., the advantages pointed out in an earlier portion of this chapter. They have obvious advantages in cases where cost of transport renders the use of other kinds of pipes almost prohibitive. Block tin tubes are not generally used for gas in England, but in Scotland they have been somewhat extensively used. They are manipulated in the same way as compo. tubes, and the various joints are made in a similar manner. Owing to the comparatively low melting point of block tin, an exceptionally rich solder must be used. Even then, joint making on these tubes is a matter of great delicacy. The wall of the pipe may easily be melted down by a degree of overheating which would be negligible in the case of compo.

Brass tubes.—Brass tubes for gasfitting are made from strips of sheet brass, manufactured from an alloy of copper and zinc. The strips, on being passed through "cupping rolls," are bent round to the partially circular form. Being then transferred to the "conductor," the strip is bent to its final shape and the edges brought into close contact. The tube is then bound round at intervals with wire to maintain contact between the edges whilst they are being soldered together in the furnace, granulated brass being used with a flux of borax for this purpose. When the operation has been completed, the wires are cut away, the superfluous solder removed, and the tube pickled in sulphuric acid. A further passage through the "conductor," this time with a mandril placed within the tube, completes the manufacture.

Copper tubes.—The copper tubes used for gasfitting purposes are made in a very similar manner to the preceding, except that the superfluous solder is not removed from the joint, this being usually left in the condition in which it leaves the furnace. The seam in both brass and copper tubes is their weak spot, as the solder, which is a mixture of zinc and brass, sets up a galvanic action which leads to its destruction. Only solid drawn copper tubes should, therefore, be used in work which is out of sight.

How to obtain the weight of brass tubes from the table.—The table on page 353 shows the various standard weights and dimensions of copper tubes.

Brazed copper tubes which are not mandril-drawn are rather heavier than the above weights for the same thickness, varying in degree with the character of the joint. The weights of brass tubes of similar size and thickness may be obtained by multiplying the weights given in the table by 0.994 for a 2 to 1 alloy and by 0.9626 for a 70 to 30 alloy.

Use of brass and copper tubes in internal fitting.—Apart from their use in the manufacture of the various fittings, such as brackets

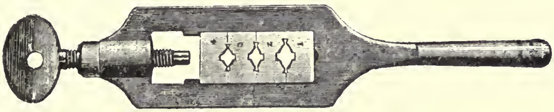


FIG. 317.—Stocks for Brass Tubes.

and pendants of one kind and another, a use which is outside the scope of this work, brass and copper tubes are used for the purpose of internal fitting, principally in their smaller sizes, for connecting up the pendants or brackets to the piping of the premises. This is especially the case where premises are fitted with compo. pipe. In one form or another, brass or copper tubes are an indispensable intermediary between the compo. pipe and the brass work of the bracket back or pendant head. For this purpose they are threaded

STANDARD DIMENSIONS, THICKNESS AND WEIGHTS PER LINEAL FOOT, IN POUNDS, OF MANDRIL-DRAWN BRAZED COPPER TUBES.

B. W. G.		20	19	18	17	16	15	14	13	12
Internal Diameter in										
mm.	Ins.									
9.5	$\frac{3}{8}$	0.17	0.21	0.25	0.31	0.35	0.39	0.46	0.54	0.64
12.7	$\frac{1}{2}$	0.23	0.28	0.33	0.39	0.45	0.50	0.59	0.69	0.81
15.9	$\frac{5}{8}$	0.28	0.34	0.40	0.48	0.55	0.61	0.72	0.83	0.98
19.0	$\frac{3}{4}$	0.33	0.41	0.48	0.57	0.65	0.72	0.84	0.98	1.14
22.2	$\frac{7}{8}$	0.39	0.47	0.55	0.66	0.75	0.83	0.97	1.12	1.31
25.4	1	0.44	0.53	0.63	0.75	0.84	0.94	1.10	1.27	1.47
28.6	$1\frac{1}{8}$	0.49	0.60	0.70	0.84	0.94	1.05	1.22	1.41	1.64
31.7	$1\frac{1}{4}$	0.55	0.66	0.77	0.92	1.04	1.16	1.35	1.56	1.81
38.1	$1\frac{1}{2}$	0.65	0.79	0.92	1.10	1.24	1.38	1.60	1.85	2.14
50.8	2	0.87	1.05	1.22	1.45	1.64	1.82	2.11	2.43	2.80

at one end with stocks and dies, shown in Fig. 317, in a similar way to iron tubes, and, at the other end, are soldered into the compo. pipe in the way previously described in the case of a meter union. Speaking generally, brass tubes are most frequently used when the pipes are in view and a degree of neatness in appearance is desired ; but where the pipes are covered up, or in damp situations where corrosion is to be feared, the use of copper tubes is to be preferred.

Importance of proper size and proportioning of internal piping.— We have already seen that the distributory mains of a district should be properly proportioned to the work required of them, that they should be too large rather than even slightly inadequate, and that some degree of forethought should be exercised in view of the contingency of further extensions being required. It is obvious that exactly the same principles apply to the consumer's premises, especially when these are of a large and extensive kind. This is a subject which has received, and must undoubtedly receive, a considerable amount of attention from gas undertakings. Much annoyance and expense, both to the consumer and the undertaking, are caused through an unwise economy on the part of builders in fitting premises with pipes of an inadequate size or in improper proportions. So acutely has this been felt that many undertakings now issue a schedule to be observed in this matter, and also exercise a right of inspection and testing whilst premises are still in the "skeleton" condition, and when, consequently, any imperfections may be put right with the least disturbance, and at a minimum of expense.

Size of Pipe in Inches.	Greatest Length allowed, in Feet.	Greatest Number of Burners allowed.	Remarks.
$\frac{3}{8}$	20	3	In this table the consumption per burner is estimated at 6 cubic feet per hour.
$\frac{1}{2}$	25	6	
$\frac{3}{4}$	40	20	
1	60	30	
$1\frac{1}{4}$	100	60	
$1\frac{1}{2}$	150	100	
2	200	200	
$2\frac{1}{2}$	300	300	
3	450	400	
4	600	700	

The table on page 354, being substantially what is recommended by such authorities as Mr Thos. Newbigging, the North British Gas Association of Gas Managers, and the Consolidated Gas Company of New York, may be considered fairly typical and satisfactory.

The "Regulations" issued by the Commercial Section of the Manchester District Institution of Gas Engineers, which contain the following table as to proportioning internal pipes, agree fairly well with the preceding schedule :—

Internal Diameter of Pipe in Inches.	Greatest Length allowed, in Feet.	Maximum Number of Lights allowed.
$\frac{1}{4}$	6	1
$\frac{3}{8}$	20	3
$\frac{1}{2}$	30	6
$\frac{5}{8}$	40	11
$\frac{3}{4}$	60	18
1	80	35
$1\frac{1}{4}$	100	60
$1\frac{1}{2}$	150	100
2	200	200
3	400	450
4	600	800

In order to have a sufficient margin in proportioning consumers' fittings, consumption should be allowed for at the following maximum rates, viz. :—

Flat-flame burners, each	6 cubic feet per hour.
Ordinary upright incandescent burners .	5 ,, ,,
,, inverted ,, ,,	4 ,, ,,
Bijou ,, ,, ,,	3 ,, ,,
Griller	15 to 20 ,, ,,
Cooking stove (according to size) from .	80 ,, ,,
Geyser ,, ,, ,, .	40 ,, ,,
Gas fire ,, ,, ,, .	25 ,, ,,
Gas engine (per h.-p.)	25 ,, ,,

It is understood, of course, that all the above figures give a margin even above the maximum rates of consumption which should, in any ordinary case, be anticipated. They may vary very considerably, according to the size of burner, stove or engine employed and the conditions of working. For instance, although 25 cubic feet are allowed above, the best makes of gas engines are now turned out to take only about 16 cubic feet per horse-power per hour, for continuous working under normal conditions.

CHAPTER XX

INTERNAL FITTING

It is obvious that the time when consumers' premises may be most easily and economically fitted with the necessary piping for gas consumption is when they are in course of construction, and before floors are laid or plastering is commenced. Pipes may then be buried in the walls, or laid under the flooring, with a minimum of disturbance; labour costs are lessened, and the whole work greatly facilitated by being undertaken at this stage. Fortunately, this is now so generally recognized that it is quite the exception for new property within any area of supply to be built without its being done. Occasionally, however, the work has to be taken in hand in connection with old property, and a consideration of such as applied to cottages will be a convenient starting-point for a discussion of internal fitting.

Fitting pipes in old property. Example I.—Assume, then, that we have an old cottage or dwelling-house to fit up with gas pipes. The pipes may be either let into the plaster or left to show upon the surface. The amount of dirt, disturbance, and cost will necessarily be much greater in the former than in the latter case. But as in a cottage there is no very great objection to the pipe being in sight, that is the course usually taken.

The first thing, of course, is to determine the position of the lights, which we may presume will consist of pendants in front room and kitchen, bracket in scullery, and brackets in two bedrooms. The exact positions of the pendants will generally be determined by the arrangement of furniture, shape of the room, and other local circumstances; but assuming that the room is fairly square in plan, with a table more or less in the centre of the room, then the pendant should also be approximately in the centre of the room, or a little nearer the fireplace than that exact point. If this position should happen to coincide with that of one of the joists carrying the floor above, and it is intended that the pipes should be in view, the pendant head may be screwed directly to the joist. Failing this, a portion of the floor boards in the room above, directly over the position of the pendant, must be taken up and a wood block fixed in the floor space, between and securely nailed to two adjacent joists, as shown in Fig. 318. A hole must then, of course, be cut through A, at the exact point through which the pipe runs. When the precise position for the pendant has been determined, a long gimlet (Fig. 320), passed through the ceiling and the covering floor board, will show in the room above the correct position for the block. If this happens to lie at the side of a joist, the supporting block, A, may take the form shown in Fig. 319. A notch is cut out for the pipe to pass through, and the block then nailed to the side of the joist, as shown.

The bedroom brackets will be most conveniently placed by the

Fig. 318.—Wood Block between Joists.

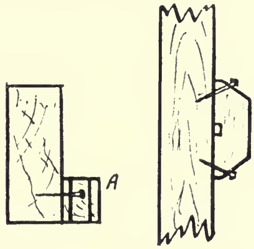


Fig. 319.—Elevation and Plan of Wood Block Nailed to Side of Joist.

side of the window, for two obvious reasons. Such a position suits the general arrangement of the furniture much better than any other, and prevents objectionable shadows being thrown upon the blinds. The height of the bracket from the floor is usually about 5 feet. For similar reasons to the foregoing, the bracket in the scullery is usually fixed by the side of the window. In both cases, when the positions of the lights have been determined, the wall must be plugged with wood for the support of the bracket.

If the piping is to be in view, it will be found most convenient to use compo. This requires fewer joints, is handier to use, accommodates itself most easily to any irregularities in the walls of the

Fig. 320.—Long Gimlet.

rooms, and involves less injury and disturbance to the property than does wrought-iron tubing.

It is assumed that the meter will be fixed either in the cellar, or cupboard in room at the front, or in kitchen or scullery at back of the house. The positions of the lights having been determined, the necessary holes through walls and ceilings having been made, the walls plugged and the ceilings blocked, where necessary, we are now in a position to commence fixing the piping.

The horizontal pipe will, most naturally, be fixed in the angle made by the ceiling with the wall of the room. But ceilings are not always perfectly true. To ensure perfect alignment of the pipe a string line should be stretched along the wall upon which the pipe is to be carried. This serves to show the exact line for the pipe hooks, which, with the clasp portion opened wide, should be partially driven into the wall at intervals of about 15 inches apart. These hooks will then be ready to receive the piping as the work proceeds.

Starting from the meter, or other convenient point, the compo. piping may be unrolled into position, run up the wall angle, bent over at the ceiling on to the pipe hooks already in position, unrolled along the wall, and passed through the partition wall into the kitchen. In the kitchen the same process will be repeated, and the tubing carried through into the scullery, where the horizontal run of pipe ends. As it is obviously impossible to pass a roll of piping through a small hole in a wall, the tube must be cut in both rooms so as to leave the ends sufficiently upon one or other side of the wall to allow a joint to be made, as shown at Fig. 301, p. 345.

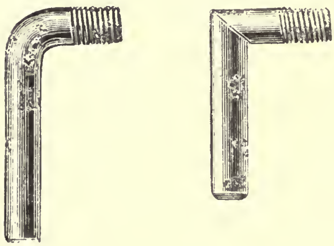


Fig. 321.—Bent and Brazed Elbows.

Preparation must now be made for the branch pipes to supply the pendants in front room and kitchen, by stretching our line across the ceiling from the position of the light, at right angles to the main pipe, which is already loosely in position. Along this line, hooks with clasps open should be partially driven into each of the joists carrying the floor above. The position of these joists may be easily determined by lightly tapping the ceiling with a hammer. The difference between the resistance of the solid portion, due to the presence of the joist immediately above, and the hollow portion between the joists is very noticeable.

The bent or brazed elbow (Fig. 321) which forms the connecting piece between the compo. pipe and the pendant head (Fig. 327) should be firmly soldered into the end of the branch pipe before the latter is placed in position. When this has been done, a length of the pipe which, with the elbow, will exactly reach from the main pipe to the position of the pendant is cut off and placed upon the hooks prepared to receive it, and a tee joint made between it and the main supply pipe, as shown in Fig. 310. Care, of course, will be exercised to see that the end of the brazed elbow looks squarely in a downward direction before the tee joint is made.

The pipe to supply the brackets in the two bedrooms will now demand our attention. We will assume that the position for this is immediately over the main supply pipe, now lying loosely upon the hooks in the room below. It will then be necessary to remove a portion of the skirting board in the bedroom and cut a hole through the floor board and through the ceiling for the rising pipe to pass through. As an alternative, in place of removing the skirting board the plaster may be cut away from behind it with a long, thin chisel, and a portion of the brickwork too, if necessary, to give room for the pipe to pass. Should the end joist carrying the floor run parallel and close to the wall upon which the bracket is to be fixed, as shown at A (Fig. 322), it will be necessary to take up a floor board and either chase a groove in the brickwork, as shown at B (Fig. 322), to allow the pipe to pass between joist and wall, or notch the top of the joist and carry the pipe into the room below, down the side of the joist farthest from the wall, as shown at C (Fig. 322). As this last involves four bends in the pipe, the plan should never be resorted to if it can possibly be avoided. A line of hooks to receive and fasten

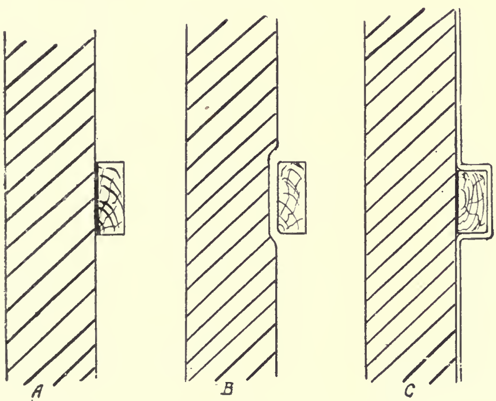
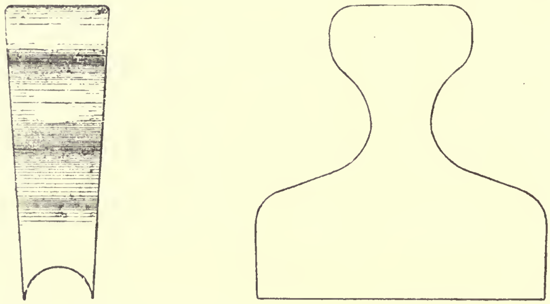


Fig. 322.—Joist placed close to Wall.

the upright pipe should be fixed in the wall. The joints of the brickwork of the wall may be found with a bradawl or pricker. Should the joints be wide, or the mortar poor, the wall must be plugged with wood to receive the hooks.

The exact length of piping which, with the brazed elbow (Fig. 321), will be required may now be cut off, and the elbow soldered into one end. The other end is then passed through the floor by the hole already cut to receive it, and a tee joint made with the main supply pipe, as shown in Fig. 308, p. 347. Here, again, care must be taken to see that the horizontal or nozzle portion of the elbow looks out squarely from the wall, in readiness for the bracket attachment, before the joint is made in the room below. And as this joint, in common with the horizontal tee joint for the pendant supply pipe, is placed close to the ceiling, and very difficult of access when the pipe is finally fixed in position, very great care must be exercised to ensure a thoroughly sound and perfect joint.

If the main supply pipe does not pass directly beneath the position determined upon for the bedroom bracket, the piping for the latter



Side Elevation. Front Elevation.

FIG. 323.—Compo. Straightener.

must be passed through the floor, in the way previously described, and then carried round the ceiling angle of the room below, and jointed up to the main pipe by means of a tee joint, as shown in Fig. 310, p. 348. As an alternative to this, the pipe may be run round the top of the skirting board in the bedroom until it is brought immediately over the pipe in the room below. As a third alternative, the necessary floor boards may be taken up and the bracket pipe carried under the floor to the most convenient point for jointing up to the piping in the room below.

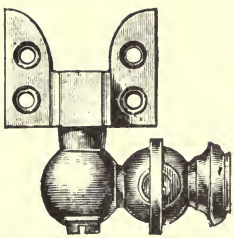


FIG. 324.—Wing Bracket Back.

The joints having now been all made, the pipes may be straightened up, all irregularities taken out, and the pipes properly bedded to the walls and ceilings by means of a hammer and grooved piece of wood (see Fig. 323). The hooks may then be driven home, the clasps gently tapped round to fit the pipe, and this part of the work finished off and left in a shipshape and workmanlike manner.

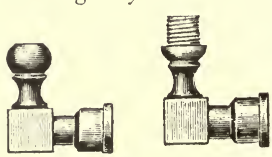


FIG. 325.—Elbow Burners.

The arrangements for gas supply in the kitchen and back bedroom being similar to those in the front rooms, the various operations detailed in the preceding paragraphs will necessarily be repeated there, and there is no need to go over the ground again.

The piping which has been taken into the scullery may be brought to the side of the window, or other convenient position. The pipe should end either with a brazed elbow similar to those used for the bedroom (Fig. 321), or, in work of a cheap character, may end in a short piece of brass or copper tube, set off to connect with a wing bracket back, such as that shown in Fig. 324. A very cheap bracket may be made of such a bracket back and short length of $\frac{3}{8}$-inch brass tube and elbow burner (Fig. 325).

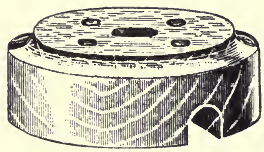


Fig. 326.—Grooved Block.

The piping having now been fitted throughout the house, the system should be thoroughly tested for soundness, in the manner described later in this chapter. If the work has been done in a careful and workmanlike manner, it will stand any reasonable test, and we may therefore now go on to consider the fixing of the various brackets and pendants.

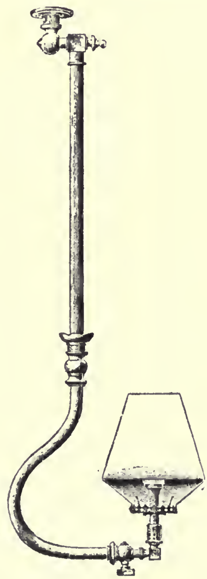


Fig. 327.—Kitchen Pendant.

First of all, a round moulded mahogany block, grooved at the back to fit over the pipe (see Fig. 326), must, in the case of the pendant (Fig. 327), be firmly screwed up to the ceiling by means of wood screws. These pass through the mahogany block, and are screwed into either the joist or the special rough block which has been previously fixed in the floor space, as shown in Figs. 318 and 319. In the bedroom these blocks (Fig. 326) will, of course, be firmly screwed up to the wall, by means of wood screws driven into the plugs fixed previously, as described. In both cases the threaded end of the brazed elbow must project through the block sufficiently, and only sufficiently, to connect properly into the gas fitting adopted. These mahogany blocks afford a firm and neat base to which the fitting may be attached, and give rigidity and strength to the attachment without involving the slightest strain upon either pipes or joint. The threads of the elbow are then well smeared with white lead, or other mastic, and the ceiling plate, pendant head, or bracket back carefully screwed tightly home upon it. If the projecting portion of the elbow is of the correct length, the pendant head or bracket back will be brought into close contact with the mahogany block, to which, when in position, it is securely attached by means of small brass screws. When all the various fittings have been fixed, the whole system should again be tested thoroughly for tightness, and any possible fault remedied.

The next and final stage in the business will be to connect up the outlet of the meter. The meter, it may be assumed, will have already been fixed, as described in a previous chapter. At the commencement of laying the main supply pipe, the end near the meter will have been left sufficiently long to make the necessary connection. This must now be bent to the shape and position required, and cut to the correct length. The end may then be bent upwards, and the meter joint soldered in, as described on p. 351.

The main cock may now be turned on, and gas admitted through the meter. The bracket and pendant taps having been opened, the air in the piping system and the meter must be blown away through the burners. As the proportion of air becomes less and less, the mixed gas and air issuing from the burner should be lighted

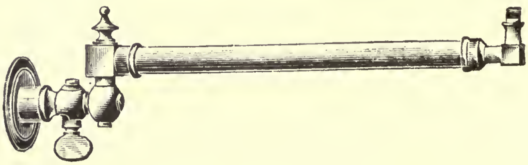


FIG. 328.—Bedroom Bracket.

as soon as possible, and kept lighted until the whole of the air has been expelled. The supply should then be in perfect order to hand over to the consumer.

Example II.—The next case, that of an old dwelling-house which is to be fitted up with piping for a gas supply, and in which all the pipes are to be buried in the plaster on the walls, or in the floor spaces, will not detain us long. Here either wrought-iron or compo. pipe may be used. But inasmuch as the use of iron pipe would inevitably involve much more disturbance of the fabric of the building than compo., in most cases it will be found both more convenient and cheaper to adopt compo.

The position for brackets and pendants must be determined as before, and the shortest and best route for the main and subsidiary pipes decided upon. Where the route taken traverses the wall areas, a narrow groove of sufficient width and depth to receive the pipe and allow of it being covered must be cut in the plaster and underlying brickwork. To ensure this being done in a neat and satisfactory manner, and to make certain of definite and uniform fall for the pipe, the horizontal chases should be very carefully lined out before they are cut. The walls must also be plugged to receive the bracket attachments.

A sufficient number of the floor boards in the room through which the pipe passes from front to back must be removed to permit of the pipe being placed in position. At least one board must be over the position for the pendant in the room below, and another at the point of junction of the lateral subsidiary pipe with the main supply pipe. Blocks will also have to be fixed in the floor space, as shown in Figs. 318, 319, to which the attachment for the pendant in the room below may be made. Wherever the pipe crosses the joists at right angles, the crossing should always be arranged as near to the joist ends as possible. On no account should the piping be taken across the centre of the room at right angles to the direction of the joists, as here the weakening effects of the notching of the joist is at its maximum. Where compo. piping crosses a room in the floor space and alongside a joist, it is usual to support the pipe by grooved wood strips, as shown in Fig. 329, where A is the grooved strip, and B is the joist to which it is securely nailed. This gives the pipe a support throughout its entire length, and prevents the sagging which might otherwise take place between the supports if only hooks were used. These strips are made by cutting, say, $2\frac{1}{2}$ by 1 inch deals, according to the size of the pipe to be supported, down diagonally, and grooving the thick side out to fit the piping. The strips are then cut into such suitable short lengths as may conveniently be introduced into the floor space without disturbing too many floor boards, and firmly nailed to the side of the joist, care being taken that they are fixed either perfectly level or with a slight fall to the main supply pipe.

FIG. 329.—Grooved Wood Strip Supporting Pipe.

Having now cleared the way by cutting the necessary chasing in the walls, notching the joists, breaking the necessary holes through partition walls, plugging the walls for brackets, and blocking the floor space for pendants, we may commence to run the piping. In the previous example, the run of piping in a single length was limited only by the convenience of handling and the distance apart of partition walls through which the pipe had to be threaded. A third factor is brought in in the present case, however, by the obvious necessity that all the joints under the flooring must be brought to readily accessible points, which may be more or less limited in number. In other words, the joints must be arranged for those points where it is possible to remove the floor boards to allow them to be made.

A suitable length of piping is therefore taken, keeping this requirement in mind, and either passed downward through the ceiling from the room above, or upwards from the room below, as may be most convenient. This will form the first length from the meter to the position of the first joint on the main supply pipe. Having bedded this very carefully into the groove cut into the wall, turned the pipe round the bends without kinking, and hooked it as far as possible into its place, we may proceed with the second length. This will be passed under the flooring from back to front, to meet length number one. Should this pipe cross the joists at right angles, care must be taken to see that there is no sagging of the pipe between the joists. If the piping runs alongside the joists, it must, of course, be properly bedded in the grooved supporting strips (Fig. 329). The piping should be carefully straightened out before being passed under the floor, and all irregularities removed. A similar proceeding with a third, and as many other lengths as may be necessary, will bring us to the end of our main pipe line.

The subsidiary pipe to supply the pendants will be jointed into the side of the main supply pipe by means of a tee joint, as shown at Fig. 310, p. 348. At the pendant end of this pipe, the common practice of carrying the compo. to within two or three inches of the pendant

FIG. 330.—Coil Syphon.

head and connecting to the latter with an equal length of brass or copper tube should be avoided. It is obvious that in screwing the pendant head to such a nozzle, there is great possibility and probability of twisting the compo. pipe and straining the joint. A much better plan is to finish the length of subsidiary pipe with about 18 inches, more or less, of brass or copper tube. This should be bent to the necessary shape, cut to the correct length, and threaded to fit the pendant head before being jointed to the compo. pipe. When this has been done, and the brass or copper tube securely hooked to the side of the joist, it is impossible to put any strain upon either the joint or compo. pipe without very violent wrenching, and any torsionary strain must be taken up by the copper tube itself.

It may occasionally happen that the pipe must be laid so that the fall is directly toward the pendant. Any possible condensation, however, should on no account be allowed to drain into the pendant itself. A syphon under the floor may be very readily formed by taking a sufficient length of piping from the main pipe line to form a coil of two or three rings of the tube, as shown in Fig. 330, the end of which may be stopped by a male and female gas cock and cap. This may lie upon the plaster in the floor space between two joists. A short piece of floor board should be screwed down immediately over the syphon, so that it is readily accessible. If necessary, the condensation may be removed through the cock into a saucer or other shallow receptacle. But generally the condensation collected in winter is evaporated again in the summer, so that in practice such a syphon rarely needs any attention. The supply pipe for the pendant is, of course, taken out of the upper portion of the coil by means of a compo. tee joint.

The subsidiary piping for the brackets required will, of course, be connected up in the same way as described in Example I., except that in this case the necessary tee joint will have to be made under the flooring instead of beneath the ceiling. The brazed elbow, too, must be longer at the threaded end by as much as the pipe is buried in the wall.

The pendants and brackets will, of course, be fixed in exactly the same way as described in the previous example, except that in this case, the pipes being buried in the wall and the flooring, the mahogany or other blocks used (Fig. 331), need not be grooved. It is unnecessary to traverse the same ground again.

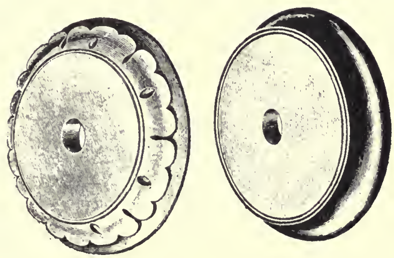


Fig. 331.—Moulded and Ornamental Strip Wood Blocks.

For the sake of clearness and simplicity, no mention of gas cooker, griller, or boiling ring has been made in the above description. But inasmuch as no cottage equipment is complete without one or other of these great conveniences, it is obvious that some provision must be made for them.

In the case of cottages such as those of the two examples above considered, no very special arrangement will be needed for supply to griller or boiling ring. In many instances it is inconvenient, through lack of suitable position, to have them permanently fixed at all. A tee joint on the compo. pipe supplying the scullery bracket, a length of pipe sufficient to carry the supply to the most convenient point, and ending with a gas cock and nozzle, to which flexible tube may be attached, will be all that is required. Of course, where it is possible to find a place where the stove may be permanently fixed, this should always be done. The compo. piping in that case is carried to a point in close proximity to the stove, and the latter connected up with the union gas cock (Fig. 332), with a short length of brass or copper tube.

Where cookers are used in cottages for ordinary domestic purposes, they are not generally of sufficiently large size to need very special provision for supply. It is always advisable in fitting up such property to carry a large enough pipe through into the scullery to be equal to any reasonable demands on it for this duty. The provision may be made very economically when premises are being fitted up; the only extra expense being the slight difference in first cost of piping, an extra which is quite inconsiderable beside the convenience secured, labour costs being about the same in either case.

Example III.—We come now to our third and final example, final because all others are simply enlargements and adaptations to local circumstances of the principles and practices which are here enunciated. The system of piping for the factory, workshop, warehouse, retail establishments, etc., are simply extensions, of greater complexity, but of essentially similar character, to those of more moderate-sized installations. The larger premises will, of course, need much more careful planning, but that planning will run along the lines of greater elaboration of detail, combined with perhaps more accurate and systematic proportioning of the piping, rather than in difference of principle.

We will take as this example a villa residence having cellar, ground

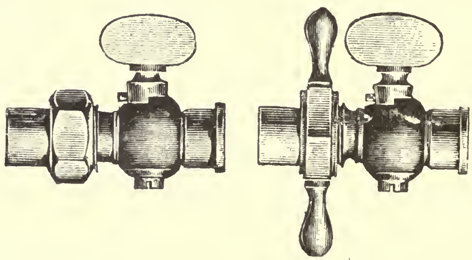
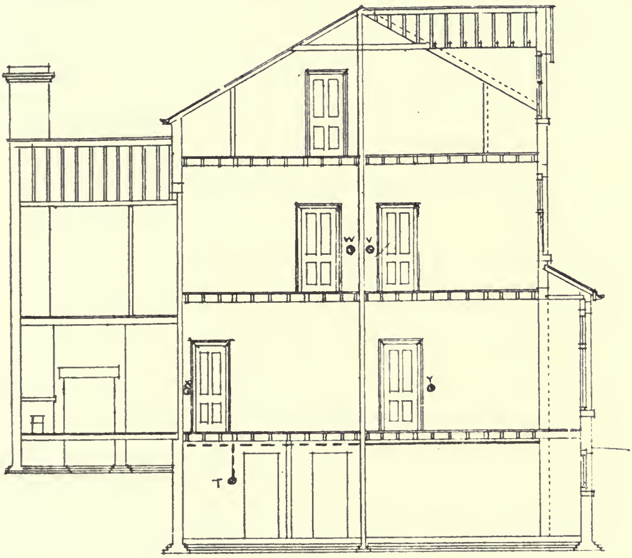


FIG. 332.—Union and Wing Union Gas Cocks.

floor, first floor, and attic, as shown in Fig. 333. We will also assume that the premises are to be fitted with piping whilst they are in the skeleton condition, or in course of erection, and before the plastering has been commenced, or the floor boards laid down.

In premises of this character, fitted under these conditions, no compo. piping should be used. The whole system should be built up of first-class quality wrought-iron tubes. It should really be accepted as an axiom that in all cases where piping is to be buried in walls or floor spaces only wrought-iron pipes should be used. It has already been pointed out that compo. pipes have certain advantages over iron in being smoother in the internal surface, and non-corrodible, etc. But the risk of injury to piping or joints during completion of building operations, and the disadvantages inseparable from the use of piping which a chance nail or tack may penetrate, throw the balance of advantage rather heavily to the side of the more cumbersome but more solid, substantial, and practically undamageable wrought-iron pipe. The only exception to this rule should be in such a case as was taken for the second example, where practical considerations of convenience, coupled with the difficulty of fitting iron pipes in finished buildings, makes the use of compo. the easier and more economical.

The first thing necessary is, of course, to fix the exact positions for the various lights throughout the premises. These will be determined mainly by the size, shape, and character of the rooms, and the degree of illumination required. Lights for bed and bath rooms will be best near windows, and other lights as shown on floor plans



Section through A—B, Fig. 336.
FIG. 333.—Elevation of Premises.

in Figs. 334 to 338, or as may be determined by considerations of convenience. The various positions are shown by small circles.

The second is obviously to choose the best and shortest route for the supply pipes and the most convenient position for the rising main, meaning by that, the main from the meter to the ceiling of the ground floor rooms. This should be placed as centrally as the local circumstances allow, so that the lateral pipes running from it may be as short as possible. The position for the rising main is shown on the plans in Figs. 334 to 338. The most suitable position for the rising main having been determined, the best route for the subsidiary mains may be arranged. The course taken should obviously be the most direct, except where this would lead across the centre of floors at right angles to the direction of the joists. In that case a less direct line, but one which will avoid cutting the joists across the centre of their span, should be adopted. It is a serious fault to use even a single foot of pipe more than is absolutely necessary.

In Chapter III., when dealing with the proper proportioning of mains, we found that it was necessary to work back from the extremities to the centre, considering what each section must supply, and adapting the size of main to the duty required of it. Precisely the same principle holds in connection with internal fitting. We must consider the quantity of gas required upon each floor, and in the different sections of each floor, and grade the piping accordingly, working back towards the meter, until we obtain the diameter necessary for the rising main. This may be done by a careful application of the table of lengths and sizes required given on p. 354 to the case in hand. If none of the lengths given exactly meets the requirements, the next size larger should always be taken. Short lengths

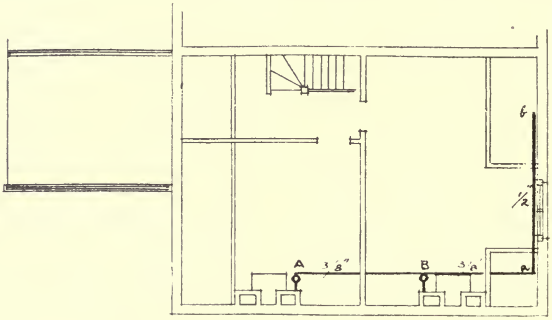


FIG. 334.—Attic Floor Plan.

of piping to supply single lights may be of ¼-inch internal diameter. Pendants supplying more than three lights should not be fitted with less than ½-inch piping. Gas fires may be fitted with pipes of either ⅜ or ½-inch diameter, according to size. Nothing less than ½-inch should be run for a cooking stove, while for a house of the size we are considering, ¾-inch piping should certainly be allowed. It is advisable, wherever it can be conveniently done, that this pipe should be run directly from the meter.

Proceeding to apply the table, and commencing at the attic, we find that bracket A requires 12 feet 6 inches of piping beyond B, and must, therefore, be of ⅜-inch diameter. Both A and B must have ¼-inch risers from the floor level, and these will terminate in cast-brass elbows (Fig. 335), to receive the bracket attachment. From B to *a* is 10 feet, *a* to *b* is 15 feet, and *b* to first floor level is 10 feet. The length, B*a*, may, therefore, be of ⅜-inch diameter, although this very slightly exceeds the length allowable in the table. The fact that they are both servants' bed-

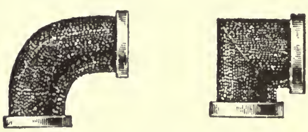


FIG. 335.—Cast-brass Elbows.

rooms, and, therefore, not likely to be used during hours of maximum consumption, together with their position at the top of the house, makes this permissible. From *a* to first floor level and junction to the rising main there, the piping must be of $\frac{1}{2}$-inch diameter. This pipe also supplies the bracket light, C, *en route* from first to second floor (see Fig. 336).

On the first floor, our plan shows two brackets, D, E, one on either side of the window, and a gas fire, F, in the front bedroom. These are supplied direct from the rising main, the brackets, as also those in the back room, being fitted with Pneumatic switches, W and V, Fig. 333 (see Chapter XXI, p. 408). The horizontal pipe, 17 feet

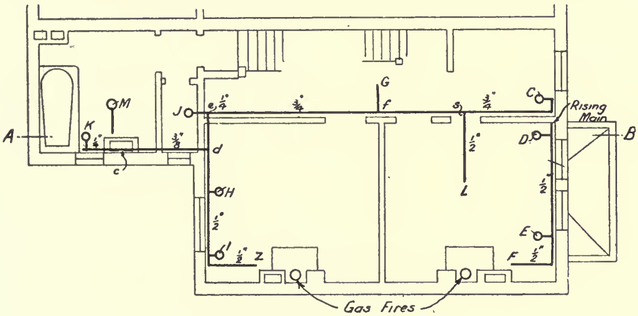


FIG. 336.—First Floor Plan.

6 inches long, from rising main to F, must, therefore, be of $\frac{1}{2}$-inch diameter, the risers to the brackets, D and E, being $\frac{1}{4}$-inch, as before.

Working now from the back of the house, the distance from bracket, K, in the bathroom, to pipe supplying M, the kitchen pendant, at *c* is 3 feet 6 inches, therefore the section, K*c*, may be of $\frac{1}{4}$-inch diameter. From *c* to M is 5 feet, so that the pipe, *c* M, may also be of $\frac{1}{4}$-inch diameter. From *c* to *d* is 8 feet 6 inches, so the section, *d c*, may be of $\frac{3}{8}$-inch pipe. The section, *d* H I Z, supplying the two back bedroom brackets and gas fire, is 15 feet 6 inches in length, and may be of $\frac{1}{2}$-inch diameter. The section, *e* J, supplying bracket in W.C., is a very short one, and may be of $\frac{1}{4}$-inch pipe. From *e* to the rising main on the first floor is 33 feet, and *e* to *d* a further 4 feet, making 37 feet in all, which has to supply nine lights (including the hall lamp, which must be supplied off this pipe at *f* and the pendant, L, in the dining-room supplied from the same pipe at *s*), and the gas fire, Z. The section from rising main to *d* must, therefore, be of $\frac{3}{4}$-inch diameter, the short supply pipe, *f* G, of $\frac{1}{4}$-inch, and the pipe supplying *s* L of $\frac{1}{2}$-inch diameter.

The distance from first floor level to meter is 15 feet, and the main rising through that distance must supply, as we have seen, the system of pipes on first floor and attic, which run to fourteen lighting burners and two gas fires. This riser, therefore, must not be of less diameter than 1 inch.

It will be noticed on the plan that the dining-room (front room ground floor) is to be lighted by a pendant from the centre of the room at L. This will be lighted and extinguished by means of either a "Telephos" or Pneumatic switch (see Chapter XXI, p. 408 *et seq.*), shown at Y in the sectional elevation (Fig. 333).

In the drawing-room (back room ground floor) there are three brackets, N O P, and the gas fire, *l*, to be supplied. The three former are to be controlled by the pneumatic or "Telephos" switch at X, in sectional elevation (Fig. 333).

Starting now in the basement, at the point farthest away from the

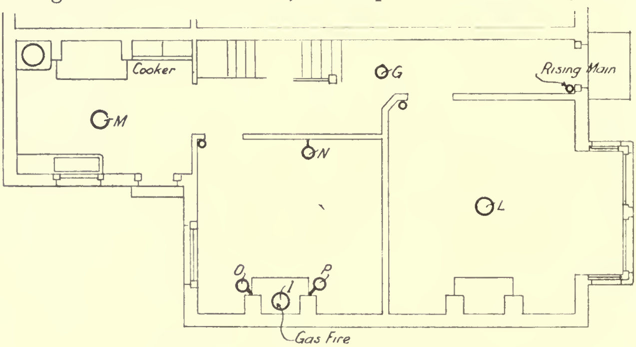


FIG. 337.—Ground Floor Plan.

meter, we have the supply for the gas cooking stove, U. The length *h* U, is 10 feet, and should be of ½-inch or ¾-inch, according to the size of stove required. Working back from P to *h* we find this section is 35 feet long; but as it has only two burners to supply, piping of ½-inch diameter will be sufficient.

Still working back towards the meter, picking up the larder light, T, and the bracket light, N, on the way, we come to the junction, *m*, which supplies the gas fire, *l*, in the drawing-room upstairs. This fire might, of course, have been supplied by the pipe *h*, O P, but we are assuming here that this is one of the cases where it is best to supply the fire direct from the main outlet by an exclusive pipe. The pipe supplying the fire is 15 feet in length, and must not be of less than ½-inch diameter. Working back still further we pick up the stair light, S, and the cellar light, R, on the way, and so are brought to the outlet of the meter.

We will assume now that the section, *h* U, should be of ¾-piping to supply the cooker. The length from *h* to *m* is 12 feet 6 inches, and has to carry four lights (three in drawing-room and one in larder) and the gas fire in the drawing-room, in addition to supplying the cooker. Reckoning the gas fire as equal to five burners, we find, on reference to the tables (pp. 354-355), that the section, *h m*, must be of 1 inch piping.

The length, *m o*, equals 21 feet, and, in addition to supplying the piping beyond *m*, has also the stair bracket light, *s*, and the light, R, in the front cellar, or three lights in all. Referring to the table, we find that the requirements would be barely covered by extending 1 inch piping from *m* to *o*, but as it is most important that with a large cooker and gas fire to be supplied, the pipes should be fully

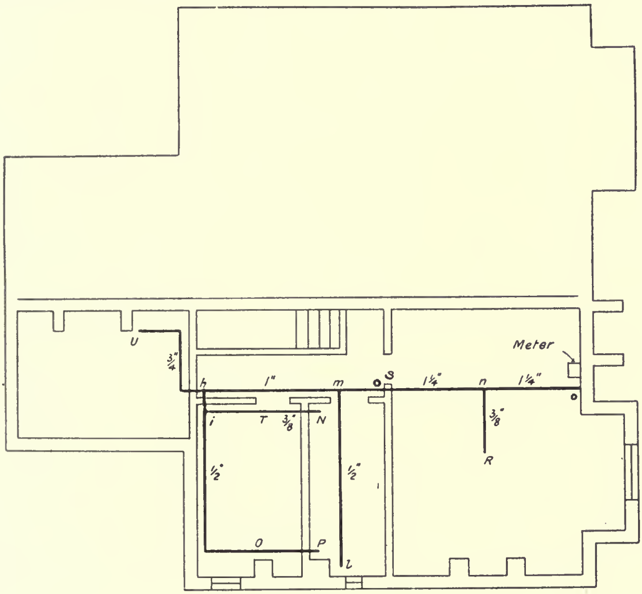


FIG. 338.—Basement Plan.

adequate with a margin to spare, it will be better in these circumstances to allow for 1¼-inch piping from *o* to *m*.

Having determined the position of the lights, the route which the pipes are to take, and the various sizes which will be required in each section, we may now proceed to place the pipes in position.

The first step will obviously be to chase the different walls to receive the piping for brackets, switches, and rising main, to notch the joists to receive the pipes to be laid under the floors, and to cut the necessary holes through the walls where the pipes pass from one room to another. Wood blocks must be fixed in the flooring above the dining-room and kitchen lights, in the way previously described, to which the pendant heads may be securely attached. The walls, too, must be plugged for the bracket back attachments.

The pipes themselves must be cut and screwed to the correct lengths, and care taken to ensure a full and straight thread upon the ends cut. It is important to notice that the torsional strain involved in screwing the pipe does not open the weld seam in the tube, as it may very well do if the dies are rather worn. The fittings are not always screwed true with themselves. Elbows which should give a perfect right angle have an awkward knack of making the angle either obtuse or acute. Tees which should give a straight extension and a right angle often vary considerably from a true alignment, as shown in an exaggerated form by either of the dotted lines in Fig. 339. All these, and other similar irregularities, must be fully corrected before the pipes are placed in position. Especially is this the case where pipes drop from a tee for the pendant below. Unless the pipe at A and the tee outlet each have a "square" thread, considerable difficulty may be experienced in removing the drop pipe to cut it to the correct length required when fittings are attached. Failure to "square up" may not only make a very clumsy looking and inconvenient job, but may also deflect the level of the pipes under flooring just sufficient to allow a little condensation to collect, which will involve trouble with flickering lights later on.

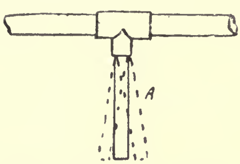


Fig. 339.—Drop Pipe for Pendant.

Precautions to be observed.—In piping any premises for gas with iron pipes, there are certain common precautions which should always be observed, and which, for the sake of brevity, may be thrown into the familiar form of a series of "don'ts." They may be summed up as follows, viz :—

Don't forget to see that every pipe is clear and free from obstruction before it is screwed into place.

Don't bend a long length of tube to carry the supply round a right or other angle. Always use suitable fittings.

Don't fix pipes under the joists to be buried in the plaster of ceilings.

Don't lay pipes under tile floors, tile hearths, or inlaid floors.

Don't fix gas pipes in contact with electric wires.

Don't use elbows where bends may be used. Where the use of elbows is unavoidable, always use the round type.

Don't omit to have a properly disposed syphon at a convenient point, if unable to get a fall back.

Don't use white lead, or other mastic, so lavishly as to block the gas-way.

Don't put the mastic upon the female ends of fittings. Always smear well the male end.

Don't omit to thoroughly and properly support horizontal pipes so that all possibility of sagging is effectually prevented.

Don't cross and notch joists more than three feet away from the supporting walls.

Don't nail floor boards over gas pipes. Always fasten them down with screws.

Don't forget to paint or tar all gas pipes fixed in damp or exposed positions.

Testing the pipes.—When the premises have been completely installed with the necessary series of pipes, the next and final step at this stage is to thoroughly test the whole system for soundness. This, of course, must be done before any of the pipes are covered up.

All the outlets but one must be soundly plugged or capped, and a small force pump and pressure gauge attached to that one, the most convenient for the purpose being chosen. By means of the pump, the pressure of air in the pipes should be gradually raised until the gauge shows a pressure of, say, 5 lbs. per square inch. The valve connecting the pump should then be closed and the gauge watched. If the index pointer remains stationary, say for half an hour, the job may be passed as satisfactory. If, on the other hand, the pressure begins to fall, it is obvious that air is leaking from the pipes at some one or several points. These must be found by going over the whole of the piping and joints with brush and soapy water, if the leak is not sufficient to declare itself by hissing or whistling. Should a pin hole be found in fittings, or crack or other fault found in the pipe, the faulty portion or fitting should be cut out and replaced with good. Hammering up should never be permitted in any case, nor any other of the expedients commonly resorted to to make a piping system temporarily sound, for the sake of passing an inspector's test.

Fitting up of larger premises.—It has already been said that the lighting of larger premises than those shown in Fig. 333 involves simply an amplification and extension of the principles enumerated in that example. Whilst this is perfectly true, there are, however, a few particulars in which the lighting of mills, factories, and workshops will need special treatment.

These vary very much in their general conditions one from the other, but a few things they have in common. In the case of single storey buildings of considerable size, where mains have to be carried down each side of the workshop or mill, to supply either overhead or bench lights, it will be advisable to connect the mains together at the ends most remote from the meter, so as to make a complete circuit, and that any inequalities of consumption or pressure upon one side may be compensated by the other.

In the cases we are now considering, the pipes will all, of course, be in sight. It is important that they should be readily accessible, and also that they should be kept as far away as possible from moving machinery. They should be of wrought-iron, and sufficiently large to allow of future extensions. Nothing is more annoying, either to owner of premises or supplier of gas, than to find that the pipes have been planned on so pinched and meagre a scale that extensions are made impossible without a large re-arrangement of the existing system.

Equalizing supply upon different floors : Three methods.—Then, where several floors are supplied from one meter, as in the case of mills, it is obvious that there may be very serious differences of pressure between the lights on the upper and the ground floors. This may be provided against in three ways. First, separate risers may be fitted each to supply a separate floor, from a common outlet, such as that shown in Fig. 340. This arrangement has obvious advan-

Fig. 340.—Common Outlet for Separate Risers.

tages, in that it allows of each floor being considered as a separate and complete unit in itself, and may be treated accordingly. It may also be applied to those cases where it is desirable to have separate leading mains to different parts of the same storey, or where the lighting of offices and workshops are required to be under separate control.

The second method of equalizing pressure over the different floors of a several storeyed building is by decreasing the size of the rising main as it ascends, thus, to some extent, throttling the supply. This is a very inadvisable expedient, in that it leaves no margin for extensions in the future, and also none for the corrosion which is sure, sooner or later, to form in the pipes and restrict their carrying capacity.

The third way is to carry a rising main of ample dimensions through all the floors from basement to upper room. At the outlet from this upon each floor a governor should be fixed, controlling the pressures supplied through this subsidiary main. These governors are illustrated and described in Chapter VII. (see Figs. 25-27, pp. 78-80). If, therefore, the pressure at the bottom of the rising main were 25-tenths, and at the upper end it rose to 30-tenths, it would, by means of these governors, be possible to so regulate the supply that each floor should be supplied at exactly 20-tenths, or any other common or variable pressure as may be desired.

CHAPTER XXI

INTERNAL LIGHTING

Although the problems connected with artificial illumination are by no means new, it is only in recent years that they have received the detailed and scientific study which their intrinsic importance deserves. Questions relating to combustion, the quality of light to be desired, the proper disposition and distribution of the light centres, the kind of unit to be employed, the proper objective of artificial lighting and how that objective may be best attained, the best and most economical setting for artificial light—these are some of the problems which confront us upon the very threshold of the subject. It is impossible, of course, to enter upon these in any great detail here, but a brief preliminary discussion is necessary to an intelligent comprehension of the subject of internal lighting.

The universal adoption of incandescent gas lighting, with the almost complete elimination of the flat-flame burner, renders it necessary that a clear grasp should be obtained of gaseous combustion as it takes place in a bunsen burner.

Combustion in a bunsen burner.—The method of combustion in a bunsen flame has been frequently described, but by none more succinctly than by Dr H. Bunte, who, in an address to the German Association of Gas and Water Engineers, in June 1907, said :—" In the ordinary bunsen flame about one-half of the air (about 3 volumes of air to 1 volume of gas) required for the complete combustion of the gas passes through the air inlets at the bottom of the mixing tube. The inner, lower cone of the flame is formed by the combustion of this air in the gas, and there results the mixture of water vapour and carbonic oxide with hydrogen and carbonic acid (in proportions constituting equilibrium), together with nitrogen. Water gas and nitrogen pass thence to the outer zone, and there the water gas is burned by a fresh supply of air, which reaches the outside of the flame. When a mantle is put over this upturned bunsen flame, the water gas formed in the flame is just inside the mantle, and the secondary air supply is just outside it. The two meet on the mantle itself, and the resulting combustion of the water gas raises the mantle to incandescence. Fig. 341 shows the composition of the bunsen flame, and the manner in which it may be split up. The following is the composition of the water gas mixture, in volumes per cent. :—

Nitrogen, 71.8; hydrogen, 13.3; carbonic oxide 10; carbonic acid, 4.9."

Combustion in an inverted burner.—The proportion of air entering the mixing tube of an inverted burner is less than in the case of an upright burner, and falls off very considerably as the burner and lamp become heated. The amount of this diminution of the induced air has been stated by Herr Winkler to be "from 3.5 volumes, when cold, to 2.04 volumes after the burner has been alight for five minutes, to 1.90 volumes after the burner has been lighted eight minutes, and to 1.65 volumes in twenty-five minutes after being lighted." There can be little doubt that this variation in the primary air supply is responsible for the disappointing results which have sometimes been experienced on the introduction of inverted burners. However, "the wire gauze fixed in the burner head tends to equalize matters to some extent, because the resistance offered by the gauze varies with the specific gravity of the gas passing through, and therefore offers much less resistance to a heated gas than a cool one."

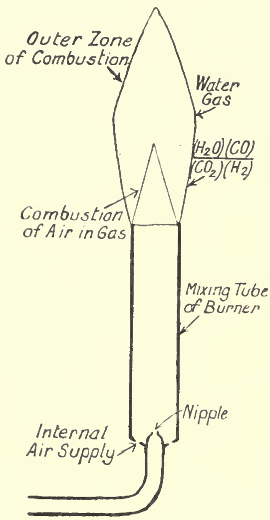


FIG. 341.—Details of Bunsen Flame.

With respect to the combustion of the gaseous mixture in an inverted burner, we cannot do better than again quote from the address of Dr Bunte, previously referred to:—"The heating of the gas and air which took place when the burner was inverted was, however, advantageous and quickened combustion. There was the green cone of air burning in gas, and outside (but within the mantle) a reservoir of water gas. In the inverted burner, the area of the outer zone was normally smaller, and the temperature became higher. Notwithstanding the preliminary heating of the gas and internal air supply, the inner cone was much contracted and the outer one reduced in area."

It has been found that a 16 candle-power gas requires about $5\frac{1}{2}$ volumes of air to 1 of gas for its complete combustion. It has already been stated that in the upright incandescent burner about half this quantity is induced into the mixing tube through the air inlets. The extreme importance of this air adjustment being properly made, and its influence on the illuminating power obtained, may be seen from the following experiment by Professor Lewes with 16 candle-power London gas at a pressure of 15-tenths:—

Condition of Flame.	Rate of Flow, in Cubic Feet.		Ratio.		Candle-power per Cubic Foot of Gas.	Temperature of Mantle 1 Inch above Burner Head, in Degrees Fahr.
	Gas.	Air.	Gas.	Air.		
Under aërated .	4.5	10.0	1	2.2	14 4	3416
Best „ . .	4.5	12.75	1	2.75	20.0	3479
Over „ . .	4.5	15.25	1	3.4	17.7	3461

It is seen, therefore, that both over and under aëration of the mixture diminish the candle-power obtained per foot of gas very considerably.

The bunsen burner.—There are a few elementary points in connection with the construction and use of the incandescent burner which are frequently overlooked ; with the result that imperfect mixing of the gas and air, and the consequential imperfect combustion, are a source of much irritation and annoyance. It may be useful to set these out briefly in order.

1. The nipple must be drilled perfectly true with the axis of the bunsen tube.
2. The nipple must be placed perfectly concentric with the bunsen tube.
3. The nipple perforation or perforations must be perfectly round. There must be no abrasions or irregularities on the edges, which would tend to divert the stream of gas from the central position.

Any failure in these three respects tends to direct the stream of gas to the side of the bunsen tube, in which case the mixture does not become homogeneous and the combustion must necessarily be imperfect.

4. For the same reason the interior finish of the mixing tube and gas passage must be as smooth as possible.
5. The gas as well as the air supply must be readily adjustable.
6. Suitable arrangements must be made, either in the provision of a mixing chamber, wire gauze, distributors, or similar devices, for the perfect admixture of the gas and air before they arrive at the point of combustion.
7. The mixture should be heated up before being burned.
8. With inverted burners, it is important that the air supply holes should be so placed that the air supply shall not be contaminated by the products of combustion.
9. The air holes of the bunsen tube must also be placed in such a position that the free inflow of air is not interfered with by the upward draught of heated air from the burner.
10. The nipple must be easily accessible for regulation and cleaning.

11. The pressure of gas at the nipple and consequent velocity of the stream of gas must be such as to induce a sufficient inflow of air to give a mixture with the gas of the correct proportions of each.
12. In order to ensure the latter point, all features tending to offer frictional resistance to the flow of the gases should be reduced to a minimum.

It follows from this that the burner must be kept perfectly clean. The gauze must be periodically cleared of dust and dirt. Owing to the expansion of the gauze wires through oxidation after being in use for some time, and the consequential reduction of area of free gas passage, the gauze should be regularly renewed.

13. Especially in the case of inverted incandescent burners, it is important that the gaseous mixture should be projected to the point of combustion at the maximum velocity.
14. The air and gas supply must be adjusted so as to give a violet-blue tint in the zones of the flame. As the proportion of air is increased, the inner zone gradually takes on a greenish tint, the flame becomes fiercer, and a humming noise is produced. If the proportion of air is still further increased, an explosive mixture is formed, and the light may flash back. Less air is necessary if there is an admixture of water gas than for ordinary coal gas alone.
15. The mantle must fit the flame. The hottest part of the bunsen flame is just beneath the outer surface. If the best results are to be obtained, the mantle must be immersed in this. It is obvious that if the mantle be too large it will be outside this zone of highest temperature. If too small, the mantle is within the hyper-incandescent zone, and therefore the highest possible mantle temperature is not reached, while combustion is seriously interfered with. The importance of these considerations will be apparent when we remember that the intensity of the light produced is dependent upon the mantle temperature, and that slight variations here involve tremendous differences in the amount of light developed. The light given by an incandescent body at high temperatures is proportional to the twelfth power of the temperature, so that a difference in temperature of only one or two per cent. makes a very great difference in the light evolved. The mantle must, therefore, be placed and kept in the zone of highest temperature. For this reason a shrunk upright mantle must always be faulty, and give less than the maximum candle-power possible. On the other hand an inverted mantle shapes the flame to itself within limits, and should therefore err, if at all, on the small side.

Adaptability and sufficiency of small units.—The question of the unit of light to be adopted is important from many points of view, two only of which can be touched on here. It is evident that small units may be more suitably placed, and for the same total candle-power evolved give much more effective illumination. The greater number of lights inevitably means better diffusion of light, and greater absence of deep shadows and violent contrast, which fatigue the eye and give a most unpleasant effect. The small unit lends itself to more ornate fittings and decorations, and altogether is more suitable for interior lighting in small apartments.

And it so happens that these considerations are reinforced by the fact that with small units a higher comparative efficiency is developed than with larger ones. This has been recently demonstrated in a most striking way in a paper read by Mr F. H. Gilpin before the Illuminating Engineering Society at Chicago in September 1911. As a result of his tests, particulars of which are given, Mr Gilpin shows that comparing burners of fifty mean spherical candle-power with others approximating to half that intensity, the latter show a greater efficiency per cubic foot of gas consumed of 25 to 30 per cent. over the former. One reason of this increased efficiency he traces to the relative temperatures of the mantles.

"In order to form some idea of the extent to which the mantle causes this difference of efficiency between the large and the small units, a short investigation was made of the relative flame and mantle temperature of two lamps of the same make, but of different sizes. The same procedure was followed in testing both lamps. A new lamp was erected and fitted with a new mantle that appeared to be of average size and shape by inspection, no glassware being used. After burning off the mantle the lamp was adjusted at 2.5 inches pressure to the point of maximum brilliancy. After the lamp and mantle had become thoroughly heated, temperature readings were obtained at uniform distances on the surface of the mantle by means of a platinum-rhodium thermo-couple having a bead of 0.028 inch (0.71 mm.) diameter, and standardized in connection with a milli-voltmeter. The mantle was then removed, and, without readjustment, temperature readings were taken in a similar manner on the surface and in the interior of the flame. The dimensions of the free flames were also ascertained. The mantle was then replaced and check measurements made."

In the illustration (Fig. 342) full size sketches of the flames and mantles are shown and the temperatures are recorded. The averages show the remarkable difference in mantle temperatures obtained with practically the same unconfined flame temperatures. The comparison is of interest, inasmuch as it apparently corroborates the actual photometric efficiencies obtained.

The problem of the most suitable unit of light to be employed must, however, not be approached merely from the æsthetic and economical standpoint. The further question of the brilliancy of light source which may be accomodated by the human eye without distress or injury must also be considered.

Maximum intensity of source of light permissible.—In a most valuable series of articles contributed by Dr Karl Stockhausen to the *Zeitschrift für Beleuchtungswesen,* and reproduced in part in *The Gas World* for 6th August 1910, p. 161, this question comes in for a very careful discussion. In the course of one of these articles

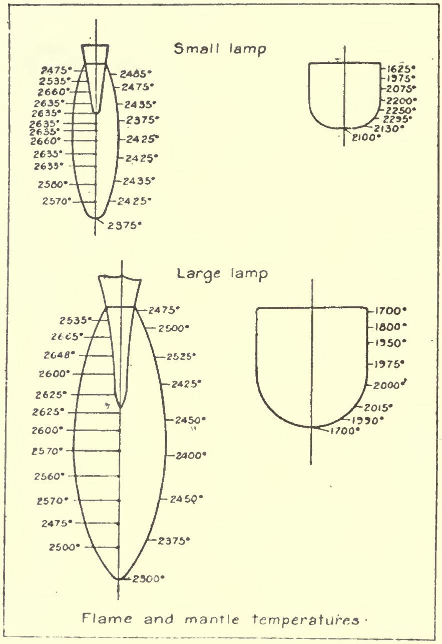


Fig. 342.—Flame and Mantle Temperatures.

Dr Stockhausen says : "The maximum permissible brilliancy would be that which comes just short of fatiguing the eye, and this is something short of the light of the open sky in June or July. This is now usually taken as being equivalent to the brightness of a source of light giving out about 4.35 British candles per square inch. It is hardly correct in principle to use the light of the sky as a standard, but in the meantime we may accept a limit of 4.35 candles per square inch as that which ought not to be exceeded. We ought, therefore, in order to avoid fatiguing the eyes, to arrange matters so that our sources of light shall have a brightness not exceeding 4.35 candles per square inch of effective illuminating area.

"Anything brighter than this (4.35 candles per square inch) should be placed well up, out of the ordinary visual field. This last is, however, only a partial remedy ; diffusing opal, matt or milk glass globes should be used. Most of those that are in use fail to give an approximately uniform brightness over their visual area ; when they do (mercury vapour lamp in a milk-glass casing), the effect is artistic and restful. It would need a very thick milk-glass globe to give a uniform brightness ; but if the light be cased in a very small globe of the holophane type, and then this be surrounded by a thin opal or ' silk matt ' glass globe, the effect is extremely satisfactory, and the loss of light very small."

Having decided what should be the maximum permissible brilliancy of our light source, we may now consider how these lighting points should be disposed. It is obvious that anything in the nature of glare must be avoided at all costs. Glare has been defined as the excessive contrast of the illumination of adjacent objects. It is not dependent upon the intrinsic brilliancy of the light source, but upon the comparison of the light source with its surroundings. A flame arc lamp may be very glaring when viewed alone in a gloomy setting and look very dull when bathed in a July sunlight. It is the violent contrast of light and shade which is so unpleasant and fatiguing to the eye.

But whilst we avoid the patchiness of excessive brilliancy and deep shadow, we must also avoid the opposite evil of eye strain consequent upon inadequate and insufficient illumination. This may be as bad in its effect as glare. What is needed is a balance which shall approximate as nearly as possible to the conditions of daylight. Here we have wide and perfect diffusion, which at the same time maintains a restful proportion of light and shade. Given a sufficiency of light, this is largely a matter of the proper disposition of the light sources.

Three methods of interior lighting.—There are three general methods of disposing of light sources for the illumination of interiors. First of all there is what is called the indirect method. This consists of placing the lights out of sight, behind mouldings, cornices, and ornamental screens, and allowing the light rays to fall upon ceiling and walls, to illumine the apartment by reflection. In this way a beautiful white, soft, diffused light may be obtained ; but obviously it is a very expensive method.

The second method is to light an apartment directly, but by means of lamps or burners placed at a sufficient height to keep them out of the ordinary field of vision. This, of course, gives a very good general illumination which, when supplemented where necessary with direct lighting for special purposes, is perhaps the most satisfactory yet devised.

The third method is by direct illumination, in which the immediate object viewed is lighted whilst the surroundings remain unilluminated. Such a case is seen in an office with a single desk light, or a workshop with a single machine light, or a library in which the book being read is the only object illuminated. It is obvious that this is most unsatisfactory, as, directly the eye wanders from the illuminated object it is obliged to accommodate itself to the surrounding gloom, an adjustment which must be exactly reversed on coming back again to the lighted object. This is not only extremely discomforting, but positively fatiguing to the visual organs.

Quantity of light required.—The amount of light required in any apartment, room, or hall will obviously depend very largely upon the particular purposes for which the room is designed. In a paper read before the Liverpool Engineering Society in January 1911, Dr G. N. Marchant gave the following list of the standards of illumination which are at present considered to be adequate for various purposes :—

	Foot-Candles.
Desk	3 to 4
Machine shop	1 to 1.5
[1] Drawing office	3 to 5
For reading	2 to 3
Well-lighted room	1 to 3
Railway station platform	0.05 to 0.5
Street	0.01 to 0.5

[1] This is rather low for an office where much fine work is done. In that case 5 to 10 foot-candles may be required

It is interesting to note that the illumination of a room with average window space, in May, would vary from 20 to 40 foot-candles, and that of a white surface exposed to sunlight may be as great as 10,000 foot-candles.

In considering the quantity of light to be provided for, due regard must necessarily be paid to the character of the furniture and the wall decorations. If these are of a generally dark and light-absorbent character, more light will obviously have to be provided than if the decorations are light in character and of good reflecting power. It is obvious that if the rays of light from a lamp fall upon a good reflecting surface, and say 80 or 90 per cent. of the light is reflected or diffused, for practical purposes this light is used over twice.

Experiments of Messrs Lansingh and Rolph.—In this connection the experiments of Messrs V. R. Lansingh and T. W. Rolph, as given in their paper before the Illuminating Engineering Society at New York, in the early part of 1909, as reported in the *Journal of Gas Lighting*, 2nd March 1909, are most interesting.

Four different sets of tests were made with tungsten lamps (40 watts, 150 volts) employed as follows :—

(*a*) One bare lamp close to ceiling and in centre of room.
(*b*) The same with a bowl reflector.
(*c*) Three bare lamps under same conditions as in (*a*).
(*d*) Three lamps with bowl reflectors.

Tests were made under the following conditions :—

(1.) Ceiling, walls and floor dark.
(2.) Ceiling light, walls and floor dark.
(3.) Ceiling and walls light, floor dark.
(4.) Ceiling, walls and floor light.
(5.) Walls light, ceiling and floor dark.
(6.) Walls and floor light, ceiling dark.
(7.) Floor light, ceiling and walls dark.
(8.) Ceiling and floor light, walls dark.

Condition as Stated.	One Bare Clear Lamp.	The Same, Frosted Tip, with Prismatic Reflector.	Three Bare Lamps.	Three Lamps with Frosted Tips, with Reflectors.
Test No. 1, foot-candles	0.19	0.36	0.48	0.91
,, 2, ,,	0.34	0.48	0.94	1.17
,, 3, ,,	0.56	0.63	1.57	1.74
,, 4, ,,	0.68	0.90	1.96	2.27
,, 5, ,,	0.31	0.43	0.85	1.15
,, 6, ,,	0.34	0.49	0.92	1.23
,, 7, ,,	0.21	0.37	0.50	0.90
,, 8, ,,	0.37	0.49	0.99	1.20

The tests were taken at a height of 2 feet 6 inches above floor level, and the mean of the averages taken proved to be as given in the above table.

It is shown conclusively, therefore, that under the conditions stated there was more than three times the illumination from a single lamp when ceiling, walls, and floor were light (test No. 4), as compared with the conditions of test No. 1. when walls, ceiling and floor were dark, while with three bare lamps the proportions realized as between tests 1 and 4 were approximately as 1 to 4.

Mr T. Schofield's Experiments.—As a more extended series of experiments upon the effect of different coloured wall papers upon the illumination of a room, the tests of Mr Thomas Schofield of New York, published in 1911, are very instructive. Five booths, each 5 feet wide by 4 feet deep, by 9 feet 4 inches high, each papered with different coloured wall-paper and each lighted in exactly the same way, were experimented upon, the tungsten standard lamp being used in the photometer. The results were as follows :—

Booth No.	Colour of Wall-Paper.	Foot-Candles observed.	Percentage of No. 1.
1	Salmon . .	6.248	100.00
2	Red . .	2.105	33.69
3	Cream . .	3.975	63.62
4	Green . .	3.553	56.86
5	Blue . .	2.510	40.17

"The difference in the colour of the reflected light was very clearly brought out on the photometer-screen, booth No. 1 more nearly matching the tungsten standard lamp than any of the others. The percentages have therefore been worked out with that as 100."

Mr Haydn Harrison's Experiments.—The result of these tests of Mr Schofield's are broadly confirmed by a somewhat similar series of experiments on the reflecting power of different coloured surfaces, carried out by Mr Haydn Harrison, and embodied in a paper read before the Illuminating Engineering Society in April 1911.

"In some experiments he had made to ascertain the increased illumination necessary to be given to different coloured wall-papers, in order that the rays reflected from such wall-papers should have the same effect on the eye as when a white paper of similar surface to the photometer screen was used, he had obtained the following results :—

Colour of Wall-Paper.	Increased Illumination necessary.
Bright red	3.5 times
Dull cardinal red	6.5 ,,
Medium blue	4.8 ,,
Light blue	3.2 ,,
Dark green	7.0 ,,
Light green	2.2 ,,

The Lumeter.—A very simple instrument for measuring the actual amount of surface illumination—termed the improved lumeter—was described and illustrated in *The Gas World*, 29th June 1912.

Position of lights : dining-room.—The placing of the light in the different rooms will, of course, vary with the use to which the rooms are put. In an ordinary dining-room, with table in the centre, a pendant, such as that shown in Fig. 343, from centre of ceiling, is obviously the natural method to adopt. If this be fitted with inverted burners, a good light is thrown directly down upon the table, and any shadows which may be cast by persons using the room will be thrown, not upon, but away from, the centre. In large rooms, the pendants may be duplicated, or the centre pendant supplemented by brackets fixed around the walls, or there may be a combination of pendants and brackets. This gives an admirable effect. The light sources are out of the direct line of vision, and, the light rays crossing in all

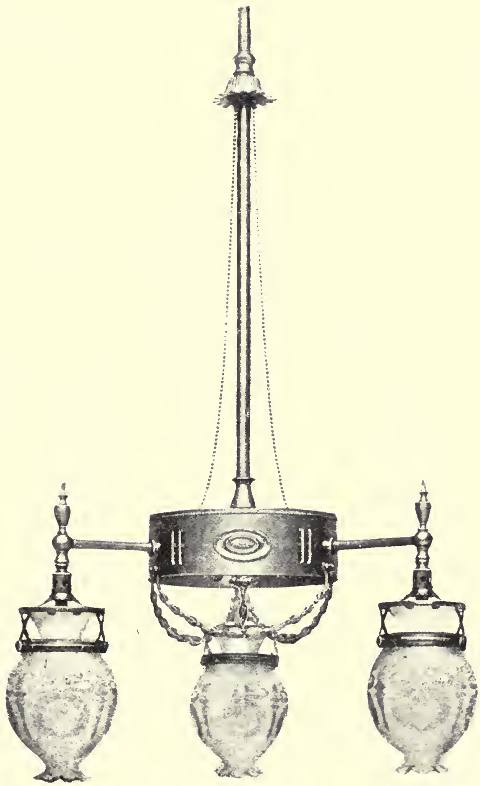


FIG. 343.—Dining-room Pendant.

directions, the lighting becomes, in its degree, a copy of nature. The use of suitable globes and shades should give a result pleasant to the eye and effective from a lighting point of view.

Drawing-room.—In the ordinary drawing-room, with the centre more or less clear of furniture, and such furniture as there is suitably disposed for the free movement of those using the apartment, when the room is of small or medium size it may be lighted entirely from the walls by means of brackets, such as shown in Fig. 344. If the room is too large to be lighted entirely from brackets, the brackets may be supplemented by pendants, as in Fig. 345. In this case the pendants must be high enough from the floor level, not only to allow of tall persons to pass freely beneath, but also to keep the lights well above the line of sight, so that any dazzling effect may be effectually prevented. In rooms of moderate size, a very pleasing effect may be obtained by a combination of bijou burners with appropriate shades and design of fittings to harmonize with the decoration and furniture of the room.

Entrance lights.—The entrance hall will most appropriately be

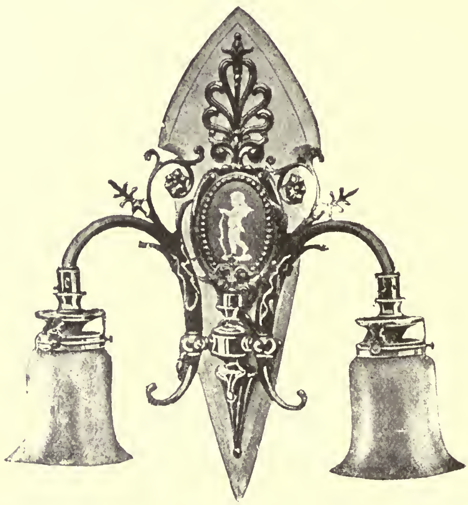


FIG. 344.—Drawing-room Bracket.

lighted by a pendant (Fig. 346) fixed sufficiently high to allow tall persons to pass beneath. In this position it is most out of the way, and the lighting is most effective. In the case of a house standing well back from the roadway, it may be advisable to have an outside lamp to illuminate the path or drive. Medical men, too, generally require an exterior light, for professional purposes. In each of these cases a good wind-proof lantern, of appropriate design, should be fixed either upon column or bracket. The lamp ought to be fitted with a good by-pass and pilot light, and controlled from the hall, near the front door, so as to avoid having to go out to light and extinguish.

Library.—The library or study may well be lighted by either pendant or bracket of the "Surprise" type (Fig. 347), capable of being raised or lowered to any suitable position, as may be desired, for either reading or desk work. This may be supplemented by a table lamp (Fig. 348), suitably shaded, where necessary.

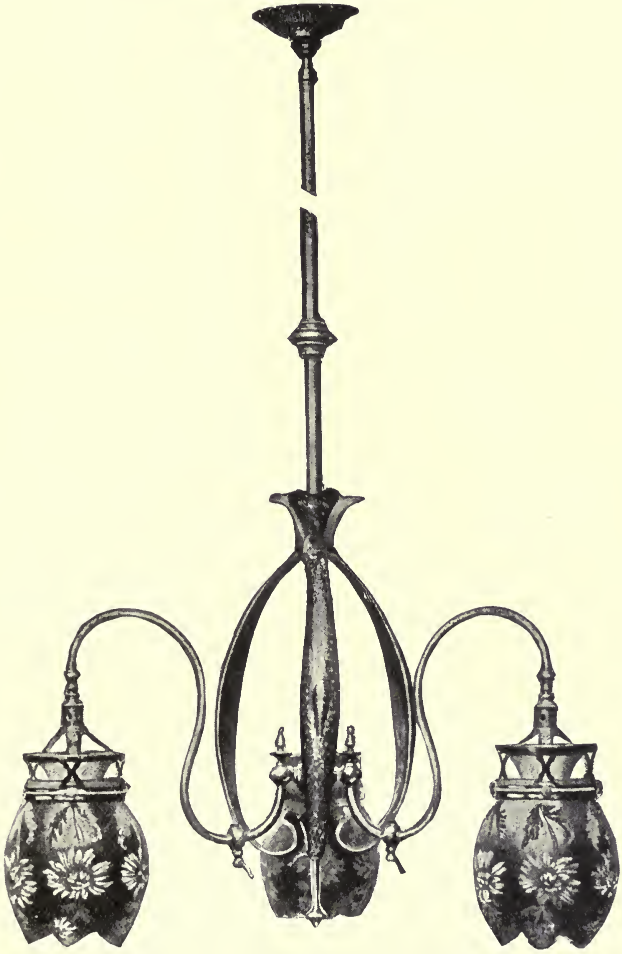


FIG. 345.—Drawing-room Pendant.

Billiard Room.—The efficient lighting of a billiard table is perhaps the most exacting piece of illumination which can be undertaken. The light must be absolutely steady, and the illumination perfectly uniform, and brilliant. Also the fitting must be capable of withstanding the shocks it occasionally receives from accidental knocks with cues, etc. Fig. 349 shows the alternative arrangement of upright and

FIG. 346.—Hall Lamp.

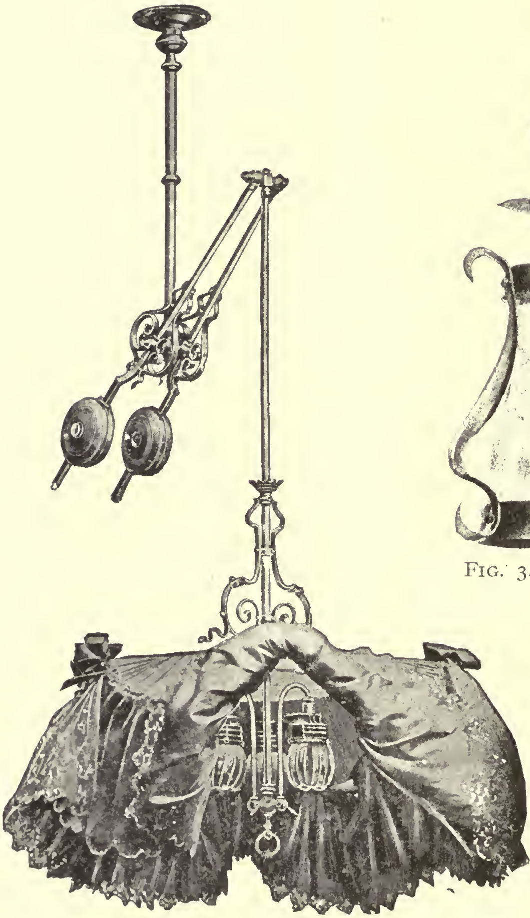


FIG. 347.—" Surprise " Pendant.

inverted burners and suitable shades of an excellent billiard room pendant as made by Messrs Foster and Pullen, Limited, of Bradford. Each burner is fitted with one of their " A.V.I.L." holders.

Kitchen.—The kitchen should be lighted by means of a pendant fixed over the kitchen table. This not only gives an effective

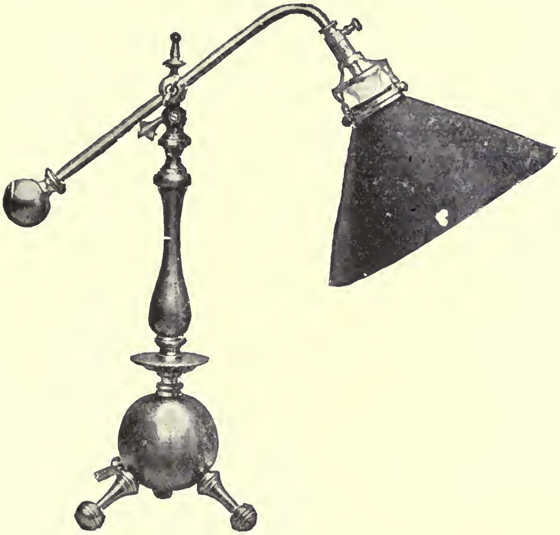


Fig. 348.—Reading Lamp.

illumination at the point where it is most often needed in the routine work of the kitchen, but also allows of a good light being thrown on to kitchener, oven, cooker, or boiler. To have the lights so placed

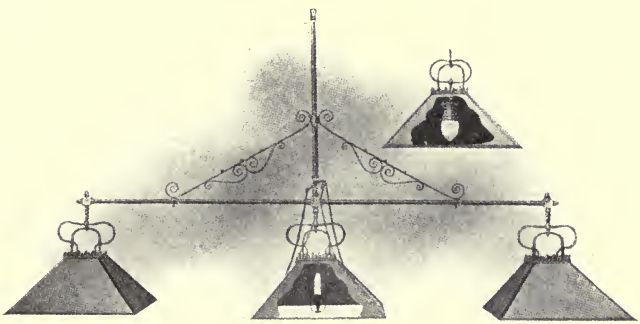


Fig. 349.—Foster and Pullen's Billiard Room Pendant.

that these appliances are thrown into shadow is a manifest disadvantage. In cases where a gas-heated flat iron is used, a tap and nozzle may be easily fitted at A, on the counterbalance side of a pendant such as that shown in Fig. 350.

Upper rooms.—The natural positions for the remaining lights in such a house as that shown in Fig. 333 (p. 367) are sufficiently obvious. As has already been pointed out, all bed and bath room lights should be placed at the side of the window. Where bedrooms are large the advantage of well diffused light is likely to be appreciated by the mistress of the house, and additional lights so placed as to illuminate large mirrors become a necessity. In residences of a larger kind, the additional rooms, such as boudoir, lounge, and smoke rooms may very well be lighted by either single-light drop pendants

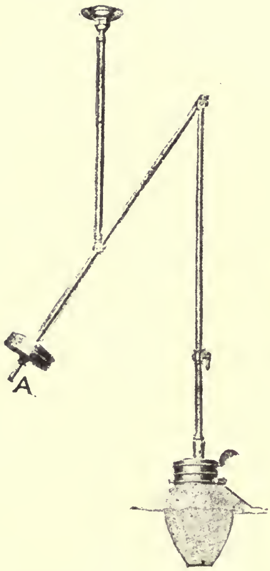


FIG. 350.—Counterbalance Pendant for Kitchen.

FIG. 351.—Bedroom Bracket.

or brackets, or these in combination, according to the size and shape of the rooms.

Shop lighting.—Shop lighting may be divided into four sections, namely (*a*) shop lighting proper; (*b*) interior window lighting; (*c*) exterior window lighting; and (*d*) lighting for advertising purposes.

The best method of lighting any shop will naturally depend upon the size and loftiness of the premises, the kind of business carried on, the disposition and arrangement of showcases, and the general arrangement of the goods. The question whether to adopt units of large or small illuminating power, and, if the latter, whether singly or in clusters, will also depend, to a large extent, upon the factors just mentioned. The point to be aimed at is, obviously, to illuminate the goods with a pure white light. This should be well diffused throughout the shop, with an entire absence of shadows. The light should be unobtrusive, if not unseen, and should be so placed and of such a character as to direct attention to the goods—not attract attention to itself. A strong, glaring light may suit the cheap jeweller, but for good shop lighting it should be avoided at all costs; and, lastly, the light should, if possible, and if not altogether, as far as possible, be removed from the direct line of sight.

With regard to the amount of light required, the conditions vary so completely in different business premises that no rule of general application can be given. Each case must be decided in accordance with the exact conditions obtaining. The standard of lighting has, however, been very considerably raised in recent years. A short time

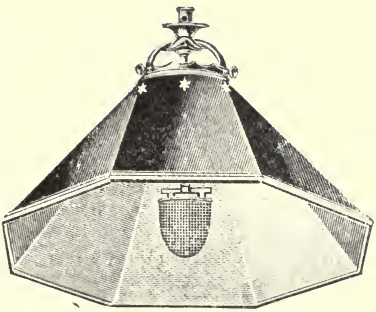


FIG 352.—Octagonal Reflector Light, for Shop Window Lighting.

FIG. 353.—"Everbrite" Ribbed Glass Reflector, for Shop Window Lighting.

ago it was considered sufficient for shops where a moderate amount of light is required to allow 1 candle-power for each 2 to 3 square feet of floor. To-day the minimum is 3 or 4 candles per square foot of floor space, whilst it rises in many cases to 10 or 12 candles per square foot of floor area. One method of estimating, which takes into consideration the loftiness as well as the floor area of the premises, is to allow 200 to 250 candle-power to every 1000 cubic feet content of the shop. If there is no obstruction and the floor space is clear, conditions, however, which seldom, if ever, exist, the lights should be spaced at a distance apart equal to twice their height. It is obvious, however, that these suggestions must necessarily be modified to suit the special arrangements of shop furniture and fixtures.

With regard to shop window lighting, much, evidently, depends upon the way the window is dressed. Particular trades vary very much from others in their methods in this respect. In the simplest case, that in which the goods are laid upon the floor of the window space, and especially where the window is cased in, the best form, undoubtedly, is a series of lights placed immediately above the glass top of window casing, fitted with silvered glass reflectors, such as those shown in Figs. 352 and 353, which throw the light rays down within a comparatively small angle. The "Everbrite" reflector gives a particularly powerful and pleasing lighting effect. The ribbed glass surface splits up the light rays, gives a very even distribution of light within the angle affected, and a perfectly clear white reflected light of great intensity. Other reflectors which are used with brilliant effect are the "Holophane" series, described at the end of this chapter.

The great aim of the shopkeeper is, of course, to brilliantly light his goods. It is, therefore, a huge mistake to so place the lights as to attract attention from the goods to the light itself. If possible, the light should be out of the line of sight altogether. In any case, it should be of such a character as to permit of goods being viewed without discomfort. In other words, there must not be the slightest approach to glare. Given suitably placed lights of a suitable character, the more brilliant the lighting the more successful from a shopkeeper's standpoint. The illumination frequently obtained in practice is as high as 30 foot-candles.

In the very different case of the furniture dealer or clothier, whose goods usually range far back from the window front, cluster lighting by inverted burners, either ordinary or of the self-intensifying type, gives a very pleasing and effective lighting of the goods displayed.

A third case, very distinct from either of the foregoing, is that of the milliner and haberdasher, whose goods are generally placed well forward, if not close to the glass of the window. In this case the best kind of window illumination will evidently be that obtained from outside reflecting lamps of a powerful type, as shown in Fig. 355, These, by throwing the light well forward, may be made to give a splendidly-lighted shop front. One great advantage in this arrangement is that there are no lights in the window itself in close proximity to inflammable goods, from which the heat and products of combustion are also kept. As these lamps must be placed well above the heads of passers-by upon the pavement, they should be made to reflect downwards as well as inwards, so as to illuminate the whole window from top to bottom.

With the development of high-pressure lighting there can be little doubt that high-pressure lamps will claim this field of exterior shop lighting as one peculiarly their own. They combine a high degree of illumination with a pleasing quality of light of great diffusive power. They are, therefore, particularly adapted to light the goods in shop windows brilliantly, while at the same time forming a very effective general advertisement. Fig. 354 shows the splendid lighting effect obtained by a series of Keith high-pressure lamps when used for outside shop lighting, while Fig. 355 shows one of Keith's 1000 candle-power high pressure lamps specially adapted for this particular service, fitted with a parabolic reflector. The polar curve reveals the very high degree of illumination projected upon the shop window by such a lamp. The light concentrated between

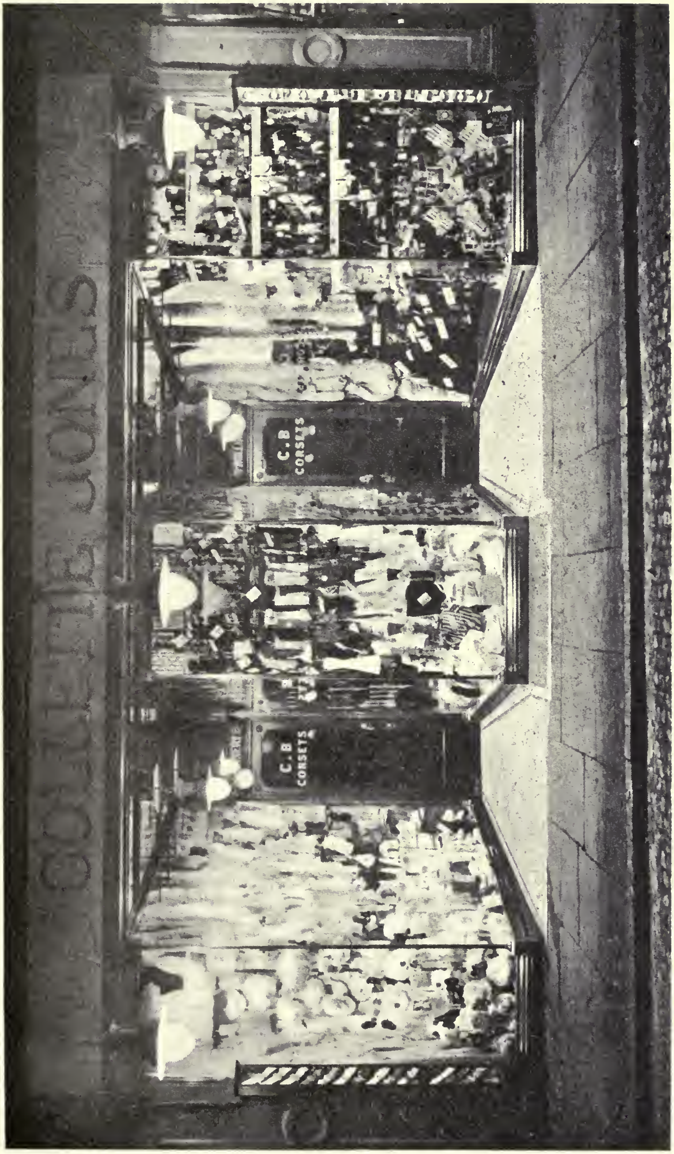


Fig. 354.—Outside Shop Lighting by Keith High-pressure Lamps.

the angles of 20° and 40° below the horizontal—the exact direction in which it is most required for this purpose—is 1475 candle-power, or about 50 per cent. greater than the illumination upon the horizontal line of the same lamp without reflector. The general subject of high-pressure lighting and lamps is discussed in a subsequent chapter.

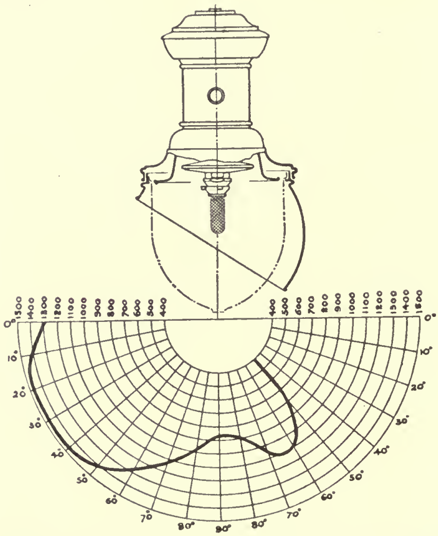


FIG. 355.—Keith's 1000 candle-power high-pressure lamp with parabolic reflector, showing illumination curve.

Lamps for advertisement.—Outside lamps may obviously combine the primary purpose of window lighting with advertisement, as in Fig. 356; but in all these cases it is the lighting effect, the illumination of goods, not the lights themselves, which should be in evidence. For advertising purposes pure and simple, a string of high-power lamps, fixed at a good height, say 10 or 12 feet above the pavement, may be made very effective. The electrician has shown us very well how not to do this kind of thing. Nothing could be more repellent or more likely to defeat its object than the blinding glare of a number a flame arc lamps fixed low enough to be within the line of sight. Such distressing installations ought really to be prohibited, as inimical to the eyesight of the public.

Warehouse lighting.—The method of lighting the average warehouse, with its counters fixed against the wall upon each side and also in the centre of the room, the lighting effect being needed upon the counter itself, is pretty obvious. Brackets must be fixed at suitable intervals along the walls. Such rooms are usually well supplied with windows for natural light, and the work is generally done in front of the windows in the day-time, as far as the counter accommodation will permit. It will be well, therefore, to fix the brackets on either side of the window, so that the artificial illumination may be concentrated at the points where the daytime work is done. Over the counters running down the centre of the room, a

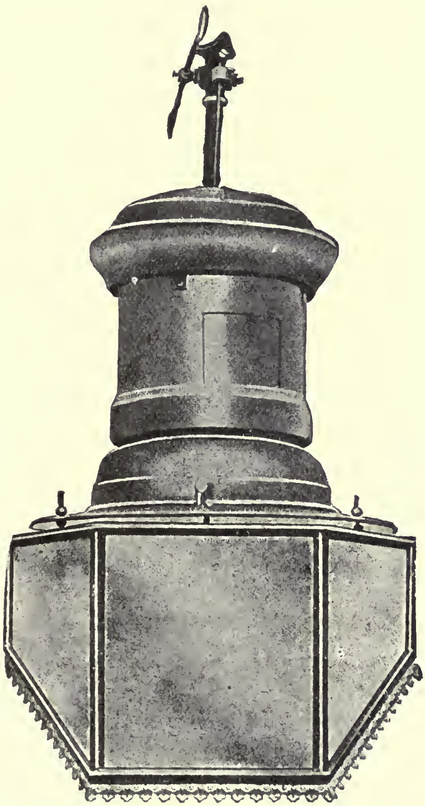


FIG 356.—Lamp for Advertising and Shop Window Lighting.

series of 2-light pendants may be fixed at intervals, spaced to suit the particular kind of work done. In cases like these, where a strong downward light is required, the inverted incandescent burner is most suitable. The upright burner may also be adopted, but where vibration is experienced it should be fitted with an "A.V.I.L." frame and reflector. Rising and falling adjustable lights may also be used, if required, such as those shown in Fig. 357.

This is an exceedingly handy form of adjustable pendant, suitable either for warehouse or factory point lighting. The patent swivel joint permits free movement of the bracket arm with the burner in any direction within a radius of several feet. The light may be lowered close to the work, or put up out of the way, or moved completely round in a circular direction. All these movements are

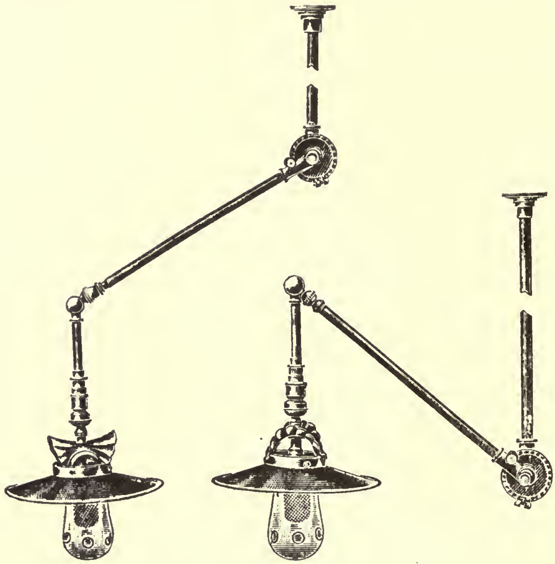


FIG. 357.—Foster and Pullen's Adjustable Pendant.

effected by very slight pressure. There is no strain or stiffness, and the burner remains in the exact position required.

Lighting large interiors.—For the effective lighting of large rooms, halls, churches, libraries, etc., a widely diffused light is required. The lamps should, therefore, be placed sufficiently high to be well out of line of vision and to give a good general and even illumination. The general lighting may then be supplemented, where necessary, by individual lights for special purposes. Two or three examples will be sufficient to illustrate this.

In a public library the general lighting of the room, for instance, which may give a floor lighting effect of, say, one foot-candle must be supplemented by reading table or desk lights giving an average illumination of 3 to 4 foot-candles. The latter should be effectively screened, so that no direct rays can reach the eye of the reader from the light source. In the same way, churches and chapels need, in addition to the general lighting of similar intensity, special lights for pulpit, organ, choir stalls, etc.

The general assembly room of a school, again, needs only a good general illumination, but in the class-rooms more particular attention must be paid to lighting the desks and blackboard. For desk illumination the light source must be well above, to the left, and in front of the desk. Ideal conditions require that no child should be more than 7 or 8 feet from the nearest lamp, which should be sufficiently powerful to give a desk illumination of $3\frac{1}{2}$ to 4 foot-candles, with rays impinging upon it at an angle of 45°. For pencil drawing and fine needlework the illumination should rise to 8 foot-candles. The blackboard, charts, or maps used should have an illumination of $2\frac{1}{2}$ to 3 foot-candles.

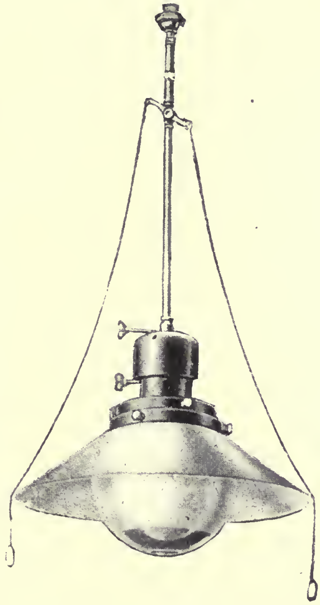


Fig. 358 —Sugg's 200C Lamp, General Elevation.

A lamp that has proved very satisfactory for lighting class-rooms is Sugg's 200C, which is shown in general elevation in Fig. 358 and in sectional elevation in Fig. 359.

This is regenerative in type, the distinctive feature being the superheater, H, above the burners, and the cast mixing chamber, E, at the top of the lamp. The products of combustion pass round both these chambers, heating, in the first case, the gaseous mixture before it passes to the burner, and, in the second case, heating the primary air supply before it enters the bunsen tube. A is the gas regulator, B the mixing tube, C the air adjustment screw, and N the long burner nozzle of fireclay, fitted with gauze to prevent firing back. The primary air being taken in below the outlet for the products of combustion, there cannot be the slightest vitiation of the primary air supply.

A lamp of a similar type, but a smaller unit, made without the superheater, is shown in Fig. 360. The illustrations are similarly lettered. The lamps are fitted with opal shades, and clear or part clear globes.

The lighting of the hospital ward presents us with conditions which in many respects are an inversion of those ordinarily obtaining. The usual line of sight of a person either standing or sitting is normally along the horizontal, or within a few degrees of it. To a person lying in a hospital ward the ordinary line of sight may be within a few degrees of the vertical. It is, therefore, impossible to keep any lamps as usually arranged overhead out of the direct line of sight of the patient. Also, the condition of physical weakness renders the patient particularly susceptible to glare, and even very ordinary degrees of brilliancy may be the cause of much discomfort. The ward should have general illumination of about 0.5 foot-candles minimum as well as local lighting points for the beds and the nurses' tables. The latter may need an illumination ranging as high as 8 foot-candles. Indirect lighting by reflection from the ceiling and upper portions of the walls would be unsuitable, because these bright

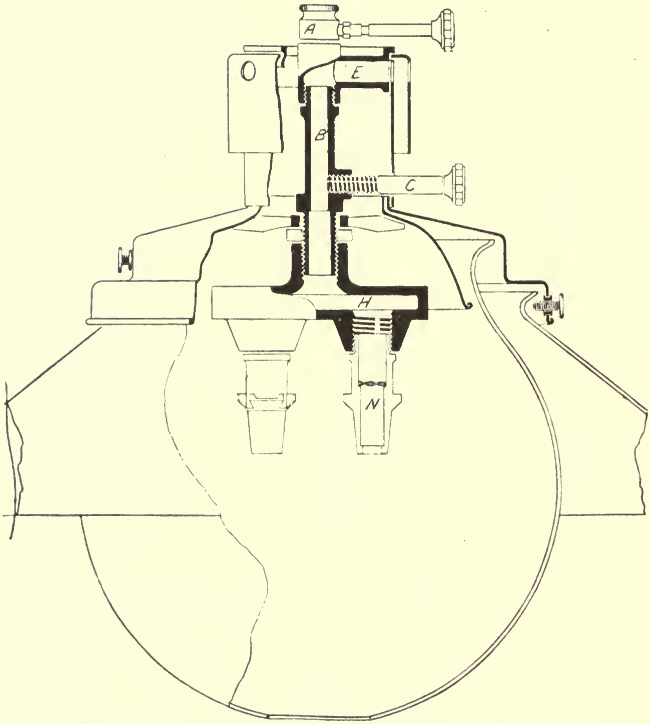


FIG. 359.—Sugg's 200C Lamp, Sectional Elevation.

reflecting surfaces would be normally in the field of vision of the patient and would cause distress. Direct lighting must, therefore, be largely resorted to; and the conditions make it essential that all lights should be effectively screened and directed by shades and reflectors properly designed to suit this particular purpose.

Workshop lighting.—In factories, mills, and workshops of the engineering class, where moving machinery crowds the floor space, the general lighting may well be effected by means of high-pressure gas. This is discussed in another chapter.

The upright incandescent burner.—The upright incandescent burner may be divided into two classes, the "C" and the Kern. The latter will be described more particularly in connection with public lighting (see Chapter XXVII). When used for domestic lighting,

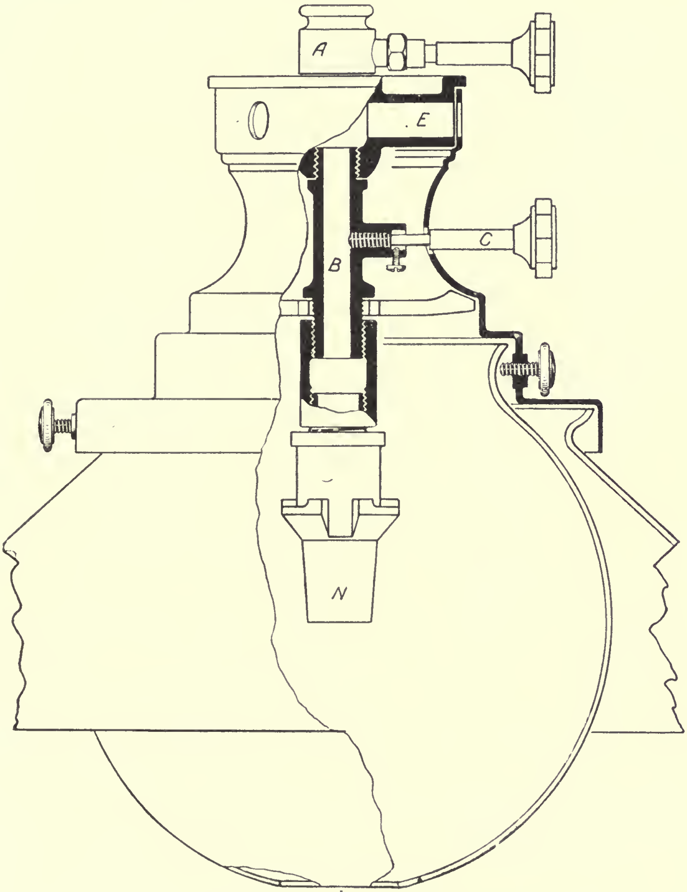


FIG. 360.—Sugg's 1908 Lamp, Sectional Elevation.

especially where pressures are variable, the burners should be fitted with regulators, many suitable types of which are upon the market. These, together with the movable collar which controls the air supply, give a range of adjustment and nicety of control which almost approaches perfection. Various other points in connection with upright burners of larger units are dealt with in the chapters on public lighting.

Of the many good burners of the upright type upon the market, that of Messrs. Geo. Bray and Co., Limited, of Leeds, may be taken as an example. The distinctive features of this burner are: (*a*) Its compactness—it is considerably shorter than those of most other manufacturers. (*b*) The enamel burner head. This consists of a double enamel top of special manufacture, perforated by a series of holes arranged in concentric rings. (*c*) The perforations in the upper portion of the mixing tube (Fig. 362). This ensures a thorough mixture of the gas and air. An inverted cone attached to the under side of the burner head stops the flow directly through the tube and compels a passage through the perforations. (*d*) The gas regulator. To enable all wire gauze to be dispensed with, the holes in the nipple have been decreased in size, and increased in number to five, arranged as shown in Fig. 362. The spindle of the regulator is cut away on one side in such a manner that, as it is revolved by means of the milled head, it will completely close the whole or any part of the three holes in the centre line. The quantity of gas to the burner, may, therefore, be adjusted without at the same time reducing the pressure. (*e*) The ready way in which the burner may be taken to pieces for purposes of inspection or cleaning. In other respects the burner follows the main lines of other low-pressure incandescent burners.

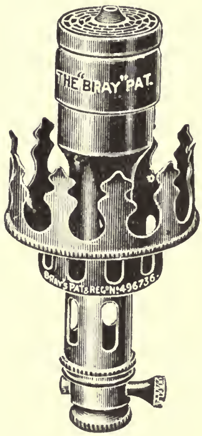


Fig. 361.—Bray's 07C Burner.

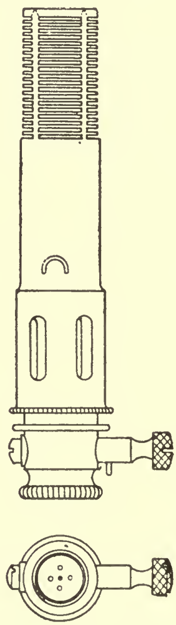


Fig. 362. — Bray's Mixing Tube and Injector.

The inverted incandescent burner.—An elevation and section of one of the best known inverted burners for internal lighting is shown in Fig. 363. It will be seen that the burner consists of four separate portions, namely, the regulator and injector, the mixing tube and chamber, the canopy, and the light framework supporting the canopy.

The bunsen tube, B, is greatly restricted in diameter from the injector to the point, C, from which a cone-shaped lead opens out through the wire gauze, D, to the mixing and heating chamber, E. The effect of the restriction is to increase the velocity of the travelling mixture of gas and air; and of the gauze, to ensure a perfect mixture of the gas and air and to minimize the tendency to light back.

The porcelain canopy, I, which, at its lower end, forms the nozzle, serves three very necessary purposes. As it is separate from the metallic mixing chamber and tube, and is a bad conductor of heat, it tends to prevent firing-back and the conduction of heat from the burning gases to the tube. The upper inverted conical portion forms a shield which protects the bunsen tube from becoming over-heated by the rising products of combustion, and gives the current of heated and exhausted air a direction away from the primary air supply.

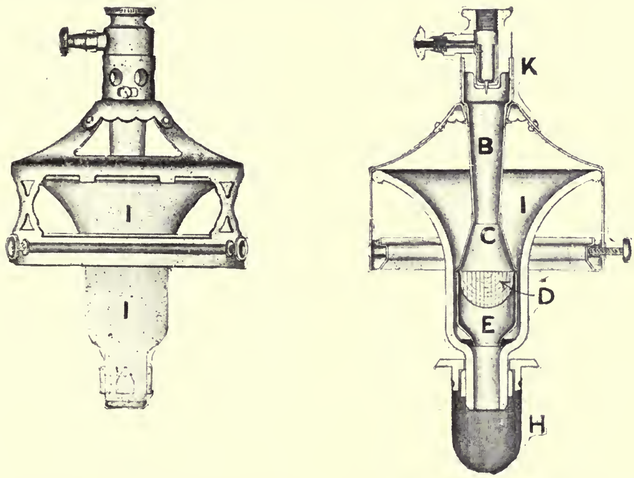


FIG 363.—Elevation and Section of "Nico" Inverted Burner.

It is most important that the products of combustion should be kept away from the air supply, and that the latter should be as pure and uncontaminated as possible. It will be noticed that a space is left between the exterior of the burner nozzle and the interior of the mantle ring for the escape of the products of combustion. Failing this, the burning gases must, obviously, pass through the substance of the mantle, causing a loss of illuminating power, and probably also a deposit of carbon upon the mesh of the mantle. The best width for this annulus has been found to be 3 mm.

The regulator.—An enlarged section of the needle regulator, K, is shown in Fig. 364. One prime necessity of any type of regulator to be used on a bunsen burner is, evidently, that, while controlling the gas supply, it shall not reduce the gas pressure. The whole value of the injector depends upon the maintenance of a suitable pressure; otherwise the induced air supply is bound to be faulty, and the gaseous mixture incomplete. The importance of this may be seen in the result of one of Dr Wedding's experiments. It was found that the pressure is reduced to one-tenth of the original immediately after passing through the orifice of the injector, with a further reduction in the bunsen tube, to less than one-hundredth of the original pressure at the final outlet. The type of governor shown in Fig. 364 fulfils the condition fairly well. The need for such a governor where pressures fluctuate, and consequently where the volume of gas supplied through any orifice must fluctuate accordingly, is sufficiently obvious. In addition to this, where carburetted water gas is supplied with ordinary coal gas, the mixture may not always be uniform, and a simple device for controlling the gas as well as the air supply becomes a valuable aid in immediately adjusting the burner to the needs of the moment.

The action of the regulator will be readily understood from the cross-section. A is a hollow tube, open at one end and closed at the other, with the exception of the perforations, L, and is capable of free movement within the casing, F. The closed end of A carries the spur, S, which passes through and more or less throttles the injector, I. The tube, A, is moved by means of the milled screw head, H, acting through crank, J, which engages in a slot in the wall of tube, A. By turning the head, H, the spur, S, may be raised or lowered in the injector, I, and the orifice more or less closed accordingly.

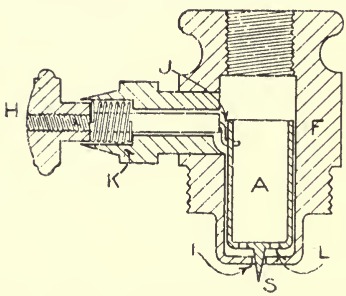


FIG. 364.—Section through Needle Regulator.

The action of the spur is two-fold. Not only is the volume of gas passing through the injector controlled, but in addition, instead of the gas flowing as a solid stream, it issues as a hollow or crescent-shaped stream, a form which lends itself much more readily to the perfect aëration desired. The spring, K, keeps the regulator gas-tight, and the eccentric action of the crank, J, effectually prevents the spur from becoming jammed. The only defect the author has experienced is that after the burner has been alight for a little time the milled head, H, becomes too heated to be adjusted comfortably. This has, however, now been overcome by the substitution of vulcanite for the original metallic head.

Intensified inverted burner.—Fig. 365 shows one form of self-intensifying inverted lamp, fitted with the needle regulator just described. The mixing tube, A, is in this case both narrow and parallel, and opens out into the mixing chamber, H. It is well known that where an inverted burner has a parallel mixing tube, the increase of volume due to heating, as the gas passes from the injector to the burner, sets up additional friction, and tends to make the burner fire back. This tendency is partially neutralized by the enlarged chamber, H, and partially by the gauze at its lower end, which allows the gas and primary air to pass through its meshes more readily when hot than cold. In addition, the velocity of the gas through A, and the eddying motion set up by the enlargement, makes for perfect mixing of the gas and air before reaching the nozzle.

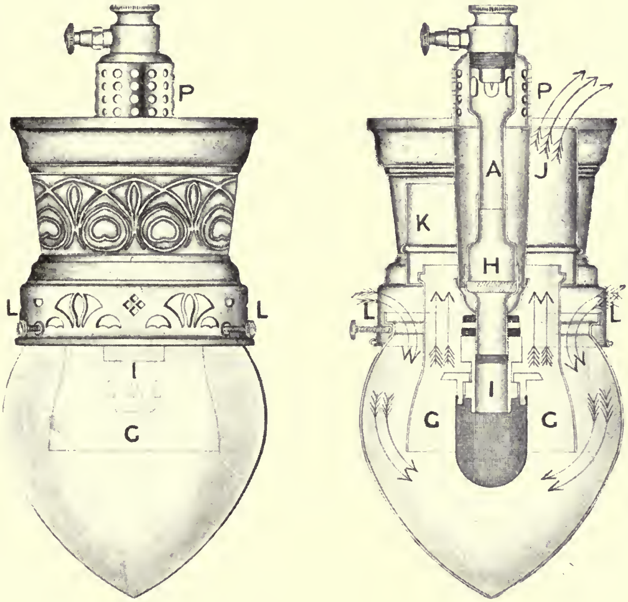


FIG. 365.—Elevation and Section of " Intense " Burner.

To prevent the mixing tube becoming overheated by the too direct action of the products of combustion, an air jacket is formed around the tube, enclosed by the casing, J.

The lower portion of the tube, the burner, and the greater portion of the mantle is enclosed in the glass chimney, G, which is loosely hung by means of a bayonet attachment to the base of the shaft, K. The effect of the chimney is (*a*) to neutralize the ascensional force of the heated mixed gases in the bunsen tube by increasing the velocity of their travel, and so ensuring the steadiness of the flame; (*b*) to induce an increased supply of secondary air to the outside of the mantle, as shown by the arrows, by means of the up-draught; and (*c*) to carry away the products of combustion to a point higher than the inflow of the secondary air supply through the ornamental perforations in the metal casing at L. This air supply, in its passage over the surface of the chimney, G, becomes heated, and is supplied to the mantle hot, so avoiding the cooling effect of the inflow of fresh air upon the mantle which would otherwise take place, and thus increasing the illuminating power. In lamps of this character, the uprush of heated products of combustion through the chimney is so great that the chimney must be brought well down over the mantle, to ensure the lower portion of its surface receiving a full supply of the inflowing fresh air. It is usual, also, to affix a shield at the upper portion of the chimney shaft, for the purpose of diverting the heated products of combustion away from the primary air supply inlets, P.

A very pleasing effect is obtained in the "Omar" lamp of Messrs Moffats, by lining the perforated brasswork of the body of the lamp with an opal glass collar or chimney. This serves two very useful purposes. It protects the metal casing, by preventing access of the products of combustion, and, secondly, it allows a portion of otherwise waste light to pass through the perforations to light the upper portion of the apartment where the burner is fixed. It is easily removed for cleaning purposes.

Devices for keeping burner cool.—Many devices have from time to time been adopted to prevent the mixing tube of an inverted burner from becoming overheated. These have included the making of the tube in several pieces, each separated from the other by an insulating socket of non-conducting material; sheathing the tube with a metal casing and filling the annulus with asbestos; placing the mixing tube within a hollow jacket of insulating tube; while in still another, the same end is attained by inserting a short length of asbestos tube between the mixing chamber and the down tube of the burner.

Illumination curves.—The advent of the incandescent burner, and particularly that of the inverted type, has rendered quite inadequate the method of stating the candle-power of burners upon the horizontal line passing through the zone of greatest illumination. To gauge the comparative value of lamps we need to know not only the candle-power along the horizontal plane of the lamp, but also the amount of light given off both above and below that plane at various angles between the horizontal and vertical planes. The illuminating power obtained at these various angles is usually shown graphically by an illumination curve, in the following way. Take a sheet of paper and describe thereon a series of concentric circles, each being equi-distant from the preceding and succeeding one. Let each succeeding circle represent a uniform increment of a convenient unit of light, say 1, 5, 10 or 20 candles, according to the power of the lamp to be tested and degree of accuracy required. From the centre of the circles draw lines at each successive 10° above and below the horizontal. Imagine a lamp to be placed at the centre of the circles. The quantity of light emitted on the horizontal and at each succeeding 10° both above and below that line is then ascertained by one of the several methods adopted for this purpose, and plotted on the corresponding radial line at the distance from the centre of the circle agreeing with the candle-power found. If, now, these separate points be connected by a line, we have a curve representing the illuminating power given at various angles. Fig. 366 shows such a curve, describing the distribution of light in both upper and lower hemispheres for an upright and inverted incandescent burner, given by Dr Bunte in a lecture to the Association of German Chemists

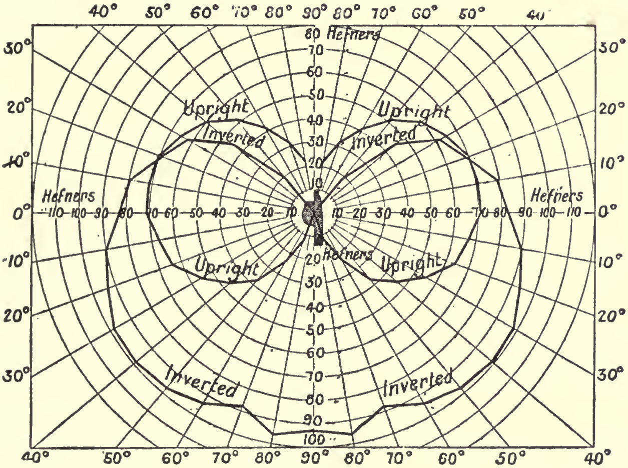


Fig. 366.—Illumination Curves, showing the distribution of light of an upright Welsbach burner (without shade) and of an inverted incandescent burner.

in 1910. In this illustration the successive circles mark an increment of 10 Hefners—shown along the horizontal and vertical axes of the circles—the angular measurements being shown on the borders of the figure.

If, now, we imagine the lamp under test to be placed at the centre of a hollow globe, we may assume that at the same angle below the horizontal and for equal distances from the source, the light emitted will be equal. But a moment's reflection will enable us to see that in ascertaining the mean spherical illumination it would be quite incorrect to take the mean of the readings recorded at the different angles. As a great deal of confusion of thought exists on this point, we may reproduce the lucid explanation given by Dr H. Krüss, as reported in the *Journal of Gas Lighting* for 10th December, 1907, p. 777, which is as follows. Speaking of the illumination curve, he says: "In order to employ these curves in the calculation of the corresponding mean spherical illuminating powers, the space each curve encloses when rotated about its axis of symmetry has to be calculated, and the radius measured of a sphere equal in cubical contents. It is not correct to take the arithmetical mean of the several photometric readings, as is sometimes done, for the mean spherical illuminating power of any given source of light is the amount of light projected in any direction by an imaginary luminiferous object of equal total illuminating powers which casts rays of equal intensity in all directions."

The formula for determining the mean spherical illuminating power is given as

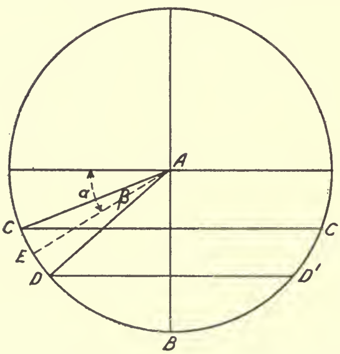
$$I_0 = \sin \frac{\beta}{2} \Sigma\, I\alpha \cos\alpha$$

and that for the mean lower hemispherical illuminating power, as

$$I_\sigma = 2 \sin \frac{\beta}{2} \Sigma\, I\alpha \cos\alpha$$

where

β = the angular distance between successive photometrical readings.
α = the angle formed by a line bisecting the angle at which successive readings are taken with the horizontal.
Σ = Sigma, a sign which denotes the sum of all such things as, in this case, the sum of the various values of $I_\alpha \cos_\alpha$ taken at successive angles.



A reference to the diagram, which is a reproduction of that used by Dr Krüss in his article, will enable these terms to be easily understood. The light is assumed to be fixed at A, which is the centre of a sphere. The angle C A D is equal to 15° and is termed β. The line E A bisects the angle β, and α is the angle made by E A with the horizontal.

The method of using the formula may be best realized by taking a practical example. Assume the case of an inverted incandescent burner giving a light of

70 candles at	5°	below the horizontal		
80	"	15°	"	"
90	"	25°	"	"
100	"	35°	"	"

etc., down to

40 candles at 85° below the horizontal

Then $\beta = 10°$, $\sin \frac{\beta}{2} = 0.0872$, and our example beeomes

Angle α.	Assumed illumination at angle α.	Values of $\cos \alpha$.
5°	70	0.996
15°	80	0.966
25°	90	0.906
35°	100	0.819
etc.,		
85°	40	0.0872

Then the equation

$$I_0 = \sin \frac{\beta}{2} \Sigma I\alpha \cos\alpha$$

for the above readings, when $\beta = 10°$ and $\frac{\beta}{2} = 0.0872$, will be

$$I_0 = 0.0872[(70 \times 0.996) + (80 \times 0.966) + (90 \times 0.906) + (100 \times 0.819) \text{ etc. down to } (40 \times 0.0872)]$$

and, continuing similarly throughout the entire circle,
= Mean spherical illuminating power required.

The mean lower hemispherical illuminating power may be similarly calculated, using the proper formula, given above. The process of calculating these values may seem a very tedious one; but the importance of knowing precisely the quantity of light emitted at various angles, in its bearing upon the proper designing of shades and reflectors, is sufficiently obvious.

Ornamental fittings and switch devices.—Along with the introduction of incandescent gas lighting, and particularly of the inverted burner, a great modification has been introduced in the general character of the fittings adopted. The old clumsy, inartistic chandelier, pendant and bracket, have been or are being rapidly superseded by the graceful and ornate types of fitting now supplied, which lend themselves to decorative effects which a few years ago would have appeared absolutely impossible. A few illustrations of typical examples of these are given in the preceding pages. (See Figs. 343 to 351.)

Undoubtedly one advantage which the electric light has had over gas has been the facility with which the lights, either singly or in large clusters, could be switched on and off from a single convenient centre. For some years now, however, the switch arrangement has been successfully applied to gas for internal lighting, principally along two widely dissimilar lines. In the first method, the object sought has been to simply actuate the gas valve from the switch, the gas itself being ignited by a pilot light. The latter, of course, must be kept constantly burning. In the second type an electric current is utilized to turn on and ignite the gas at one operation, and thus save the cost of the pilot light.

As an illustration of the first class, we may take the Pneumatic distance lighter, which is a device for operating a gas valve by means of such a conveniently placed switch. As its name implies, the controlling valve is actuated altogether pneumatically, the gas supply being turned off and on by air pressure and suction applied through a very fine brass tube connecting the switch and the special valve at the burner.

The back of the switch consists of a small drum-like chamber, within which a piston, capable of moving with an air-tight motion, is placed. This piston is connected by means of a short shaft to the actuating knob. Therefore, when the knob is pulled out, the piston is pulled out with it, and the suction thus applied is conveyed by means of the pneumatic tube to the controlling valve.

A section through this valve, which is fixed immediately above or below the burner, according as the burner used is an inverted or upright one, is shown in Figs. 367 and 368. It consists of the long

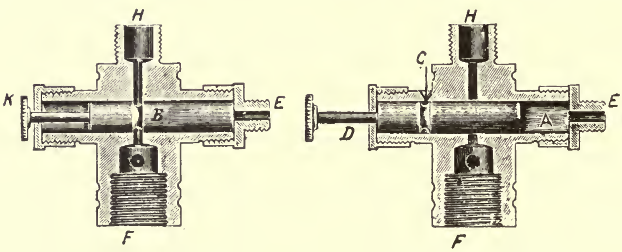


Fig. 367.—Open. Fig 368.—Shut.
Sections through Pneumatic Valve.

circular chamber, A, in which the piston, B, is capable of moving freely. The piston is turned out at the correct point to form a circular groove, C, running round the piston. The piston is open to atmospheric pressure at the end, D, and the pneumatic tube to the switch is connected at E.

Assume, now, that the gas is lighted. The valve will then be in the position shown in Fig. 367, the gas passing upward from F to H, around the groove, C, in the piston B. The switch knob will also be pulled out. When it is required to turn the gas off, the switch knob must be pushed in. With the knob, the piston in the chamber at the back of the switch is pushed in too. This tends to compress the air in the drum, and the pressure impulse is conveyed by means of the tube to the connection E, and acting upon the end of the piston, B, presses it into the position shown in Fig. 368. The groove, C, is thus thrown out of alignment with F and H, and as no gas can pass, the light is extinguished.

When, now, it is required to light the burner again, the switch knob is pulled out, and with it the piston in the drum at the back. This tends to create a vacuum in the tube between the switch and

E, which the atmospheric pressure upon the piston, B, at K, immediately restores, by moving the piston, B, to the position shown in Fig. 367. The groove, C, being thus again brought into alignment with F and H, gas passes through to the burner, and is lighted by the pilot light. In the event of the pneumatic tube being damaged or thrown out of order from any cause, it is obvious that the valve may be operated by hand at the burner.

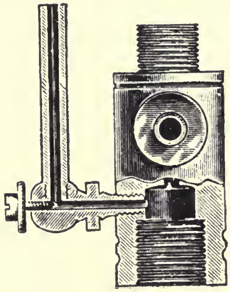


FIG. 369.—By-Pass Attachment.

Fig. 369 shows the by-pass attachment to the valve and the screw for adjusting the gas supply to the pilot light. The by-pass tube is made to suit all kinds of incandescent burners, and is fitted at the end with a steatite tip, with either side or end holes, as may be necessary.

The switch may be applied to the control of clusters as well as single lights, and has been successfully installed in many large halls, churches, and chapels, special modifications being adopted to suit the local conditions. In place of the pull and push arrangement of the switch, a tumbler lever, similar to the electric switch, may be adopted. In that case the piston in the drum at the back of the switch is actuated by a cam upon the back of the tumbler acting upon a roller upon the piston, the latter being pressed forward against the cam by means of a wire spring acting between the rear of the piston and the back of the drum.

As an example of the second type we may take one of the most ingenious and yet really simple of devices for distance lighting, that known by the name of "Telephos." This is made to suit either the upright or inverted forms of burner, and is shown in Figs. 370 to 373.

In the upright form (Fig. 370) the apparatus consists essentially of three parts. At the base of the burner is fixed a metal chamber, A, which contains an electro-magnet, M, with wire terminals, T. At the side of the magnet is placed the armature, L (Fig. 372), which is capable of free movement around the pivot, F. Upon this pivot is fixed a spring in torsion, the purpose of which is to keep the armature away from the electro-magnet when no current is passing.

The armature on its lower edge carries the bent lever, H (Fig. 371), pivoted at I, the lower limit of which contains an oblique slot within which is a fixed pin. The effect of this slot and pin device is to give the lower limit of the bent lever a slight rotary movement. The forward edge, U, of the lower limb is cut out to engage with the edge of the disc-valve, K.

Upon the centre of the base-plate of the chamber, A (Fig. 370), a small disc-valve, K, is placed, which is ground to its seating and kept in gas tight contact with the gas supply by the small spring, N. The disc-valve contains a series of gas passages (Fig. 372), arranged at equal distances from the centre, which alternately register and break with a similar series in the base-plate. These open into the head

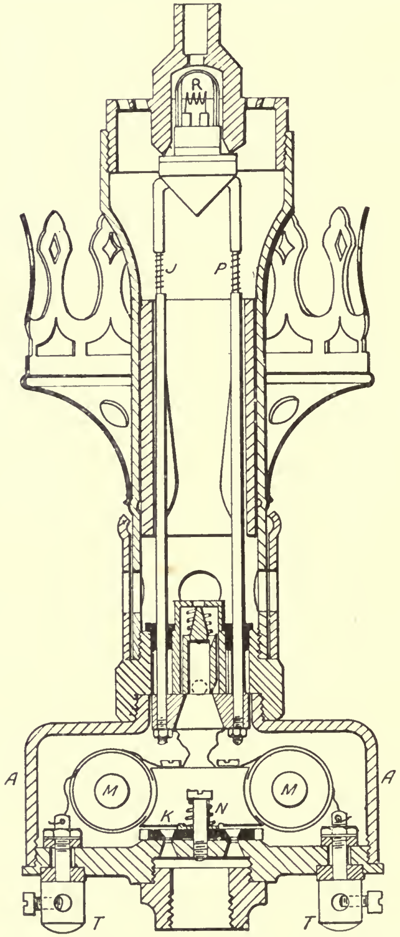


FIG. 370.—Sectional Elevation through "Telephos" Switch and Upright Burner.

of the gas-supply pipe, and are shown in register in the elevation (Fig. 370). When the holes through the disc-valve and those in the base-plate coincide a free passage is permitted to the flow of gas, but when they are out of alignment the gas passages are closed.

The wires J, P, are carried within the burner tube from the electro-magnet, and are connected at the base of the burner head by a very fine platinum wire, R.

The wires for conveying the current for operating the apparatus are carried from the burner either within or without the fittings to an ordinary contact maker of the push knob variety, fixed at some easily accessible and convenient point on the wall of the apartment. From this wires are taken to the small battery necessary, which may be fixed in the basement of the house or other suitable place.

The operation is as follows. Assume that it is desired to light up. When contact is made at the wall plate, by the knob being pressed inward, the current generated in the battery flows through the wires to the electro-magnet, M. The magnet attracts the armature, L, which

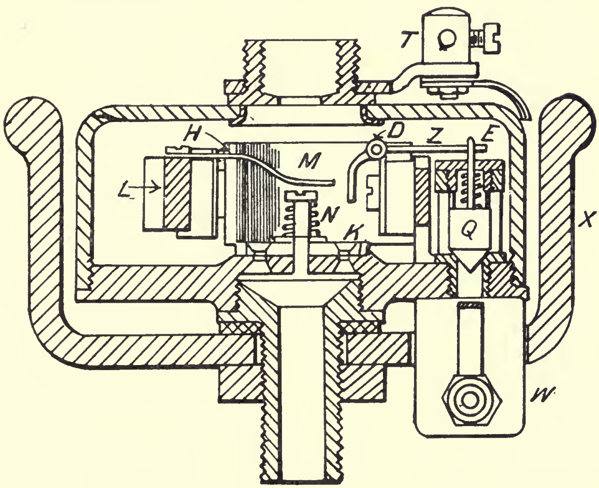


FIG. 371.—Sectional Elevation through "Telephos" Switch and Inverted Burner.

in its movement carries inward the bent and slotted lever, H. The point, U, of the lever engages with one of the cogs of the disc-valve, K, and, owing to the part circular movement imparted by the oblique slot working on the fixed pin, rotates the disc-valve through the distance of one tooth. At the same time the back edge, V, of the lever, H, is brought down firmly on the second cog to the rear, thus ensuring the disc being moved into the exact position necessary for lighting up, and preventing any intermediate position being taken. At the same time, the current flowing through the wires J, P, and through the fine platinum wire, R, at the head of the burner, raises the latter to incandescence and ignites the issuing gas. The pressure on the push-knob is then released, contact is broken and the armature is released.

The latter is drawn by the spring at F to its original position ready for another operation. Although this takes an appreciable time to describe, it will be understood that the action itself is instantaneous. The one operation of making contact at the wall plate turns the gas on by means of the armature, and ignites the gas by means of the incandescent platinum wire, R.

When it is desired to turn the gas off again, all that is necessary is to push the knob at the wall plate, to make contact and complete the

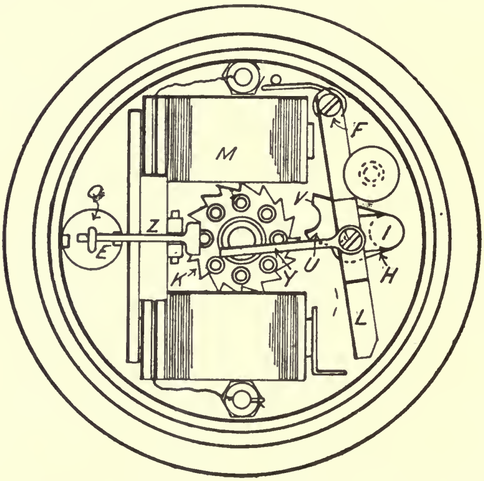


Fig 372.—"Telephos" Switch: Plan and Disc-Valve and Magnet Chamber.

circuit once more, when the disc-valve is again moved on the same way as before, the gas passages are moved out of register and the supply of gas consequently cut off.

Operation by hand.—In the event of either battery or wire getting out of order the armature may be operated by hand from the outside by means of a small knob (not shown in illustration) underneath the base of the electro-magnet chamber. This is attached to a small spindle carrying at its upper end a small inverted cone. When the spindle is moved in a downward direction the cone surface presses the armature inwards and actuates the disc-valve; and the gas is lighted by hand. A small spring on the spindle keeps the cone out of contact with the armature during the ordinary operation of the instrument.

It is obvious from the construction that only one "Telephos" can be controlled from one push with one battery, although fifty burners may be controlled if each has a separate push. Where it is essential to work two lights from one push it is necessary to place them in series with two batteries in series, but two is the maximum number which may be so actuated.

The adaptation of the "Telephos" switch to the inverted burner, involves, necessarily, a very different method of working the lighting arrangement, a section and plan of which is shown in Figs. 371 and 372.

The disc-valve, electro-magnets, and armature remain as before. There is in addition a small valve, Q, which admits gas to the ignition tube (Fig. 373), which is attached at W. The armature supports a bent lever, Y, which, when carried inwards with the armature, is brought into contact with the valve lever, Z. This lever is pivoted at D. When, therefore, the lower end of Z is moved inward, the lever turns on its pivot, D, and the further end, E, is lifted and in turn lifts the valve from its seating and permits gas to pass to the igniter.

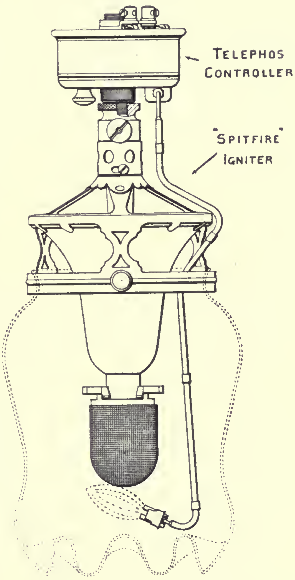


FIG. 373.—"Telephos" Switch: "Spitfire" Igniter.

The igniter consists of a pair of capillary brass tubes, properly insulated, which act as conductors for the current to pass to the fine platinum wire connecting the two lower ends of the tubes, and also as passages for the momentary stream of gas flowing through the valve, Q. These tubes are neatly bent to the shape of the burner as shown in Fig. 373.

When used with the inverted burner the controller is placed within the porcelain dish, X, for the sake of protection.

The weakness of the "Telephos" controller is, of course, that the disc-valve and operating parts must work in a gas atmosphere. This has been found a distinct disadvantage in automatic controllers designed for street lighting purposes, and it remains to be seen whether the objections noticed in the latter case do not equally apply to the "Telephos."

On the other hand, the "Telephos" device eliminates both the cost of, and various difficulties associated with, a pilot-light.

Shades, globes, and reflectors.—The use of auxiliary apparatus, such as globes, in gas lighting, can only be touched upon in the briefest possible manner here.

These may be roughly divided into three classes—namely, shades, globes, and reflectors. Shades may be used for purposes of decoration, or to cut off the light rays in certain desired directions. Globes are used to more or less encircle the light source, and may be used either for decorative effect; to protect the light from draughts; minimize glare, and so soften the character of the light; or the two latter combined. Reflectors, as their name implies, are used to reflect light rays which would otherwise serve no useful purpose into directions where their light is required.

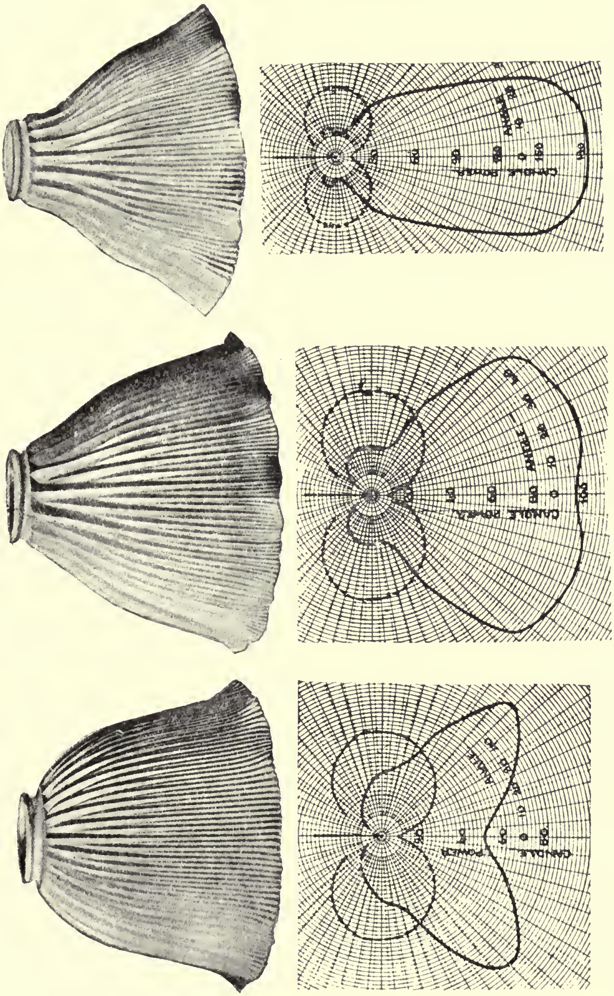
The extent to which the materials used in the manufacture of globes may influence the transmission of light is one of very great practical importance. In his presidential address to the Manchester District Institution of Gas Engineers, Mr H. Kendrick gave some most instructive figures, the result of tests made to determine the obstruction of light from different kinds of shades. The burner used was of the best "C" type, and gave the following results:—

Globes, etc. used.	Gross Candle-power.	Gas used per Hour, Cubic Ft.	Candle-power per Cubic Ft.
No chimney or globe	69.27	3.46	20.02
Straight chimney	74.21	,,	21.44
Straight chimney and metal reflector	88.00	,,	25.42
Clear domestic chimney	71.44	3.55	20.12
Clear domestic chimney and opal reflector	92.12	,,	25.95
Opaline chimney	61.29	,,	17.26
Opal globe	34.81	,,	9.81
Pale ruby globe frosted	36.56	3.45	10.59
Pale ruby globe cut	45.83	,,	13.28
Pale green globe frosted	44.11	,,	12.78
Pale yellow globe frosted	51.93	,,	15.05

Another point in connection with the use of globes is that they vary very considerably in the uniformity of brilliance of the surface according to the material of which they are composed. For instance, it has been proved that an opaline globe gives approximately an evenly illuminated surface and is thus more agreeable and restful to the eye, while the frosted globe has a brilliantly illuminated central area which shades off to comparative dulness around the circumference. The local brilliance together with the loss of clearly defined form associated with the infinite number of reflections from the minute roughened surfaces is not only disagreeable, but also positively fatiguing to the eye.

Ground glass also absorbs from 20 to 40 per cent. of the light, and, therefore, upon figured globes, the ground part should be reduced in extent as far as possible. Very pretty effects may be obtained by the use of tinted glass globes, but they are high absorbents of light. Professor Lewes has found that a pink tinted frosted glass globe absorbs 23 per cent., and a pink tinted opal globe absorbs 34 per cent. of light. Prismatic globes, such as the holophane, are very superior to those previously mentioned, owing to their giving more uniform distribution of the light, and the reflection downwards from the upper prisms of light rays which otherwise would be lost in the upper portions of the apartment.

Reflectors are divided into those giving (*a*) regular, and (*b*) diffuse



Extensive (E) Type Reflector. Intensive (I) Type Reflector. Focussing (F) Type Reflector.

Fig. 374.—Holophane Reflectors, showing representative Distribution Curves.

reflection. In the first class are reflectors with plain surfaces, in which the angle of incidence is equal to the angle of reflection. An example of these is seen in Fig. 352, p. 391. In the second class, the light rays falling upon the reflecting surface are broken up and distributed, as previously described in connection with Fig. 353, p. 391. It must not, however, be assumed that these two classes are mutually exclusive. Both types give both kinds of reflection, but in each, one kind largely predominates. The most common kinds of reflectors are the silvered glass (mirror), metallic, opal, and prismatic, each of which has its own particular use and value.

An excellent series of prismatic reflectors, adapted to suit practically every requirement, have been placed upon the market by the Holophane Company. These are shown in Fig. 374, and consist of three types. In the extensive, or E, type, the reflector is designed to give its maximum illumination at an angle of 45°, and is suitable for general lighting when the light units are placed a distance apart equal to twice their height above the working plane or planes of illumination (desk, counter, etc.). The distribution of light from the intensive type does not cover so wide a field, and is adapted to general illumination when more than one light is employed, spaced apart at a distance about equal to $1\frac{1}{2}$ times their height above the working plane. The focussing, or F, type, will give equal illumination when the distance apart of the unit is equal to the height above the working plane. It therefore, as is seen in the illumination curve, concentrates the light strongly within a few degrees of the vertical, and is designed for the lighting of desks, shop windows, watchmaker's bench, and other places where a strong light is required. It is also useful for the lighting of large apartments, halls, etc., where the light may be placed at a great elevation from the ground level. In this case the circle of lighted area has a diameter equal to half the height of the unit above the plane of illumination

CHAPTER XXII

GAS FIRES AND COOKERS

In view of the great improvements introduced in connection with the modern gas fire and its general adaptability to the conditions of house, office, and workshop, there can be little doubt that, great as has been the development of the use of gas for heating during the past twenty years, the future has much greater progress in store. In briefly considering this subject, it may be well to state (*a*) What are the general advantages enjoyed by gas as a fuel for heating purposes; (*b*) In what way or ways the heating process may be carried out; and (*c*) What are the essentials of a good heating stove.

To begin with, gas as a fuel is clean, and, when properly burned, produces neither soot nor smoke. Having no ash, it produces no dirt. Unlike solid fuel, gas will find its way of its own accord to the exact point at which it is required, if the proper channel is laid for it. The temperature of a gas-heated room is under perfect control, and may be varied at will, according to the extent to which the room is used or the fluctuations of the outside temperature—no small boon in a climate where rapid changes are common, as in this country. The gas fire requires no preparation; it is available at a moment's notice, and can be dispensed with as quickly. When the fire is needed it is possible to obtain in ten minutes a radiation efficiency which it would take five times as long to obtain with a coal fire. When lighted, it requires no attention whatever, but will burn for as long as the gas supply is maintained.

The instruments by which the potential heating properties of the gas are converted into actual heating effect may be divided into three classes, namely, those depending chiefly upon (*a*) radiation; (*b*) convection; and (*c*) those arranged to combine these two methods. Although, for the sake of convenience and clearness, they are classified in this way, it must not be assumed that the two first kinds are mutually exclusive. They are not. Stoves which disseminate radiant heat set up, to a greater or less degree, air currents which heat by convection, whilst a flueless gas radiator will also yield some 15 to 20 per cent. of its heat by means of radiation. In this respect the Glasgow experiments of 1909 are very instructive. An average of seven tests on a radiant fire showed that $16\frac{3}{7}$ per cent. of the heat given off was in the form of convected heat, the maximum obtained being 29 per cent. and the minimum as low as 7 per cent. The amount of convected heat given off from a coal fire was found to be 2.3 per cent.

Considering the great antiquity of the operation, it is surprising how little is understood, except by experts, about such a simple matter as that of heating an ordinary room. Perhaps it may be well, therefore, to explain the difference between heating by radiation and convection, and the results which follow in each case.

Radiant heat.—In speaking of radiant heat, the late Professor Tyndall says :—" You must figure the molecules of the heated body as in a state of motion ; you must figure that motion as communicated to the surrounding ether, and transmitted to it with a velocity which we have the strongest reason for believing to be the same as that of light. When, therefore, you turn towards a fire on a cold day and expose your chilled hands to its influence, the warmth which you feel is due to the impact of these ethereal billows upon your skin. They throw the nerves into motion, and the consciousness corresponding to this motion is what we popularly call warmth. The heat thus propagated through the ether is called radiant heat." These heat rays follow generally the laws of light ; they travel in straight lines, they are reflected in the same way, and may be similarly focussed. The intensity of the heat varies inversely with the square of the distance from the source. The calorific rays, when intercepted, raise the temperature of the body by which they are intercepted. " In gaseous bodies the inter-atomic spaces are so vastly augmented, compared with those of liquids and solids—the molecules, moreover, are so completely released from all mutual entanglement, that scientific men were almost justified in concluding, *à priori*, that gases and vapours would furnish a perfectly open door for the passage of the heat waves." The air is, therefore, perfectly transparent to radiant heat, or may be considered as a perfect vacuum as regards the heat rays. Radiant heat passes through the atmosphere without absorption, but, as has been pointed out, it heats intercepting bodies.

The hygienic effect of these properties, when radiant heat is employed for the heating of a room, is very important. It is essential that human beings should have pure cool air for respiration. The weight of oxygen in any given volume of air is, of course, proportional to its temperature. The ideal warming arrangement would be, therefore, one which keeps the air cool but warms the floor, walls, furniture, and the human body, sufficiently to give the sensation of comfort to those occupying the room. These conditions are satisfied when an apartment is warmed by means of radiant heat. When solid bodies are touched in such a room, there is no absorption of heat from the hands, and, consequently, no sensation of cold. In addition to this, the appearance of glowing bodies from which heat rays emanate is a pre-eminently cheerful one, so much so that even when this appearance is imitated it gives an impression of warmth and comfort, although none may be actually experienced.

Heating by convection.—In the case of convected heat, these conditions are almost entirely reversed. Currents of air are passed over heated surfaces. In their passage they absorb heat. Owing to expansion, and consequently a lowering of the specific gravity, the heated air ascends and sets up a more or less gentle motion in the air of the room. These warm currents are not capable of imparting much heat to the walls, floor, and furniture, but leave them comparatively cool. Consequently, solid surfaces feel cold to the touch, even when the air around is sensibly warm. The convected air currents are somewhat rapidly cooled by the cold walls and furniture, and fall, causing down draughts.

One of the effects of the heating and consequent expansion of the air is felt in the lessened weight of oxygen present in any given volume. There is, therefore, less for respiration. This reacts upon the human organism, inducing sleepiness, weariness, and a sense of oppression. Quite as bad, from the hygienic point of view, is the "moisture hunger" which is set up, and gives the sensation of dryness of the air. This has undoubtedly been the cause of much of the prejudice against the use of gas heating appliances. Many kinds of hot-air stoves are made to be used without flues. In these cases the products of combustion are discharged into the apartment, thus vitiating the more or less attenuated air of the room.

Heating by hot air is considerably cheaper than by radiant heat, and is the most convenient method of warming large halls, churches, theatres, etc., the latter method being obviously inapplicable in such cases. Heating by convection may also be adopted for passages, halls, shops, and other places where there is a considerable movement of people, and where air space is not restricted. This method should, however, never be adopted for sitting-rooms or apartments which are occupied by inactive persons.

Radiant heat stoves.—We may now proceed to consider the instrument by which the potential heating power of the gas is converted to its useful form as radiant heat. This consists of (*a*) the burner; (*b*) the refractory material to be raised to incandescence; and (*c*) the setting of the whole.

The burner should be constructed to suit the particular duty required of it, and the circumstances in which it is intended to be used, so as to ensure perfect combustion. It should have a mixing chamber sufficiently large, and so proportioned to the number of outlets it has to supply as to ensure a sufficient velocity and thorough mixture of the air and gas passed into it. It should be so designed as to give flames of equal length and width, equally aërated, and with the same pressure at each of the outlets. Both air and gas supply should be easily adjustable *in situ* so that a well-aërated flame may be obtained under any reasonable variation of pressure, consumption, or composition of the gas. In this connection it may be remembered that, even with gas of the same candle-power, the adjustments will have to be varied according as to whether the fuel is an unmixed coal gas or a mixture of coal gas and carburetted water gas. If the latter, the adjustment will also vary according to the proportion of water gas present, the reasons being that the specific gravity of water gas is higher than that of coal gas, and, therefore, the nipple velocity is less for the same pressure, and also that less air is necessary for complete combustion as the proportion of water gas rises. But whatever quantity of air is needed, it is essential that the gas and air be thoroughly mixed before reaching the point of combustion.

It is of great importance that the arrangement for adjusting the gas supply should be of the proper kind. The point to be observed

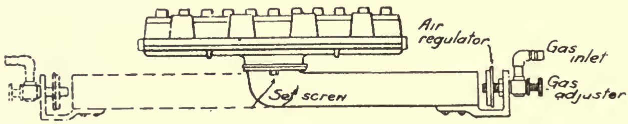


FIG. 375.—Fletcher, Russell, and Co.'s Reversible Non-lighting-back burner, with gas and air adjustment.

is to regulate the volume of gas without decreasing the velocity of flow. For this purpose it is well to have an injector with several holes, similar to those of the Bray's burner, previously described (see p. 400), one or more of which may be cut off without interference with the others. A proper aëration, which depends upon the velocity of flow at the nipple, is thus maintained. It is obvious, too, that where gas is issuing from the nipple in several fine streams rather than in one of greater size, the aëration of the mixture may be carried out much more perfectly for the same consumption of gas.

The burners for a fire may be either single tube or duplex. The latter is supplied through two separate gas cocks, each controlling alternate outlets, or by a special duplex gas cock such as that of Wilsons and Mathiesons Limited, described later in this chapter. The advantage of the duplex arrangement is that when it is desired to diminish the heat produced by the fire, half the outlets may be turned completely off whilst the other half are maintained at full duty. In this case the velocity of the gas at the nipple is not reduced for the set kept burning, and consequently a sufficient quantity of air is drawn in to keep the mixture satisfactory. If, on the other hand, in the case of the single burner, the gas cock is turned down to half, the gas velocity at the injector is reduced, with a consequential change in the relative proportions of gas and air in the mixture. Flames vary in size and shape according to the amount of aëration. When the gas is turned down below two-thirds on, the flame shrinks, is brought out of contact with the fuel, and a considerable loss of radiant efficiency ensues. The extent of this loss is very well demonstrated in the following experiments of the Gas Research Committee at Leeds University, as reported to the Institution of Gas Engineers in June 1910 :—

Experiment.	Calorific Value at 60° F., 30 Inches, wet.	Gas Rate at 60° Fahr., 30 Inches, wet.	Radiant Efficiency, per cent.
Seven burners full on. . .	136.1	18.01	37.73
Seven burners turned down .	137.4	9.62	30.74
Three middle burners full on. .	136.5	9.75	36.93

With approximately equal consumption of gas the radiant efficiency was over 6 per cent. greater with three burners turned full on than with seven burners turned partly down.

One of the best methods of applying the duplex principle is shown in Fig. 376, in which, instead of alternate burners being governed by each tap as was originally arranged, the two right and left hand burners are separately controlled from those in the fire centre. When, therefore, it is desired to shut down the heat the outer burners are turned

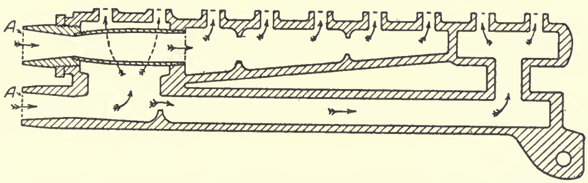


Fig. 376.—Section through Wilsons and Mathiesons' Duplex Burner.

off whilst all those in the centre remain alight. The heat is, therefore, concentrated in a smaller space and better results obtained.

Wilsons and Mathiesons' duplex tap.—In association with their duplex burner a very ingenious gas cock has been devised by Messrs Wilsons and Mathiesons, which avoids the clumsy appearance of some others. This is shown in Fig. 377. In this A is the lever handle of the tap. The tap itself consists of a long hollow plug, C, accurately ground to its seating. The gas enters the interior of this plug as shown at F. From the plug are two outlets, B and D. The former is an oblong hole of twice the length horizontally of the latter. As shown in Fig. 377, both B and D are in alignment with the gas outlet and consequently all the burners are turned on. By turning the lever through a part of a revolution equal to the width of the hole, D, that hole is moved out of alignment with the lower gas passage, E, and the gas is therefore shut off from the burners which that pipe supplies, while, in consequence of the upper hole, B, being of twice the length, although part is moved out of alignment, part still remains open, and so the gas supply to the burners which the upper tube supplies is maintained.

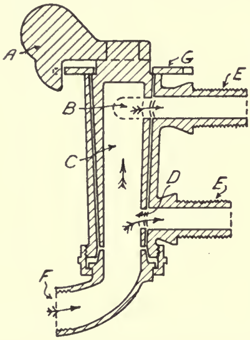


Fig. 377.—Section through Wilsons and Mathiesons' Duplex Tap.

Curved burners.—It has already been stated that radiant heat travels in straight lines from its source. It follows naturally from this, that the heat generated will be better distributed from a curved burner with the convex side outwards than from a straight burner. The total heat developed will be the same, other things being equal, but with the curved burner, the heat rays will diverge at a much wider angle.

Peebles' volumetric governor for gas fires.—In addition to having gas and air adjusters (as shown in Fig. 375), each fire burner should be supplied with gas at a pressure of not less than 20-tenths. Constant pressure and constant calorific quality of gas are indispensable for good gas fire results. The fire should therefore be protected by a suitable governor from the considerable variation of pressure which may be experienced during the twenty-four hours. Such a governor is shown in Fig. 378. In this, the

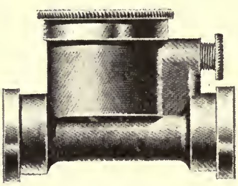
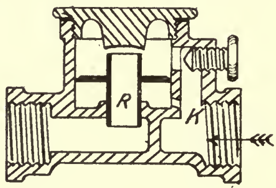



Fig. 378.—Peebles' Volumetric Governor for Gas Fires and Stoves.

gas passes up the inlet port, K, and through the tube, R, of the regulating disc, and away to the burners. At the same time, a small quantity of gas at full pressure is allowed to pass to the under side of the disc. In this way the disc is balanced between the two pressures, namely, the full inlet pressure under the disc closing it, and a modified pressure, according to the position of the regulating screw plus the weight of the disc keeping it open. Any increase or decrease of pressure raises or lowers the disc, thus opening or closing the tube against the cover of the governor and keeping the volume constant.

Noisy burners.—It is very necessary to the comfort of the user that a gas fire should burn as quietly as possible. The noise and roaring frequently experienced with a poorly-made burner prove very objectionable in a comparatively small apartment. The noise sometimes made even in a well-designed burner may generally be traced to one or more very simple causes. Roaring may be caused by over-aëration. The remedy is obvious. It may be due to excess of pressure at the nipple. Here again the remedy is obvious. Or it may be due to some roughness, unevenness, or sharp edge in the nipple. In this case, the nipple must be taken out and the roughness removed. Or it may be caused by roughness or projections within the burner itself. Any such are almost sure to set up a whistling or hissing noise. Or, again, similar noises may be caused by sharp or uneven edges in the port through the plug of the controlling tap. In that case the offending edges may be removed or the tap replaced by a Carter's valve. Where the control is open, and above the floor level, the use of such a valve is always advisable, inasmuch as it is not liable to be turned on inadvertently.

One of the quietest and best injectors yet produced is the "Ollo" injector, patented by Mr Walter Grafton, of Glasgow, which the author has had fitted to one of Main's "St Nicholas" fires, with excellent results.

This injector (shown in Fig. 379) is divided into two collecting and diffusing chambers, separated by a medium affording minute passages distributed over its entire area, in which chambers the flow of gas is impeded and the stream brought to a unform speed before it leaves one chamber to enter the next. The gas-way in the inlet of the injector is a simple opening of an area equal to, or less than, the aggregate area of the holes in the outlet chamber, the latter being numerous and scattered.

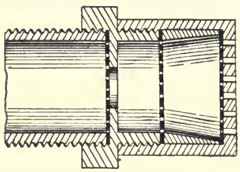


Fig. 379.—Section through "Ollo" Injector.

With an injector so constructed, a broad-based stream of gas issues silently, while air is induced to produce the required combustible mixture, which, when ignited, gives the desired character of flame without noise. The injector is also so constructed that it is self-regulating in respect to the resultant admixture with air; that is to say, the more or less gas that is passed through the injector the more or less air will be induced for primary combustion.

Removable burners.—Seeing that, owing to the crumbling or chipping of the refractory material and the presence of dust in the room, there is a tendency for the burner, air box, and injector to become more or less obstructed, necessitating clearing out from time to time, it is a great advantage when the design of the stove allows for the removal of the burner. It is obvious that the clearing of the burner can very easily be carried out under such conditions. This is recognized now by many makers; and fires are made in which not only the burner, but the whole front of the stove is readily detachable. The advantages are apparent. In stoves where the burners are fixed, the latter may be cleaned by blowing through with an ordinary pair of dining-room bellows.

The refractory material used in the fire may be either asbestos fibre, fireclay, or iron fret. Either of these gives a fire of considerable radiant efficiency. The demand of the public, however, for a fire resembling as nearly as possible the appearance of a coal fire has caused the first and third of these to fall largely into desuetude.

Depth of radiant.—It has now become an axiom that the depth of radiant from back to front must be kept as shallow as possible. A moment's consideration will show the reason for this. The portion of the fire immediately above the burners is obviously the hottest. But there are always some portions of the radiant which project in front of the zone of greatest heat. These are either not incandescent at all, or not nearly so much so as the portions behind, and consequently act as obstructors of the heat rays emanating from the hotter portion of the fire. This is not all loss, however. Some of this obstructed heat, possibly a large portion of it, is reflected back again to the portion behind, thus serving to maintain and conserve the heat in the body of the fire.

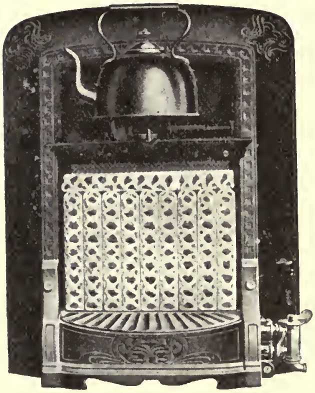
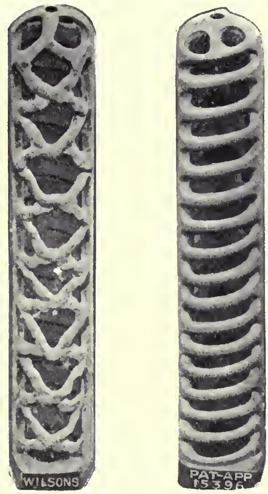


Fig. 380. — Wilsons and Mathiesons' "Savoy" Gas Fire: Nursery Pattern, with Boiling Burner.

Placing of radiant.—In order to avoid premature flame contact, and, consequently, incomplete combustion, the radiant should be placed well above the tip of the hollow portion of the flame, if small fireclay radiants are used. The radiant must not, in any case, be laid so as to break into the inner cone of the flame.

Columnar radiant must fit flame.—It has already been pointed out that the hottest portion of a bunsen flame is that just below the outer envelope. Where columnar radiant is used, it follows that the latter must fit the flame, so as to be in intimate contact with and abstract as much heat from the flame as possible. It is well known that different gases give different sized flames. A varying mixture will also give a varying size of flame. This is one reason why the chemical composition of the gas should be kept as constant as possible. If through varying composition the flame shrinks from the fuel, it is obvious that the efficiency must be impaired. The radiant should also be so shaped and placed that air for combustion has access to the back as well as to the front of the flames.

The construction of the radiant, too, not only has a great influence on the appearance of the fire but also on its efficiency. The aim should be, of course, to construct a radiant of low conductivity, light in structure, but strong enough to withstand wear and tear, and to give as free and unimpeded a radiation from the fire as possible. The patent radiant of Messrs Wilsons and Mathiesons is shown in Fig. 381. The back of the radiant forms a "Louvre" of fireclay, which, when looked at from the angle at which the fire would be viewed when used, gives the appearance of a solid back, while the "Louvres" allow free access of air to the back of the flame for combustion. The front of the radiant is so designed as to offer the minimum screen to heat rays coming off at angles just above the horizontal. Inward projections keep the radiant in intimate contact with the high temperature portion of the flame, while an inward taper from bottom to top shapes the radiant to fit the flame. The importance of a closely fitting radiant may be realized from the fact that at gas fire temperatures the radiation varies approximately as the fourth power of the temperature. Consequently a small variation in temperature, due to shrinking flame or ill-fitting radiants, has a very great effect on the radiant efficiency, which is dependent upon the temperature of the refractory material.



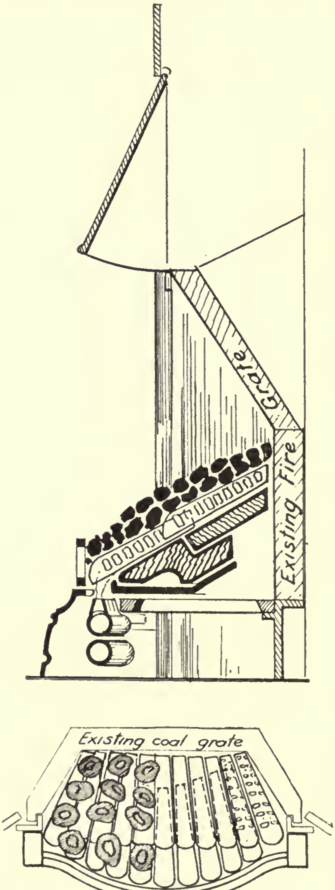
Front View. Back View.

Fig. 381.—Wilsons and Mathiesons' Radiant.

Long radiants.—In order to obtain the greatest possible duty from the gas consumed, the columnar radiant is now being made rather longer than was originally the case, extending to 8 inches in length. The reason for this is obvious. The upper portion is not expected to become incandescent, but it takes up and preserves for useful heating work in the apartment a portion of the heat that might otherwise find its way to the flue, besides tending to maintain a higher temperature in the incandescent portion itself.

Reinforced radiants.—It is obvious that a radiant of so delicate a design is not capable of withstanding very rough usage. With the object of obtaining additional strength a make of radiant has been recently introduced in which the fireclay is reinforced with nickel-steel wires. Whether the unequal expansion of metal and fireclay will prove so disintegrating as to prejudicially affect the life of the radiant we have not as yet sufficient experience to enable us to determine.

The fire setting.—The setting of the fire may be either of two kinds. The existing fireplace may be adapted to receive the fire, somewhat on the lines of Messrs R. and A. Main's "St Nicholas" fire (shown in Fig. 382). All that is necessary in this case is to remove the front bars from the existing stove, place the firebrick in position, with sides in close contact with interior of fireplace. If the latter is deep, a vertical fireclay block must be fitted behind the fire. In any case, a tight joint must be made at the back.



Plan and Sectional Elevation.

FIG. 382.—Messrs R. and A. Mains' "St Nicholas" Fire.

As will be noticed, this fire differs from others on the market inasmuch as the refractory columnar radiant is placed at an oblique angle, and, in addition, has fuel lumps laid upon these. The effect is most pleasing, and is the nearest imitation of a coal fire we have seen. Great stress is laid upon the proper placing of the fireclay radiants. These must be laid in such a way that the flame after striking on them is deflected backward, and it will only do this when laid as shown. The black fuel of the latest type may be laid at random upon the radiants in such a way as to provide a good imitation of a coal fire. The whole arrangement is very convenient, involves little disturbance, and utilizes existing fittings, but it obviously cannot give quite such a high efficiency as a self-contained fire. A greater proportion of the heat passes away to the chimney; and more is lost by conduction to the mass of brick and iron work surrounding it. Where strict economy is not the determining factor, however, these disadvantages are fully compensated for by the cheerful appearance and artistic setting of the fire. This comes out very clearly in Fig. 383, which shows a "St Nicholas" fire fitted into one of Main's tiled alcoves.

Another very good fire for adaptation to existing grates is the "Jet" fire of Messrs Fletcher, Russell and Co., Limited. This is shown in sectional elevation, and the burners in plan, in Fig. 384. The body of the burner is shaped to fit the grate recess, and the nipples are all in front and readily accessible. Nipples of different lengths may be used to conform to the shape of a curved front. Each burner is provided with gas and air adjusters, which are easily accessible from the front of the fire. Pillar radiants are used, each piece interlacing with its neighbour, and horizontal pieces are placed on the top. A fire of good heating power and very pleasant appearance is produced.

Fig. 383.—"St Nicholas" Fire in Tiled Alcove.

The self-contained stove.—The self-contained stove, which has become so common, has undoubtedly many advantages. In this, direct conduction of heat to the chimney stack is entirely prevented. The stove may be brought farther forward into the room. The flue is more perfectly under control, and the whole apparatus is designed to give a high duty for the quantity of gas consumed. The radiating efficiency for a fire of this type may

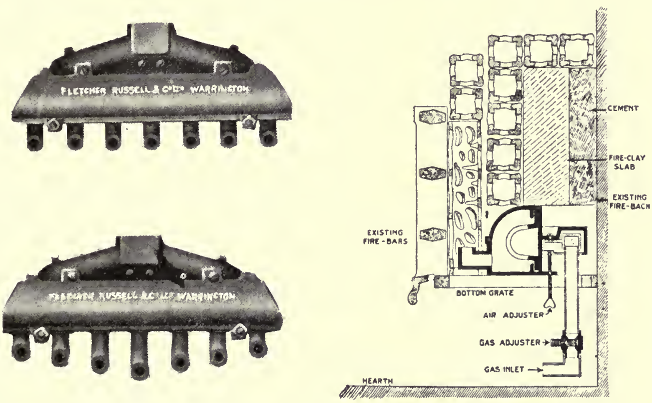


Fig. 384.—Fletcher, Russell and Co.'s "Jet" Fire.

be as high as 55 per cent. Seeing that about 25 per cent. of the heat evolved must go to the flue to maintain the draught, a radiating efficiency of over 50 per cent. leaves very little for convection and losses by conduction, and must be considered a very good result indeed. The constant aim of every gas fire manufacturer is to develop the highest possible percentage of radiant heat with a small proportion of convected heat at comparatively low temperature.

In a properly designed stove of this character, there are one or two constructional points, in addition to those already mentioned, which may be referred to here. The cast iron body should be tough and as light as is consistent with strength; and of sufficient surface, and kept sufficiently cool, to maintain convection at a low temperature. The front bars, which act as so many screens to the radiant heat, should be dispensed with. The back brick should be made as non-conducting as possible, so that a very large proportion of the heat evolved may be thrown forward into the apartment. It should be so placed in relation to the radiant used that access is provided for sufficient air for the proper combustion of the gas at the back of the flame. To ensure non-conductivity at the back, one manufacturer has an air cushion at the back of the back brick. Another arrests a portion of the escaping heat by causing it to pass through the upper portion of the back brick.

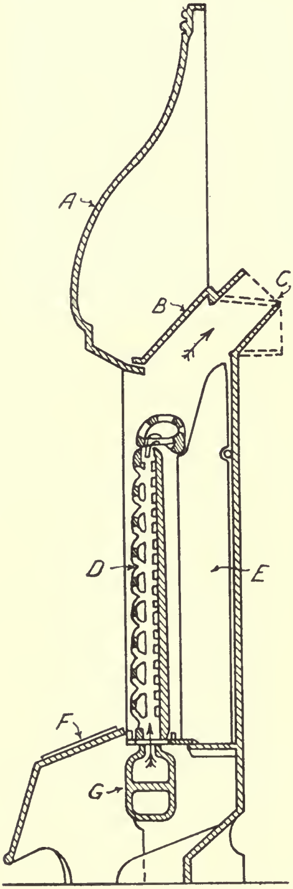


FIG. 385.—Wilsons and Mathiesons' Fire.

The back brick should also be formed with a series of small projections over its front face for the absorption and retention of as much heat as possible. The area of the flue, in relation to the size of the fire, and its exact position, which should be as high as possible in the stove, are very important points. The flue should be almost as broad as the canopy, so as to collect the product of combustion from the full width of the fire, while at the same time narrow enough to prevent an undue loss of heat. Sufficient heat must be lost to maintain a chimney draught, and this is usually about 25 per cent. All above this is pure waste of fuel. When we consider that the Glasgow experiments showed that the amount of heat lost to the chimney ranged from 26 to 58 per cent. for gas stoves, and no less than 75 per cent for a coal fire, it may be realized what a tremendous loss of effective heating power is continually going on.

The size and shape of the canopy also must be so proportioned in relation to the flue that (*a*) the temperature of the gases passing to the chimney should not rise above about 200° Fahr.; (*b*) that the air to supply the up-draught of the chimney should not pass, more than is absolutely necessary, through the incandescent "radiant"; and (*c*) that none of the products of combustion should be able to escape from under the canopy into the apartment to be heated. No gas fire which allows of the latter ought to be tolerated for a moment. The fireclay deflector fitted to some gas stoves is an excellent arrangement, so long as this simple requirement is not transgressed. If the fire is to be fixed into a tiled alcove, such as is shown in Fig. 383, the latter should have as great an angular opening to the room as may be, in order that the calorific rays may be widely distributed.

One of the fires which combine most, if not all, of the points advocated above is that of Messrs Wilsons and Mathiesons, Limited, a section through which is shown in Fig. 385. This is fitted with the duplex burner, G, and patent radiant, D, already mentioned. The latter is long and shallow, and is placed so as to allow of air access between it and the back brick, E, for combustion at the back of the flame. The canopy is wide and well proportioned, and the flue has a movable nozzle, C, so as to allow of the use of an obtuse angle flue elbow into the chimney stack. In addition, the fire is fitted with a fret with copper reflector, F, for the purpose of better distributing the heat emitted from the fire. This not only serves the purpose of a reflector, but also of a regenerator chamber. The under part is formed of curved plates, which form channels through which the air passing to the burners and flames is preliminarily heated. It is claimed that the reflector increases the radiant heat emitted by about 30 per cent. And last, but not least, the fire has no front bars to obstruct and impair the radiant efficiency of the fire.

Flue necessary.—Incandescent gas fires always require a good flue. No gas fire should be fixed to a chimney where there is a down-draught without special precautions being adopted. Without such it is bound to be not only unsatisfactory, but probably a thorough nuisance. Every care should, therefore, be exercised in this respect in all cases, and particularly where it is proposed to fix such a fire in a sick-room. A faulty or even a doubtful flue should always be considered a bar to the employment of a radiant stove until special means have been adopted to make it satisfactory. Under proper conditions the radiant fire, with its glow and cheerful appearance, is admirably suited to a sick-room.

Imperfect Flues.—Imperfect flues are of two different kinds (*a*) those without a natural pull, and (*b*) those having a positive down-draught. The former may usually be overcome by blocking up the fire front or the register, and extending the stove flue pipe for a short distance up the chimney, leaving it with an open end (no conical cap), so that the velocity of flow may be maintained as high as possible. In the case of down-draught one of the best devices, of a cheap and simple kind, is that shown in Fig. 386, and described by Mr E. W. Browning in a paper read before the London and Southern District Junior Gas Association in January 1911. In this the register is blocked, the flue pipe open at the end as seen at B, while, in addition, the chimney top is also stopped, the stopping being fitted with a flue pipe surmounted by a conical cap as shown at A.

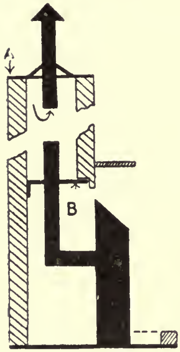


Fig. 386. Browning's Flue Device.

Another very simple and homely device which has relieved the nuisance of down-draught is to fix a wire basket, filled with coke, into the top of the chimney. The coke allows sufficient vent for the flue gases from the fire, while effectually baffling any current of cool air tending in a downward direction.

Flue as ventilator.—In addition to carrying off the products of combustion it must be remembered that the flue may be a most efficient, and in many cases is the only means of ventilating an apartment. The extent to which the air of a room may be changed by the flue up-draught is very considerable. To quote the Glasgow experiments once more, it was found that with a gas fire the flow of chimney gases varied from 6440 to 14,181 cubic feet per hour, the average flow being sufficient to change the air of the apartment 5.2 times per hour. The flow of chimney gases with a coal fire was found to be 17,500 cubic feet per hour, or sufficient to change the air of the apartment ten times per hour.

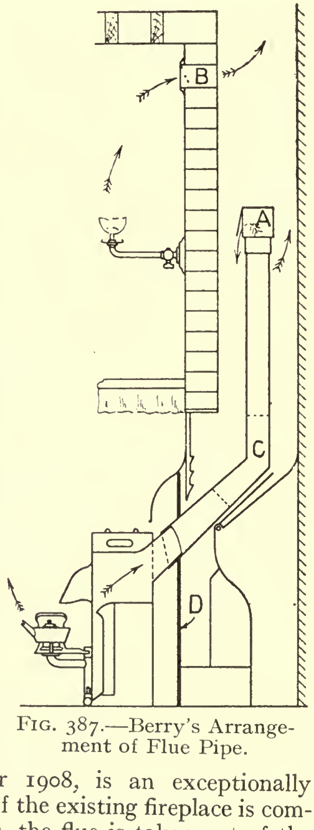


Fig. 387.—Berry's Arrangement of Flue Pipe.

The arrangement of fire, flue, and flap valve of Mr E. Berry, shown in *The Gas World* of 12th December 1908, is an exceptionally good one (Fig. 387). In this the front of the existing fireplace is completely blocked by plates of Uralite, D, the flue is taken out of the stove at an upward angle, from which the flue pipe is brought square into the chimney by the obtuse angle, C, the up shaft being capped by the mica flap valve, A. The stove stands well out into the room, the direct conduction of heat to surrounding brick or iron work is reduced to a minimum, and the heating effect correspondingly increased. The mica flap valve, B, is shown fixed in the chimney breast, near the ceiling, for the purpose of ventilating the room.

It has been pointed out, in connection with the flow of gas in pipes, that sharp elbows obstruct the flow very considerably. Obviously the same principle applies equally to flue pipes. The systematic way in which this elementary rule is disregarded in the case of these almost makes one wonder whether some malign influence is not at work to throw as many obstacles as possible in the way of satisfactory working. Instead of the sharp tee or elbow joint, all flue pipe connections to fire, cooker, hood, etc., should be made by means of bends of as wide radius as possible, so that the flow of hot gases may be facilitated to the greatest extent. The flue pipe may also be tapered down as it ascends, so as to maintain the velocity of the escaping gases.

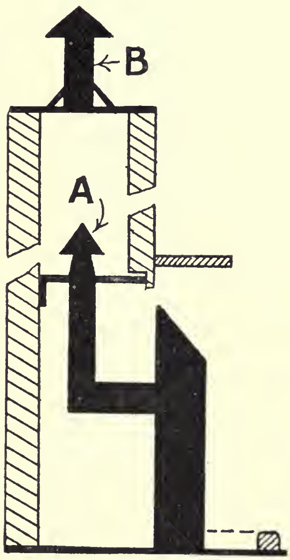


FIG. 388.—Browning's Excessive Flue Draught Device.

Mr Browning, in the paper previously referred to, has an excellent device for dealing with a chimney with an excessive draught. When the chimney draught is excessive, the area of the flue pipe from the stove should be reduced, fitted with a conical cap as shown at A (Fig. 388), and the chimney opening restricted by being closed around the stove flue pipe. The top of the chimney should also be stopped, and fitted with flue pipe as shown at B.

Combined radiator and hot air stove.—Many stoves of the radiant type are fitted with hot air tubes for supplementing the warming effect of the radiant by convected heat. The air supply for these tubes may be taken from the room to be heated or directly from the outer air, by means of special air shafts. This cool air is passed through or over tubes fixed in the back of the stove. The tubes are subjected to the heating effect of the fire and the products of combustion. In its passage, the inflowing current of air absorbs heat from these hot surfaces, which it carries forward into the room. Whilst of advantage in some respects, this arrangement is not all gain. The amount of radiant heat given off by such a fire is very considerably less than that obtained from a similar fire but without the hot air tubes. The reduction was found by Mr Brearley to be in the proportion of 59 to 44.

Heating by convection.—The general effect of heating any apartment by means of air currents has already been stated, and it is only necessary here to consider the apparatus by which this is effected. These may be divided into two general classes, namely, those working by means of hot air, water, or steam pipes, and those for warming currents of air by passing them over directly heated surfaces.

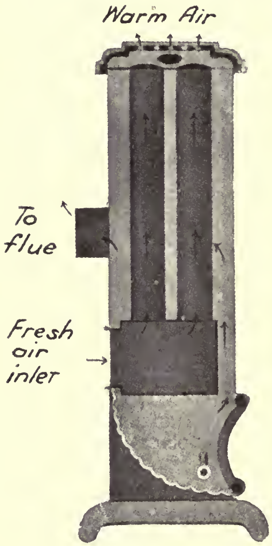


FIG. 389. — Vertical Section through Fletcher, Russell and Co.'s 3 F Hot Air Stove.

We have already been considering the arrangement for heating air in connection with a combination stove. Hot air stoves, pure and simple, depend upon a somewhat similar setting. In Fletcher's tubular stove, fresh air is passed from an enclosed chamber at the back of the stove through a number of horizontal tubes placed over the burners, and discharged in a more or less heated condition into the room. Fig. 389 shows a vertical section through another type of hot air stove, in which the fresh air introduced from the outside is heated in its passage upwards through the vertical tubes by the heated current from the gas flames in the base of the stove. At the same time, a very cheerful appearance is given, and a certain amount of radiant heat thrown into the room, by means of the planished copper reflector placed behind the burners. The surfaces which impart heat to the inflowing current of air may themselves be heated by means of either atmospheric or luminous gas flames. There are an almost infinite variety of stoves upon the market which are designed to utilize the calorific power of the gas in one or other of these ways. It should always be remembered, in this connection, that the heating power is exactly the same for a given volume whether the gas is burned in a bunsen burner or with a luminous flame, given perfect combustion in each case. The principal thing is to so arrange the apparatus that the combustion is perfect, and carried out under such conditions as will return the greatest duty in heating effect for the quantity of gas consumed.

Hot air stoves are popularly supposed to require no flue, and many devices have been adopted to conceal the fact that in all such cases the products of combustion are discharged into the apartment. It should be taken as an elementary principle that even with hot air stoves a flue should always be provided, wherever possible. In any case, no stove of this class should ever be fixed without a flue in any room which is not lofty, or of great cubical capacity, or which is badly ventilated, or which is generally closed up, or occupied by persons engaged in sedentary occupations.

" Radiator " series.—The radiator type of stove, which has come into vogue during the last few years, bids fair to gradually squeeze out the older type of hot air stove. They are cheap, adaptable, and economical in use. As to the name, although these stoves are termed radiators, it must not be assumed for a moment that their heating effect is chiefly by means of radiant heat. In fact, from that point of view, the name " radiator " is quite a misnomer. As far as the author is aware no one has established the proportion which the radiant heat bears to the whole emitted, but it is probably not more than one-fifth, leaving four-fifths of the total to convection. This may be proved by any one who will go to the trouble of boxing a radiator in, leaving a longitudinal strip along one side near the bottom for testing by means of a galvanometer.

Radiators may be made both horizontally and vertically, but it is found that far higher results are obtained from the vertical than from the horizontal form. The reason for this is not far to seek. The circulation of heated water, or steam, or air, is far more rapid in pipes arranged vertically than in those placed horizontally.

The point to be aimed at in convection heating by radiators is to obtain a fairly rapid and even distribution of heated air throughout an apartment. Therefore the radiator is made with as large a surface as possible for the size of the loops. These should not be placed too close together, or the fullest efficiency will not be obtained. Fresh cool air must have the freest access to the surfaces of the radiator loops, and the passage of the heated currents away from the top of the radiator should be absolutely unimpeded. On this account ornamental iron or marble tops, which baffle the ascending current of warm air, should always be avoided.

The particular circumstances of different apartments vary so widely that the calculation of the amount of radiating surface required to heat any room of given size is not a very simple matter. All that can be attempted here is a brief discussion of the factors underlying the problem, giving simple rules which generally work very well, but which may need qualification according to local circumstances.

The unit of heat, or British thermal unit, used in England is the heat required to raise 1 pound of water 1° F. The specific heat of air is .2375. At zero one cubic foot of air weighs .0864 pound and

$\frac{1 \text{ lb.}}{.0864} = 11.574$ cubic feet. Then $\frac{11.574}{.2375} = 48.73$ cubic feet of air raised 1° F. by one B. Th. U.

The emission of B. Th. U.'s by the surface of the radiator has next to be considered. The following transmission table showing the B. Th. U.'s emitted per square foot of heating surface per hour has been compiled from data given in the National Radiator Company's handbook :—

Radiator. No. of Loops. — "Ideal" Radiators.	Height of Radiator in Inches.	Heating Surface per Loop, in Sq. Ft.	Temperature difference between Radiator and surrounding air.			
			150-60°	160-60°	170-60°	180-60°
1	38	3	150	165	182	198
2	45	5	140	155	171	186
3	46	6	131	145	160	174
4	38	8	121	135	148	162

That is to say, that a single loop "Ideal" radiator will emit 150 B. Th. U.'s per square foot of heating surface per hour when the radiator is at a temperature of 150° F. and the surrounding air is at a temperature of 60° F. It must always be remembered, in working out heating problems, that, according to the Stefan-Bolzman law, the radiation from a black body varies proportionally to the fourth power of the absolute temperature.

The problem now becomes one of ascertaining the number of square feet of heating surface which will be necessary to heat the air of any room. Take as a simple concrete example the case of a room $16' \times 14' \times 10'$. Then the cubical capacity of such a room is 2240 cubic feet. It is required to raise the temperature of such a room from 50° F. to 60° F., or a rise of 10° F., and the radiators are at a temperature of 150° F. Then, on the basis of an emission of 150 B. Th. U.'s per square foot of heating surface,

$$\frac{2240 \left(\text{cubical capacity of room}\right) \times 10 \left(\text{rise of temperature in degrees Fahr. required}\right)}{48.73 \left(\text{cub. feet air raised } 1^\circ \text{ F. by 1 B. Th. U.}\right) \times 150 \left(\text{B. Th. U. emitted per sq. ft. of heating surface}\right)} = 3.06 \text{ sq. ft.}$$

radiating surface required.

The gas consumption necessary may also be similarly calculated. We have seen above that 48.77 cubic feet of air may be heated 1° Fahr. by 1 B. Th. U. In the preceding problem, then, the quantity of gas required will be as follows :—

$$\frac{2240 \left(\text{cubical capacity of room}\right) \times 10 \left(\text{rise of temperature required, in degrees Fahr.}\right)}{48.73 \left(\text{cubic ft. of air raised } 1^\circ \text{ F. by 1 B.Th. U.}\right) \times 500 \left(\text{assumed B.Th. U. per cubic feet of gas}\right)} = 0.9193 \text{ c. ft. of gas required.}$$

These, of course, are purely theoretical results. It will be obvious to any one that such an amount would be totally inadequate. In actual practice the result would require multiplying by 5 or 6. The reason is that no account is taken in the above calculations for the heat losses which are continually taking place. What are these losses ?

(1) Loss due to the change of air which is continually taking place. In an occupied apartment where the ventilation is at all adequate the whole cubical contents of air are changed six to eighth times in an hour,.

(2) Loss from the cooling effect of glass windows. These and sheet or corrugated iron are the worst and most extreme of cooling surfaces. Sheet or corrugated iron surfaces in a building, if uncased, must therefore be treated as glass for purposes of calculation.

(3) Loss by absorption and conduction by means of walls and ceilings.

(4) Losses through entrances, especially if these open directly into the outer air. It is obvious that the loss must be much less when the entrance is from a lobby, corridor, or other interior apartment.

(5) Where radiators are heated by boilers fixed in other parts of the premises, the losses of heat due to radiation from the connections must also be taken into account in estimating the quantity of gas required.

The extent of these losses are given in the National Radiator Company's handbook as follows :—

4½-inch brick wall	0.5	Loss in B. Th. U. per hour per square foot of surface per degree difference F between room and outside atmospheric temperature.
9-inch brick wall	0.35	
14-inch brick wall	0.27	
18-inch brick wall	0.23	
Panelled wood door	0.45	
Single windows	1.03	
Double windows	0.48	
Single skylights	1.11	
Corrugated iron roof	2.17	
Lath and plaster ceiling	0.40	
Joist floor with 1¼-inch boards. Plaster ceiling under, cold air above	0.17	
„ „ cold air below	0.07	
Per cubic foot of air—		
When changed once per hour	0.019	
„ „ twice „ „	0.038	
„ „ thrice „ „	0.057	

For north or east exposures 10 per cent. should be added to the above figures.

To calculate heating surface required.—A very good simple rule for calculating the heating surface required for heating an apartment, which takes into account the sources of loss above mentioned, is as follows :—

To obtain 60° Fahr. in any ordinary brick-built room when it is 30° Fahr. outside,

Allow one square foot of heating surface to each five square feet of glass, with the addition of twelve square feet of heating surface to each 1000 cubic feet of space in the room. Add 10 per cent. to the latter if two of the walls are exposed.

Applying this rule to the room mentioned above, and assuming that it contains 100 square feet of glass surface and only one exposed wall, the calculation would be :—

$$\frac{100}{5} + \frac{2240 \times 12}{1000} = 46.88 \text{ radiating surface required.}$$

Another rule which gives approximately corresponding results is :—

Divide the glass area in square feet by 6 ; divide the exposed wall area in square feet by 12 ; divide the cubical capacity of apartment by 120. Add the quotients together, and they equal the radiating surface required. Put in form of an equation this is :—

$$\frac{\text{Glass area}}{6} + \frac{\text{Exposed wall area}}{12} + \frac{\text{Cubical capacity of apartment}}{120}$$
$$= \text{Radiating surface required.}$$

Applying this rule to the foregoing example, and assuming the exposed wall to be 16′ × 10′, we obtain

$$\frac{100}{6} + \frac{160}{12} + \frac{2240}{.120} = 48.65 \text{ super. feet}$$

as radiating surface required, a rather higher result than that given by our first rule owing to the extra allowance for exposed wall surface.

Convection currents limited.—The extent of the heating required for any room will, of course, vary with the purpose to which it is put, but the standard for lecture halls, churches, chapels, and other such buildings, is usually from 60° to 65° Fahr. It is a curious fact, proved by reliable experiment, that the heat—the convected air current really—from radiators or hot water pipes placed near the ground has little circulation, and therefore little heating effect, at more than 15 or 16 feet above ground level. At that height the air currents spread and descend, unless the motion is counteracted. This may be done by other radiators placed at this level, or by heated pipes carried along.

Radiators may be divided into steam radiators, hot air radiators, and hot water or steam circulating radiators. The two former are self-contained, whilst the latter is connected up to an outside boiler. The latter system is shown in Fig. 390, and follows the well-known principle of the hot water circulating system. With a radiator of this type it may be taken that the water capacity equals one-fifth gallon per square foot of radiator surface. If such a radiator is to be used economically it is necessary that some automatic device should be attached for the purpose of closing down the gas supply when a predetermined heat has been attained. This will be considered in fuller detail later, and it will be sufficient here to say that in this particular type the gas supply is controlled entirely by the steam pressure, and waste in gas consumption is thereby altogether prevented.

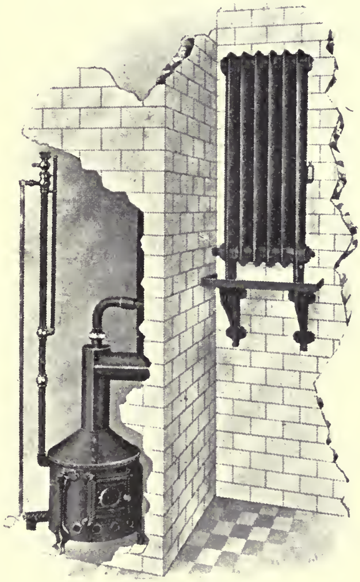


FIG. 390.—Radiator Connected to Boiler.

Precautions in fixing.—There are a few simple precautions to be taken in fixing hot water circulating radiators if the installation is to be a success. There should always be an air vent at the highest point in the installation. The series should always be filled from the bottom, so that the air may be driven forward through the vent or vents. Should the whole of the air not be expelled, a portion of the installation may become airlocked and circulation fail. The flow pipe from the boiler is, of course, the hottest part of the circulatory system, and a great quantity of heat may be lost from the connections before the radiators are reached. It is important, therefore, that all connecting pipes should be properly and sufficiently lagged. For this purpose slag wool, which is a silica-wool, a waste product from blast furnaces, may be used, if it is possible to case the pipes; or one of the numerous non-conducting compositions on the market may be used. And lastly, a cock should be provided at the lowest point of the installation for the purpose of emptying. If the installation is of sufficient size and is to be frequently emptied, a hose connection and flexible tube to convey the water to the nearest drain trap should also be provided.

Steam radiator.—The steam radiator consists of a series of single or double columns, up to any convenient number, so arranged as to give the greatest possible surface for their size. The tubes are connected into a common bottom chamber, A (Fig. 391), and each pair is connected into the next pair at the top by a loop, as shown at RR. Water is introduced into the base of the radiator, the exact height being shown in a gauge glass, W, at the side. It is important that no greater quantity of water should be admitted to the radiator than that which, if all converted into steam, would still keep the steam pressure generated well within the safe working limit of strength of the apparatus. The height of the water level should therefore never exceed about half the height of the gauge glass. In order to avoid undue internal pressure it is also necessary to attach a reliable automatic valve to each steam radiator, in order to reduce the gas consumption when a certain predetermined pressure has been reached. The water is heated by a row of bunsen jets, J, fixed under the chamber, A. As steam is generated, the air contained in each loop is expelled through the vent, V. As the temperature rises in the radiator, the steam heated columns, by heating the contiguous air, set up air currents, which, in a gentle motion, are propagated through the apartment.

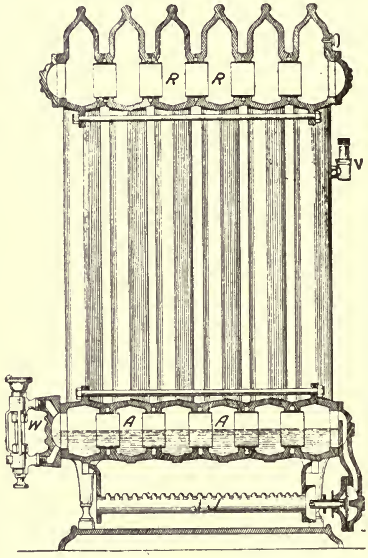


FIG. 391.—Sectional Elevation of "Main" Steam Radiator.

Thermostat.—The economical working of such an apparatus depends largely upon the gas supply being checked when the maximum required temperature has been reached, and also that this check should be automatic in its operation. This is provided for in Main's gas-heated steam radiator (Fig. 391) by the simple device shown in enlarged section in Fig. 392. This consists primarily of a pilot injector, B, flanged at one end and capable of a sliding movement within a larger injector, C, in such a way as to control the gas way through the latter. In proximity to the flanged end of the pilot injector a flexible diaphragm, A, is fixed, one side of which is open to the steam chamber of the radiator. When the steam is generated, pressure is exerted upon the diaphragm, which, in yielding, pushes the pilot injector, causing it to slide within the outer tube, thus partially closing the larger injector, C, and reducing the gas supply. When owing to reduced gas consumption the pressure on the steam side of the diaphragm has been relaxed, a spring surrounding the pilot flame injector, B, presses the flange of the latter against the diaphragm. The movement of the diaphragm, therefore, withdraws the pilot injector away from C, thus opening the gas way more fully until the balance has been once more restored. The full bore flame may be adjusted by the milled screw, E, and the air supply by the plate, F, which may be screwed into position in relation to the mouthpiece, G, of the burner to control the air passage as required. A lock nut secures the whole in place when the final adjustment has been made *in situ.*

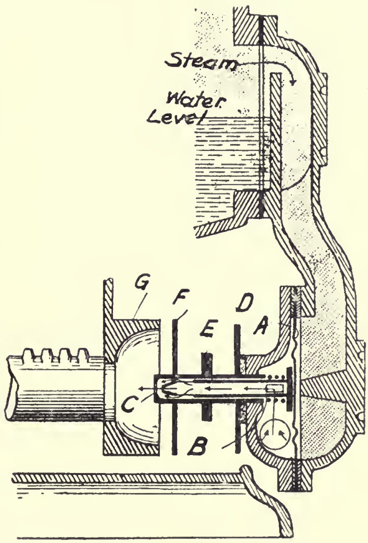


Fig. 392.—Enlarged Section through the "Main" Automatic Valve.

Steamless radiators. — The steamless radiator follows generally the same line of construction as the above, but in this, instead of first converting the calorific power of the gas into steam, and using this as the heating agent, the steamless radiator depends upon hot air alone for its heating power. Figs. 393 and 394 show one type of such a stove which the author has found to give excellent results. In this, the outer loop, A, is fitted with an inner tube, E, which passes throughout the length of the loop. The inner tube is stopped at the upper end, and perforated with a series of holes, F, on opposite sides. A burner jet, K, is placed immediately below each of these inner tubes. The rising current of heated air passes, therefore, directly into this inner tube, and, the tube being blocked at the end, the air has to find its way through the perforations into the loop tube. The effect of this arrangement is to baffle the heated air to some extent, and maintain a warm temperature near the floor. As the heated air rises to the top of the loop, it is discharged into the apartment through the grating, V; the process being continued as long as the stove is kept alight. These stoves are now being made with a base entirely independent of the columns, to which is fitted the burner, gas connections, governor, and regulating jet. The advantage of being able to add the loops after the base has been fixed, and all painting and decorating has been finished, is sufficiently obvious. One advantage the steamless radiator has over others is that, because of there being no internal pressure, the loops may be made of lighter castings. There is, therefore, a smaller mass of iron to heat and the action is correspondingly quickened. As these radiators are usually fixed without a flue, the gas supply should always be governed by a good regulator, so that when the adjustment of gas and air supply is finally made, it may not be upset by possible fluctuations of pressure.

The gas cooker.—The prejudice which the introduction of gas heating stoves has had to overcome was greatly intensified in the case

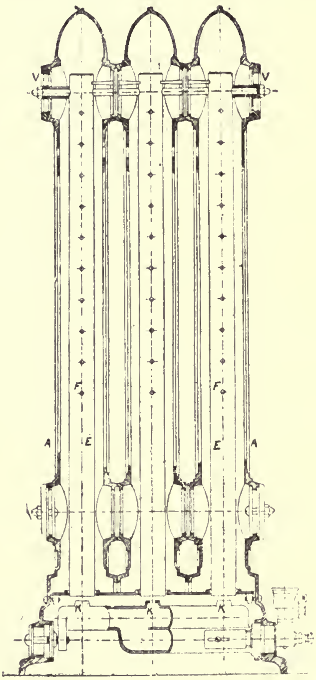


FIG. 393.—Sectional Elevation through Davis Steamless Radiator.

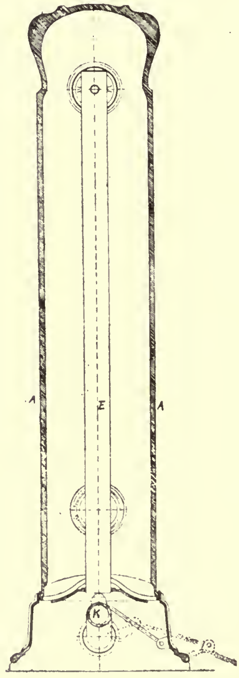


FIG. 394.—Side Sectional Elevation of Davis Steamless Radiator.

of the gas cooker. Owing to an entire misapprehension as to the physical laws involved in, say, roasting a joint of meat, it was concluded, quite erroneously, that the joint must inevitably absorb, to some extent at least, the products of combustion, and become "tainted." This is now known to be a sheer physical impossibility; and the huge proportions to which the demand for gas cookers has grown show that the public are quite aware of the fact.

When we consider the great advantages of cooking by gas, we are not surprised at the general demand for these stoves, which but a few years ago would have seemed quite incredible. They are clean and economical. They require no cellar for fuel storage, and the fuel does not require carrying from one point to another. The entire absence of dirt and dust enables many housewives to undertake in comfort themselves much work in the preparation of food which previously had to be left to servants. Household expenses may, therefore, be cut down considerably in this direction, and greater personal oversight in the kitchen work rendered possible. The stove is always available at any hour of day or night, without the slightest preparation, beyond striking a match, and may be closed down by the simple operation of turning the lever of a gas cock. Temperatures are under complete control, and may be graded with a degree of accuracy absolutely impossible with a coal stove. Owing to the fluid nature of the fuel, the heat may be well distributed and equalized throughout the oven. Finally, the gas cooker is not only adapted to every kind of cooking, but, if used with any ordinary degree of care, will compare very favourably in cost for fuel for ordinary household purposes, and for the same duty, with any coal stove on the market.

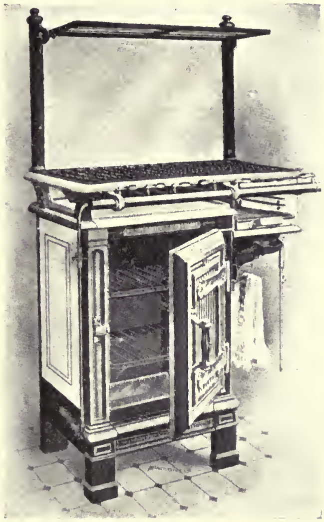


FIG. 395.—Wilsons and Mathiesons' "Advance" Cooker.

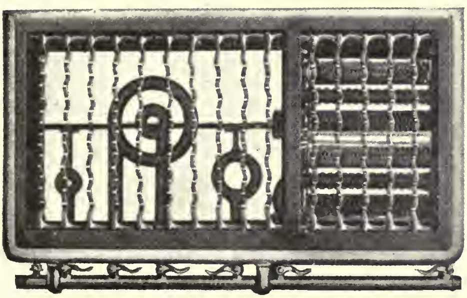


FIG. 396.—Top Plate of Wilsons & Mathiesons' Stove.

The closed oven, which was originally, in part, a costly concession to some of the prejudices noted above, has quite given way to the open form shown in Figs. 395 and 396, which has now been adopted by all makers. The outer shell of such an oven has, obviously, a very great surface in contact with the atmosphere.

If, therefore, the stove is to be economical in fuel costs, some steps must be taken to prevent radiation from this extended surface. This may be accomplished by double casing the oven, and so forming an air jacket; or, more generally, filling in the two inches or so of space between the shells with non-conducting material. Slag wool is the material generally used.

The oven of a cooking stove may be heated by either luminous flame or atmospheric burners, but the latter are most generally used. These should be so proportioned as to make a perfect mixing chamber, large enough to give a full supply to each jet, and so designed as to develop to the greatest extent the calorific power of the gas. The burners should be so placed as to ensure the most perfect and equable heating of the oven, and, in the open type of oven, should be protected from dropping fat; the air and gas adjustment should be easily get-at-able; and where fluctuations of pressure are experienced to any great extent, the gas supply should be properly governed, so as to ensure perfect combustion, and to check possible waste.

The oven should be sufficiently roomy to allow of the heat being equally diffused, and be well ventilated by a gentle inflow of fresh air. This is not only needed to support the combustion of the gas, but also to give the effect of roasting rather than that of baking the joints to be cooked. The roof of the oven should be of such a character as will deflect a portion of the heat there back again on to the upper surface of the food being cooked. In order to reduce the waste heat to a minimum, the flue should be under perfect control, that the outward rush of hot air from the oven may be checked to any desirable extent. The firebrick radiating slab, fixed in the roof of the oven by one maker of repute, by absorbing and retaining a portion of the heat, tends to keep down the fuel cost.

It has been already pointed out that the cooking stove is naturally a very clean instrument. In this respect its advantages have been materially increased by the general adoption of removable linings. Made of enamelled iron, the oven interior, in most makes of stove, is so constructed as to be easily removed, thus facilitating scouring whenever this can be best fitted into the domestic arrangements of the household. The burners, too, are liable to become choked with dust and dirt, the air boxes to become obstructed, and the nipples to need attention. For all these purposes, it is necessary that all the burners should be readily detachable.

The arrangement of the top plate of a cooking stove is a matter of considerable importance, because here a great variety of adaptation is necessary. Some modification is necessary, according as grilling, frying, or boiling is in process.

The burners themselves should be of different sizes, to suit the various duties required of them, and so spaced over the available area as to give each sufficient room for its work. It is most important that the burners be placed at the correct distance below the top bars. If fixed too near the under surface, when the vessels are placed over them there will be interference with combustion, while if placed too far below the full duty from the gas consumed is not obtained. In either case there is a loss of efficiency. For toasting or grilling, various forms of deflectors are used by different makers, whilst one well-known firm, by an arrangement of rack and cogged wheels, has made it possible to completely turn the grilling burners over, a device which gives excellent results in practice. Wherever it is possible to do so, a hood should be placed over the top plate and connected into a flue, to take away the steam generated in the boiling vessels and the smell from frying, etc. It is an advantage, also, if the discharge pipe from the oven is connected into a good flue, to take away the products of combustion and smell from the oven.

The "Advance" cooker of Messrs Wilsons and Mathiesons is an excellent type of this kind of stove, combining in itself most, if not all, of the essentials mentioned above. The oven is roomy, but by an ingenious shelf rest attachment it may, when not all wanted, be reduced in size. This means economy of gas consumption, inasmuch as only the oven space actually required is heated. The oven burner gas and air adjustments are easily accessible, and the oven is shielded from draughts by the drip tin sliding like a drawer into the bottom of the oven, allowing only sufficient air for combustion to pass. The oven is double air jacketed, the centre casing consisting of polished tinned steel, to reflect and so prevent loss of heat. The flue space is accessible for cleaning by simply removing the dome of the oven. The hot plate burners are accurately spaced and placed, and a double concentric burner gives a wide range of heating capacity for large vessels. The griller is formed by an extension of the hot plate, and the heat deflectors to each burner may be raised and lowered quite independently. In addition to the above technical points, the stove also contains many auxiliaries of a character which appeal strongly to the housewife. These consist of the provision of a towel rail, plate rack, which may be raised or lowered at will, receptacle for matches and taper, enamelled crown plate, raised oven, and other conveniences.

"Sealed oven" stove.—The latest form of gas cooking stove to be introduced is the "sealed oven" stove of Mr Thos. Potterton, of Balham. This is essentially a reversion to the closed oven type, so common in the early days of cooking stoves, with a good many modern improvements added. The stove consists of an outer casing, well lagged, to prevent radiation. In the annular space between this outer casing and the oven proper are fixed a series of baffle plates. The oven is heated by two burners placed on either side at the bottom of the stove, the heated gases from which are caused to take a zig-zag path by the baffle plates, so that the greatest amount of duty may be obtained from the gas consumed.

Flap doors on the front bottom of the stove control the secondary air supply to the burners when the latter are alight. By replacing these when the gas is turned out the annular space becomes air-locked, and consequently, the loss of heat being small, the oven may remain in use for some time after the gas is turned off. Safety is ensured by the necessity of opening the doors before the gas can be turned on.

It is obvious that in a stove of this construction the advantages of the " roast " are sacrificed for those of the " bake." Amongst the latter are less evaporation, and consequently a smaller loss of weight in cooking.

Hot water supply.—A difficulty with respect to hot water supply has always been felt in connection with the use of gas cookers. It has become such a necessity of modern household arrangements to have an automatic hot water supply, usually heated by the kitchen range, laid on to kitchen, bath room, and lavatory, that the absence of it during the summer months, when the range has been supplanted by the gas stove, has been acutely felt. Various devices, of but very partial application, have from time to time been adopted to meet the want as far as the kitchen is concerned. The problem has now been solved by the provision of a water circulating system, gas heated, from which the hot water pipes may be taken to any point of the house.

Two systems.—These may be of two distinct kinds. The first has a small boiler, which takes the place of that usually fixed at the back of the kitchen fire grate, from which the water circulates to a storage cylinder, and from the cylinder through the various hot water pipes to the various points of service. In the second type the boiler and storage cylinder are combined in one vessel. Each of these has its own uses and advantages. When the gas heated system is required simply to supplement an existing system at such times as the kitchen grate is out of use, the first is obviously the best type. It may be easily connected up to the existing pipes, involves little interference with the building, no interference with systems already installed, may be taken away, and by stopping the ends of the connection, the house system is left quite intact. The boiler in this system takes up but little room, and a further advantage is that as soon as the water begins to circulate the hot may be drawn off for use, owing to the fact that the flow is to the top of the storage cylinder from which the supply is taken. Against this must be set the loss in efficiency due to radiation and other heat losses in the pipes connecting boiler and cylinder. These losses may be minimized of course by suitable lagging ; but the cylinder should always be placed as near as possible to the boiler.

Boiler-cylinder system.—The second type, the combined boiler and cylinder, is very suitable for a new and self-contained system, for premises where there is no existing hot water system. The source of heat being under the boiler there is none of the heat lost in connections, and less surface loss owing to the smaller exposed surface in one vessel than in the separate boiler and cylinder. The circulator-cylinder is also very useful for supplementing a defective or inadequate existing system. The storage may be increased to any reasonable extent, and the heating speeded up as may be required. Against these advantages may be set the greater space occupied, and also the longer period taken from the time of starting up cold before the water is available for use. In both types of apparatus care must be exercised to avoid narrow passages, which may become furred up, and provision should always be made for clearing out chalky deposits, through suitably disposed cover plates, without taking the whole apparatus to pieces. It is found that the amount of deposit below a temperature of 150° Fahr. is very small, and as water at this temperature meets nearly all domestic requirements, it should be considered the maximum to be attempted in a gas heated water circulator.

Precautions in fixing.—Most of the precautions mentioned in connection with hot water radiators apply to the hot water system too. In the hot water system an expansion pipe must also be taken from the highest point to above the level of the supply cistern. This provides, in addition to expansion, for the exit of the air when the system is first filled. If water be heated from the point of greatest density, or approximately 39° Fahr., to 180° Fahr., it expands one-thirtieth of its volume. That is to say, that 30 gallons become 31 on being raised 141° Fahr. There must, therefore, be a corresponding capacity of cistern above the level kept by the ball tap of one gallon for each 30 gallons contents of boiler and pipes, or it may overflow.

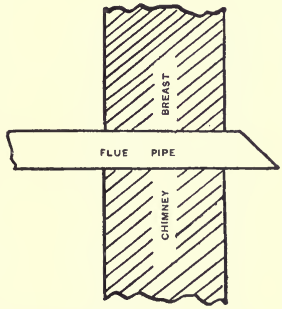


FIG. 396A. — Section of Chimney Wall showing Bevelled End of Flue Pipe.

When fixing a horizontal flue pipe from circulator or stove into the chimney, it is well to bevel the end which extends through the chimney wall, as shown in Fig. 396A, in order to prevent the possibility of the products of combustion being cut off by the up-draught from the kitchen fire.

It is also usual to put a dip or syphon on the cold water service at or near the point at which it joins the boiler, to prevent hot water working up the vertical pipe. This dip should not exceed six inches in depth.

Horizontal pipes should always be laid with a rise from the boiler, and the greater the rise the more rapid will be the flow. This rise should never fall below 1 inch in 10 feet. A rise of 4 inches in 10 feet gives a very good flow.

A great deal of difficulty is frequently caused by improper connections, and it is therefore necessary that this point should receive especial care. Fig. 401 (p. 449) shows a very good arrangement. The cold water feed should always be brought into the boiler as near the bottom as possible. The house service should always be taken off the flow as direct as possible to the supply point. Where a cylinder is used, the supply must be taken off the flow from cylinder, not the flow from boiler to cylinder. The fewest possible number of bends should be used, and these of a good sweep. Where pipes have to be bent, kinks must be avoided. If elbows are used, they should be of the round type. Lead pipes are preferable to iron, as wider sweeps in the bends may be obtained. It is necessary, however, to support them on wood strips or they may sag, and each sag is a potential source of air locking. An additional advantage of lead over iron is, of course, the elimination of the corrosion difficulty.

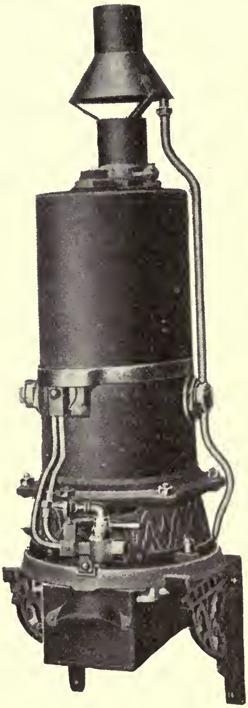


Fig. 397.—Wilson Circulator: General Elevation.

Wilson "circulator."—The Wilson "circulator" of Messrs Wilsons and Mathiesons, shown in general elevation in Fig. 397 and in sectional elevation in Fig. 398, is an excellent type of gas heated boiler. In this A is the flow connection, F the supply connection, and G the return. H is the burner box, from which the heated products of combustion pass upwards through the flue boxes, D, each fitted with suitable baffle plates, to the flue outlet, B. It will be seen, therefore, that the heated surface of the flue boxes, D, in contact with the water in the water chamber, E, is exceptionally large, whilst the water envelope is at no point very deep. This all makes for the efficiency of the apparatus, inasmuch as the heat from the gas is transmitted to the water over as wide a surface as possible; and this, of course, secures the greatest possible abstraction of heat and a quick flow of water from and to the boiler. But while the exposed surface is so great, there are no narrow interspaces which may become filled with a non-conducting deposit, to the detriment of the efficiency of the circulator. As shown in Fig. 397, the circulator is fitted with copper hood, piping, and tray, into which the condensation of the products of combustion occurring in the flue are drawn and collected, instead of being allowed to drain back into the flue boxes, D, of the circulator.

The circulator is fitted with a thermostat, clamped to the side of the boiler (as shown in Fig. 397) by an iron band surrounding the boiler just above the return connection, G. A section through the thermostat is shown in Fig. 399. This consists of a capsule formed of an envelope of very flexible metal containing ether and another constituent. The capsule is contained in the valve box as shown, and is kept lightly pressed against the side of the circulator by the spring, A. When the apparatus is cold there is a clear gas-way from the inlet, E, through the valve, D, and from the latter downwards to the burner again. The capsule is then in the position shown by the thick dark line. As the circulator becomes heated, and when the water has reached the predetermined temperature, the capsule expands, presses back the spring, A, and takes the position shown by the dotted lines, C, and partially closes the valve, D. When, either through conduction or hot water being drawn off, and a consequential inflow of cold water into the system, the temperature has been lowered, the capsule contracts again, the valve is opened, and a larger volume of gas is allowed to pass until the temperature is again restored.

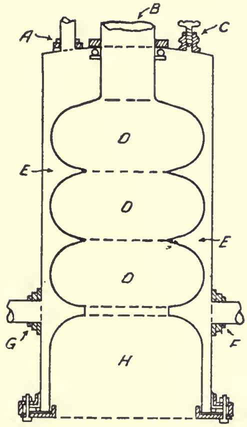


Fig. 398.—Wilson Circulator: Sectional Elevation.

The "Sun" automatic high-pressure boiler of Messrs John Wright and Co. is shown in part sectional elevation in Fig. 400. This consists of a cylinder, A, constructed of $\frac{1}{8}$-inch galvanized wrought iron enclosed within an outer casing, D, of 18 gauge iron, the annular space between being filled in with non-conducting material.

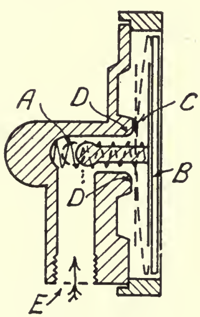


Fig. 399. The Wilson Thermostat.

A very large surface is presented to the heating agent by means of the annular chamber, H, within which is placed the heat director, I. The heated gases from the burner are thus given a very considerable contact with the cylinder before passing away to the flue, F. The hot water flow is seen at J, the cold water supply at K, and the cold water cistern at L.

The gas supply is taken to the burner at P, and the burner itself is partly seen at R.

The gas supply is fitted with a patent thermostatic valve, made of metal throughout. This consists of an outer box of brass, which alone is in contact with the water of the boiler. Within this brass chamber is fixed a rod of nickel steel, formed of 36 per cent. nickel, which carries at its free end a valve head. The action of the thermostat is based upon the difference in the expansion under heat of the two metals. The co-efficient of expansion of the brass casing

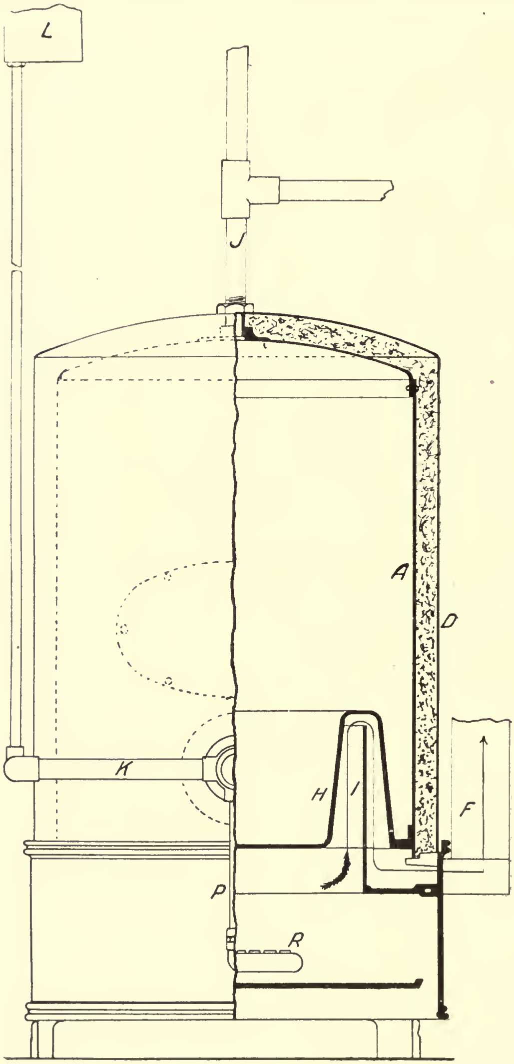


Fig. 400.—Wright's " Sun " Boiler : Part Sectional Elevation.

is .0000189 and that of the nickel steel, or invar, is .0000009, giving a difference between the two of ·000018. If, therefore, the temperature of the water rises 40° F., and the thermostat is 10 inches long, the difference in the expansion of the two metals will be $.000018 \times 10 \times 40 = .0072$ inches. Under those conditions the valve would be closed by that amount, and, of course, proportionately for any other

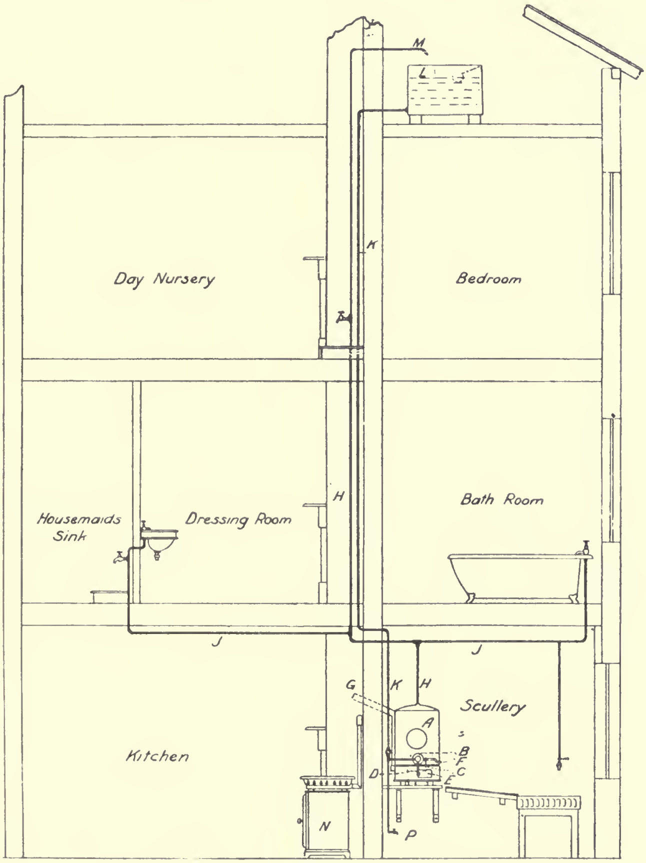


FIG. 401.—Circulating Hot Water System.

lengths and temperature increments which may be taken. When the reverse action takes place, and the water becomes cooler owing to some of the hot having been drawn off, and a consequential inflow of cold, the brass casing contracts whilst the "Invar" remains comparatively stationary, and thus the gas passage is correspondingly opened.

It is obvious that such a thermostat as this of Wright's or that of

Main's, previously described, may be fixed either on the flow or return. It may also be noted, in passing, that both Wright's and Main's thermostats are comparatively slow in action, whilst in the Wilson thermostat there is no action until the predetermined temperature is attained, and then the action is quick. Gas engineers are divided in opinion as to which is the better, the slow or quick acting principle. Good reasons may be adduced for either type.

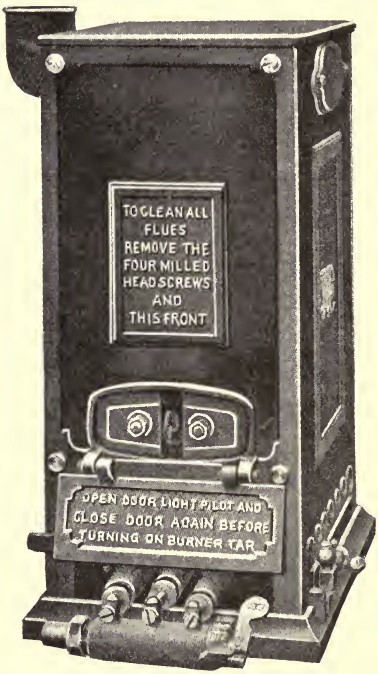


FIG. 402.—General Elevation of "Calefactor."

Hot water supply for domestic purposes.—The various pipes necessary for carrying a hot water supply over a moderate sized house and the method of connecting up to boiler are shown in Fig. 401.

In the illustration A is a "Sun" boiler; B, the thermostatic valve; C, the pilot light; D, the gas supply to the boiler; E, the lighting door; F, the gas supply from the main; G, the flue pipe; H is the rising main; J, the hot water service pipes; K, the cold water supply; L, the cold water cistern; M, the expansion pipe; N is a gas cooking stove; and P, the emptying cock.

The boiler is shown fixed in the scullery; but, of course, it may be placed in any other convenient position, either on the same floor, or in the room above or cellar beneath, so long as access may be obtained to a good flue for carrying away the products of combustion from the burner.

The latest water heater placed upon the market is the "Calefactor" of Messrs John Wright and Co. This is shown in general and sectional elevations in Figs. 402 and 403.

The boiler is of cast iron, in one single casting, arranged in a cast-iron casing, and readily accessible on removal of the front plate. Removal of the latter also gives full access to the flue passages. The boiler is so constructed that the return water is heated up again to some extent before it reaches the actual boiler, the latter and the preheater being included in the one casting.

The casing is rectangular in shape and free from projections. The heaters may, therefore, readily be arranged in batteries of two or more together. The casing is well lagged, to prevent loss of heat from the system on the one hand, and, on the other, to prevent the inconvenience of overheating the kitchen through radiation from the boiler.

The "Calefactor" is arranged with larger flow and return pipes than are usual, so as to provide for quicker flow, and therefore a larger supply of water at the moderate temperatures required for domestic purposes.

The boiler is heated up by three bunsen burners, one of which is smaller than the other two. This may be sufficient to maintain the water at the desired temperature at times of minimum demand, while the others may be lighted as necessary. A specially constructed gas cock gives perfect control of all the three burners.

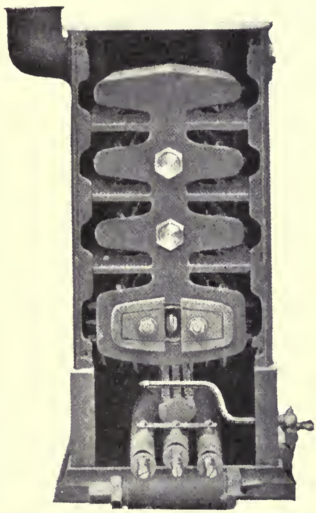


FIG. 403.—Sectional Elevation through "Calefactor."

The "Calefactor" is supplied alternatively with bunsen burners and special tap, or with luminous flame burner and thermostat. The adoption of the luminous flame burner permits the gas to be turned down very low, and eliminates the lighting back trouble.

We have considered the application of gas to the three main domestic purposes of heating rooms, cooking, and heating water. Other forms of apparatus for the latter purpose include geysers, various types of boiling burners, from the small kettle boiler to the powerful eight-bar parallel standard burner of Messrs Fletcher, Russell and Co., Limited. For the more secondary household purposes, gas is also successfully used; for smoothing irons, washers, drying and airing stoves, and coffee roasting, amongst others of a less important character.

Gas for industrial purposes.—Of the various uses of low-pressure gas for industrial purposes, apart from gas engines, to which a separate chapter is devoted, it is only possible to write in the briefest terms. (High-pressure-gas, in this connection, is referred to in Chapter XXXV.) The applications of gas as a fuel are of such a bewildering variety that the merest catalogue of them would occupy pages of this book. When we consider the multitude of industrial operations where exact heating, under absolute control, is required, we cannot wonder that in such a fluid fuel as gas, workers in widely different fields have found a most convenient and adaptable means of heating. From the very nature of the case, it is capable of being applied exactly at the point required. It may be used for highly concentrated heating, as in the case of blowpipe or crucible work, for localized heating, as in the case of welding steel mains, or for the more diffused heating of an oven. It may be applied simply at a single point for the heating of a tool, or equally well in a much more complex form for purposes such as heating hoops to be shrunk on wheels, which require equal heating over a considerable surface, and for which no other form of heat is so adaptable and manageable. The many kinds of apparatus for utilizing its calorific power command a wide range of temperatures, from the heating of a tailor's flat-iron to furnaces working by blast, with gas under pressure, at considerably over 2000° Fahr., the melting point of gold. Above all, it is cheap. In one type of furnace on the market, in ten minutes after starting cold, a temperature of 1000° Fahr. may be obtained with a consumption of $4\frac{1}{2}$ cubic feet of gas. In one hour a temperature of 1850° Fahr. may be attained at an expenditure of 30 cubic feet of gas, while in two hours a temperature of 2000° Fahr. may be reached.

An interesting paper by Mr E. C. Riley, read before the Southern District Association of Gas Engineers, shows in some measure the widely varying uses to which gas has been put in the industrial work of the Great Western Railway Company (see *The Gas World*, 7th November 1908). The expansion of steel tyres, the heating of rivets, heating of core ovens, drying moulds, melting galvanizing metal, and brazing and tempering of various kinds, all come in for mention and illustration. It is, however, in the direction of furnaces of limited size, requiring comparatively high heats, that gas has made great strides. These now comprise a great variety of types, sizes and powers, arranged for both blast and draught, and designed for both industrial and laboratory purposes. They apply to such widely different purposes as annealing gold, silver, and copper bars; enamelling of various kinds, from iron to glass and china painting; japanning; ovens and furnaces for tool makers, from blueing to tempering high-speed tools; furnaces for tube and chain brazing; assaying; crucible furnaces for all kinds of blowpipe and blast work; injector furnaces for jewellers and dentists; stands for tobacco toasting and ovens for tobacco dressing; dipping tanks for tempering tools by means of lead or oil bath; dipping tanks for tinning iron and steel plates and wire; stoves designed for heating tools for bookbinders and shoemakers, tinman's copper bits and joiner's glue pots; and blowpipes for all classes of work, from the finest goldsmith's work to the double concentric blowpipe for glass workers; and for use with oxygen, for purposes of rapid fusion.

Out of such a list of applications of gas, which is, however, by no means exhaustive, it is impossible to refer in detail to more than one or two. Fig 404 illustrates the double cyclone crucible furnace of

Messrs Fletcher, Russell and Co., Limited, in which an interesting attempt to economize fuel by utilizing the waste heat is made. The crucible is in duplicate, the waste heat from one passing over and partially heating the second. When the metal in the first crucible is sufficiently heated, the burner for that one is turned off, and that under the second is lighted. This has already been partially heated, and so much time and fuel have been saved. The waste heat from No. 2 is now turned into No. 1, and so on, each crucible being lighted up and a melt obtained from each alternately.

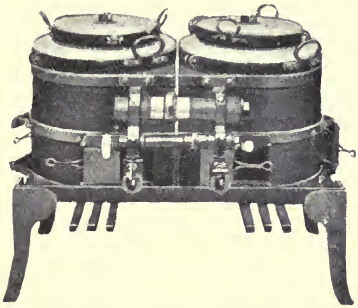


Fig. 404.—Double Cyclone Crucible Furnace.

Fig. 405 shows a very handy and compact brazing hearth fitted with double blowpipe and Roots blower, suitable for medium classes of work.

An ingenious arrangement of circular blast burner, with fireclay surrounding wall, designed for expanding tyres to be afterwards shrunk on to locomotive wheels, is shown in Fig. 406. The illustration shows the arrangement very clearly, and no further verbal explanation is necessary.

Proportions of mixing tubes and burner orifices.—A very interesting table, giving the proportionate discharging powers of mixing tubes and orifices of burners used in cookers, kettle boilers, and others of a similar character, has been compiled by Mr Alfred Mansfield, of Birkenhead (see p. 454).

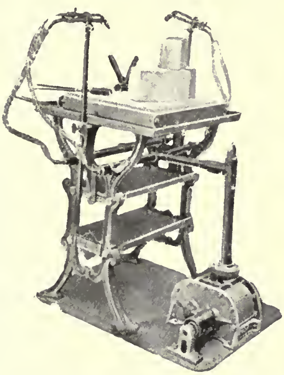


Fig. 405.—Brazing hearth.

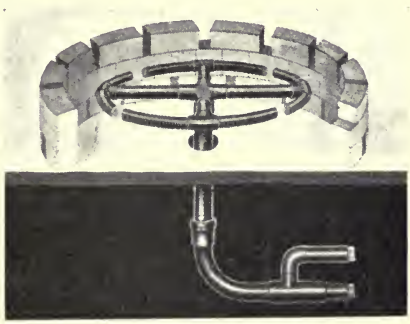


Fig. 406.—Blast Burner for Locomotive Tyres.

The method of using the table is as follows:—In a ring or bar

Diameter of Tube.	Discharging Power.	Diameter of Tube.	Discharging Power.
Inch.		Inch.	
0.01	0.000003927	0.51	0.072716956
0.02	0.000022030	0.52	0.076572534
0.03	0.0000612495	0.53	0.080307165
0.04	0.000125701	0.54	0.084171856
0.05	0.00021945	0.55	0.088163192
0.06	0.0003462	0.56	0.092157208
0.07	0.00050895	0.57	0.096327063
0.08	0.00071099	0.58	0.100607694
0.09	0.00095439	0.59	0.105001214
0.10	0.0012417	0.60	0.109504537
0.11	0.0015758	0.61	0.11412532
0.12	0.0019589	0.62	0.118860511
0.13	0.002392824	0.63	0.123732063
0.14	0.002880047	0.64	0.128677199
0.15	0.00342788	0.65	0.13376656
0.16	0.00402140	0.66	0.138971019
0.17	0.00467918	0.67	0.144292267
0.18	0.00539807	0.68	0.149737384
0.19	0.00617942	0.69	0.155321824
0.20	0.00702494	0.70	0.160992736
0.21	0.00793630	0.71	0.166804745
0.22	0.00912483	0.72	0.17274081
0.23	0.0099626805	0.73	0.17879855
0.24	0.01108112	0.74	0.184985262
0.25	0.01227163	0.75	0.191298624
0.26	0.0135362396	0.76	0.197740142
0.27	0.01487587	0.77	0.204310018
0.28	0.01629161	0.78	0.211008430
0.29	0.01778467	0.79	0.217833146
0.30	0.01934692	0.80	0.224793031
0.31	0.0208862225	0.81	0.231884606
0.32	0.02280796	0.82	0.239108236
0.33	0.0245669	0.83	0.246466096
0.34	0.02686858	0.84	0.253957638
0.35	0.028459006	0.85	0.261584117
0.36	0.03053749	0.86	0.269341352
0.37	0.032701083	0.87	0.277240719
0.38	0.034955617	0.88	0.285276714
0.39	0.037301373	0.89	0.293451529
0.40	0.039739037	0.90	0.301765246
0.41	0.04328975	0.91	0.310217927
0.42	0.044892819	0.92	0.31880625
0.43	0.047613274	0.93	0.32754123
0.44	0.050430274	0.94	0.33641819
0.45	0.053344937	0.95	0.34543790
0.46	0.056358364	0.96	0.35460111
0.47	0.059471646	0.97	0.36390858
0.48	0.062684304	0.98	0.37335499
0.49	0.066000462	0.99	0.38295387
0.50	0.069420208	1	0.39269850

burner, it is well known that the total discharging power of the drilled holes must bear a definite relationship to the discharging power of the mixing tube. Take, for example, an ordinary ring boiling burner. It is decided to drill 70 holes 0.11 inch diameter. What will be the diameter of the mixing tube? If we refer to the table, we find the discharging power of an orifice 0.11 inch diameter is 0.0015758. The total discharging power for 70 orifices will therefore, be 0.1103060. Glancing down the column of discharging powers, we find a single tube between 0.60 and 0.61 inch diameter will have a similar discharging power. Mixing tubes are not either perfectly circular or absolutely smooth. The discharge varies also, of course, according to the length. A margin of, say, 10 to 20 per cent., according to circumstances, should, therefore, be allowed on these accounts.

CHAPTER XXIII

GAS ENGINES

One of the most remarkable developments in the gas industry during the last twenty years has been the rapid growth in favour of the gas engine as a motor for small and medium powers. This has been largely contributed to by several factors. Improvements in methods of manufacture, leading to lessening of cost of production, have made it possible to bring the price of gas so low as to enable it to compete with other fuels, within certain limits. On the other hand, there have been such improvements introduced into the engine itself as to make it a most efficient and economical motor. Alike in first cost, fuel cost, and cost of maintenance, an up-to-date gas engine compares very favourably with other sources of power.

Gas Engine *v.* steam engine.—A comparison made between the installation of gas and steam engines reveals some of the particulars in which the advantage lies with the former. For instance, a steam engine requires a boiler, boiler setting, chimney stack and accessories, and costly foundations. A gas engine, on the other hand, is self-contained, needs comparatively little foundation work, and requires only to be connected to an adequate gas main. In running costs, too, for fuel, oil, attendance, interest, and sinking fund charges on capital expended, and general maintenance, to say nothing of convenience, cleanliness, control, and other such important matters, in motors of moderate powers, the gas engine has great advantages. Considerations of space make it impossible to follow these points out in detail, even if they were not outside the scope and purpose of this book, but the intelligent student will have little difficulty in prosecuting further inquiries himself.

Gas engine *v.* electric motor.—The most persistent and keen competition which the gas engine has to meet to-day for small power purposes is undoubtedly that of the electric motor. As most absurd claims are continually being advanced on behalf of the latter it may be well to consider them here.

In the large industrial city of Leeds the author finds that the crux of the whole business is that of running costs. The capital cost involved, the amount of floor space occupied, and similar items, are of secondary consideration. A larger initial expenditure may soon pay for itself in reduced costs of working. It is necessary, therefore, to prove to possible customers that in this all-important matter a good gas engine can easily beat its rival.

Take as a basis of comparison the running costs of a 10 h.p. motor as against a 10 h.p. gas engine. One unit of electricity will give $1\frac{1}{4}$ b.h.p. effective, a 10 h.p. (effective) gas engine will require 18 cubic feet per b.h.p. per hour. We will also assume that electricity is being sold for power purposes at 1d. per unit and that gas is sold at the Leeds price of 2s. 2d. per 1000 cubic feet, less 5 per cent. Then a 10 h.p. electric motor working 55 hours per week will require

$$\frac{55 \times 10 \times 4}{5} = 440 \text{ units @ 1d.} = £1, 16s. 8d. \text{ per week.}$$

In the case of a gas engine the calculation would be as follows :—

$$55 \times 10 \times 18 = 9900 \text{ cubic feet @ 2. 2d. less } 5\% = £1, 0s. 4.6d.$$

The comparison is therefore :—

Electric motor . .	£1	16	8
Gas engine . . .	1	0	4.6
Difference per week in favour of gas	0	16	3.4

The cost of depreciation, interest, repairs, oil, water, and attendance will vary according to local circumstances, and must be worked out accordingly. But that the economy in running charges is very real is proved by the number of those who having originally had gas engines, have installed electric motors, and have now reverted to gas again. Amongst a number of other cases may be quoted that of a Leeds manufacturer who recently told the author that he was saving 30s. per week by reverting to the use of a gas engine, as compared with his former electric motor.

It is, of course, impossible, in the limited space at the disposal of the author, to do more than glance at the more salient features of gas engine construction, and give a general description of the practical working of the engine under ordinary conditions. For more detailed discussion of the various matters mentioned, as well as for the more theoretical examination of the scientific principles involved and the data applicable to and connected with the design and working of the gas engine, the student is referred to the several excellent treatises which deal with the whole subject in an exhaustive manner.

Vertical gas engines.—The gas engines used in this country are usually of the horizontal type, and our main consideration must be given to these. It may, however, be noted, in passing, that for small powers, say up to 4 or 6 horse-power, engines of the vertical type are built. They have the advantage of occupying little floor space ; but when made with the cylinder beneath, and the crank shaft, flywheel and driving wheel in the upper part of the engine, it is obvious that the centre of gravity is raised inconveniently high. To avoid this, and to ensure stability, some American manufacturers have reversed the above arrangement, placing the cylinder and piston in the upper,

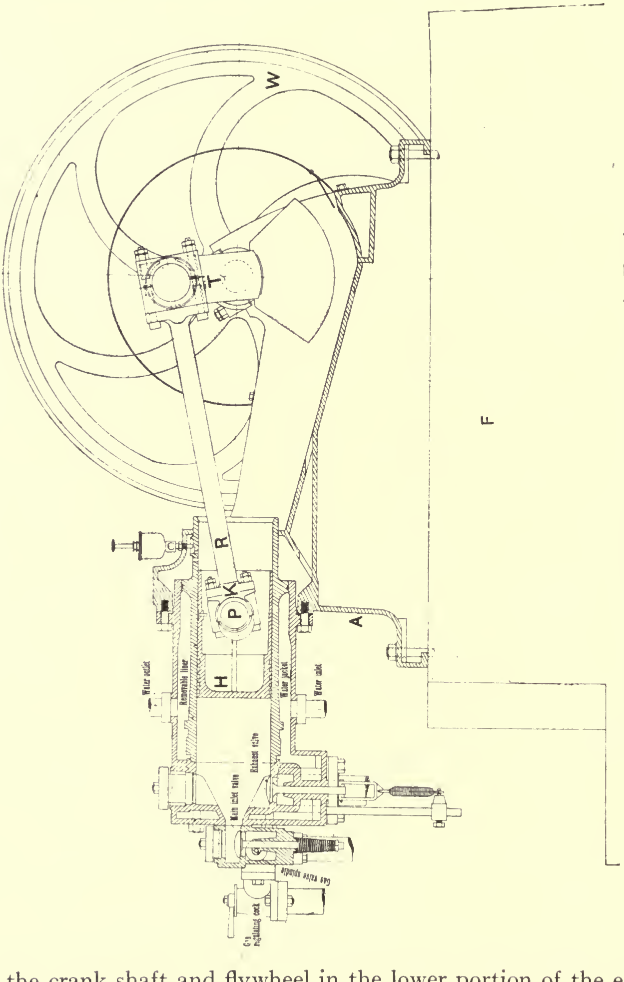


FIG. 407.—National Gas Engine Company's Engine.

and the crank shaft and flywheel in the lower portion of the engine, and as near the ground as possible.

Horizontal gas engines.—The horizontal gas engine consists essentially of a bed plate, cylinder, with valves and other accessories, piston and connecting rod, crank shaft and flywheel, and the side shaft carrying the cams which actuate the valves.

The bed plate or frame, A (Fig. 407) is a strong, heavy, broad-based casting, which supports the engine. The vibrations and shocks which the frame has to withstand are very heavy indeed, and it is, therefore, necessary that it should be rigidly maintained in position by being firmly attached to a suitable base, F. The foundation may be formed either of natural stone, concrete, or brickwork. It should be separated from any wall of the building in which it may be placed, by a cushion of earth of at least 18 inches in width, so as to avoid vibrations incidental to the working of the engine being communicated to the building itself.

In the natural stone foundation, holes must be drilled to take the

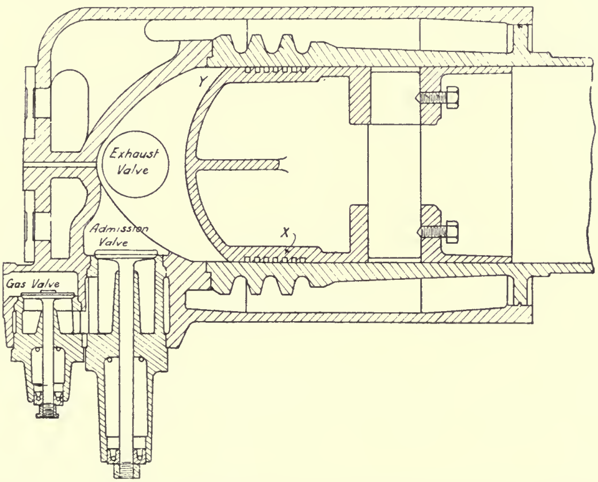


FIG. 408.—Section through one of Crossley's Gas Engine Cylinders and Valves.

holding down bolts. If concrete is used, then spaces may be left for this purpose. In the case of a brickwork foundation, it is important that the space left for the bolts should not have a plain surface, but one in which the brickwork breaks joint, so that when the space surrounding the bolts is run in with cement, the latter may properly bond into the brickwork. With stone or concrete foundations, it is advisable that the bolt holes should be larger at the bottom than at the top, in order that, when the bolts are cemented in, resistance to the lifting caused by the vibration of the engine may be as great as possible.

The cylinder within which the piston works may be formed either in one single casting, or the outer casing containing the water jacket may be separate and distinct from the liner, as shown in Fig. 408. The liner is then simply a cast-iron cylinder, flanged to joint up to the outer casing. At both ends a water-tight joint must be made, to prevent leakage from the water jacket into the cylinder. That at the back (see Y, Fig. 408) must be made especially strong, because it has to resist the pressures set up by the combustion of the charge. For this purpose, coppered asbestos rings are generally used. It is obviously the better arrangement to have liner and outer casing separate, as in that case, in the event of the liner becoming worn or deranged from any cause, it may either be repaired or a new liner inserted without interference with the remaining portion of the engine. For the same reason, if a single casting is adopted, the cylinder should be a separate casting from the engine bed. It goes without saying that the cylinder must be accurately bored out, and highly polished, so that, while the piston may move within it with a minimum of friction, there should be no leakage past the piston at the high compression pressures now adopted in all modern engines.

The piston (H, Fig. 407) consists of a hollow metal cylinder, closed and preferably plain at the rear surface, accurately turned and polished to an exact fit to the cylinder. On the rear exterior surface of the piston (see X, Fig. 408) a number of grooves are cut to accommodate the piston rings, which may vary from five to ten in number. These are prevented from revolving on the piston by a series of tongues, which fit within corresponding longitudinal grooves cut in the piston. If the rings were allowed to turn, sooner or later the joints in the series of rings might synchronize, and thus allow a clear gas-way through them.

The attachment, K (Fig. 407) of piston, H, to piston rod, R, and of the piston rod, R, to the crank shaft, T, are two of the most important parts of the engine. These, from the nature of the case, have to take up the violent shocks caused by the successive explosions at the back of the piston. The wear and tear of these parts is, therefore, correspondingly great, and they must be made proportionately strong. The piston pin, P, is made of case-hardened steel, while the bearings are made in two parts, which are readily adjustable to take up the slackening effect of vibration upon the screws, or of wear and tear upon the bearings themselves. These bearings are usually made of bronze.

The crank shaft, T (Fig. 407) in a modern engine is cut out of the solid metal, and so shaped as to be rectangular in section. This form is found to give a stronger and better balanced crank shaft than the forging which was originally used.

The flywheel, W (Fig. 407) is intended to store energy to carry the engine over the dead centres, and to correct and counteract any cyclic irregularity, variation of speed, or other inequality of working. For this purpose it must, of course, be of a weight proportional to the size and power of the engine, and, to ensure smooth working, should be properly and accurately balanced. It should be mounted upon the crank shaft as near to the bearings as possible, and is usually secured to the shaft by an accurately fitting key wedged into corresponding slots upon the shaft and wheel. To prevent accident to the attendant it is usual to cover the projecting portion of shaft and key with a movable sleeve, made of light metal, so that no portion of the workman's dress can be caught by these when the engine is working. If the wheel contains curved spokes, then it must always be mounted so that the concave portion of the spoke is turned in the direction of the revolution of the wheel. It is obvious that the wheel must be so mounted as to run perfectly true. Any "wobbling" necessarily increases very materially the vibration of the engine, and puts a very great strain upon the holding down bolts and the frame of the engine. In the larger types of engine, the use of two flywheels, one upon each end of the crank shaft, and, of course, upon opposite sides of the engine, gives greater balance and more perfect equalization of the effects of inertia.

The side shaft (Fig. 409) is a light shaft running longitudinally at the side of the engine, which, by means of bevel wheels, or worm and wheel, is geared to the crank shaft, and caused to revolve with it, and at speeds proportional to the speed of the engine. The side shaft is geared down to revolve at half the speed of the crank shaft, and carries the cams actuating the valves at the inlet and exhaust ports. At the opposite end to the gear wheels, the shaft is carried by a light bracket, bolted up to the side of the cylinder. This bracket also carries a spindle at its lower end, upon which the levers rock which are used to transmit motion from the cams to the valves.

The method of introducing the explosive mixture into the cylinder is by means of properly arranged valves. Originally, these were of the "slide" order, having a very wide bearing surface, needing a great amount of lubrication, and were pressed to their bearings by external springs. These did good service in connection with the low compression engines made years ago, but have now become almost, if not quite, obsolete. They are altogether unsuited to the high compression engines which are made to-day, for the simple reason that they could not be made and kept tight without creating so much friction as to greatly impede and reduce the work performed by the engine. In addition to this, the restricted gas-way through the ports tends to choke the induction charge and set up counter pressures, which again would restrict the effective working of the engine.

The valve adopted in the modern gas engine is of the mushroom type, mounted upon a spindle, and suitably guided, as shown in Fig. 408. The valve must be turned up true in the lathe, and well ground in to its seating, to make a perfectly sound joint. The advantages of a valve of this kind are obvious. It is quickly actuated; it contains no rubbing surfaces, and consequently needs no lubrication; if properly proportioned it involves no throttling of the charge, and is pressed more firmly to its seat as the pressure increases. It may be so placed as to be readily accessible for inspection, and is kept in good order by the simple process of occasionally

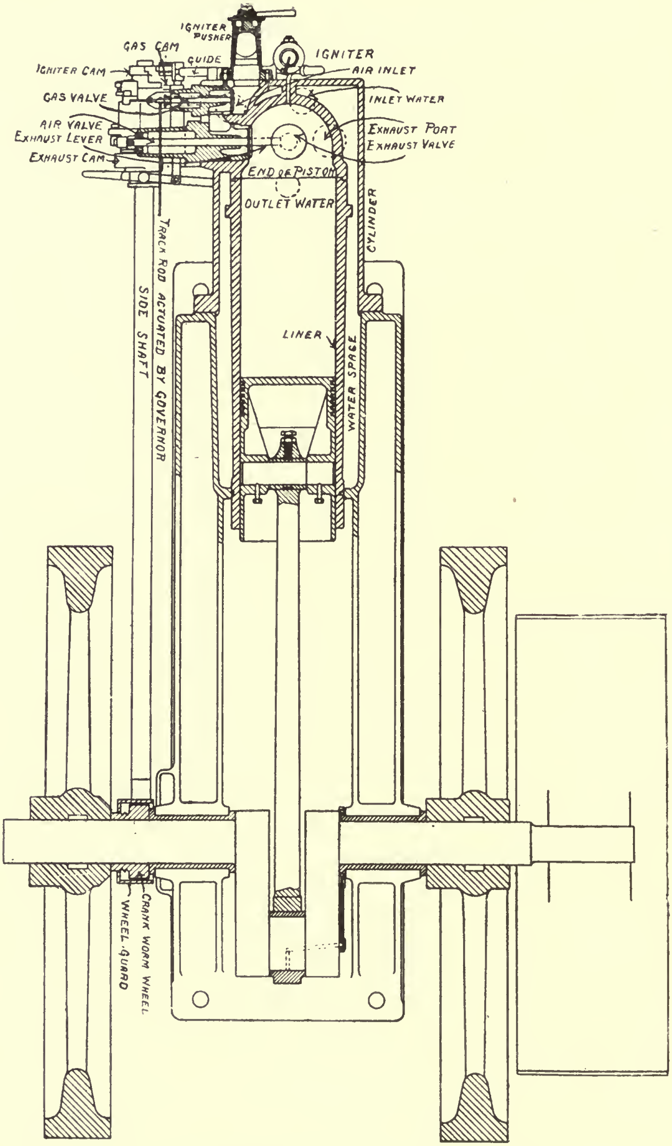


FIG. 409.—Sectional Plan through one of Crossley's Engines.

grinding it in to its seating again. The same type is equally suitable for the admission and discharge ports. These valves were originally made of forged steel, simply turned to fit the valve seating. The high temperatures they have to withstand, however, caused them to warp and allow pressure to pass to meter and mains under the compression stroke. All such valves are now, therefore, carefully tempered to resist this distortion. The valves usually have coned seats, cut to an angle of 45°, and a lift equal to one-fourth the diameter of the valve gives a full and unrestricted passage.

The high temperatures at which the exhaust gases are expelled, combined with the friction of the impinging current, travelling at high velocity, often causes small pittings and cavities in the faced portion of the valve. Forged steel valves are much more liable to deterioration from this cause than those of cast-iron. Whenever, and however, these pittings are developed, the only remedy is to re-grind or re-face the valve.

Methods of governing.—Different methods of governing gas engines are very succinctly summed up by Mr J. Atkinson in his paper on "The Governing and Regulating of Gas Engines," read before the Institution of Mechanical Engineers, in April 1908, as follows:—

"Methods of governing gas engines may be divided into two classes. In the first the volume of the charge remains constant, and sufficient to fill the cylinder as nearly as possible at atmospheric pressure, but the proportion of gas to air is varied according to the load. In the second, the proportion of gas to air is kept approximately uniform, but the volume of the charge is varied, either by closing the admission valve before the end of the suction stroke, or by throttling; the result in either case being a charge sufficient to fill part of the cylinder only at atmospheric pressure. The first method is commonly called the 'quality' method, the latter the 'quantity' method. The former may be sub-divided into hit-and-miss governing, variable gas admission uniform during the suction stroke, and variable gas admission caused by opening the gas valve earlier or later during the suction stroke, but always closing it at the end of this stroke, the contents of the cylinder, when reduced loads are being carried, being to some extent stratified, air being next to the piston and a rich mixture, drawn in last, remaining near the firing point. The quantity method of governing may be divided into throttle governing and cut-off governing. With one or two unimportant exceptions, all types of governing are included in the above.

"For many years hit-and-miss governing was universally and exclusively employed; and it still remains the usual method for small or moderate sized engines. So far as the author is aware, its economy has practically never been excelled; being only equalled on full loads by very carefully arranged methods, while on light loads it is still necessary to combine hit-and-miss governing with other methods to obtain such results."

Governing by this method is usually carried out by means of a centrifugal governor of the type with which we have become familiar in connection with the steam engine. An example of this form of governor is shown in Fig. 410, where A is a spindle which is geared to the side shaft by means of bevel cog wheels (not shown), and therefore caused to revolve with it. E is a movable sleeve, which actuates the levers, L and M. The lower end of the lever, M, carries the governor die, X, through which the pusher plate (not shown), carried by a lever actuated by a cam on the side shaft, actuates the valve spindle, W. When the engine is working normally, the governor die, X, is in register with the pusher plate on the one side and with the valve spindle, W, on the other. When, however, the engine speeds up, the action of the governor lifts the governor die out of register with the pusher plate, and the gas valve is not actuated until the engine slows down sufficiently to bring the governor die into register again.

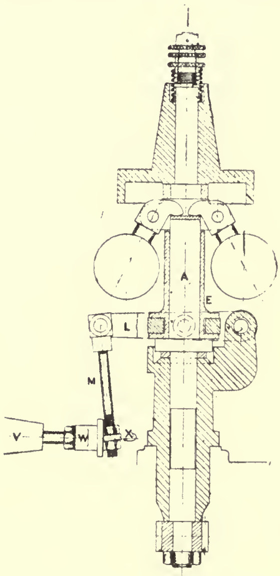


Fig. 410.—National Gas Engine Company's Governor.

Igniting the charge.—The methods by which the charge may be ignited are of two kinds, namely, by means of an incandescent tube or by means of an electric spark. Although a few naked flame ignition devices may still be seen at work, this type has become practically obsolete. The incandescent tube is the most common for engines of small and moderate powers, and is very reliable in its action.

The general principle of tube ignition is to have a small tube of some refractory material, to which the explosive mixture contained in the cylinder obtains access at the exact moment for ignition. This tube is heated to incandescence by an exterior bunsen flame. Fig. 411 shows the tube ignition device of the National Gas Engine Company. In this the passage, E, communicates with the cylinder and the interior of the ignition tube, C, through the valve, B. This valve has a double seating. Immediately after ignition takes place, the valve closes the passage, E, being pushed in by the lever, A, which is operated by a cam on the side shaft of the engine. The pusher on this lever has a certain amount of flexibility, so as to ensure that there is always a definite pressure of the valve, B, on the seating, E. The object of this is to keep the contents of the cylinder shut off from the hot ignition tube during the period of admission of the fresh charge and the succeeding compression stroke. At the proper moment the operating cam on the side shaft allows the lever, A, to fall away from the spindle of the valve, B, and the valve shoots back upon its second seating under the influence of a strong external spring. The compression in the cylinder causes a rush of explosive gases through the port, E, into the ignition tube, C; an explosion takes place, and the ignition is transmitted to the working cylinder. Thereafter the valve, B, closes down on the valve seating, E, as before.

The continuation of the passage, E, to the cylinder is unavoidably of considerable length, the water jacket having to be passed through, as well as the two thicknesses of metal. As the compression pressure in the cylinder is considerable, it may sometimes happen that the passage remains filled with spent gases from the previous ignition, and the compression pressure is insufficient to bring a portion of the fresh charge into contact with the incandescent part of the ignition tube each time the valve, B, is opened. This is provided against in the device shown by the provision of the vent tube, F, by means of which the volume of the passages may be increased or decreased as desired. Similarly, a hollow plug, G, is provided at the top of the ignition tube. In order to further ensure the inflammable gases reaching the hot tube at starting, a small relief valve, D, is provided at the top of the tube. This valve is kept open until the engine attains its full speed. The construction of the remaining portions are apparent from the illustration.

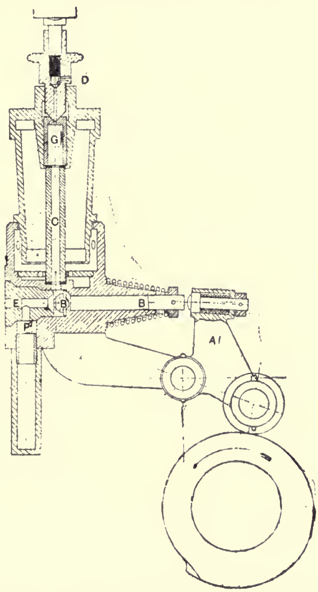


FIG. 411.—National Gas Engine Company's Tube Ignition Device.

The second method of igniting the charge is by means of an electric spark. This brings the exact moment of firing under complete control; but, for reasons which need not be entered upon here, it is thought by some that the power developed by firing in this way is not so great as with the incandescent tube.

The spark may be produced in two ways, by either an ordinary battery and spark coil, or by a magneto machine. The former plan is cheap and easy to manipulate, but requires careful attention, because it very easily gets out of order. All that is needed for this is a battery, coil, and sparking plug, and a mechanical arrangement governed by the engine itself for the purpose of making and breaking contact in the circuit.

The method of ignition by electric spark, however, which has

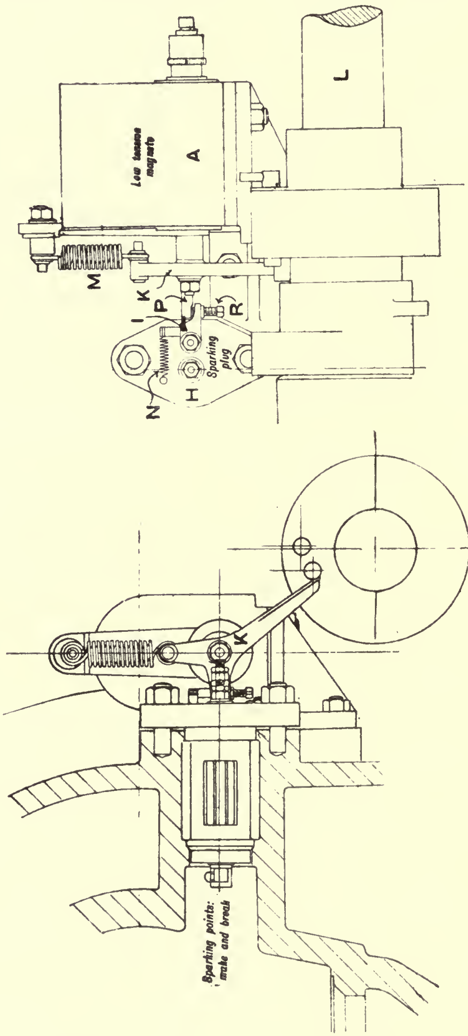


Fig. 412.—National Gas Engine Company's Low Tension Magneto Machine.

come into most favour is by means of the low tension magneto machine (Fig. 412). This is both dependable and durable. It consists of the usual horse-shoe magnet or magnets, A, between the poles of which the armature rotates or oscillates. The igniter, H, fixed on the back of the cylinder, has one of its axes permanently connected to the magneto, while to the other, I, is fitted a percussion lever, capable of making and breaking contact with a percussion pin, to form a sparking point. The ignition may be controlled either by a cam, or, as in Fig. 412, by a peg upon the side shaft. At every revolution of the side shaft, the peg catches the lever, K, and carries it through a certain distance before slipping off. On slipping off, the spring, M, brings the lever, K, back very quickly, and this rapid back motion causes an electric current to be induced in the armature of the magneto. Whilst the lever, K, is in its normal position, the spring, N, keeps the adjustable screw, R, to its seating on the pin, P. When, however, the lever, K, is actuated from the side shaft, the pin, P, is raised, the spring, N, causes the screw to follow, and the plug, I, is turned upon its axis, and breaks contact between the sparking points within the cylinder. This break of contact synchronizes with the period of maximum current, which leaps the gap, with the production of a hot spark, and the charge is ignited.

Temperature of combustion.—The ignition of the charge is, of course, attended by the production of great heat, the combustion chamber being filled with flame, at a mean temperature of 1600 to 2000° C., or very considerably above the temperature of molten iron. The answer to the question how it is possible for such temperatures to exist in an iron vessel is given by Professor Burstall in his Birmingham lecture of November 1911. He says: "The reason is because the whole mass of the charge is not at the same temperature. The explosion wave, when it spreads and hits the piston, becomes cool; and wherever it hits the metallic surface it parts with its heat so rapidly that it cannot keep up a high temperature. This operation I know, because I have measured it. When you have a temperature in the centre of the hot gas of probably 1600 to 1800° C., you have a temperature near the metal which probably does not ever exceed 200° C. It is rapidly cooled by the metallic surface; and the temperature of this metallic surface is probably in the neighbourhood of 80 to 90° C., and is never exceeded. This is an important point, because it makes clear certain phenomena which would not take place unless we were performing our operations in a conducting cylinder. If we were performing them in a non-conducting cylinder, we should get so enormous a temperature that nothing would ever withstand the shock of explosion."

Water circulation.—The high temperatures to which the liner and piston are subjected necessarily make it imperative that the water jacket cooling arrangement should work very efficiently. It is pointed out elsewhere in this chapter that the higher the temperature of combustion, within certain limits, the greater will be the efficiency of the engine. The limit is reached when the unequal expansion due to unequal heating interferes with the free motion of the piston in the liner, or causes the exhaust valve to jam; or when the temperature is so great as to cause the lubricating oil to char and lose its lubricating property. The latter is one great cause of pre-ignition, and the principal object of the water circulation is so to abstract the heat as to keep the cylinder temperature low enough to prevent pre-ignition. On the other hand, the cooling must not be taken too far, or the degree of compression will be adversely influenced, due to the abstraction of heat from the gaseous mixture during the compression stroke. The cooling process should therefore only be carried to the point at which pre-ignition due to temperature becomes impossible. A fair working temperature for the water jacket would be about 60° C.

The water circulation may be of two kinds. A stream of running water may be maintained from either the town mains or other source, passing through the engine jacket, doing its cooling work, and then flowing away to waste, or a continual circulating flow may be maintained between suitable cooling reservoirs and the engine, the same water being used time after time. The former is very simple, requires nothing more than inflow and waste pipes, is easily regulated, but is very expensive. It is essential that, however obtained, the water should be soft and perfectly clean, or precipitation may occur in the water jacket.

The usual plan is, therefore, to provide one or more large tanks capable of containing 30 to 40 gallons per horse-power of the engine, the circulation between which and the engine is maintained by the difference in specific gravity between the hot water emerging from the cylinder jacket and the cool water of the tank.

It is obvious that the portion of the cylinder particularly liable to overheating is the exhaust port and valve and its immediate surroundings. It is usual, therefore, for the cold stream of water from the tanks to be brought to this point first, so that the maximum cooling effect may be applied to the place where it is most needed. The cooling of the back portion of the liner is facilitated, in the case of large gas engines, by the corrugations sometimes cast upon the exterior surface of the liner, as shown in Fig. 408.

In order to assist the circulation, as few bends as possible should be used on the flow and return pipes, and these should be of ample capacity; in no case less in cross section than the inlet and the outlet provided in the cylinder case.

From the nature of the work required of them, it follows, naturally, that the tanks should be placed in the coolest possible position; that they should be open at the top, so that the heat may pass quickly away; and that where more than one tank is used, they should be so connected that the hot water is compelled to pass through the whole length of the series, as shown in Fig. 413. In this case the water enters at the top of No. 1, passing downwards through the tank and then upwards through internal chamber, A, to reach tank No. 2, as shown by the arrows, where the same process is repeated, the cooled water finally passing away at the bottom of tank 3. Cold water is supplied as required into chamber, W.

If it is possible to raise the tank, or tanks, so that the bottom of the tank is on a level, or even above, the engine cylinder, the flow is greatly assisted.

The water in its flow tends to leave a deposit upon the interior surfaces of the water jacket (see Fig. 436, p. 514), which in time very considerably restricts the water passage and prevents proper cooling. It is necessary, therefore, that the jacket should be flushed out occasionally, so that all incrustations and sediment may be removed before they become a source of danger to the engine.

Power of engine.—There is a very considerable amount of misunderstanding as to the terms used to denote the power of a gas engine. It may not be out of place to explain the exact meaning

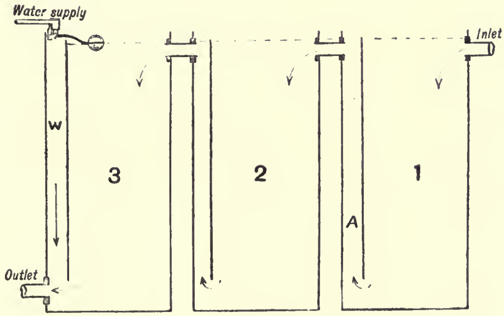


FIG. 413.—Water Cooling Tanks.

of these. Engines are variously spoken of as of so many "indicated" horse-power, or of so many "effective" or "brake" horse-power.

The indicated horse-power is the full power exerted upon the piston by the explosion of the charge, as recorded upon an indicator card, as the work done in the expansion of the gases is measured. The "effective" or "brake" horse-power is equal to the "indicated" horse-power less the power required to overcome inertia, friction, etc. The "effective" power is, therefore, that which is actually developed at the shaft or which is actually available for the purposes of the user. In other words, it is the actual efficiency of the engine; and in an engine of good make may be as high as upwards of 80 per cent. of the "indicated." "Nominal" horse-power is a lower and ambiguous term, which has not been strictly defined, and is usually equal to some small multiple of the effective horse-power.

Having now described the principal working parts of a gas engine designed for use with coal gas, it may be well to trace the sequence of operations by which the potential power of the gas is converted into useful work.

Law of expansion of gases.—The gas engine as a motor depends for its actuation upon the well-known law of expansion of gases. Reckoning from 0° C., every degree Centigrade of heat produces an increment of elastic force equal to $\frac{1}{273}$ of the volume operated upon. Consequently, by raising the temperature from 0° C. to 273° C., the volume is doubled; that is, of course, if the gas is free to expand.

The late Prodessor Tyndall, in his *Heat a Mode of Motion* uses a very illuminating illustration on this point, which may be well reproduced here:—"Supposing you have a purse containing at the outset the sum of £1, 2s. 9d. (273 pence) in penny pieces, and that you have a volume of gas at the temperature of 0° C. Let the gas be gradually warmed, and for every degree of temperature imparted to it let a penny piece be added to the store already in your purse. A single degree would then raise your money to 274 pennies; 10 degrees to 283 pennies; 100 degrees to 373 pennies; while 273 degrees would augment your store to 546 pennies. You have thus at the end twice the sum you possessed at starting, and you have twice the elastic force.

"And now let us invert the whole proceeding. Starting with a temperature of 273° C., and with 546 pennies in the purse, let us gradually cool the gas, removing a penny for every degree of temperature taken away. On reaching 0° C., we should obviously have 273 pennies in our purse; the exact sum, and the volume of gas would again have been reduced to the precise amount we started with." Applying this to the case of the gas engine, we see that the expansive power of the gas, or the actual pressure acting upon the piston, is proportional to the temperature to which the gaseous mixture is raised at the moment of combustion.

Suppose, now, we have a cylinder having a cross sectional area of 100 square inches, containing 1200 cubic inches of air at 0° C., under an exactly balanced piston, free to move. If the temperature be raised to 273° C., the volume of air will be doubled, and the piston be raised through 12 inches. The work done will be:—

100 (area of piston in inches) × 14.7 (pressure of atmosphere in pounds) × 1 foot (distance through which piston has moved) = 1470 foot-pounds.

In the combustion chamber of a gas engine, we have a properly graded mixture of gas and air, which is artificially ignited at the precise moment desired. The combustion is attended by the production of great heat, which expands the volume of gas confined within the chamber. The only direction in which this expansion can take effect is by acting upon the end of the piston, which it causes to move outwardly. This movement, conveyed, in turn, by means of piston rod, crank shaft and driving wheel, is translated into the driving power desired.

Governing principles of the construction of the gas engine.—The provisions which must govern the construction of an efficient gas engine were stated as long ago as 1862, by Beau de Rochas, to be as follows :—

(1) The greatest possible cylinder volume with the least possible cooling surface, or, in other words, the longest possible piston stroke.

(2) The greatest possible rapidity of explosion.

(3) The maximum degree of expansion, and

(4) The greatest possible pressure at the beginning of expansion.

These results were found to be best secured by an engine having the following cycle of operations, namely,

(*a*) An induction charge, during which the gaseous mixture is drawn into the combustion chamber.

(*b*) A compression stroke, during which the gases are not only compressed, but a homogeneous mixture is formed.

(*c*) Ignition as the piston is passing the dead centre, and

(*d*) Discharge of the products of combustion.

It may now be advisable to examine these points in a little more detail.

Induction.—The process which goes on during the induction charge is capable of very simple explanation. Suppose the rubber disc (Fig. 149, p. 187), is placed within a pipe, open at both ends to the atmosphere. The pressure on both sides of the disc would then be equal. When, however, the disc is moved, the air within the pipe would be compressed upon the side toward which movement was made, and the compressed air would be forced out of the pipe as soon as the extent of the compression became sufficient to overcome the friction developed by the movement of the air. Upon the rear side of the disc, an opposite process would be carried on. The movement of the disc would tend to create a vacuum within the pipe, which would be immediately neutralized by the pressure of the atmosphere forcing more air into the pipe to restore equilibrium. The latter is exactly the action set up in the gas engine cylinder on the induction stroke. The movement of the piston tends to create a vacuum at the back of the cylinder, which must be balanced by a corresponding ingress, or the piston could not be moved. But as the cylinder is not open to the atmosphere on that side, the necessary restoration of pressure can only be obtained from the inflow of air and gas through the valves provided for that purpose.

Several things follow naturally from the preceding considerations. First of all, it is evident that the extent of the inflow, or, in other words, the charge, must depend upon the capacity of the cylinder. The relative proportions of air and gas present in the charge will necessarily be determined by either the area of their inlet ports or by the relative length of time during which the ports are open during the induction stroke. The velocity of the inflow will obviously be in proportion to the relative areas of the cylinder and inlet ports and the velocity of travel of the piston. It is necessary to remember, in this connection, that the velocity of piston travel is not uniform. Starting from the rear dead centre, the velocity increases up to the half stroke, and from thence decreases again until the front dead centre is reached.

Speaking of the proportions of air and gas which give the most economical results in actual practice, Professor Bertram Hopkinson, in his paper on "The Effect of Mixture Strength and Scavenging upon Thermal Efficiency," read before the Institution of Mechanical Engineers, in April 1908, says:—"The weakest mixture used in these tests contained about 8.65 per cent. of coal gas when in the engine; the proportion of air to gas drawn in being about $9\frac{1}{2}:1$. Weaker mixtures than this, however, would not ignite regularly. At the other end of the range, the proportion of air to gas was about $7\frac{1}{2}:1$; the excess of air being about one and a half times the volume of gas. Slightly heavier charges than this could be used; but it is possible that the combustion would not be complete, and the pressures in the engine would become dangerously high. The range of mixtures tested, therefore, covers all which could be practically used. Within that range, the efficiency diminishes steadily as the strength of the mixture increases; the difference between the weakest and the strongest charge amounting to about $4\frac{1}{2}$ per cent. in efficiency, or 12 per cent. on the work done."

It is obvious, too, that the correct proportioning of the valve and valve passages is most important. If these are inadequate the charge will be unable to pass quickly enough into the combustion chamber; the inflow will be "throttled," and a great deal of unnecessary work thrown upon the engine. The valves are generally designed to allow the gaseous mixture to enter the combustion chamber at a velocity of about 80 feet per second.

The precise timing of the valves on the induction stroke is most important for efficient working. Late opening of the inlet valves obviously has the same effect as "throttling" the charge, in that it throws an undue amount of work upon the engine. The opening, therefore, is arranged to take place just before the close of the exhaust stroke, so as to give a "lead," and that the fullest advantage may be taken of the suction set up by the travelling piston. The gas valve is arranged to open later than the air valve, so that the risk of wastage of gas through the exhaust may be avoided, and to close earlier, so that the last portion of gas entering may be carried forward by the inflow of following air. The closing of the air valve must evidently be correctly timed for the instant at which the cylinder is fully charged, and immediately before the piston commences its return or compression stroke. If the valve is closed too soon, the result will be a diminished charge and consequential feeble power stroke, while if closed too late, the degree of compression must be less, whilst back pressure is thrown upon the meter and main, causing oscillation of supply to other consumers in the vicinity.

Compression.—Following the induction charge, the piston, moving back again within the liner, the valves being closed, compresses the gaseous mixture now contained between the back of the cylinder and the back face of the piston. The extent to which this compression is carried necessarily varies according to the proportion existing between the cubical area of the clearance space behind the piston and that area added to the area of piston displacement. For instance, to take simple figures, it is evident that if the clearance area equals 1 cubic foot, and the combined clearance and piston displacement equals 2 cubic feet, the piston will compress the gaseous mixture, which originally was 2 cubic feet, into the clearance space, which is only half that capacity. By varying the ratio between these two capacities, the degree of compression will be varied proportionately. In the ordinary type of gas engine, the area of the clearance chamber is usually about 30 per cent. of that of the working volume of the cylinder. The practical importance of compression will be realized when it is remembered that if the initial temperature be kept uniform, the pressure exerted on the piston is proportional to the density of the mixture. Double the density and the maximum pressure after ignition is doubled, and so on.

In the early types of gas engines, the extent to which compression was carried was very limited. It was found, however, that as compression pressures were augmented greater duty was obtained; and modern engines for use with coal gas, with pistons up to 12 inches in diameter, are designed to compress the charge to a pressure of, approximately, 150 lbs. per square inch. The greater the compression, the more intimately the gas and air are mixed, the greater the temperature of combustion, and the greater the risk of pre-ignition. It is necessary, therefore, that not only the water-cooling arrangement should act in the most efficient manner, but also that an excess of air should be provided for combustion, and that the scavenging, to which reference is made later, in connection with the exhaust stroke, be thoroughly effected. It is only by effective cooling that the danger of pre-ignition, due to possible incandescent particles of caked oil, or dust particles, or hot gases lurking in the combustion chamber crannies, may be avoided. The danger of pre-ignition from these causes has been considerably reduced in some engines by an ingenious device for spraying water into the combustion chamber during the period of compression.

It must not, however, be assumed that the economy due to increased compression is progressive for all pressures. It has been found by Professor F. W. Burstall, of Birmingham University, that after a certain point is reached, the point being 175 lbs. per square inch with the particular engine he used, there is a fall of efficiency as the compression is increased. The highest economical degree of compression would probably vary with differences in design of the engine, the extent of loss of heat by conduction from the walls of the cylinder, and the extent to which the piston and liner are gas-tight at the higher pressures.

Ignition.—It is not necessary to add anything to what has already been said as to the importance of accurate ignition timing, nor of the means by which this is secured. It has also been previously stated that the gas engine derives its motive force entirely from the expansion of the gases burned in the combustion chamber. That expansion is, of course, due to the combustion, in gas engines, of the hydrogen and carbon of the gas with the oxygen of the induced air supply. In the process of combustion at high temperatures, these gases are not only themselves expanded, but also expand the nitrogen of the air contained in the air supply, and the CO, the CO_2 and the water vapour produced in the process of combustion.

It is evident, therefore, that the greater the temperature developed, the greater the expansion of the confined gases and the greater the power exerted upon the piston.

It has previously been mentioned that a gas expands $\frac{1}{273}$, or 0.00366, of its volume for every degree Centigrade increment of temperature. The expansion of any volume of gas, and the pressure corresponding to that expansion, may, therefore, be calculated by multiplying the coefficient of expansion by the number of degrees through which the temperature is raised and by the absolute pressure. To take a simple example. Suppose the volume of gas contained in the cylinder of a gas engine be heated at constant volume from 0° C. and atmospheric pressure to 1000° C., then $0.00366 \times 1000 \times 14.7 = 53.802$ lbs. per square inch would be the theoretical pressure developed by that increment of heat. Probably about one-quarter to one-half of the total heat generated passes away through the walls of the cylinder, etc., by radiation and convection; and so in actual practice the theoretical effects are not obtained. But neglecting this loss for a moment, it is seen that the prime power agent is the heat of combustion, and that this, acting through the expansibility of the gases, is converted into active energy, represented by pressure upon the end of the piston.

Professor B. Hopkinson's tests for efficiency.—The results of the interesting tests carried out by Professor Bertram Hopkinson, and given in his paper, to which previous reference has been made, sets out more closely the economical aspect of the question. They are as follows :—

Tests for Pressure and Efficiency of 40 b.h.p. Gas engine

Gas.		Mean Effective Pressure. lbs.	Efficiency per cent.	Remarks.
Cubic Feet per Suction	Percentage of Cylinder Contents.[1]			
0.1275	11.00	102.2	32.5	Full load.
0.1147	10.00	98.4	34.7	,, ,,
0.1005	8.65	90.2	36.5	,, ,,
0.1275	9.50	108.4	34.5	Light ,,
0.1140	8.50	101.6	36.1	,, ,,

[1] Calculated on the assumption that the full load suction temperature is 100° C., and the light load suction temperature 50° C.

From this table, it appears that although a rich mixture of 11 per cent. of gas gives the highest mean effective pressure, a much poorer mixture gives the most economical result when costs are taken into account. In actual practice, a considerable excess of air is always provided for, so as to secure perfect combustion.

Exhaust.—In the fourth and last stroke of the cycle, the inward travelling piston expels the burned gases and products of combustion from the combustion chamber. Seemingly the least important stroke of the series, we shall find that upon the completeness of the expulsion of these gases much of the efficiency and economy of the engine depends.

We have already seen that the power of the engine depends very greatly upon the induction of a proper charge at the precise moment required by the travel of the piston. The degree of thoroughness of the exhaust affects profoundly the character and composition of the charge.

For instance, it is necessary for the development of the highest efficiency in the engine that the charge should be as dense as possible. But it is obvious that should any of the products of combustion remain in the chamber, the gaseous mixture would be raised in temperature, and a less quantity of both hydrocarbons and oxygen per unit of space would be present, and a weak charge be the result.

This would not be the only result. The charge would not only be raised in temperature and lowered in specific gravity ; it would also be vitiated in character, by admixture with a proportion of spent gases. This would obviously mean more or less incomplete combustion of the charge, already weak owing to high temperature, and entail other consequences which would militate against the efficiency of the engine.

It is usual, therefore, to give the exhaust a considerable lead, by causing the valve to be opened slightly before the completion of the power stroke. Usually, the valve commences to open when the piston has still about one-fifth to one-sixth of the power stroke to complete, so that the valve is fully open at the moment when the crank is at the forward dead centre. This, of course, involves a loss of pressure in the cylinder, the heated waste gases rushing through the exhaust with such velocity that the pressure is quickly reduced, approximately equal to, or even below, atmospheric pressure, notwithstanding the acceleration of speed of the returning piston.

And just as it is important that the exhaust valve should be open early enough, so, also, it is important that it should not be closed too late. If so, either one of two results, both very detrimental to the efficient working of the engine, would follow. First of all, if the exhaust is working freely and without back pressure, part of the first portion of the induced charge might pass away through the exhaust, and fuel be wasted to this extent ; or, secondly, if there is any appreciable back pressure, some of the exhaust gases might be drawn back into the cylinder, and so vitiate the next charge.

As the pressure in the cylinder reaches the minimum, the air inlet valve is caused to open. The high velocity attained by the outflow of spent gases induces, therefore, an inflow of fresh air into and through the combustion chamber, which effectually sweeps out the heated gases from the clearance area, and so prepares the way for the induction of a fresh charge. In addition to this, the inflow of cold air cools the chamber and valves, and thus tends to prevent the overheating of the following charge. This process has very fittingly been termed "scavenging," and Professor Hopkinson has found that the mean pressure exerted upon the piston for the same charge of gas is about 5 per cent. greater when the scavenging is being effectively carried out. The exhaust valve should be timed to close exactly on the return of the piston to the back dead centre, and the inlet valve to open at the same time.

It obviously follows that if scavenging is to be thoroughly carried out, the passage of the exhaust gases must be as free and unrestricted as possible. We have already seen, in an earlier chapter, how the flow of gases, even at comparatively low velocities, is retarded by sharp turns, short bends, and side friction. In order, therefore, to preserve the kinetic energy of the gases under expulsion to the fullest extent, the exhaust pipe should be kept as short as possible, should be of ample diameter, the number of turns in it kept at a minimum, and, finally, the bends used should be of such radius as to offer the least resistance to the ejected gases.

For the same reasons, all muffle chambers, silencers, etc. (Figs. 414 and 415), which may be used upon the exhaust to smother the sound of the escaping gases must be of ample area, so that the sum of the passages open to the flow of the hot gases shall be well able to allow of the outflow without causing appreciable back pressure. It is obvious, too, that these should always be fixed as far away from the engine as possible, and that the baffling material should never be allowed to become too dense. The final discharge must always be into the open air, never into chimney or sewer. Should

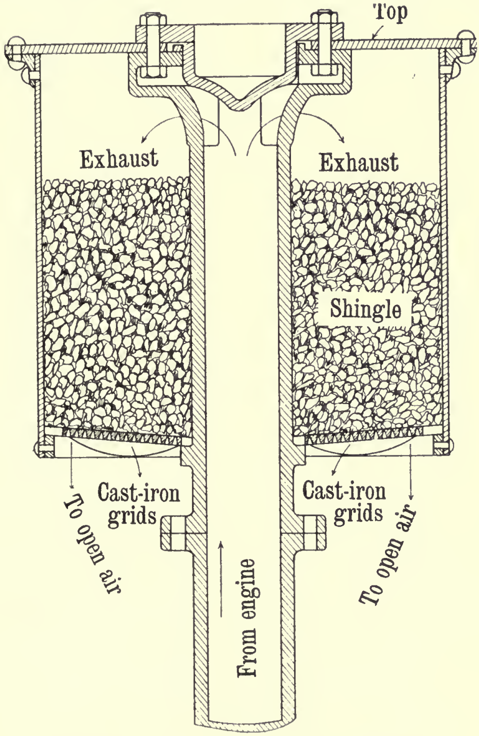


FIG. 414.—Crossley's Upright Silencer.

any unburned gases pass away to the exhaust and become confined, serious consequences might ensue.

We have now traced the four phases of the "Otto" cycle, and it may be well to add a few practical observations on the proper fixing and the general conditions of proper and economical working of a gas engine in actual practice.

Placing the engine.—Much of the satisfactory working of any gas engine depends upon its being suitably placed, housed, and properly fixed. The position chosen should be one which is well lighted, is as roomy as possible, so as to give proper access for inspection and attention, and is free from dirt, fluff, or grit, which may be carried by air currents to the working parts of the engine. In places where there is danger from these latter sources, the engine should be enclosed by match-boarding partitions, to exclude dirt; a sufficient area being boarded off to comply with requirements as to access.

Capacity of meter.—It is imperative that the meter from which

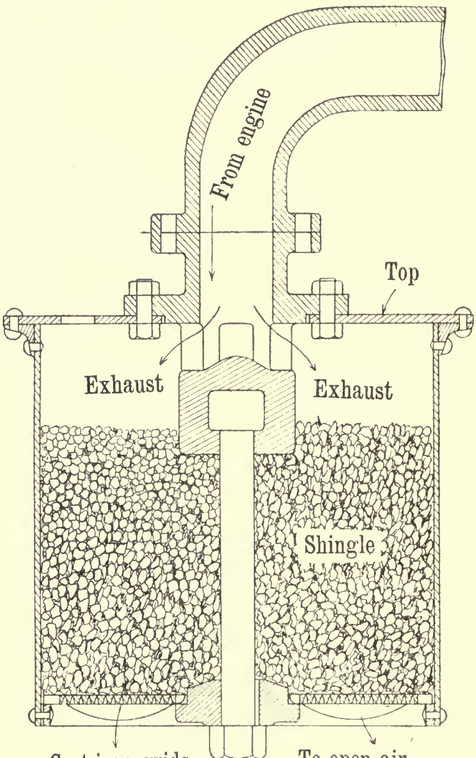


Fig. 415.—Crossley's Hanging Down Silencer.

the engine is supplied should be of ample capacity. The hourly consumption is but little indication of the size of meter required, inasmuch as the rate of consumption is not uniform throughout the hour. The demand of the engine is an intermittent one, and therefore the rate of flow when the engine is taking a charge may be several times that which the hourly consumption might lead one to expect. The meter must, of course, be large enough to pass the required quantity at the moment when the charge is passing into the engine.

Supply of gas to engine.—In carrying the supply of gas to the engine, the pipes should be so placed that the gas is not subjected to great fluctuations of temperature. The aim must be to bring the supply at as low a temperature as possible to the point of ignition. The gas supply for the ignition tube is taken off the main supply

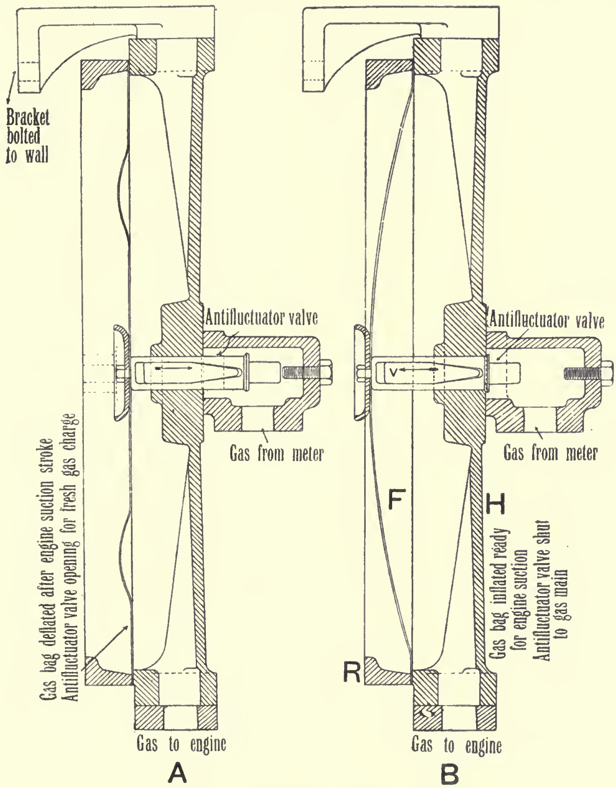


FIG. 416.—Crossley's Anti-Pulsator.

before the gas bag is reached, and the whole of the pipes must be so placed as not to impede access to the engine.

In order to avoid oscillations occurring in the gas main when the engine is being used, it is necessary to fix a flexible bag, or anti-pulsator (Fig. 416), close to the engine. This provides a reservoir from which the engine draws its supply of gas. The bag fills up during the interval between one charge and the next, and the valve prevents the suction of the engine setting up waves in the supply pipe, which, travelling back to the mains, might prove a nuisance to other consumers in adjacent premises. One form of anti-pulsator is shown in Fig. 416, the front portion, H, being a rigid metallic casing, to the periphery of which is fixed, by means of a suitable metallic ring, R, a flexible diaphragm, F, of leather, rubber, or other impermeable material. When the engine takes a charge, the suction tends to create a vacuum, and the diaphragm, in its resultant motion, actuates a small valve, V, having conical ports, which, in closing, shuts off the gas supply to the engine. In the interval between two successive charges, the entering gas, by means of the pressure at which it is supplied, distends the flexible diaphragm, filling the reservoir ready for the next demand upon it, as shown at B. The main cock controlling the supply to the engine must, of course, be placed before the anti-pulsator, so that when the engine is out of use there may be no deleterious pressure or strain upon the flexible diaphragm.

It follows naturally from what has previously been said on the question of valves, as well as from a consideration of the cycle of operations involved in the work of a gas engine, that the inflow and exhaust gas and air passages should be as unrestricted and free from throttle as possible. The air pipe should be of the shortest, and of at least equal area to the air valve. The inflowing air should be well filtered and freed from dust particles, by being passed through cocoa nut fibre contained within the inlet air chest.

Lubrication.—Another point upon which the efficiency of the engine will greatly depend is that of suitable and sufficient lubrication. Particularly is this the case in connection with the cylinder, piston rod, and crank shaft bearings. The piston travels at a very great linear velocity, and in addition to this, it and the cylinder or liner are also subjected to very high temperatures, through the combustion of the gas. The question of lubrication is, therefore, a most important one. Obviously, all vegetable oils are most unsuitable for use under these conditions. Only pure mineral oils, composed of hydrocarbons which leave no residue after being subjected to great heat, are suitable for this purpose. The ignition point of a good gas engine oil should be not less than 530° Fahr. The three members already mentioned, namely, cylinder, piston bearings, and crank shaft bearings should always be lubricated with fresh oil, whilst other and subsidiary parts may be lubricated by oil which has been well filtered, after having been previously used. It is a frequent fault to over-oil an engine. If this is done the oil may carbonise on the valves and give rise to a great deal of trouble. Or, in the case of magneto ignition, oil may be sprayed on to the sparking points, and thus prevent electric contact. The minimum quantity necessary should not be exceeded, for this reason as well as from that of economy.

Cleanliness indispensable to economical working.—To maintain a gas engine in first-class working order, it must be kept perfectly clean. Any caked oil upon liner or piston should be cleaned off by a wash of petroleum. The same applies to the governor. It is absolutely necessary that this should be perfectly free in its action. An occasional wash through the sliding collar with petroleum will clear away any viscous oily matter, and ensure the requisite degree of freedom. Economy and efficiency depend to a large extent on the compression. The various valves must not be allowed to get into a leaky state, or compression will be proportionately lost. They should, therefore, be taken out and thoroughly examined from time to time, and re-ground to their seatings as may be found necessary. This will probably be found advisable at least every three months, or more frequently if the engine is heavily worked. And, lastly, the vibrations and shocks incidental to the working of the engine tend to loosen the screws fastening the bearings of piston rod and crank shaft. These should be kept under constant observation, and any play which may be developed taken up at once.

Faults.—The troubles most frequently experienced either in starting or working a gas engine are usually one or other of the following :—

(*a*) The stiffening of the oil upon the piston when the engine cools down in cold weather. In small engines this is automatically remedied as the engine warms up after being started. In the case of large engines it may be necessary to admit steam to the water jacket before the engine can be started at all.

(*b*) Failure of ignition. If ignition tubes are used, see that the tube is properly hot and in good order. If magneto ignition is being used, withdraw the sparking plug to ascertain whether sparking is properly proceeding.

(*c*) Soot or dirt upon the seating of the exhaust valve. If this is so, then the engine will lose its compression. The remedy is to take out and clean the valve and its seating.

(*d*) Sticking of the exhaust valve spindle owing to thickening of the oil. This again will prevent the valve coming down upon the seating, and cause the engine to lose its compression. The remedy is to take out and thoroughly clean.

(*e*) Leakage between piston and liner. This may be due to (1) faulty or ill-fitting rings. If so, the remedy is obvious. (2) The wearing of the liner. In this case the only remedy is to have the liner turned out true again or to substitute a new liner.

(*f*) The jamming of the rings in the liner. This may be due to friction caused by dirt or corrosion. The remedy again is obvious.

(*g*) Sticking of the valve in the anti-fluctuator. This should occasionally be taken out and cleaned, whether trouble is experienced or not. A sticking valve throws a great deal of strain on the meter, and also causes violent oscillation in the gas supply.

(*h*) Improper setting of the ignition tube. The only remedy is to take out and re-set the tube.

(*j*) Leakage from water jacket to liner. This may have a harmful effect in two ways. The steam generated from the moisture dilutes and reduces the charge, and so diminishes the power of the working stroke of the engine. The moisture may also be carried forward through the ignition valve, at the time of ignition, and, by causing local contraction of the incandescent material, effect the fracture of either porcelain or steel ignition tubes.

It is, of course, assumed that, before looking for any other fault, it will be ascertained that the gas supply is good and the pressures fully adequate.

Gas engines for generating electricity.—When gas engines are used for running dynamos for electric lighting, several modifications are introduced. The engine is constructed to be more quick running than the ordinary type. In the U pattern, Crossley, this would be at the rate of 210 to 220 revolutions per minute, as against the usual 170.

The flywheel is made of larger diameter. Again taking the Crossley U type as an illustration, the diameter would be increased from 5 feet 6 inches to 8 feet. Except in the smallest sizes, say up to about 6 h.p. the double flywheel gives place to the single wheel, and this is made not only larger but exceptionally heavy. An additional bearing is added outside the wheel to assist in taking the weight. It is found that one flywheel takes up the oscillation better than two, even when the total weights in each case are equal. The driving belt is frequently attached to the flywheel instead of having an exceptionally large driving wheel.

Precautions must be taken against the engine misfiring, as this gives serious trouble with oscillations. If the charge is taken every cycle, then the engine runs more smoothly. The slight diminution of speed when the charge is missed, and the speeding up again when the charge is taken, is sufficient to cause fluctuations on the lights.

CHAPTER XXIV

PRESSURES: PRESSURE GAUGES AND REGISTERS

THE answer to the question as to what is an adequate pressure at which to supply gas to any given district at any given time will depend upon a variety of local circumstances. The relative size of the mains to the duty required of them is the first determining factor. If the mains are comparatively small for the quantity of gas demanded through them, the pressures must be proportionately increased. If, on the other hand, the distributing system is ample in area, then more moderate pressures may suffice. In other words, pressures are governed by the proportion maintained between the quantity of gas required and the capacity of the mains.

In considering the question a little more in detail, it is obvious that the character of the district to be supplied must be fully taken into account. The advent of the gas engine, and the wonderful development of the use of gas for power and other industrial and domestic purposes, has profoundly modified the practice in respect of pressures. It appears but a few years since a comparatively small pressure was quite adequate for all the needs of daylight consumption, whereas at the present time, in many important undertakings, the day load has grown to such proportions that it is found necessary to make but little difference between the pressures during the daytime and during the lighting hours.

The introduction and common adoption for general use of the many types of the incandescent burner has again brought new factors into the problem. The day of the old flat-flame burner, needing only some 7 or 8-tenths of an inch pressure for its efficient working, is gone for ever. In its place we have a burner needing twice that pressure, and in its inverted and regenerative forms considerably more than that, or, say, a minimum of 2 to 2.5 inches pressure.

Unaccounted-for gas.—On the other hand, the nightmare of the "Leakage Account" continually haunts the distributing engineer, and a natural disinclination to take any step which might have the effect of increasing this account has probably led, in many cases, to an unwise restriction in the matter of pressures. It is, however, very doubtful, if, in the net result, heavier pressures do involve heavier leakage accounts. There are several compensations which tend to neutralize this tendency. Actual escapes reveal themselves more quickly, and are therefore more quickly stopped. The knowledge that joints are to be subjected to heavier pressures tends to better workmanship. In addition to this, the great improvement which has taken place in the methods of main-laying and jointing of pipes enables a well-laid distributing system to resist pressures to-day which would have been disastrous under the conditions of the past. Both American and English practice in high-pressure distribution have taught us this. The excellent old maxim, "Keep down the pressures in the mains," has, therefore, when applied to modern conditions, lost most of the force it originally possessed.

The problem, therefore, resolves itself into that of giving a sufficient pressure for the adequate supply of the worst situated part—from the point of view of distribution—of the district. This is the determining point of the situation. If the worst situated area is adequately supplied other parts may be left to look after themselves. What pressures, then, should be maintained in such a locality?

Average rule.—Probably a good average rule would be to so regulate the pressures at the works governor as to maintain a minimum pressure of 20-tenths to 25-tenths in the mains at the lowest point of the area of supply, in the daytime, with, perhaps, a couple of extra tenths for two or three hours in the middle of the day, when gas cooking stoves may be expected to be working very generally. During the hours of heaviest consumption through the evening, it will most likely be found necessary to maintain a minimum of 25-tenths to 30-tenths at such a point. It is obvious that local conditions must be fully taken into account, and these may vary so much as to make it imperative to increase these pressures somewhat in special cases. But probably they would prove a rough average standard. Of course, these pressures being maintained at the lowest point implies that over the greater part of the area covered by the undertaking the pressures will be higher, in proportion to the difference in level. To take a simple illustration. In Leeds there is a difference of level of approximately 400 feet in the area of supply. It is obvious that to give a pressure of 25-tenths at the lowest part involves a very heavy pressure at the higher levels.

Pressures at works.—Accepting the above as a general standard, it remains to be determined what pressure at the works will be sufficient to maintain this. That obviously depends upon several factors. The size of the mains and general adequacy of the distributing system, the internal condition of the mains, liability to fluctuations of demand—these and other factors go to produce a problem which can only be solved, except under such ideal conditions as are not likely to be found in this country, by practical experiment.

Pressure uniformity essential.—The only safe rule to adopt is to determine what is the maximum pressure required at the consumer's meter, and then to maintain such pressures in the main as shall always be in excess of the maximum local requirements. In the hilly portion of a district this will inevitably involve governing down upon the consumers services, if wide variations of pressure, with all their disastrous consequences to the delicate air and gas adjustment of inverted burners and gas fires, are to be avoided. In more level districts it may also involve governing down at consumers' services in areas under exceptionally heavy pressures. Whatever pressures are accepted as standards, it is imperative that they should be adhered to strictly. Regularity in pressure is essential under modern conditions. The cheap and efficient pressure regulators now manufactured make this possible. Uniformity should, therefore, be the aim of every gas distributor.

With respect to the augmentation of pressures as the greater consumption of the lighting hours commences, it is obvious that this should be done progressively as the need increases. It is better to add a little every fifteen or twenty minutes, until the desired maximum is reached, rather than add more at greater intervals. In this way violent fluctuations of pressure are avoided, and the increased pressure is made coincident with the gradually increasing consumption. The converse of this applies equally in the case of reducing pressures as the consumption falls off again.

Time to commence raising pressures.—The time at which to commence to increase pressures will vary somewhat with differing local conditions and with the state of the weather. Apart, however, from exceptional circumstances, the author has found it a very good general rule to commence the increase in the winter months one hour before sunset; at mid-summer this is varied to the time of sunset itself; and in the intervening months the time is graduated between the two, somewhat as follows, viz :—

December	21	commence to increase pressure			one hour before sunset.
March	21	,,	,,	,,	one half-hour ,,
June	21	,,	,,	,,	at sunset.
September	21	,,	,,	,,	one half-hour before sunset.

Pressure tables.—The table of pressures given on the next page, as varied at a large provincial gasworks situated in an industrial quarter, has been found to give very satisfactory results and is offered as an example.

The time-table should, of course, be varied from week to week as the seasons change, advancing or retarding the time of commencing to increase the pressures, as the summer or winter approaches, by a difference of, say, ten to twenty minutes per week. For the three or four weeks in the depth of winter and the height of summer respectively, the table may remain unaltered. In the case of sudden fog or darkness, and the absence of responsible officials, the pressures should be advanced at discretion by the man in charge.

Variation for Sundays and Bank Holidays.—In industrial centres it may be both possible and expedient to work at 1-tenth or 2-tenths less pressure upon Saturday afternoons, Sundays, and Bank or other holidays, than is usual at other times.

Time.	Week ending 1st January.	Week ending 1st April.	Week ending 1st July.	Week ending 1st October.
	Tenths.	Tenths.	Tenths.	Tenths.
5.0 a.m.	22	..	..	20
5.30 ,,	24	..	..	22
5.45 ,,	26	..	..	24
6.0 ,,	28	20	20	26
6.15 ,,	30	..	..	..
8.0 ,,	28	..	..	24
8.15 ,,	26	..	..	..
8.30 ,,	24	..	..	22
9.0 ,,	21	..	..	20
3.0 p.m.	22	..	..	..
3.15 ,,	24	..	..	..
3.30 ,,	26	..	..	..
3.45 ,,	28	..	..	..
4.0 ,,	30	..	..	..
4.15 ,,	32	..	..	..
4.30 ,,	35	..	..	..
5.0 ,,	..	..	..	22
5.15 ,,	..	..	..	24
5.30 ,,	..	..	..	26
5.45 ,,	..	..	..	28
6.0 ,,	..	22	..	30
6.15 ,,	..	24	..	33
6.30 ,,	..	26	..	..
6.45 ,,	..	28	..	..
7.0 ,,	..	30	..	..
8 15 ,,	..	..	..	..
8.30 ,,	..	..	22	..
8.45 ,,	..	..	24	..
9.0 ,,	..	..	26	..
9.15 ,,	..	..	28	..
9.30 ,,	..	..	30	30
10.0 ,,	32	28	..	28
10.15 ,,	..	..	28	..
10.30 ,,	28	26	26	26
11.0 ,,	26	24	24	24
11.15 ,,	24	22	22	22
11.30 ,,	22	20	20	20
11.45 ,,	..	..	..	..
12.0 ,,	20	18	18	18

Areas supplied from more than one point.—In large towns and cities where the district is supplied from, say, three or four gas-works and several out-stations, the problem of pressures becomes a much more complicated one. A balance must be maintained so that each works and distributing station obtains its own share of the general output. The pressure necessary at each to ensure this will, of course, be determined largely by difference in level of the works and stations, the character of the trunk main systems, and the local area to be supplied, mainly, by each. It may possibly also be further complicated by an uneven distribution of stocks. But all these questions must be determined locally, according to the prevailing conditions. The chief thing is to determine what the maximum and minimum pressures are to be at the worst point of supply. Having fixed the standard, it will not be difficult to arrange initial pressures, and so manipulate the other factors which have been suggested as to make them conform to the general scheme.

Pressures stated in inches head of water.—For the ordinary purposes of low-pressure distribution, gas pressures are always reckoned in inches of head of water. That is to say, the pressure of gas necessary to balance a column of water 1 inch in height is spoken of as a pressure of 1 inch; that necessary to balance a column of water $2\frac{1}{2}$ inches high, as a pressure of $2\frac{1}{2}$ inches, and so on. For convenience in dealing with intermediate pressures, the inch is sub-divided into tenths. One-tenth, therefore, becomes the unit, and in practice a pressure of 2 inches and 4-tenths is more frequently spoken of as a pressure of 24-tenths.

A simple pressure gauge.—The pressure of gas at any given point is determined by means of an instrument called a pressure gauge. This, in its simplest form, consists of a U-tube, shown in Fig. 417, having a scale between the two arms graduated into divisions of 1-tenth inches from a zero in the centre to the top and bottom of the scale. The tube is filled with water to the level of the zero mark on the scale, and one arm of the tube connected to the gas pipe at the point at which it is desired to ascertain the pressure given, whilst the other arm is open to the atmosphere.

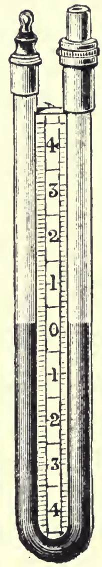


FIG. 417. Simple U-Tube Pressure Gauge.

When the gas is turned on, the result is to depress the water in the arm of the tube which is connected to the gas pipe, whilst the water level in the other arm is correspondingly raised. The difference in the levels of the water is then read off upon the scale between the two arms, and this is the pressure given at that point.

Owing to the influence of capillary attraction, the surface of the water in the arms of the U-tube is not perfectly level, but is cup-like in form, the water being depressed in the centre of the tube. It is usual, therefore, to read the pressures as from the bottom of this cup, or meniscus, in each arm of the gauge.

Single column gauges.—An interesting development of, and improvement upon, the U-tube has been introduced by Mr Short in his patent single column gauge. The steps through which this has been evolved are shown clearly in Fig. 418, which is a reproduction of a sketch kindly sent to the author by the patentee. The gauge itself (shown in Figs. 419 and 420) consists of a brass basal chamber, A, upon which a square brass column, K, is fixed, the column being inserted into the chamber to within about ¼-inch of the bottom. This column is hollow, and has water connection at the bottom with the basal chamber.

Within the column is placed a small, light celluloid float, F, from which a silk cord is taken over an anti-friction wheel, V, at the top of the column. From the end of the silk cord, passing downwards

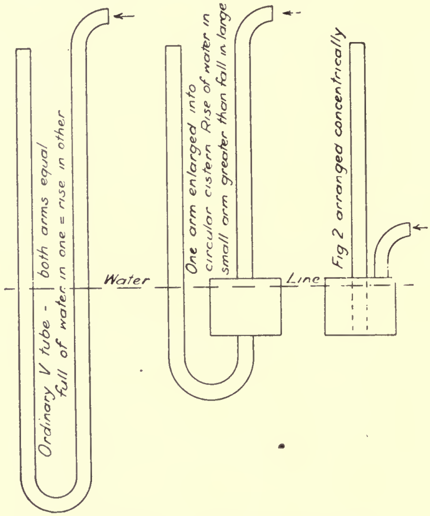


FIG. 418.—Evolution of Short's Single Tube Gauge.

in front of the column, K, the indicator, I, is suspended, whilst the face of the column upon that side is graduated by a scale into inches, which are again sub-divided into tenths.

The column is enclosed within the cylindrical glass cover, J, which is fitted into a socket upon the basal chamber and surmounted by a brass cap, R. The base is charged with water to within ¼-inch of the top, and the gas is introduced above the level of the water through the tube, Q.

When, therefore, the gauge is connected up and the gas turned on the first effect is to depress the surface of the water in the basal chamber and cause that within the column to rise. The rise in the column is, of course, inversely proportional to the difference in area between it and the surface immediately acted upon by the gas. The float, F, within the column is lifted with the surface of the water, the cord is paid out over the wheel at the top of the column, and the indicator, I, in front falls to the position corresponding to the gas pressure in the base, the extent of which is read off on the scale.

The scale is greatly simplified, broken up, and opened out, each

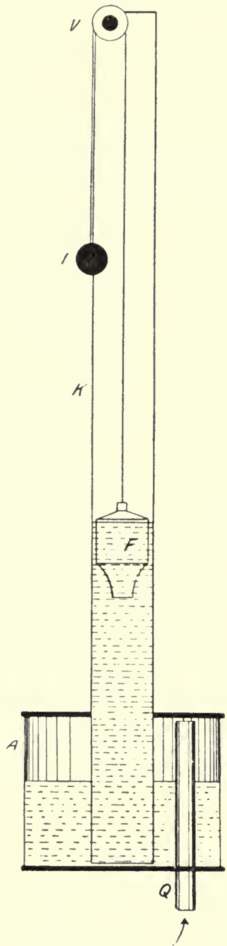


FIG. 419. — Short's Single Tube Gauge: Sectional Elevation.

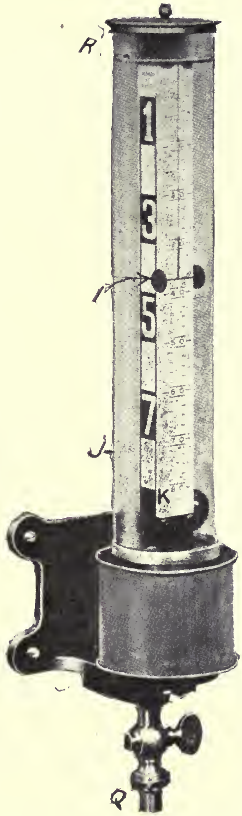


FIG. 420.—Short's Single Column Gauge.

individual tenth being numbered. The reading is therefore absolutely direct, and parallax error is eliminated. Being completely enclosed, the evaporation of water is very small indeed. To compensate for this slight loss an ingenious device termed the zero setter is provided, which gives a $\frac{1}{2}$-inch range of adjustment.

Pressure gauges with compensating floats.—The principle of the Sanders and Donovan wet meter float has recently been successfully applied by Messrs J. Milne and Son to the adjustment of water level in their single tube gauge, where several are fixed upon a common

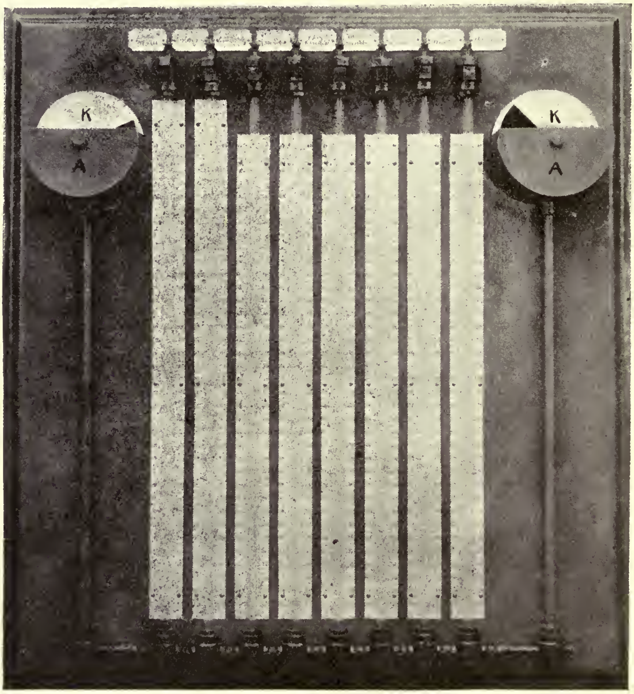


FIG. 421.—Milne's Compensating Float and Battery of Single Tube Gauges.

back plate. In the battery shown in Fig. 421 the gauges are simple single tubes fitted for gas connection at the top, the second limb of the U-tube being a wrought-iron tube at the side common to the whole of the gauge tubes.

The compensating arrangement consists of two enamelled tinned steel reservoir tanks, A, one on either side of the board. These communicate with the bottom gauge mountings by means of wrought-iron piping, the connection between each gauge being provided with isolating cocks so that any one particular gauge can be shut off from its neighbour for the purpose of cleaning or replacing glass tubes without affecting the rest of the gauges. Each of these reservoir tanks is provided with a semi-cylindrical enamelled steel float, K, suspended in bearings on the sides of the tank. This float is so poised in regard to its centre of gravity that the withdrawal of any water from the tank is accompanied by the descent of the float into the liquid to such an extent that the increased area, or cubic content, of float immersed is equal to the amount of water withdrawn. Similarly, any addition of water to the reservoir tank is compensated for by the rising of the float out of the water to such an extent that the decreased area or cubic content of float immersed is equal to the volume of water added. By this means the level of the liquid is kept up to the predetermined height, which is zero on the gauge scales. It will be seen, therefore, that by maintaining the water level in the reservoir tanks at a constant height, the depression of liquid in the gauge tubes due to the pressure of the gas represents the full pressure in inches of water, and thus the gauges are direct reading over a full size scale, *i.e.* 10 inches gas pressure will give exactly 10 inches depression of liquid in the gauge tube.

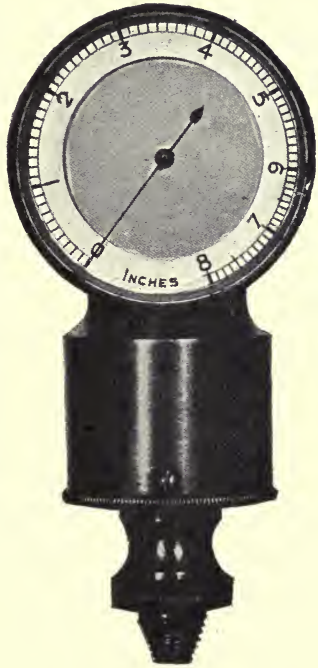


FIG. 422.—Hohmann and Maurer's Aneroid Pressure Gauge.

The aneroid pressure gauge.—The exceedingly handy dry pressure gauge shown in Fig. 422, and manufactured by the Cambridge Scientific Instrument Company, is one of the most convenient gauges yet introduced for the ordinary purposes of gas distribution. This is an adaptation of the aneroid principle to the pressure gauge. The body of the instrument contains a cylindrical metal box (shown in Fig. 423), made of extremely elastic material, so that it readily yields to differences of pressure, and deeply corrugated so as to offer the greatest possible surface to the influence of the gas pressure.

To the top of this corrugated metal box a delicate lever is attached, which carries a pivoted forked end attachment, which engages a pin in a finely-balanced toothed wheel. This, in turn, is geared into a pinion, the spindle of which extends through the centre of the dial plate to carry the index pointer. When, therefore, gas is admitted to the flexible metallic box, the top of the box is raised. This movement is communicated by the lever and toothed wheel to the pinion, causing the latter to rotate, and moving the index hand proportionately over the dial.

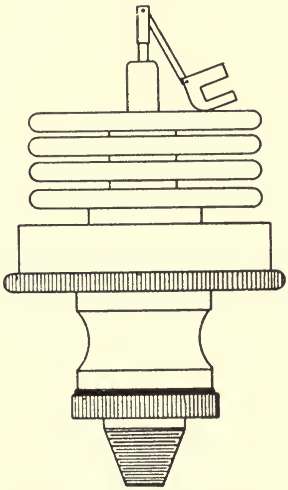


FIG. 423.—Hohmann and Maurer's Aneroid Pressure Gauge: The Metallic Chamber.

Any slight deviation of the index hand (when at rest) from the zero of the scale may be adjusted by moving the dial round, by means of the milled edge, to the extent necessary.

King's gauge.—King's gauge (shown in Fig. 424) is an adaptation, as far as the base is concerned, of the simple **U**-tube principle, previously described, to an apparatus designed to give magnified and delicate indications of small differences of pressure. The base consists of a tank containing two chambers, one of which is closed and within which the gas exerts its pressure. The second is open to the atmosphere at the top and in water-way communication with the first at the bottom, and within this a float is placed capable of vertical movement.

In King's gauge the float is suspended by a cord passing over a grooved wheel, and the axis of the latter carries a long index pointer which travels over a scale arranged in the form of an arc of a circle. The rise and fall of the float are communicated by the cord to the pulley, and consequently to the pointer, which indicates the pressure maintained by the gas in the tank.

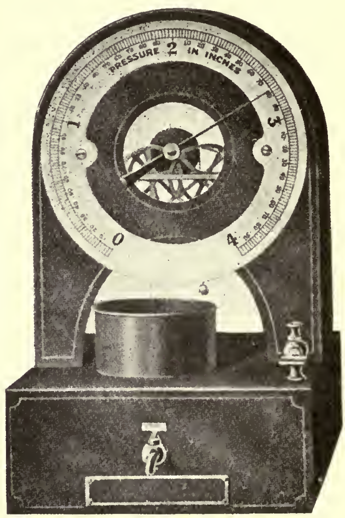


FIG. 424.—King's Gauge.

Continuous records.—It is extremely important that at all gas-works and distributing stations, and, where possible, at convenient central points in the area of supply, arrangements should be made, not merely for pressures to be ascertained at any particular time during the day or night, but that a continuous record be kept covering the whole of the twenty-four hours. Any fluctuation of demand, either local or general, is thus brought at once into notice, and steps can immediately be taken to remedy any fault or lack of pressure which may be evidenced. It is in this way that the distributing

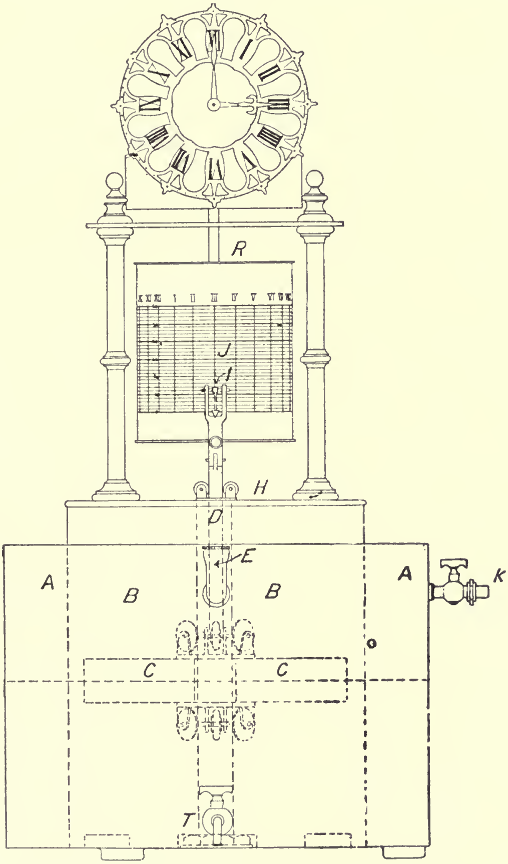


FIG. 425.—Milne and Son's Pressure Register: Section.

engineer keeps his finger upon the pulse of the whole distributory system.

Milne and Son's pressure register.—Many forms of automatic pressure recorders are made. Fig. 425 shows a very good type manufactured by Messrs Jas. Milne and Son, Limited, of Edinburgh. This consists of a closed circular tank, A, partially filled with water and having within it a concentric cylinder, B, open at the top to the atmosphere, and at the bottom in water communication with the outer tank. Within the inner cylinder a metal float, C, is placed, which carries upon the top a rod, D, which is maintained in a true line by the guide wheels, H. To the upper end of this rod a pen or pencil, I, is fixed ; the whole being capable of movement in a vertical direction.

Beneath the clock is fixed the drum, R, upon which is clamped the recording chart, J. This is a sheet of paper divided horizontally into twenty-four equal divisions, corresponding to the twenty-four hours of the day, and vertically into the equivalents of inches and tenths of inches of pressure The drum is geared up to the clock-work above, and caused to revolve exactly once in twenty-four hours.

The working of the register will be readily followed. Water is inserted through the filling tube, E, until the float rises sufficiently to lift pen or pencil to the zero line of the chart. If too much has been inserted, the surplus may be drained off at the tap, T. The instrument having been connected up to a suitable point in the main, and gas admitted by the cock, K, the effect is to depress the surface of the water in the outer tank and raise it in the inner cylinder which contains the float. The float, rising with the water, carries with it the pen also, which, in rising, marks the paper accordingly. The drum in its revolution continually carries fresh portions of the chart past the pen. The pen inscribes the varying levels of the float, and consequently the pressure, upon the chart, which is thus converted into a continuous and permanent record.

A similar register is also made for recording high pressures. In this case mercury is substituted for water, the effective range of the instrument reaching to 100 inches head of water.

As illustrated, Messrs Milne and Son's apparatus is surmounted by a skeleton clock of tasteful design ; the chart, drum, and clock being enclosed by a glass shade.

Thorp's pressure register.—Another very good design of recording pressure register is that patented by Mr T. Thorp, and manufactured by the Gas and Mechanical Speciality Company, of Manchester. Fig. 426 shows a sectional elevation of this instrument.

The base consists of a circular cast-iron tank, A, closed at the top by the roof, C, and containing the cylinder, B. The latter is open to the atmosphere at the top, and in water communication with tank, A, by means of the tube, G. The cylinder, B, contains the float, D, which is guided in a vertical direction and prevented from turning by means of vertical channel guides. Upon the roof of the float the pen rod is affixed, which, at its upper end, carries the well-known capillary pen, I, of this firm. The point at which the ink flows to the diagram is higher than the reservoir containing the ink supply, an arrangement which has stood the test of twenty years' experience. The pen rod is bent slightly out of the true vertical line to maintain a slight pressure of the pen upon the chart.

Whilst free water-way communication is maintained between tank and cylinder so long as the former is properly charged with

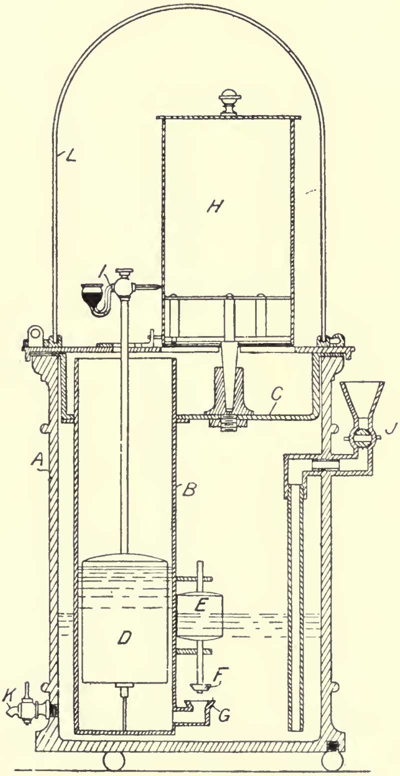


FIG. 426.—Thorp's Pressure Register: Section.

water, a very simple arrangement prevents danger arising from any sudden access of pressure forcing the water out of the tank, to the possible injury of the clockwork or the inconvenience of an escape of gas. This consists of the float, E, which carries at its lower extremity a conical valve, F, made to accurately fit the valve seat, G, carried by the end of the connecting tube. In the event of an excess of pressure beyond that which the register is designed for, the water falls suddenly in the outer tank, conveying with it the float, E, and valve, F, and completely closing communication between the two chambers and preventing any overflow of water.

The chart is carried by the drum, H, which contains a strong lever clock, the whole being surmounted by a glass shade, L. The clockwork is made to revolve once in twenty-four hours. As usually printed, the charts are lettered to run from mid-day to mid-day, but the time of changing can, of course, be varied to any other more convenient period.

Water is poured into the tank by means of the funnel tap, J, at the back of the instrument, and any surplus may be drawn off from the drip tap, K. The general working of the instrument will be readily followed from the previous description of Messrs Milne and Son's apparatus.

If the areas of the outer tank and inner cylinder were equal, the elevation of water level in the cylinder would be exactly equal to the depression of level in the tank. It is obvious, however, that with the comparatively small pressures used in low-pressure distribution, this would give much too small a range of difference on the paper record for it to be of any great practical value. Taking advantage, therefore, of the fact that the comparative rise and fall of the water level in the tank and cylinder will be inversely proportional to their areas, the cylinder is made small enough proportionately to the tank to give the pen a range over the paper to the extent desired. Taking the tank area as A and the cylinder area as B, then $\frac{A}{A+B}$ inches gives the extent of the actual rise of level of the water in B, and, consequently, of the float, for every inch difference in pressure. Putting this into figures, if the areas of A and B are in the proportion of 7 to 1, the water level in A would be depressed $\frac{1}{8}$-inch. Under these conditions the pressure paper would have to be ruled on the scale of $\frac{7}{8} = 1$ inch.

Simmance - Abady "Dead Beat" pressure recorder.—The aneroid principle has been successfully applied to the pressure register in the Simmance-Abady recorder, manufactured by Messrs Alex. Wright and Co., Limited. This is shown in Fig. 427, with front cover removed.

The variations of pressure are transmitted, by an extremely flexible metallic chamber, through a vertical adjustable plunger, which is attached to a horizontal shaft by means of a link or lever which is also adjustable in length. The shaft attached to the vertical adjustable plunger is supported by a bracket, and is normal to the plane of the chart-disc; it converts the reciprocating motion of the flexible chamber and plunger to a rotary motion.

The pen arm, or pointer, is suspended from the shaft at right angles with it, so that when the shaft revolves the pen arm moves parallel to the chart, keeping the pen gently pressing against the surface of the chart. The action being peculiarly sensitive, the pen comes

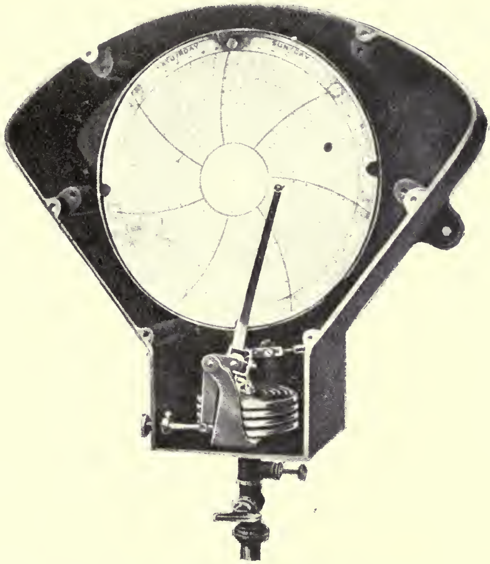


FIG. 427.—The Simmance-Abady "Dead Beat" Pressure Recorder.

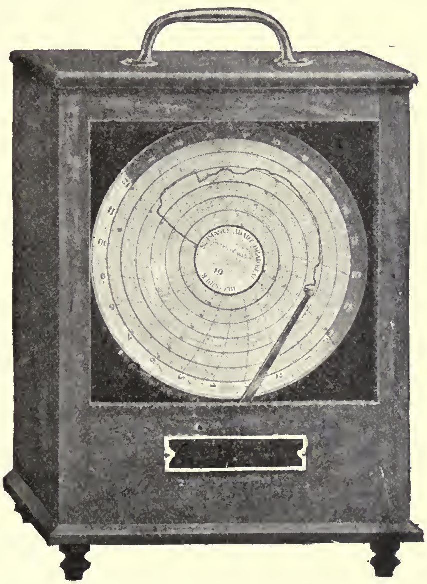


FIG. 428.—"Dead Beat" Portable Pressure Recorder.

to rest at once, and shows the pressure accurately. From this immediate response to variations of pressure the instrument derives its name of "Dead Beat."

The register is adapted for high pressures, but in this case "Bourdon" tubes are used in place of the flexible chamber.

"Dead Beat" portable recorder.—The "Dead Beat" portable recorder is of similar construction to the stationary one, and, containing no liquid, is particularly useful for moving from place to place. It is suitably mounted in a strong wooden case, and may be readily attached to consumers' fittings. It is, therefore, invaluable for investigating complaints of shortness of supply, inadequate pressures, and similar problems.

Seven day charts.—In all these types of instrument it is found most convenient, for general purposes, to arrange for the chart to run for twenty-four hours. But by diminishing the scale of the vertical divisions of the chart, enlarging the diameter of the drum somewhat, and modifying the clockwork arrangement accordingly, the chart may be made to run for seven days instead of one. The convenience of this when the registers have to be fixed in places which are not readily accessible has only to be suggested to be fully recognized.

CHAPTER XXV

COMPLAINTS AND REPAIRS

It is almost a truism to say that a great deal of the success and satisfactory working of any gas undertaking depends upon the spirit in which the distributory staff approach their work. It is as true in this as in any other business that the relations between buyer and seller must be of the most cordial nature, if success and prosperity are to be attained and maintained. The old "take it or leave it" temper is, and should be, a thing of the past. One of the most deplorable results of the monopoly which gas undertakings enjoyed in days gone by was the arbitrary, and oftentimes somewhat arrogant, spirit which it engendered on the part of officials.

It is only fair to say, on the other side, that many customers were, and are even to-day, very unreasonable in their demands and expectations, and seriously tax the temper of the most patient official. Occasionally such an attitude has been adopted as would lead to the supposition that the idea was entertained that officials exist for the purpose of being baited. However, it is a good thing that these experiences are becoming "fine by degrees and beautifully less." The pressure of competition has led to the necessary conciliatory attitude on the one side, whilst a spirit of sweet reasonableness has undoubtedly manifested itself upon the other.

Especially is the most perfect courtesy and consideration necessary in dealing with that class of work which comes under the heading of consumers' complaints. These complaints, as far as they refer to distribution, may be roughly divided into two classes, namely (*a*) escapes; and (*b*) insufficiency of supply.

Escapes: Immediate attention necessary.—From the point of view of both consumer and supplier, class (*a*), although fewer in number, is much the more important of the two. For the consumer there is the inconvenience and annoyance of vitiated atmosphere; the consequential danger to health; the risk of explosion, with its danger to life and property; and the monetary loss which these involve should the leakage prove to have existed in the house fittings. If the escape arises from some fault in either gas mains or services, the considerations of danger to person and property apply even to a much greater extent, owing to the increased seriousness of the fault and the enlarged possibilities of mischief involved.

It is, therefore, of the utmost importance that suitable arrangements be made for immediate attention to complaints of this character. Complaints of escapes should be receivable at any hour of the day or night. In connection with large undertakings workmen should be kept upon the premises ready to respond to a call at any hour of the day or night. Where great distances may have to be covered, a motor, fitted with the necessary equipment and capable of carrying an emergency gang, should be kept ready for use at a moment's notice. Where the size of the undertaking would not warrant this, lists of workmen, with their addresses, should be posted in the night watchmen's lodges at the gasworks, out stations and depôts ; and, in the event of complaint of this nature being reported at night, directions given to ensure the prompt despatch of the nearest man to the seat of danger. Escapes which are reported in the daytime are much more easily dealt with. If there is no one upon the premises available for the duty, a message should be sent to the man working nearest to the place of the escape to proceed there at once.

As a check upon possible slackness of workmen, the author has found it useful to note upon the counterfoil the time at which the message left headquarters and the time it was delivered to the man by the messenger. Any neglect can then at once be traced to its source. In the matter of escapes, promptitude is essential. The delay of half an hour may mean all the difference between being in time to prevent serious accident and arriving after it has occurred. Everyone who has had any experience at all in dealing with these matters could give numerous instances of this kind. The author has in mind a particular case in which a complaint was received at one of the depôts during the night. Although the address from which the complaint came was upwards of two miles distant, a man was on the spot within a very short time of receipt of complaint, but was too late by ten minutes to prevent very serious damage to property, caused by a plumber most imprudently attempting to locate the defect with a naked light. Even the utmost promptitude will not always prevent accident, but it will go far to minimize the risk.

Then, again, consumers should be encouraged to report at once to the proper quarter as soon as any smell of gas is noticed. It is astonishing to find how very careless many people are in this respect. It is frequently left until the meter inspector goes round, or the master of the house "goes up town," or other convenient season arrives, when all the time a postcard or telephonic message might easily be sent at once. In the case previously mentioned it was acknowledged afterwards that the smell was noticed two or three hours before the fact was reported. That delay cost over £1000. In another case brought under notice, a whole family were found insensible in the early hours of the morning by a policeman, who, noticing a smell of gas outside, and obtaining no response to repeated knocks at the door, broke into the house. Upon being questioned later, the head of the house confessed that he had noticed the smell on the previous day, and intended to report it "when he had time."

In attending to escapes of gas, it is imperative that only thoroughly reliable and trustworthy workmen should be employed. Any carelessness, or lack of proper precaution, may have most disastrous results. The importance, therefore, of employing only well-trained and experienced men upon this class of work cannot be over-estimated.

Two classes of escapes. Escapes of gas may be divided into two classes, viz.: (*a*) Those arising from defects in consumers' fittings, including meters and connections; (*b*) those arising from defects in mains and services.

Ventilation of rooms, and extinction of lights and fires, a first precaution. The method adopted in dealing with the matter will, of course, necessarily depend upon which of these divisions the leakage comes under. This it will be the workman's first duty to discover. But before doing anything else, the room, or rooms, in which the smell is noticed should be well ventilated by the opening of doors and windows, and the fires extinguished. It is presumed that all lights will have been put out when the smell was first noticed. If the investigation has to proceed at night, one of the numerous types of portable electric lamps now made should alone be used to give the necessary amount of light, which it will do without being in itself a source of danger.

If the escape is a serious one, it is not likely to be a difficult matter to decide whether it arises from some cause inside or outside the premises. If from the outside, the smell may be noticed particularly in the basement, where the gas service enters the premises; along the inside of the wall nearest to the main; may follow the course of the water pipe; or may be noticed outside, issuing from cracks in the paving, or from untrapped street gullies, or from manholes into the sewers.

Should any or all of these indications be entirely wanting, and it proves impossible to locate any leak internally by sense of smell, if the escape proceeds from the internal fittings it will, of course, be stopped by turning off the main tap at the meter. To confirm this negative evidence, the gas may be turned on again and the small dial of the meter watched to see if gas is registered after all burners have been turned off. If the negative evidence is confirmed by the positive method, and still further by a return of the smell, then it may safely be concluded that the escape arises from some defect in the fittings or piping of the premises.

If the leakage upon a consumer's premises is a small one, it may frequently be very difficult to locate. The smell is often carried about from one room to another, or wafted to different parts of the same room, or carried through floor spaces and hollow partitions, by draughts and light air currents, in a most baffling way. The writer vividly remembers a case in which an escape complained of strongly at one house was ultimately located in the pipes of the next house but one. The smell had been carried through floor space and cracks in the walls, across the intervening premises, without being noticed either there or on the premises in which the escape originated.

Use of lights to locate even small leakage to be avoided.—When a small escape can be traced to a single room, it will be advisable to close all doors, and stop, as far as possible, all draughts. The line of pipes, as far as it is known, should be followed, and the sense of smell alone depended upon to locate the leak. Even if the odour is very slight indeed, and the pipes bare, and there would apparently be no risk involved, it is still very undesirable to use a naked light in searching for an escape. It must be remembered, in this connection, that carburetted water gas is much less odourous than coal gas, and consequently, if this be present, the pungency of the smell is correspondingly decreased. In addition to this, a lighted match or taper, by the slight smell it leaves behind when used, tends to neutralize the keenness of the olfactory nerve of the workman. It may be well, also, to bear in mind the fact that even after very considerable ventilation, explosive mixtures may linger in floor spaces or other gathering places. Indeed, some time ago, a house was wrecked by an explosion of gas contained in the floor spaces, by the incautious introduction of a light, even after all doors and windows had been open and a free current of air passed through, and the place was apparently free from all traces of gas. Upon all grounds, therefore, the use of a naked light is to be strongly deprecated, even when it may appear quite safe.

Use of force pump and ether for locating escapes.—Should a thorough examination of all the taps, swivels, joints, water and cork slide pendants fail to reveal the source of the trouble, it may not be amiss to inquire whether any nails or tacks have been recently driven into the walls, and, incidentally, through the gas pipes buried there. If these and other ordinary means adopted for locating a possible leak remain unattended by success, then the following method may be adopted with every hope of success. First take down all water-slide chandeliers and pendants, and plug up the pipes. Then disconnect the meter, and with a force pump, into which a small quantity of ether has been placed, charge the fittings to a pressure of 4 or 5 pounds per square inch. The ether issuing from the leak will quickly lead to its discovery. If ether is not available, ammonia or oil of peppermint will make a very effective substitute.

It is necessary, however, to apply this method with considerable care, or more harm than good may be done. Should any of the pungent liquid be spilt in the basement, the result may be most baffling. The odours may be wafted over the premises by light draughts and quite spoil the test. The best plan to adopt is to carry a pipe from the rising main (meter outlet) through one of the windows or doors to some convenient place in an outhouse or open space. Fix on the end of this pipe a small closed receptacle. The bottle syphon shown in Fig. 48, p. 96, will answer admirably. Connect up the force pump to the side opposite to the house connection. Then through the hole in the top pour a small quantity of ether, and immediately replace the plug. Upon putting the house piping under pressure by means of the force pump, the vapour from the liquid will be carried through the fittings to the point where the escape is taking place. By adopting this or a similar method all risk of vitiating the test by any mishap in applying it is entirely avoided.

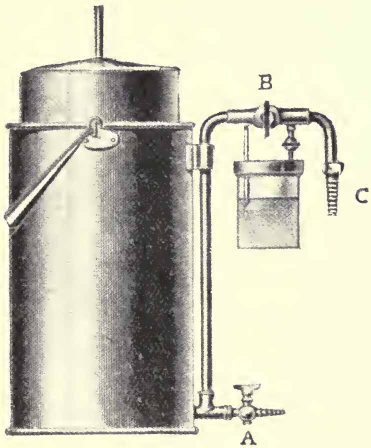


FIG. 429.—Milne's "Reliable" Leak-Testing Machine.

Milne's "Reliable" leak-testing machine.—An excellent device for testing the fittings of any premises to ascertain if leakage is going on is made by Messrs James Milne and Son, Limited. It is shown in Fig. 429, and consists of a small air or gasholder capable of being weighted upon the crown to give any pressure up to 6 inches head of water. The outlet pipe carries a small glass vessel, containing clear water, into which an inlet pipe dips, whilst the outlet pipe is simply connected to the roof of the vessel. The inlet and outlet are separated by the tap, B. The instrument is used in the following manner. In the first place, the holder is inflated with either gas or air through the tap, A. The tap is then closed and the holder weighted to the desired extent. The outlet pipe, C, is connected by rubber tube to some portion of the fittings to be tested, in the basement by preference. The tap, B, is then opened, and the holder pressure thrown upon the fittings. The bell of the holder falls until all the fittings have a pressure upon them equal to that thrown by the holder. The tap, B, is then closed. All the points of consumption having been shut off before the pressure was thrown upon the fittings, it is obvious that if leakage is taking place the pressure upon the fittings must tend to fall. This reduction is immediately made good by the communication through the glass jar. The air or gas passing to restore the balance flowing through the water causes bubbles to rise, and the number of air bells noticed in a given length of time indicates the relative extent of the leak. Even the most minute escape, down to a cubic foot in 350 hours, is revealed by this instrument. But although the instrument is extremely sensitive to the least escape, it does not help us to localize it, except in so far as gas is used in the instrument, and the additional pressure makes it easier to trace the escape by the sense of smell.

Leakage from meters.—The tin cases of both wet and dry meters, particularly the latter, are frequently the cause of trouble through leakage, especially when fixed in damp situations. In such positions the moisture sets up small centres of corrosion on the weakest portion of the casing, and, as the pittings approach to the full perforation of the plates, allow small quantities of gas or water to pass through. If, therefore, the escape is noticed in the neighbourhood of the meter, and it cannot be located elsewhere, it will be well to disconnect and thoroughly examine the meter, scraping and exposing every suspected place until either the fault is found or it is ascertained that the meter casing is thoroughly sound.

Leakage from main cock or connections.—The main cock and connections of the meter would naturally be thoroughly examined before the meter itself. The plug of the cock, in course of time, works rather loose, allowing gas to escape slightly round the plug. The cap and lining attached to the cock and the meter unions are other possible sources of leakage, owing to fresh washers having become necessary, or through pinholes in the soldered joint.

Escapes from mains or services.—Should the indications point to the escape proceeding from the exterior of the premises, after thoroughly ventilating the rooms affected, the first step would naturally be to examine the service pipe. Even if the latter is found to be perfectly faultless the excavation will be of great use. The mere fact that gas leaking from a main in the footpath or roadway percolates through the ground to the interior of the building indicates that this is the line of least resistance. In other words, owing, probably, to the water-tight character of the roadway or pavement over the faulty pipe, it is easier for the gas to find its way through the interstices of the subsoil, and through cracks in the brickwork of the underground wall, or alongside the service pipe, than to make its way upwards through the soil. The excavation will, however, provide a still more easy way of escape, and so partakes of the nature of a vent, and thus frees the premises from a dangerous inflow of gas.

It will probably happen in most cases that the leakage which is the cause of the trouble is actually taking place in the service pipe. It may be that the pipe will be found to be badly corroded through having lived its normal life ; that it is prematurely decayed owing to the rapid action which some soils unfortunately have upon wrought-iron; or, possibly, owing to some strain due to heavy traffic, or subsidence of the ground, the service may be found to be broken off near one of the sockets. In cases where the main lies in the roadway, the point at which the service leaves the region of heavy traffic, that is, the roadway, for the comparative immunity of the footpath, and so has to take up frequent and severe strains, is a very likely spot for this to occur. The same thing often happens at the point where the service is connected to the main, where the latter is in the roadway, and is frequently caused by the continual passage over it of road rollers, traction engines, and other heavy traffic.

In all these cases there is, of course, only one remedy. The corroded or damaged pipe must be removed and replaced by new. Where it is impossible for this to be completed before the lighting hours supervene, and the service is required for supply, temporary relief may be obtained by wrapping the broken or injured part round with canvas well smeared with white or red lead, keeping the whole well bedded and properly adjusted by tying it tightly in place with strong cord. If, however, the service has become badly corroded for any great distance along its length, this remedy may be inapplicable. Such a pipe may not prove strong enough to have the earth cleared away from it; and it might possibly crumble under the process. If, therefore, in such a case, it is impossible to at once replace the corroded with good pipe, the service should be traced back to a good socket and there severed and plugged for the night. But if the services of the undertaking are examined regularly and periodically, as suggested on p. 525, such a bad case will very seldom be found.

It may, however, possibly happen that in searching for an escape the service pipe is found to be in a perfectly sound condition. It will then be necessary to search for it along the line of the main. If the latter is laid under a footpath, as is usual to-day, and the path is an unpaved one, the search is rendered comparatively easy. An ordinary crow-bar is driven down by the side of and below the level of the bottom of the main at intervals of a few feet, until some spot is found where the smell is most pronounced. At this place an excavation is made, and the fault found by baring the main. Should the footpath be paved or flagged a portion of the paving must be removed to allow the bar to be used. This use of the crow-bar is, however, only advisable in places where it is known that there are no electric cables buried near the gas main. In the event of a bar being driven through the insulating material of such a cable, a severe shock, with possibly fatal results, may be experienced. Workmen should, therefore, be warned accordingly.

If the main lies in the roadway, the same principle, that of gradual localization, is applied. Where the roadway is unpaved or merely macadamized, this generally presents no very serious difficulty.

In the event of the roadway being not only paved but concreted, the process is a little more complicated and troublesome. Owing to the shrinkage of the earth underneath, there are frequently air spaces just below the concrete, in which the gas may collect and travel for a considerable distance before evidencing itself above ground. This is often the cause of misleading indications, and of additional work being necessary, through men being led off on a false scent.

Probably, as the use of concrete under the paving of our roadways is extended, it may become necessary to have inspection tubes, say of 3-inch wrought or cast-iron piping, concreted in when the road is being made. These tubes, placed at intervals over the gas main, and themselves piercing through the body of the concrete, and being surmounted with an ordinary syphon-indicating box, would form very convenient places at which observations could be made, and a troublesome escape to some extent be localized. Failing these, one or more of the wood blocks or granite setts with which the roadway is paved must be removed to allow the concrete to be pierced and the source of leakage gradually localized, as in the previous cases.

Short's gas leakage indicator.—A very great aid in localizing the source of leakage from mains and services has been placed at the service of distributing engineers in the gas leakage indicator originally patented by Mr George Ansell as long ago as 1865. The construction of the instrument is based upon the well-known law governing the diffusion of gases, namely, that the velocity of diffusion of different gases is inversely proportional to the square roots of their densities. This principle is applied by means of an elastic metal chamber, at the base of which is a porous tile through which the diffusion takes place.

The original clock form of the instrument has given place to the vertical arrangement shown in Figs. 430 and 431, designed by Mr Short. The other improvements introduced are the extension piece designed to keep the diffusion plate away from grit and dirt, the substitution of an improved method of ventilating the chamber, the removal of the scale from the front to the top, and the revolving and modified arrangement of the scale.

When this indicator is brought into an atmosphere containing an admixture of coal gas, the hydrogen of the gas passes through the porous tile into the elastic chamber more quickly than the nitrogen of the air can pass out, the comparative velocities being in the proportion of $\sqrt{1}$ to $\sqrt{14}$. This action causes pressure in the chamber, by the increase of volume, and the motion imparted to the elastic surface is communicated to the mechanism which causes the index hand to move over the dial. The latter is graduated to show the percentage of gas present. The instrument is extremely sensitive, and if brought into any confined space near to an escape which is too small to light, it immediately gives indications of the presence of gas. The maximum effect is attained in two or three minutes. Its small size and portability, and its ease of manipulation and accuracy of indication, make it almost invaluable to the outdoor staff of a gas undertaking.

The tap and valve are always kept open to the atmosphere, except when the instrument is to be used. When an observation is about to be made, and before the instrument is brought into a suspected atmosphere, the extension piece is screwed up and the chamber closed. Being brought within the area of suspicion, if coal gas is present the index will almost immediately commence to move, until it shows on the dial the percentage of gas in the atmosphere. After the test has been made and the valve opened, the indicator

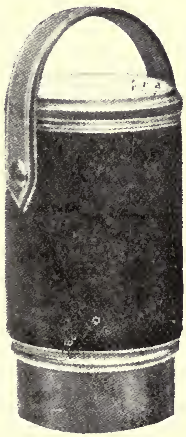


FIG. 430. — Short's Improved Leakage Detector.

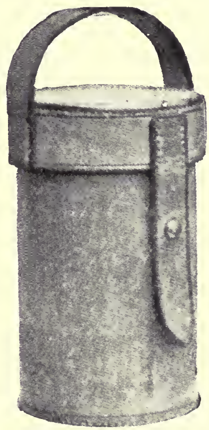


FIG. 431. — Short's Improved Leakage Detector in Leather Case.

will return to zero; and when the instrument has been purified by exposure to an uncontaminated atmosphere, it is ready for another test.

It will readily be seen, from the brief description just given, that not only is the apparatus almost invaluable in vaults, basements, subways, and other underground, more or less enclosed spaces, where it would be extremely dangerous to introduce a naked light, but it may also be used in the open air for the purpose of locating leakage from street mains. It is especially valuable in tracing escapes in busy thoroughfares, where great inconvenience would be caused by the roadway being taken up more than is absolutely necessary, or where the roadways are paved in modern fashion with wood blocks or granite setts upon concrete, or asphalt composition, or other materials not easy either to remove or to replace.

When it is to be used for this purpose, holes are pricked down to below the level of the suspected main with a crowbar, as already described. A small ring, or bed, of dense and plastic material, such as clay or putty, is laid round the edge of the hole made, sufficiently wide to leave the whole of the porous tile of the instrument open to the effect of any gas finding its way upward. The instrument is then pressed down tightly upon the plastic bed, with the porous tile exactly covering the hole in the ground. If gas is escaping from the main near the point under observation, the fact and the percentage will be indicated upon the dial. By repeating this operation at intervals in the suspected area, and carefully noting the varying

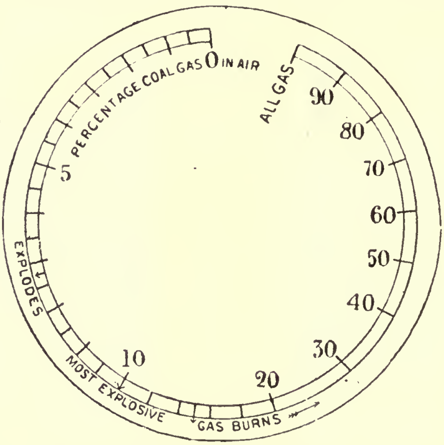


FIG. 432.—Short's Detector Dial.

indications, if any, the place where the leakage is going on may be located within a few feet. At this point an excavation must be made, the main bared, the leakage traced, and repairs carried out in the usual way.

The scale is designed to read up to 100 per cent., but by an ingenious device Mr Short has arranged that while the first 10 per cent. of the scale shall be comparatively open, and thus allow of extreme sensitiveness with small proportions of gas, from that point to the extent of the scale a restrainer is brought into operation, thus enabling the full 100 per cent. of the scale to be indicated within the circle. The difficulty sometimes experienced in getting the index hand to zero in the original form has been surmounted in Short's instrument by adjusting the dial to the pointer, the dial being made to rotate for the purpose.

It will be observed that the efficacy of the method of localizing leaks in mains by means of a leakage indicator depends almost entirely upon an exact knowledge of the position of the mains. It has, so far, been assumed that this is accurately known. But every practical man is painfully aware that it is not always possible to be absolutely correct in this matter. However faithfully maps may be posted, unless these are of very large scale it is impossible to show upon them the position of a main to a few inches, or even sometimes one or two feet. The matter is frequently further complicated in some of our large towns owing to street improvements, the removal of landmarks, and other such alterations as are continually going on.

Influence of soils.—In connection with escapes of gas percolating through the ground, it must be remembered that some soils have the power of more or less deodorizing the gas. It is, therefore, almost imperative that such a mechanical means of supplementing the sense of smell, for the purpose of locating any possible escape, as Short's indicator, should be used if the leakage is to be quickly traced and stopped.

Then, again, some clayey soils are so dense as to be practically impervious to gas. In these cases it is possible to prick down to within a very few inches of a serious escape without getting any appreciable smell. Where an escape is known to proceed from a main which is buried in stiff clay, if the source of the trouble is not quickly found it may frequently be the quickest and cheapest plan in the long run, where it can be done without serious inconvenience to the users of the roadway, to strip the main entirely and subject it to a thorough examination for as great a length as may prove necessary. The opportunity should, of course, be taken to set up all joints uncovered in this way, whether found to be leaky or not.

Palladium test.—Another aid which the writer has found useful is the reaction produced upon a solution of palladium chloride by the carbon monoxide in the gas. In many cases it is almost impossible to say, from the evidence of the senses, whether a particular smell complained of is caused by a small escape of coal gas, or sewer gas, or arises from some trade refuse or effluent. The difficulty prevails to a serious extent in the neighbourhood of industries where naphtha and other similar materials are used. A few pieces of white blotting paper saturated with a weak solution of palladium chloride will, by the darkening of the colour of the solution, show whether coal gas is present or not. These strips may be left for hours in cupboards, basements, under floors, in gulley grates, or any other place where the smell is noticed. The strips of blotting paper should be saturated just before they are needed, and one strip retained for purposes of comparison.

In cases where it is suspected that an escape of gas is making its way into a sewer, and from thence either into the streets or adjoining premises, it is possible to apply the chloride of palladium test in a very much more delicate form. A sample of air should be aspirated from the suspected sewer into a test bottle, and removed to a laboratory. The air should then be caused, by displacement, to pass through a solution of caustic soda, to take out any possible sulphur compounds, and afterwards passed slowly through a solution of palladium chloride. If coal gas is present, the solution is chemically acted upon by the carbon monoxide in the gas, the tint of the solution being darkened, proportionately to the amount of carbon monoxide present, by the precipitation of metallic palladium.

As a result of experiment it has been found that a 0.1 per cent. mixture of Leeds gas with air does not give an appreciable smell. The same mixture, however, passed through a 0.1 per cent. solution of palladium chloride gives a distinct reaction. With a 2 per cent. mixture of coal gas and air there is a strong reaction on aspirating so small a quantity as 100 c.c. through a 0.1 per cent. solution of palladium chloride. When a 0.11 per cent. mixture of coal gas and air, the former containing 7 per cent. of carbon monoxide, was aspirated to the extent of 900 c.c. through a 0.1 per cent. solution of palladium chloride, a very distinct darkening took place. A sample of the original solution should, of course, be reserved as a means of comparison.

It is not pretended, of course, that this test is absolutely conclusive. If there is no reaction, then there is no carbon monoxide present, and consequently no coal gas. If, however, there is a reaction, it does not necessarily prove the presence of coal gas, as the carbon monoxide causing the reaction may conceivably be present from other sources. The test is given for what it is worth. The writer has many times found it very useful.

Subterranean conduits. — In many large cities, old stone and earthenware drains, which are serving no useful purpose, having been replaced by modern sewers, are to be found in the subsoil. These are frequently supplemented by old gas and water mains which have been abandoned, and are lying useless. In the event of gas from a faulty joint or pipe finding its way into one of these, it is often a very tedious and costly business to locate the leak. In many of these disused underground conduits, subterranean air currents exist, which may, and in fact frequently do, carry the escaping gas long distances before the leakage is evidenced above ground. It may, therefore, be well here again to emphasise the point that all abandoned mains should be well plugged at each end, so that difficulties of this kind may be avoided. The same remark applies also to abandoned water mains. It is equally to the interest of both gas and water undertakings that these underground channels should be closed against leakage from live mains.

Where an escape of gas is getting into an old drain in the way suggested, it will probably save time, in the long run, to break through the roof of the drain and ascertain by means of a pith ball the direction of the current, if any. Then the drain should be filled in for a short distance with rough concrete, or clay, well pounded in, or built up with brickwork, so as to effectually prevent any air current passing. If, after this has been done, the smell ceases at the point where it was originally noticed, we have an indication at once in which direction to proceed with the examination. By repeating the blocking operation as often as may be necessary, the point at which the gas is getting into the drain will be at length approximately located. It can then be dealt with in one or other of the ways subsequently described.

Drawing of joints.—The most common cause of leakage from a main is, of course, the drawing or disturbance of the joints. This may occur through the action of expansion and contraction, subsidence of the subsoil, or vibration due to heavy road traffic. Most of these cases, presuming that the main has been properly laid at a sufficient depth in the first instance, call for little comment. An excavation must be made round the pipe, and the joint thoroughly well set up again. If the joint is slack, *i.e.*, if insufficient lead has been run into it in the first instance, the old lead should be picked out as far as may be necessary, and the joint made good again with lead wool, lead wire or run lead.

In colliery and mining districts, where considerable subsidence is continually proceeding, the use of some form of expansion joint, similar to that described in Chapter X, p. 161, may be adopted. This should be built in an underground shallow vault, so as to facilitate adjustment from time to time. Or a special form of joint may be adopted. The author has used the "Forster" joint, described in Chapter X, p. 147, in a district where continual settlement is going on, with very satisfactory results.

Fractured mains.—It will frequently happen that the leakage proceeds from a more serious cause than drawn joints. The pipe itself may be found fractured, or one of the sockets cracked. A fault of this kind may be temporarily dealt with in the same manner as a broken service pipe, as already described. The pipe should be thoroughly cleaned for some six or eight inches on either side of the fracture, and the injured part wrapped round with coarse calico or sacking which has been previously well smeared with white or red lead, the whole being tightly bound together with strong cord. If the main is more than five or six inches in diameter, it is better to use a band of thin sheet lead, if it is procurable, instead of the sacking. This should be well bedded to the pipe with white or red lead, and strongly tied round with copper wire. If from any cause it is impossible to permanently repair the injury for a few days, the wire should be reinforced by a couple of clips, made of flat iron in two sections, as shown in Fig. 433, and bolted together, one on either side of the fracture.

Cracked sockets.—The case of a split socket may be temporarily dealt with on similar lines, or the crack may be simply filled in with white or red lead or iron cement. The rent in the socket having, to some extent, relieved the strain which caused it in the first instance, it is unlikely to go still further. But if the pipe is of large diameter it is always well to leave the ground open and a reliable watchman on the job until the damage can be permanently made good.

Two methods for permanent repairs.—There are two ways of permanently repairing such damage as the above. First of all, the injured piece of pipe may be cut out, a new piece laid, and the whole

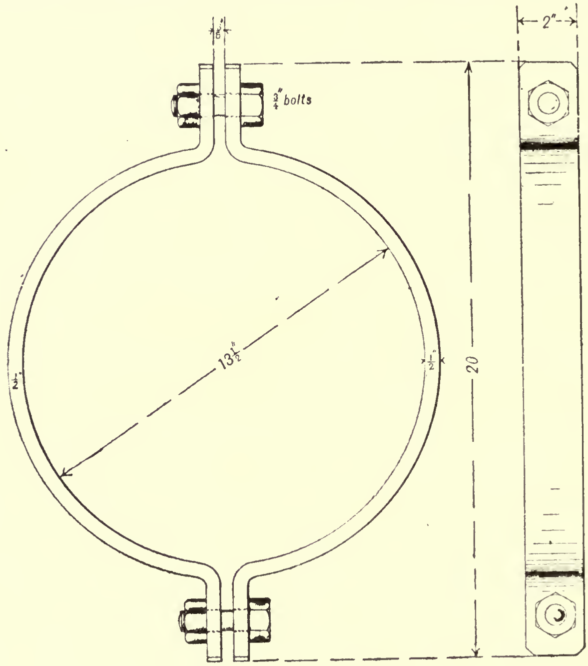


FIG. 433.—Pipe Clips.

connected up again by the use of a collar. In this case the operation will have to be carried out in a similar manner to that described in Chapter XI., pp. 189-192, in connection with the insertion of a tee in an existing line of main, and need not be further elaborated here. If the main is only supplied with gas in one direction, it will be necessary to connect up a by-pass of sufficient size to prevent continuity of supply being interfered with whilst the repairs are in progress. If the fracture has been occasioned by subsidence of the subsoil, care must be exercised to ascertain that the original inclination of the main has not been altered except at the point of fracture. If the main has sagged for any great distance, then a sufficient length must be bared and lifted to restore the fall, or a syphon inserted. It is always necessary in repairs of this kind, in which the natural bed of the pipe has been interfered with by the necessary excavation, that the newly inserted pipe should be well packed up. If not, a second

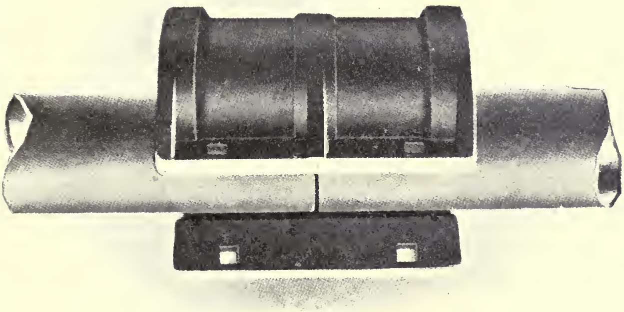


FIG. 434.—Split Collar, Showing Method of Attachment.

fracture is likely to follow, owing to the ground under the new portion of main being less firm than the bed of the original pipe on either side.

But a much easier, cheaper, and in many respects better way of dealing with these cases is by means of the split collar shown in Fig. 434. These collars are made in two sections, with longitudinal flanges machined true, which are bolted together, with a thin strip

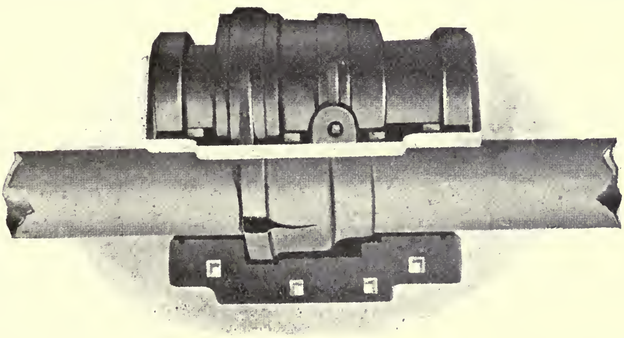


FIG. 435.—Ruscoe's Split Collar for Socket, Showing Method of Attachment.

of sheet lead, smeared with red or white lead, as a bedding material between the flanged faces. These are placed round the fractured main, with an equal length of the collar on each side of the injury, and the flanges bolted tightly together. The end joints of the collar are then made in the usual manner with lead and yarn.

The case of a cracked socket may be similarly dealt with by means of the shaped collar shown in Fig. 435, which is made to fit over the socket. With these collars an additional element of safety is introduced, in the provision of a plug hole through which, after the end joints have been made, the central portion of the interior of the collar may be run full with liquid cement.

Insufficiency of supply.—Complaints of insufficiency of supply may arise from many causes: inadequacy of size of main or service for the work it has to do; corrosion in the main or service, reducing its area and partially choking it; waterlogging of main or service; naphthalene; frost; insufficiency of pressure; various faults in meters—these and others, either singly or in combination, may be the source of the inconvenience.

Fig. 436.—A Neglected Engine Cylinder.

Faulty meters. — With regard to meters, but little need be said here. The principle causes of failure in them are inattention to water-line, sluggishness of working, leakages, and other similar faults. With the exception of the first, where the remedy is obvious, none of these can be properly dealt with upon the consumer's premises. The meter must be changed and the faulty one brought in to the workshop for proper overhauling and repair.

Insufficiency of pressure.—In respect of pressures, this is a matter on which it is sometimes very difficult to satisfy consumers. More often than not, when this is the alleged cause of failure, it turns out, upon examination, that the real cause is some fault or inadequacy in the consumer's own fittings or apparatus. Gas engines are often neglected or improperly attended to, are frequently subjected to the dust of a workshop and allowed to get dirty, or the water jacket is allowed to become foul, all of which tend to cause over-heating of the cylinder and heavy working of the engine. Fig. 436 shows the exterior of the cylinder of a gas engine which came under the notice of the author. As will be seen from the illustration, that which should have been the clear way of the water jacket had been allowed to become almost silted up, the water being considerably retarded in its circulation by the accumulated deposit upon both surfaces. Naturally, under the circumstances, the cylinder rapidly and continually became overheated. In many cases, stoves, fires, engines, and other apparatus are fixed with pipes too small for the duty required of them. Especially is this the case in many workshops, where misplaced notions of economy have led to fittings being planned without the least allowance of margin, and, consequently, the presence

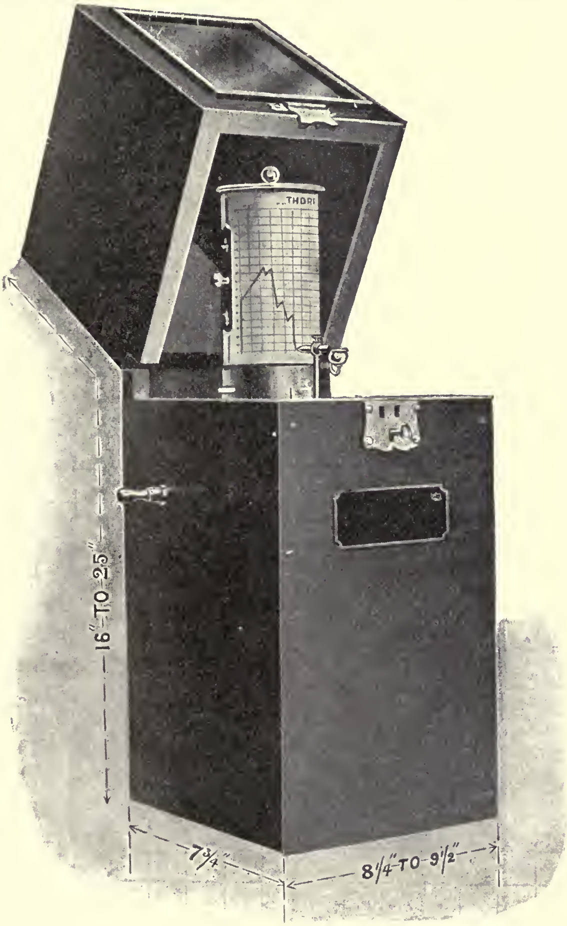


FIG. 437.—Thorp's Portable Pressure Register.

of a little corrosion in an elbow or bend, or the inevitable addition of a few extra lights, has rendered the whole system quite inadequate.

Many people find it much easier to blame pressures, and put a gas department to considerable cost in sending to investigate the cause of complaint, rather than examine to see if the real fault cannot be found on their own premises. In all cases where shortness of pressure is complained of the author has for years adopted the simple plan of fixing one of Thorp's portable automatic pressure registers (Fig. 437), upon, first, the inlet, and if the pressure there is shown to be adequate, then upon the outlet of the meter, the supply from which is complained of. It may also be advisable to fix the register at the point

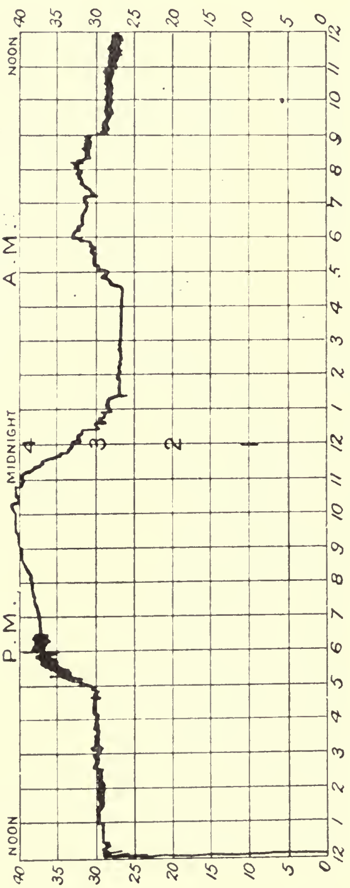


Fig. 438.—Pressure Chart.

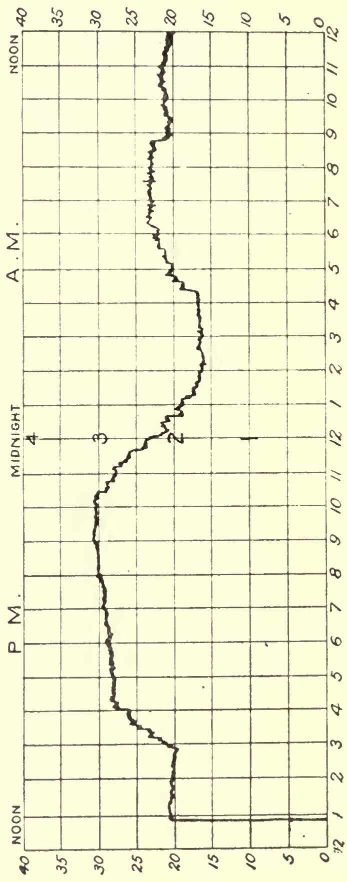


Fig. 439.—Pressure Chart.

of worst supply, so as to obtain a record of inlet pressure and fittings pressure for purposes of comparison. The working of the instrument is explained in simple terms, and the pressure at which the engine, stove, or burner should give good results is also made perfectly clear, and the complainant invited to inspect the register from time to time through the twenty-four hours. In most cases, if the complaint is not well founded, the record is sufficient to assure people who simply will not be convinced in any other way.

The charts reproduced in Figs. 438 to 440 are typical. In the case illustrated by Fig. 438 repeated complaints of insufficiency of gas for cooking in a private dwelling were received. It was quite in vain that assurances were given that pressures were ample and that the fault was in the stove fittings, but the silent testimony of the pressure record was at once accepted.

The chart shown in Fig. 439 was taken at the 200-light meter supplying part of a clothing factory where a considerable number of gas irons were being used, and from which complaints were repeatedly being received. The thin black line of the chart proved convincing where all verbal assurances were received with polite incredulity.

The third instance, shown in chart (Fig. 440), is probably unique in its way. In one portion of a mill a gas engine had displaced the steam power employed previously. Complaints of insufficient pressure were at once received. The chart shown, which was taken off the engine supply pipe, effectually disposed of that as the cause of the trouble experienced. Investigation ultimately showed that it took no less than 12 horse-power to drive a portion of shafting crossing underground from one part of the mill to another.

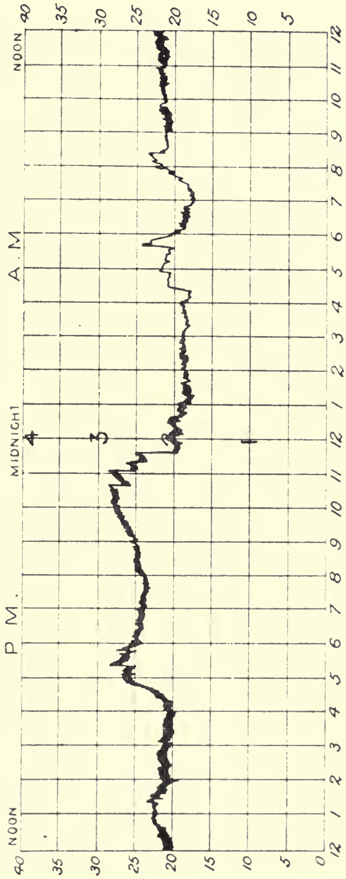


Fig. 440.—Pressure Chart.

If the record, on the other hand, shows that the pressure really is insufficient, it is greatly to the interest of the gas undertaking to know the fact and to take immediate steps to remedy the complaint. To be sellers of a commodity such as gas, and yet really, even though unintentionally, restrict the output is recognized on all hands as poor business. In these days of keen competition it is simply suicidal. It remains, therefore, for the staff to discover the cause of the insufficiency. This may be either an inadequacy of initial pressure at the works; or that the mains or services are too small for the requirements; or corroded; partially water-logged; or obstructed in some similar way.

Should the pressure maintained at the works governor be too low, the fact will be indicated by the complaint of slackness being general, and not singular. The pressures taken at intervals along the principal line of mains at times of heaviest consumption will show a gradual and comparatively uniform progressive decrease from the works outwards. This is a class of complaint, however, which, although frequent enough a generation ago, when rules which are now obsolete governed gas administration, is very rarely met with to-day.

Mains of inadequate capacity.—It may, however, possibly happen that similar general results are observed, although the pressures maintained at the works are as high as it is convenient to keep them. It is obvious that this condition of things denotes that the demand for gas has outstripped the carrying capacity of the trunk main system, and that the latter is inadequate for the duty required of it. The remedy is, obviously, to bring up the distributing system to the capacity required. This may be done in one of three ways, as follows:—

(*a*) By replacing existing mains with others of adequate capacity.

(*b*) By supplementing the existing system with an additional trunk main, run from the works to some convenient central position, for the reinforcement of the supply at that point.

(*c*) By reinforcing the supply at some one or more convenient points by means of a high-pressure main.

The first (*a*) is a very costly and inconvenient undertaking, inasmuch as it implies very considerable disturbance of existing plant, whilst, at the same time, a continuous supply must be maintained.

The second (*b*), whilst much easier to carry out, involves the disadvantage of adding another to the many underground conduits which crowd the subsoil of our modern cities. The third alternative (*c*), is undoubtedly the best and most economical solution of the problem. This will, however, more fittingly be discussed in connection with high-pressure distribution.

The next case taken in sequence is that in which the complaint applies only to a particular district, or part of a district, whilst the supply to other areas of supply is fully adequate. This may be due to one of two causes. Either there is some obstruction in the leading or subsidiary mains, or they are overworked. The proper way of ascertaining which of the two causes is at work is to take the pressures at the street lamps, from some point on the trunk main system where the supply is known to be good to and through the area affected. If there is local obstruction, such as naphthalene deposits, or water-logging, it will be denoted by a sudden and otherwise unaccountable drop in the observed pressure. If the mains are overworked but clear, or badly corroded through a considerable length, the diminution will be a gradual one.

Obstructed mains.—When the indications point to an obstruction in the mains, the length of main from the point where the sudden drop of pressure is noticed to the point where it is known to be normal must be subdivided, and observation of the pressures taken at gradually decreasing intervals, until the stoppage is located. The obstruction may prove to be due either to an accumulation of corrosion or deposit of naphthalene, or waterlogging through subsidence of subsoil and main and accumulation of condensation.

In the first case, the remedy is either to cut the main out altogether, clear it of the corrosion with a strong steel-wire brush (Fig. 441), or with Smith's pipe scraper (Fig. 442), and re-lay the main again after

FIG. 441.—Steel Brush for Clearing Main.

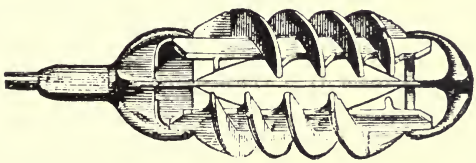


FIG. 442.—Smith's Patent Pipe Scraper.

the clearance; or, if the main is of small diameter, portions of it may be removed at suitable distances apart, and the remainder cleared *in situ* by the wire brush being forced through by successive lengths of $\frac{1}{2}$-inch tube, in much the same way that a chimney is swept.

If the obstruction is found to be a deposit of naphthalene, this may be removed either by cutting holes in the main, through which the main may be "wired," and the naphthalene thus broken down, or it may be dissolved by the introduction of benzol, petroleum spirit, or naphtha into the main. The solvent may be used in the liquid form, in which case, frequently an arch of naphthalene is left unattacked in the upper portion of the main. A much better plan is to spray the solvent, in the form of a fine fog, into the stream of gas. In that event it is carried forward by the gas, and attacking the naphthalene deposit in its passage, gradually dissolves it out.

Should the main prove to be either partially or wholly waterlogged, there is here, again, a choice of remedies. Either the main may be stripped as far as necessary and the proper inclination restored, or the main may be cut and a syphon introduced.

If, however, the fall of pressure in any particular area should prove to be gradual and general, it may be concluded that the mains supplying the area are overworked, and one of the three remedies already mentioned applied. The suggestion (*b*) would, of course, then be modified to include such supplementary distribution mains as might be found desirable.

Local mains overworked.—It may, however, be found that the difficulty is a strictly local one, only one particular street main being affected. If such a main is only supplied at one end, an obvious remedy, where it is possible, is to introduce an auxiliary supply, either at some convenient point in its length or at the other end, from some other adjacent main. Or it may be that the main in question supplies the premises on both sides of the street or roadway. If there is in such a case an approximately equal demand on either side of the main, the difficulty may frequently be best overcome by laying a second main upon the opposite side of the street to the first, and transferring to the new main all the services upon that side, and thus relieving the original main of half its load. This will be cheaper than replacing the latter with a main of greater capacity, and will avoid the necessity for long services crossing the roadway. The service pipes upon that side will thus be shortened, the attendant risks of leakage and cost of maintenance will be correspondingly reduced, and the distribution made much more effective.

If the latter remedy is adopted it must not be considered sufficient to simply connect the service pipes to the new main as they are crossed. The services should, in every case, be cut off at the old main, and the latter plugged. If the portion of the old services crossing the roadway are left and simply plugged where they are cut for connecting to the new main, the disused pipe left in the ground will assuredly be the cause of considerable trouble, annoyance, and expense, through leakage at some future time, and that probably when its very existence has been forgotten. It is a good working rule that pipes which, from any cause, are permanently put out of use should always be disconnected from the main.

Faulty service pipe.—Having thus briefly referred to the more serious causes of shortness of pressure, we may now turn to the simpler and more every-day cases which are continually arising. It may happen that the particular complaint being investigated has its source in similar causes located in the service pipe to those we have been considering in connection with mains—namely, corrosion, naphthalene, or waterlogging.

In the last case, temporary relief may be obtained by blowing the water back to the main, either by mouth, force pump, or exploder. This may be effective for a short time, but the trouble is certain to recur. It will, therefore, be absolutely necessary to find the point where the condensation has collected, and to restore the inclination to the main or syphon, or to insert one of the latter at the place where the "sagging" of the service has taken place.

If the shortness of supply arises from a deposit of corrosion in an otherwise good service pipe, the obstruction may be removed by

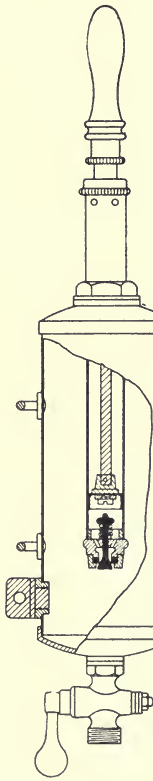


FIG. 443. FIG. 444.

Hutchinson's Light Service Cleanser.

either force pump or exploder. Of the former there are many excellent types in the market.

A small and handy service cleanser, suitable for small consumers' services or lamp services, is that shown in Figs. 443 and 444, manufactured by Messrs Hutchinson Brothers, Limited, of Barnsley. It consists of an outer vessel of strong, solid drawn brass tube, with cast brass ends. One end carries the pump, which consists of a

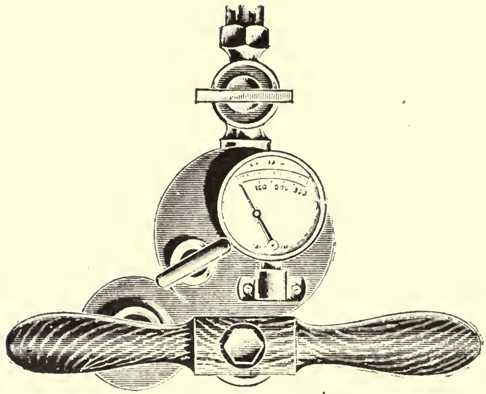


FIG. 445.—Enlarged Plan of Top of "Compound" Service Cleanser showing "Schaffer" Gauge.

strong brass barrel, in which works a cup-leather fitted on a rod attached to a wooden handle. On the end of the pump barrel is fitted an air valve, seated on a rubber ring, and kept down on its seat by a spiral spring. At the other end of the air vessel a gun-metal blow-off cock is fitted, to which is attached a length of flexible tube with which are provided various sizes of connectors to suit different sizes of pipes. A screw plug is provided on the air vessel, so that a charge of naphtha or other spirit may be introduced if required; when this is used the cleanser should be held upright before blowing-off. Two leather straps are fitted, so that the cleanser can either be carried by hand or slung over the shoulder. The whole apparatus weighs only 7 lbs. complete, and is a very strong, reliable, and handy tool for the purpose of clearing stoppages in lamp services or in internal fittings.

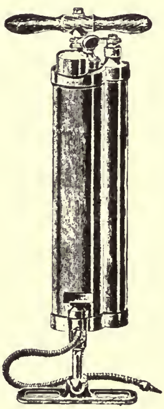


FIG. 446. Hattersley and Davidson's "Compound" Service Cleanser.

One of the best force pumps upon the market, of a more powerful type, suitable for the purpose of service cleansing is the "Compound," manufactured by Messrs Hattersley and Davidson, Limited, of Sheffield, and shown in Figs. 445 and 446. As its name implies, in this pump the cylinders are compound, and the air is thus forced into the receiver with both up and down strokes, the pressure being raised with corresponding quickness. As in the preceding case, the plunger consists of a leather cup, which is easily kept pliable by the occasional use of a few drops of olive oil. The pump is fitted with a "Schaffer" gauge, so that the workman may know exactly what pressure the pump is throwing at any time. A thumb screw fitted into the receiver admits of petroleum spirit being used for clearance of naphthalene stoppages. The foot is fitted with a ball and socket joint to secure the avoidance of strain. The whole apparatus is light and portable, is strong in materials and construction, and is in every way an excellent instrument for the purpose for which it is designed.

Goldsmith's exploder.—The exploder shown in Fig. 447 is a modification of the arrangement patented many years ago by the late Mr Geo. Goldsmith, of Leicester. This consists of a brass boss screwed to fit a ¾-inch service pipe, and a projection screwed for, and fitted with, a loose collar made to pass easily within the same size of tube. The opposite end of the exploder terminates in a gun nipple. In the centre of the boss, and running longitudinally with it, a powder chamber is drilled out, of such size as to hold about 40 grains of coarse gunpowder, such as Curtis and Harvey's Field, B. No. 2.

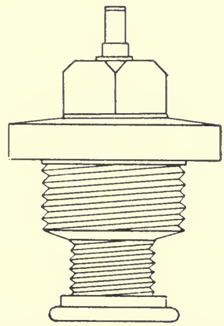


Fig. 447.—Goldsmith's Exploder.

When the instrument is to be used, the loose cap is removed and the powder chamber filled with gunpowder. A diaphragm of thin tissue paper is then stretched across the open end to prevent the powder falling out, and the collar screwed down over the edges of the paper. The collar is, of course, fitted loosely enough to screw down without tearing the paper. The meter having been disconnected, the exploder is screwed on to the main cock by means of a socket or diminisher, and a gun cap placed upon the nipple. The main tap is then turned on, and the charge exploded by the gun cap being smartly struck by a pair of pliers, or small hammer.

The arrangement is an exceedingly simple one, and any intelligent man can work it. In its compactness and lightness it is in great contrast with the cumbersomeness of even the best force pumps, and it it can be used more quickly. One man with an exploder can do as much work as several with the pump, and that, of course, without the slightest leakage. In capable hands it is perfectly safe.

Fig. 448 shows an improved form of exploder, devised by Mr J. H. Brown, late of Nottingham, in which, instead of the loose powder used in the Goldsmith exploder, a separate cartridge containing 40 grains of powder is used. The arrangement will be readily understood from the sections shown, in which A is the brass body, F the cap, K the needle hammer, J the bushing piece which retains K in position, and H is the cartridge containing the charge.

Provision is also made for using solvent in combination with the exploder by means of the extension piece, L (shown in Fig. 449), which

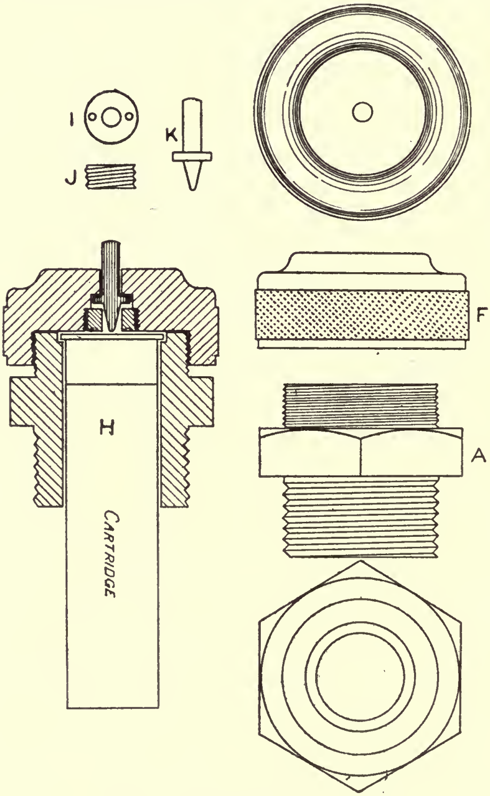


FIG. 448.—Brown's Exploder.

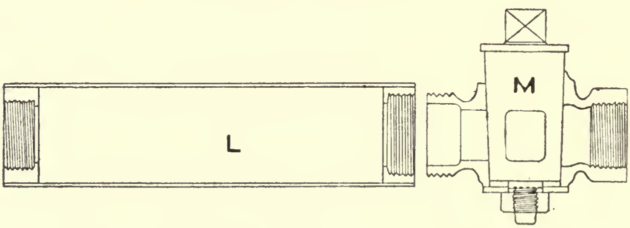


FIG. 449.—Extension Piece for use with Solvent.

at one end is screwed on to the main-cock, M, of the service, and to the other end of which the exploder is attached.

Frozen lamp services.—Times of very severe and continued frost are also times of considerable trouble with service pipes, particularly those connected with the public lighting. As a result of the gas leaving the comparative warmth and quick motion of its subterranean passage for the colder atmosphere and slow flow of the lamp service, rapid condensation takes place, which becomes frozen on the interior of the service pipe, gradually but surely choking it. Thawing by the usual means of hot water, or fire, although giving temporary relief, necessarily leaves the pipe more liable to future stoppage. The heat applied liquifies the ice crystals within the pipe, but the moisture does not all pass away into the main. Some of it clings to the rough interior surface of the pipe and becomes frozen again. These re-frozen particles form the nucleus around which other condensation gathers, which, in turn, is frozen, and thus the pipe is gradually but surely choked up again.

One remedy which the author has found of great service in times of prolonged frost is a solution of calcium chloride, which has, of course, a lower freezing point than water. This solution should be of the specific gravity of 1.21 to 1.26, and may be obtained by dissolving 50lbs. of calcium chloride in 6 gallons of water. Each service to be cleared will require from three to four fluid ounces of the solution. This, by lowering the freezing temperature, not only dissolves the ice crystals already formed, but by adhering in some part to the interior of the pipe tends to prevent their re-formation. A service pipe freed in this way will remain clear for a much longer period than by the adoption of any other means known to the author.

Periodical testing of mains.—With a view to lessening the number of complaints, curtailing the leakage account, and maintaining the distributory system in the highest condition of soundness and efficiency, it is customary in many places to thoroughly test, and, if necessary, to overhaul the services and smaller distributing mains at intervals of, say, ten to twelve years or thereabouts, taking different districts each year. Although this may appear on the face of it a rather costly undertaking, the author is convinced that it is an expenditure of a wise character, which is amply justified by the results obtained. It has also the incidental advantage, in connection with small or moderate sized works, of keeping a number of trained men in work during the summer months, who are thus always at hand to attend to any breakdown or other work of an urgent nature.

The method usually adopted for this work is to select comparatively short lengths for each test, say from 100 to 200 yards, depending upon the number of services in the length. If these are few, the length may be proportionately extended. At the supply end of the main, or the most convenient end should the section be supplied at both ends, three holes are drilled about 2 feet apart, the two outer for $\frac{1}{2}$-inch pipe and the centre one of such size as will allow a bag sufficiently large to bag the main off to pass through. To the two outer holes stand-pipes are connected, as shown in Fig. 450, to which flexible tubes may be attached to form the inlet and outlet of the test meter used. The latter is generally of the wet test meter type,

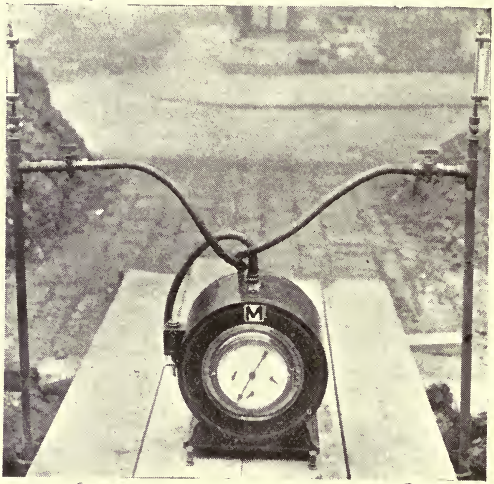


FIG. 450.—Arrangement for Testing Mains.

fitted with circular spirit level, sight box for water-line, and levelling screws, and indicating consumption per hour by observations of one minute.

When these preparations have been carried out the section of main is carefully bagged off at (*a*) the hole between the inlet and outlet

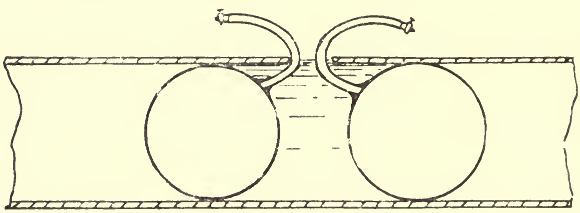


FIG. 451.—Section through main showing double bags.

supply pipes of the meter, and (*b*) at the end of the length of main to be tested. Great care must be exercised in this, or the test will be vitiated. Proof of the perfect tightness of the bags may be obtained by observing whether the pressure in the main can be completely exhausted through a small tap at the top of the outlet stand-pipe, intended for the pressure gauge. If this be so, the bags are effectually shutting the gas off. If not, the gas is getting past one or other, or both the bags. Should much trouble be experienced in this matter, two bags may be inserted, as shown in Fig. 451, and the intervening space filled with water, and kept full by constant attention during the period of the test. If the main is badly corroded, it may be necessary to use a thin liquid cement between the bags in order to obtain a thorough and complete seal. Whilst this preliminary work is in progress, a man should be told off to go to each consumer's

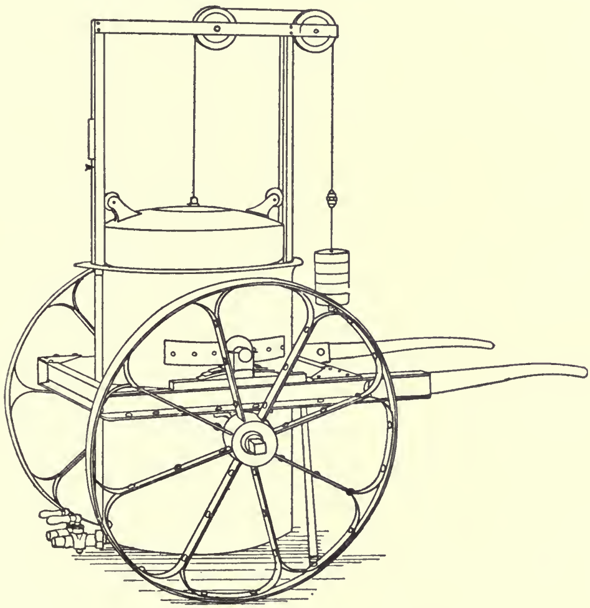


FIG. 452.—Portable Test Holder.

premises to close the service main cock, and in doing so, make sure that the cock is in good condition and shuts the gas completely off. It is, of course, necessary to choose such an hour for the test as will give the least possible amount of inconvenience to the consumers upon the section of main.

The gas inlet tap of the test meter may then be turned on, and the index hand of the meter will be found to move rapidly until the gas previously exhausted from the main has been entirely replaced. When the meter has settled down the tests may commence. The observations should be not less than five, generally with one minute interval between each, or, if preferred, a continuous test of ten minutes' duration may be taken. If, then, it be found that the large pointer has moved round the dial ten times in ten minutes, the wastage on the main tested will be 1 cubic foot per hour, and proportionately for any other number of revolutions.

Another method of testing mains which is used largely in France is by means of a portable test holder such as shown in Fig. 452. The advantage of such an arrangement over a test meter is that the pressure is completely under control, may be varied to any desired extent within certain limits, and a series of tests for comparative purposes may be made at a uniform pressure.

The hydraulic isolator used for isolating the section of main under

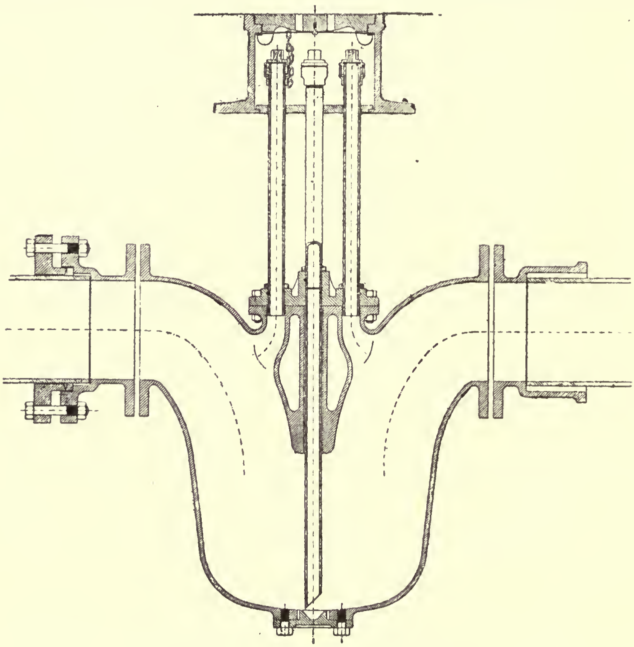


FIG. 453.—Hydraulic Isolator.

test is shown in Fig. 453, and does not vary in essentials from similar English apparatus, except that in the French type the isolator web and the connections to the main are curved to facilitate the flow of gas when the instrument is not being used for testing purposes. The centre tube of the three is used for charging the isolator with water, and for pumping the same free again after the test is concluded. Of the two outer tubes one is used to fill the unweighted holder at the ordinary pressure of the mains, previous to the tests, while the other is connected to the outlet of the holder, and conveys gas to the main tested. The three tubes are surmounted at the street level with a syphon cover, so that tests may be made at any time without disturbance of the roadway. The method of making the test is very similar to that with the test meter previously described.

Results of tests.—The question has frequently been asked, what amount of wastage may legitimately be looked for in a sound system of mains, and some very extravagant estimates have from time to time been given. It seems very difficult to understand why a comparatively short length of main, such as 200 yards, with a fair proportion of services attached, should not, when new, prove bottle-tight over a ten-minutes' test. The author has frequently found that in a test of that duration there has been absolutely no movement of the index hand of a test meter indicating hundredths of a cubic foot. On the other hand, leakage has been found going on at the rate of 40 cubic feet per hour and upwards, in lengths of from 100 to 200 yards of main. In relatively long lengths of mains even, it has been found possible to obtain very good results. In a test taken in a country district, where the services were few, a length of nearly 3000 yards of mains was under observation. The length was made up of

1816 yards	of	6-inch	main,
732	,,	4	,,
402	,,	3	,,

and at a pressure of 4.2 inches the wastage did not exceed $\frac{1}{40}$ cubic foot per hour over an extended test of twenty minutes' duration. In another recent case, 300 yards of 3-inch cast-iron main, newly laid, tested out at $\frac{1}{600}$ cubic foot per hour at 4 inches pressure.

Thorp's diagrammatic meter.—In this connection the novel gas consumption and leakage recorder invented by Mr T. Thorp may be very usefully employed. It is shown in Fig. 454, and consists of an outer iron case, somewhat similar in construction to that of the rotary meter (Fig. 262, p. 297), and an internal conical tube, T, in which the circular disc, H, is free to move in a vertical direction. To the disc is attached a vertical rod, V, which, at its upper end, carries the pen, E, which records upon the revolving drum paper the extent of rise and fall of the disc, and, consequently, the quantity of gas passing through. The paper upon the drum is calibrated to the special specific gravity of the gas with which it is being used. The working parts may all be removed without disturbing the case.

This diagrammatic meter may be used in two ways. It may be used upon the outlet of the station governors to give a continuous record of the gas passing into the distributing system. The diagram would then show, at any minute of the day, the rate of flow per hour. From observation of the chart the man in charge would see at once whether the draught varied from the normal. If it was much larger than usual, without any apparent sufficient reason, he would conclude that the cause was to be found in a broken main or mains.

The chart shown in Fig. 455 shows a continuous twenty-four hours' record taken in this way at Newcastle-under-Lyme. It will be observed that from 10 to 11 a.m. the quantity of gas passing varied from 500 to 550 cubic feet per hour. From 11 to 12 a.m., it rose to 600 to 620 cubic feet per hour. Between 2 and 3 p.m. the record shows two sharp rises in the consumption, in the first case from

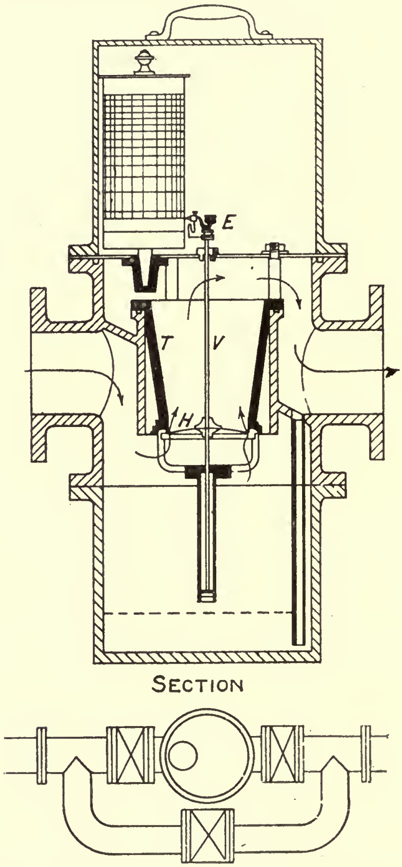


FIG. 454.—Thorp's Diagrammatic Meter.

500 cubic feet to 750 cubic per hour, and in the second case from 600 cubic feet to 1000 cubic feet per hour. At 5.45 p.m. a very considerable rise sets in, until, at 7.15 p.m., the consumption has reached its maximum of 4800 cubic feet per hour. From 9 p.m. a gradual decrease commences, until at midnight the outflow is shown to be 1400 cubic feet per hour.

If, now, any serious escape due to a broken main occurs, the diagram would at once show it by the abnormal record, and the engineer would be able, immediately, to take steps to discover and remedy the fault.

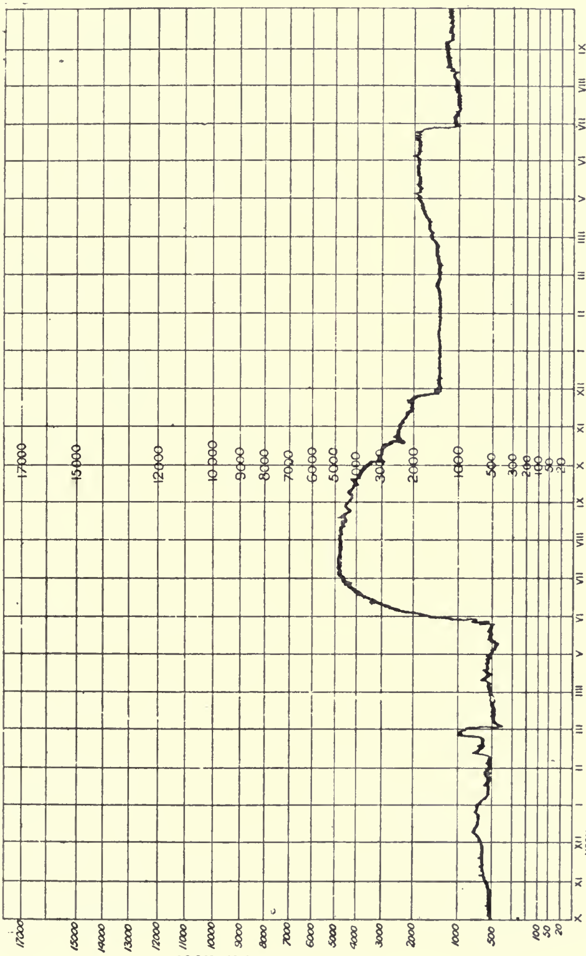


Fig. 455.—Record taken on Thorp's Diagrammatic Meter.

Then, for district purposes, the diagrammatic meter enables the engineer to sectionalize his mains and keep them under periodical observation. He will be able to see not only what quantity of gas passes any defined spot during the twenty-four hours, but also how the draught varies during the day from hour to hour. The advantage of this from the point of view of efficient distribution is sufficiently obvious.

When, therefore, an engineer obtains a record showing an increase over that naturally expected, and finds that such increase has been continuous throughout the day and night, it may be inferred that it is in consequence of leakage, seeing that consumers, speaking generally, do not use gas through the night and day. On the other hand, if he finds a large increase in the amount passing into the district between certain hours and that then the quantity returns to the normal, he at once knows that the increase is due to increasing consumption. In addition, he knows the amount taken per hour and the times at which it is taken, and can therefore adjust the pressures in the district to a nicety.

In the event of a number of these instruments being fixed in any distributing system for the purpose of taking periodical observations, the outer cases may be obtained and fixed, and one or two only of the internal working parts. When it is desired to make an observation, the latter can be dropped into position, and removed again when the test has been completed. When not being used for diagrammatic purposes, the case would act as an ordinary street syphon.

CHAPTER XXVI

GAS AS AN AID TO VENTILATION

One of the disadvantages frequently urged against a system of lighting by gas is the amount of heat and CO_2 given off. This, it is argued, makes a room stuffy and uncomfortable, and induces headache, lassitude, and a general sense of discomfort. Not only is much made of the undue heating and so-called poisoning of the air of the apartment, but the grave disadvantage of having the oxygen of the air in the room used up to support the combustion of gas, which might otherwise have been available for the vital human functions, has also been insisted upon, both in season and out of season. The aim of much of this criticism has, of course, been directed towards emphasizing the advantages of electric light, as a saner, more hygienic, and less polluting source of light for general purposes.

Gas *v.* electricity.—It may not, therefore, be amiss to examine this question as briefly as possible. Considerations of space preclude any detailed discussion, but enough may be said to satisfy any unprejudiced person that, so far from gas being deleterious, it is, when rightly considered and properly applied, of the greatest assistance in removing vitiated air and promoting the efficient ventilation of any room in which it may be used. The truth of this has lately been confirmed in a most practical way by the highest authorities on health subjects in the country. The use of gas was reverted to in 1910 for the purpose of lighting and heating the offices, demonstration and exhibition rooms at the headquarters of the Society of Medical Officers of Health, in Russell Square, London. The Society originally used gas. They discarded it for the assumed superiority of electric light. After experience with both carbon and metallic filament lamps, they have now gone back again to the use of gas. When we consider all that is involved in such a reversion, and the weight and authority of the body concerned in it, it surely constitutes one of the most remarkable testimonies to the advantages of the use of gas which has ever been given. At a meeting of the Society, subsequent to the changes having been made, the following remarkable testimony was given by Dr Reginald Dudfield, the chairman of the committee which had supervised the new scheme. He said that "no member who had experience of their meeting rooms under the old conditions could deny the improvement that had taken place since gas had been substituted for the electric light and the new system of heating and ventilation had been installed."

It is a matter of common knowledge that in rooms and halls which are electrically lighted, unless special ventilating arrangements have been installed, very great trouble is experienced with down-draughts. Many concrete instances of this might be given. Let one suffice. A church in Leeds, very well known to the author, is electrically lighted. The nave is ventilated by means of coronas fixed under ventilating shafts in the roof, which, by the way, consume as much gas as would go a long way towards efficiently lighting it. But in the transept and choir, where no such provision is made, the down-draughts are so cutting as to create the greatest discomfort to all those subjected to them. To prevent these draughts, probably similar arrangements to those in the nave will have to be extended to the transept and choir. The total quantity of gas so consumed would, if used in modern appliances for lighting, be almost enough for the illumination of the church, its action as a ventilating agent would not be diminished, and the electric lighting bill would be saved.

A few moments' consideration will enable us to see why, in such cases, these down-draughts must always be expected. Elementary physiology teaches us that an average adult, breathing calmly in a sitting position, breathes about 13 to 15 times per minute. At each inspiration about 30 cubic inches of air are taken into the lungs. At each expiration the same, or a slightly smaller volume—allowing for the increase of temperature—is expelled from the lungs, at a temperature of 98° to 100° Fahr. This expired air contains CO_2 in the proportion of 47 parts in 1000. In addition to this, heat and CO_2 are also given off from the skin. It has been estimated that an adult gives off 340 B.Th.U. of heat, 0.8 cubic foot of CO_2 and 700 grains of water per hour. These exhalations, being warmer than the surrounding atmosphere, rise to the higher portions of the apartment. If there they are brought into contact with cold walls, ceilings, cornices, and windows, a cooling process is set up. The cooled gases are then displaced by the upward current continually proceeding, and fall, more or less rapidly, in proportion to the extent of the condensation, creating the draught which is the cause of the discomfort complained of. This action is, of course, accelerated by the greater specific gravity of the cooled CO_2, and by the cooling process which goes on through contact with colder walls and windows during the descent. It is obvious that the velocity of these currents will vary very considerably, according to the number of people present and the degree to which the cooling process may be carried in the upper portions of the apartment.

If, now, we proceed to inquire what takes place when, instead of the comparatively non-heating electric light, gas is consumed in the room for lighting purposes, we shall find that the point which has been urged against gas, namely, the heat given off during combustion, is in reality a boon and advantage, from the point of view of ventilation.

When gas is properly burned, and complete combustion is attained, carbon dioxide and aqueous vapour are given off. The combustion of 10 cubic feet of 16-candle coal gas would give, approximately, 5 to 6 cubic feet of CO_2 and 13 to 14 cubic feet of water vapour. These products of combustion, being evolved at a high temperature, set up an ascending current of air. General Morin found that one cubic foot of gas in combustion discharges 1000 cubic feet of air. This is confirmed by Mr J. H. Brearley, who has shown that a bijou burner, when burning under a tube and at a distance of 4 feet below it, is capable of setting up an air current with a flow of 1980 cubic feet per hour. If the distance of burner from tube be diminished to 2 feet, then the same burner will induce an air current of 3060 cubic feet per hour. These hot currents heat the upper regions of air in the apartment, together with the walls, windows and ceilings, which were the cooling agents previously. The result is, naturally, that the risen air is prevented from cooling down again before it can pass from the apartment. Not only so, but dry air has a comparatively low specific heat, and very quickly parts with heat to the cooler walls of the room. Therefore, if the ascending currents of air were dry, the rapid cooling of them by the windows, walls, etc., would tend to set up a circulating current of air which would be most uncomfortable. But steam has a much higher specific heat, and therefore retains heat longer, and when brought into contact with cooler bodies, heats them to a correspondingly higher degree. The continual reinforcement of the cooling air at the ceiling by the vapour-laden ascending currents maintains the temperature, and keeps the air in a state of continual but gentle motion.

It is important for us to remember that, however we may try to prevent draughts, no room is intended to be anything like air-tight. They would be woful failures if they were. There are innumerable ill-fitting doors and windows, cracks and crannies in all directions, porous ceilings, and a thousand and one ways in which these heated gases escape from any room. This process is going on to a much greater extent than would at first sight appear possible.

Diffusive action.—In a very interesting experiment described by Professor Vivian B. Lewes, in the course of his lecture before the Gas Institute in 1893, it was found that no less than nine-tenths of the products of combustion are removed from an ordinary apartment by diffusion, without any special appliances. Again, in his lecture before the Institution of Gas Engineers in 1907, in speaking of this process, Professor Lewes says: "But here comes into play the process of diffusion—a process by which gases, instead of arranging themselves like other forms of matter, according to their weight, undergo a mingling or diffusion, the rate of which is dependent upon their weight; a light gas mixing rapidly with others, while a heavy one diffuses more slowly. It is found that, once mingled, the gases remain in perfect admixture, so that in the present case the heavy carbon dioxide will not again separate from the air into which it has become diffused.

"This diffusion takes place even more rapidly through porous solids than when gases are left simply in contact with each other. As plaster and bricks, or other building materials of which walls are composed, are full of minute openings or pores, they allow gases to diffuse through with considerable rapidity—the force of diffusion being aided by a second force called capillarity. The result is that diffusion through the ceilings and walls in the upper part of the room provides so rapid an egress for the hot gases that they have not time to mingle with the air in the lower portion of the room, while fresh air is being constantly drawn in through every crack and crevice left by the jerry builder." It has been found that in gas heated apartments the natural ventilation is increased by no less than 38 per cent.

Pettenkofer's experiments.—The value of diffusion of air through walls and the influence of temperature on this diffusion are well illustrated by some experiments of Pettenkofer. When the difference between the inside and outside temperatures was 34° Fahr. (66°-32°) and the doors and windows were shut, an ordinary room in his house of the capacity of 2650 cubic feet, which was built of brick, and furnished with a German stove instead of an open fireplace, had its entire atmosphere changed in one hour. With the same difference of temperature but with the addition of a good fire in the stove, the change rose to 3320 cubic feet per hour. On lessening the difference between the external and internal temperature to 7° Fahr. (71-64) the change of air was reduced to only 780 cubic feet per hour. In these experiments all crevices and openings in doors and windows were pasted up. It is instructive to note the proportional amount of ventilation effected through the walls and by the draught of the stove. In the first experiment the ventilation due to diffusion and difference of temperature equalled 2650 cubic feet of air; that due to the draught of the stove was 670 cubic feet of air.

Mr Brearley's Longwood tests.—In the absence of special ventilating devices, in the case of an electrically lighted room the carbon dioxide and organic exhalations given off from the lungs and skin of persons occupying it are diffused more generally throughout the room, rendering the air much more deleterious to health than in the case of a gas lighted apartment. This comes out very clearly in the interesting experiments carried out at the Longwood Liberal Club, the results of which are given in the presidential address to the Manchester District Institution of Gas Engineers, at their meeting in February 1906, by Mr J. H. Brearley of Longwood. He says:—

"We obtained permission to test the atmosphere of the reading room, which has a cubical capacity of 1732 feet, with gas and electricity respectively. The door of the reading room was closed at seven o'clock each evening, and ten persons remained in the room for two hours. Samples of the air were taken at seven and nine respectively; in each case five feet above the floor level. These were tested by the Wanklyn bottle method for carbonic acid, using barium hydrate as an absorbent, titrating with oxalic acid, and with phenolphthaleine as indicator. On each side of the room a thermometer was fixed, and the increase of temperature noted. The heating apparatus was let down at the same hour on each of the two days upon which the tests were taken. The quantity of vitiated air expelled per minute by the ten persons would be approximately 5000 cubic inches, of which 4.35 per cent. would be carbonic acid. At the end of the two hours, therefore, if all the carbonic acid remained in the room, there would be 8720 volumes per million, plus, in the case of gas, that produced by combustion. The following are the comparative results obtained:—

	With Gas.	With Electricity.
Average increased temperature	$5\frac{3}{4}°$	$3\frac{3}{4}°$
Increased volume of carbonic acid per million .	1,196	1,543

"It will be observed that in each case the carbonic acid at the end of two hours was less than the theoretical quantity; due, undoubtedly, to the partial ventilation of the door and window crevices, and the ventilators; but the greater induction given to this by gas is clearly demonstrated. It will be recognized that the conditions of these tests were stringent, and the increased quantity of carbonic acid here obtained would never be found in a room under ordinary conditions."

Professor Lewes' tests for carbon dioxide.—These results are confirmed in a striking manner by the experiments made by Professor Lewes, and published in his Institution lecture in 1907, to which reference has already been made. These were as follows:—

Distribution of carbon dioxide in the air of a dwelling room (capacity 2700 cubic feet) with gas and electric incandescent lighting.

GAS LIGHTING.

Two Welsbach "C" burners (on pendant), each consuming 4 cubic feet of gas per hour, and giving 140 candles.

	Carbon Dioxide. Per Cent.	Temperature. Degrees Fahr.
Outside air	0.03	61.0
Between joists	0.06	66.0
Ceiling level	0.44	74.7
Breathing level	0.05	63.0

ELECTRIC LIGHTING.

Three 16 candle-power Incandescent Lamps.

	Carbon Dioxide. Per Cent.	Temperature. Degrees Fahr.
Outside air	0.03	61.0
Between joists	0.04	61.5
Ceiling level	0.09	62.5
Breathing level	0.06	61.7

"Renotoxin."—Up to this point we have been considering the production of heat and CO_2 in the combustion of gas and as exhaled from the human body, on the assumption that however they may vary in quantity they are identical in character. But it is well known that the exhalations from the human organism are highly contaminated with organic substances, poisonous in character, to which Herr Weichardt has given the name of renotoxin. It is now generally recognized that it is these organic substances, which are usually associated with the CO_2 of rooms inhabited by human beings, and not the CO_2 itself, which are so deleterious in character. The eminent German scientist, Pettenkofer, found that pure CO_2 in the proportion of 100 to 10,000 was not injurious to human beings, while one-tenth that amount if derived from human respiration rendered the air unfit for a person to remain in for any length of time. Dr Rideal mentions the fact that many persons have lived in rooms containing as much as 50 volumes of CO_2 per 10,000 of air without any apparent injurious effects; whilst Dr Angus Smith shut himself up in a room until the proportion of CO_2 rose to 229 volumes in 10,000, without apparently suffering any ill effects. Experiments have also been made upon animals in respired air which had been deprived of its CO_2. These quickly sickened and died, clearly proving that the poisonous matter was in the organic substance and not in the CO_2.

The whole battle of the comparative pollution of the air we breathe has very improperly revolved around the question of the amount of CO_2 present. It is easy to see how this has been brought about. It has been found that the organic substances previously referred to are usually present in proportion to the quantity of CO_2. The amount of the latter is comparatively easy to determine, and so the vitiation of the air has been expressed in terms of CO_2. Then by an easy transition of thought the deleterious effects of polluted air have been ascribed to CO_2 itself and not to its accompaniment, of which it is the comparatively inocuous index.

Cremating effect of gas flame.—In addition to the organic impurities referred to, the air of any living room contains dust particles, microbes, and disease germs in countless multitude and variety. It is in relation to the whole of these that again we find the combustion of gas performing a beneficial function. As the burning gas sets the air in motion, a continual current of air is brought either into actual contact with, or within the influence of, the burning gas, and so is subjected to an amount of heat which cremates organic impurities, incinerates dust particles, and with them the microbes with which they are associated, and so the burning gas tends to sterilize at the same time as it heats up the air of an apartment. The blackening of ceilings over gas burners, which is so often complained about, is one evidence of this incinerating effect. The discoloration is simply caused by a deposit of dust which has passed through this crematorium and been filtered out, whilst the gaseous accompaniments have passed on through the plaster of the ceiling by diffusion.

We have now seen that the combustion of gas is accompanied by the evolution of considerable quantities of CO_2, heat, and water vapour. Also that the CO_2 is not so deleterious as it has commonly been supposed to be, the heat and water vapour actually assist in keeping the air of an apartment pure by promoting the diffusion of heated and contaminated air through the walls and ceiling, by preventing rapid condensation of warm air in large rooms through contact with cold surfaces, and by the cremating action of the gas flame upon the bacilli of the air surrounding it.

Dr Toogood's experiment.—These conclusions are abundantly confirmed by the series of experiments carried out at the Lewisham Infirmary in November 1910, by Dr F. S. Toogood, M.D. Lond., D.P.H., as reported by him in *The Medical Magazine* for February 1911. At the close of his detailed account of the experiments, Dr Toogood sums up the results in the three following general conclusions. He says :—

"These experiments may be regarded as having proved conclusively :

"(1) That in both large and small apartments which have normal means of ventilation, gas consumed in modern incandescent burners can be used for lighting without any detriment to health, being found, in fact, to assist ventilation by the increased circulation of the air.

"(2) That a gas fire, properly constructed and fixed, not only does not vitiate the air, but is a valuable adjunct to the ventilation of the room. Its advantages in the sick room—in respect of its reliability, avoidance of noise, freedom from dust-producing propensities, and saving of both work and anxiety—are obvious to every professional man and woman.

"(3) That in large rooms, adequately ventilated, flueless gas stoves can be used for heating without any hygienic disadvantages, the heated products of combustion (mainly CO_2 and water vapour) ascending quickly above breathing level. This method of heating—by radiation and convection from flueless gas stoves—is economical, but proper ventilation of the buildings in which it is adopted is essential, which, of course, is also the case whatever means of heating be adopted. A ward or other public building in which gas radiators cannot be used with advantage is improperly ventilated."

The natural ventilation which is always proceeding in a gas-lighted room should always be reinforced by the provision of suitable arrangements for abstracting the heated air from the upper portions of the room. The simplest and most inexpensive method of doing this is by means of the mica valve chimney-breast ventilator, such as shown in Fig. 456, which, as its name suggests, discharges into the chimney stack ; or direct into the outer air by means of an aluminium outlet ventilator, with valve sensitively balanced to resist, if necessary, any possible tendency to inflow rather than outflow (see Fig. 457).

Ceiling outlets.—A much better plan, however, is to take off the vitiated air from a room by means of an outlet in the ceiling and a

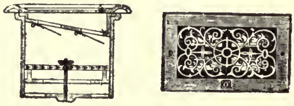


FIG. 456.—Mica Valve Ventilating Trap.

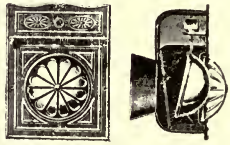


FIG. 457.—Aluminium Outlet Ventilator.

conduit for the heated gases to some suitable discharge. Fig. 458 shows this system applied to a schoolroom, in which the heated exhalations from lungs and skin of the pupils is seen rising through

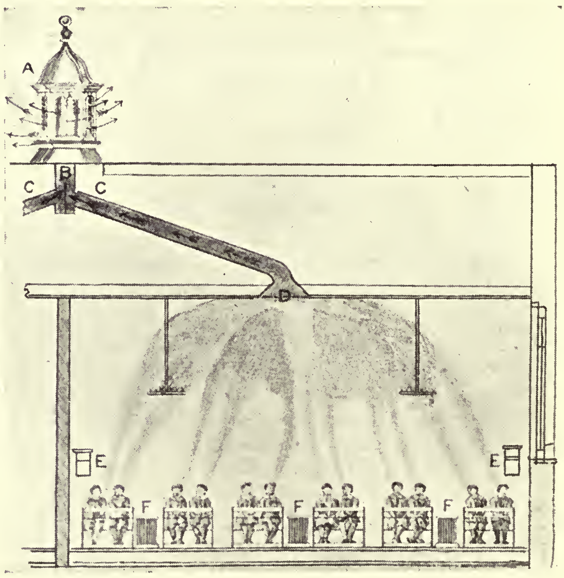


FIG. 458.—Classroom Ventilator.

the foul air exit, D. This is fixed in the ceiling close to the wall on the side opposite to the air inlets, EE and FF, the fresh air from which must, therefore, traverse the full width of the schoolroom. The heated gases then pass through the ventilating shaft, C, to the main upcast shaft, B, away to the roof ventilator, A, being assisted in their journey by the upward current set up by the gas flames, which at the same time are used to illuminate the classroom. FF

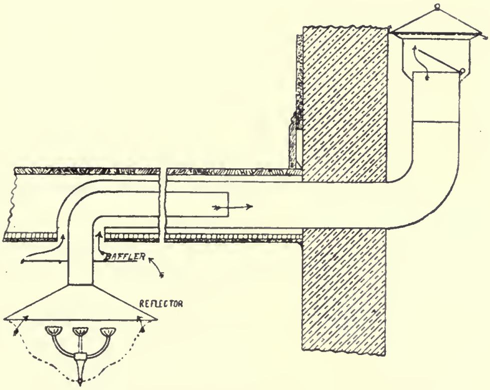


FIG. 459.—Injector Ceiling Exhauster.

are radiating inlets for fresh air, which, both here and at EE, is screened and admitted at low velocity, to secure perfect diffusion. In this case the shafts from several rooms are brought together to a common outlet upon the roof.

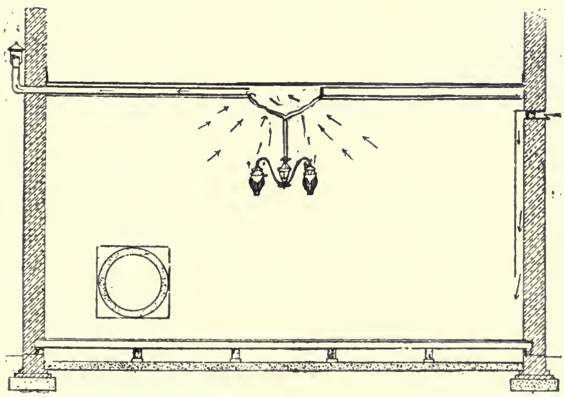


FIG. 460.—Dining Room Ventilated through Centre Flower.

The arrangement shown in Fig. 459 is one of the injector type, discharging direct into the air through the outer wall. The heated products of combustion pass away from the upper portion of the reflector through the bent tube above it. When we remember that

Mr Brearley found that one Kern burner consuming 4 cubic feet of gas per hour is capable, when fixed 2 feet below a suitable tube, of setting up an air current of 5730 cubic feet per hour, nearly equal to the cubical contents of a room 22 feet by 22 feet by 12 feet, we shall realize the great quantity of vitiated air which such an arrangement is capable of directly abstracting. But in addition to the quantity thus directly acted upon, the injector action of the inner tube aspirates a further considerable quantity through the annular space between the inner and outer tubes, the action being prevented from being too direct by the baffle plate shown above the reflector. Professor Lewes has suggested that the flue pipe of a gas fire should be used as an injector to induce a flow of vitiated air into the ordinary chimney stack.

FIG. 461.—Ornamental Ejector Ventilating "Sandringham" Regenerative Gas Lamp.

Another arrangement of a simple type is that shown in Fig. 460, in which the vitiated air is carried off through the centre flower of an ordinary residential room, by an air shaft in the floor space, to the outlet fixed upon the exterior of the outer wall. The great danger with such an arrangement is that the pull of the fire, taking advantage of a sticking or ill-fitting outlet valve, might convert what should be an outflow into an inflow, thus reversing the direction of the current. For this reason it is always better to carry the discharge pipe into a chimney stack with a good up-draught, wherever possible.

The "Sandringham" regenerative gas lamp, shown in Fig. 461, is a further example of the adaptation of the principle of the ejector to the products of combustion rising from the high-power lamp fixed under the shade. These are carried upwards through a tube running through the centre piece, and aspirate heated air through the annular space shown around the ejector in the upper portion of the illustration, both being then carried off by an air shaft to the ventilating outlet. Such an arrangement as this is, of course, applicable only to large rooms; and it is equally obvious that it may be applied to any inverted or other lamp, as may be desired.

The "Nonpareil" ventilating inverted incandescent gas sunburner, shown in Figs. 462 and 463, is one of the latest devices for combining the inverted gas burner with a ventilating arrangement for use in large halls. In the No. 1 size, 28 separate inverted burners are arranged, adjusted to consume 2.8 cubic feet each, at 20-tenths pressure. Both gas and air are warmed up before combustion, thus promoting efficiency. As shown in the sectional elevation, the whole arrangement may be lowered for cleaning and inspection. The control cock may be placed in any convenient position in the hall, and, by means of pilot lights or flash lights, the arrangement is under complete control, and may be immediately switched on or off, as may be desired. The author understands the arrangement has given entire satisfaction in the halls in which it has been installed.

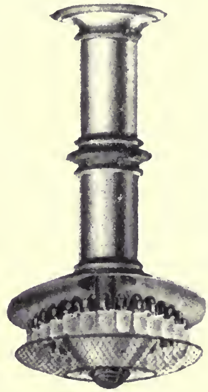


Fig. 462. — "Nonpareil" Ventilating Light: Elevation.

The "Nonpareil" lights have just been adopted for the large hall of the new Teachers' Training College now being erected in Leeds. Fig. 464 shows the detail of the ornamental mouldings and setting designed by the architect, Mr G. W. Atkinson, to whom the author is indebted for the drawings.

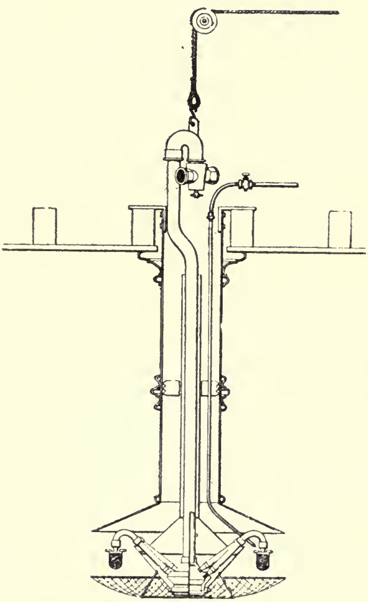


Fig. 463.—"Nonpareil" Ventilating Light: Section.

The heated products of combustion pass upwards through the bell-shaped shafts placed immediately above the burners, and carry with them directly a considerable quantity of the vitiated atmosphere from the hall below. The short shaft also acts as an injector, drawing a further and larger quantity of vitiated air from the apartment through the annular channel provided within the carved moulding. This annular passage, together with the uptake shaft, discharges into the ventilating tube, as shown in Fig. 464. The lighting and ventilation of the hall is accomplished by four of these "Nonpareil" lights.

Another type of ventilating light formed of inverted gas burners is that of Mr Wm. Edgar, of Hammersmith, which he calls the "Colombo" ceiling light. The present chapter opens with a

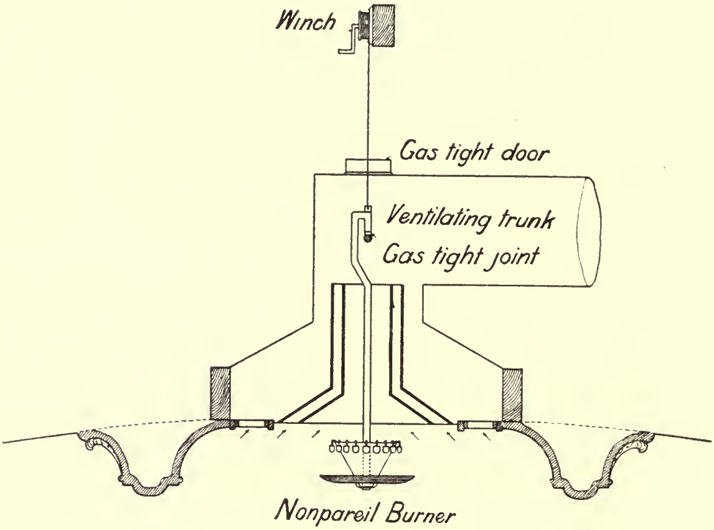


FIG. 464.—Section through setting of "Nonpareil" Lights at Leeds Teachers' Training College.

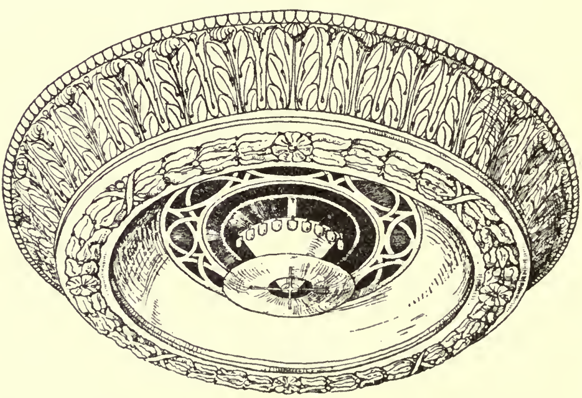


FIG. 465.—Perspective of setting of "Nonpareil" Lights at Leeds Teachers' Training College.

reference to the re-installation of gas at the headquarters of the Society of Medical Officers of Health in Russell Square, London. It is gratifying to all interested in gas distribution to know that the

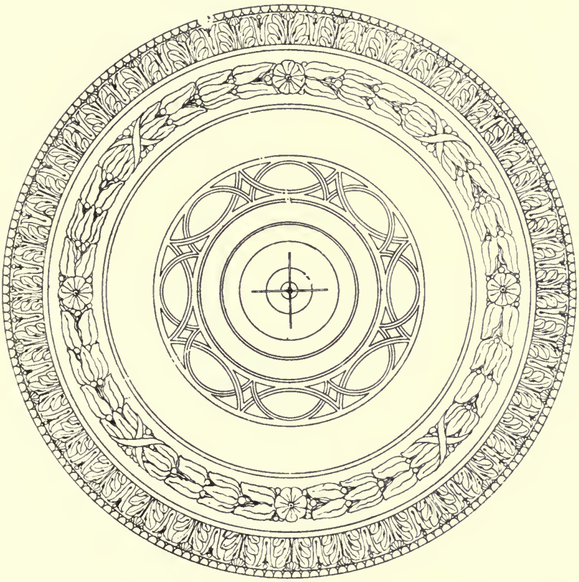


FIG. 466.—"Nonpareil" Lights and Mouldings at Leeds Teachers' Training College, as seen from below.

"Colombo" ceiling light has recently been adopted by another scientific body whose primary concern is hygiene, namely, the Royal Sanitary Institute, for the lighting and ventilation of the library and

FIG. 467.—Side view of Moulding around "Nonpariel" Lights at Leeds Teachers' Training College.

lecture hall of their new premises in Buckingham Palace Road, London.

Fig. 468 shows a sectional and Fig. 469 a general elevation of a five burner "Colombo" light. Those used at the Royal Sanitary Institute consist of clusters of eight large incandescent burners of the angle type, mounted in a circular ceiling rose, 5 feet in diameter, centred with a polished brass and copper fitting. Each burner has its air and gas adjustments, which, for convenience, are brought through the reflector as shown in the sectional elevation. The burners at the Institute have each their independent gas cock and by-pass, while in Fig. 468 the two switches control two and three burners respectively, each being brought to a conveniently placed switch-board. Each lamp is also fitted with a mercury seal to prevent access of air to the pipe during the time the main burners are unlighted.

The lights being directly in the line of sight of persons occupying the gallery in the hall, the lamps are fitted with satin-green opalescent globes, which not only give a very pleasing effect, but conduce to the comfort of the occupants.

The ventilation of the hall is provided for by a series of hot

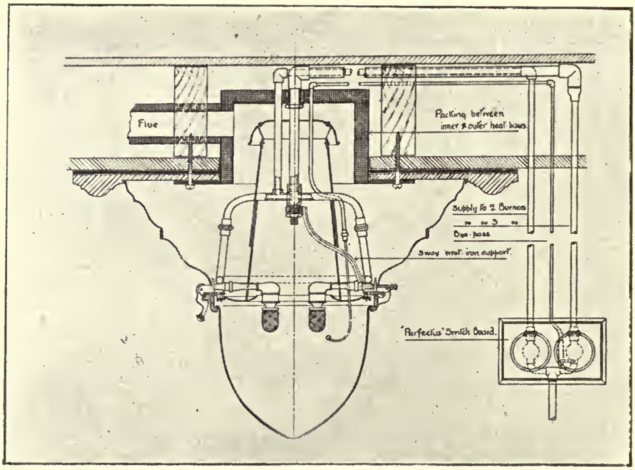


FIG. 468.—Sectional elevation through "Colombo" Lamp.

air shafts carried through the floor, through which the vitiated atmosphere is carried by the induced draught set up by the heated products of combustion from the burners and passed away to the outer air. The lamp discharges its heated gases into a heat box formed of a double casing, the annular space between the inner and outer boxes being filled in with non-conducting material, with which also the flue shaft is lagged.

Professor Frankland's experiments.—Reference may here be made to the experiment of Professor Percy Frankland at the Birmingham Art Gallery in 1902 as showing the practical utility of the ventilating ceiling lights employed there. Briefly summarized his results were :—

(*a*) In the absence of any artificial illumination there was a slight increase in the percentage of carbonic acid in the air of the Gallery during the day.

(*b*) With arc lamp illumination, the increase in the percentage of carbonic acid was distinctly more marked.

(*c*) With incandescent gas illumination, instead of there being any increase, there was a distinct diminution in the percentage of carbonic acid in the air. Professor Frankland reported :—" The explanation of this diminution is not far to seek ; it being obviously due to the more efficient ventilation of the Gallery, which is caused by the great draught of heated air through the shafts, which are placed above the incandescent burners. The circumstance that the percentage of carbonic acid actually diminishes during the use of the incandescent gas burners conclusively proves that the products of combustion, from which damage to the pictures might be apprehended, are com-

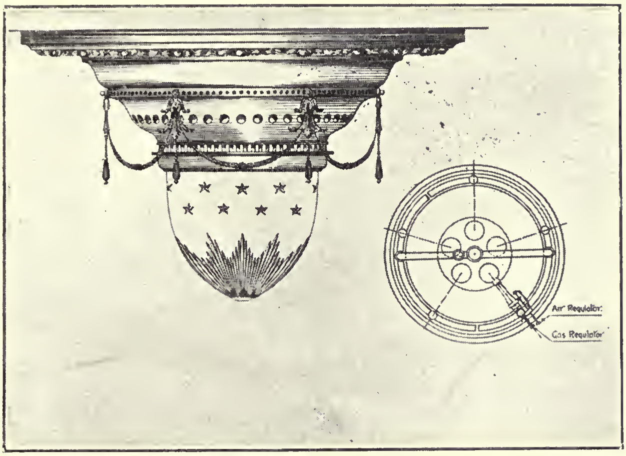


FIG. 469.—General elevation of "Colombo" Lamp.

pletely carried away by the ventilation which is so much promoted by these burners."

Fresh air inlets.—In the rooms of any ordinary residence the necessary inflow of fresh air is maintained through and around doors, windows, and other natural air inlets, which generally abound in houses of all classes. The extent to which this process is going on will be apparent at once from the fact that every adult needs about 3000 cubic feet of fresh air per hour, whilst an ordinary open coal fire, with a chimney of good draught, requires approximately 2000 cubic feet of air per hour. The up-draught of 2-tenths of an inch water pressure in a chimney gives a velocity of 6 feet per second, and it is this pull, previously referred to, which often converts what are intended for ventilation ports into air inlets.

In those cases where these large quantities of air cannot be obtained through open doors, window and door chinks, and other similar inlets, without the discomfort of cutting draughts, direct provision must, of course, be made for a sufficient inflow of pure air by means of tobin tubes, or direct air inlets, as shown at E and F, in Fig. 458, or by some such provision as is shown in Fig. 460.

Fresh air necessary to production of maximum lighting effect.—There is one other incidental aspect of this question of effective ventilation which may be briefly alluded to. It is of the utmost importance for the purpose of obtaining the greatest possible illuminating power from the gas consumed in any apartment, that an adequate supply of fresh air should be available. This is absolutely necessary if the maximum lighting effect is to be secured. Professor Lewes found, as a result of experiment, and stated in the lecture to which reference has already been made, that a vitiated atmosphere may depreciate the amount of light obtained by no less than 12 per cent.

In summing up the various aspects of the relation of the combustion of gas to the purity of the air of apartments, we may fairly claim that, although such combustion is attended with the production of CO_2 and heat,—

(1) The CO_2 given off, in the quantities likely to be found in an occupied room, is not deleterious to health.

(2) That the real danger to health is not in the CO_2 as such, but in the organic matter with which it is always associated in respired air.

(3) That the heat generated may be a most valuable instrument in ventilation, if properly applied.

(4) That the ventilating action of a gas flame is so great as to compensate for the production of heat.

(5) That this ventilating action may be perfected by the provision of inexpensive yet effective auxiliary apparatus.

(6) That by this means the air of a room may be kept in gentle motion towards the outlets without cutting draughts or other inconvenience.

(7) That the heat generated by the combustion of coal gas for lighting purposes acts as a positive purifying agent on the air of rooms, owing to the cremation of bacteria.

This chapter may be fittingly closed with two short quotations, both from unimpeachable authorities. The first is from the paper contributed to the *Journal of the Royal Sanitary Institute* in March 1908, by Dr Rideal, which is as follows :—"The products, viz., heat, CO_2, and moisture are derived more from the inmates than the illuminant. Thus a room of moderate size can be efficiently lighted by gas without the amount of these three products being sensibly affected. . . . The medical observations, as well as the chemical and physical data obtained, demonstrate that the choice between gas and electric light does not depend on hygienic considerations."

The second is from Vol. III. of the most up-to-date and exhaustive work on building construction, namely, *Modern Buildings, their Planning, Construction, and Equipment*, by Mr G. A. T. Middleton, A.R.I.B.A., vice-president of the Society of Architects, who may obviously be taken as an impartial witness. He says, on p. 160, in a chapter devoted to "A comparison between Gas and Electric light": "It is somewhat a matter of opinion as to whether either illuminant has any deleterious effect, providing there be an ample supply of oxygen for the gas as well as for human consumption, together with an outlet for the products of combustion." In view of the unfair criticisms often levelled at gas, these testimonies deserve the widest publicity.

CHAPTER XXVII

PUBLIC LIGHTING—LOW-PRESSURE SYSTEM

What is required.—In approaching the problem of the lighting of our public thoroughfares, it is well to form a clear conception of exactly what is required. In the first place, the fullest recognition must be made of the fact that it is the roadway and footpaths which need lighting. We should avoid diffusing the light in mid-air, or upon the upper storeys of surrounding premises, and expend it in the practical work of illuminating the road surface. The lights, therefore, should be placed high enough to avoid inconvenience and distress to pedestrians through the glare from the source of illumination whilst low enough to give a maximum of lighting effect, per unit of cost, upon the roadway.

What constitutes satisfactory street lighting.—Dr Drehschmidt has pointed out that " satisfactory street illumination depends less upon the light which falls upon the ground than on that which impinges upon an imaginary vertical surface crossing the road obliquely. When a person studies a plan, he intentionally places himself in such a position that the object receives the best illumination ; but in walking or driving along a street he is chiefly dependent on the light falling on those parts of pedestrians or vehicles that are turned towards him."

The maximum lighting effect of an upright incandescent gas burner is obtained along, or within a small angle of, a horizontal line drawn through the centre of the source of illumination, and the lighting effect diminishes as the angle from the horizontal, in both directions, becomes less acute. But we cannot afford to have any of the light dissipated by its passing away into the upper air. It is required by the road users.

In the second place, the road surface must be evenly illuminated. In this connection, the alternation of restricted areas of brilliant illumination with patches of deep shadow is an abomination. Such conditions are dangerous for traffic, dazzling for pedestrians, and altogether to be avoided. They are wasteful, too. It is only the light rays actually received by the eyes that are effective. But immediately a person is brought within range of a light of excessive brilliance, the eye adapts itself to the conditions, and, by a contraction of the iris, practically rejects the superfluous light rays. For the convenience and comfort of the users of the roadway, therefore, the lighting effect must approximate as nearly as possible to daylight conditions; it must be as uniform as the circumstances of artificial illumination will allow.

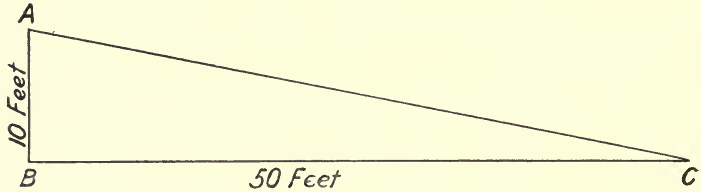
The third requirement of good public lighting is that it should be of a soft, grateful, and diffusive character. The latter quality is especially necessary during the periods of mist and fog, so common in this country during certain periods of the year. At such times gas is acknowledged to have pre-eminence in penetrative power as compared with the electric arc lamp, inasmuch as that power decreases as the higher vibrations of the spectra are approached. It is generally admitted that the flame arc lamps are superior in power of penetration, under adverse conditions, to the old arc lamps, but both alike fall far behind the incandescent gas lamp in this respect. In addition to this inherent disability, the electric arc lamps are necessarily placed so high, to avoid dazzling the road users, that in time of fog the disadvantage of the less diffusive power is increased by reason of the distance of the lamp above the roadway.

The problem of street lighting, therefore, resolves itself into the provision of a suitable number of lights, at such an elevation, at such distances apart, and of such a quality and intensity, that the roadway and footpaths shall be evenly and uniformly illuminated, with a soft and grateful light of great diffusive power.

It has been pointed out how splendidly gas meets these requirements. That was true in the days of the now obsolete flat-flame burner. It is still more true of incandescent gas lighting.

The question naturally at once arises what should be accepted as the standard of illumination to adopt. Except in the case of very out-of-the-way back streets, the minimum lighting effect at the point midway between successive lamps should be such that the print of this book may be easily read by any one with ordinarily good eyesight. It is possible for the author to read such print at a distance of 12 feet from a candle of six to the pound of the usual kind provided for photometrical purposes. On that basis, therefore, the lighting effect midway between two successive lamps would be equal to 0.007 foot-candle. This should, therefore, be the minimum light supplied, and the lamps should be placed sufficiently close together to afford this degree of lighting effect. In busy thoroughfares this degree of illumination will have to be increased to approximately 0.6 or 0.7 foot-candles.

The intensity of illumination at any point served by a lamp may be readily calculated if the illuminating power of the lamp and the distance are known. Suppose it is required to find the amount of light received at a point C from a burner placed at A, which is 10 feet above the ground level at B, and that $BC = 50$ feet. We will assume that the light emitted from A along the line A C is equal to 100 candles.



Then $\frac{I}{D^2} = x$, where

I = the light emitted along the line A C.
D = the distance along the line A C in feet.
x = the illumination received at the point C.

The first point is to determine the distance A C, as follows:—

$$AB^2 + BC^2 = AC^2$$

then $$AC^2 = 10^2 + 50^2 = 2600$$

and $\frac{100}{2600} = 0.0384$ foot-candle = light received at C from A under the conditions specified.

It is obvious that if C were a point midway between two lamps, each of which conformed to the preceding conditions, the result 0.0384 would need multiplying by 2, as an equal amount of light would be received at that point from each of the lamps.

Uniform illumination.—It follows also, from what has previously been written, that to secure the uniform and sufficient illumination of our roadways it is better to have a large number of lamps of comparatively low illuminating power than a small number of centres of great brilliance. In order to secure the ideal of uniform illumination, three factors must be taken into account:—(1) height of lamp; (2) distance apart of lamps; and (3) angle of maximum intensity from the source of light.

Taking the last factor first, the intensity of the light given being inversely proportional to the square of the distance from the source, it is obvious that if the light source emitted its rays equally at all angles throughout the lower hemisphere, there would be a patch of highest illumination immediately beneath the light, decreasing in brightness very rapidly with each increment of distance. If the lighting is to be uniform a burner must, therefore, be adopted from which the intensity of the rays of light shall be greater in an obliquely downward direction than in the vertical plane. It has been found by experiment that the angle of maximum intensity giving the most even illumination is that of 20° below the horizontal. There is, however, no gas burner made which of itself gives a lighting curve of this character. Reflectors must, therefore, be employed to bring about some approximation to the result desired.

It may be objected, however, that uniformity of illumination is quite unnecessary in street lighting. If the term is to be construed with mathematical exactitude, it must be confessed that the objection is a perfectly legitimate one. No one suggests that a photometrical test taken at each foot of distance from a lamp should show absolutely identical results. That is absurd. To understand the term we must consider present conditions. In many thoroughfares the light at the point of minimum intensity may be only one-fifteenth of that of the maximum. If, therefore, the maximum difference in intensity can be brought down one-fourth to one-sixth that may for all practical purposes be considered uniform.

Height and distance apart of lamps.—With regard to the height and distance apart of lamps, it is obvious that there must be a definite relation between distance and height if uniformity is to be secured. This relation may be thrown into the form of a simple equation. Let

D = Distance apart of the lamps in feet.

H = Height of lamp above ground level in feet, then $\frac{D}{H} = 6$.

This value with high-pressure lamps fixed at 18 feet above ground level would give a distance apart of 36 yards, which would give good uniform lighting, suitable for a busy thoroughfare in a large city. At important street crossings, considerations of public convenience and safety would necessitate higher values of lighting, either by the substitution of higher units or a lessened distance apart. As we recede from the main to the unimportant thoroughfares, the pretence or even aim at uniformity is frankly abandoned. The constant 6 in the above equation may, and frequently is, increased to as high a figure as 12 to 15. Therefore in the ordinary street of, say, 50 feet in width, including the footpaths, where the traffic is small and the lighting has little, if any, assistance from the illumination of the abutting premises, single No. 3 or No. 4 Kern burners are usually placed about 50 yards apart. If these lamps are fixed at a height of 10 feet, the value of the constant in the equation would be raised to 15. In the more important thoroughfares, accommodating a greater amount of traffic, lamps containing a couple of burners in each may be placed at intervals of not more than 30 yards. On the assumption that they are fixed at a height of 10 feet this leaves the value of the relation $\frac{D}{H} = 9$ still below the uniform illumination standard, although considerably higher than in the previous instance.

Wide thoroughfares.—For the widest thoroughfares and open spaces, lights of greater intensity, of course, would have to be provided, and these would probably be placed in the centre of the roadway, and supplemented, where necessary, by additional lamps upon the side walks. Here, obviously, the distances would have to be regulated by the character of the area, and the constant 6 in the above equation may be reduced to 4 or even 3. In each case the object to be aimed at is uniformity of illumination of sufficient intensity. In one of the most brilliantly lighted open spaces the author has seen, the Place de la Concorde in Paris, the lamps vary from 15 to 20 yards apart, and the lighting, as seen from the Quai de la Conference, is very brilliant. In the Rue de la Paix, which has been termed the best lighted street in the world, the lamps are only about 30 feet apart. In some of the principal thoroughfares of Berlin the lamps are only 14 yards apart. In other large Continental towns and cities similar spacing may be observed; the standard of public lighting being considerably higher upon the Continent than in our own country.

Relation of lamp to height and distance.—The height of the lamp will obviously be determined by the candle-power of the unit employed. For a No. 3 or 4 Kern or a No. 4 "Nico" inverted burner the best results would be given when fixed at a height of about 10 feet. From this the height would be increased in accordance with the candle-power of the lamp used, until with a large unit of high-pressure gas an elevation of 20 to 25 feet may be reached.

To sum up, therefore, we find that the height of the lamp will be determined by its intrinsic brilliance, and that it must be placed at a sufficient elevation to avoid glare and visual distress. The character of the lamp must be such that the angle of maximum intensity is about 20° below the horizontal, and that for uniformity of illumination the lamps should be so spaced that the 20° rays from successive lamps may meet at ground level, and that these conditions are met in the equation $\frac{D}{H} = 6$.

These conclusions are fully supported by a table given by Mr Jacques Abady in a paper read before the Institution of Gas Engineers in 1910, on the subject of public lighting. The table refers to the relation of the height to the distance between successive lamps in order that rays emitted at different angles below the horizontal may meet, and is as follows:—

Height of Light.	10° Meeting 10°.	15° Meeting 15°.	15° Meeting 20°.	20° Meeting 20°.
Feet.	Feet.	Feet.	Feet.	Feet.
11	125	82	72	60
12	136	90	78	66
13½	153	101	88	74
15	170	112	98	82
20	227	150	130	110
25	284	187	162	138

It may be at once admitted that the 20° standard is higher than the average practice in this country, but our standards, on the other hand, are considerably below that of the best public lighting in Continental cities.

The lamps should be placed upon alternate sides of the roadway, on what has come to be known as the "hit and miss" principle. Better general illumination is in this way obtained, because the light at the lowest point of illumination from any one lamp is reinforced from opposite sides by the two next lamps. The inconvenience, too, of having all the shadows falling in one direction is effectively avoided.

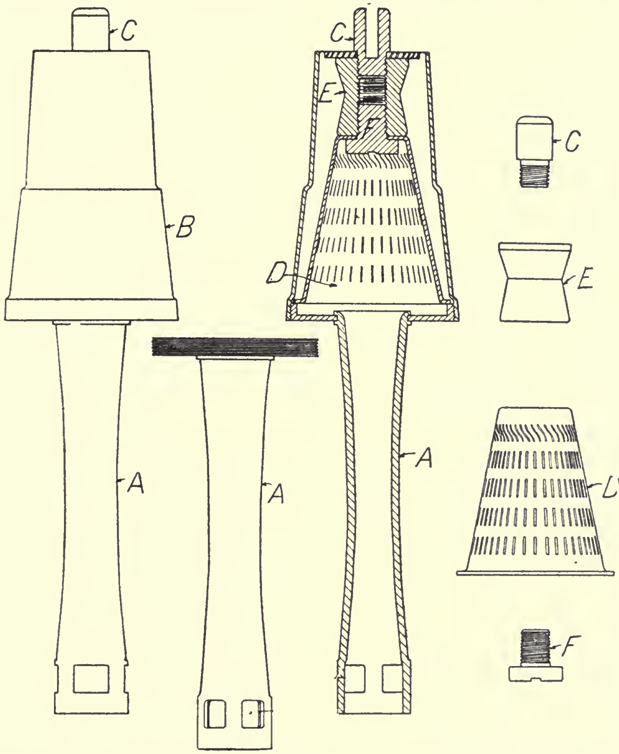


FIG. 470.—Elevation, Section, and Details of Welsbach-Kern Burner.

Incandescent lighting for public lamps.—Incandescent gas lighting for public lamps falls naturally into three classes, namely,—

(*a*) Low pressure lighting ;
(*b*) High-power low-pressure lamps, and
(*c*) High-pressure lighting.

These classes may again be subdivided into those containing (*a*) vertical burners, and (*b*) those fitted with inverted burners. One of the upright burners very generally adopted for use in public lighting is the Welsbach-Kern. The Kern burner, an elevation and section of which are shown in Fig. 470, consists of a bunsen tube, A, of the Venturi type, surmounted by a mixing chamber, B, which contains the perforated cone, D, inserted to ensure a perfect mixture of the air and gas, and the double-cone arrangement, E, which is inserted to accelerate the velocity of flow of the mixture to the point of combustion. The place of the wire gauze in the older form of burner is taken in the Kern burner by a circular metallic disc, in the periphery of which small teeth are cut. These teeth are cut at an angle, as also are the upper perforations in cone, D, and thus impart a rotary motion to the stream of issuing gas and air. C is the mantle rod holder, and F the screw which secures cone, D, in position.

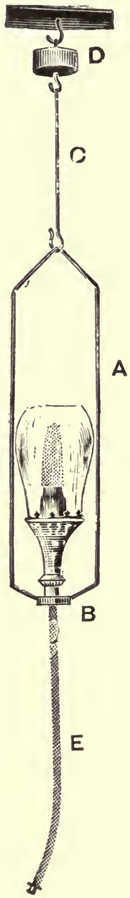


Fig. 471.—One-Light Patent "A.V.I.L." Frame.

The advantages justly claimed for this burner are (*a*) an increased lighting efficiency, as compared with the "C" burner, approaching 50 per cent. This is due in part to the thorough admixture of the gas with the primary air supply secured by the perforated cone, and partly also to the large capacity of the burner head, which acts as a small heating chamber from which the gas flows in a heated condition to the point of combustion. It is well to remember in passing, that the pre-heating of the gaseous mixture in an upright burner tends to increase the velocity of flow. (*b*) Although these burners are made in various sizes, consuming from $\frac{3}{4}$ cubic foot to 4 cubic feet per hour, the lighting effect per cubic foot of gas consumed remains fairly constant. (*c*) No governor is required for use with the burner. Increased pressure, and therefore increased consumption, within the limits met with in ordinary practice, do not impair perfect combustion of the gas. And lastly (*d*) as no chimneys are necessary with the Kern burner, a very fruitful source of annoyance, inconvenience, and expense is eliminated. Against these advantages must, however, be placed the frequent cleaning and particular attention which this burner needs, and also the fact that it is more costly in mantles, owing to the rotary motion of the gas tending to cut the mantle at the level of the burner. The flame, also, being smaller and more intense, tends to concentrate the intensity of the light over a smaller area of the mantle, and thus increases the wear and tear and reduces the life.

Although chimneys are not necessary for the proper working of the Kern burner, it is usual, in the case of street lighting, to shield the mantles with short glass protectors of the straight type, or by means of clear glass bulbs similar to that shown in Fig. 471. In this way, not only is the life of the mantle greatly extended, but a greater lighting efficiency is developed, through the mantle being shielded from the action of air currents. These currents not only impair the effectiveness of the lighting in themselves, but in the dust they deposit upon the mantles are tiny particles of silica, which form infusible silicates, which prevent the mantle emitting the maximum quantity of light of which it is capable.

Anti-vibrators.—For the protection of the mantle against the shaking caused by passing vehicles and the ofttimes heavy traffic of our thoroughfares, which otherwise would have a detrimental effect upon the life of the mantle, it has been found necessary to use an anti-vibrator in the public lamps fitted with upright incandescent burners. This is an apparatus designed to take up in itself the tremors and shocks which otherwise would be communicated to the fragile mantle and speedily destroy it. These take many forms, each having its own particular advantages and disadvantages. Those which allow of lateral movement of burner head and mantle are apt to prove less protective to the mantles than those which allow of a free swing of the whole burner attachment.

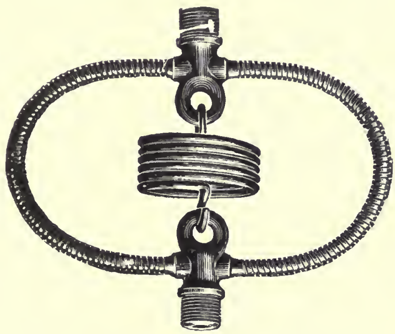


Fig. 472.—" A.V.I.L." Steel Tube Anti-Vibrator.

Amongst the forms of anti-vibrators which have been placed upon the market, the "A.V.I.L." of Messrs Foster and Pullen, Limited, of Bradford, one of which is shown in Fig. 471, may be placed very high. It consists of a light wire frame, A, to the flat base, B, of which the burner is fastened by means of a screwed collar. The frame is suspended by means of a connecting rod, C, to a wire coil spring within the brass sheath, D, the whole being carried by a light rod or plate placed across the top of the lantern. The burner is connected to the rising pipe in the lamp column by means of the flexible tube, E. The whole arrangement is capable of moving very freely in the lantern, is not rigidly fixed in any part, and is found to be very efficient in actual working. A similar arrangement may be adapted to a multiple cluster of Kern or other burners.

Fig. 472 shows a steel tube anti-vibrator manufactured by the same company, designed to carry heavy fittings, and capable of supporting weights up to 50 lbs.

Whilst the rubber connecting tube of the " A.V.I.L." anti-vibrator affords a very flexible and handy attachment between lamp cock and burner, it has the disadvantage of being unable to withstand the chemical action of benzolized gas, and also is easily choked by small deposits of naphthalene or very small quantities of condensation.

Two of the series of incandescent gas burners suitable for street lighting manufactured by Wm. Sugg and Co., Limited, of Westminster are shown in Figs. 473 and 474.

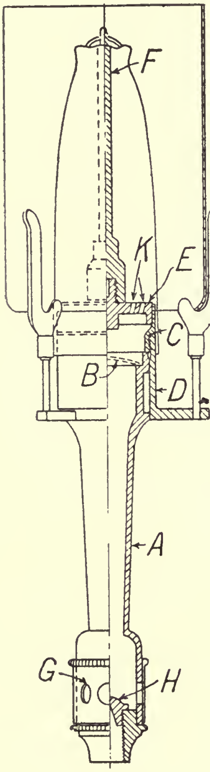


Fig. 473.—Wm. Sugg and Co.'s Low-Pressure Burner.

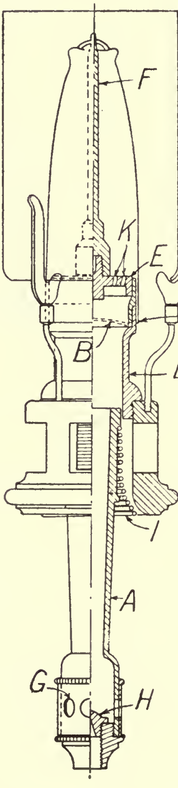


Fig. 474.—Wm. Sugg and Co.'s Low-Pressure Burner, with Anti-Vibrator.

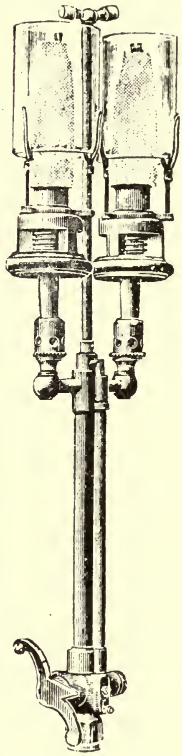


Fig. 475.—Wm. Sugg and Co.'s Two-Light Cluster, with Carpenter's Flash-light.

Fig. 473 shows a section through the ordinary form of burner without anti-vibrator. In this, A is the strong bunsen tube terminating at its upper end in the nickel gauze, B, which is inserted to prevent lighting back. The burner head consists of a sleeve of brass, C, which fits loosely over the tube, A, of the burner, and also carries the gallery support, D. The sleeve, C, is internally threaded to receive the steatite disc, E, which is perforated with two rings of holes, K, and also has a threaded boss in the centre, which forms the base of the mantle rod, F. The mantle is thus assured of a perfectly central and firm support.

The air adjustment is made by means of the sleeve, G, which may be rotated to open or close the air supply holes as required. H is the steatite ejector.

Fig. 474 shows the same burner fitted with the well-known anti-vibrator of this firm. This consists of the spiral spring, I, upon which the burner head, D, rests. The latter, in this arrangement, is made much heavier, to give "ballast" and lower the centre of gravity of the loose upper portion of the burner, which would otherwise be of an unstable character. The whole burner head and weight, with the mantle, as it rests upon the spiral spring, is free to move up and down upon the bunsen tube, A. The spring also gives a limited amount of lateral movement, and thus all shocks are taken up and neutralized, and the burner head kept perfectly steady.

These burners are exceedingly strong and durable, being cast of yellow bronze ; and no stamped parts are used in their construction. The admission holes for the air supply are, therefore, not likely to become distorted or broken at the edges, either by wear and tear, or by accident. The regulating nipple and the top of the burner are constructed of steatite, which is capable of withstanding both the heat generated and the action of the gas without deterioration.

The upper portion of the burner is readily removable with the mantle, for the purposes of either cleaning the lantern or clearing the service. As shown in Fig. 474, the burner is fitted without by-pass, but the 2-light cluster shown in Fig. 475 is fitted with Carpenter's patent single-tube flashlight. The latter is a very ingeniously arranged by-pass, which flashes out into a long flame at the moment of turning on the lamp cock. The one operation of the lamp cock admits gas to the burner and simultaneously an increased supply to the by-pass, which, projecting a jet of flame over the main burner, ignites the gas and is immediately shut down again.

Lighting of Place de la Concorde.—The lighting of the Place de la Concorde, in Paris, has previously been referred to (p. 553), and as this is a very good example of low-pressure incandescent gas lighting it may be further noticed here. The effect obtained can be only faintly appreciated by reference to Fig. 476, which falls far short of doing justice to the splendid lighting effect obtained.

The burner used in these lamps is of the Bandsept type. The body of this burner consists of two concentric tubes, as shown in Fig. 477, the outer of which is capable of a sliding rotary movement over the inner. Both are perforated at intervals for the admission of air to the mixing chamber.

Within the body of the burner the metallic cones, A,B,C, are arranged. The stream of gas from the jet, J, passes up through the

Fig. 476.—Lighting of Place de la Concorde, Paris: View from Quai de la Conference.

centre of these cones, whilst the air supply, admitted through the perforations, is directed by the cones and brought into intimate contact with the stream of gas, with which it passes upward. This process is repeated with each successive cone, until, in the upper portion of the burner, a thoroughly homogeneous mixture of gas and air is obtained. The mixed gases are then conducted through two separate layers of wire gauze, D and E, which still further ensure the perfectly intimate mixture of the component gases as they pass to the point of combustion, and also prevent lighting back.

The lamps in the Place de la Concorde each contains a two-light cluster of these Bandsept burners, each burner consuming 150 litres of gas (= 5.29 cubic feet) per hour, at an average pressure of 60 to 70 mm. head of water (= 2.3 to 2.7 inches). The already splendid illumination of the Place, shown in Fig. 476, has recently been still further increased by the installation of a number of high pressure "Pharos" lamps of 2000 candle power each.

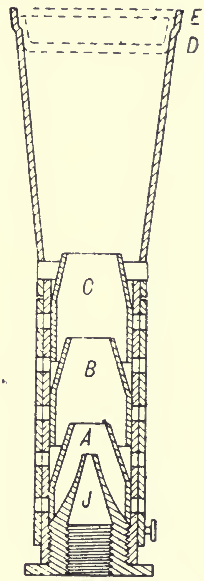


FIG. 477. — Section through the Bandsept Burner.

Qualities of a good lantern.—The introduction and general use of the incandescent mantle for public lighting has emphasized the importance of the weather-proof lantern. Even with the flat-flame burner, it is necessary, for efficient illumination, that the burner should be shielded and screened from air currents. That necessity has become imperative in connection with the newer forms of lighting, for the threefold purpose of protecting the mantle, developing a high illuminating power, and preventing the extinction of by-pass lights.

The lantern to be used must, therefore, not only be strongly made, and preferably of copper, for reasons of durability, but must also be wind and storm-proof. To ensure this, all the doors in the lantern should be practically air-tight. In addition to the foregoing, a good lantern should comply with the following requirements :—

(1) All the products of combustion should be carried away by means of a chimney which rises above the final outlet.

(2) The air inlet passage should be placed sufficiently below the outlet for exit gases as effectually to prevent contamination.

(3) The air inlet should be placed above the reflector, so that the incoming air may be warmed before proceeding to the point of combustion.

(4) The air inlet passages should be sufficiently roomy in

comparison with the exit passage to avoid a high velocity of travel within the lantern.

(5) The reflector should be convex-parabolic in form, and so arranged as to reflect the upward rays to between 5° and 10° below the horizontal.

(6) The metallic vertical angles of the lantern should be small, and reinforced with stiffening rods, to ensure rigidity, and to preserve the mantles, as far as possible, from shock.

(7) In order to avoid the destructive effects of hacking out on re-glazing, most copper lamps are now made of the puttyless type.

(8) In order to obtain the best illuminating effect, no lamp of less than 16 inches square should be used.

It is found that the best illuminating effect is obtained when the centre of the light is about two-thirds to three-fourths of the distance from the bottom up the lantern, depending upon the type of the latter.

The "Windsor" lantern.—Fig. 478 shows a part sectional elevation of the well-known "Windsor" lantern manufactured by Messrs Wm. Sugg and Co., Limited, which, in itself, illustrates many of the improvements introduced into the modern gas lamp. It is perfectly storm-proof. The air for combustion and for the bunsen tube is introduced into the lantern under the spinning, C, and passes down the interior of the lantern and past the edge of the reflector, A, as shown by the arrows, to the burner. On its way the air becomes heated, and so a greater efficiency is obtained from the burner, at the same time cooling the top of the lamp and so increasing its life. The products of combustion pass away through the conical chimney B, and under the canopy, D. The chimney, like the reflector, A, may be made of either porcelain or enamelled iron.

The base of the lantern is fitted with Carpenter's patent frog, which is designed to give greater rigidity and strength than the old type. This consists of a cast-iron socket, E, securely fixed to the lamp column by means of the set screws, H, the upper portion of which forms a square flat base for the lamp, as shown in the sketch plan. This strong base undoubtedly relieves the lantern to a considerable extent of the racking strains to which it was subjected by the old method of attachment, and, incidentally, greatly facilitates the fixing and removing of the lantern.

As shown in the illustration, the lamp is fitted with Messrs Sugg and Co.'s ball trap-door. F is a glass ball, about 2 inches in diameter, which is free to run up and down an inclined channel, but is prevented from leaving its course by the wire guard, G. This ball when at rest lies in, and closes, a hole at the bottom of the incline. When the torch is inserted for the purpose of lighting the lamp, the ball is displaced and runs up the incline as shown. On the removal of the torch the ball returns again to its seating, and maintains the wind-proof character of the lantern.

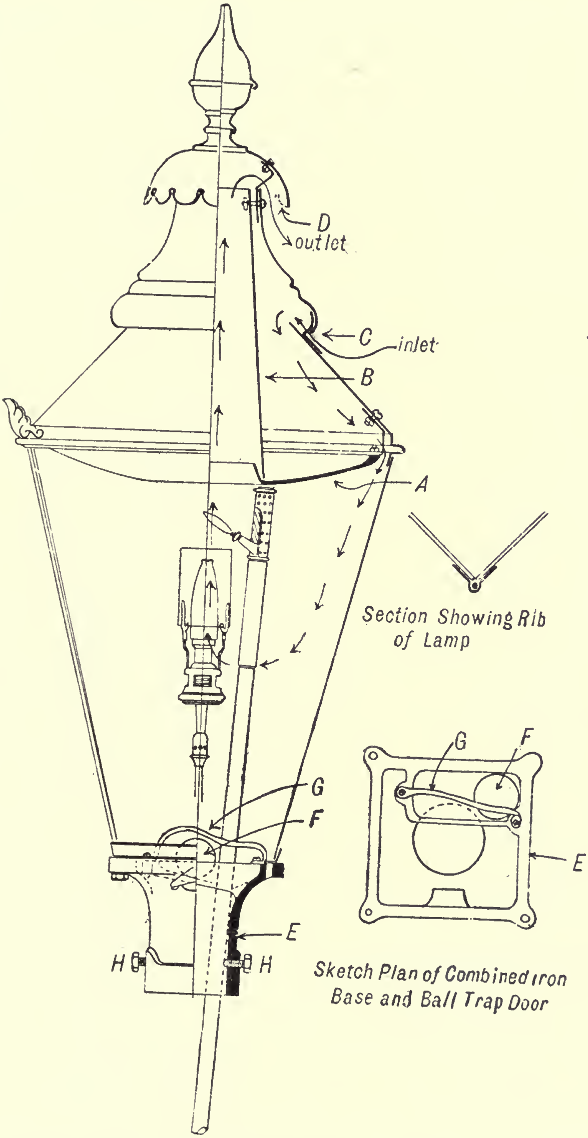


FIG. 478.—Sugg's "Windsor" Lantern: Sectional Elevation.

The illustration shows the gas being ignited by a Glover-Foulger torch. In place of this arrangement, however, the lamp may be fitted with Carpenter's single tube flashlight.

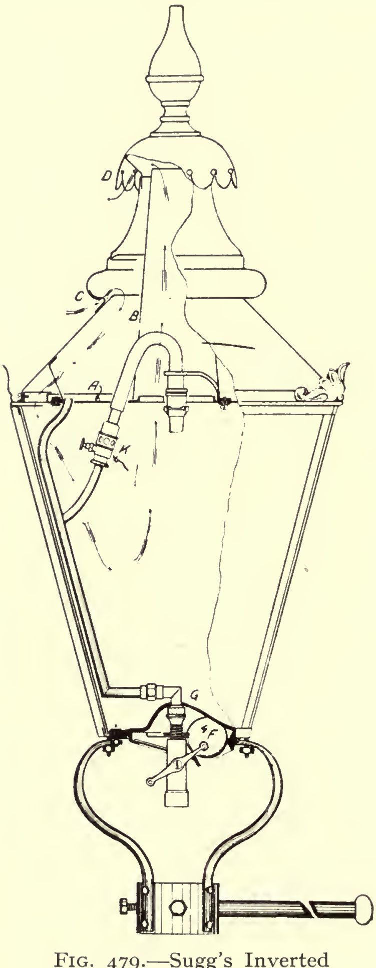


FIG. 479.—Sugg's Inverted "Windsor" Lamp.

Sugg's inverted "Windsor" lamp.—This lamp is now fitted, as shown in Fig. 479, with an inverted burner and deep convex reflector with or without mantle protector, to give a better distribution of light. The illustrations are similarly lettered, and much of the description of the one applies to the other.

In the inverted lantern the air chamber of the burner, with air and gas regulators, is placed below the reflector, at K, for convenience of adjustment, and the mixing tube passes through and over the top of the reflector down to the nozzle.

Smith's lamp.—The lamp shown in Fig. 480, designed and patented by Mr A. G. Smith, superintendent of street lighting in Liverpool, and made by Messrs D. Anderson and Co., London, is also a very good type for ordinary street lighting. The general construction and the arrangements for air inlet and exit for the products of combustion constitute this a thoroughly storm-proof lantern, a matter of extreme importance where small pilot lights must be kept alight in all weathers. The significance of bringing the lamp cock into the lantern itself will be appreciated by all who are troubled with naphthalene. The wheel in place of the ordinary lever upon the plug of the tap is an admirable device for reducing shocks in lighting and extinguishing, and so tends to prolong the life of the mantles. The air supply entering at A passes by the expansion chamber, G, and over the enamelled steel reflector, D, being heated in its course before being brought to the point of combustion.

Inverted burners for public lighting.—The great advantages connected with the use of the inverted incandescent burner for general purposes, and its rapid growth in public favour, have caused a widespread adoption of this form of incandescent lighting for our public thoroughfares. The effective illumination is greater with the inverted, even when compared with a vertical burner consuming more gas, whilst the general appearance is undoubtedly greatly superior, when proper lanterns are used.

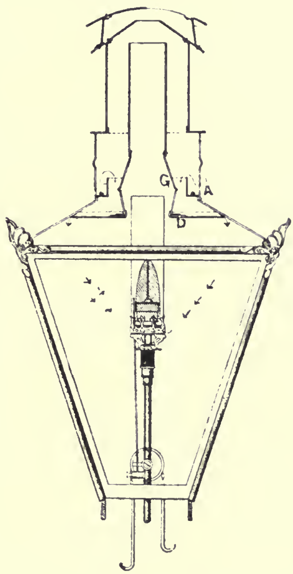


FIG. 480.—Smith's Lantern.

The reason for this superiority in illuminating effect is not far to seek. It is well-known that the light rays from an upright incandescent burner radiate to a greater extent at angles above than below the horizontal line. Dr Dreschmidt, of Berlin, has shown that with the upright Welsbach burner only 45.8 per cent. of the light is thrown below the horizontal line. This result has been confirmed by Professor Wedding, who has found that the maximum value from an upright incandescent burner is obtained at an angle of about 20° above the horizontal, and that the ratio of luminous energy developed above the horizontal plane to that developed below is as 1.73 to 1. The form of the mantle would, apart from any direct experiment, have led to the conclusion that this would be the case. Therefore, if these rays are to be made available for street lighting purposes, they must be reflected in a downward direction. But in this operation a proportion of the light, possibly 20 to 25 per cent. of the maximum light developed, is lost. And, in addition to the above, in the case of the upright burner the base of the burner must throw a shadow immediately under the light, a shadow which is increased by the bottom of the lamp and by the lamp column. By using the inverted burner, this shadow may be avoided altogether. Indeed, if the use of the inverted burner for street lighting develops to a very great extent, as there is every indication that it will, the present upright lamp-post will inevitably be superseded by a post with a bend-over top, not so high, but similar in pattern to those now so generally used for the electric arc lamp. The shadow immediately under the light would thus be entirely done away with.

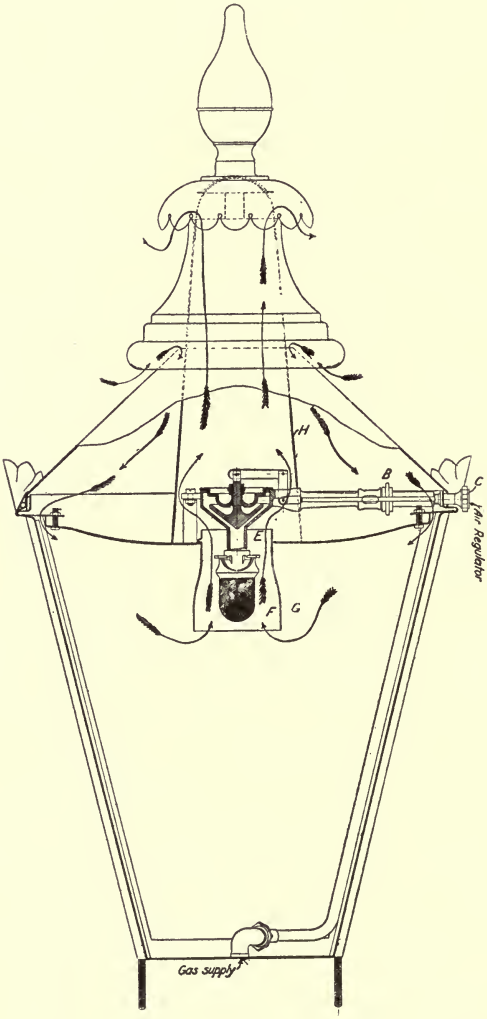


FIG. 481.—Willey's Lantern: Sectional Elevation.

In strong contrast with the upright burner, the radiation from an inverted incandescent burner is greatest at an angle of about 45° below the horizontal, and does not fall off very rapidly on either side of this angle. If the light along the horizontal line be taken as 100, it has been proved, as a result of the interesting experiments of Dr Drehschmidt, that no less a proportion than 63 to 65 of the total is thrown below the horizontal, and that the radiation both downwards and sideways affords better general illumination than either upright incandescent gas burners or electric glow or arc lamps. Or, put in other words, an equal mean hemispherical illumination may be obtained from an inverted burner with a gas consumption of 0.043 cubic foot per hour as with an upright burner with 0.08 cubic foot per hour. The light is, therefore, more widely diffused, the illumination more evenly distributed, and the general efficiency for street lighting purposes greatly increased.

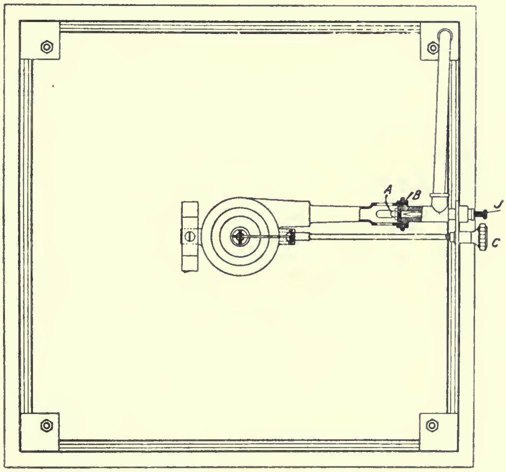


Fig. 482.—Willey's Lantern: Plan.

Willey's lantern.—One of the latest types of square lantern fitted with single low-pressure inverted burner is that of Messrs Willey and Co., Limited, of Exeter, a section through which is shown in Figs. 481 and plan in Fig. 482. The arrangement of the lamp will be readily followed from the illustration, in which A is the gas injector, B the coupling nut, C the air regulator, D the adjusting cone, E the burner nozzle, F the mantle, G the glass cylinder, H the chimney, and J the gas regulator. The special feature of the lamp is the adjusting cone situated immediately above the burner, which is actuated by means of the knob, C, outside the lamp. This not only regulates the air supply, but also divides the inflowing gaseous mixture into a thin stream which, passing between the heated surfaces

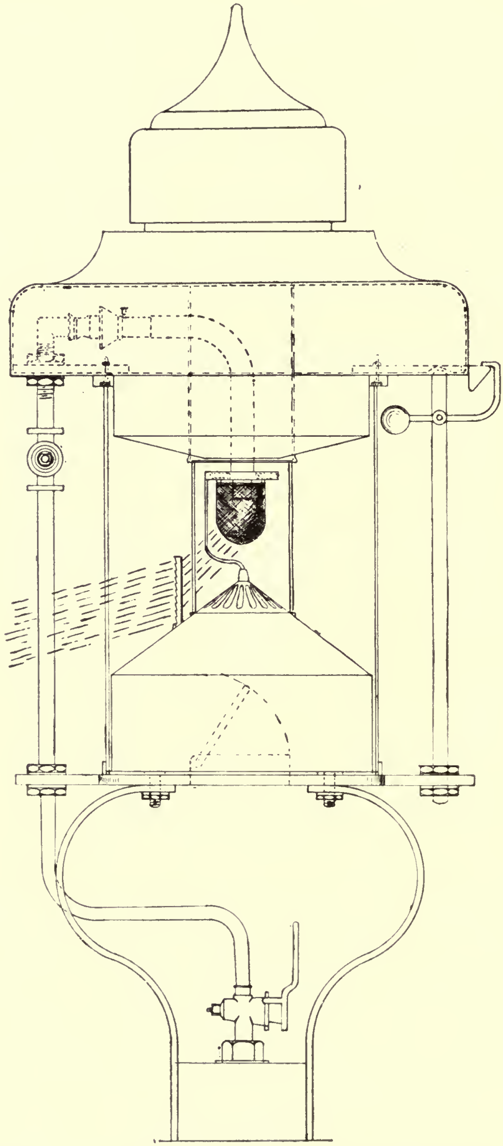


FIG. 483.—Copp's Double Reflector Inverted Lamp.

above the burner, becomes itself preheated before arriving at the point of combustion, and thus increases the illuminating power developed in the lamp. The inflowing stream for both primary and secondary air supply is caused to pass over the chimney and reflector and so becomes heated, the former before becoming mixed with the gas in the burner tube, and the latter before reaching the mantle for combustion.

It has previously been pointed out that with the inverted incandescent burner, the angle of maximum intensity is about 45° below the horizontal, while for even illumination the angle of maximum intensity should be about 20° below the horizontal. With the object of redirecting some of these 45° rays and thus correcting the distribution of light from the burner, Mr H. E. Copp has invented the lantern shown in Fig. 483. In this lantern double reflectors are used, one above and one below the burner. The upper is, of course, to deflect the upper rays of light downward and the lower to reflect a portion of the lower rays upwards, thus securing a light curve more nearly approaching that required. The lower reflector is placed between the inner and outer glass cylinders, and consists of a plate of prismatic glass. There is no circulation of air between the inner and outer cylinders and the annular space is, therefore, practically dust-proof, and thus admits of the introduction of the glass reflector. Another feature of the lamp, one which is becoming increasingly adopted with all the best types of modern lanterns, is that the burner is attached to the top of the lamp and is removable with it. The mantle is thus protected by being moved out of the way whilst the lamp is being cleaned. The lantern was described in detail by Mr Copp in his paper on street lighting presented at the annual meeting of the Institution of Municipal and County Engineers in 1911.

Form of lantern most suited to the system.—In connection with the adaptation of the inverted burner to street lighting it is obvious that a great mistake will be made, and some disappointing results ensue, if the burners are fitted into the ordinary type of street lantern. The lantern which was very suitable for the obsolete flat-flame system of public lighting is quite out of character with this modern form of lighting. There can be no reasonable doubt that the lantern with a clear glass bottom, similar to those shown in subsequent illustrations, and allowing for unobstructed radiation in all directions except upwards, will be the type ultimately adopted.

Lamp brackets.—In the early days of street lighting by means of gas, the lanterns were usually suspended by means of brackets attached to premises abutting upon the footpath. These, however, caused so much friction with owners, who objected to their property being used for the purpose, that they have been generally discarded in favour of the lamp column. This, being placed on or within the kerb, brings the lantern also into a much more advantageous position for the effective lighting of both footpath and roadway. Fig. 484

shows two types of brackets used to-day in positions where columns would be inconvenient, while for a more ornamental type the one

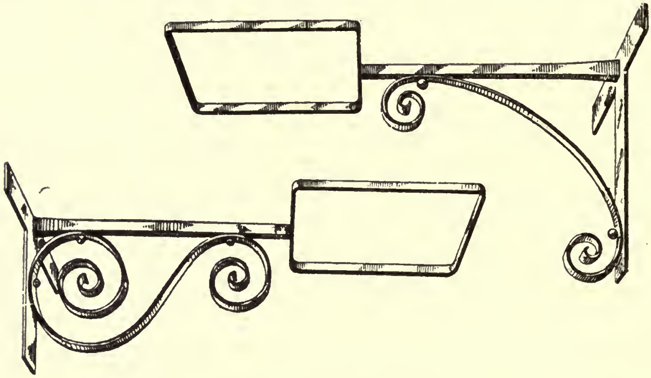


FIG. 484.—Lamp Brackets.

shown in Fig. 485, which is the pattern used in the high-pressure lighting in Fleet Street, London, is an excellent example.

Lamp Columns.—The reproach which has been so frequently cast

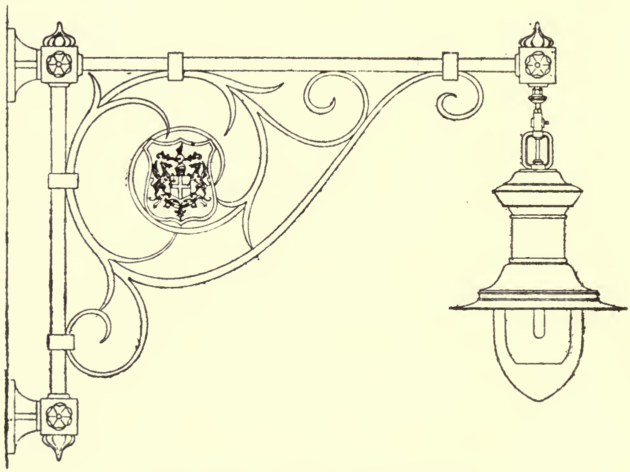


FIG. 485.—Fleet Street Bracket.

at lighting authorities and gas undertakings, of filling our streets with clumsy, ill-shapen, inartistic lamp columns, is becoming less deserved every year. The candid observer cannot but note an increasing tendency to level up our English practice in this respect.

It is still, unhappily, true that we lag far behind our Continental neighbours in this particular, but the chaste and artistic designs which are now being put upon the market show that a real awakening on the matter has come at last. Fig. 486 shows a few of the patterns made by Messrs Wm. Sugg and Co., Limited, Westminster, which

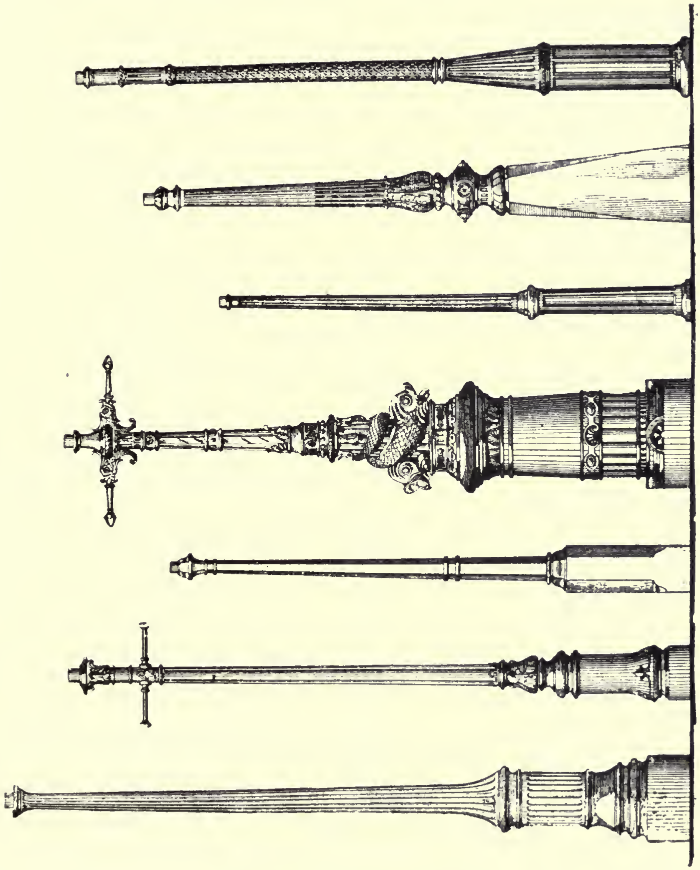


Fig. 486.—Selection from Wm. Sugg and Co.'s Lamp Columns.

are gradually but surely superseding the ugly types of a generation ago.

Of columns suitable for suspended lamps a typical selection of the graceful and pleasing designs of Messrs Hardy and Padmore, of Worcester, is seen in Fig. 487.

Swan-necks for ordinary columns.—One difficulty incidental to the substitution of the bend-over column for the ordinary pattern, for use with inverted burner lamps, "arc" lamps, and others of similar types, is found in the practical impossibility of discarding the thousands of upright columns already in use for public lighting. It would, naturally, be considered extremely wasteful, and would, in

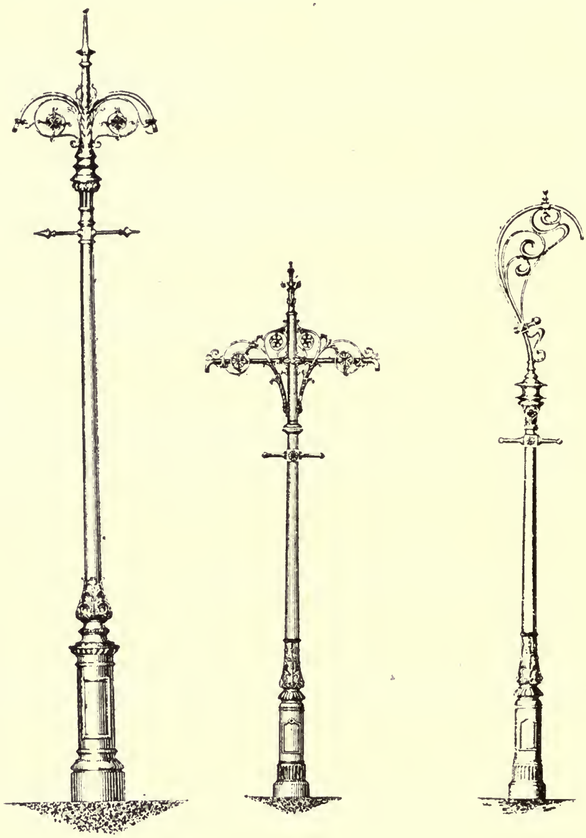
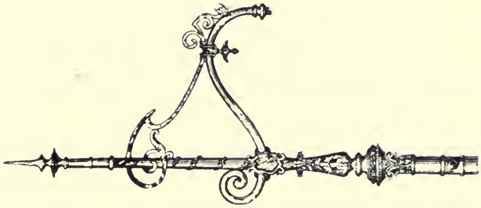
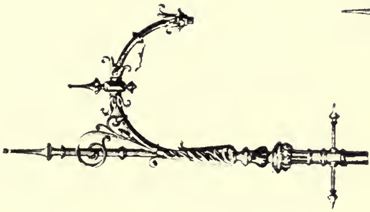
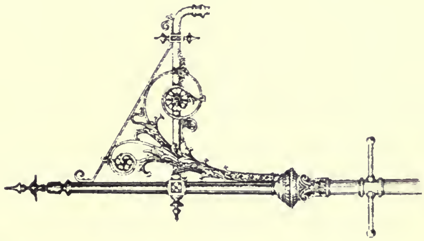


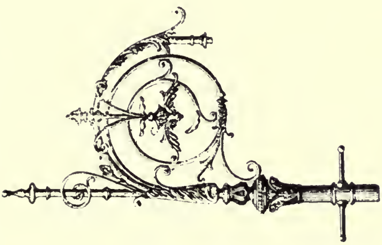
FIG. 487.—Selection from Messrs Hardy and Padmore's Lamp Columns.

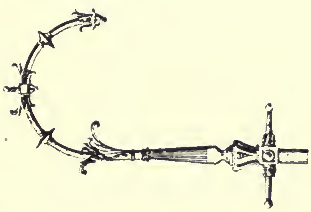
fact, be directly contrary to the genius of the English race, to "scrap" in this wholesale fashion apparatus from which further useful service may be obtained. This obstacle may, however, be easily surmounted by the employment, upon the existing lamp columns, of brackets of the type shown in Fig. 488. These are illustrations of the neat and graceful designs manufactured by Messrs Hardy and Padmore, and

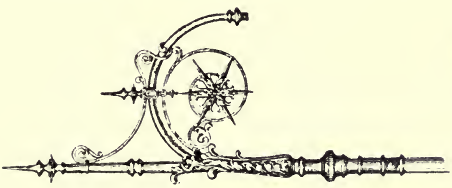


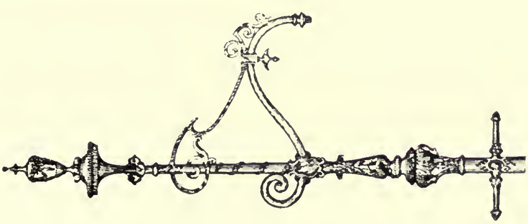












may be easily adapted for the purpose suggested. Should these be considered too elaborate, others of a similar type, but simpler in character, may readily be obtained. Fig. 489 shows the ornate harp head for lamp columns of Messrs James Milne and Son, Limited.

Wrought-steel lamp columns.—Reference has been made to the extending use of steel in another department of gas distribution (Chapter IX), and it is interesting to note that this material is gradually securing a place for itself in connection with lamp columns. Some of the reasons which have led to its adoption for pipes apply also to its use for this purpose. It is much lighter than cast-iron, and therefore more easily handled, and charges for carriage and transit are correspondingly reduced. Being less bulky, the columns may be placed in positions where the use of cast-iron would be inconvenient. It is also claimed that, in consequence of their greater resilience, the necessity for mantle renewals is not so frequent as in the case of the more rigid cast-iron column. As may be seen from Fig. 490, which shows a few of the patterns of wrought-steel columns supplied by the Welsbach Light Company, Limited, this material lends itself to very graceful treatment, the columns being considerably lighter in appearance than those of cast-iron. For the Mannesmann steel single and cluster lamps column used in the installation of high-pressure public lighting at Leeds, see Figs. 537 and 538, pp. 624-625.

Fig. 489. — Ornamental Harp-type Lamp Head for "Arc" Lamp.

Importance of efficient lamp governors: methods of charging.—Although occupying very little prominence in itself, one of the most important pieces of apparatus in connection with public lighting is the lamp governor. To begin with, it is very generally the basis of charge for the public lighting. There are two methods of arriving at the quantity of gas consumed by the public lamps. There is, first of all, the "average meter system," by which is meant that a proportion of the lamps in any district are supplied through meters, and the average consumption recorded by the meters is accepted as a basis of charge for the whole number of lamps supplied. The meter used for this purpose is placed in the base of the lamp column, which is fitted with a basal chamber for the purpose, as shown in Fig. 491.

The other method is to regulate the quantity of gas supplied to each lamp by means of properly adjusted lamp governors, and multiply this out over the number of hours each lamp has been alight. It is evident that under either system grievous error may arise, and a large quantity of gas may be supplied in excess of that charged for, if any great number of the lamp governors should fail to act properly. If for this reason only, it is incumbent upon any gas undertaking to see that only perfectly reliable governors are used for this purpose.

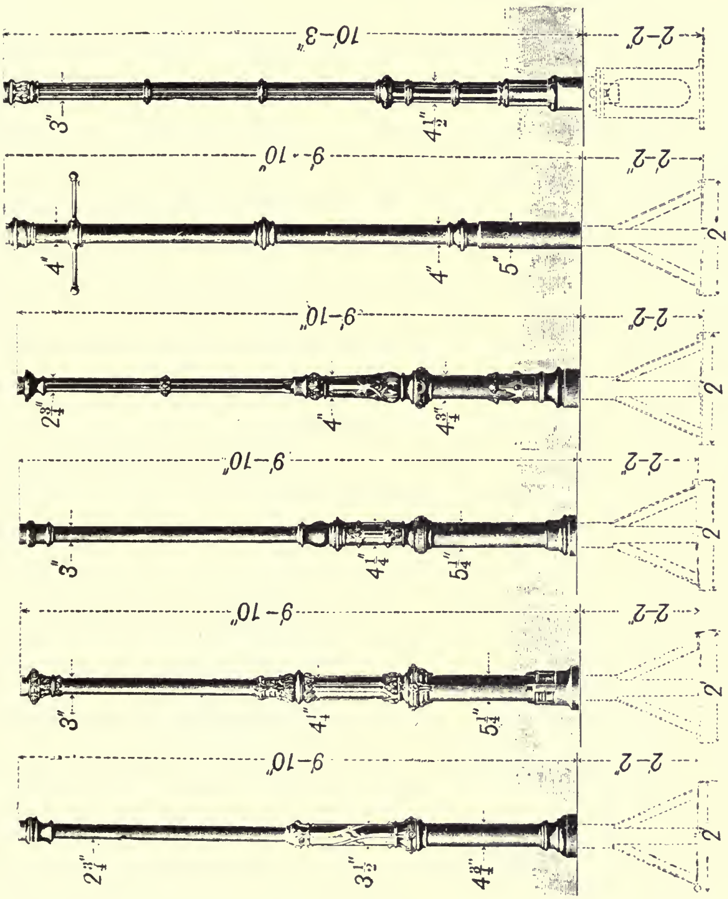


FIG. 490.—Welsbach Company's Wrought-Steel Lamp Columns.

Supply must be constant.—But the rapid growth of incandescent lighting for the public streets supplies an additional reason for emphasizing the importance of the lamp governor. The bunsen flame is the product of a very carefully adjusted mixture of air and gas. Efficiency demands that when once adjusted the conditions should remain constant. But if the governor sticks, does not work freely, or perform the duty required of it, the conditions must vary with every change of initial pressure. Whilst the air supply remains constant, the quantity of gas passing to the burner will increase with every increment of pressure, and diminish as the pressure falls.

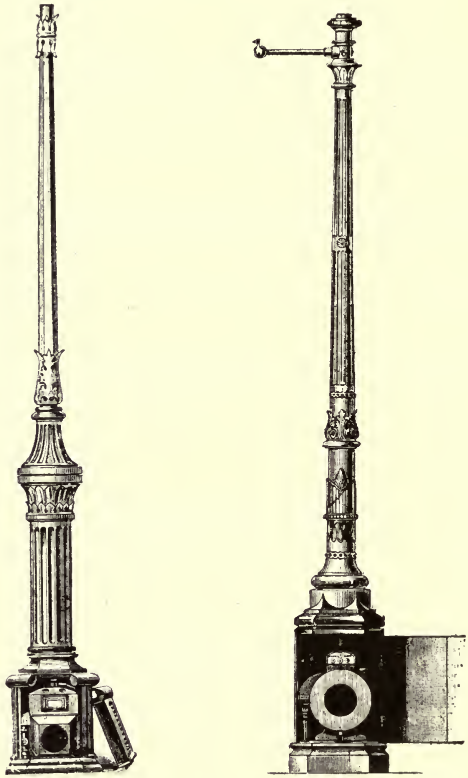
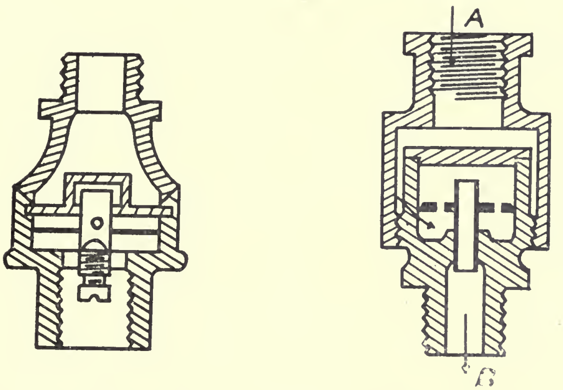


FIG. 491.—Columns Showing Meter in Basal Chamber.

Should the gas supply fall below the quantity for which the burner is adjusted, the result is humming and oscillation of the lights to a corresponding degree, and, if carried far enough, may cause the light to jump out altogether.

Fig. 492 shows Peebles' volumetric lamp governor as adapted for use with upright incandescent burners. The internal arrangements are very similar to those previously described in connection with the volumetric governor for gas fires (see Chapter XXII, pp. 422) and need not be again described here. It will be noted, however, that in this case the regulating screw is attached to the tube of the disc.

Fig. 492 also shows a section through a Peebles' governor as



For Upright Burner. For Inverted Burner.

Fig. 492.—Peebles' Lamp Governor.

arranged for the inverted burner. In this case the gas enters at A, as shown by the arrow, and passes down the side passages into the central chamber at the bottom to the under side of the disc. The disc is perforated with a series of holes through which the gas finds access to the disc tube and passes away from B, as denoted by the arrow.

Fig. 493 shows a section through the familiar Borradaile governor, in which the disc, A, carrying the disc tube, B, is capable of free vertical movement within the chamber, C. The upper end of the disc tube passes within the cap, which is perforated for the gas outlet in the two channels, D and E, which are out of register with the end of disc tube, B. As in the case of the Peebles' governor, the diaphragm, floating in the stream of gas, is raised by an excess of pressure and correspondingly restricts the area of the gas channel leading away from the upper portion of the disc tube, while reduction of pressure causes the diaphragm to fall and open the gas-way proportionately

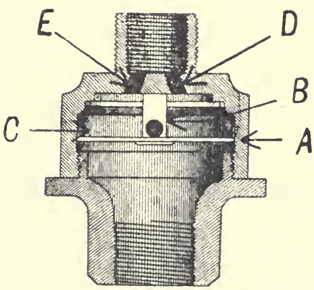


Fig. 493.—Borradaile Lamp Governor.

The Simmance-Abady patent volumetric governor, manufactured by Messrs Alexr. Wright and Co., Limited, is a very useful and convenient form of governor for incandescent lighting, and is shown in Fig. 494. This is especially adapted for use with the Kern burner. In that case the nipple is screwed into the valve plate of the governor. The dome, C, of the governor, to which is screwed the base, B, of the bunsen tube, is fitted to the base, A, of the governor by either a cone joint and set screw or bayonet joint. In the event, therefore, of the nipple requiring any attention or cleaning, the dome of the governor, together with the bunsen tube and mantle, may be completely removed, and, owing to the comparatively wide diameter of the base of the dome, may be placed on any firm support whilst the nipple is receiving the necessary attention. It is obvious that such an arrangement must result in a great saving of mantles.

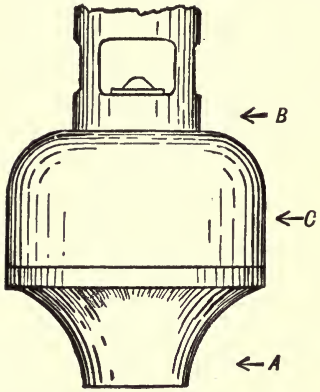


FIG. 494.—The Simmance-Abady Volumetric Lamp Governor.

CHAPTER XXVIII

PUBLIC LIGHTING—HIGH-POWER LOW-PRESSURE

INTERMEDIATE between the ordinary low-pressure lamps and the several systems of high-pressure lighting which are rapidly becoming

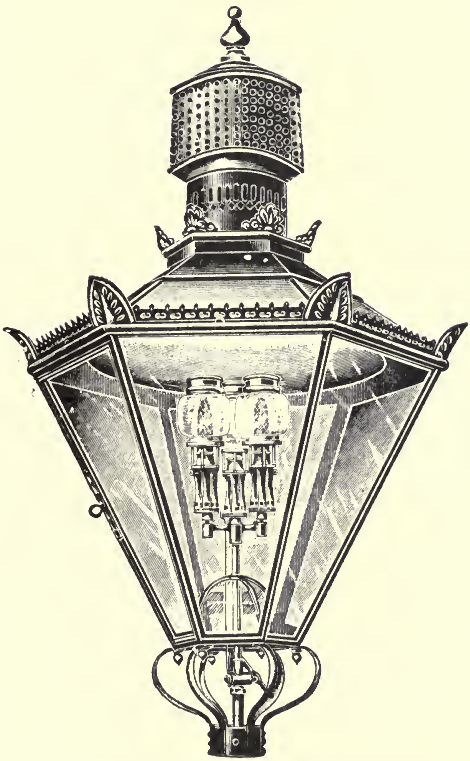


FIG. 495.—Welsbach High-Power Lamp.

so familiar, there is a class of lamps of which the high-power Welsbach, Podmore, "Regent," "Nico," "Pintsch," and Graetzin lamps may be taken as types.

These again may be divided into two classes (1) those fitted with upright burners, and (2) those in which the inverted burner has been adopted. Each of these may again be sub-divided into (*a*) those dependent for their increased illuminating power upon a strongly induced primary air supply due to the pull of the chimney, and (*b*), those in which the effect of this induction of air supply under draught is supplemented by a pre-heating of either air or gas supply, or both. Each of these types is illustrated in the following examples.

Welsbach high-power lamps.—In the Welsbach high-power lamp the burner is surmounted by a glass bulb, upon which the chimney fits tightly, the whole being one continuous shaft from the burner head; the effect being to induce an air supply at a greater velocity, and therefore pressure, than is possible in the ordinary open arrangement of burner. A secondary effect of the continuity of the shaft from base of burner to top of chimney is the protection of the mantle from the cooling effect of any direct contact with the outside colder air, and consequent lowering of temperature and luminosity. Fig. 495 shows one of the more powerful of the Welsbach high-power lamps suitable for the lighting of refuges and open spaces. These are made in various sizes up to 1800 candle power, and are housed in storm-proof lanterns, with enamelled iron reflector and fitted with ordinary by-pass.

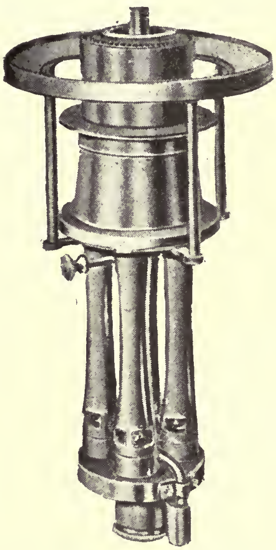


Fig. 496.—Welsbach High-Power Kern Burner.

The special form of Welsbach-Kern self-intensifying burner used in these lamps is shown in Fig. 496, that illustrated being the 600 candle-power burner. The body of this consists of four separate bunsen tubes, slightly constricted in the centre, after the fashion of the Venturi tube, which receive their gas supply from a common base and discharge into a mixing chamber at the head of the burner. Here the streams of gas and air received from the bunsen tubes become perfectly mixed, by being caused to pass through the perforation of the inner cone, illustrated in the details of the burner (Fig. 497), a perfectly homogeneous composition being passed on to the point of combustion.

A. E. Podmore and Co.'s lamps.—Of the numerous family of high-power lamps, those patented by Messrs Podmore and Thomas deservedly hold a high place. Two of these are shown in Figs. 498

and 499. In these lamps the recuperative principle is applied with considerable success. The fresh air, both primary and secondary, is admitted to the lamp, in proper quantities, by means of a series of perforations in the lantern hood. The air is passed from the hood into an inner chamber, absorbing heat in its passage, and in the chamber it becomes superheated.

From the superheater a pipe descends to the gas supply pipe, as shown in Fig. 498, and is connected just beneath the burners, the necessary current being induced by the upward flow of gas. The smaller current of gas is warmed up from this point by the hot

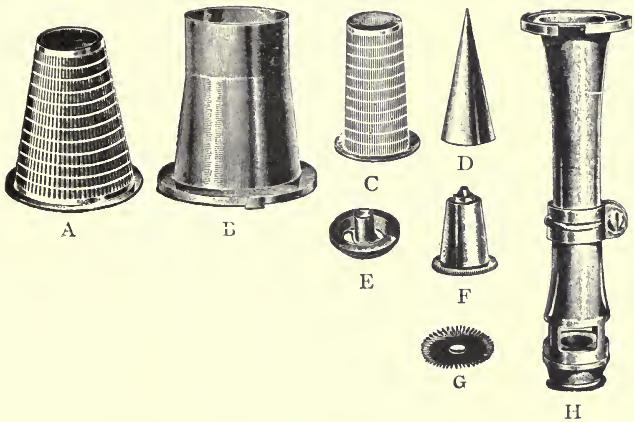


Fig. 497.—Details of Welsbach Burner.

A.—Inner Cone for 600 Candle-Power Burner. B.—Outer Cone for 600 Candle-Power Burner. C.—Inner Cone for 150 and 300 Candle-Power Burners. D.—Solid Inner Cone. E.—Rod Holder for 600 Candle-Power Burner. F.—Socket and Nipple for 150 and 300 Candle-Power Burners. G.—Wheel for Burner Head. H.—Bunsen Tube and Platform for 150 and 300 Candle-Power Burners.

primary air, and the mixed air and gas pass to the point of combustion in a highly heated condition.

Any cooling of the mantle by the secondary air supply is prevented by admitting the air in fine streams at the waist of the lamp, in quantities limited to the extent necessary for complete combustion at the burner. This air in its passage to the burner also becomes heated, and is directed by a special form of glass holder, assisted by the shape of the chimney itself, in a thin stream to the base of the mantle. The result is that a very high efficiency is obtained per cubic foot of gas consumed.

Fig. 499 shows a hexagonal form of lantern for clusters of three or four burners. This is suitable for wide thoroughfares and open spaces. While containing all the special features of the lamp just described, a very useful additional arrangement has been introduced into this lantern by means of which the burners may be rotated to any desired position. The cluster may, therefore, be so arranged as

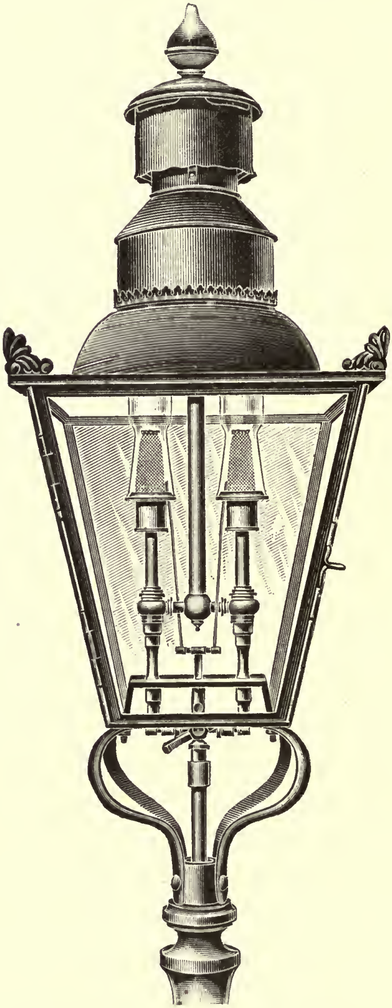


FIG. 498.—Podmore and Co.'s "Leek" Lamp.

to give its maximum lighting effect in any desired direction. In addition to this advantage, in the event of a new mantle being required, the burners may be rotated so that the one requiring attention is brought next to the door, and the inconvenience of reaching over other burners entirely obviated.

A special feature of these lamps consists in the fact that the bunsen part of the burner is enclosed. The trouble, frequently experienced in country districts, of insects choking the bunsen is rendered im-

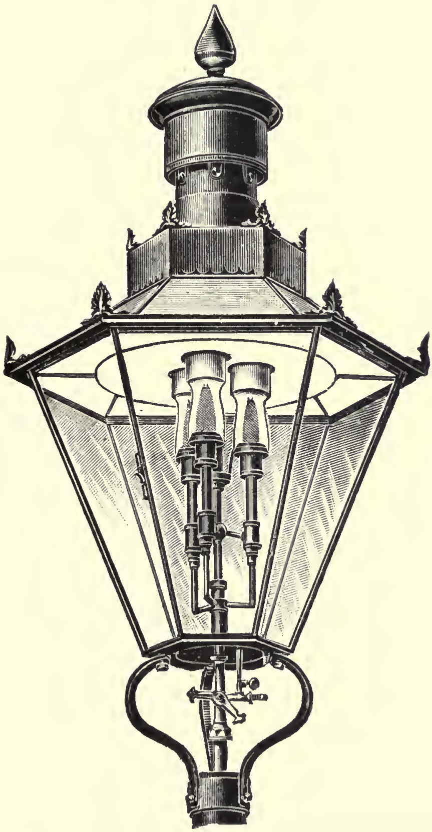


FIG. 499.—Podmore and Co.'s Hexagonal Lamp.

possible. By the same means, any depreciation of the light owing to a very similar town trouble, namely, dust and fluff impeding the air and gas passages, is altogether avoided. There is always a clear air and gas-way.

Turning from the upright to the inverted type of lamp we come to a class in which the regenerative principle is very easily and successfully applied. It may be said with truth that all inverted burners are, from the very nature of the case, regenerative in character.

to some extent at least. When, however, this native utilization of waste heat is reinforced by a suitable build of lantern the regenerative principle is employed to such a degree as to increase very materially the illuminating effect produced.

Chimney draught.—In addition to the preheating of the gaseous mixture, in all lamps of this type the long chimney arrangement for

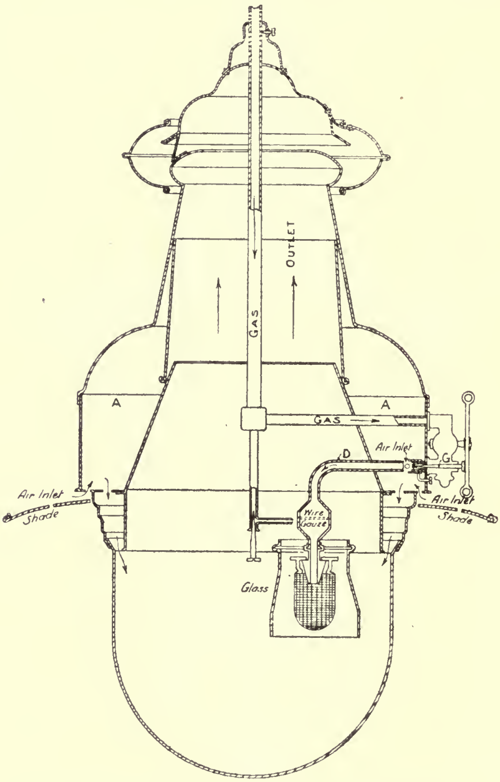


FIG. 500.—Podmore's "Bourne" Lamp.

the exit of the products of combustion has practically the effect noted in connection with the Welsbach lamps, of producing a strong chimney draught, and therefore of inducing a greater quantity of primary air into the bunsen tube. This again, in turn, tends to a more complete combustion, with production of a greater flame temperature and consequently increased illuminating power.

It is obvious that all lamps of this class are subjected to great heat, and therefore the body of the lamp, and the burners and tubes employed, must be of the most substantial character and highest class of workmanship.

The "Bourne" regenerative lamp of Messrs Podmore and Co. is a fair example of this type of lamp, and is shown in Fig. 500. The centre portion of the lamp consists of an annular air chamber, A, closed at the upper and lower parts, and through the centre of which the chimney carrying off the products of combustion passes. In the base of the chamber, A, are two concentric rings of holes, separated by the ring of the globe holder. The outer ring allows air to enter the chamber from the atmosphere, which, after being heated, passes down through the inner ring, for the secondary air supply. At the

1. Cast Brass Burner Elbow. 2. Cast Brass Bunsen Tube and Injector. 3. Nickel Gauze. 4. Burner Nozzle for Mantle. 5. Gas Adjusting Screw. 6. Gas Nipple. 8. Brass Knob for Air Regulator. 9. Air Shutter. 10. Air Adjuster Spring. 11. Horizontal Gas Service. 12. Gas Tap. 13. Lever of Gas Tap. 14. Set Screw to fasten Bunsen. 15. Nut of Screw.

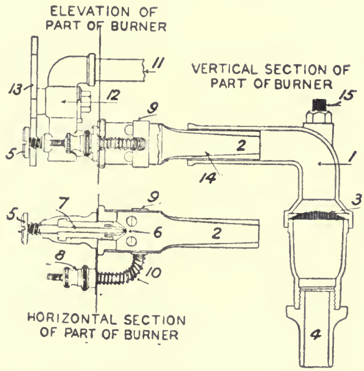


Fig. 501.—Podmore's "Bourne" Lamp: Enlarged Sections through Burner.

same time the reservoir of heated air in the chamber, A, is also drawn upon for the primary air supply at the air inlet to the bunsen tube. The preheating of the gas supply is secured by bringing the supply pipe through the chimney of the lamp.

An enlarged section through the burner employed in the "Bourne" lamp is shown in Fig. 501. It will be noticed that both gas and air adjustments are brought to the exterior of the lamp and placed in a very accessible position. The cock controlling the gas supply is also brought to a much better position than is usual with this type of lamp. The air adjuster spring is an excellent little device, and in common with other parts of the burner will amply repay detailed study.

It is claimed that with a consumption of gas of 3¼ cubic feet per hour per burner this lamp develops an illuminating power of 120 candle-power per burner, or 360 candle-power for a consumption of less than 10 cubic feet per hour, in the three burner lamp shown.

Sugg's inverted "Regent" lamp.—Among lamps of the high-power low-pressure type, the "Regent" lamp of Messrs Wm. Sugg and

Co., Limited, deservedly takes a high place. It is shown in part elevation in Fig. 502.

In this lamp there are two distinct chambers separated by the enamelled shaft, A, the inner one stopped at the upper end by the heat plate, Y, providing for the escape of the products of combustion,

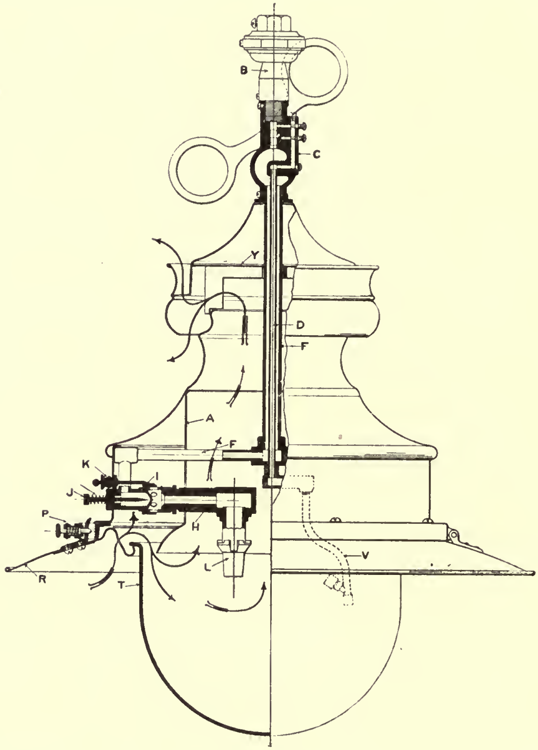


FIG. 502.—Sugg's Inverted "Regent" Lamp: Part Section and Elevation.

which are discharged at the upper portion of the lamp, as shown by the arrows.

The gas supply is brought from the ball joint, B, supporting the lamp, through the spectacle lever cock, C, which provides for flashlight ignition, the flashlight tube, D, being carried down the interior of the main gas supply pipe, F.

The burners, H, are of the angle pattern, with air adjustment, I, and gas adjustment, J, both accessible from the outside of the lamp. The former is of the sliding collar type, manipulated by means of the exterior screw knob, K, and the latter of the needle pattern, operated from the screw, J. The burners, H, are made of cast-iron where they are in contact with the flame gases, and are fitted with incorrodible steatite or fireclay nozzles, L. The gas is heated in its

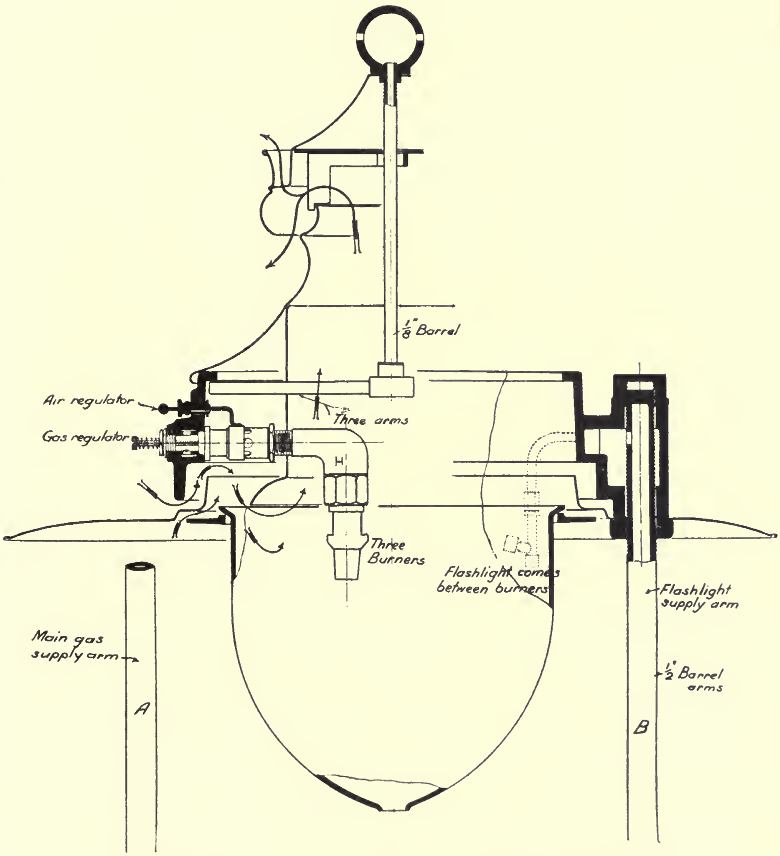


Fig. 503.—Sectional Elevation of "Regent" Upright Lamp, showing various fittings.

travel through the lamp and the gaseous mixture is partly superheated in the burners.

The air supply, both primary and secondary, is admitted to the lamp through a series of perforations beneath the reflector, R, shown by the arrows.

The lamp is thoroughly wind and rain proof. This is secured by means of the special wind guard, which successfully baffles the wind from all directions.

The flashlight, V, is of the atmospheric type; one flash lighting the whole of the burners. It is maintained at the extremely low consumption of one cubic foot in twelve hours. Maintenance charges are also reduced by the elimination of the mantle protector. The globe, T, is supported by the usual metal ring, and maintained in position by the spring bolt, P.

Upright "Regent" lamp.—The "Regent" lamp is also supplied with an upright fitting, for street lighting. A sectional elevation through this lamp and the various fittings is shown in Fig. 503.

The lamp is carried by wrought-iron tubular arms rising from a cast-iron base. The base is designed to accommodate either an ordinary or flashlight cock, or an automatic lighter. The arm, A,

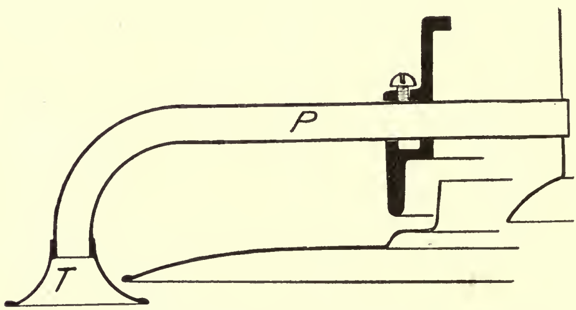


FIG. 504.—Trumpet Piece for Pneumatic Torch Lighting.

serves as the main gas supply pipe, while B is the pipe supplying gas to the flashlight.

The burners, H, are screwed on to a cast annular gas chamber, to which the flat enamelled shade and casing are fitted. The air supply, both primary and secondary, enters the lamp, as shown by the arrows, both above and below the reflector, while the air and gas adjustments are similar to those of the suspended "Regent" lamp.

Details of the ordinary and also of the flashlight cock are given, and will be readily understood from the illustrations.

These lamps are sometimes fitted with a torch lighting arrangement, as shown in general elevation in Chapter XXX (Fig. 557). A special flashing spirit torch is provided, charged with methylated spirit. The cock in the base is turned on, and the end of the torch inserted in the trumpet end of the tube; the rubber ball is pressed lightly, and a small portion of the spirit, atomised and blown across the permanent flame in the torch, is ignited, and shoots a flame of ample volume into the lamp. Details of this arrangement are shown in Fig. 504, where T is the trumpet piece into which the torch is inserted, and P the pipe carrying the vaporized and ignited benzoline across the top of the burners.

Other details are shown in Figs. 505 to 509. Fig. 505 shows a section through an ordinary gas cock, having the main gas supply on the left hand side when looking at the lever. Fig. 506 shows a

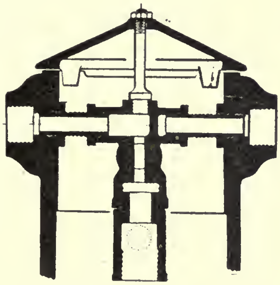


Fig. 505.—Section through ordinary gas Cock.

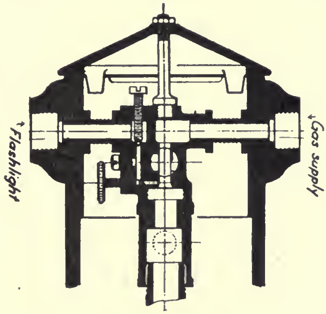


Fig. 506.—Section through flashlight Cock.

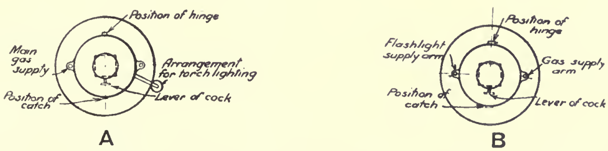


Fig. 507.—Section showing, A, position of connections for torch-lighting. B, position of connections for flash-lighting.

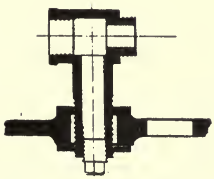


Fig. 508.—Showing detail of blow-out.

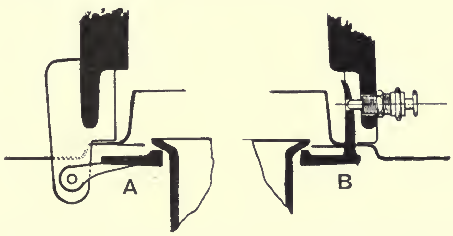


Fig. 509.—Section showing, A, Detail of Hinge, B, Detail of Catch.

similar section through the flashlight cock. When looking at the lever, the main gas supply comes in on the right hand side and the flashlight connection on the left hand side, the flashlight being governed by the two screws shown in vertical and horizontal positions to the left of the plug of the cock. Fig. 507 shows at A the arrangement of connections when the lamp is lighted by means of the trumpet piece shown in Fig. 504 and pneumatic torch, while at B a similar plan of the position of the connections when flash-light lighting is adopted is shown. Fig. 508 shows details of the

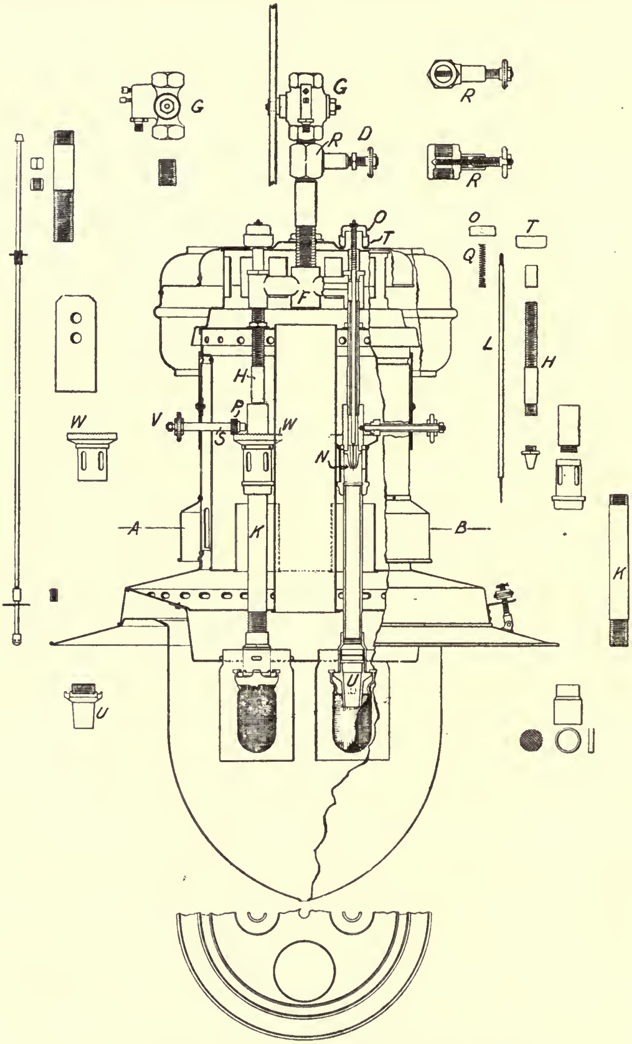


Fig. 510.—" Nico " High-Power Lamp.

blow-out, and Fig. 509 shows at A details of the hinge, and at B the detail of the catch devices respectively.

The " Nico " high-power lamp.—Another excellent lamp of the inverted regenerative type is the "Nico" high-power low-pressure lamp, which is giving very good results in both public and private lighting at Leeds. This lamp differs very materially in its construction from the preceding types, both in the disposition of the supply pipes to the burners and in the arrangements for adjustment.

The mixing tube, K, is of the straight down type, the air adjustment being controlled by the pinion, P, fixed on spindle, S, and actuated by knob, V, from the exterior of the lamp. The loose sleeve forming the air supply adjustment is surmounted by a crown wheel, W, which engages with the pinion, P.

The gas is admitted to the lamp through the cock, G, below which the gas regulator, R, of the screw type, is placed. When once the adjustment has been made, the regulator is held in position by a lock nut. The gas is led from a common body, F, through the tube, H, to the injector N. As all who have had to deal with lamps of this character have found out, one difficulty is to keep the injector perfectly clear of obstruction by dust or dirt. One of the unique features in the "Nico" lamp is the simple and effectual device employed for this purpose. Within the gas tube, H, a small rod, L, is inserted, allowing, of course, a full gas-way through the annular space between the rod and the interior of the tube, H. The rod, L, terminates in a long needle point at the lower end, which point is inserted through the ejector, N, as shown. The rod is held in position by small nuts screwed on to the upper rod, which passes through the cap, O, which is supported by the spring, Q. The cap, O, fits loosely into the annular cup, T, the cup and rod being capable of a limited vertical movement within the gas tube, H. When, therefore, it is desired to clear the ejector, N, of any obstruction, or to ascertain that it is perfectly clear, a slight pressure is applied to the cap, O, which, in yielding against the spring, Q, carries with it the rod, L, the lower needle point of which is projected through the orifice of the ejector, N, effectually removing any possible deposit. On releasing the pressure, the resilience of the spring, Q, lifts the rod into permanent position again.

The other details of the lamp will be easily followed from the sectional parts, which, in the illustration, are placed over against their actual position in the lamp, and are each similarly lettered. The lamps are made in three sizes, with two, three or four burners respectively. Each burner consumes six cubic feet of gas per hour at the 18 tenths to 20 tenths pressure at which the greatest efficiency, that of upwards of 40 candles per cubic foot, is obtained.

The Graetzin Lamp.—The last of this type to which reference need be made is the Graetzin lamp, a section through which is shown in Fig. 511. This lamp is eminently suitable for lighting wide open spaces and for general outdoor use. Several which the author has fixed in large yards, where the surroundings are dark and light absorbing, are giving excellent results.

This lamp differs very materially in construction from either of the two preceding types, chiefly in the extent to which the regenerative principle is carried. As in the case of the "Nico" high-power lamp, the

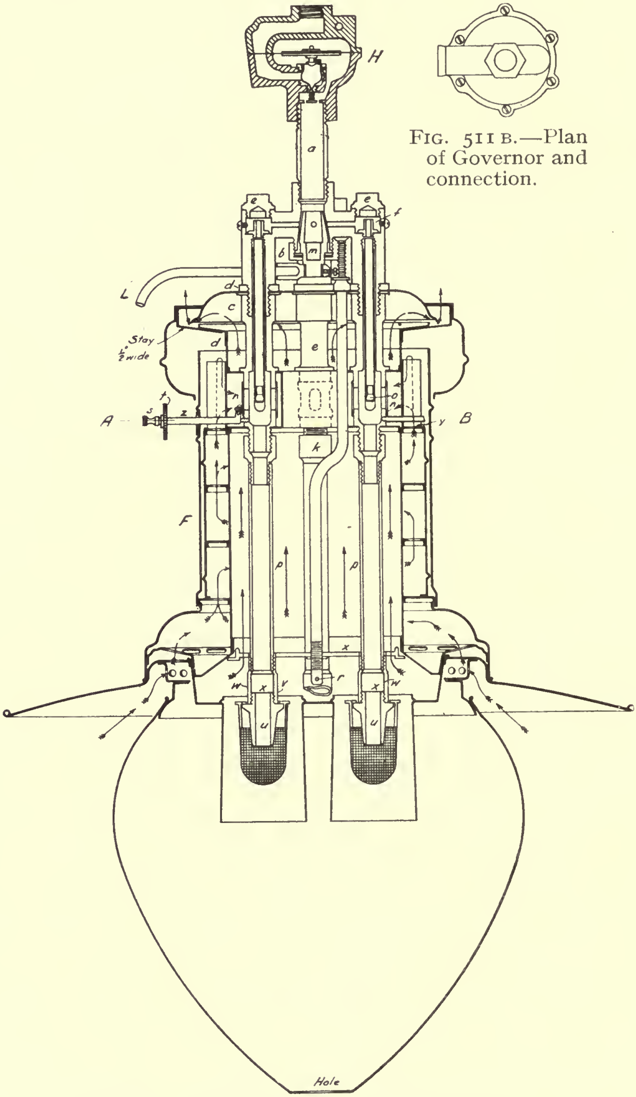


FIG. 511 B.—Plan of Governor and connection.

FIG. 511.—Section through Graetzin Lamp.

gas supply and bunsen tubes are carried through the centrally placed chimney of the lamp, where they are subjected to the waste heat rising from the burners, become very hot, and transfer a portion of their heat to the descending gaseous mixture in its passage to the nozzles for combustion, whilst the products of combustion are discharged from beneath the upper spinning of the lamp, as shown by the arrows.

Between this inner chamber and the outer casing of the lamp is an annular space, F, divided horizontally by a series of baffle plates. The cool outside air, entering under the reflector, is introduced into the lower of a series of horizontal chambers, through which it successively passes on its way to the primary air supply for the bunsen tube. The entrances from one chamber to the next are placed upon alternate sides of the lamp, as shown by the outer series of arrows, so that the air in its passage circulates completely round the exterior of the chimney, abstracting heat in its travel, so that it arrives at the bunsen tube in a highly heated condition. From the annular space, F, shallow, air-tight chambers, K, are built out into the chimney to accommodate the air inlet to the bunsen, as shown in section through A, B, Fig. 511 A. From this point in its travel to the nozzle, the gaseous mixture becomes very highly preheated, and consequently arrives at the point of combustion at a very high temperature, and thus develops a very high efficiency.

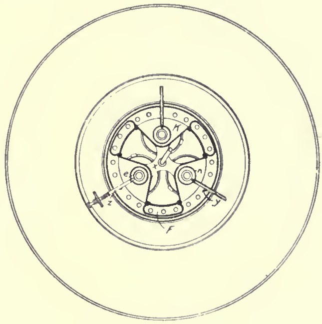


FIG. 511 A.—Showing section along line A, B.

Adjustment.—The injectors are of the fixed jet types, the three being regulated in common by means of the diaphragm governor, H, fixed on the supply pipe. The air supply is adjusted from the outside of the lamp by means of the milled wheel, *t*, and which, in actuating the spindle, z, causes a turning movement of the loose collar by means of the stud and slot shown at n. The velocity of travel of the heated products of combustion generated by the very high flame temperature, combined with the long chimney pull, induces such a suction at the primary air inlets that a great proportion of the air necessary to combustion is admitted and thoroughly mixed in its descent with the stream of gas.

The lever, L, actuates a Berlin cock placed at the top of the lamp, by which either one or two of the three burners may be turned out at midnight. The further construction of the lamp will be readily understood by a reference to the details shown in Fig. 511.

In the lamp as described above the gas is controlled by a diaphragm governor, H. A separate regulation of each jet may also be obtained by a very simple device shown in enlarged section in Fig. 512, which is now being generally fitted to these lamps.

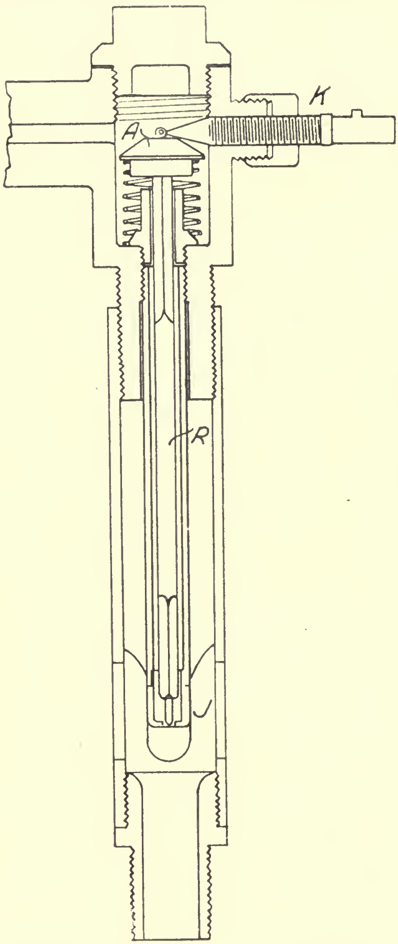


FIG. 512.—Separate Adjustment for Graetzin Burner.

In this arrangement the build of the gas passage is considerably modified. At the head of the tube is an annular chamber, which accommodates a conical cap, A, from the under side of which depends the partially fluted rod, R, terminating at its lower end in a point, capable of passing easily through the jet, J. The rod is held in suspension by the spring, L, acting upon the under side of the cap, A. Through the side of the annular chamber the screw, K, projects. The fore-end of the screw is conically shaped, and is fitted to engage with the upper surface of the conical cap, A. There are, therefore, two conical surfaces placed at right angles and engaging each other. The screw, K, is actuated by means of a slotted sleeve and knob (not shown), which slips upon the outer end of K. It is obvious, therefore, that when K is screwed into the chamber, pressure is exerted upon the upper side of the cap, A, which is in consequence depressed, carrying with it the rod, R, which at its lower end closes the gas way through the nipple. When the screw, K, is withdrawn the operation is reversed, and the gas way through the nipple is correspondingly opened. It will be seen, therefore, that the arrangement admits of very fine governing of the gas supply.

The Pintsch Lamp.—The Pintsch outdoor lamp, which is now receiving a good deal of attention in this country, is very similar in essentials to the Graetzin, but it has one or two special features of its own.

The Pintsch lamp has no draught cylinder, or mantle protector, and consequently the obstruction to light so frequent from dirty interior glass ware is avoided. Also, of course, maintenance charges are lessened.

The lamps are fitted with a Berlin cock, and the gas ignited by either a by-pass—which is turned out when the main burners are alight,

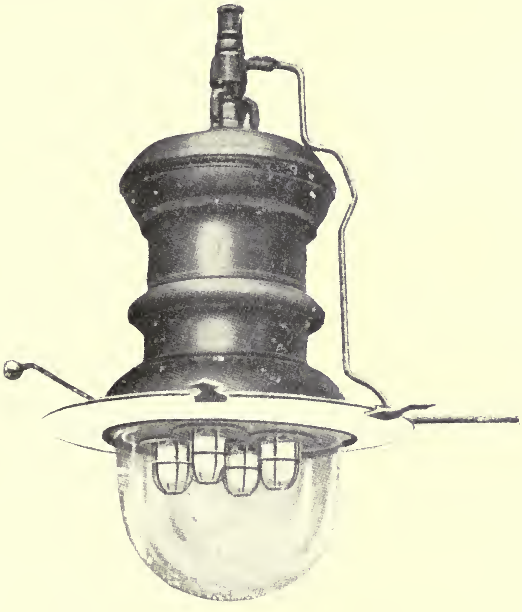


Fig. 513.—Pintsch 4-Light Lamp.

and relighted when the main supply is turned off—or a combined flash light and by-pass. A third alternative is to ignite by means of flash ignition, lighted from the exterior of the lamp by means of a torch, the gas being turned off from the flash after the main burners have been lighted up, as the main tap reaches the full open position.

One very special feature of the Pintsch lamp is the provision of a combined mantle carrier and guard. This is shown in Fig. 514. The changing of mantles is thus facilitated, and mantles may be removed from and replaced in the lamp without risk of injury. The guard also protects the mantle from damage during cleaning. The bearing of all this upon maintenance charges will be easily realized by any one who has had experience with this class of lamp.

Sugg's 1911 Lamp.—One of the best low-pressure lamps which the author has come across is Sugg's 1911 lamp, shown in part sectional elevation in Fig. 515.

In this lamp every effort has been made to produce and maintain a high flame temperature, and thus obtain a high illuminating power from the gas consumed. As may be perceived on a study of the illustration, every detail of the lamp has been designed with this aim in view.

The primary air enters just above the reflector at A. Passing upwards it becomes heated by contact with the division cylinder, F, which separates the primary air from the products of combustion ascending from the burners. The heated air is then carried to the bunsen tube, K, by means of a neatly arranged three-way casting, H. At the lower end of the bunsen tube, and immediately above the burners, is placed the superheater, L. This is a broad, shallow, cast-iron chamber, so arranged that the whole of the gaseous mixture passes over a wide heating surface. The mixture is then passed on to the nozzles in a highly superheated condition.

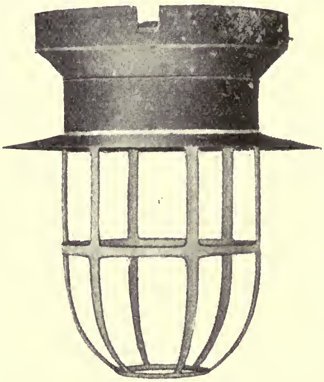


Fig. 514.—Pintsch Mantle Guard.

The flame temperature is still further increased by preheating the secondary air. This passes through the chamber, V, just above the burners, and down round the outside of the mantle protectors. An incidental but very real advantage of this is that the inflowing secondary air cools the chimneys and keeps them from melting by reason of the great heat generated.

The mantle used is of considerable size, and requires a consumption of six cubic feet of gas per hour to keep it well filled and give the best results.

The gas and air adjustments are both made from the exterior of the lamp. The gas is regulated by means of the knob, Y, which actuates the needle plunger by means of a lever working in a slotted collar at the upper end of the needle. The air supply is adjusted by means of the knob, R, and the screwed plunger working on the bunsen tube.

The lamp is made in three sizes, containing two, three, or four burners of 250 candle-power each at a pressure of two inches head of water. An efficiency of over 40 candles per cubic foot of gas has been obtained by the author with this lamp.

The Dacolight Lamp.—A lamp which has recently been introduced, being shown, indeed, for the first time at the Smoke Abatement Exhibition in London in March of the present year, is the "Dacolight" of Messrs D. Anderson and Co. This lamp, which is shown in Fig. 516, has several interesting and special features. Contained within the body of the lamp is a circular cast-iron chamber, A, into which the primary air for the bunsen is admitted through baffled air ports, P, one of which is shown on the opposite side to that of the control door, F. This chamber, which is heated by the rising products of combustion from the burners, serves two very important

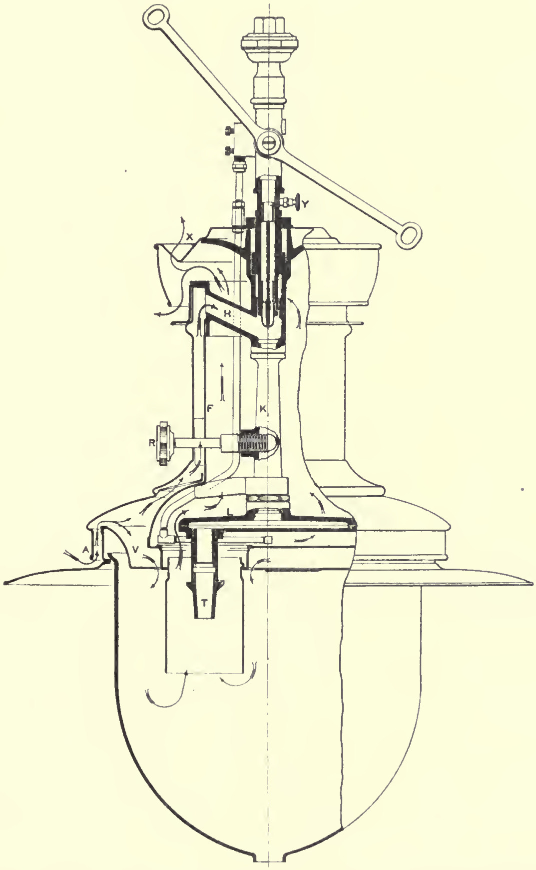


FIG. 515.—Sugg's 1911 Lamp: Part Sectional Elevation.

purposes. In the first place it serves as a heating chamber for the primary air supply. In the second, the contained air being free from any oscillation due to the action of wind, a constant supply of air at constant pressure is available for the bunsen tube, and so objectionable flickering is avoided.

Access to the gas nipple and air adjustments is obtained by the simple opening of the control door, F. Whatever the number of burners in the lamp, only one nipple is used. To this is attached a spring plunger for the purpose of occasionally clearing the nipple of

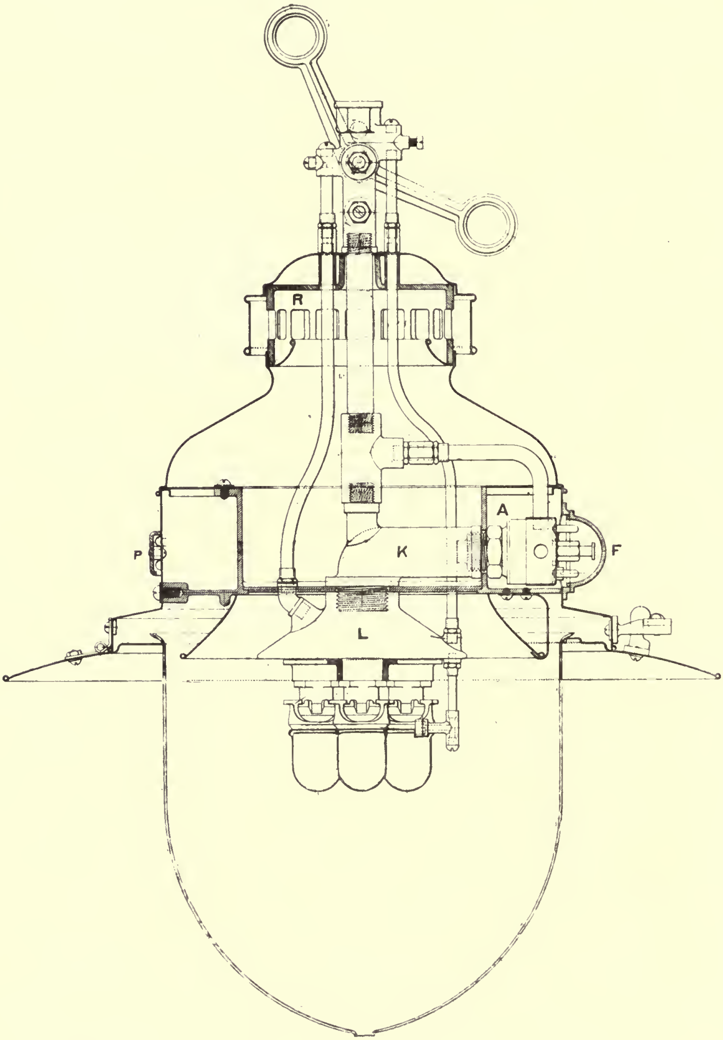


FIG. 516.—Anderson's "Dacolight" Inverted Lamp.

dust or obstruction. The bunsen tube, K, is common to all the burners, and is connected to the shallow cast-iron preheater, L, to the lower side of which the burner nozzles are attached. The preheater may be so divided as to give sectional control for reducing the number of burners in use after midnight, if required.

The products of combustion pass away through the cast-iron perforated radiator, R. This not only allows the escape of the heated gases, by means of the ports, but also, by reason of its mass, and the ready radiation and conduction of heat from it, serves to keep the lever cock cool.

The other features of the lamp are of a more ordinary character, and will be readily understood by those who have followed the preceding descriptions of other lamps.

One feature common to nearly all the inverted lamps described in this chapter is the heavy character of the burner and immediate accessories. The temperature attained in these burners is so high, that, in order to preserve the life of the burner, it is necessary to provide for the rapid conduction of heat from the nozzle and adjacent parts. This end is achieved by means of the mass of metal to which reference has been made.

Controlling from a common centre.—One of the great advantages enjoyed by the electric lighting system has undoubtedly been the facility with which a large number of lights, either for indoor or outdoor illumination, could be controlled from one point. The possibility of simultaneously lighting and extinguishing a large number of centres of illumination by means of a single switch, when compared with the slower and more tedious method usually employed in connection with gas, has long been felt, in many circumstances, to constitute a heavy handicap for gas.

The great difficulty experienced has, of course, been the practical inconvenience of having long lengths of piping open to the air when the gas was turned off, and the nuisance involved in having to expel the air from the system each time the lights were required before the gas could be ignited. Such inconvenience was not very serious in connection with the old "Sun" burners of a large hall, in which a large number of small jets, supplied by a single pipe, were clustered together in a very restricted area, but it is absolutely fatal to the modern conditions of incandescent lighting.

The ingenious way in which Messrs. Wm. Sugg and Co. have surmounted this obstacle is seen in Fig. 517, which shows a section through the mercurial seals. The object of this apparatus is to prevent the admission of air to the gas pipe system when the main cock which controls a number of lights is shut off, and thus keep the pipes continually charged with gas.

The illustration shows the double seal, in one instrument, for the supply and flashlight pipes respectively. When the gas is turned on to the main supply pipe, the pressure is exerted beneath the bell of the mercury seal, and lifting it clear of the liquid, gives a free and unimpeded gas-way. When, however, the gas is turned off and the pressure falls, the bell descends into the mercury and effectually seals the pipe until the gas is once more turned on.

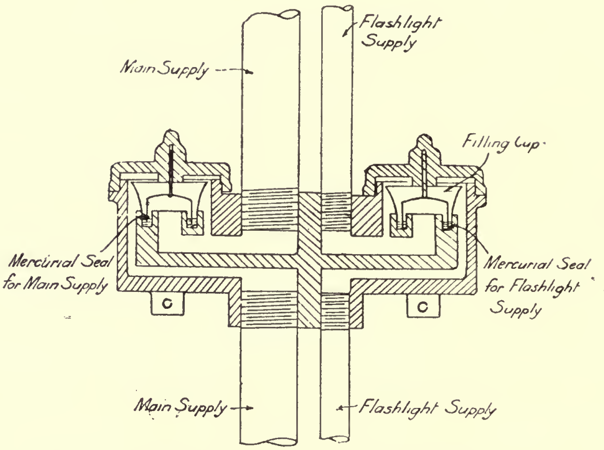


FIG. 517.—Wm. Sugg and Co.'s Mercurial Seal.

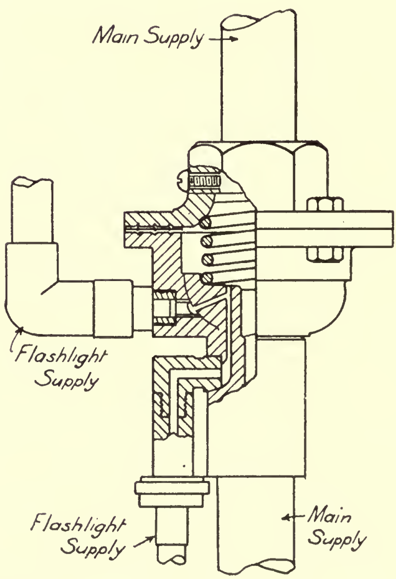


FIG. 518.—Wm. Sugg and Co.'s Special Cup and Ball Joint.

A similar arrangement is applied to the flashlight supply pipe shown on the right-hand side of the illustration. This seal is set to close at about 5-tenths or 6-tenths pressure, and consequently is readily lifted by the ordinary pressure in the mains.

Fig. 518 shows an enlarged section through the specially designed cup and ball joint of Messrs Sugg and Co., illustrating the attachment of the flashlight supply to the movable joint from which the lamp is suspended. The cup is strengthened upon one side to receive the flashlight supply tube, the gas from which is carried, by means of a special passage, through the cup portion of the joint, and out again from the joint, by the channel shown, to the flashlight tube continuation. The two gas supplies are kept altogether separate and distinct, although both pass through the same joint and receive in common the extent of movement permitted by the joint.

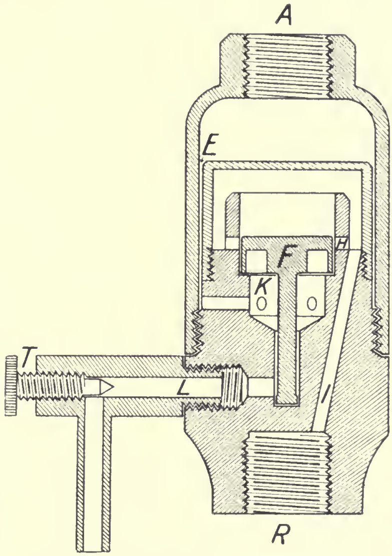


FIG. 519.—Sugg's Low-Pressure Distance Controller.

Another type of distance lighter recently introduced by Messrs Sugg and Co. is shown in Fig. 519. This is of the "dry" kind, the place of the mercury seal being taken by a brass float. The controller is adapted to either upright or inverted burners, that in the illustration being the inverted type. The main cock controlling the gas supply to the lamp is fitted with a small by-pass tap, adjusted to pass only the quantity required for the pilot light. From this the gas, entering at A, passes down the annular space, E, between the outer casing and the metal cap to the under side of the float, F, and from thence through the annular space round the stem of F, through pilot tube, L, to the pilot light. The gas for the latter is adjusted by the screw, T.

When the main tap is turned on, and full pressure admitted to the under side of the float, F, the latter is lifted until the bottom edge of the float clears the ports, H. The gas then has an unrestricted flow through H, the channel, I, to the outlet, R. At the same time, the bead on the lower part of the float shaft is lifted above the channel to the tube, L, and partially closes the vertical passage to the by-pass tube, and thus, while keeping the pilot alight, very considerably economises the consumption of gas.

CHAPTER XXIX

PUBLIC LIGHTING—HIGH-PRESSURE SYSTEM

So far as we have gone in our consideration of methods of street lighting, the apparatus required has been of the simplest possible description. The lamps have been self-contained, and the burners supplied at the ordinary pressure from the street mains. With high-pressure lighting, however, this condition of simplicity is altered to a large extent, and various kinds of apparatus of an auxiliary character become necessary. There must be some means provided for raising the pressure of the gas to the required extent; a special system of distribution to carry the compressed gas from the pressure raiser to supply the various lights; special burners for efficient combustion; and other accessories of a special character. But, notwithstanding the additional complication and cost, the illuminating effect obtained is so high, compared with the consumption of gas, that the first expense has been readily incurred for the sake of the additional advantages received.

How increased illumination is obtained.—It may be interesting to ask what is the source of the increased duty obtained from high-pressure gas? How is the greater illuminating power evolved? The answer to these questions is fourfold. First of all, the mere fact of the gas issuing from the ejector at a high pressure, and therefore high velocity, induces a far greater flow of air through the primary air ports. In fact, so much air may be drawn in that no secondary air is required for combustion. The cooling of the mantle by a secondary air supply is therefore avoided.

It is obvious, however, that such a mixture of gas and air is a highly explosive one, and therefore a high velocity of travel of the mixed gases is necessary to prevent the flame striking back. This tendency to light back is partly neutralized, of course, by the gauze in the head of the burner. The velocity of flow, therefore, plus the resistance offered by the gauze, must be greater than the flame velocity. In the inverted type of burner the disposition to strike back is increased by reason of the direction of flow being opposed to the force of gravity.

The mixture of gas and air under pressure, in the proper proportions for combustion, under conditions which are calculated to produce a perfectly homogeneous mixture, also tends to produce perfect combustion, or in other words, to generate the highest possible temperature from the combustible material. It has previously been pointed out that the amount of light obtained from an incandescent mantle is dependent upon the temperature of combustion.

In high-pressure lighting the combustion is greatly intensified by being brought about in the smallest possible compass. The generation of heat, and, therefore, the evolution of light from the mantle, is highly concentrated. Dr Bertelsmann has said that "the high-pressure gas flame is sharply differentiated from the ordinary bunsen flame. The core of the high-pressure flame is turquoise blue in colour, stumpy, and only about one-twentieth of the size of the whole flame. The size of the flame is only about one-third of that of the ordinary bunsen flame for the same quantity of gas, and hence the outer surface of the latter flame is about $4\frac{1}{2}$ times as great as that of the high-pressure flame. The heat radiated from the flame, being proportional to its outer surface, is about four times as great with the high-pressure flame as with the bunsen flame. This reduction of the loss of heat is the fundamental reason of the higher temperature of high-pressure gas flames in general."

Also, the mixed gases are brought to the point of combustion at as high a temperature as possible, the heated products of combustion being in one form or another employed for this purpose. In this way, part of the absorption of heat in raising the gases to the temperature of combustion is avoided, and higher temperatures are attained.

To sum up then, the increased illumination is secured by means of (*a*) a greater proportion of primary air; (*b*) a more homogeneous mixture; (*c*) concentration of combustion; and (*d*) preheating of the gaseous mixtures.

Comparison of costs.—In view of the keen competition now proceeding in many of our large towns between high-pressure gas and electricity for street lighting, and the necessity of making frequent comparisons of cost, it may not be out of place to discuss the matter briefly here.

In all such cases there are certain data which are the basis of all such calculations. They may be summed up under three heads, namely—(*a*) capital cost; (*b*) running charges, and (*c*) maintenance.

With regard to running charges the data are as follows:—

Electricity.—Carbon filament lamps require 3.5 watts per candle-power.

Metallic filament lamps require 1.2 watts per candle-power.

Arc lamps require 1 watt per 3 candle-power.

A metallic filament lamp has an average life of 1000 hours. 1000 watts exerted over one hour = one Board of Trade unit.

High-pressure gas.—Keith high-pressure gas lamps give 60 candle-power per cubic foot of gas consumed. This is the makers' claim; but the author's experience of over twelve months with upwards of 70 of these lamps, of 1500 candle-power each, shows that it is an understatement, the consumption being less than the claim. The cost to light, extinguish, clean, and maintain these lamps is 30s. per lamp per annum.

In Leeds the attempt to compete with high-pressure gas by means of electric arc lamps has been frankly abandoned, and clusters of metallic filament lamps are being tried.

It may, therefore, be well to work out the hopeless position of electric light competition on these lines. Assume that 50 lighting units of 1000 candle-power each are required, and that in the electric cluster there are five lamps of 200 candle-power each. The comparative costs, then, are as follows :—

Electricity : Capital Cost.

	£	s.	d.
50 × 5 metallic filament lamps @ 4/5 each net . . .	£55	4	2
50 lanterns @ (say) £2 net	100	0	0
	£155	4	2

Gas : Capital Cost.

	£	s.	d.
50 1000 c.p. Keith h.-p. lamps @ £4 14s., less 25 %,	£176	5	0

Electricity : Running Charges.

$$\frac{50\left(\begin{smallmatrix}\text{No. of}\\ \text{lamps}\end{smallmatrix}\right)\times 1000\ (\text{c.p.})\times 1.2\left(\begin{smallmatrix}\text{watts per c.p.}\\ \text{per hour}\end{smallmatrix}\right)\times 3640\left(\begin{smallmatrix}\text{Hours lamps}\\ \text{alight}\end{smallmatrix}\right)}{1000\ (\text{watts per unit})} =$$

	£	s.	d.
218,400 units @ 1¼d. per unit (price charged for street lighting in Leeds)	£1,137	10	0

Gas : Running Charges.

50 (No. of lamps) × 17 (cubic feet per hour per lamp) × 3,640 (hours lamps alight) = 3,094,000 cubic feet gas used.

50 pilot lights at 4000 cubic feet each per annum = 200,000 cubic feet.

	£	s.	d.
3,294,000 cubic feet of gas @ 2/2 per 1,000 cubic feet, less 5 %	£339	0	2

MAINTENANCE.

Electricity : Renewal of Lamps.

50 (No. of lanterns) ×.5 (No. of lamps in each lantern) × 3.6 (No. of renewals per year on basis of 1,000 hr. life) = 900

	£	s.	d.
900 lamps @ 4/5 each net	£198	15	0
50 globes (1 per lantern per annum) @ 10/- each . .	25	0	0
Add depreciation, 10 % on capital cost . . .	15	10	5
Labour costs @ 6/- per lamp per annum . . .	15	0	0
	£254	5	5

Gas.

	£	s.	d.
50 lamps @ 30/- (cost of lighting, cleaning, and maintenance per lamp per annum)	75	0	0
Add depreciation @ 10 % on capital cost . . .	17	12	6
	£92	12	6

Tabulating these totals we obtain :—

	Capital Cost.	Running Charges.	Maintenance.
Metallic filament lamps,	£155 4 2	£1137 10 0	£254 5 5
Keith high-pressure lamps	£176 5 0	339 0 2	92 12 6

Showing, for gas, with an increase in capital expenditure of only £21, 0s. 10d., a total saving in running costs and maintenance of £960, 2s. 9d. per annum over the 50 lamps on the basis of equality of candle-power supplied.

For the purpose of this comparison, the wattage of the metallic lamp claimed by the electric industry has been taken. There can

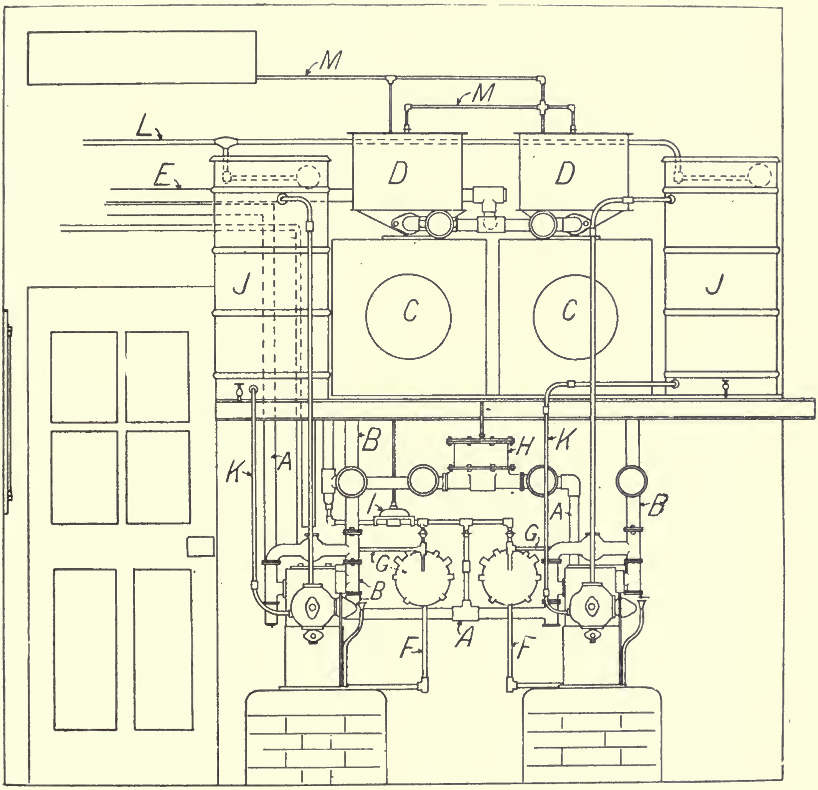


FIG. 520.—Wm. Sugg and Co.'s Compressing Plant: Elevation.

be little doubt, however, that a consumption of 1.2 watts per candle-power is far too low. Mr Jacques Abady, a disinterested investigator, has recently put it at 1.59 watts per candle-hour. He found, as the result of a large number of experiments, on lamps varying from 16 to 100 candle-power, that the maximum duty obtained was 1.42 watts per candle; that the minimum duty was 1.81 watts per candle; and that the mean duty was 1.59 watts per candle. He also points out that the candle-power of metallic filament lamps is generally overstated. "Most of these lamps have their genesis in Germany, where the candle-power is the Hefner, which is only 90 per cent. of an English candle-power. In their export to this country the 'Hefner' candle-power figures are set out in the English lists, whereas they should, of course, be reduced on this account by 10 per cent."

Of the many systems of high-pressure lighting now before the public, probably the best known are those of Messrs Wm. Sugg and Co., Limited, the James Keith and Blackman Company,

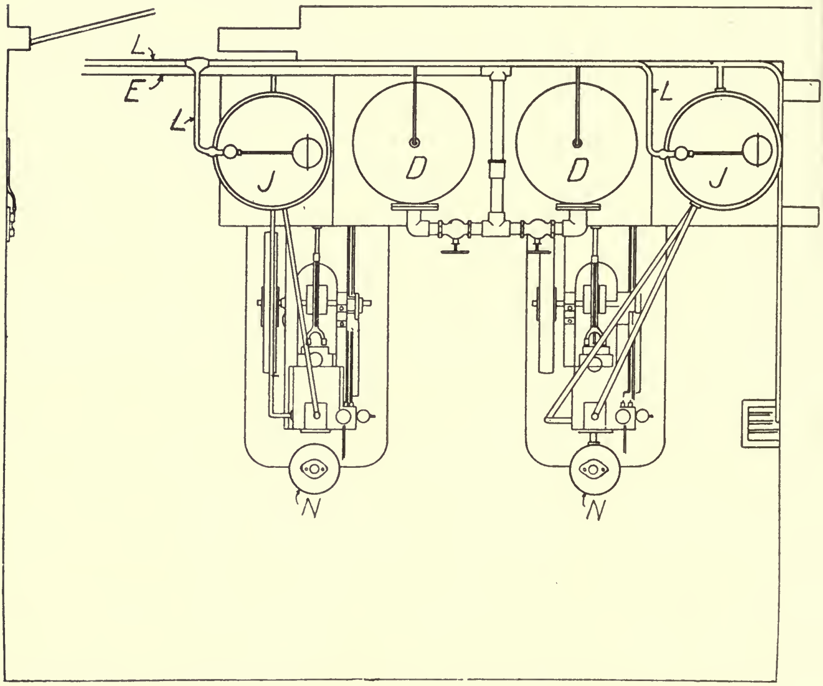


Fig. 521.—Wm. Sugg and Co.'s Compressing Plant: Plan.

Limited, the "Pharos," the "Selas," and the system of the United Kingdom Lighting Trust, Limited; and the author proposes to give a brief description of these as typical of this class of work.

Sugg's system.—The general arrangement of the compressing plant of Messrs Wm. Sugg and Co. is shown in elevation and plan in Figs. 520 and 521, and this is the model on which most of their latest installations, working up to 60 inches pressure, have been fitted.

The plant, which is in duplicate throughout, derives its motive

FIG. 522.—Wm. Sugg and Co.'s High-Pressure Lamps at Buckingham Palace.

power, in this instance, from the gas engines, provided with silencers, N, shown upon the plan (Fig. 521). The low-pressure gas is brought to the compressing chambers by pipes, A A, and leaves it for the high-pressure gas containers, C C, by the pipes, B B. The gas containers act as gasholders or reservoirs. From the latter the gas supply is taken through the high-pressure cast-iron governors, D D, and thence passes away to the lights by pipe, E.

The supply of gas to the lights upon the circuit is, by means of these governors, regulated to a constant and uniform pressure.

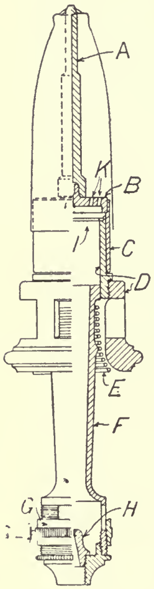


Fig. 523.—Part sectional elevation of Sugg's High-Pressure Burner, with Anti-Vibrator.

The low-pressure gas supply to the gas engines is shown in pipes, F F, and the connection to the gas engine burner is by the gas bags and tubes, G G. The high-pressure governors are fitted with relief valves and vent pipes, connected up to the low-pressure gas supply to the compressors, and the accumulation, through any temporary fault in the apparatus, of undue or dangerous pressure is thus effectually prevented.

The automatic by-pass valve, H, is adjusted to permit of a supply of gas at ordinary pressure to pass to the burners when the compressor is not at work.

The water tanks, J, supply the water jackets of the gas engines in the usual way, by means of the pipes, K K, and themselves receive their supply from water supply pipe, L.

The installation of high-pressure gas lamps in front of Buckingham Palace (shown in Fig. 522), carried out by Messrs Sugg and Co. some few years ago, has proved very successful. Altogether there are 28 lamps in this system. On each of the four pillars at the two Sovereign's gates (shown at the extreme left and right of the illustration), there are five lamps, four in the same horizontal plane, the fifth being raised above the others. The latter contains two 500 candle-power burners, and the four each contain one burner of the same capacity. The four lamps erected upon the railings between the two Sovereign's gates each contain two burners of 500 candle-power each, and surmounting the two columns at each of the ordinary entrances are fixed four other lamps, each containing two burners of the same candle-power as those upon the railings. The burners are supplied at about 16 inches pressure.

The direct driven compressor is worked by a $1\frac{1}{4}$ horse-power gas engine, the apparatus being duplicated as a precaution against any possible breakdown ; and the whole of the lamps are lighted simultaneously by starting the compressor.

The low-pressure burner of Messrs Wm. Sugg and Co. has already been fully described, and the high-pressure burner (shown in Fig. 523) does not vary very materially from the low-pressure type. There is a slight modification in the arrangement of the burner head, the sleeve, C, in this case fitting more deeply upon the upper portion of the bunsen tube, F, thus giving greater strength and rigidity to the burner head, while, at the same time, maintaining the facility of removal for purposes of cleaning the gauze, I. The arrangement and working of the anti-vibrator are the same as described in Chapter XXVII, in connection with Fig. 474. There is also a modification in the air supply adjustment, which, in the case of the high-pressure burner, consists of an internally threaded collar, G, which may be screwed up or down to lessen or increase the air supply apertures as may be required. When properly regulated, the collar is maintained in position by means of the set screw, S.

The high-pressure inverted lamp of Messrs Wm. Sugg and Co. is shown in part sectional elevation in Fig. 524. This has many of the excellent features of the 1911 lamp of this firm, every detail being designed to produce the greatest efficiency from the quantity of gas consumed. The high efficiency is attained by superheating both primary and secondary air as well as the gaseous mixture. Exactly how these objects are secured will be readily understood on reference to the illustration.

The primary and part of the secondary air supply enters the lamp just above the reflector, at A. Proceeding upwards, the air is heated by contact with the chimney cylinder, E. Entering the cast-iron bridge piece, H, the heated air is introduced into the mixing or bunsen tube, K, at the base of which is fixed a Keith superheater, L, fitted with diaphragm plate and thermostat, adjusted by the screw, I, as more fully described in connection with the Keith lamp later in this chapter.

The lamp is fitted with a stirrup-piece, V, removable nipple, T, and a bunsen flashlight. The latter is supplied by a governed by-pass, adjusted to pass 1 cubic foot in twelve hours. The air regulation is made at the knob, P, which actuates the screw plunger in the bunsen tube.

Another feature in the lamp is the cast-iron heat plate, X, fixed at the top of the chimney, which deflects the ascending hot products of combustion to the outlet at Y.

The lamp is fitted with the usual type of pointed globe for the more effective diffusion of the high illuminating power developed by it.

The Keith Compressor.—The Keith light, which, in its upright form, proved so successful in Queen Victoria Street and in front of the Mansion House, London, as well as in many places in the provinces, is now entirely superseded by the new high-pressure inverted Keith lamp.

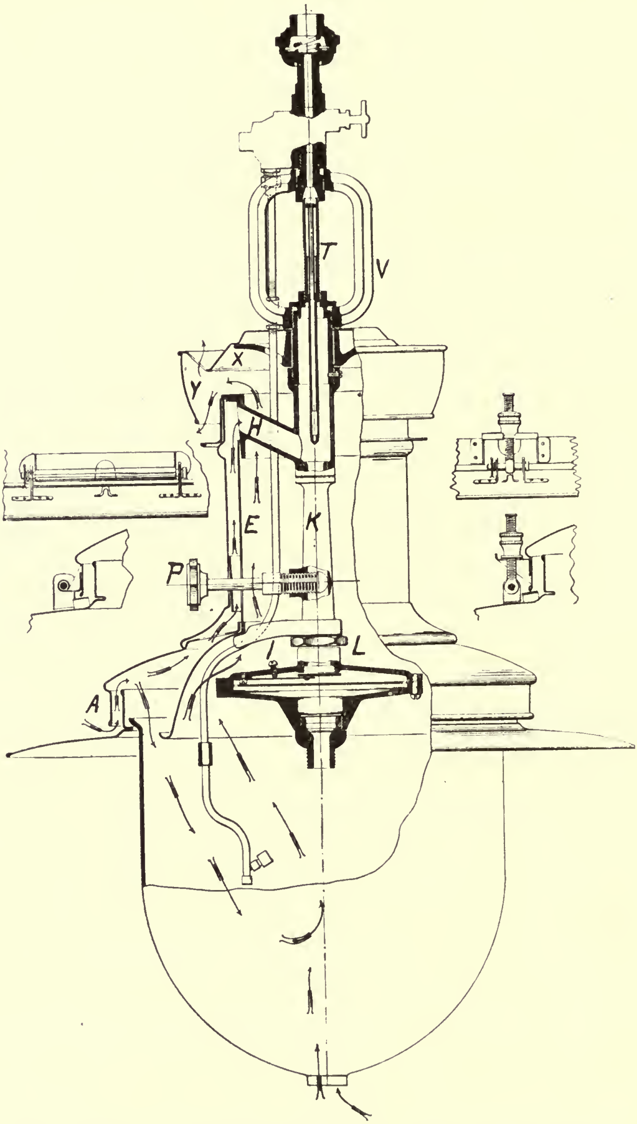


FIG. 524.—Part sectional elevation of Sugg's High Pressure Inverted Lamp.

The compressor used is a modification of the familiar rotary exhauster, in which special arrangements are made with the aim of reducing to a minimum the pulsations and consequential oscillations in the flow of gas.

As will be seen on reference to the sectional illustration (Fig. 526), the apparatus consists of two distinct parts, the basal chambers, P and Q, and the compressor proper. The separate chambers in the box base are intended to form a cushion in which any slight pulsations not corrected by the special arrangement in the compressor itself may be taken up.

The only communication between the inlet chamber, P, and the outlet chamber, Q, is by means of the by-pass valve, R. This is weighted to lift at any predetermined pressure, and pass gas from

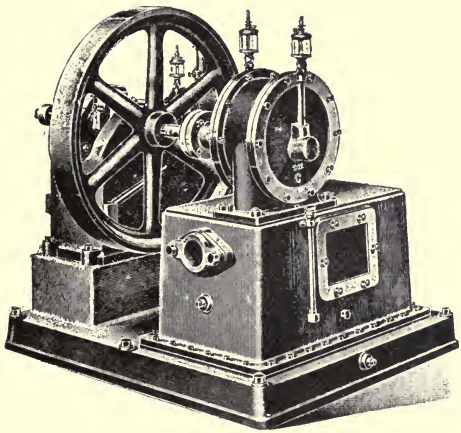


FIG. 525.—Elevation of Keith's Rotary Compressor, with Direct-Coupled Gas Engine.

the outlet to the inlet again should that pressure be exceeded, from any cause, in the chamber, Q. Resistance to vibration and sensitiveness of action is secured by means of the dash pot, U, filled with oil, which passes through the small passages, S, of the valve spindle. These channels are controlled by the screw, T. The whole valve and valve seating may be inspected, and removed, if necessary, through door, Y. A fresh supply of oil may be introduced to the dash pot as required through the tube closed by plug, J. As the valve spindle is always working in oil, there is no fear of it working stiffly, and the large area of the gas-way ensures instant relief immediately the valve commences to lift, without important fluctuations of pressure.

In the compressor proper, B is the outer casing and A, A are the blades. Unlike other rotary compressors, the blades in this are placed at right angles to each other, and are made hollow to reduce the weight and also the centrifugal effect. They are arranged so that the opposite blades almost completely balance each other.

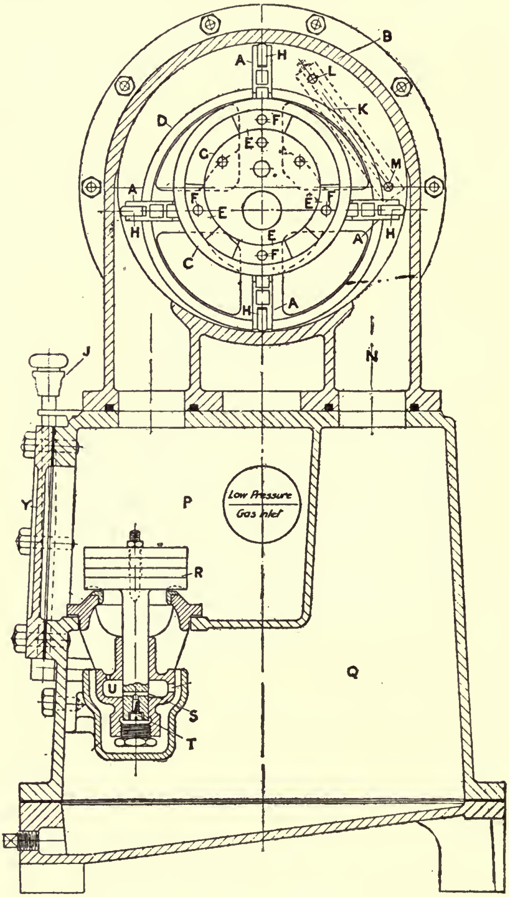


FIG. 526.—Section through Keith's Rotary Compressor.

Contact with the interior of the casing, B, is made by means of the sliding packing pieces, H, H, which are kept out to their bearing by centrifugal force.

The eccentrically placed drum, D, revolves in the same manner as in the older types of rotary blower, and the amount of slip at the ends of this drum is minimized by the insertion in one of the end covers of a piston ring, which is caused to press lightly on the end of the drum by a series of small springs. This not only allows a certain amount of play for the expansion which occurs as the

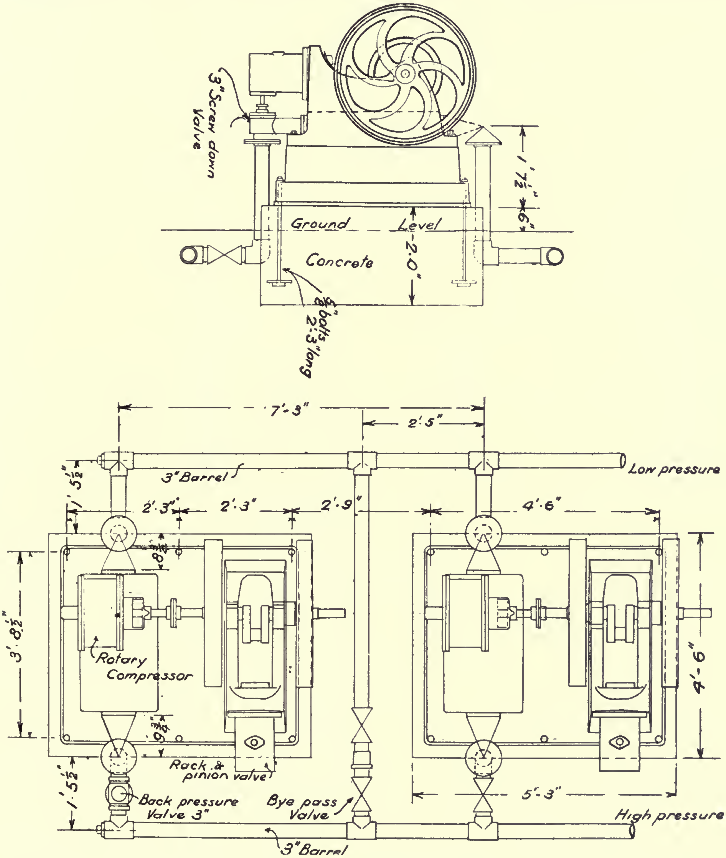


FIG. 527.—Leeds High-Pressure Plant: Plan of Compressors, Gas Engines, and Connections.

apparatus becomes warm in use, but also takes up automatically any possible end wear of the drum.

The balance of the blades is brought about by the use of a pair of floating rings, C, one of which is fixed at either end of the drum, with which they revolve, but in a circle concentric with the outer cylinder. At the inner end of each of the slides, A, gun metal segmental blocks, E, are fixed, which work on the steel pins, F. The outer sides of these blocks press against the inner surfaces of the rings, C, and so limit the centrifugal action on the blades. The opposite or inner surfaces of the blocks, E, are in contact with the discs, G, which are also fixed concentric with the outer casing, B, and act as guides for the blades, A. As the floating rings, C, revolve with the blades, they receive the pressure due to centrifugal force, and reduce frictional loss very considerably, whilst the inner discs, G, which, being fixed to the cover plates, are stationary, act merely as guides.

One of the novel features of this compressor is the arrangement of a special port, K. This, by means of the openings, L and M, is designed to minimize the pulsations which always occur in this type of apparatus, owing to the sudden compression which takes place as the gas between each pair of blades is brought round to the discharge. The object of the device is to minimize the shock of the

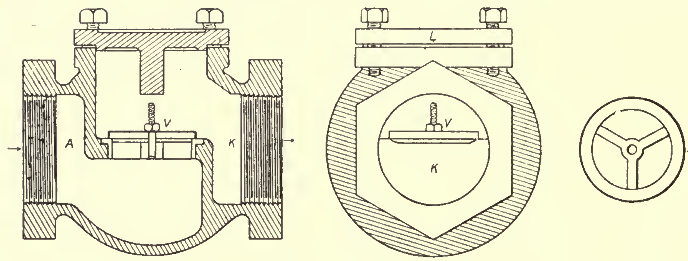


FIG. 528.—Keith's Back-Pressure Valve.

sudden compression, by feeding the space between the blades gradually, and for this purpose the opening, M, is always in connection with the discharge port, N.

The end plates are jointed to the body of the compressor by means of a rubber ring, which loosely fits into a small groove turned in the flange of the casing, and stands proud of the flange until compressed by the tightening up of the cover plate bolts.

This compressor is capable of working up to 5 lbs. per square inch, but the lighting is usually carried out at a pressure of 4 inches mercury, or, approximately, 2 lbs. per square inch.

Fig. 527 shows the foundation plan, side elevation, and connections of the Keith compressors used in one of the Leeds installations of high-pressure plant, that in Duncan Street and New Market Street.

This consists of two "D" type compressors, each of a capacity of 4000 cubic feet per hour, driven by two "National" gas engines of six horse-power. They are housed in a temporary brick structure, erected on Corporation land at the corner of New Market Street and Kirkgate. Although the plant has only been put down about twelve months there are already 22 public lamps of 1500 candle-power each and over 40 private lamps of 1500 candle-power each connected, and orders and inquiries are continually coming in.

A section through the back-pressure valve is shown in Fig. 528.

The object of this is, of course, to allow low-pressure gas to pass during the time the compressor is not running, for the purpose of maintaining the pilot lights in the public and private lamps. The low-pressure gas enters at A, and lifting the valve, V, passes on to the outlet. As soon, however, as the compressor is started, the high-pressure gas, coming back through K, presses the valve firmly on to its seating, and thus prevents passage of high-pressure gas back to the inlet of the compressor.

One of the disadvantages which came out in working the plant was that the gas-engine had always to be started under full load. There is no loose pulley, the compressor shaft being coupled

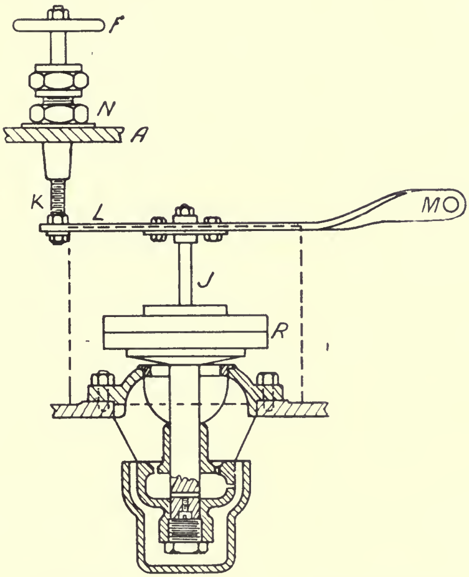


FIG. 529.—Keith's Valve Unloading Device.

direct to the driving shaft of the engine. The difficulty has now been overcome by the simple device shown in Fig. 529. This is fixed immediately above the weights, R (shown in Fig. 526), and consists of a weight lifting device, which takes the load from the by-pass valve, and so allows the compressor to revolve in its own gas without compression.

The top plate of the basal chamber is shown in part at A. Through this an internally and externally threaded boss is screwed and secured by the back nut, N. Through this a screwed shaft, K, actuated by the wheel, F, is inserted and the lower end attached to the lever, L, which has its fulcrum at M. From the lever, L, depends the shaft, J, which passes through the weights, R. The weights are free to move vertically without the shaft, J, but the shaft in moving upwards must lift the weights.

The action is, therefore, very simple. When it is desired to start the compressor the wheel, F, is turned from left to right, thus unscrewing the shaft, K, which rises, and in rising lifts the lever, L, and with it the shaft, J, and consequently the weights, R. The by-pass valve is then fully open and the compressor blades in revolving simply pass the gas from the outlet to the inlet chamber through the

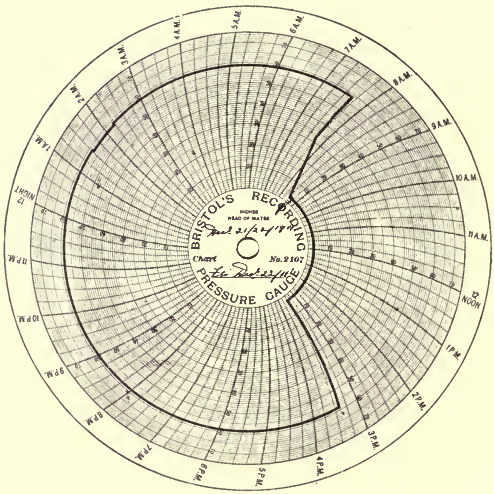


FIG. 530.—Leeds Pressure Chart.

valve. When the engine is satisfactorily running, the wheel is screwed down until the weights are released and are berthed upon the valve. The valve then being loaded no gas can pass from the outlet to the inlet chamber until the pressure in the former is sufficient to lift the weights, or, in other words, until the maximum pressure is attained at which the compressor is adjusted to work.

The satisfactory way in which the compressors work is shown by the regular line on the pressure chart reproduced in Fig. 530.

The Keith lamp.—One of the most recent developments in high power inverted gas lamps is the Keith lamp, shown in Figs. 531 and 532.

The body of the lamp, which is double cased, is suspended from the ball joint, G. From the latter depends the flashing by-pass cock, the details of which are shown to enlarged scale in Fig. 532. The injector, I, is attached to the connecting piece, K, the set screw, L, effectually preventing any accidental unscrewing of the lamp.

The bunsen tube, T, passes downward through the body of the lamp, the air supply entering at M being controlled by the screw, W, which is operated from the outside of the lamp casing, and which throttles the clear way of the tube to the extent desired.

The unique feature of the lamp is the heater, C, which is fixed immediately above the burners and at the lower end of the mixing tube. The heater is a broad, shallow chamber, made up of two flat

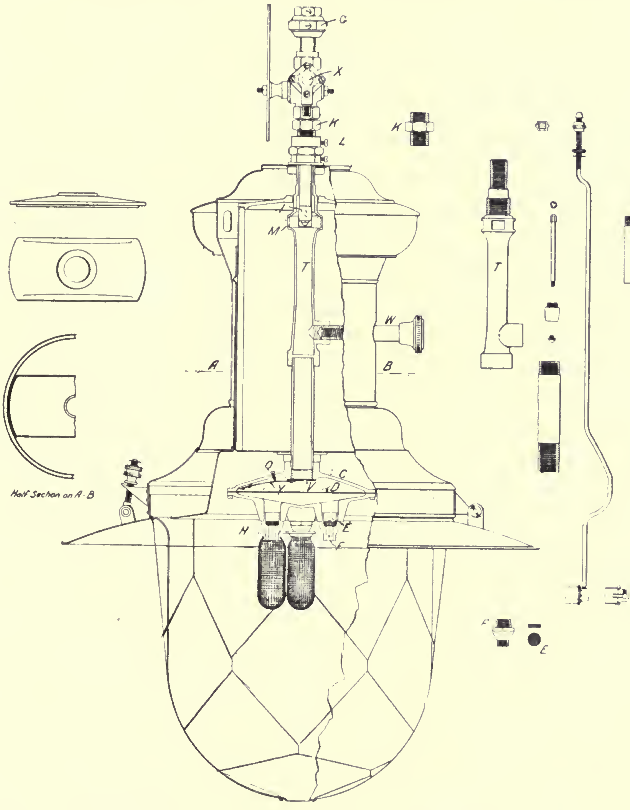


FIG. 531.—Keith's 1500 Candle-Power H.-P. Lamp: Sectional elevation.

cones placed base to base, between which is fixed a metallic diaphragm, D, pierced with a ring of small holes near its outer edge. When the lamp is in use, this diaphragm, together with the whole chamber, C, becomes very hot, and the descending mixed gases, spreading over the diaphragm and passing through the perforations on the way to the burner, become highly heated.

Thermostat.—An ingenious arrangement, depending upon the differing expansibility of metals, is used in lamps of over 500 candle-power to automatically check the air supply when the lamp is first lighted. This thermostat, Y, is constructed of two strips of metal, one being of brass and the other an alloy with a low coefficient of expansion.

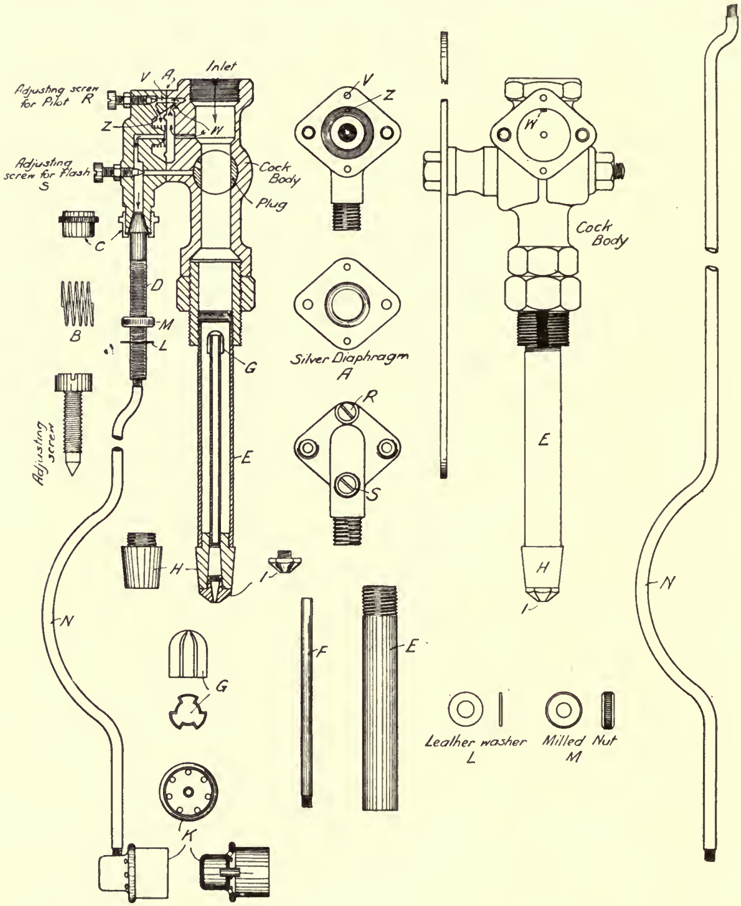


Fig. 532.—Keith's Lamp: Details of Governed Flashing By-pass.

The brass is placed uppermost, and the compound strip is fastened at one end to the outer edge of the heater, C, the free end carrying a disc, V, which is placed across the lower end of the mixing tube. The distance between the disc and the tube is adjusted by means of the set screw, O. The action is as follows: Before the lamp is lighted the thermostat occupies the position to which it is adjusted by means of the set screw, O, and retards the flow of the mixed gases to that extent. Seeing that the gas supply is constant, the retarding action tends to diminish the air supply. When, however, the lamp is lighted up, and the chamber, C, becomes hot, the greater expansibility of the brass strip makes the thermostat curl away from the mouth of the mixing tube, leaving a clearer passage for the descending gases. This reacts again on the character of the mixture, by inducing a larger air supply until the proper mixture is obtained. The action of the thermostat is, therefore, quite automatic, and is intended to ensure the lamp lighting up quietly and the due protection of the mantle.

The nozzle, F, is fitted with the gauze, E, and is screwed upon its exterior to receive the mantle ring, H.

The globe is placed in a hinged gallery, from which it may be easily removed for purposes of cleaning.

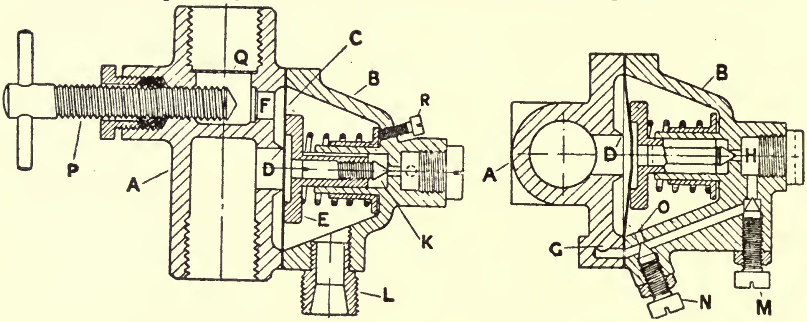
These lamps may be fitted with either flashing by-pass cock, or with an automatic lighter actuated by an increase of pressure, for collective lighting.

By-pass cock.—The governed by-pass cock and by-pass governor are shown in Fig. 532. The operating part is a silver diaphragm, A, clamped between the flanges of the governor. At the back of the silver diaphram is placed the light spring, B. When the gas is under low-pressure, the diaphragm, A, allows a small quantity of gas to pass through port, W, along adjusting passage, V, through port, Z, and so away to the pilot light. When, however, high-pressure comes on, the gas passes along the same passages but the increased pressure, acting against the resilience of the spring, B, partly closes the outlet port on the by-pass side of the diaphragm. The pilot light is then lengthened, but only to about one inch in length. When, however, the lamp cock is turned, and the pilot light passage in it coincides with the flashlight channel, the flashlight is projected across the mantles and ignites the issuing gas. This flash is, of course, only a momentary one, as the revolution of the plug of the cock immediately moves the two channels out of alignment again, and the flash becomes once more a pilot light. The remainder of the construction will be easily followed from the illustration, the same parts being similarly lettered throughout.

Distance lighter.—The simultaneous lighting and extinguishing of a series of Keith lamps by means of the increased pressure given when the compressor is started is controlled by the automatic distance lighter shown in sectional plan and elevation in Fig. 533.

The lighter consists of two main parts, the valve body, A, and the cover, B. The valve seat, D, is constructed upon the former, to which is opposed a thin silver diaphragm, C, which is normally pressed upon the valve seat by the plunger, E, actuated by a spiral spring, as shown. The spring is arranged to resist pressures up to a predetermined amount. Assuming the instrument to be under low-pressure merely, the gas, entering at Q and passing through port, F, is debarred further progress by the valve, D. When, however, the compressor is started, and the pressure rises above the amount of resistance of the spring, the pressure forces back the metallic diaphragm, C, as shown in the sectional plan, and gas is allowed to pass through the valve, D, to the outlet. When the compressor is stopped and the pressure falls, the diaphragm, C, is again pressed against the valve seat, and the supply is cut off.

With any arrangement such as this, it is obviously necessary to control the pilot light arrangement, or the increase of pressure would



Sectional Elevation. Sectional Plan.

FIG. 533.—Keith's Valve, for Lighting and Extinguishing.

lengthen the small light maintained under low-pressure, which, of course, apart from its other objectionable features, would be very wasteful. The movement of the diaphragm in opening the valve on the one side is, therefore, also used to govern the pilot light on the other, by means of the small valve, K, fixed upon the rear end of the plunger, E.

In the valve body, A, a small port, G, is formed, which is always open to the gas supply both at high and low pressure. This communicates by means of the channel shown in the plan with the chamber, H. When the valve, D, is in the closed position, there is always a free gas-way from H, through the valve, K, to the interior of the cover, B, and thence to the pilot light through the connection, L, the quantity of gas passing being controlled by the adjustable screw, M. When, however, the pressure is increased and the valve, D, opened, the movement of the plunger presses the valve, K, upon its seating, and closes the passage at this point entirely. In order to maintain a small pilot light at high pressure, which can come into operation again under low-pressure conditions, and to exclude air from the pilot tube, a small port, O, is constructed in the cover, through which high-pressure gas can pass directly into the cover space. This port is controlled by a second adjusting screw, N.

By means of the screw down valve, P, which works through a stuffing box packed with asbestos cord, and closes down on to the valve seating prepared in the port, F, the gas may be shut off altogether from the back portion of the lighter. This arrangement allows of the cover, B, being removed for the examination and cleaning, when necessary, of the diaphragm, the valve seat, or spindle of plunger, without interference with any other lamp connected in the same series. The gauze at Q is inserted to prevent dust or other solid particles being deposited upon the valve seat, D.

Stirrup piece.—In order to facilitate the inspection and cleaning of the nipple when necessary, an ingenious modification of the

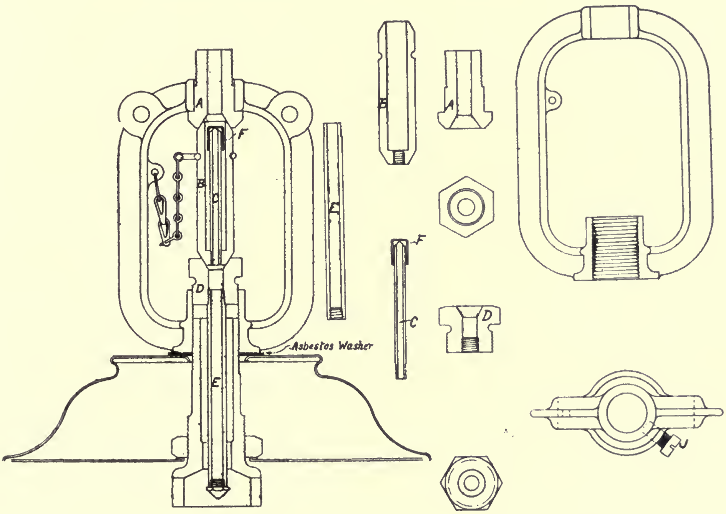


FIG. 534.—Keith Lamp Stirrup Piece and Accessories.

upper part of the lamp has recently been introduced. This consists of a stirrup piece, which, with its accessories, in shown in Fig 534. The device will be readily understood. The distance piece, B, fits tightly into the coned seating at top and bottom, shown on A and D respectively. On slacking the nut, D, the distance piece, B, is released, and may be removed. The boss, D, and injector, E, may then be unscrewed and removed from the lamp for cleaning.

The following table gives the results of tests of the Keith inverted lamp, made at the Edinburgh Exhibition in 1908 by Mr W. R. Herring :—

Pressure in Inches.	Height of Lamp from Floor.	Distance of Lamp from Photometer Disc.	Angle.	Foot-Candles at Photometer Disc.	Consumption per Hour in Cubic Feet.	Candle-Power.	Candle-Power per Cubic Foot.
	Ft. In.	Ft. Ins.					
61	4 9	40 0	4°	1.04	22.9	1655	72.2
61	16 0	42 1	20°	0.95	22.9	1685	73.6
61	20 0	28 9	37°	1.90	22.9	1572	68.6

These favourable tests of Mr Herring's have lately been strikingly confirmed in the report of Mr J. W. Bradley, M.Inst.C.E., city engineer for the City of Westminster, and published in the *Journal of Gas Lighting* of 16th January 1912, p. 157, from which the following particulars are extracted :—

Description of Lamp.	No. of Lamps in use of Class specified.	No. of Tests made during the Quarter.	Average Candle-Power per Lamp.	Total Cost per Candle-Power per Annum.
3000 candle-power lamps .	20	16	4118	1.23*d.*
1800 candle-power lamps .	173	12	2074	1.89*d.*

The total cost per candle-power per annum of the 1227 electric arc and flame arc lamps reported on worked out to 10.86d., while the 2912 high and low pressure gas lamps cost only 3.68d. per candle-power per annum. It will be seen, therefore, that this report, from a quite impartial engineer, constitutes one of the best of testimonials as to the economy of high-pressure gas for street lighting purposes.

Whilst considering the question of tests of lamps it is worthy of note that the distribution of light from a high-pressure gas lamp is far better for general illumination than that of the electric arc lamp. In a previous chapter we have seen that if equal illumination is to be obtained, the angles of greatest intensity must be those of 10° to 30° below the horizontal. In an article, to which reference has previously been made, Dr Bertelsmann gives the following table of distribution of light from high-pressure gas lamps and electric arc lamps on the basis of a mean hemispherical illuminating power of 3600 candles.

Angle.	High-Pressure Gas. Candles.	Excello Arc Lamp.	
		Yellow. Candles.	White. Candles.
Horizontal	3540	2287	2372
10°	3688	2656	2668
20°	3752	3099	3162
30°	3798	3748	3695
40°	3763	4324	4348
50°	3582	4559	4546
60°	3200	4707	4604
70°	3009	4457	4447
80°	2542	3335	3300
Vertical	2549	2538	2506

The polar curves shown in Figs. 535 and 536 amply confirm the tests of Dr Bertelsmann as far as these refer to high-pressure gas lamps. Fig. 535 shows the polar curve given by a 1000 candle-power Keith high-pressure lamp without reflector, and with all

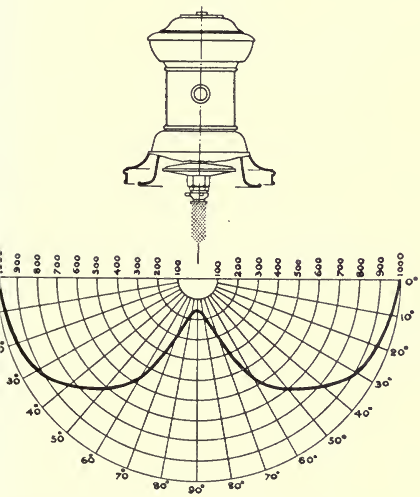


Fig. 535.—Polar Curve of Keith 1000 candle-power lamp without reflector.

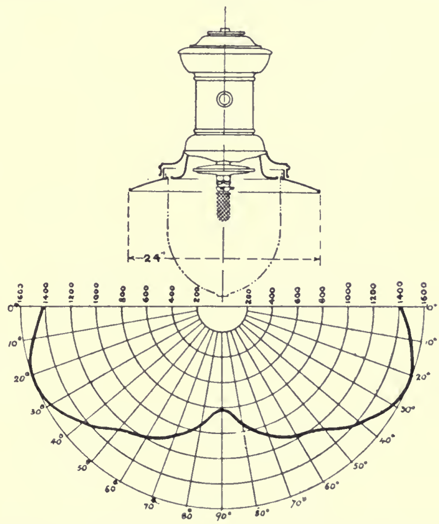


Fig. 536.—Polar Curve of Keith 1500 candle-power lamp with standard type of reflector.

reflecting surfaces blackened. When used in this way the light rays of maximum brilliancy are emitted along the horizontal line and are gradually reduced until the angle of 40° below the horizontal is reached. It is obvious, therefore, that a reflector must be used. Fig. 536 shows how this distribution of light is modified by the use of the standard reflector. Here we find the rays of light so reflected and deflected as to conform to the requirements already noted as necessary for good street lighting, namely, that the rays of greatest intensity must be emitted at angles between 10° and 30° below the horizontal.

Leeds lamp columns.—The lamp columns used in the Leeds public lighting installation are of Mannesmann steel, with a cast-iron base, as shown in Fig. 537. The distance from ground level to burner mantle is 16 feet 6 inches, and the lamps, which are of 1500 candle-power, are spaced 30 yards apart. They are placed near the edge of the footpath, on either side of the roadway, and are arranged on the hit and miss principle. The minimum illumination given at ground level is 0.358 foot-candles.

Cluster lamp column.—Considerable difficulty was experienced in obtaining a column suitable for the cluster of four lamps erected upon a passenger refuge. The details ultimately adopted are shown in section and plan in Fig. 538, which were made to the design of the author and proved thoroughly satisfactory.

Pintsch apparatus.—Another excellent high-pressure lighting system is the Pintsch apparatus of the Brimsdown Lamp Works, Limited, of Brimsdown, Middlesex.

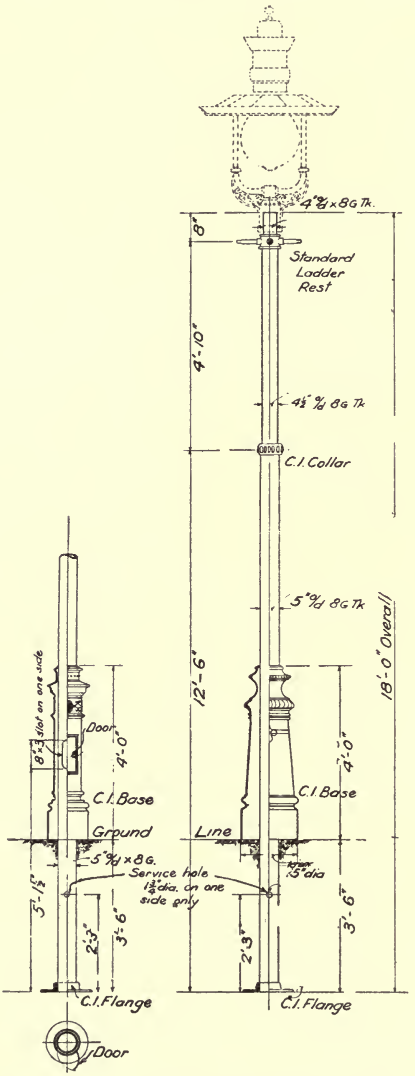


Fig. 537.—Single-Lamp Leeds Column.

The Pintsch compressor is one of the smallest and most compact in relation to its capacity of any known to the author. The general arrangement is shown in front and side elevation in Figs 539 and 540.

The compressor, A, is of the rotary type, the drum being placed

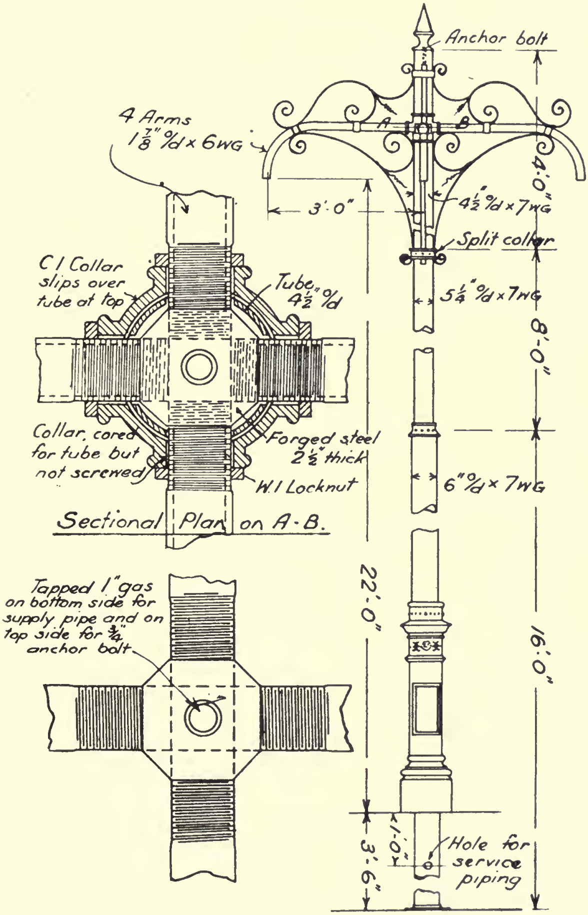


FIG. 538.—Column for Cluster of Four Lamps at Leeds.

eccentrically to the casing, as in the ordinary exhauster. It is fitted with eight to twelve blades, which are thrown outwards, and kept in intimate contact with the rotor lining by centrifugal force. The effect of the large number of blades, together with the very high speeds at which the rotor is worked, is to produce a regular delivery without the least oscillation. Each compressor is water jacketed, so that the covers and lower part of the casing may be cooled if and when necessary.

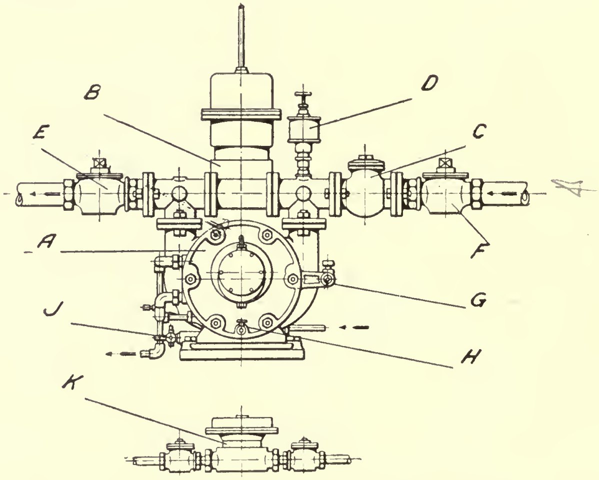


FIG. 539.—Pintsch Compressor: Front Elevation.

The gas enters the compressor by the main cock, F, and leaves by that shown at E. Between the two, and forming the by-pass connection, is the by-pass regulator, B. This is of the diaphragm type, and is exceedingly sensitive in action. The diaphragm is weighted to open when the standard pressure of 60 inches head of water on the outlet is from any cause exceeded, and allow part of the gas to pass back again to the inlet. C is the non-return flap valve. This opens and allows gas to flow through at normal pressure, but when high-pressure gas is being by-passed it closes, and thus prevents access of the compressed gas to the low-pressure main.

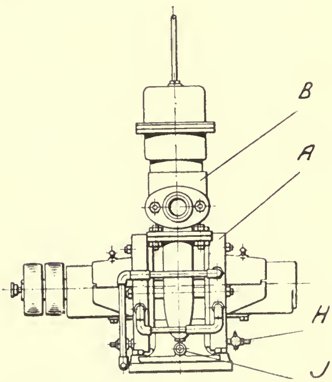


FIG. 540.—Pintsch Compressor: Side Elevation.

The non-return valve, K, fitted between the suction and pressure sides of the rotor, closes the passage between suction and pressure pipe when the compressor is started, thus preventing compressed gas working back to the inlet. As soon, however, as the compressor is stopped it automatically opens again, and allows low-pressure gas to pass for the maintenance of pilot lights in the day time. The following table gives details of capacities of, and power required for, the various standard sizes of the Pintsch compressors:—

Compressor No.	Revolutions per Minute.	Output, Cubic Feet per Hour.	Horse Power required.	Size of Connections.
I.	500 650 750	350 450 550	·5	$1\frac{1}{4}''$
II.	500 650 750	900 1050 1250	·75	$1\frac{1}{2}''$
III.	500 650 750	1600 2000 2300	1.125	2″
IV.	500	3550	2	3″
V.	500	7050	4	4″
VI.	500	14,100	8	5″

It will be noted that the speeds at which the compressors are run are from two to three times that of the ordinary rate of the usual type of rotary compressor.

The Pintsch apparatus may be used as a compressed air instead of a high-pressure gas system. The advantages and disadvantages of the alternatives are discussed later in this chapter.

The Pintsch high-pressure lamps, of which one is shown in Fig. 541, are strong, well made, and weatherproof, and the adjustments for both gas and air are accessible from the outside of the lamp. They may be fitted with either lever cocks or with the automatic Pinstch pressure lighter, which is operated by the starting and stopping of the compressor.

The action of the pressure lighter (shown in Fig. 542) is very simple. When the compressor is started, the pressure acting on the diaphragm lifts the valve and admits gas to the main burners, and at the same time closes the by-pass port. Before the latter is quite closed the by-pass flame is flashed, thus ensuring ignition of the gas at the main burners. When the compressor is stopped the reverse of this action takes place, the pilot light being ignited again as the main burners are shut off. The pressure air lighter works in a similar manner, the valves being actuated by high-pressure air instead of gas.

The "Pharos" light.—Another form of high-pressure lighting, which has aroused a good deal of interest in this country on account of the simplicity of the apparatus employed, the wide range of power of the burners which may be served, the small space occupied by

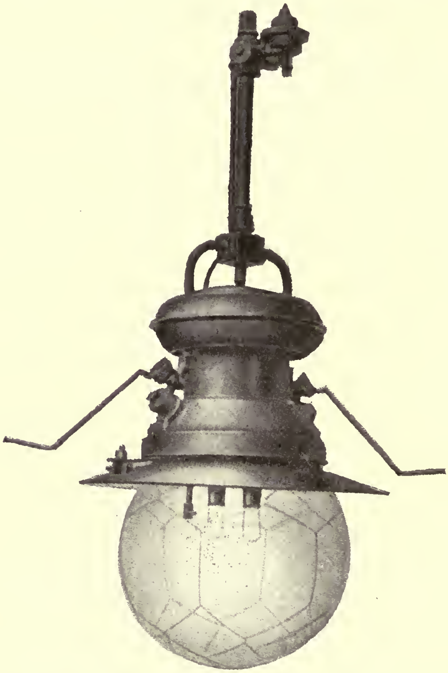


FIG. 541.—Pintsch 1500 C.-P. Lamp, with Automatic Lighter.

the compressors, and the high lighting efficiency developed, is the "Pharos" light, for which the Welsbach Light Company, Limited, are the agents in this country. This system may be applied as either a compressed gas or a compressed air system.

The "Pharos" gas compressor which is shown in Fig. 543, consists of the cast-iron hollow box, A, which forms the base carrying the electric motor, K, and compressor. The base box is divided by a partition into two chambers, one of which, *s*, serves as a reservoir for gas at ordinary pressures, or a suction chamber, and the other, *d*, as a receiver for compressed gas. The gas is admitted to the lower chamber by the inlet, *a*.

The extent to which compression is carried is regulated by means of a piston, *r*, which is held in place by a spring of calculated power equal to the pressure to which the gas is to be compressed. In the event of this pressure being exceeded, the piston valve is opened and gas passed from the outlet *h*, to the inlet, *b*, of the compressor until the balance is restored. The spring is usually adjusted to resist pressures up to 55 inches column of water, but gas may be supplied to the burners at a pressure of from 54 to 90 inches.

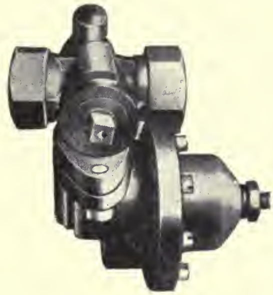


Fig. 542.—Pintsch Automatic Pressure Lighter.

The compressor, *c*, is of the rotary type, the well-balanced blades being pressed into close contact with the casing, partly by centrifugal force and partly by springs. The shafts revolve in gas-tight stuffing boxes, and a feature of the compressor is the very long bearings of hard bronze in which they run. To ensure freedom of running the cogwheels are enclosed in a cast-iron casing, which is utilized to provide

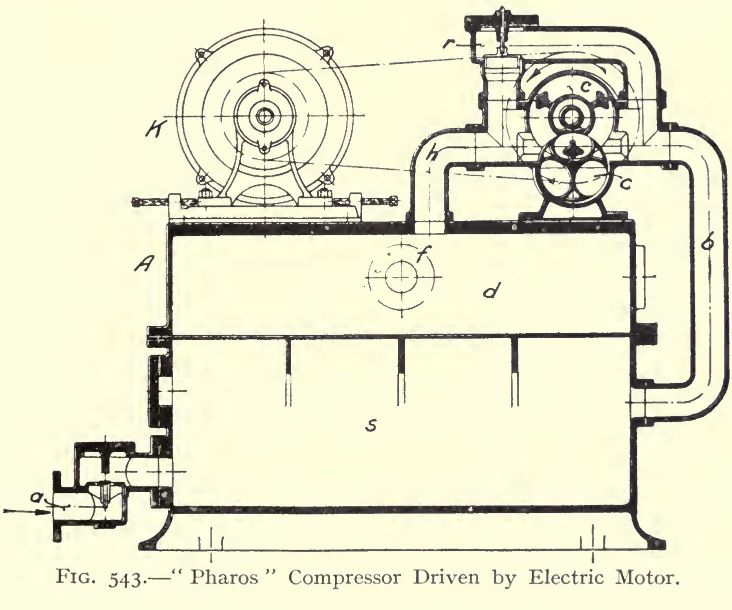


Fig. 543.—" Pharos " Compressor Driven by Electric Motor.

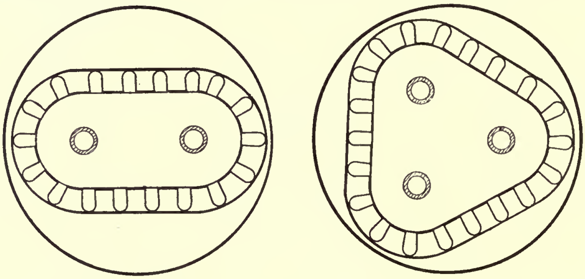
an oil bath for them. The compressor may be driven either from existing shafting, by means of a gas engine, or, as in the illustration, driven by a small electric motor.

A small pipe from the inlet or suction chamber to the pressure pipe is arranged to pass sufficient gas to keep the by-pass flames alight when the apparatus is not working.

The "Pharos" high-pressure gas lamp has several distinctive features quite its own.

The lamp is so constructed that all the air necessary for combustion is introduced into the gaseous mixture at the primary air ports. This arrangement eliminates the cooling of the flame temperature by an in-draught of secondary air, and also serves to keep the bunsen tube at a moderate temperature.

The air is introduced into the lamp just above the reflector, and passes into the heating chamber formed in the body of the lamp.



For two burners. For three burners.

FIG. 544.—Section through "Pharos" Lamp, showing Preheating Chamber.

To give as large a heating surface as possible, the heating chamber is constructed of a series of corrugations from the up-shaft, as shown in Fig. 544.

The air, after having passed through the pre-heater, enters through channels into the air ports of the burners, at which point the supply may be regulated as necessary by means of the screw, A. Before entering the bunsen tube the air is passed through a dust trap.

The position of the cock is so arranged that it receives no strain, and takes no weight of the lamp. By loosening a nut on the bottom of the cock the injector which carries the nipple can be taken out by a simple turning movement, the injector being in the form of a crank. The head of the burner can also be taken off from the bunsen tube, and the latter separated from the injector.

The burner head is made of chrome-nickel, drilled in such a way as to prevent lighting back. The clay nozzles supporting the mantles are screwed tightly upon the burner head.

As in other lamps of this type soft mantles are used, which are tied round the clay nozzles by asbestos thread. These mantles are of the auto-shape type, which adapt themselves to the size and shape of the flame. When a new mantle is required it is simply screwed into position, and left until the compressor is started, or high-pressure gas turned on, when the mantle is lighted up by the pilot and the mantle forms itself to the full pressure flame. No previous burning off is required.

The lamps are supplied either with a simple "Berlin" cock with swing lever, or fitted with an automatic lighter actuated by the high-

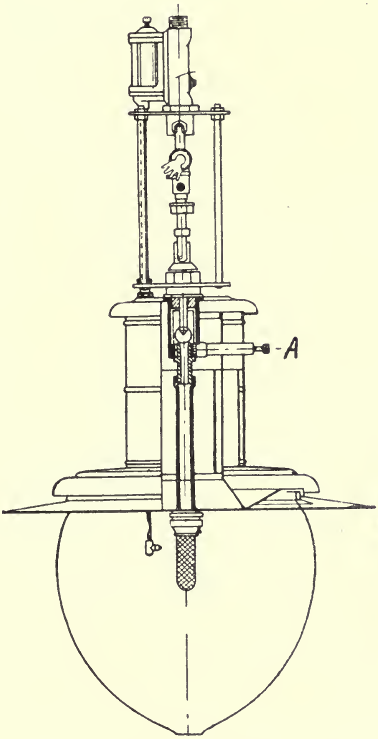


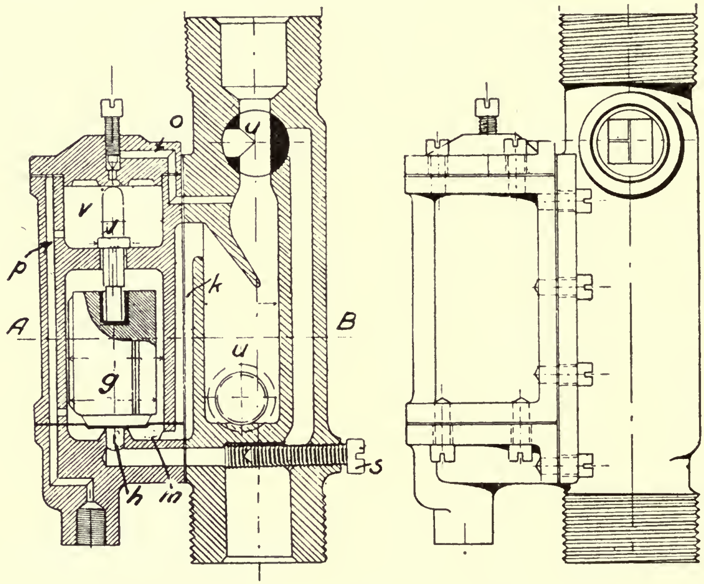
Fig. 545.—Sectional Elevation of "Pharos" Lamp.

Fig. 546.—General Elevation of "Pharos" Lamp.

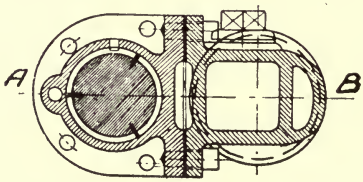
pressure gas. These may also be adapted to the case of multiple burner lamps for the purpose of turning off any number of the lights at any time by a simple wave pressure, produced by a temporary alteration of the regulator at the compressor.

One form of the "Pharos" automatic distance lighter is shown in Fig. 547. This consists of a weight laden flexible diaphragm, *m*, the weight, *g*, of which carries the valve, *v*. When the controller is supplied with low-pressure gas the lead weight, *g*, presses the diaphragm, *m*, upon its seating and closes the passage, *h*. At the same time, the valve, *v*, is open and the low-pressure gas passes through the by-pass channel, *o* and *p*, away to the pilot light.

When the high-pressure gas is turned on it passes down the channel, *k*, to the underside of the diaphragm, *m*, and, overcoming the down-



Sectional Elevation. General Elevation.



Cross Section along line AB.

Fig. 547.—" Pharos " Automatic Distance Lighter.

ward pressure of the weight, *g*, lifts the diaphragm, uncovering the passage, *h*, and passes away to the main burners. Simultaneously the lifting of the weight closes the valve, *v*, and shuts the gas off from the pilot light. The length of the valve is arranged so that the pilot is shut off a little later than the opening of the passage to the main burner.

The automatic distance lighter has also a by-pass, *u*, which can be brought into connection with the three-way valve, so that if the automatic distance lighter should not work, owing to any blocking up by napthalene or other particles, the high-pressure gas can be supplied direct to the burner. In that case the screw, *s*, must be withdrawn to permit the high-pressure gas free access to the burner.

The " Selas " light.—The method adopted in the " Selas " system, of the Selas Lighting Company, Limited, Manchester, is very different.

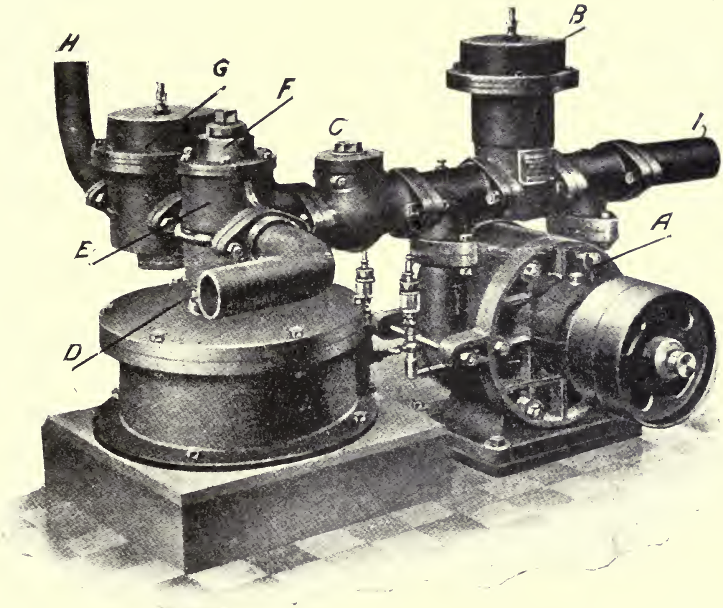


FIG. 548.—" Selas " Compressor and Motor.

It consists in mixing together definite proportions of gas and air. The actual proportions vary slightly according to the different calorific values of the gas in different districts, but usually in the ratio of 1 part of gas to $1\frac{1}{2}$ to 2 parts of air; and this mixture is passed to the point of combustion at a pressure which may be regulated at will.

The apparatus, which consists of a mixer and compressor of the rotary type, is exceedingly simple. The power required is $\frac{1}{2}$ to 1 horse-power for a plant supplying from 10,000 candle-power to 75,000 candle-power. The compressor may be driven from existing shafting, gas engine, electric motor, or water turbine.

The apparatus will be easily understood from Fig. 548. A is a rotary compressor acting as a suction on C, and delivering after a thorough compression into the service at I. The valve shown at C acts as a back pressure valve, so that the mixture, when compressed, cannot again obtain access to the mixer and thus unduly strain the diaphragms. B is a governor of the piston type, which controls the pressure at delivery. If the demand is only a small proportion of the capacity of the compressor, the piston is raised proportionately, allowing the excess to pass back to C, and thus prevents any further mixture of gas and air being drawn in. In that case, the gas and air is passed through the compressor over again. The mixer arrangement is a most ingenious piece of mechanism, though simple in action, and cannot be put out of order. Gas is admitted at H to governor, G, which consists of equilibrium valves to break up the inlet pressure to atmospheric pressure. D is the air inlet pipe carried to the atmosphere. Thus gas and air meet under atmospheric conditions. E is a cylindrical chamber, with ports which automatically open or close according to the demand of the compressor. F is a regulating valve allowing the mixture to be regulated to any desired composition, either richer or poorer, thereby providing for differing calorific values in the particular gas being used.

As the mixture already contains air, it is not necessary to draw in the same amount of air at the burner as in the case of pure gas; neither need the pressure be so high, as nothing like the same quantity of air has to be induced into the burner. Besides, the actual force and velocity of the mixture at the aperture of the nipple is greater than with pure gas; its specific gravity is greater, and as the aperture has to be larger on account of passing air as well as gas the force lost by friction is very much less. The result is that combustion takes place in the smallest possible space, which, in effect, produces a small, but intensely hot flame, an ideal flame for the purpose. The regulation of the burners is extremely simple, which is an important point in the case of factories, workshops, etc., where the lamps have to stand rough handling from the workpeople. All parts are easily removable for purposes of cleaning. The mantles, too, are put on "raw," and are much smaller than those ordinarily adopted, which gives them a low maintenance cost. A very successful installation of "Selas" lamps has recently been erected at the Manchester public abbatoirs.

The following advantages are claimed:—

(1) Owing to the small amount of extra air required at the burner, it will be apparent that the usual trouble from dust and fibre being drawn in at the air regulator in factories and dusty places, thereby choking up burners, is greatly minimised.

(2) Owing to the gas and air being thoroughly mixed, perfect combustion is obtainable, and consequently a high efficiency.

(3) The flame being small and intensely hot, a very small mantle can be used. Other things being equal, a small mantle is less subject

to breakage than a large one. The mantle expenditure is thus brought down to a minimum.

(4) Owing to the mixing of gas and air before entering the service pipes, less pressure is required to induce at the burner the remaining air necessary for complete combustion.

(5) It is claimed that an efficiency of not less than 50 candle-power is obtained on small candle-power lamps, and 65 to 70 candle-power on larger units.

(6) " Selas " is applicable to high candle-power gas, such as oil gas, with equally excellent results, the drawback of carbon deposits on the mantle from rich gases being entirely obviated.

(7) It is equally adaptable to high-pressure heating of furnaces, muffles, etc., off the same service.

United Kingdom Lighting Trust system.—In the high-pressure lighting systems of Messrs Wm. Sugg and Co., the James Keith and Blackman Company, and the " Pharos " we have seen that the compression is applied to the gas. In the " Selas " system a mixture of gas and air is compressed. In the alternative " Pharos " system, or the one now to be described, that of the United Kingdom Lighting Trust, Limited, the air supply only is compressed, the gas being supplied to the burner at ordinary pressure.

The compressor.—In this system the air is compressed, either by means of a hot air engine, or belt-driven rotary blower for large installations, or, in the case of smaller installations, by a hydraulic ram, A (Fig. 549), actuated by water pressure from the town's water mains, the supply from which enters the apparatus at D. The water is directed through the master valve, L, to act alternately above and below the ram, the exhaust water being discharged in each case through E and E.[1]

The chamber, N, contains a double-acting compressor, and the compressed air is discharged alternately at either end, through valves marked F, into the air holder or receiver, B. This acts simply as a cushion, to avoid oscillation. From B the air is conveyed to the burner through the governor, C. This is an ordinary diaphragm governor, weighted to give an outlet of pressure of 2 lbs. per square inch, at which pressure the air is supplied to the burners.

The air supply is conveyed from the receiver, B, through pipes, G, and the air regulating cock, T, to the centre perforation in the nipple, the gas being supplied by means of pipe, P, through either a series of holes arranged in a circle around the air perforation, or through a fine circular slot. The air supply is adjusted by means of the regulating cock at the burner ; and the pressure at which gas is supplied is immaterial, as the air supply may be regulated accordingly. H is a small cock for the pressure guage, J.

The advantages claimed for the system are—(*a*) the ordinary meters and fittings are utilized for the gas supply ; (*b*) there is no interference whatever with other gas supplies; (*c*) the compression being applied to the air, any leakage from the high-pressure apparatus or pipes is innocuous; (*d*) any possible leakage from the gas pipes is

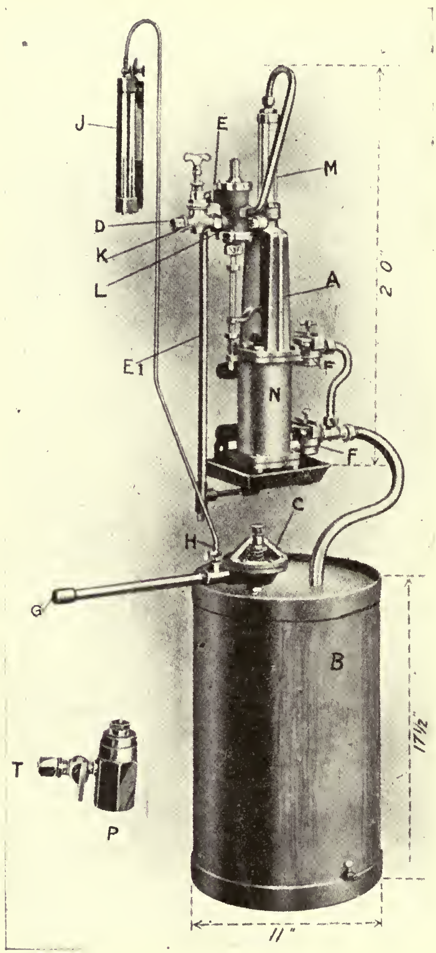


FIG. 549.—United Kingdom Lighting Trust Compressing Plant.

less material; (*e*) less danger, correspondingly, to trees and vegetation; (*f*) it is considerably cheaper; (*g*) in the event of failure of the water supply, the lights will not be extinguished; it is only necessary to reduce the gas supply to correspond to the air then supplied through the holes of the bunsen tube.

Fig. 550 shows the burner attachment and general arrangement of the burners in a street lantern.

Elevating and lowering gear.—In view of the disposition of certain public lighting authorities to adopt central lighting for busy thoroughfares, and the advantages attaching to such a system where the roadways are narrow and congested, it has been necessary to evolve some arrangement by which gas lamps may be adapted to these conditions. There is, of course, no more difficulty in suspending a gas lamp than one of any other kind. The problem has been to adapt elevating, lowering, and traversing gear to the particular conditions of high-pressure supply. This has meant, in effect, the provision of such gas connections as would enable the lamps to be readily raised to, or lowered from, their permanent positions.

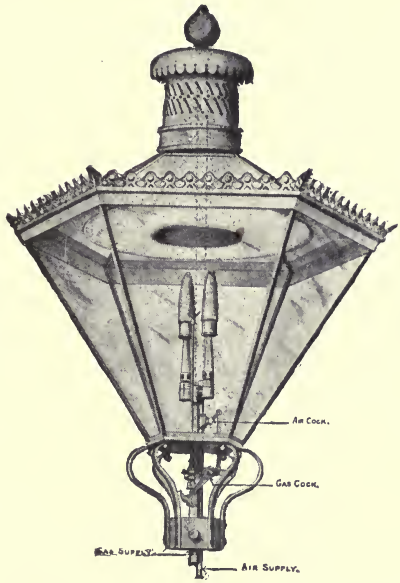


Fig. 550. — United Kingdom Lighting Trust System Applied to Public Lamps.

The first efforts in this direction involved the provision of flexible tubes so arranged as to allow the lamps to be lowered and raised without breaking the gas connection. These have proved unsatisfactory owing to the sagging of the horizontal traversing pipe, and consequent collection of condensation; the difficulty of keeping the piping working under such conditions permanently gas tight at high pressures; and the difficulty of preventing kinking or straining of the tube as the lamp was being moved.

These difficulties have led to the adoption of Keith's patent ball joint device, which dispenses with the use of flexible tubes. This is shown in Figs. 551 and 552, and is described by Messrs Keith, Blackman as follows:—In place of the flexible tube a metallic pipe, A, of ample dimensions, is carried by the suspending rope, B, to the point from which the lamp normally hangs, and permanently connected by a ball coupling to a "hanger," C, also suspended from the rope.

The lamp is suspended from a carriage, D, which is traversed inwards and outwards by means of the usual double winch. A special form of cup and ball joint is arranged, the ball half, E, being fixed to the hanger, and an inverted cup, F, being fixed to a form of stirrup piece, G, attached to the top of the lamp. The joint is so arranged that it takes the weight of the lamp when shipped into

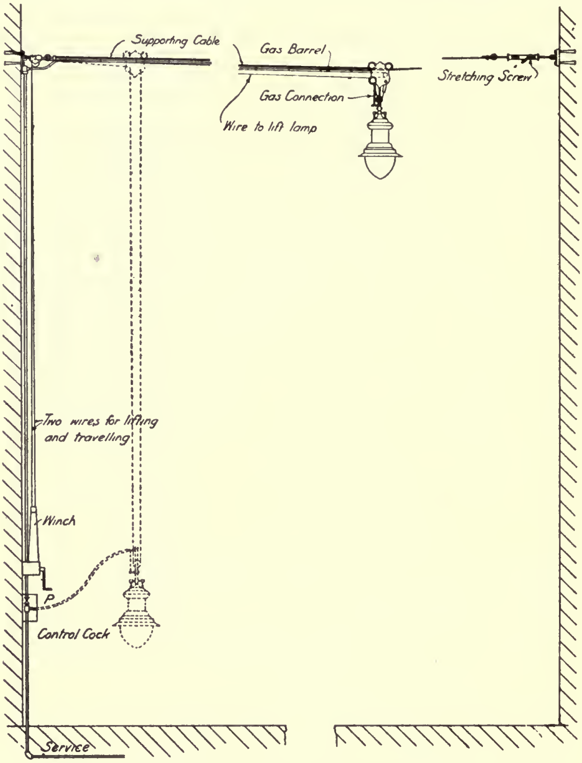


FIG. 551.—Traversing Gear for Centrally Hung Lamps: General Arrangement.

position, independent of the supporting wire rope, H. This ensures a tight joint, and at the same time affords a safety catch for the lamp, and relieves the running wire rope of the weight.

To unship the lamp, the winding drum is turned so as to raise the cup off the ball, and clear of the safety guide, J, and the carriage, with the lamp, can then be traversed inwards towards the pavement and lowered. When in the lowered position, if a supply of gas is required, this may be connected temporarily by means of a flexible tube, one end of which is connected by a simple form of coupling to the cup, F, on the lamp, and the other end to a supply in the box containing the control cock of the lamp. This is shown at P, in Fig. 551. Between the stirrup piece and the lamp is fixed a special automatic lighter, K, which controls the by-pass arrangements in such a way that whilst there is low pressure in the supply pipe the

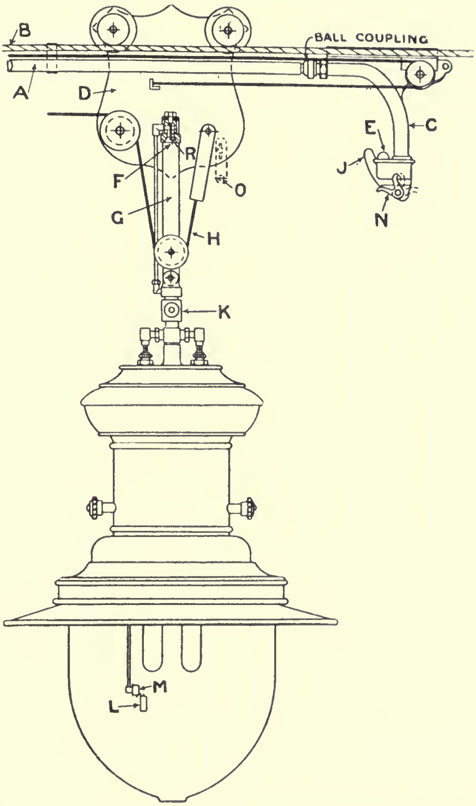


FIG. 552.—Keith Patent Cup and Ball Joint Attachment.

gas is cut off from the burner and diverted to the pilot light in the lamp. When the full pressure is admitted to the service pipe, the main valve to the burner is opened automatically, and the pilot light, whilst giving a temporary flash during the rising of the pressure, is eventually cut down to such a size as will just ensure that the by-pass tube remains charged with gas. Upon disconnecting the lamp from the supply, the by-pass is, of course, extinguished, but provision is made for re-lighting this by attaching a small tube, L, fitted with an asbestos wick, to the by-pass protector, M. Before raising the lamp, this tube is charged with methylated spirit or paraffin, and lit, so that when the lamp is put into its position the pilot supply is relit from it.

As the supply pipe between the wall and the hanger is attached

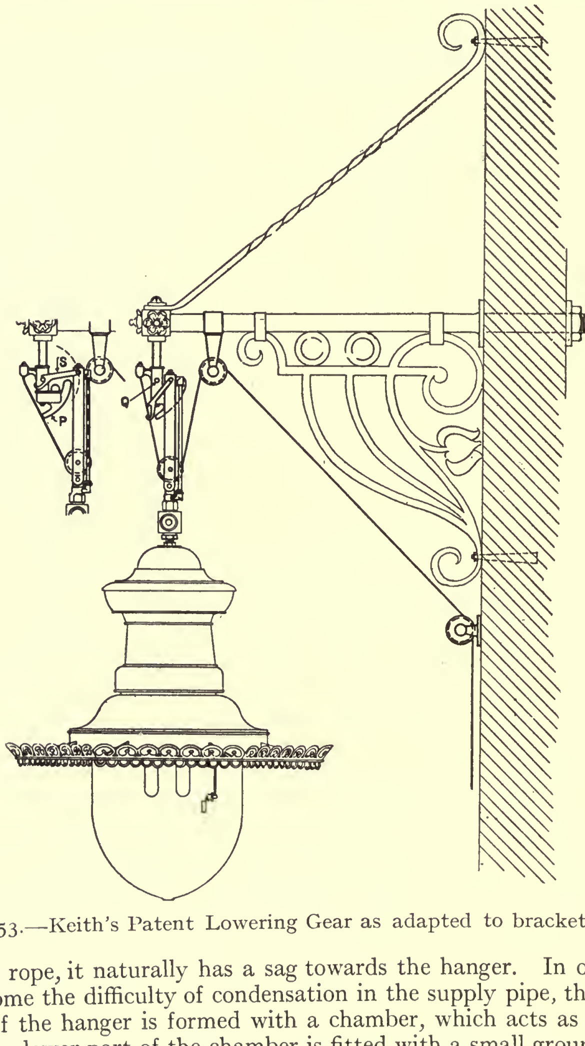


FIG. 553.—Keith's Patent Lowering Gear as adapted to bracket lamps.

to the rope, it naturally has a sag towards the hanger. In order to overcome the difficulty of condensation in the supply pipe, the lower part of the hanger is formed with a chamber, which acts as a trap, and the lower part of the chamber is fitted with a small ground cock with a bell crank lever, N. A pin, O, on the traversing carriage, is arranged to engage with the bell crank on the cock, and open it whenever the carriage is moved inwards towards the wall, and close it when it is moved outwards to a stop in the normal position.

This gives a very positive action, and by its use any condensation may be discharged from the chamber without disconnecting the lamp from the supply, even although the lamp may be alight.

In order to prevent an escape of gas whilst the lamp is unshipped, a spherical valve is arranged inside the " ball " E, and is held open by a pin, R, when the lamp is in position, but is closed by a spring when the lamp is removed.

The general arrangement of the whole traversing gear is shown in Fig. 551, which explains itself.

The arrangement for adapting the traversing gear device to lamp columns or lamp brackets is shown in Fig. 553. " The gas joint is made in the same manner as in the case of the traversing gear, but the lamp is raised and lowered by a single winch. In this case, however, provision has to be made to enable the lamp to be raised and lowered without the use of the traversing arrangement, and this entails the addition of a pair of levers, S, to the stirrup piece. When the lamp is raised, the cup on the stirrup piece comes in contact with an inclined prong, P, on the lower part of the hanger, which pushes it out of the centre as it is raised. On being raised above the prong, the cup swings inwards to the centre exactly over the ball, so that upon being lowered it will drop on the ball, and make a gas-tight joint by its own weight. To lower the lamp, it is first raised until the ends of the two levers engage with a pair of pins, Q, fixed on the hanger in such a way that upon again lowering the lamp these levers cause the upper portion of the stirrup, with the cup, to describe a radial path which clears the prong.

Where the conditions require it, the ball half of the joint can be fitted with an automatic ball valve which closes by a spring as soon as the joint is broken, so that the lamp may be removed even if the high pressure is present up to the joint. The by-pass is relit in the same manner as in the case of the traversing gear. A spherical valve is arranged inside the ' ball ' for the purpose explained in the description of the traversing gear."

Mantle manufacture.—Although a consideration of the manufacture of mantles opens up a very wide subject, which does not come within the purview of this work, yet, as the mantle has necessarily been frequently referred to, and forms a very important essential in modern gas lighting, it may not be amiss to give here a brief description of the method of manufacture.

A tubular web woven from cotton, ramie fibre, or silk thread, termed the stocking, is taken, and cut into suitable lengths. One end of these lengths is gathered up by means of an asbestos thread to diminish the diameter of the tube, and form the top of the mantle. Across this constriction an asbestos loop is formed, to act as a support for the mantle. The web base of the mantle is then immersed in a bath containing, approximately, 99 per cent. of thoria and 1 per cent. of ceria. The former is an extremely bad radiator of heat, and, therefore, is capable of attaining a very high temperature. It, however, possesses only poor light-giving properties, nearly the whole of the incandescence being due to the ceria. It is found that the proportions named give the best results in light-emitting properties. Both thoria and ceria are extracted from the monazite sands found in Brazil, North and South Carolina, and South Nigeria, and thoria from the thorianite of Ceylon.

After immersion in this bath until the network has taken up as much as possible of the solution, the mantle is taken out and the superfluous solution removed by a process of wringing. The mantle is then stretched on a shaping cone, to be moulded to the required shape, and allowed to dry.

The mantle, after drying, is ready for one of the most delicate processes in its manufacture, namely, the burning off. This may be done by hand or machinery, and upon the care bestowed upon the process, the shape, the life, and the efficiency of the mantle to a very large extent depend. A light is applied to the top of the mantle, which is allowed to burn slowly and uniformly downward. After this process of burning off has been completed, the mantle is an extremely fragile thing.

To strengthen it sufficiently to allow of handling and transport, the burned off mantle is dipped in a strengthening solution of collodion. This collodion is burned off by the consumer when applying a light to the mantle for the first time, in the manner which has now become so familiar.

Various substitutes for thoria-ceria in the manufacture of mantles have been used, principally consisting of zirconia, alumina, and chromium. Silica solution has also been used to strengthen the burned off mantle, in lieu of the collodion mentioned above. The materials previously referred to, however, are those most generally used. They have proved themselves to provide the three essentials of a good mantle, namely, cheapness, durability, and high light emissive power.

The remarkable development in the use of the incandescent mantle for both domestic and public lighting has naturally led to endeavours to produce a mantle which should prove more durable and of greater light emissive power than that ordinarily used. It is well known that not only are these mantles easily destroyed by vibration and shock when in use, but that in packing and transit great numbers are rendered useless.

An attempt to remedy this defect has been made in the Plaissetty soft mantle, in which, by new processes of manufacture, a mantle has been produced upon an artificial silk base which, until it has been placed upon the consumer's burner and burned off, may be crushed in the hand with absolute impunity. The Welsbach-Plaissetty mantles are, however, made of cotton fibre, and before impregnation the fabric is heated by a special process which artificially ripens the cotton base, and thus to a great extent eliminates the shrinkage incidental to cotton mantles of other types. A Welsbach-Plaissetty mantle will, as a rule, maintain its light for a longer period than cotton mantles of any other type, for the simple reason that as the mantle shrinks very gradually it will keep longer in the hottest zone of the flame given by the burner.

In comparing the Welsbach-Plaissetty mantle with its prototype the Welsbach "C" mantle, probably the light emitted from the latter when first used would be about 90 candles, as against 80 candles from the former. But after, say, 400 hours' service, the proportion would be 45 to 50 candles from the Welsbach as against about 60 candles from the Plaissetty. The latter has, therefore, great advantages over the former for street lighting purposes, for three reasons—(*a*) the great amount of vibration it will bear when in use; (*b*) the even character of the light produced; and (*c*) the rough usage it will stand in transit and handling.

Perhaps one of the greatest improvements introduced in connection with the manufacture of incandescent mantles has been the substitution of ramie fibre for cotton fabric as a base. This material, known in other connections as China grass, has been used for ages by the Chinese and Japanese for the manufacture of their clothing materials. Owing to its toughness and durability it is even used for cordage, and is found to be capable of withstanding a greater tensile strain than hemp.

Its chief advantage over cotton for the purpose of the incandescent mantle is that its component fibres, of which there are about 90 to the strand, as compared with, approximately, 300 in the cotton yarn of the ordinary mantle, do not shrink and coalesce in use to anything like the same extent, and consequently the luminosity of the mantle is maintained to a much greater degree. The ramie mantle is also much less friable than the cotton mantle, and may be handled after burning off with almost as much freedom as the ordinary collodionized mantle.

Another artificial fibre as a base for mantles has recently been introduced—namely, copper-cellulose. This is made by dissolving cellulose in ammoniacal copper oxide, and forcing the solution through very fine tubes into dilute acid, in which it rapidly hardens. Very fine filaments of considerable length are obtained in this way, and are then woven into the tubular web required. The advantages claimed for this material are:—(1) It does not absorb moisture; and (2) produces a mantle much more capable of sustaining shocks.

CHAPTER XXX

PUBLIC LIGHTING—LIGHTING AND EXTINGUISHING LAMPS

The general adoption of incandescent burners for public lighting has necessarily led to considerable modifications in the previously simple torch for lighting and extinguishing the lamps. In the days of the obsolete flat-flame burner, the lamplighter's torch, as shown in Fig. 554, met the requirements of the case very well indeed.

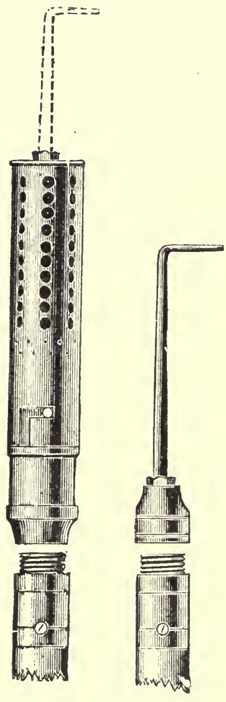


Fig. 554.—Hutchinson's Lamplighter's Torch.

The Foulger-Glover torch is a variation of the old straight torch. In this instrument the lamp within the torch is hinged. It may be used, at will, either upright in the way usual with an ordinary torch, or, when used for lighting incandescent burners, the light may be projected over the mantle at an angle by means of the hinge.

By-pass, flashlight, and torch systems.—The advent of the fragile mantle, and consequent necessity of avoiding vibration or shock, has made an improved method of lighting an absolute necessity. This has been met in four ways, namely :—

(*a*) By means of the by-pass.
(*b*) „ „ „ flashlight.
(*c*) „ „ improved torches.
(*d*) „ „ automatic apparatus for lighting and extinguishing the lamps.

Of these, the method of the by-pass is extremely simple, and equally familiar. With this system a small jet is kept continually alight, and it is only necessary for the lamplighter to turn the principal tap on at the appointed hours, and extinguish by turning the cock off again at the right time. Unfortunately, this involves a considerable addition to the gas bill, as the pilot jet, although only a small one, is necessarily burning throughout the twenty-four hours, or that number less that of the lighting hours ; and this, multiplied out over the thousands of lamps which may be used in a district, makes up a rather formidable total of additional gas used. There is also the danger that if the lantern is not absolutely storm-proof the jet may be extinguished by the wind. The latter difficulty, plus the cost, has made public authorities rather indisposed to adopt the by-pass upon a large scale.

The flashlight method may be applied either by means of the gas supply inside the lamp or by means of a specially constructed torch. The arrangement shown in Fig. 555 in connection with the Simmance-Abady lamp cock of Messrs Alex. Wright and Co. is one that commends itself to many engineers. In this a flashlight tube is run from the lamp cock up one of the angles of the lantern, with the upper end bent over.

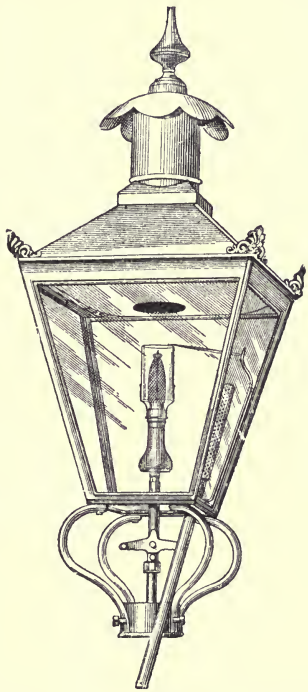
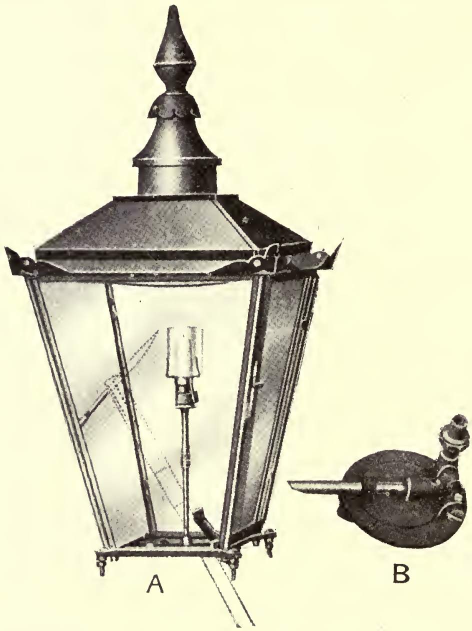


Fig. 555.—Lantern with Flashlight in Operation.

The lamp cock is turned half on in the course of inserting the ordinary torch within the lamp. This admits gas to both the jet tube and the burner, and the flashlight is ignited by the torch in the usual way, as shown in Fig. 555. The jet from the flashlight passes across the top of the mantle, and ignites the gas issuing from the main burner. On the withdrawal of the torch, the lamp cock is turned full on, an operation which extinguishes the flashlight. The advantage of the pilot light is thus secured, whilst the consumption of gas is reduced. A clearance plug, which forms part of the lamp cock, is provided for removing obstructions of naphthalene, or for taking pressures, without disconnecting the fittings of the lamp.

Messrs Geo. Bray and Co., Limited, Leeds, in one of their lamps, have carried the flashlight above the reflector. In this case the flashlight is ignited by the usual torch, through a hole in the reflector, and lights the gas issuing from the burner by flashing across the ventilating holes in the reflector.

A capital device for the lighting of inverted burners in public lamps has been placed on the market by Messrs Foster and Pullen, Limited, of Bradford. This consists of a small round trap-door (shown in Fig. 556), with which is combined a small flashlight tube. In this arrangement the main tap is turned on in the ordinary way, and the torch inserted a few inches through the trap-door. The hinge upon which the door works is also an auxiliary gas cock. The operation of lifting the door turns the gas on to the flash tube. This is ignited by the torch, and the jet being directed towards the main



A, For Upright Burners. B, For Inverted Burners.
FIG. 556.—Foster and Pullen's Flashlight Device.

burner the gas is there ignited also. On withdrawing the torch the door falls into place, and in closing turns the gas off at the auxiliary gas cock. A similar device is also used for the upright burner, but in this case the flash is fixed in an angle and about half-way up the lantern, as shown in Fig. 556. The gas for the flash is turned on by the auxiliary trap-door tap as in the case of the inverted burner.

The Simmance-Abady torch of Messrs Alexander Wright and Co., Limited, of Westminster, is an excellent device for attaining the same end—namely, the lighting of the gas without injury to the mantle. In this torch two wells are used. One contains ordinary colza oil, and supplies a wick in the usual way. The other contains a supply of common benzoline, and should be freshly charged each evening. A pneumatic tube with bulb head (shown in Fig. 558), which is operated from the torch shaft, communicates with the benzoline chamber. Upon pressure being applied, this causes a jet of benzoline vapour, which on issuing from the well

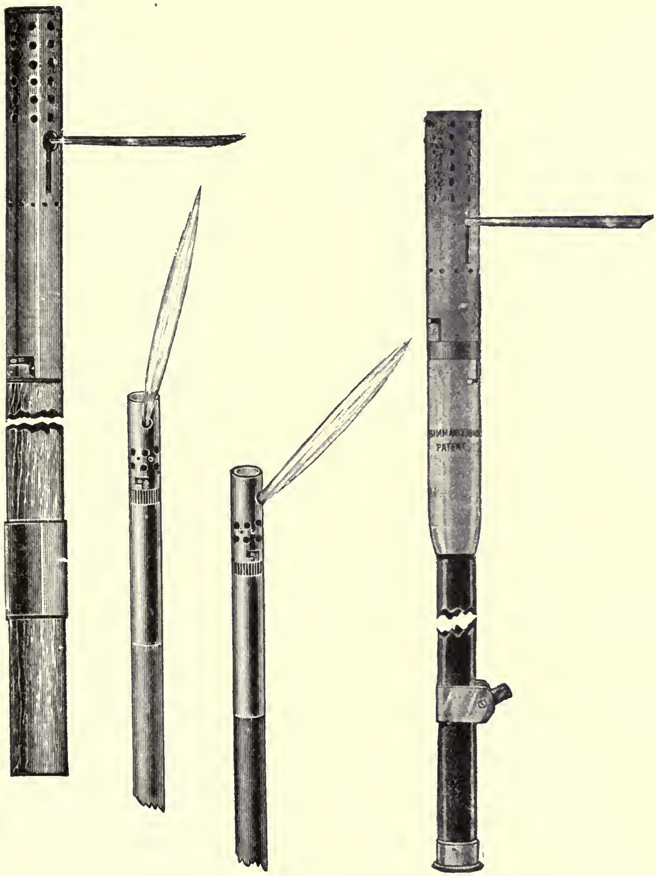
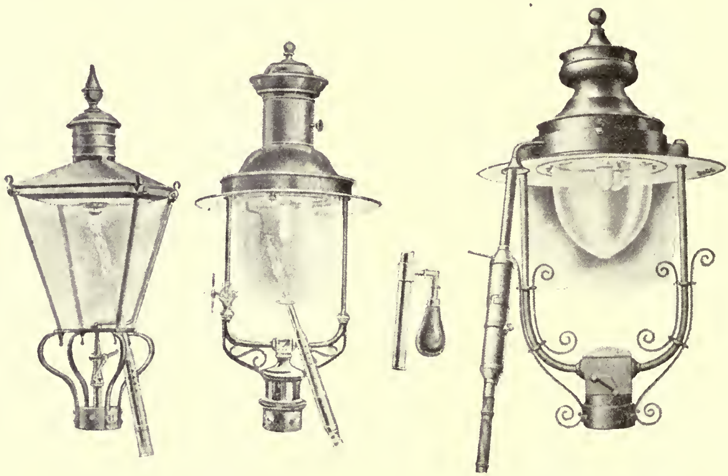


FIG. 557.—Simmance-Abady Torch.

is ignited by the torch, to flash across to the burner and ignite the issuing gas. Fig. 557 shows the torch arranged both for a straight and inclined flash at differing angles for upright and inverted burners respectively, and fitted with either wood or steel shaft.

A modification of the flashlight torch, by which the jet is projected from the head of the torch, has also recently been made. This is shown as applied to both high-pressure and low-pressure lamps in

Fig. 558. Another adaptation of the same torch for projecting a jet across the heads of inverted burners in cluster lamps is shown in Fig. 558. This is accomplished by means of a trumpet piece, the details of which were shown in Fig. 504, p. 588.



For Low-Pressure Lamp. Bulb Attachment.

For High-Pressure Lamp. For Lighting above Reflector.

FIG. 558.—Simmance-Abady Momentary Flash Torch.

The patent double roller lighting trap-door (Fig. 559), manufactured by Mr Wm. Edgar, is an ingenious device for facilitating the lighting

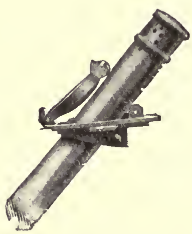


FIG. 559.—Edgar's D.R. Trap.

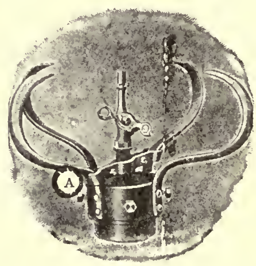


FIG. 560.—Edgar's Patent Safety Clamp.

of lamps without causing vibration or shock which would damage the mantle. As seen in the illustration, this consists of a special door fixed in the base of the lamp, through which the torch is inserted. In lifting, the torch passes quite smoothly between the rollers fixed on one side of the door frame and the door itself, and thus avoids injury to the mantle through shock or carelessness.

The patent safety clamp shown in Fig. 560 is another very simple contrivance designed for the elimination of shock and preservation of the mantles. It consists of a clamp, A, which grips the stand pipe, and is attached to two prongs of the wrought-iron frog. It is calculated to serve two purposes. In the event of the spigot of the lamp column being broken, it prevents the lamp from falling to the ground; and, in the second place, it holds the stand pipe perfectly rigid during the turning on and off of the lamp cock, and thus tends to prevent vibration, due to that cause, being communicated to the burner and mantle.

Advantages of automatic lighting and extinguishing of public lamps.—Reference is made in Chapter XXXVI. to the possibility of loss to any gas undertaking through lamplighters failing to keep the exact times laid down for lighting and extinguishing the public lamps. It is obvious, too, that under the manual system a great waste of gas must take place owing to many of the lamps being lighted before they need be, if all are to be alight by the time they are required. The desire to eliminate the variable factor, and also to save the expense and labour involved in a personal visitation of every lamp twice a day, has led to many automatic lighting devices being placed upon the market. The automatic lighting of the lamps, especially when this is done on the collective or group system, permits advantage being taken of exceptionally bright days to delay lighting until the lamps are actually required, and also, on the other hand, admits of accelerating the lighting at times of gloom. It also fits in with the imperative necessity of protecting the fragile mantle from the shocks and vibration incidental to the most careful manipulation of the lamplighter's torch.

The lines upon which any automatic apparatus for lighting and extinguishing public lamps may proceed are twofold, namely, those designed to affect simultaneously a number of lamps from one centre, and those dealing with each lamp separately. This means, in actual practice, those actuated by a pressure wave from the gasworks; those actuated by clockwork attached to each separate lamp; and those which depend upon a combination of the two.

The enormous advance which has been made during the past few years in the method of lighting lamps by means of wave pressure, and the experience which has been gained, have undoubtedly proved the adaptability of this system to many and diverse local circumstances. The fears and objections felt by many when the method was first introduced have been found to be either groundless or capable of being fully met by adaptations to suit local requirements. The wave is propagated with great rapidity throughout the distributing system, and, given a reasonably symmetrical, adequate, and clear series of mains, has proved itself quite capable of performing the duty required. The difficulty of applying the system to lighting areas where differences of altitude have involved considerable variations of pressure has not been found insurmountable, whilst, on the other hand, the baneful results of the temporary increase of pressure, which were so freely prophesied, have not been experienced when the system has been intelligently applied and proper precautions taken.

There can be no doubt that the system of central control, whether by pressure waves or by other means, is the one to be desired. Indeed, the ideal system would be one allowing the whole of the lamps of any undertaking to be simultaneously lighted or extinguished at will. Many devices to secure an approximation to this result have from time to time been produced. These naturally divide themselves into two very different classes—namely (*a*) those with an inverted bell, freely floating in some liquid, upon which the pressure wave may be exerted, and (*b*) those in which the wave acts upon a diaphragm.

Before proceeding to describe either of these types of apparatus it may be well to consider in detail what are the requirements to which it is necessary for a good distance lighter to conform. They may be summarized as follows :—

(*a*) The whole apparatus must be small, so that it may be berthed at the base of the lantern and cast no shadow.

(*b*) It must be easily attached and detached.

(*c*) It must be strong and durable.

(*d*) It must be simple in construction and easy to manipulate.

(*e*) The operating mechanism should be outside the gas chamber, and easily get-at-able.

(*f*) The mechanism should be capable of working at any predetermined pressure or rise of pressure.

(*g*) When properly adjusted it should be incapable of derangement by any outside influence or unintentional condition.

(*h*) The gas passages should be so arranged that risk of stoppage by naphthalene is reduced to a minimum.

(*i*) The gas passages should be easily accessible for clearing in case of stoppage.

(*j*) The operating pressure should be the full and not the surplus pressure.

(*k*) The apparatus should be proof against accidental recurrence of operating pressure.

(*l*) It should not operate too quickly or too slowly. In the case of an intermittent by-pass, if the operation is too quick the pilot light may fail to light upon the extinction of the main burners, owing to the air in the pilot tube not being expelled. If the operation is too slow, the gas may strike back in the bunsen tube. Proper timing is therefore essential.

(*m*) No diaphragm apparatus should be fixed within a lantern.

Where leather is used as a diaphragm it should have a good protective coating to resist oxidation.

(*n*) With every automatic lighter there should be provision for hand lighting when and if necessary.

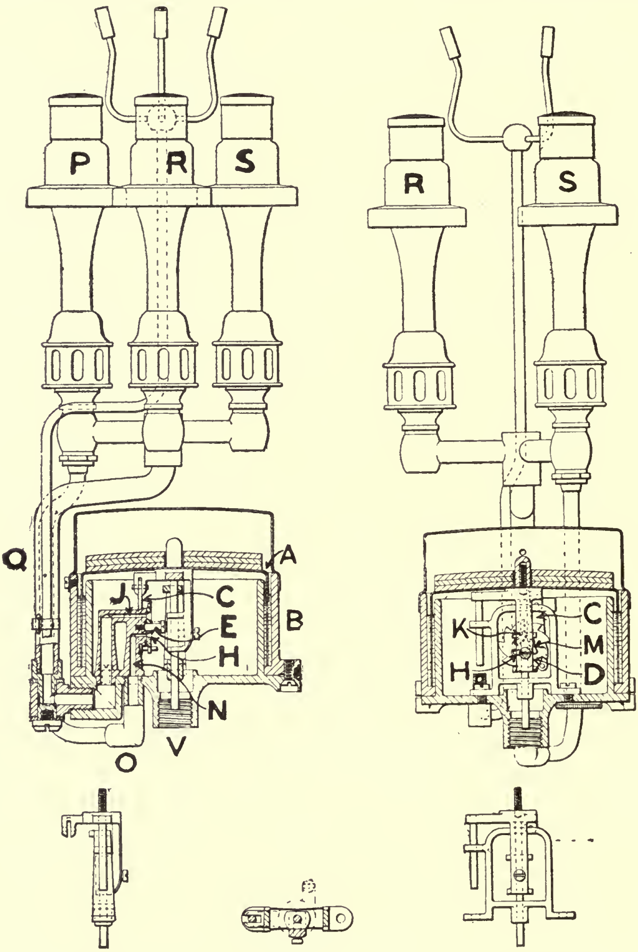
Pressure wave and clockwork controllers.—In the following examples of pressure wave and clockwork controllers, of which three types of each, and one in which both are combined, are illustrated and described, the reader will be able to judge as to how far the above requirements have been met.

Alder and Mackay's apparatus.—The first type taken is that of Messrs Alder and Mackay, of Edinburgh. In this apparatus an increase of pressure in the gas mains, operating through a small gasholder bell, turns a rotary disc valve of the step-by-step type. One form of the mechanism is seen in Fig. 561, which shows two sectional elevations taken through the apparatus at right angles to each other.

In this, A is the gasholder bell working in an annular tank, B, containing about 8 ozs. of mercury as a seal. From the roof of the bell depends the pendulum link, C. At the lower end of the link, a short pin, placed at right angles to the link, engages in the teeth of the plate of the rotary disc valve, D. The latter is pivoted upon the screw, E, under the head of which a spring resiliently presses the valve home to its seating. The seat of the valve is provided with two gas-ways, H and J, at different radial distances from the axis of rotation of the valve. The gas-way, H, communicates with the tube, N, and by means of the pipe, O, with the burner, P. The gas-way, J, communicates by the pipe, Q, with the two burners, R and S.

The arrangement of the slots in the disc will be readily followed from the enlarged scale drawing (Fig. 562). The radii of the holes, H and J, are shown at R^1 and R^2. Upon the two radii, S and T, drawn at an angle of 40°, and radius R^1, two holes are pierced as shown. Upon a third radius, W, drawn at an angle of 40° behind T, in the direction of rotation of the disc, shown by the arrow, a third hole is pierced at distance, R^2, from the centre, of equal size with the previous two. A curve linking up the three holes gives the shape of the slot, K and M, required for a disc valve having three slots in its face.

The operation of the apparatus is as follows:—As shown in Fig. 561, the gas-way to each of the three burners is open, and gas, entering the apparatus at V, passes through the valve openings and by way of pipes, O and Q, to the burners. When the pressure is applied, the bell, A, is raised, and carries with it the link, C. The latter being engaged with the valve, causes it to rotate to the extent of one tooth, or through an angle af 40°. The portion, M, of the slot is thus moved out of communication with the hole, J, closing the gas-way, while the opening, H, being at a smaller radius than J, still remains uncovered. The effect of this is to cut the gas supply off from the two burners, R and S, whilst continuing it to the burner, P. The next increase of pressure causes the valve to rotate through another



Side Elevation. Plan. Longitudinal Elevation.

Enlarged Views of Guide and Bridge Piece.

FIG. 561.—Alder and Mackay's Lighting and Extinguishing Apparatus.

angle of 40°, and moves the slot, K, out of communication with the hole, H, and thus cuts off the supply to the burner, P. The next following increase of pressure rotates the valve again, and opens both gas-ways, H and J, thus supplying gas to each of the three burners and commencing another cycle of operations.

The slots are preferably made with rounded corners, as shown in Fig. 562, this form being found to lessen any possible tendency to deposits of naphthalene. In the later forms of the apparatus the bell, A, is completely enclosed by a cover. This serves two purposes. In the first place it prevents the admission of dust and dirt to the mercury cup, and in the second it forms an air cushion and steadies the action of the bell. The vent hole in the cover is made small in comparison with the area enclosed, and the cushion thus interposed effectually prevents the apparatus being operated by the oscillatory

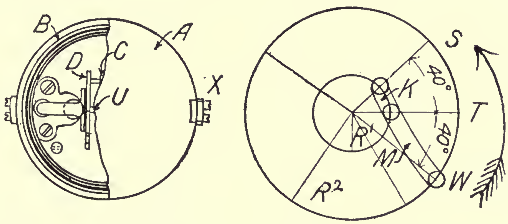


FIG. 562.—Alder and Mackay's Apparatus : Arrangement of Slots.

action caused in the mains by wind pressure on gasholders supplying comparatively small areas.

Another improvement which has been recently introduced is an internal guiding spindle. In the original apparatus the central upright spindle was externally guided through a bridge piece. This became oxidized, caused friction, and impeded free working. The guiding apparatus in now inside the bell, and cannot therefore be so affected.

The apparatus may be adapted to varying lighting conditions. As shown in Fig. 561, some of the burners in cluster lighting may be extinguished, whilst the remaining burners are left alight. Lamps in unimportant streets may be extinguished while those in the busy and important thoroughfares remain alight, or the lamps may be extinguished in groups as required. In suburban districts the lamps in all or any of the outlying districts may be extinguished, whilst those in the centre remain alight. In the last two cases, where it may be desired to extinguish the lamps at midnight, an apparatus is supplied having a simple three-stage step-by-step valve.

A part of the disc arrangement for extinguishing two out of three burners has already been described. In this apparatus there are two sets of holes at different radial distances, shown as R^1 and R^2 in Fig. 562. In the outer set there are four holes at equal distances apart. In the inner set there are eight holes in groups of four pairs, each member of the pair being 30° apart, and each pair being 90° apart.

To operate the mechanism, it is necessary to increase the pressure at the gasworks or distributing station to the extent of 15-tenths above the day maximum. Pressures have been found to travel with considerable rapidity, and the author has heard of a case in which an apparatus was operated at a distance of three miles from the gasworks, and 15 feet below it in level, in the exceedingly short time of 15 seconds. It is claimed that the system can be satisfactorily worked if the additional pressure is maintained for 30 seconds.

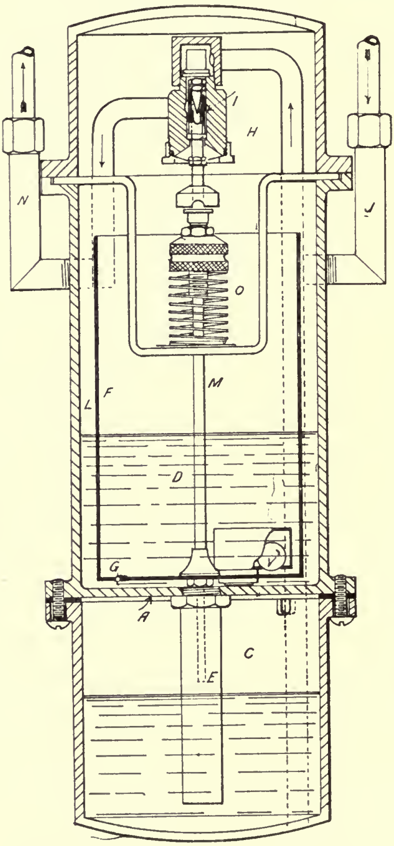


FIG. 563.—Sectional Elevation of Broadberry's Apparatus.

The apparatus is very simple in construction, there being little to get out of order, takes up little room, and is comparatively inexpensive. When once adjusted, the only attention needed is to oil the guides when necessary, so as to reduce friction to a minimum.

It is obvious that the great test which any apparatus of this kind must meet is that of absolute reliability. It does not matter how ingenious an apparatus may be; if it cannot be depended upon it is useless. With the object of securing a twelve months test of reliability the Newcastle-on-Tyne Gas Committee, in 1909, had 250 of the Alder and Mackay lighting devices fixed, and in January 1911 the results of the experiment were published. In the 365 days over which the observations were taken 250 devices were used to operate the lamps 96,250 times. The failures due to defects in the apparatus were as follows :—

On actuations 0.023 per 100 = 1 lamp per 4348.
On lamps lighted 0.071 per 100 = 1 lamp per 1408.

The average saving per lamp was found to be 939 hours 19 minutes, and the total saving on account of gas and maintenance on the 250 lamps for the year was £119 15s. 10d.

Broadberry's device.—The Broadberry apparatus shown in Fig. 563 is an excellent type of a distance lighter operated by pressure waves from a central station.

It consists of a base box divided by the horizontal partition, A, into the two divisions, C and D. The lower chamber, C, is partially filled with a mixture of glycerine and water, which is both non-freezing and non-evaporating. Communication is made between the lower and upper chambers by means of the brass tube, E.

In the upper chamber, D, a float, F, is placed, capable of vertical movement. The bottom of the float is pierced at G, the perforation

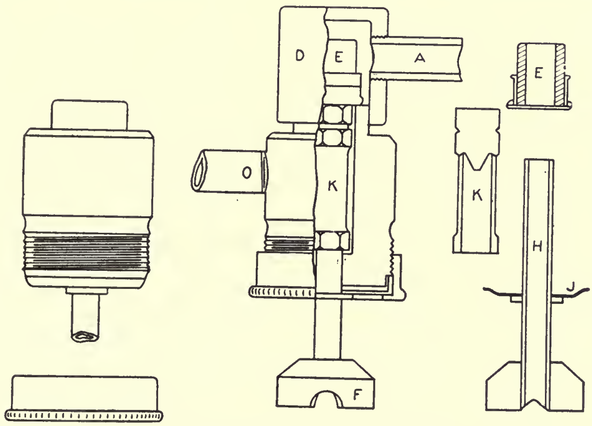


FIG. 564.—Section through and Details of Valve of Broadberry Apparatus.

being of such a size as to allow the glycerine mixture to flow through at a predetermined rate. The weight of the float is counterbalanced by the resilience of the spring, O. In the side of the upper chamber, D, a gas connection is attached from which a common pipe proceeds in a downward direction to the chamber, C, and in an upward direction to the gas connections in the attic, H.

The valve, I, is of quite ingenious construction, and will well repay detailed consideration. It is shown in enlarged section and details in Fig. 564.

The gas is brought into the valve at the top by means of the ¼-inch copper tube, A, which is screwed into the upper end of the valve body, D. From thence it can only flow to the outlet, O, of the valve by passing the seating on which the valve cap, E, rests. The gas being brought in at the top makes a much sounder joint than if it were brought underneath the valve cap, E, and only the weight of the latter produced the gas tightness.

The action of the valve is, therefore, as follows. The float in the box (Fig. 563), being raised, the guide rod, M, comes in contact with the lead weight, F (Fig. 564), and lifts it. The hollow tube, H, to which the weight F is attached is given a limited amount of vertical travel by the flexible diaphragm, J. The weight, F, and tube, H, being lifted, the upper end of H comes into contact with the male cone on the secondary tappet, K, which in turn is lifted. The tube, H, must, however, be lifted quite 0.5 millimetre before it raises the valve cap clear of the seating. The closing up of the tube, H, by the male cone of K must be accomplished before the inlet seating is cleared, otherwise the gas would pass away to the atmosphere instead of to the diaphragm at the back of the operator.

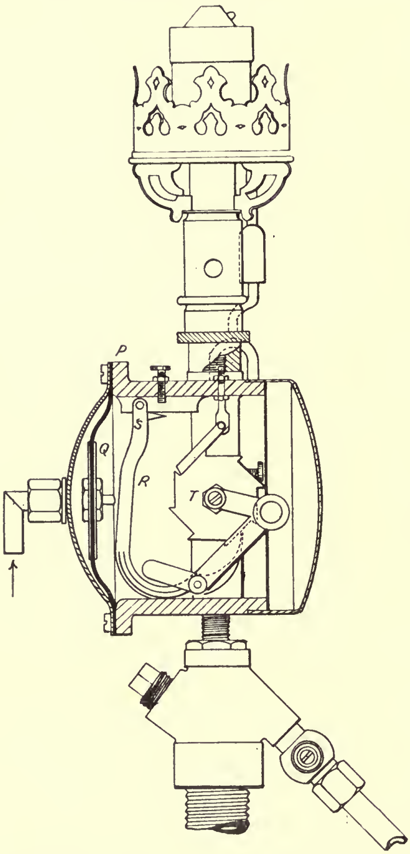


Fig. 565.—Section through Operator of Broadberry's Apparatus.

The function, then, of the cone is to close the outlet, and whilst remaining closed on the hollow shaft, H, it travels a little further up and lifts the valve cap, E, and thus opens the inlet.

When the opening has been carried through and the float (Fig. 563) begins to fall through the levels of the glycerine inside and outside the float being restored, the weighted shaft, H, falls with it, the secondary tappet, K, losing its support falls also and the valve cap, E, is once more brought down upon its seating and the inlet closed. A little further movement and the secondary tappet, K, comes to rest on its stop, and the hollow shaft, H, then falls clear of the male cone of K, thus opening the outlet and allowing the diaphragm in the operator to recede to its normal position.

The operator (Fig 565) consists of a vertical flexible diaphragm, Q, clamped between the flanged surfaces of the box, P. Within the box a curved lever, R, capable of free movement is suspended from the pivot, S. When the diaphragm moves in an outward direction the curved lever is carried with it, and the arm engages one of the teeth of the ratchet wheel which forms the head of the lamp cock, moving it round through one-sixth of a revolution, opening or closing the gas way according to the particular point of the cycle reached.

The plug of the cock differs from others in being cylindrical in form, revolving in a similarly shaped socket. All nuts and screws have been eliminated, and the plug of the cock is held in position by a simple clip, and may be easily released by the pressure of a finger.

When, now, a sudden access of pressure is applied to the apparatus the impulse is conveyed through the gas connection to the surface of the liquid in the basal chamber, C. This is depressed accordingly, and the liquid forced up the pipe, E, into chamber, L. The inflow is far too rapid to pass through the perforation, G, in the same time. The level of the liquid is therefore raised in the outer chamber, L, the float, F, becomes buoyant, and is raised floating upon the surface of the liquid. In rising, the guide rod, M, lifts the valve, I, from its seating, and allows the full pressure of the gas to pass from the inlet pipe, J, to the outlet, N, and so to the operator.

The pressure wave passing from N acts upon the diaphragm Q (Fig. 565), pressing it in an outward direction. The bent lever, R, is carried forward accordingly, the arm of which engages the tooth of ratchet wheel, T, and moves the lamp cock through one division to a new position, either opening or closing the gas way.

Meanwhile the liquid in L has been slowly passing through the orifice, G, and gradually filling the float, F. As the float fills it becomes non-buoyant, sinks, and releases the pressure upon the base of the valve I; the conical surface, K, drops upon its seat; the gas way is closed; the pressure upon the diaphragm is released, and the apparatus is ready for another cycle of operations.

It is obvious that at all times the level of the liquid in the basal chamber, C, is determined by the gas pressure exerted upon its surface conveyed through the inlet pipe, J. In some districts the pressure falls very rapidly as lighting-up time for the lamps approaches, due to increasing consumption. The liquid passes, therefore, from chamber, D, to C, correspondingly to the fall of pressure. It might, therefore, happen that the time for lighting the lamps would synchronize with the time at which liquid was slowly passing from the float, F, to chamber, D, to replace that which had passed from D to C owing to the fall of pressure. When, therefore, the pressure wave was applied for the purpose of lighting the lamp, the apparatus would fail to act owing to a portion of the increase being required to balance the non-buoyant character of the float at that particular moment, the effective increase of pressure being correspondingly lessened.

To meet this condition a special valve, V, has been inserted in the bottom of the float, which, when the level of the liquid is falling in D, allows that in the float F to pass into D at an equally rapid rate, thus always keeping the level of liquid equal in the two chambers when the instrument is not in action.

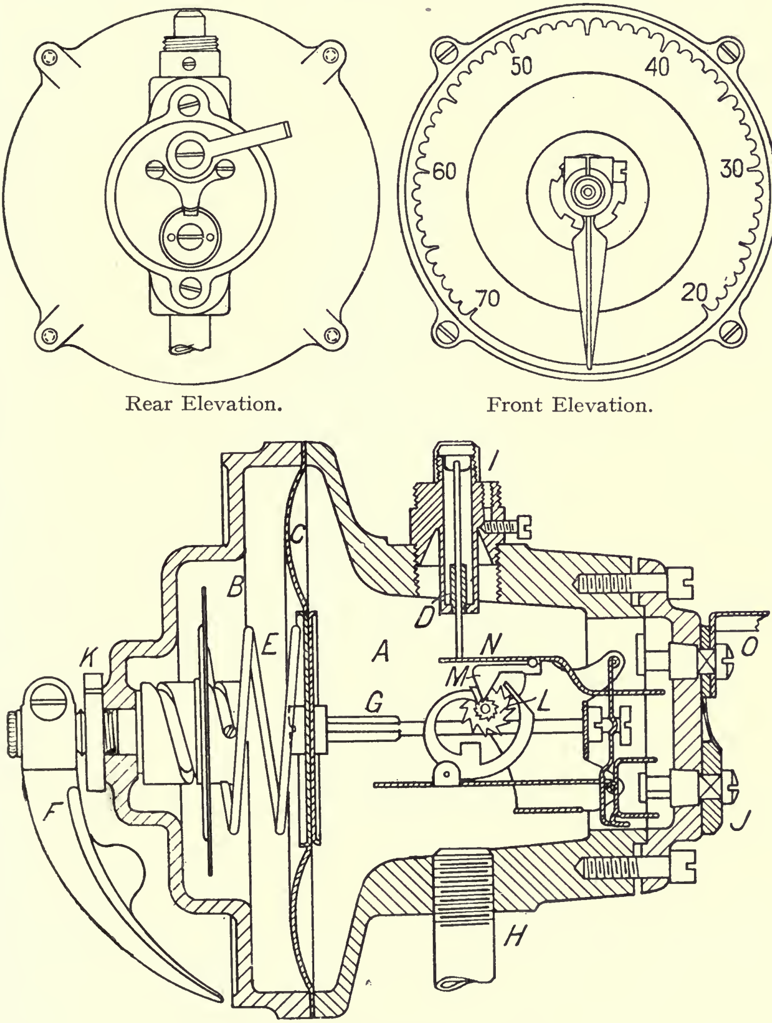
The great advantage of this instrument is, of course, that it is quite independent of pre-existing pressure conditions so long as these are normal. It does not matter whether the pressure is 15-tenths or 30-tenths, a sharp rise of 5 or 6-tenths actuates the apparatus, while it is quite unaffected by the slow variations of pressure, however great their range, which accompany fluctuations of demand.

Then, again, all working parts are outside the gas chamber, and do not therefore work in a gas atmosphere. The by-pass is an intermittent one, and is maintained therefore with a corresponding saving in the consumption of gas. The gas way is a straight one from supply pipe to burner, and provision is made at plug V for clearance in the event of napthalene troubles.

The "Bamag" patent distance lighter, which derives its name from the initial letters of the manufacturers of the apparatus, the Berlin Anhaltische Maschinenbau Aktiengesellschaft, one of the largest firms of gas plant makers on the Continent, of whom the Distance Lighting Company are a branch, is one of the best known distance lighters of the "diaphragm" class.

The apparatus is shown in front and rear elevation and longitudinal section in Fig. 566. The "Bamag" lighter is divided internally into two chambers, A and B, separated from each other by the diaphragm, C. This diaphragm consists of a fine, firm, closely and uniformly woven membrane, saturated with a special varnish. The gas passes through the rear portion of the apparatus from the inlet pipe, H, to the nipple, I. The front portion of the lighter contains the spring, E, one end of which presses against the centre of the diaphragm, C, and the other against a plate working in a spiral thread or slot upon the spindle carrying the indicator, F. K is a lock nut by which the indicator is prevented from moving out of position after the proper adjustment has been made. By rotating the indicator, F, the tension of the spring may be varied to resist any movement of the diaphragm due to pressure of the gas, as may be predetermined, up to twelve inches. The vent necessary to allow perfect freedom of movement of the diaphragm, C, is provided by a small orifice in the front casing, which thus throws the chamber open to the atmosphere.

Upon the rear side, the diaphragm, C, is connected to the shaft, G. By means of a vertical strip and lever, this shaft is capable of communicating action to the ratchet wheel, L. Assuming that the valve is closed, as the wheel, L, is rotated in the direction of the hands of a watch, the pawl, M, is caused to ride up the curved surface of the wheel tooth, and in so doing lifts the balanced strip, N, which,



Longitudinal Section.
FIG. 566.—The " Bamag " Lighting and Extinguishing Apparatus.

in turn, raises the valve, D, from its seating, and allows gas to pass to the nipple, I. A break action prevents the wheel turning so far as to allow the pawl, M, to fall into the following notch until the rod, G, is actuated a second time.

The action of the instrument is comparatively simple. Assume that the lighter is set to open at 40-tenths, and that the valve is closed. When pressure to this extent is applied by means of the gas to the rear face of the diaphragm, C, the resilient action of the spring, E, is overcome; the diaphragm, C, in its movement, carries with it

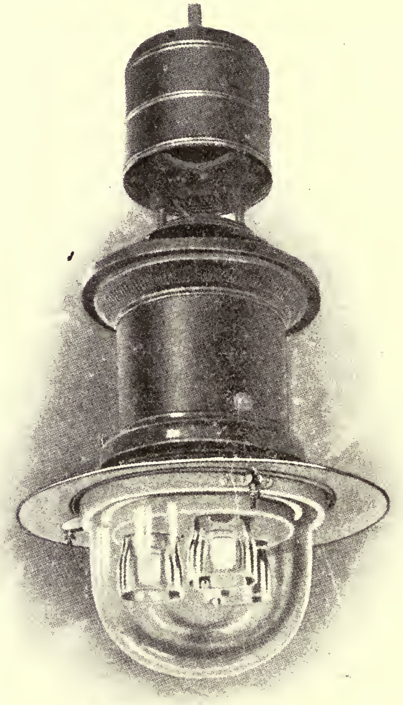


FIG. 567.—Inverted "Bamag" on top of Graetzin Lamp.

the rod, G; the motion of G is communicated in the way already described to the ratchet wheel, L, which, in its motion, lifts the valve, D, by means of the pawl, M, and balanced plane, N, and gas is allowed to pass to the burner, I. When, at the time for extinguishing, pressure is again applied to the necessary extent, the motion of the diaphragm is conveyed by G and lever to ratchet wheel, L, causing further movement, which results in the pawl, M, dropping into the next notch of the wheel, causing N to fall, and valve D to drop upon its seating and close the gas-way.

Fig. 567 shows the "Bamag" apparatus as applied to a Graetzin lamp, the lighter being protected by being placed under a cover fixed upon the top of the lamp.

Provision is made in the "Bamag" lighter for the gas to be turned on to the burner by hand. For this purpose a small lever, as shown in the rear elevation (Fig. 566), actuates a cam, which, when the lever is turned from right to left, depresses the rear end of the balanced plane, N, and opens valve, D.

Reference has already been made to the tests carried out in New-

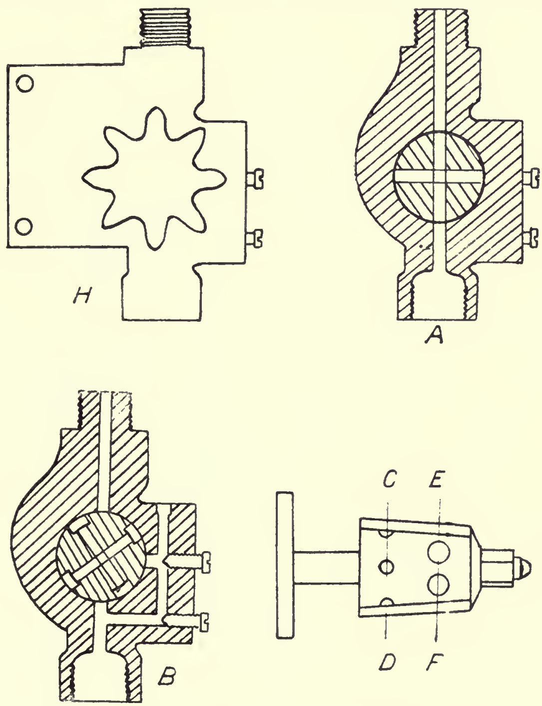


FIG. 568.—Gunning's Rotary Lamp Cock: Sections.

castle during 1909-10 with the Alder and Mackay apparatus. The "Bamag" device was concurrently subjected to the same test, with the following result. Over the 365 days during which the experiment extended, the 250 instruments were used to light the lamps a total of 91,250 times. The failures due to defects in the apparatus were as follows :—

On actuations 0.028 per 100 = 1 lamp per 3571.
On lamps lighted 0.085 per 100 = 1 lamp per 1176.

The average saving per lamp was 939 hours 19 minutes, the same as with the Alder and Mackay apparatus, and, of course, the saving in gas and maintenance was also the same, namely, £119, 15s. 10d. for the 250 lamps.

Gunning controller.—Probably the clockwork apparatus best known in this country for dealing with each lamp separately is that described by Mr W. R. Mealing at the Southampton meeting of the Gas Institute in 1902, namely, that patented by Mr John Gunning, of Bournemouth. Briefly described, this instrument consists of an arrangement of

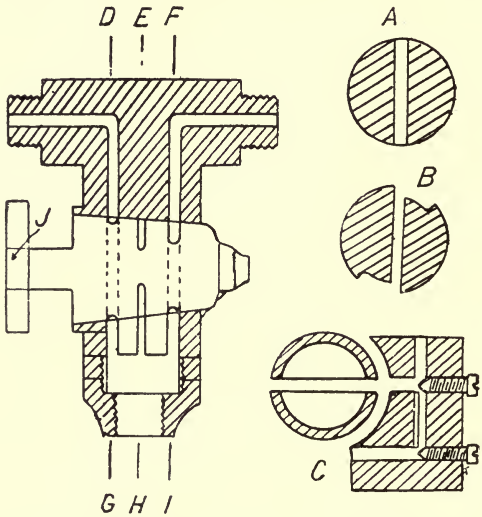


FIG. 569.—Gunning's Rotary Lamp Cock for Midnight Attachment.

clockwork, a perforated disc, a number of pawls, and a special form of lamp cock.

The clockwork causes the circular disc to revolve once in twenty-four hours, and the edge of the disc is divided into twenty-four equal divisions, corresponding to the hours of the day. The pawls are clamped to the revolving disc and rotate with it. By means of the slot shown in the disc, the position of the pawls may be varied in relation to the disc at will. The clockwork is fastened to the gas cock in such a way that the pawls, as they rotate, will engage with the cogs forming the head of the plug of the gas cock, as seen at H (Fig. 568), which shows the front elevation of a single-way cock.

In the case of a simple on and off arrangement, the plug of the lamp cock is drilled for a double gas-way, one being at right angles to the other, as seen in Fig. 568, A, which shows a section through the main gas-way. Fig. 568, B, shows a section through the by-pass, while C D shows the arrangement of the plug of the lamp cock through sections shown at A, and E F the arrangement through section B. When, however, it is adopted for cluster burners with partial extinction at midnight, the gas-way through the rotary lamp cock takes the form shown in Fig. 569. In this illustration J is the spur wheel, containing six spurs. A shows section through the plug of

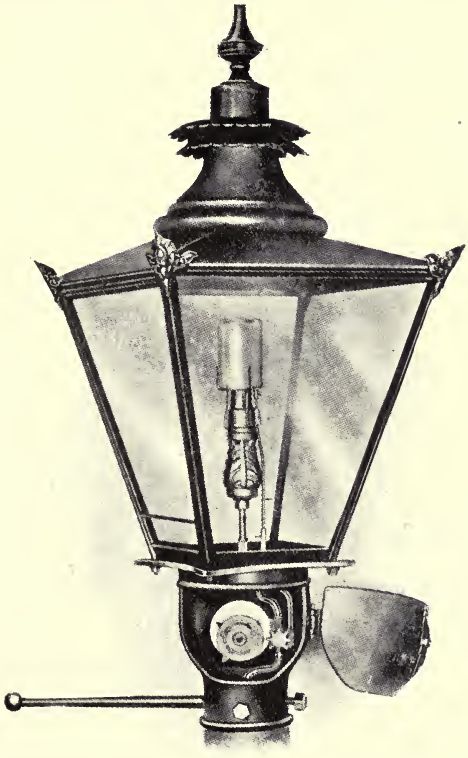


FIG. 570.—Gunning's Automatic Controller: Box Open for Winding and Setting.

the lamp cock along the line DG; B shows section through the plug along the line F I; and C shows the groove for the by-pass along the line F I.

The operation of the apparatus is very simple. The lamplighter, when cleaning the lamp, rotates the disc until the hour at which the operation of winding is performed, as marked upon the rim of the disc, is in exact line with the pointer forming part of the keep plate which holds the plug of the tap in position. The pawls are then fixed to the disc at the times following at which it is desired to light and extinguish the lamp. Thus, if the hour at which the apparatus is wound up is 3 p.m., and it is required to light the lamp at 6 p.m. and extinguish it at 5 a.m., the operator would first of all place the disc with the figure 3 exactly opposite the pointer referred to, and clamp the "on" pawl to coincide with the figure 6 following and the "off" pawl to coincide with the figure 5 following that. The controllers are made to go for 14 days with one winding, and are now fixed in a patent controller box, fixed upon the head of the lamp column, as shown in Figs. 570 and 571. These effectually protect the controller, not only from the heat and fumes of the gas but also from interference by unauthorized persons.

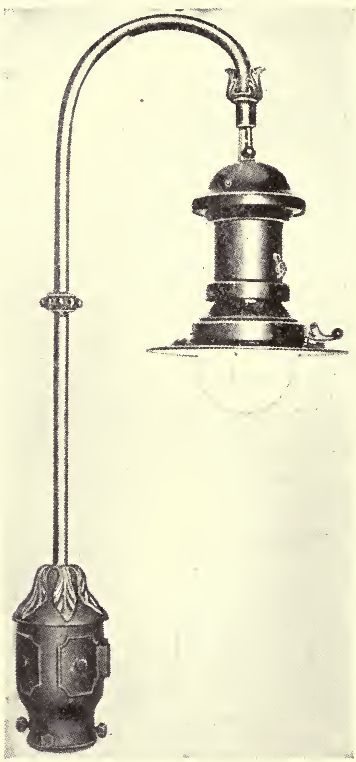


FIG. 571. — Gunning's Automatic Controller: Box Closed and Weather-Tight.

Horstmann controller. — Another automatic lighting apparatus of the same general type is the Horstmann gas controller, made by the Horstmann Gear Company, Limited, of Bath. Like the Gunning arrangement, this is actuated by clockwork but differs from the former essentially in the fact that the times of lighting and extinguishing are automatically adjusted daily at the times predetermined for the whole year, and that, when once made, precisely the same adjustments recur annually. While, therefore, giving the required number of hours for the gas to be burned per annum, the controller may, by means of these automatic daily adjustments, be set to follow a short curve corresponding to that of the rising and setting of the sun, or any deviations from this which may be required.

The instrument is shown in Figs. 573 and 574 with the front and back covers of the drum removed. The dial plate, A (Fig. 573) is made to rotate once in twenty-four hours in the direction of the arrow, in unison with the hands of the clock on the other side. In so doing the star wheel, B, comes in contact with the pin, C (the latter being a fixture to the case), which causes B to revolve one-quarter of a turn. The star wheel, B, is attached to the end of the spindle, D, which is provided at its centre with a worm, E, the function of which is to gear into two wheels, F and G, and cause them each to rotate once in a year on their respective spindles. Attached to and beneath the wheels, F and G, are the cams, H and I. Against these cams rest the two pins, K and L, respectively. These cam pins are each fixed into a disc pivoted centrally with the dial plate, A. The discs are placed one below the other, and each disc carries at its outer edge, or on an extended arm, other pins, K^1 and L^1, which actuate the tap by pressing the wedge surface of the end of the lever, M, outwards. The pin, K, is connected with the pin K^1, and moves uniformly with it, and in like manner, L is connected with L^1.

FIG. 572.—Gunning's Controller, for High-Pressure Burner.

It will be seen that the two pins, K^1 and L^1, correspond with the stops which have to be set in other controllers, but which in Horstmann's controller are varied daily quite automatically. The unique feature of the controller is, therefore, the operation of cams, H and I, which rotate once a year by minute daily movements, and are continually presenting fresh radii against which the pins, K and L, rest, and, therefore, are varying daily the positions of the pins, K^1 and L^1, around the circumference of the dial plate. The making of the cams has now been reduced to a very simple process. Fig. 575 represents a radial curve chart, each curve of which, being $\frac{1}{365}$th of the circle, represents one day. The circles represent the hours and minutes of the day, so that if the times of lighting are marked where the date line crosses the time line, and this is continued round the chart, a curve is produced which will be found, when reproduced in metal in a reduced form, to be the exact shape required to enable these times to be indicated on the controller for the predetermined lighting times. A similar chart will have to be marked for the extinguishing time.

Fig. 574 shows also the device for enabling the light to be turned on or off at will without interfering with the sequence of operations of the controller. A pin, F, protrudes from the face of a wheel or disc, A, the disc making a half revolution at each movement of the lever, M (Fig. 573). The pin always stops either at top or bottom position. In its circular movement, the pin, F, works between two shelves, C and D, in the upward movement propelling, C, and in the downward movement, D, but at the stopping points the pin is quite free of the shelves, enabling the slide, E, to be moved up or

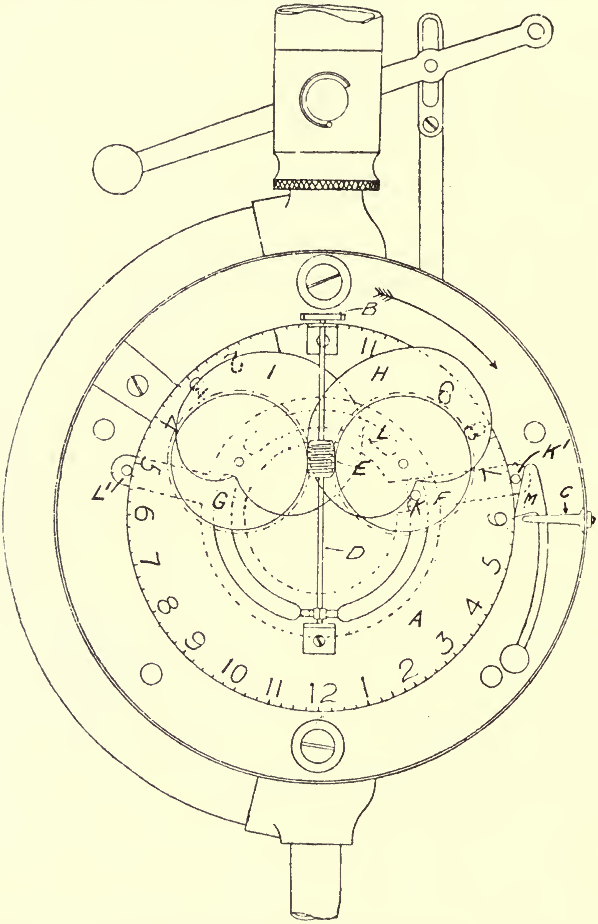


Fig. 573.—The Horstmann Gas Controller, Type 1 : Front View.

down at will. It will be seen that should a fog come on and it be found necessary to turn on the gas by hand, this can be done, the shelves, C and D, being then clear of the pin, F. At the next operation, the pin, F, makes its half-circle unaccompanied by the slide, but engages the shelves again when the time for extinguishing occurs, and so resumes normal method of working.

In the latest types of these instruments, the gas cock has been removed to the side of the controller, of which it forms a part. The slide, E (Fig. 574) is made to work horizontally instead of vertically,

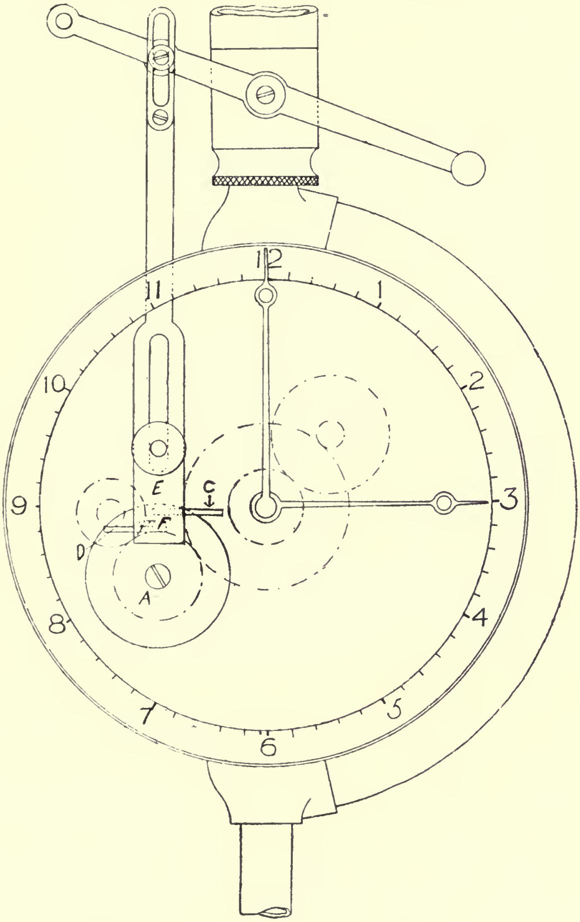


FIG. 574.—The Horstmann Gas Controller : Rear View.

and thus a considerable reduction in the height of the controller is obtained.

An addition has recently been made to the type I controller in the shape of a date-dial, fixed over the cam wheel, G, on which is inscribed the months of the year. A point near the circumference of the wheel, G, traverses this dial and indicates on the same the time of year to which the cams relate. This is an important addition, for to the attendant the date is of the utmost significance, seeing that the times of lighting and extinguishing, being in accordance with a given schedule, recur annually.

Of necessity, a gas controller with automatic adjustment is a more complicated apparatus than one in which the lighting and extinguishing times are set by hand, and in the Horstmann controller trouble was sometimes occasioned by the attendant forcing the automatic

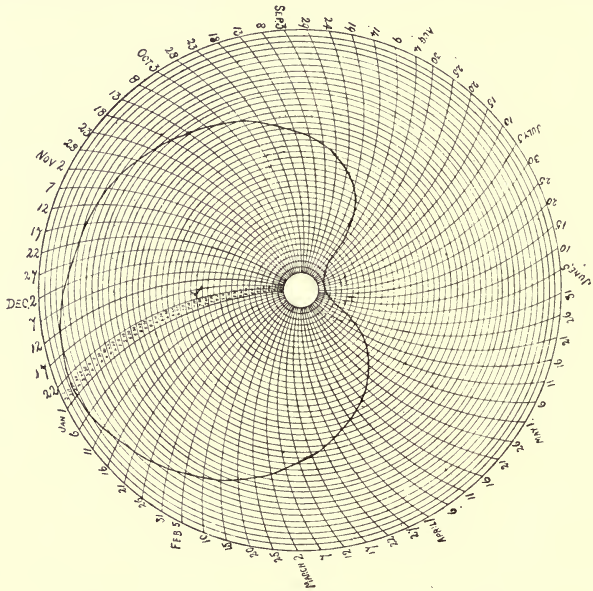


FIG. 575.—The Horstmann Controller Chart.

mechanism out of unison with the hands. By simplifying the construction of the automatic adjustment and relieving the external dial plate of the mechanism, the whole of the adjustments are now brought to one side of the apparatus, the winding only being on the other.

The improvements thus secured are :—(*a*) Both the lighting and extinguishing cams being attached to one spindle, they are free of backlash in relation to one another. (*b*) The hand which indicates the time of year on the date dial is rigidly attached to the spindle which carries both the cams, and can be set by a key. (*c*) An adjustment, which can be manipulated by hand, is provided between the point of contact with the cams and the extremity of the discharging lever. As it may sometimes occur that, while preserving the contour of lighting and extinguishing curves of a schedule chart, local authorities may desire to light and extinguish several minutes earlier or later than the schedule times, the adjustment above referred to is for producing parallel curves before or after the schedule times.

Two main advantages are, therefore, claimed for the Horstmann auto-adjustment controller, viz. :—(1) There is a perfect automatic adjustment of the times of lighting and extinguishing. (2) Any schedule can be complied with, whether a rational or astronomical schedule, or one dictated by local custom, and, having established

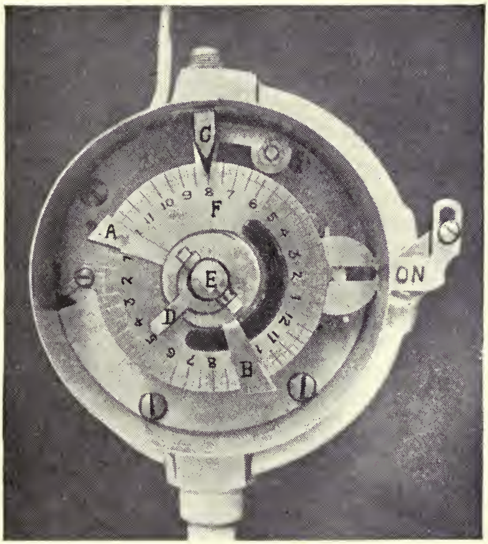


Fig. 576.—Horstmann Hand-Adjusted Controller.

cams for same, adjustments for parallel deviations before or after schedule time are possible.

The Horstmann Company have also a controller in which the times of lighting and extinguishing are set by hand. This is shown in Fig. 576. The action of the tap in this controller is the same as in the standard type, the difference between them being that in this case there is a twenty-four hour dial plate, F (which takes the place of the hands), with a pointer, C, fixed on the exterior of the same indicating the time of day on the dial. One half of the dial plate is marked in black, from 6 p.m. to 6 a.m., which indicates night, the remaining portion indicating day. The lighting and extinguishing times are set by raising the lever, D, which permits the two fingers, A and B, to be moved to the desired times of lighting and extinguishing. When this is done, the lever, D, must be pressed back again, which in this movement permanently locks the index fingers, and prevents them being moved. The winding of the controller is done at E, the winding square projecting beyond the dial.

The Horstmann Company have no less than seven variations in type of their controller, one or other of which covers almost every possible requirement of a lighting authority.

It is claimed for the Horstmann apparatus, in addition to the other advantages of an automatic lighting and extinguishing apparatus, that (*a*) There is a perfectly automatic adjustment day by day, needing no attention whatever beyond the weekly or fortnightly winding-up of the clockwork. (*b*) There is a practically simultaneous action of all controllers timed to a given chart. (*c*) That as the apparatus works in exact conformity with the chart laid down, the number of hours that lamps are supplied with gas may be determined with great precision. (*d*) That they are all quick lighters. Slow lighting may, of course, lead to lighting back at the burner. (*e*) The winding arbor is independent of the time adjustments. (*f*) The gas cock is operated very powerfully, but without vibration.

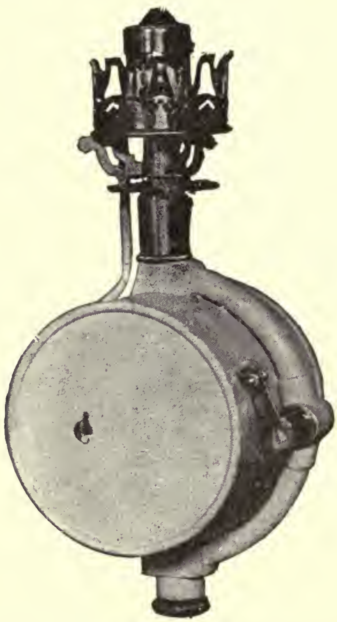


FIG. 577. — Horstmann Improved Controller, with Tap at Side, and Free By-pass.

"Dacolight" controller.—One of the latest instruments of this class to be placed upon the market is that of Messrs D. Anderson and Co., named the "Dacolight" controller, from the initial letters of the name of that firm.

This depends for its action upon the sliding motion imparted to a piston valve, similar to that of the pneumatic distance lighter (see Figs. 367, 368, p. 408), having a circumferential groove or grooves, which are brought into and out of register with the gas-way by means of clock-work actuated cams. The device is made in two forms, for (*a*) hand adjustment, and (*b*) automatic adjustment.

The arrangement, which is exceedingly simple, will be readily understood from the elevations and sections shown in Figs. 578-583. Fig. 578 shows a front elevation of the controller, with the dust-proof cover, Y (Fig. 579), removed. The clock face shown is firmly attached to the spindle, B, by means of the nut, C, and to the clockwork contained in the aluminium case, D. It is caused to revolve in the direction shown by the arrows exactly once in twenty-four hours. The operating levers, E, are carried by cog wheels behind

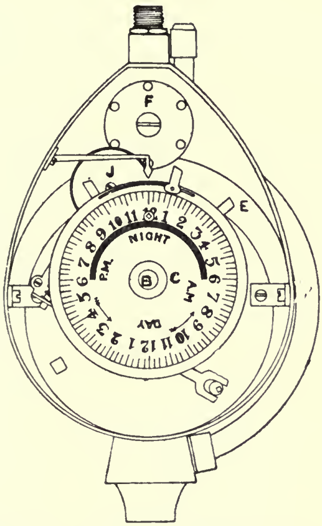


FIG. 578.—Front elevation with cover removed.

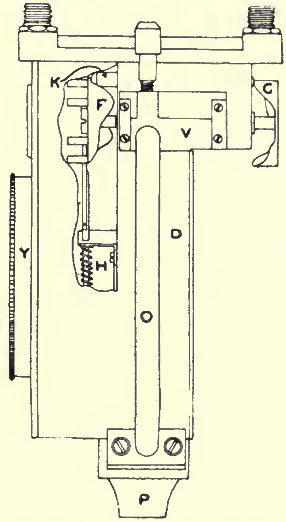


FIG. 579.—Side elevation showing valve and cams.

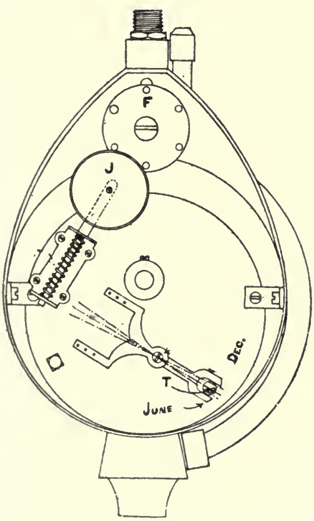


FIG. 581.

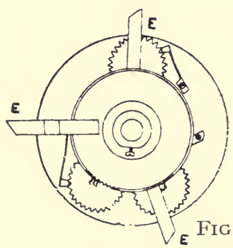


FIG. 580.

Back view showing operating levers.

Front view showing nuts for hand adjustment.

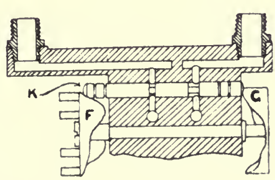


FIG. 582.—Section through valve showing midnight reducing device.

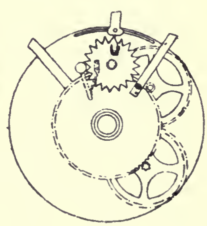


FIG. 583 — Star wheel for automatic device.

Details of the " Dacolight " Controller.

the clock face as shown in Fig. 580 (back view). These, in the hand-adjusted form of the device, are moved by the attendant by means of the keys, A (Fig. 580), when the device is adjusted from week to week, to conform to the varying time-table for lighting and extinguishing.

As the clock face revolves, the levers, E, are brought into contact with one of the six pins studding the head of the circular cam, F. The latter is, therefore, caused to rotate through one-sixth of a revolution, and is brought to rest in its exact position by means of the freely revolving wheel, J (Fig. 578). This wheel is pressed tightly into position between two successive pins of the cam head by the spring, H (Figs. 579 and 581), which allows the wheel, J, to be pushed back during the passage of the pin over its periphery, but brings it back again into position immediately the pin has passed the centre line.

As the cam, F, is thus rotated, the piston valve, K, which is kept in its precise position by the reciprocating cam, G, attached to the same spindle, is pushed by the cam surface to a new position in relation to the gas-way of the valve (Fig. 582). The pressure thus brought to bear alternately upon the front and rear ends of the piston, K, causes the latter to slide backward or forward accordingly, as shown in Fig. 582. To prevent undue wear of the phosphor bronze piston, K, owing to the continual bearing of the cam surfaces, the ends are fitted with a polished steel ball. The midnight reducing arrangement is exceedingly simple, and is shown in Fig. 582. In this case, two circumferential grooves are cut in the piston, K. The grooves may be in register with the separate gas-ways, M and N. The groove in connection with the latter is, however, cut twice the width of the former. Assuming, therefore, that the full number of burners are being used, the position of the piston would be as shown in Fig. 582. When the time for reduction comes round, the cam, F, acting on the end of the piston, causes it to slide far enough to throw the valve out of register with gas-way M, while keeping the gas-way to N open. A further movement at the time for extinguishing the lights altogether will throw both grooves out of register.

The gas supply pipe, O, is carried round the exterior of the clock casing, from inlet, P, to valve, V, within which the piston, K, works. The pilot light supply is altogether separate from the controller.

The automatic device is fitted with the double-forked member, R, pivoted at X, the fork, S, of which encloses the cam, T, which may be rotated by means of a spindle passing through the front case. The opposite fork is fitted on each limb with a number of pins, three being shown in Fig. 581, and, according as the cam, T, is placed, the pins are brought into register with one side or other of the star wheel, U (Fig. 583). Each pin represents half a minute, and as the dial turns round, the pins come into register with, and actuate, the star wheel, U, proportionately to the number of pins used. If three are used the times are advanced or retarded by 1½ minutes each day. If four pins are used, the corresponding modification is of two minutes per day. When the pointer on the cam is turned towards June, the star wheel, U, acting through the wheelwork of the mechanism, causes an acceleration of the time of lighting up, corresponding to the decreasing period of daylight, while, when the cam, T, is turned in the direction opposite to December, the pins upon the second limb of fork, R, are brought into register with the opposite side of star wheel, U, and cause a corresponding retarding of the time of lighting up, in accordance with the lengthening days of the first half of the year. Again, by turning the spindle, T, so that the cam is in a neutral position as regards the fork, S, the pins at R are brought clear of the star wheel, U, and no acceleration or retardation takes place. Provision is thus made for the few

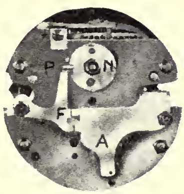


Fig. 584. — The "Automaton" Controller : Rear View of Motor with Back Plate removed.

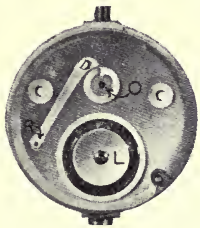


Fig. 585. — The "Automaton" Controller : Front View of Rear Plate with Motor removed.

weeks in the depth of winter and height of summer, when no alteration is made in the time-table.

Combined automatic and clockwork controller.—Hitherto the controllers described have belonged to one of two totally distinct classes—those actuated by pressure waves and those dependent upon the action of clockwork. The last to engage our attention is one which combines both these methods, being dependent upon a pressure wave to release the clockwork, which then turns on the gas.

The "Automaton" is the invention of the late Mr Geo. Robson, and consists of a small spring motor encased in a strong metal box. Fig. 584 shows a back view of the motor, with the exterior plate removed. A and F are two bent trigger levers. On the lower limb of A being pressed it moves around its pivot and raises the front limb of the trigger plate, which in turn lifts the locking lever, H (Fig. 586), out of the stop in the engagement wheel, I, and thus releases the spring and sets the motor in action.

The pressure at which the motor is set going is determined by the weight, J, attached to the levers, of which there are two, one only of which, K, is shown, the other being in connection with the trigger plate, F, and on the opposite side of the motor. These weights may be adusted to any pressure at which it is desired to work, and will, of course, resist any action before the predetermined pressure has been attained. Suppose the maximum pressure in the district is 30-tenths, then the levers are weighted to resist pressure to that extent. When, then, the additional 5-tenths usually employed to operate the apparatus are applied, the lever weights are over-balanced and the locking lever lifted out of engagement.

Looking now at Fig. 585 we see the method in which the series of levers are first actuated. This shows the interior of the back plate, the two faces seen in Fig. 584 and Fig. 585 being in conjunction when the apparatus is put together. L is the expansible gas chamber which, upon being inflated with gas at sufficient pressure, presses upon and moves the lower limb of the trigger plate, A, in a horizontal direction, lifts the front limb of the same plate, and releases the clock-work.

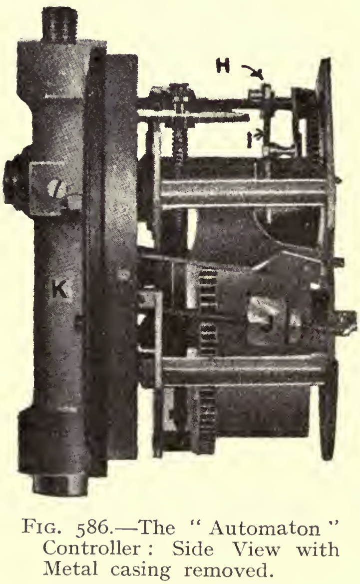


FIG. 586.—The "Automaton" Controller: Side View with Metal casing removed.

The release of the motor spring, acting through suitable wheelwork, causes the cam plate, N, to revolve. The cam plate has upon its surface two cams, shown at the top and bottom of the plate in Fig. 584. One of these in revolving engages with the contra-cam on the plug of the lamp cock, O, and carries the plug round through one-fourth revolution, thus turning the gas on.

It has been previously pointed out that the levers must be weighted the maximum pressure existing in the district, and that the operating pressure is a certain number of tenths, usually 5, above that maximum. It is obvious, therefore, that modification will be required in turning the lamps out in the morning. Assuming the maximum night pressure to be 30-tenths, the pressure in the early morning will be considerably below that amount. The difficulty is surmounted in this apparatus in a very simple and ingenious manner, by securing a double duty from the two cams on the cam plate, N. As shown in Fig. 584, the cams are in a vertical line and the lamp cock is closed. As the cock is revolved by the cam plate, one of the cams is brought under an upward extension, P, of the trigger plate, F, thus lifting it out of engagement with its companion trigger plate, A. When, therefore, the next wave impulse is applied for the purpose of extinguishing the lamp, the plate, A, only has to be moved—not A and F together as at lighting—and consequently only the weights on the lever, K, attached to plate, A, have to be overbalanced. If, now, the weights on K are adjusted to morning pressure, say 18-tenths, and those on the companion lever to 12-tenths, that would give 30 in all for lighting time but only 18-tenths for extinguishing time. It is seen, therefore, that by a proper adjustment of weights any reasonable difference of pressures for lighting and extinguishing may be provided for.

There are two great economies obtainable by the use of the "Automaton." The pilot light supply is saved for, roughly, 3500 hours during the year, and as the motor is only actually at work for about 4 hours in the year there is little wear.

It will also be noticed that at no point is the gas itself brought in contact with the operative part of the controller, and that the gas supply, K, is a straight through connection.

The "Automaton" may be actuated by hand by simply pressing a stud on the reverse side of the lever, R (Fig. 585). The lever is thus brought into contact with and actuates the trigger plate, A, in the same way as is done by wave pressure.

It is obvious that in all these automatic lighting mechanisms, one of the prime requisites is an unfailing pilot light. Where the lanterns are thoroughly wind-proof there is little difficulty. But in thousands of cases there are lanterns in use which are good and serviceable in all other respects, but which, by admitting air currents too freely into the lantern, permit the pilot light to be blown out. Without the pilot light the whole apparatus becomes useless. The pilot light must, therefore, be fully protected from draughts by one of the several devices on the market, or wind proof lanterns adopted, or both.

Relative advantages and disadvantages of collective lighting.—The relative advantages and disadvantages of the collective and the unit systems of automatically controlling the public lighting of any area, as against the ordinary method by manual labour, are as follows :—

Advantages.—(*a*) The saving of labour involved in personal attention to each lamp twice daily by the lamplighter in the usual way. (*b*) The saving of gas due to the lamps all being lighted up simultaneously at the exact time they are required. (*c*) The saving in mantles due to the elimination of the shock involved in the opening of the lanterns, turning the lamp cock, and use of the torch. (*d*) The saving of glassware, chimneys, and broken glass in lanterns due to operating with torch. (*e*) The saving in lamplighter's equipment. (*f*) The facility with which the lamps may be lighted at other than the usual hours, in cases of sudden fog or gloom.

Disadvantages.—(*a*) The inadvisability of increasing the gas pressure considerably and suddenly, even for a short time. The bearing of this upon domestic gas fires and incandescent lighting will be readily realized. (*b*) If the first pressure wave should for any reason fail, it is impossible to repeat it, for the second wave extinguishes the lamp. (*c*) The inconvenience and occasional impossibility of giving the pressure desired when stocks are low in mid-winter, or time of fog, when the demand for gas is exceptional. (*d*) The neglect of one person in advancing the pressure at the proper times would affect correspondingly the lighting of a whole district. (*e*) The cost of gas for the pilot light. (*f*) The danger of extinction of the pilot light in high winds.

The unit system.—The unit systems, such as Gunning's, the Horstmann, and the "Dacolight," have all the advantages enumerated above under *a, b, c, d* and *e,* although not quite to the same extent, and in addition have the further advantage that any single faulty operation can affect only a single lamp; also it is the only system applicable to a district where the variations in pressure are very considerable, either owing to the mains being inadequate in size, and consequently overworked, or to great differences of level.

The disadvantages are (*a*) That the apparatus needs periodical attention, say weekly or fortnightly, for the purpose of winding up the clockwork, and, where automatic adjustment is not employed, adjusting the times for the mechanism to come into operation. But as personal visitation for the purpose of cleaning the lamps would be necessary under any system, this resolves itself into a question of the additional time required for adjustment when the lamp is being cleaned, and that, of course, is only very slight. (*b*) Possible irregularity. It is difficult to ensure the clockwork of hundreds of lighters keeping absolutely true time. In addition to this initial difficulty the lamp cocks in time develop differing degrees of stiffness, with the consequence that the time taken to turn the gas on becomes unequal. The appearance through a district, therefore, at lighting times tends to become spotty, due to some lamps lighting up before others. (*c*) Clockwork is obviously inapplicable where, as in some villages and small towns, the lamps are intended to remain unlighted on particularly bright or moonlight nights. (*d*) There are also certain other disadvantages incidental to the use of clockwork in exposed situations, such as condensation of moisture, dust, etc., which may lead to certain irregularities in the working of the mechanism; but against these due precautions have been made in the three systems to which reference has been made. The disadvantages noted under (*e*) and (*f*) in the collective system obviously apply equally to the unit system.

CHAPTER XXXI

HIGH-PRESSURE DISTRIBUTION—GENERAL CONSIDERATIONS

PROBABLY one of the most important and interesting of the subjects which have been occupying the attention of the distributing engineer in recent years is high-pressure distribution. Its possibilities are being keenly investigated to-day, and the exigencies of supply will undoubtedly force the problems connected with this branch of gas engineering into increasingly greater prominence in the very near future. Our great towns and cities are growing at a prodigious rate. The development of electric tramways and other means of rapid passenger traffic are relieving the otherwise inevitable congestion at the centres, by spreading the population over much wider areas than was possible but a few years ago. The gas engineer is, therefore, brought face to face with the necessity of devising some economical means of giving and maintaining a supply of gas in sparsely populated neighbourhoods at a considerable distance from his central works or distributing stations. The mains upon the outskirts of the area of supply are generally too small to adequately deal with the additional work which is thus thrust upon them, and the problem tends to become more pressing with every year that passes.

Or the question may arise one step farther back than this. The output from certain distributing stations supplying a rapidly developing district may have outgrown the provisions for supplying the station holders themselves. In other words, the carrying capacity of the mains conveying gas to an out station may have been overtaken by the increased demand for gas from the station itself. In these and similar circumstances the alternative lies between replacing existing mains with others of larger capacity or of increasing the initial pressure. The cost and the practical inconvenience of the former remedy may be, however, so great as to become unwarranted, even if not absolutely prohibitive. Hence attention has been generally directed to the increasing of pressure as the rational solution of the problem.

Further, there is a decided tendency to look upon low-pressure distribution, such as has been in vogue for the past century, as a costly and cumbersome business. Gas engineers are, therefore, examining the question afresh in the light of present-day knowledge, to ascertain whether the limitations and the cost of low-pressure distribution are sufficiently balanced by its convenience and other advantages.

This question of high-pressure distribution has been forced into the very forefront of the practical politics of gas engineering by the accounts that have been published from time to time of the success which has attended the pioneer work in this direction carried out by our American cousins. The advantages there have, moreover, been so apparent, that the example has found ready imitators in our own country, and at Nuneaton, Stockport, Newport, Birmingham, Dunfermline, and Snodland, amongst other places, under widely different local circumstances, we have systems of high-pressure distribution in full working.

It will be desirable, at the outset, to define high-pressure distribution as comprising all those systems of distribution which depend upon apparatus other than the gasholders for giving the pressures in the distributing mains. These range over such widely varying pressures as 12 or 14 inches head of water to as much as 25 lbs. per square inch. The various systems of reinforcing pressure, or boosting, as well as that which can be more properly termed high-pressure distribution, will therefore be included in the definition.

Limitations : Soundness of distributing system.—High-pressure distribution is limited in practical work by the following considerations :—

(1) The extent to which the mains, joints, and services of the distributing system, subjected to the strains and vibrations incidental to their position under the roadways of our towns and cities, may be expected permanently to resist a very considerably augmented pressure. In other words, the capability of the distributing system to withstand the increased pressure and remain in a sound condition is a first essential. In any system of distribution the safety of person and property, as far as it can be assured, must be the first consideration. As to the pipes themselves, there can, of course, be no question. Every good pipe-founder tests pipes before they leave the works to a much greater pressure than anything yet suggested for the ordinary distribution of illuminating gas. The suggestion of Mr A. J. Martin, in his paper (1906) before the Society of Arts, on long-distance transmission, of course occupies a place by itself. As most undertakings have now discarded light tubes for heavy water and steam tubes, there should be no difficulty with the services. As to the joints and connections, there would appear to be no sufficient reason why these, made under modern conditions, with the most approved tools and best workmanship, should not prove equally satisfactory at a pressure of 20 lbs. per square inch as at as many inches head of water. As to how long any system can be expected to continue in a sound condition, owing to the various vibrations and strains inseparable from its position under the roadway, only practical experience can decide. Unfortunately, the only extended experience

available is that of American engineers, who are working under such different conditions, in many respects, as to make it difficult to estimate the result under the dissimilar conditions prevailing in this country. But if mains are protected by being laid upon a good bed, at a sufficient depth, say 3 feet, to neutralize vibrations due to heavy road traffic and the effect of changes of temperature, and the services are also properly laid and protected, there does not seem to be any intrinsic difficulty in the matter. And this reasoning is fully supported by the fact that there are many undertakings in this country now distributing gas at three times as many pounds per square inch as but a few years ago were considered fully sufficient in inches head of water. And if the splendid pioneer work now being carried out by Mr Geo. Helps, of Nuneaton, and Messrs Stewarts and Lloyds, Limited., referred to in Chapter IX., pp. 113 *et seq.*, in eliminating all joints of every kind by the simple process of welding successive lengths of main and services together, as well as welding the service attachment to the main itself, proves as economical and successful as the enterprise of the workers deserves, all doubts as to leakage and consequent danger will be fully satisfied.

The pressures at which gas is distributed under any high-pressure system may well appear very moderate to those accustomed to the distribution of other fluids. It has, however, been pointed out by Mr C. C. Carpenter that "the volume leakage of coal gas is, of course, much greater than that of denser fluids, such as water; when subjected to a similar pressure—being approximately inversely proportional to the square root of the density. To put the matter in another way, the supply of gas having a specific gravity of 0.372 at a pressure of 12 inches of water is comparable, on a leakage basis, with the supply of water under a head of 2090 feet."

(2) The next consideration to take into account is the extent to which compression may be carried without prejudice either to the illuminating or the calorific power of the gas. Fortunately, we are not without information on these aspects of the question. A very interesting and instructive series of experiments carried out by Mr Chas. E. Botley, M.Inst.C.E., of Hastings, with the object of ascertaining the loss of candle-power in coal gas under compression, shows that the fears which have been expressed in this connection are entirely without foundation as far as medium illuminating powers are concerned. The results of these experiments were embodied by Mr Botley in his presidential address to the members of the Southern District Association of Gas Engineers and Managers on the occasion of their annual meeting in London in 1885.

In the experiments, coal gas of between 16 and 17 candle-power was subjected to pressures up to 200 lbs. per square inch. It was found, as the average of a large number of tests, that a gas of 16.32

candle-power might be subjected to a compression of $13\frac{1}{3}$ atmospheres, or 200 lbs. per square inch, with a loss of 2.74 candles, or 16.79 per cent. In a second series of tests it was found that by compressing a gas of 16.9 candle-power to 200 lbs. per square inch, a loss of illuminating power equal to 2.95 candles, or 17.45 per cent., was sustained. The progressive diminution of illuminating power sustained with varying increments of pressure is shown in Table A.

In his address, Mr Botley points out one very important point in connection with gas compression, which is that " churning " must be avoided if the loss in illuminating power is to be reduced to a minimum. " The pump should be so constructed as to discharge as nearly as possible the whole of its contents at every stroke ; and the inlet and outlet valves in connection, of small size, should be placed close to the pump barrel. By this means ' churning ' of the gas (which would be the result of the expansion of the gas which was not cleared out of the pump at each stroke) is avoided, as this has a deteriorating effect on the illuminating power ; in fact, it is possible to deprive it of considerable value for lighting purposes by the faulty condition of the pump."

It was found that as the pressure was reduced the gas had the power of reabsorbing the hydrocarbons which had been compressed out, and that, therefore, there was a considerable progressive increase in the illuminating power of a gas as the pressure was diminished from 200 lbs. per square inch back again to normal. The extent to which this action took place is shown in Table B. In these experiments a gas of 16.10 candle-power at normal pressure was found to give 13.35 candles at a pressure of 200 lbs. per square inch. When this pressure had been reduced to 110 lbs. per square inch the illuminating power had increased to 15.10 candles ; at 50 lbs. the candle-power had increased to 16.0 ; at normal pressure the illuminating power was found to be 18.41 candles, an increase of 2.31 candles, or 14.34 per cent. This apparent gain in candle-power is, of course, due to the irregular ratio in which the hydrocarbons are reabsorbed. A second set of experiments starting with a gas of 16.82 candle-power gave almost identical results.

" The actual loss in illuminating power by compression—taking the difference between the gain and the loss—is only about 3 per cent. The ratio seems to be about the same whatever the original illuminating value."

American tests.—These results have been amply confirmed by those of such tests as have as yet been published by American engineers. Mr H. L. Rice, in a paper referred to in Chap. IV., states that " for accurate figures we have, thus far, only three sets of tests. Those of Mr Roberts, in 1899, showed no loss in candle-power in gas pumped at pressures up to 50 inches, or a little less than 2 lbs. Those at Newton (Mass.), in 1903, showed a gain in candle-power at 5 lbs. compression, but very considerable losses at 10, 20, and 30 lbs. The

TABLE A.—EXPERIMENTS ON THE LOSS IN ILLUMINATING POWER OF COAL GAS WHEN COMPRESSED.

(Capacity of cylinder used for experiments, 170 cubic feet normal.)

No. of Experiment.	Illuminating Power of Gas Before Compression.	Compressed to								Loss.	
		Atmospheres.	3	4	5	$6\frac{2}{3}$	$8\frac{1}{3}$	10	$13\frac{1}{3}$	Candles.	Per Cent.
		Pounds per Square Inch.	45	60	75	100	125	150	200		
1	16.32 candles		16.00	15.75	15.50	15.18	14.50	14.20	13.58	2.74	16.79
2 .	16.90 ,, ...		16.45	16.10	15.75	15.40	14.90	14.60	13.95	2.95	17.45

TABLE B.—EXPERIMENTS ON THE EFFECTS ON THE ILLUMINATING POWER OF COAL GAS AFTER COMPRESSION TO 200 LBS. PER SQUARE INCH AND BROUGHT BACK TO NORMAL PRESSURE.

(Capacity of cylinder used for experiments, 170 cubic feet normal)

No. of Experiment.	Illuminating Power of Gas before Compression.	Pressure reduced to																Gain.	
		Atmospheres.	$13\frac{1}{3}$	$12\frac{1}{3}$	$11\frac{1}{3}$	$10\frac{1}{3}$	$9\frac{1}{3}$	$8\frac{1}{3}$	$7\frac{1}{3}$	$6\frac{1}{3}$	$5\frac{1}{3}$	$4\frac{1}{3}$	$3\frac{1}{3}$	$2\frac{1}{3}$	$1\frac{1}{3}$	$0\frac{1}{3}$	Normal.	Candles.	Per Cent.
		Pounds per Sq. Inch.	200	185	170	155	140	125	110	95	80	65	50	35	20	5	Nil.		
1	16.10 candles . .		13.35	13.41	13.70	14.56	14.70	14.90	15.10	15.30	15.62	15.87	16.00	16.10	16.41	16.50	18.41	2.31	14.34
2	16.82 ,, . .		13.86	13.90	14.50	14.90	15.00	15.10	15.37	15.45	15.80	16.00	16.35	16.46	16.68	16.81	19.22	2.40	14.20

figures in these tests do not check well, and the tests covered compression only, and not transmission. Finally, we have the report of a research committee before the Ohio Association in 1905, that the loss in candle-power in compressing coal gas up to the actual pressure of 25 lbs. has been 0.3 candles, and water gas within $1\frac{1}{2}$ candles, or an average of about 0.9 candle loss. This report covered six months' daily tests made at the compressor station with each kind of gas. Tests at pressures above 30 lbs. are entirely lacking, and no experiments covering the effect of compression on heat units are yet reported." Mr Rice had evidently quite overlooked the published tests of Mr Botley, referred to above.

At the annual meeting of the American Gas Institute, held at Chicago in October 1906, Mr E. C. Jones gave the results of his experiments upon the effect of compression upon the illuminating power of a gas described as "crude oil water gas" of 21.6 candle-power manufactured from crude petroleum.

At a pressure of 60 lbs. per square inch the candle-power dropped from 21.6 to 17 candles. At 180 lbs. the illuminating power was reduced to 11.1 candles, and at a pressure of 300 lbs. the candle-power fell to 5.5. On being passed over the liquid hydrocarbons which had been compressed out, the gas again absorbed the hydrocarbons, and the illuminating power was restored.

German experiments.—In the report of the Technical Committee of the German Gas Association for 1908, this matter of depreciation of illuminating or calorific power under compression is dealt with. As a result of experiments upon a line of 3.16 inch main, $12\frac{1}{2}$ miles long, under various pressures, ranging from 5.4 inches to 154.4 inches, it was found that "the illuminating power of the gas is generally reduced to only a very trifling extent by the compression and transmission. The diminution increases with the pressure, and attains a maximum where the gas is cooled to very low temperatures. Expressed in percentages, the decrease in illuminating power at the lower pressures is nil to 4 per cent., and at the higher 6 to 8 per cent.; while in winter it may on occasions be as much as 25 per cent. The calorific power of the gas is likewise reduced to an inconsiderable extent; at the lower pressures by 1 to 2 per cent., at the higher pressures by 0.3 to 1 per cent., and in the winter by 2 to 4 per cent. The decrease in specific gravity is also inconsiderable; amounting to a maximum of 2.7 per cent. in summer and 4.5 per cent. in winter."

(3) The third limitation is that imposed by regard to considerations of economy. In part, this has already been covered. But even if the fear felt by many on the question of illuminating power should prove to be absolutely groundless, there is the question of costs to be considered. The problem may be simply stated thus. Is the capital expenditure on compressors, cost of maintenance, cost of compression, provision of additional plant, governors, and other incidental charges, balanced by the saving on account of mains and

services? It is obvious that these factors may vary very considerably in different cases. It has been computed that cost of compression to 25 lbs. per square inch may be kept under 0.5d. per 1000 cubic feet, or, including interest, depreciation, and maintenance, 1.25d.

The factors.—These factors have been put in the form of an equation (by Mr J. D. von Maur) which must be satisfied in order that the advantages of both high and low-pressure systems may be equal, as follows:—

$$G \times F \times A + G \times B + \frac{C}{10} + \frac{D}{10} = \frac{6E}{100}; \text{ where}$$

A = the cost of pumping gas, including interest, depreciation, and operation.
B = the excess cost of maintenance per consumer per year, with high-pressure service, over similar cost of low-pressure service.
C = the excess cost of investment of the high-pressure service, including governor, seal, etc., over the low-pressure service.
D = the average cost of one mile of high-pressure main.
E = the average cost of one mile of low-pressure main.
F = the average sale in thousands of cubic feet per consumer per year.
G = the number of consumers per mile of main.
6 and 10 = interest and depreciation on cast-iron and wrought-iron mains respectively.

Capital expenditure on mains.—As to the economy of high-pressure distribution, as far as capital outlay on mains is concerned, there can, of course, be no question. We have only to compare the relative costs for equal amounts of work done under the two systems to see this at a glance. As an illustration, let us take the measured quantities of gas discharged from a 3-inch main, three miles long, as given by Mr Geo. Helps, of Nuneaton, namely:—

Initial Pressure.	Outlet Pressure.	Discharge per Hour.
5 lbs. per square inch	Nil	5,000 cubic feet
10 ,, ,,	,,	10,000 ,,
18 ,, ,,	,,	18,000 ,,

Now, three miles of ordinary 3-inch cast-iron pipe, with the usual open lead joint, could be laid for, approximately, £850.

To obtain the same discharge, with a fall of pressure equal to 2 inches head of water, which is as much as could ordinarily be provided for under low-pressure distribution, would require mains as follows:—To deliver 5000 cubic feet per hour at three miles distance would require a main of 7 inches diameter; to obtain a discharge of 10,000 cubic feet per hour at that distance a 9-inch main would be necessary; while for a discharge of 18,000 cubic feet per hour we should have to lay down a main of 12 inches in diameter.

Now, three miles of 7-inch main would cost, approximately, £2280. The same length of 9-inch main would cost about £2800; and an equal length of 12-inch main would cost, approximately, £4000.

Under high-pressure conditions we should obtain the same discharge from a distributing main costing only £850 as, under low-pressure conditions, we should have to expend £2280, £2800, and £4000 to obtain, or, approximately, $2\frac{1}{2}$ $3\frac{1}{3}$, and $4\frac{2}{3}$ as much again, respectively.

The further and incidental advantages of distributing gas in bulk by means of high-pressure mains are :—

(*a*) It is possible to so arrange as to take the chief distributing mains (high-pressure) along lines which are not principal thoroughfares and not subject to heavy traffic.

(*b*) The saving in first cost ensured by laying these mains in comparatively unfrequented and more or less country roads.

(*c*) The advantageous position secured as regards possible future extensions.

CHAPTER XXXII

HIGH-PRESSURE TRANSMISSION

HIGH-PRESSURE transmission may be conveniently classified under three heads, viz. :—

I. The transmission of gas from the works to the distributing stations.

II. The supply of gas into the low-pressure distributing system; and

III. The supply of gas at high pressure direct to the consumer.

Class I.—The first class includes transmission in bulk by all those mains, of a purely domestic character, which link up the place of manufacture of the gas with the various centres of distribution. These may range from the systems, common in most of our large towns, of the transmission of gas at pressures of from 8 to 12 or 14 inches, up to the supply of local holders for small townships at 20 lbs. to 40 lbs., as adopted in certain places in the United States and Switzerland.

The distributing centres, again, may be divided into two classes. First of all, the simplest case is that where it is simply a governor house, and such a main as that mentioned in the preceding paragraph merely forms the inlet to the station or district governor, through which the district may be supplied by means of the ordinary low-pressure system, or the pressure given from other centres may be reinforced during the hours of heaviest consumption. A good illustration of this class is the case of Rodley, which forms one of the outlying portions of the city of Leeds. In this case a main is taken direct from the gasholders at the works to Rodley, about four miles distant. Here the gas, after being governed down by means of a station governor, is passed into the local mains to reinforce the pressures at times of maximum consumption.

In the second class the distributing station may also be a storage station too, where gas made during the hours of lightest consumption may be stored for distribution as required. In this case the main is used to transmit the gas from the works to the gasholders at the distributing centres. Or a compound system of Nos. 1 and 2 may be arranged, similar to that of the Gas Light and Coke Company, which was described by the late Mr G. C. Trewby, in 1904 (see *Transactions of the Institution of Gas Engineers*, 1904, p. 222), as used for the transmission of gas across London from Beckton in the east to Fulham in the west and Stoke Newington in the north, at a pressure of 48 inches, or nearly 2 lbs. per square inch. In their course the mains are used for the double purpose of filling the local gasholders and also for the direct supply of the low-pressure distributing system by means of governors placed in valve houses *en route*.

For the purpose of transmitting gas in this way from works to distributing stations, some means of raising the pressure sufficiently at the discharge end to lift the gasholders must be employed. This may be done by means of rotary exhausters or fans. These may be used in one of two ways. They may be used at the works end to "push" the gas, or at the station end of the main to "pull" the gas. If the former plan is adopted, the average pressure on the mains must be very much higher than in the latter case, inasmuch as the pressure at the commencement of the main must be raised sufficiently high to allow for the loss due to the frictional resistance of the main throughout its entire length, with all the bends, tees, and curves, which are included, and still leave the discharge pressure high enough to lift the gasholder. In that case the whole weight of the latter would be thrown upon the gas contained in the main, and through it upon the forcing apparatus, which may be a considerable distance away.

A very much better plan of attaining the same end is to use the exhausters to "pull the gas." In this case they are housed at the distributing station. The gas then starts upon its journey with the weight of the gasholder behind it, if the supply is taken out of a holder, or with the pressure due to the works exhauster behind it if the supply is taken off the "make." The station exhauster at the far end takes the whole of the thrust of the storage holders. In addition it also induces a vacuum of anything up to 18 inches, varying with local circumstances, at the discharge end of the main, and so introduces the pull. The gas, therefore, in its journey, gradually passes from pressure to vacuum, the full weight of the initial pressure being taken advantage of; the auxiliary apparatus at the distributing station is only employed to the extent absolutely necessary, and leakage upon the line of main is reduced to a minimum. It is rather a disadvantage that if there should be an unsound joint upon the portion of such a main under vacuum, small quantities of air may possibly be sucked in, to the detriment of the illuminating power of the gas. But such a contingency is rather remote, and as the main is generally under pressure when no gas is passing, any possible leak is sure to be quickly detected.

In addition to the case above mentioned of the Gas Light and Coke Company, Leeds, Dover, and many other places might be mentioned in which high-pressures are used in this country for the purpose of transmission of gas from works to distributing stations. In the undertaking with which the author is connected, part of the gas made at the works is pumped across the city, to three distributing, which are also storage, stations. From the gasholders at these stations the gas is passed through station governors into the general distributing system as a reinforcement of the local supply at times of maximum demand. Amongst the small and scattered communities of the rural districts may be cited the case of the Mid-Kent Gas Company, who, from their central works at Snodland, supply gasholders at Borough Green, Paddock Wood, Laddingford, and Brandbridges. The gas is compressed by means of Reavell compressors to a pressure of 3 lbs., and distributed through Mannesmann and other tubes over a very wide area. In many places, also, in the United States and upon the continent of Europe, advantage is being taken of the possibilities of distribution at very much higher pressure for the supply of scattered townships from a central works. In Switzerland, as Dr E. Schilling, of Munich, has told us, there is at St Margrethen, a system in which the pressure is raised from the 11 inches given by the gasholders to 236 inches maximum, by means of Roots' blowers. For these mains ordinary cast-iron pipes are used, with the usual form of open lead joint, the pipes, after being laid, being tested for soundness to a pressure of 28 lbs. per square inch.

A case typical of many in the United States is that of the North Shore Gas Company of Waukegan (Ills.), as described by Mr Geo. F. Goodnow. This Company supplies six townships on the shores of Lake Michigan from the central works at Waukegan at 20 lbs. pressure per square inch. In the case of two of these townships the pressure is governed down to the ordinary low-pressure distribution system, whilst in the others the consumers are supplied direct off the high-pressure system. It is very interesting and instructive to be assured by Mr Goodnow that were he starting again, *de novo*, he would arrange for high-pressure distribution direct to the consumer in each case.

Class II.—One of the ways in which high-pressure distribution is being pressed into the service of the gas engineer is for the purpose of the reinforcement, at selected points, of the supply of gas in the low-pressure system. This is, in brief, what has come to be known as "boosting," a rather inelegant term, for which we are indebted to the electrician.

The usual way in which it is applied is to carry the high-pressure main to the predetermined suitable points for the introduction of the "feed," and by means of a governor placed in an underground vault, or in a valve house, suitably reduce the pressure as may be necessary.

There is, however, a simpler and more economical arrangement even than this, when "boosting" up to a moderate number of inches head of water. It is to ascertain, by experiment, the initial pressure necessary to give the discharge and pressure required at the point of feed, and then to run the pressure-intensifying plant at the works to give this amount, and no more. The governor may then be dispensed with, and the whole system controlled from the works. Another plan would be to arrange an alternative speed gearing upon the boosting plant in order to meet the variable demand. It is obvious, however, that where a single high-pressure main supplies two or more "feeds," the conditions may be such as to make it impossible to work on either of these plans. In that case, the introduction of the governor is imperative.

A very good example of the first kind is the system of boosting mains laid down by Mr F. H. Shelton, of New Orleans, U.S.A., which, amongst others, comprises a 6-inch main across the river Mississippi, at New Orleans, to Algiers on the opposite bank. The gas is compressed at the works at the former place to pressures varying at different periods of the day from 20 lbs. to 40 lbs. per square inch. At the inlet to the controlling governor on the Algiers side the pressure varies from 10 lbs. to 30 lbs. per square inch, while on the outlet side of the governor the pressure is steadily maintained at 2.8 inches.

Another example, upon a very much larger scale, is the 24-inch cast-iron belt line at St Louis, described by Mr Rice. The gas is compressed by rotary blowers to a pressure of 5 lbs. per square inch, and the pipe line is designed to form a complete belt round the city. "During the mornings and nights, or during the light loads, these lines act as pumping lines, to fill the various district holders from the works, and during the hours of peak load the lines may be supplied from the two works and two holder stations. At points where the pressure in the low distribution system was low were installed manholes, having a connection to the 5 lbs. medium pressure distribution system, or belt line, and outlets into the low-pressure distribution system through suitable governors." A similar belt line high-pressure main has also been laid at Edinburgh, by Mr Herring.

A typical example of the application of boosting to a low pressure system in this country, although not dealing with such heavy pressures as in the preceding cases, is that at the Tottenham gasworks, described by Mr A. E. Broadberry at the meeting of the Southern District Association of Gas Engineers in November 1905. The pressure is raised, by means of a No. 7 Sturtevant fan coupled up to a 10 horse-power De Laval steam turbine, from the 7 inches thrown by the gas-holders to 13 inches on the outlet. After being transmitted to central points from 1 mile to $2\frac{1}{2}$ miles distant from the works the gas is passed into the low-pressure system.

More recently still, Mr T. Canning has described the plant at Newport (Mon.) used for the purpose of reinforcing the pressures in the low-lying portions of that area of supply. (See *Journal of Gas Lighting*, 21st April 1908, p. 149.)

Two Scottish installations have also been described (see *The Gas World*, 25th July 1908), at Lochgelly and Dunfermline.

In the former, gas is compressed by means of a Keith-Blackman rotary blower, and used partly to reinforce the low-pressure system, for which purpose it is governed down by Milne's mercurial governor, and partly for direct high-pressure supply to independent consumers.

A very interesting point in connection with the Dunfermline installation is that the compressor is governed from the worst supplied portion of the district, by means of a small lead tube, which is laid inside the high-pressure main, transmitting the pressure back again, and controlling the supply of steam to the compressor, according to the need of the moment, and so acting as an automatic governor.

Class III.—With the growth of practical experience in the matter of high-pressure distribution, the question rapidly presented itself to the minds of gas engineers: Why should not consumers be supplied direct from the high-pressure system, rather than indirectly through low-pressure mains? Where is the need for this duplication of systems and additional capital expenditure? And it has been difficult to supply an answer. Reference has already been made to the testimony of Mr Goodnow, of Waukegan, who is working both systems, to the effect that if he were commencing afresh he would certainly supply all consumers direct with high-pressure gas, and govern down at each consumer's service.

In our own country, the need of the rather scattered would-be consumers upon the outskirts of some of our large towns, and in many country districts, must either remain unsatisfied, owing to the prohibitive cost of gas supply at low-pressure, or be met by a system of high-pressure distribution. The splendid pioneer work of Mr Geo. Helps, at Nuneaton, described fully by him in *The Gas World* for 28th May 1904, has been followed up by many engineers in different parts of the country. The experience which has thus been gained has shown conclusively what a valuable adjunct to the ordinary means of distribution has been placed at the service of the gas engineer in this latest development in gas distribution.

CHAPTER XXXIII

COMPRESSORS

Pressure raisers.—It is obvious that the first need of any high-pressure installation is an efficient instrument for raising the pressure or of compressing the gas to the extent required. This may be done in one of four ways, namely :—

(1) By means of an adaptation to the purpose of the ordinary rotary exhauster.
(2) By means of Roots' blowers.
(3) By means of fans.
(4) By means of reciprocating compressors.

The arrangement and detailed working of these machines will now be described.

The rotary compressor.—Probably the apparatus for pressure raising which is most familiar to everyone having any knowledge of gasworks practice is the ordinary type of rotary exhauster, such as is associated with the names of Messrs Geo. Waller and Son, the Bryan Donkin Company, Limited, and other firms. This apparatus has for the last half century been one of the best known pieces of mechanism used in the whole routine of the gasworks. There it is used, as its name implies, for the purpose of exhausting the gas from the retorts. A moment's consideration will, however, make it quite evident that this is essentially the same operation as that required from a pressure raising instrument. In the former case the exhauster has to force the gas forward through the various apparatus for purification, station meters, and ultimately to lift the gasholder. The amount of work thrown upon the exhauster, and therefore the extent to which pressure is raised by it, is, of course, proportional to the back pressure thrown by the various operations of the works, plus the weight of the gasholder. When used, as suggested, for pressure raising as such, the rotary exhauster simply forces the gas forward to the desired extent against the back pressure given by the distributory system.

Fig. 587 shows an end, and Fig. 588 a longitudinal, elevation of the rotary gas compressor as manufactured by the Bryan Donkin Company, Limited, of Chesterfield.

This two-bladed rotary compressor is much stronger than the ordinary type of exhauster, and more adapted for working at higher speeds and against heavier pressures. It consists of the main shell, A, which is bored out to an oval geometrical shape such that the vertical diameter is equal to a chord struck horizontally through the centre of the axle, to suit the varying positions of the two-bladed fan or slide. The revolving drum, D, is guided in the two end plates, E and F, and contains two longitudinal slots through which the slide works. The latter is cast in one piece, with guide brackets, and contains a slot at each end to accommodate the nose-strips, I, and their spiral springs. In place of the line contact of the ordinary type of exhauster these nose-strips have good surface contact so as to minimize slip.

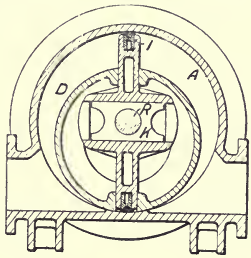


FIG. 587.—Bryan Donkin's Patent Rotary Compressor: End sectional elevation.

Guide block and slides. — The driving block, K, is of malleable cast-iron, planed to accurately fit the guide bracket of the slide. The driving block is mounted upon the strong steel shaft, R, which is carried through both the end-plates to give greater rigidity and strength.

In this design of compressor, the small number of working parts, and the comparatively low velocity of movement of the slide upon the guiding block, combined with its simplicity and strength of design, make it suitable and safe for speeds and pressures at which

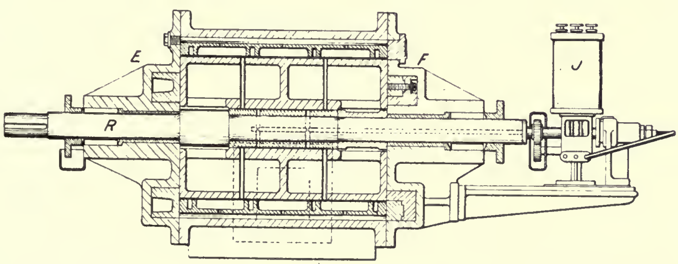


FIG. 588.—Bryan Donkin's Patent Rotary Compressor: Longitudinal Sectional Elevation.

it would be inadvisable, to work other kinds of this type of apparatus.

It will be seen, therefore, that the compressor differs from the usual type of exhauster in three main particulars :—

(1) The guiding block of the exhauster becomes the driving block of the compressor.

(2) The guiding pin of the exhauster becomes the driving shaft of the compressor.

(3) Whereas in the exhauster the drum, B, drives the slides, the

position in the compressor is reversed, as there the slides drive the drum.

One of the simplest devices for pressure raising direct into the distributing mains of a gas undertaking which the author has seen is that shown in Fig. 589. This is an adaptation to the purpose of a rotary exhauster driven by a gas engine.

In this arrangement, A is the main from the gasholder, and B is the main supplying the district which the pressure raiser is designed to affect. C is a by-pass flap valve which is weighted to remain

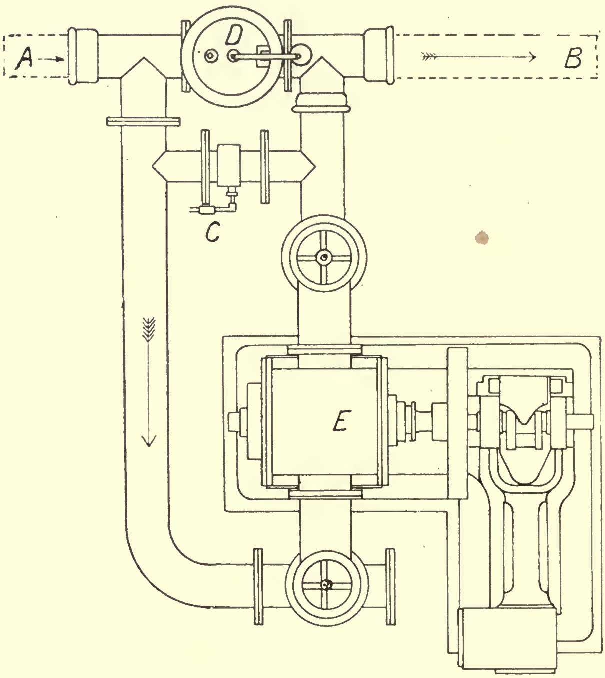


FIG. 589.—Arrangement of Simple Pressure-Raising Plant.

closed until the pressure on the outlet or main, B, exceeds a certain predetermined amount. In the event of the outlet pressure exceeding that desired, the flap of the valve, C, is opened and a sufficient quantity of gas returned again to the inlet of the pressure raiser, to reduce the outlet pressure to the necessary extent. D is an automatic governor actuating a flap valve fixed directly upon the main leading straight from the gasholder to the district main. This is so arranged that when the compressor is started the valve is automatically closed. In the event, however, of any mishap to the pressure raising apparatus, interruption of supply is avoided by the gasholder pressure opening this valve, the district main being then supplied direct from the gasholder. This arrangement, of course, enables the district to be supplied in the usual way by means of gasholder pressure during the hours of minimum consumption, the pressure raising plant being thus only brought into operation as needed during the hours of maximum consumption.

The operation of the apparatus will be readily traced. As the hours of minimum consumption merge into those of maximum demand, the compressor is set to work. At the same time the valve attached to the governor bell, which has been full open up to this time, is closed by hand. This is effected by lifting the bell of the governor, which remains constant in this position while the compressor is working. The extent to which the pressure is raised will primarily depend upon the speed at which the exhauster is run. If, however, owing to lessened consumption, the pressure on the district main is raised above the predetermined maximum, the flap valve, C, is opened automatically and a portion of the gas is passed back again to the inlet of the compressor, until the pressure in the district main is again lowered to the standard pressure which the valve, C, is weighted to resist.

In the event, on the other hand, of any mischance or accident either to the compressor or engine rendering it impossible for the apparatus to continue working, the fall of pressure in the outlet main causes the bell of the governor to descend, and in so doing, to open the valve attached to it. The gas then passes direct from the gasholder to the district main, and thus risk of total cessation of supply during the lighting hours is entirely obviated.

Although this apparatus is intended for raising pressure to a very moderate degree, far below anything usually associated with high-pressure distribution, yet the simplicity of the arrangement appears to lend itself very naturally to pressure raising to a far greater extent than is necessary in this particular case.

The need for compression to higher pressures than can be economically obtained in the ordinary single stage has led to an important new departure in this class of apparatus, in the introduction of the Bryan Donkin Company's double-stage compressor (shown in Fig. 590). This apparatus is of the compound type, two compressors being mounted upon one shaft, the slides being guided and supported by malleable iron blocks, which, in this case, instead of revolving around a central pin, are keyed on to the central steel shaft. The other details correspond largely with those of the two-bladed compressor (Fig. 587-588) previously described.

In this apparatus the gas is drawn into the large low-pressure cylinder, A, in which the first stage of compression is accomplished. The gas is then passed on through the channel, J, arranged in the bed plate, to the inlet of the small high-pressure cylinder, H, in which the compression is carried still further, to the extent of the delivery pressure desired. The two cylinders are arranged in tandem fashion, the fan blades being fitted at right angles to each other in their respective cylinders, in order to equalize the turning moment on the driving shaft. The heat generated by the working of the apparatus is abstracted by the water jacket, K. It is claimed that this compressor compares very favourably with those of the reciprocating type in the matter of efficiency; that it is simple in design, exceedingly strong in workmanship and materials, and eminently suitable for working against heavy pressures; that the number of working parts is small and entirely enclosed, so that costs of repairs and maintenance are reduced to a minimum; that there is an entire absence of all internal valves; and that, as the compressor is perfectly balanced, an easily running machine is assured. The double-stage rotary compressor was shown at the Earl's Court International Gas Exhibition in 1904, running against a delivery pressure of 20 lbs. per square inch.

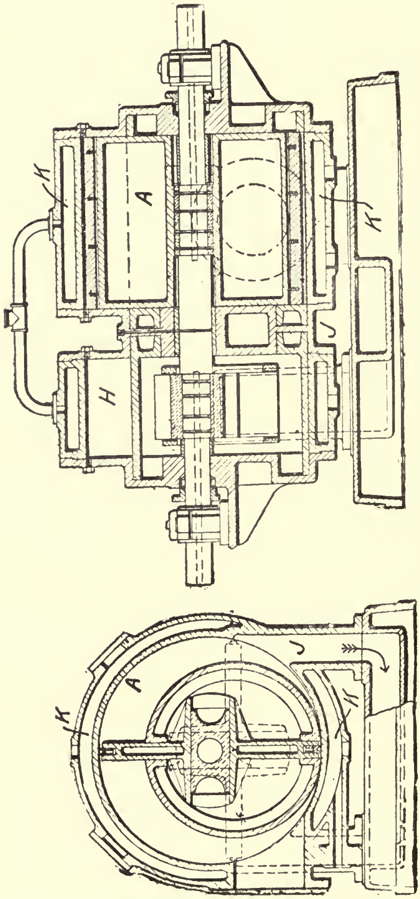


Fig. 590.—The Bryan Donkin Company's Patent Double-Stage Rotary Compressor.

Roots' blowers. — The improved Roots' blower (shown in Figs. 591 to 593) as manufactured by Messrs Thwaites Bros., Limited, of Bradford, was, in its original form, introduced by the firm of P. H. and F. M. Roots, of Connersville, Ind., U.S.A., and met with such success that it was quickly introduced into this country. It is now largely used for industrial purposes requiring the compression of moderate quantities of air to comparatively low pressures, and may be obtained of all capacities from 20 cubic feet to 25,000 cubic feet per minute, working at pressures up to 3 lbs. per square inch. To obtain higher pressures than this, with any regard to efficiency and economy, it is necessary to work the blowers in series.

The blower consists of the case, A A, the upper and lower portions of which are of semicircular section, accurately bored out to their true dimensions. The semicircular portions of the case are securely bolted to the main body of the blower case, which is of rectangular section, the front and back plates of which, respectively, accommodate the inlet and outlet of the blower of this type.

In the case as thus described, the revolvers, B B, J J, are caused

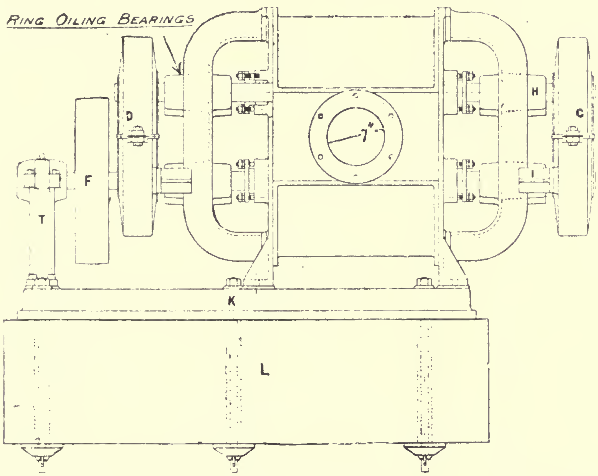


FIG. 591.—Side Elevation of Improved Roots' No. 7 Vertical Blower.

to rotate. The original revolver blades were made of wood, covered by a special plastic composition. These have, however, long since been superseded by the iron revolvers which are now in general use in this class of machine. The revolvers are each cast in one piece, of a special quality of iron. They are strong in design, light in weight, and in fitting are most carefully balanced to secure evenness of working, and to ensure an entire absence of jarring or knocking. The cycloidal faces of the revolvers are machined all over to gauge by special machinery, to accurately fit the case and each other. The degree of accuracy of fitting thus attained is such that, although there is at no point actual contact between the rotary revolvers and the containing case, the amount of "slip" is reduced to a minimum, and the mechanical efficiency of the blower, when working at moderate pressures of 2 to 3 lbs. per square inch, is correspondingly high. As shown by the arrows in Fig. 593, the revolvers rotate in opposite directions to each other; and at precisely the same angular velocity. With a view to reducing the weight of the revolvers, Messrs R. and J. Dempster, Limited, have recently patented an arrangement in which a series of diaphragms are covered with metal sheeting.

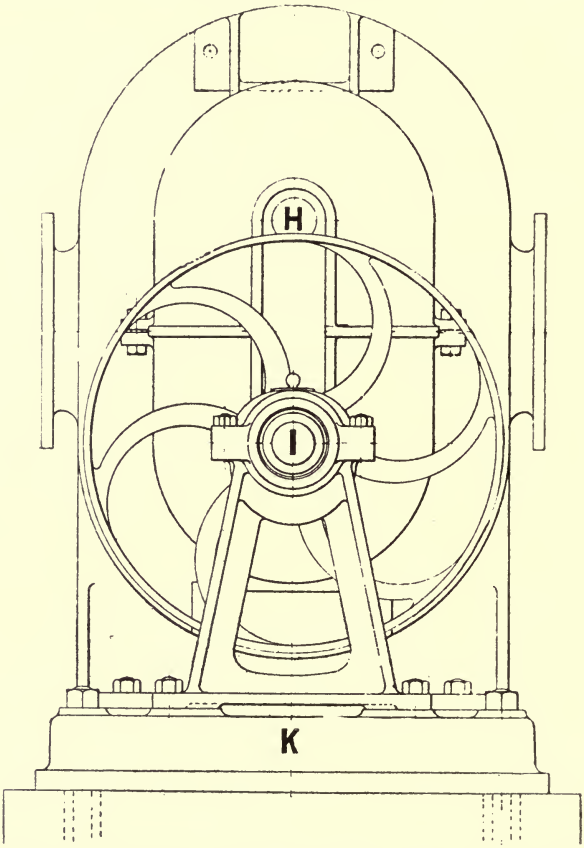


FIG. 592.—End Elevation of Improved Roots' No. 7 Vertical Blower.

The revolvers are driven by belt and pulley, F, fixed upon the revolver shaft, I. For the purpose of ensuring absolute uniformity of angular velocity, the two shafts, H and I, are geared together by means of gear wheels contained in the cases, G and D (Fig. 591). When working, these wheels are enclosed as shown, and the lower of the two dips into an oil bath. In this way, not only is smoothness of working secured, but the noise, which was such a disadvantage in some of the older types of blowers, is reduced to a vanishing point.

The blower is carried by the bed-plate, K, supported by the concrete bed, L, to which it is secured by the holding down bolts shown in Figs. 591 and 592. Additional rigidity and strength is afforded by the use of the external support, T. The shafts are fitted with ring bearings and gas-tight glands.

The following table gives additional particulars of the various

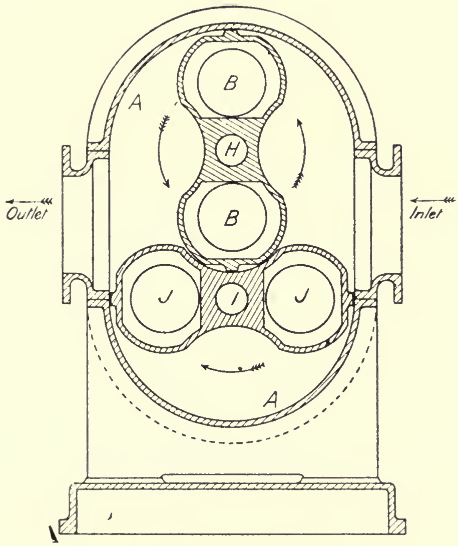


FIG. 593.—Improved Roots' Blower: Section through Revolvers and Case, with Arrows Showing Direction of Rotation of Revolvers.

sizes and capacities of Thwaites' vertical Roots' blowers of the type just described :—

Number of Blower.	4.	5.	6.	7.	8.
Maximum number of revolutions per minute	350	320	310	300	280
Air delivered per min., cubic feet	4550	6400	8680	11,000	12,500
Diameter of delivery orifice, inches	12	13½	17	19	22
Diameter of driving pulleys, inches	16	18	20	22	24
Breadth of driving pulleys, inches	5	5½	6½	7	9
Approximate indicated horse-power at full speed . .	18	25	35	44	50

An installation of Roots' blowers was laid down a few years ago in connection with the distribution of gas at pressures up to 39 inches from the works at Mariendorf to the suburbs of Berlin.

The turbo-fan pressure raiser.—An instrument which has been brought into special prominence during the last few years for the purpose of pressure raising to a moderate extent is the steam turbine coupled up to a fan. The turbine has been a very familiar piece of apparatus for many years, both in its reactionary and impulse forms. Presenting, as it does, great advantages for many purposes over some other forms of motive power, it has been largely adopted for fan driving.

Fig. 594 shows the turbo-fan pressure raiser supplied to the Mitcham Gas Company by the Bryan Donkin Company. This consists of a Rateau fan, for which this firm are the agents in this

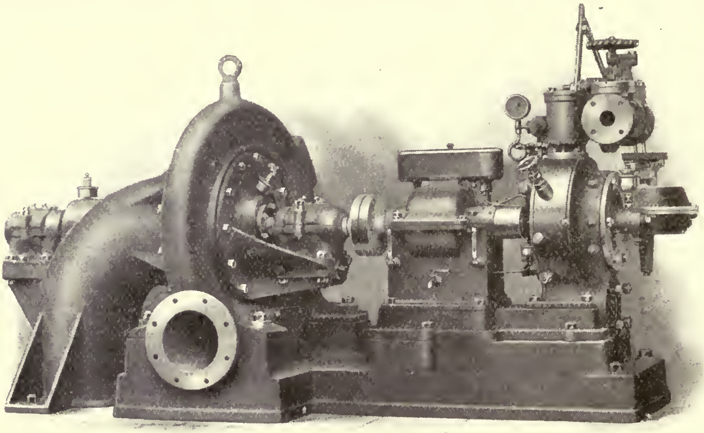


Fig. 594.—Rateau Fan and De Laval Turbine for Mitcham Gasworks.

country, direct-coupled up to a 20 horse-power De Laval steam turbine. The installation is designed to deal with 250,000 cubic feet of gas per hour against a pressure of eighteen inches. A plant of this kind is especially valuable where the gasholders are too light to give the necessary pressure at times of maximum consumption. In many gasworks the storage is quite inadequate in the periods of heavy demand, and when the holders come down to the first or even second lift the pressure given is not great enough to give a sufficient supply throughout the district. A boosting plant such as this, placed between the gasholders and the station governors, permits the practical emptying of the holders while still maintaining the required pressure however the demand may vary.

A somewhat similar plant in duplicate, supplied to the Grangetown gasworks at Cardiff, is shown in Fig. 595.

This consists of two Rateau fans designed to deliver 500,000 cubic feet of gas against a pressure of eleven inches, each coupled up to a De Laval steam turbine of 30 h.-p. The fans are used to increase the pressure at the inlet to the station governor at the Grangetown works, and also, by means of an 18-inch high-pressure main, some 2000 yards long, connecting the Grangetown works with the central station at Bute Terrace, to reinforce the pressures at the governors there. Not only may light holders be used at any time,

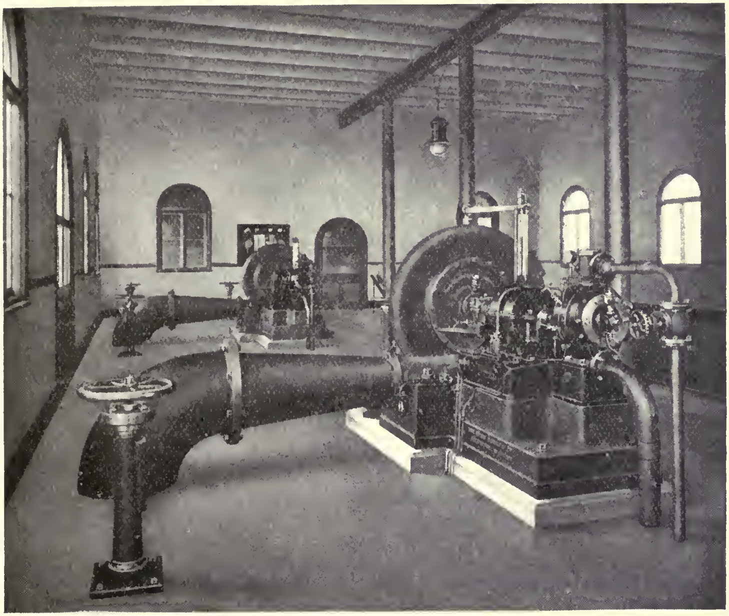


FIG. 595.—Boosting Plant at Cardiff Gasworks.

but the fans give complete control of pressures, however the demand may fluctuate, so long as there is any stock of gas to draw upon. The plant being in duplicate, both or either may be used at any-time in accordance with the demand.

A general and sectional elevation through a Rateau fan are shown in Fig. 596. The fan consists of a cast-iron casing, made in two parts. The flanges on each are machined true, perfectly fitted and bolted together. Great care is exercised in casting the casing so that no sharp corners are left, or any other obstructions allowed which would interfere with the perfectly free flow of the gas.

The fan centre is built up in such a way as to be perfectly true, special arrangements being made to prevent "slip" of gas from inlet to outlet of the fan whilst it is working. As seen in the sectional elevation, the fan blades are so set as to be alternately tangential to two circles of differing diameters. They are so designed and mounted that they run quite freely in the bearings without excessive pressure on either ends of the shaft.

The stuffing boxes for the fan shaft are specially designed, and cannot be screwed up so tightly as to affect the satisfactory running of the fan. These stuffing boxes are kept full of grease, and so run quite cool and gas-tight with the minimum amount of attention.

Owing to the great care exercised, and high-class workmanship employed in the manufacture of these fans, and the almost perfect balance obtained, they may safely be run at very high speeds. Reference will be made to this in connection with the flexible shaft in the description of the De Laval steam turbine which follows. Meanwhile we may note that a mechanical efficiency of 70 per cent.

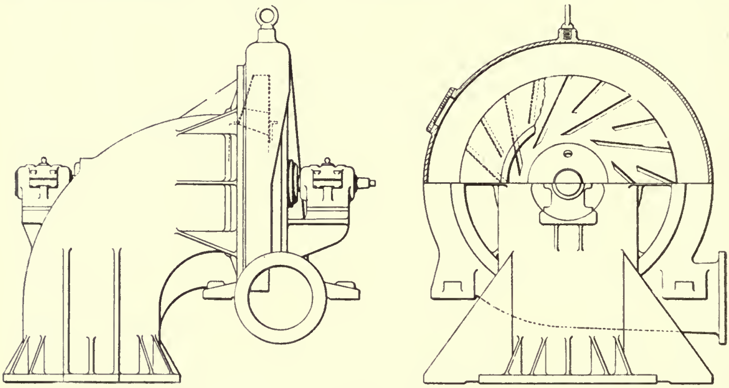


Fig. 596.—General and Sectional Elevation of a Rateau Fan.

is usually attained with the Rateau fans, and in a recent test this efficiency was exceeded.

The De Laval steam turbine has been very fully described by Mr Konrad Anderson, in a lecture delivered by him upon this subject at the Leeds University in January 1902, and also in a paper on "The Steam Turbine as applied to Blowing and Exhausting Apparatus," contributed by Mr Wm. D. Child, of Romford, to the proceedings of the Gas Institute at the meetings held at Southampton in June 1902. To both of these authors the present writer desires to acknowledge his indebtedness.

Figs. 597-599 show sectional elevation and elevation and plan of a 7 horse-power De Laval turbine motor as made by the Albion Turbine Company, Limited, of Leeds. In these drawings, A represents the steam inlet, B the turbine wheel, and C the flexible turbine shaft. E is the gear wheel, which gears into the pinion, P, on the flexible shaft, on the double helical system, and reduces the high speed of the turbine shaft to the extent necessary for driving of fans or other

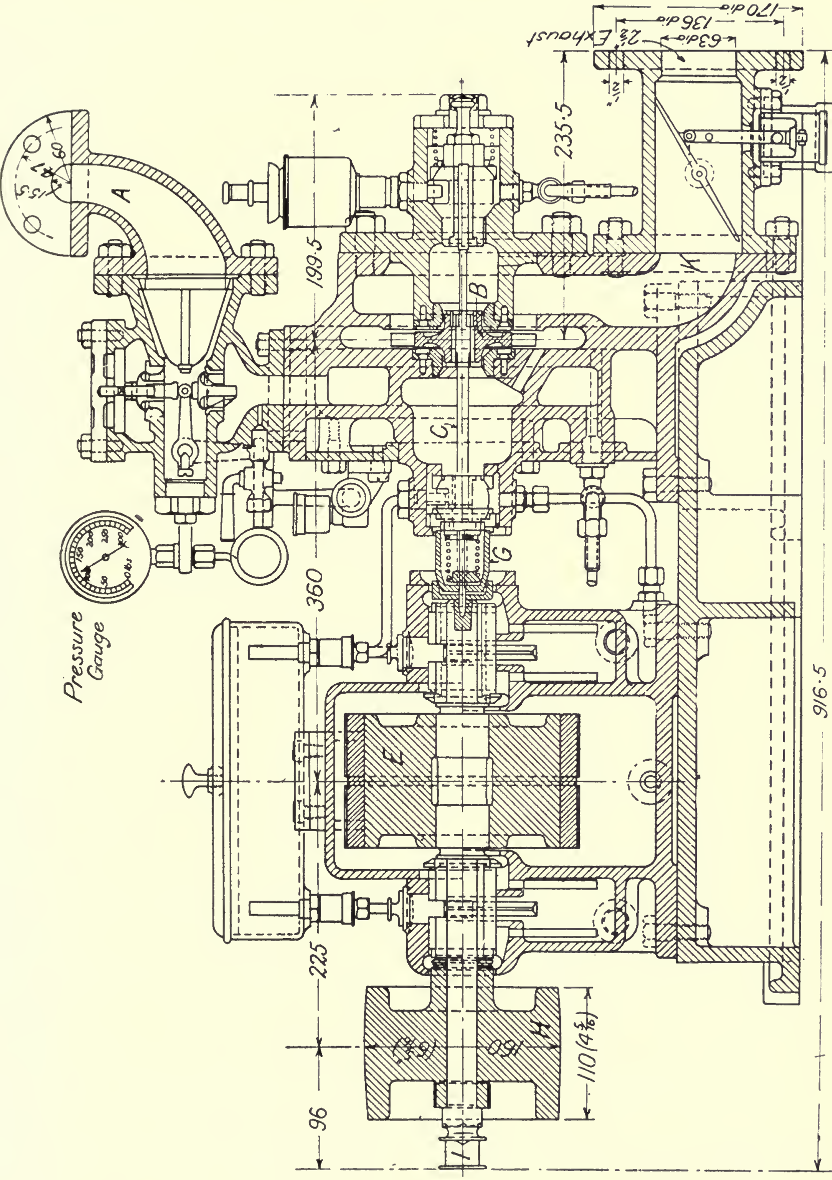


FIG. 597.—De Laval Steam Turbine: Sectional Elevation.

machinery. H is the driving pulley, and I the small pulley for connecting up to a tachometer. G is a centrifugal governor horizontally mounted upon the gear wheel shaft; and K is a chamber for the exhaust steam, leading to the exhaust outlet. The various dimensions are given in millimetres (1 millimetre = 0.03937 inch).

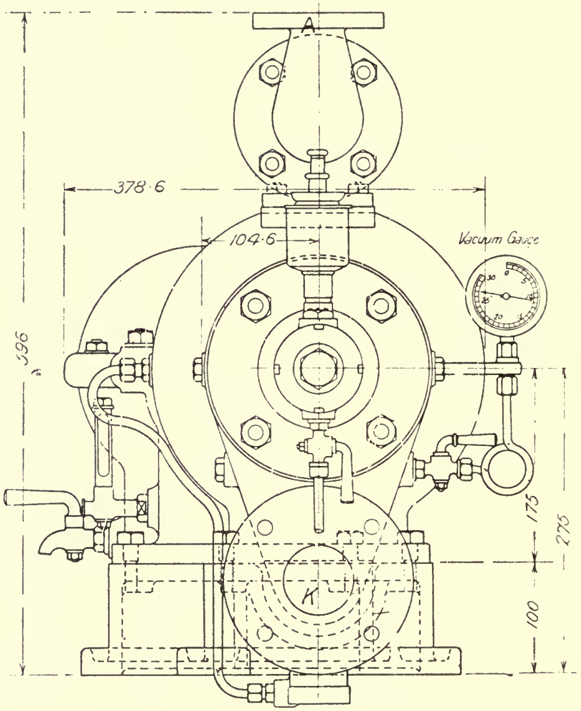


FIG. 598.—De Laval Steam Turbine: End Elevation.

The motion is derived from the action of a steam jet at high velocity impinging upon, blowing through, and expanding against a series of vanes or buckets fixed upon the periphery of the turbine wheel, as shown in Fig. 600. The steam jet is set at an angle of 20° to the plane of rotation, and about $\frac{1}{16}$-inch from the buckets, so as to reduce the loss of velocity between nozzle and wheel to the smallest extent possible.

With a view to reducing friction to a minimum, and to obtain the maximum of efficiency from the expanding steam, the chamber in which the turbine wheel revolves is kept under vacuum. The importance of this will be appreciated from a perusal of the following table of speeds of turbine wheels given by Mr Anderson in the lecture previously referred to.

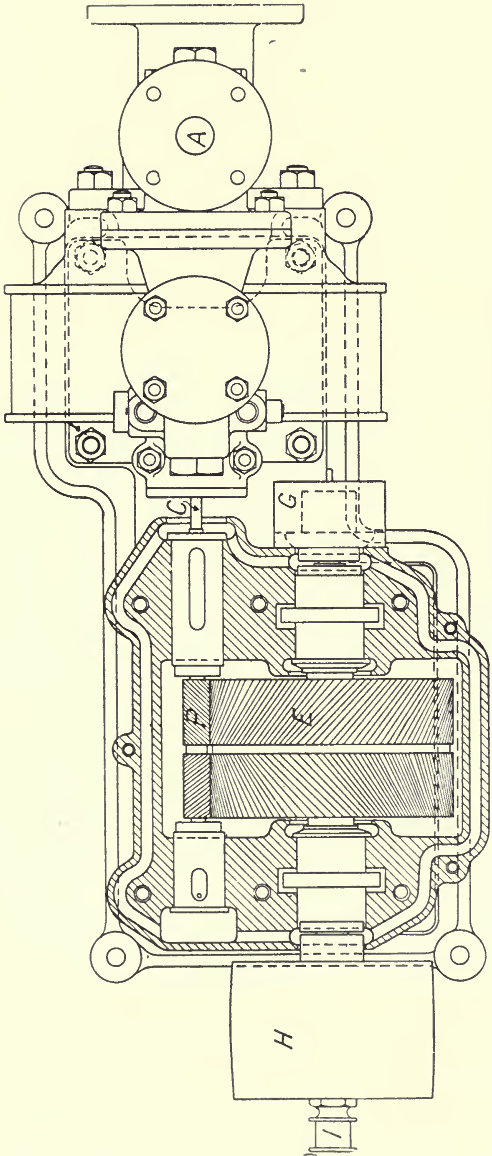


Fig. 599.—De Laval Steam Turbine: Plan in Part Section.

SPEEDS OF TURBINE WHEELS.

Size of Turbine. Horse-Power.	Middle Diameter of Wheel. Inches.	Revolutions per Minute.	Peripheral Speed in Feet per Second.
5	4	30,000	515
15	6	24,000	617
30	$8\frac{7}{8}$	20,000	774
50	$11\frac{3}{4}$	16,400	846
100	$19\frac{3}{4}$	13,000	1115
300	30	10,600	1378

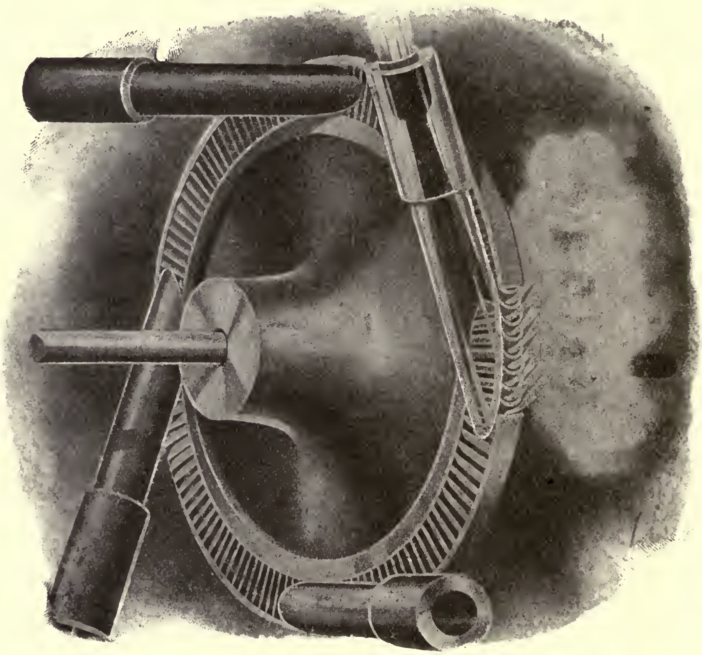


FIG. 600.—De Laval Steam Jets and Turbine Wheel.

These tremendous speeds are obtained partly from the kinetic energy of the steam supplied at high velocity to the nozzle, and partly by expanding the steam in the specially constructed conical-shaped nozzle, a section through which is shown in Fig. 601, and partly by stimulating the expansion by maintaining a vacuum. "Steam expanded in a nozzle from 280 lbs. pressure above the atmosphere down to 28 inches vacuum leaves the nozzle with a velocity of 4229 feet per second, or over 48 miles per minute."

The flexible shaft.—One unique feature of the De Laval steam turbine, which alone enables the strains and stresses incidental to such high speeds being successfully resisted, is the flexible shaft upon which the turbine wheel is mounted. In the lecture already quoted from, Mr Anderson says:—"The shaft on which the turbine wheel is mounted has the bearings on each side of the wheel at a good distance from this wheel, and the shaft is consequently flexible and can allow the wheel to swing a little in its plane of rotation. No

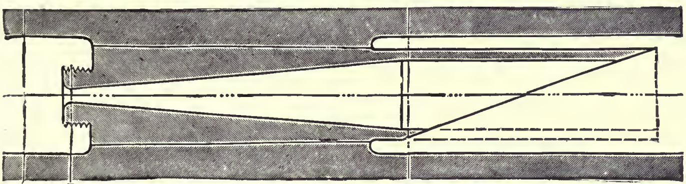


FIG. 601.—De Laval Steam Turbine: Section Through Nozzle.

matter with what nicety the turbine wheel may be turned and balanced, it is practically impossible to bring the centre of gravity of the wheel exactly into its geometrical centre round which the wheel revolves. The fault causes vibrations, which, if a firm shaft were used, would increase with the speed to such an extent that the bearings would instantly be ruined. With the employment of a flexible shaft there are also vibrations increasing with the number of revolutions of the wheel. At a certain speed, however, the phenomenon arises that the vibrations suddenly disappear, and the shaft runs smoothly in its bearings.

"The speed of the wheel at which this phenomenon arises is called 'the critical speed of the wheel,' and the phenomenon itself is termed 'the settling of the wheel.' . . . The flexible shaft and the turbine wheel are so proportioned that the settling of the wheel takes place very quickly, and the critical speed is $\frac{1}{6}$ to $\frac{1}{8}$ of the standard number of revolutions of the wheel. The diameter of the shaft in the 150 horse-power turbine is only 1 inch, and that of the 300 horse-power turbine $1\frac{5}{16}$ inches."

As will be seen, the steam nozzles are several in number, varying with the size of the apparatus. These nozzles are each fitted with a shutting-off valve, as shown in Fig. 602. In the event, therefore, of the working load being varied the number of nozzles in action may be correspondingly adjusted, the expenditure of steam being thus kept strictly proportionate to the needs of the moment.

The turbine in all its standard sizes may be used with any steam pressure varying from 50 lbs. per square inch to 200 lbs. per square inch, specially shaped nozzles being supplied to suit the steam pressure available and the degree of expansion necessary for the highest efficiency of the turbine at that pressure. It is also supplied to work either with or without a vacuum.

In his Southampton paper, Mr Child points out two additional great advantages which the De Laval steam turbine has over other types of motor. First of all, its exceeding compactness. A turbine of 15 brake horse-power, together with the "blowers, were delivered completely fitted, and were carried into the engine room packed in a case."

The second point is the entire absence of any possibility of steam

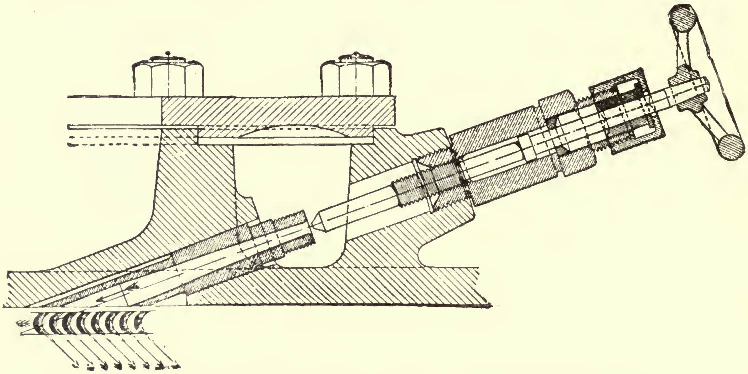


Fig. 602.—De Laval Steam Turbine: Shutting Off Valve.

leakage. "Unlike the reciprocating engine, the De Laval has no stuffing boxes, no glands, no packing, no working parts under pressure, and consequently, no leakage—in this respect differing from all other motors. The efficiency of a steam engine as given in a shop testing room may be of the best; but with each day's running leakage steadily increases and efficiency decreases; while the turbine remains practically unaffected, owing to the fact that, although a very high pressure of steam may be used, it does not come in contact with the moving part—the buckets of the wheel being the most likely to suffer from the cutting action of the steam, and these are easily renewable."

One of the earliest installations of the turbo-fan arrangement for pressure raising is that of the Dover Gas Company, laid down in 1904, and of which the late Mr Raphael Herring gave a lucid account to the Southern District Association of Gas Engineers and Managers, at their meeting in November 1905. This consists of a No. 3 Sturtevant special gas fan, driven by a direct-coupled De Laval steam turbine, of 5 brake horse-power.

This apparatus was put down for the purpose of increasing the carrying capacity of an existing main by augmenting the initial pressure at which the gas was supplied. The main in question is one running from the works to a gasholder station, situated about 1½ miles away, and which main had become quite inadequate for the duty imposed upon it.

By the courtesy of Mr Herring, the author was enabled to see the apparatus at work soon after its installation, and was much impressed, both by the exceeding compactness of the motor, to which reference has previously been made, and also by the ease of running and utter

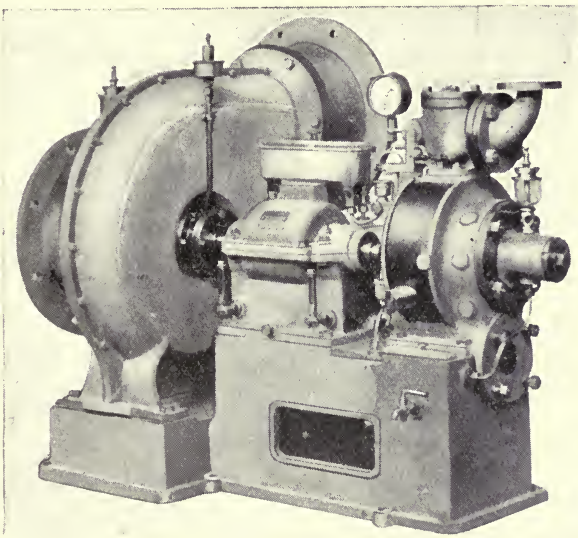


FIG. 603.—The Turbo-Fan Apparatus at Dover.

absence of vibration. In addition to these advantages, to those who have been made painfully aware of the dire results which may happen through a particular valve being open or closed at the wrong time, or through misunderstandings between men on duty at the opposite ends of a main through which gas is being pumped, there is a considerable attraction in the fact that with this apparatus, under similar conditions, no such results could occur, the fan in that case simply running in its own gas.

The following is Mr Herring's very succinct description of the Dover apparatus. "The turbine runs at a very high speed—32,000 revolutions per minute, directly geared to the exhauster running at 4000 revolutions per minute—and increases the gasholder pressures 120-tenths. It is geared down eight to one, the usual practice being to gear up. The advantages of the former method will be easily recognized. The plant has a working capacity of 2,250,000 cubic feet per twenty-four hours, the floor space occupied being 36 inches by 20 inches. The connections are 12 inches in diameter, the whole apparatus being installed in a small room 10 feet by 7 feet 6 inches. This is quite large enough for a 5,000,000 cubic feet set.

"From the foregoing particulars, you will observe that the machinery is exceedingly compact, and also very light, considering

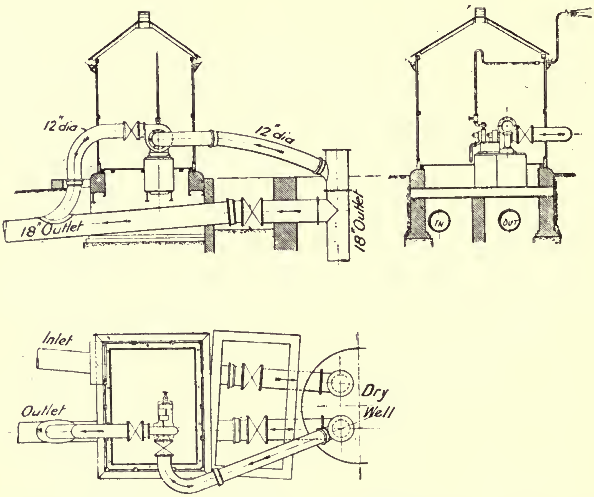


FIG. 604.—Elevation and Plan of Connections to Turbo-Fan Pressure Raiser at Dover.

the work done. The total weight of the complete plant, including the bed plate, is 7 cwts. 20 lbs."

Fig. 604 shows the elevation and plan of the fan connections. These are taken from the 18-inch outlet from the gasholder, before the usual valve is reached. When the pressure raiser is not required, this valve is opened and the gas by-passes the apparatus. When the latter is working, of course this valve is closed.

The wonderful steadiness of the outlet pressures when the pressure raiser is at work is admirably shown on the chart, Fig. 605, one of several kindly supplied by Mr Herring for the purpose of this work, and which was taken on the 29th January 1906. On that date the apparatus was started about 4.45 p.m. and ran until 9 p.m., the record showing an almost steady line between those hours after the maximum had been attained. The increase of pressure at 2.20 a.m. is, of course, due to change of holders.

Similar sets to that at Dover have since been supplied to the

Plymouth and Stonehouse Gas Light and Coke Company, and a duplicate set to the Corporation of Leicester Gas Department.

The machine shown in Fig. 606 represents one of a duplicate set installed by the Southampton Gas Company. It consists of two No. 1 special gas fans in series, fitted with a pressure lubricating system, and driven by a direct-coupled De Laval steam turbine of 7 brake

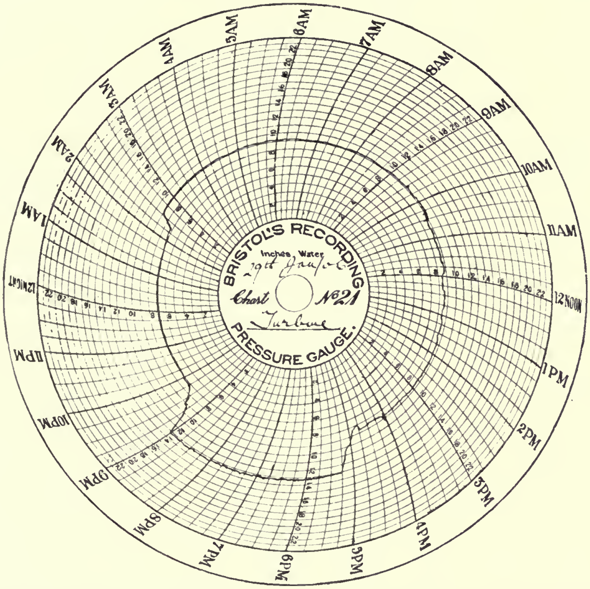
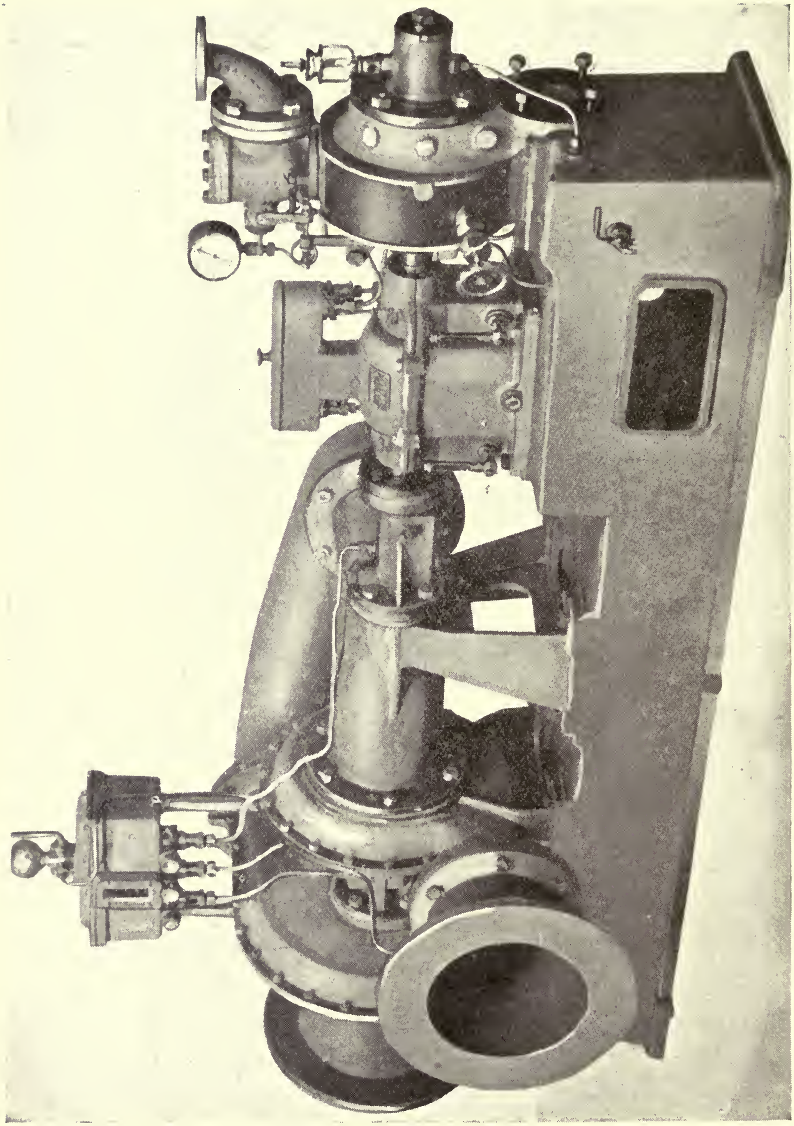


Fig. 605.—Pressure Record taken upon the Outlet of the Turbo-Fan Pressure Raiser at Dover Gasworks, 29th January 1906.

horse-power. The normal speed of the fans is 5500 revolutions per minute, and they are capable of raising the pressure of gas between inlet and discharge by 31 inches head of water, the specific gravity of the gas being taken as 0.65. The instrument is capable of dealing with 28,000 cubic feet per hour, and is used for the purpose of supplying the gasholder station at Eastleigh, 10,400 yards distant from the gasworks.

Reciprocating compressors.—The pioneer system of high-pressure distribution in this country, using the term in its now commonly accepted sense, as distribution at pressures varying from 5 to 20 lbs. per square inch, is that installed by the Nuneaton Gas Company, on the advice of their engineer, Mr Geo. Helps, in 1903. This was fully described by Mr Helps in a contribution to *The Gas World*, 28th May 1904.

The type of compressor used by Mr Helps is a horizontal tandem



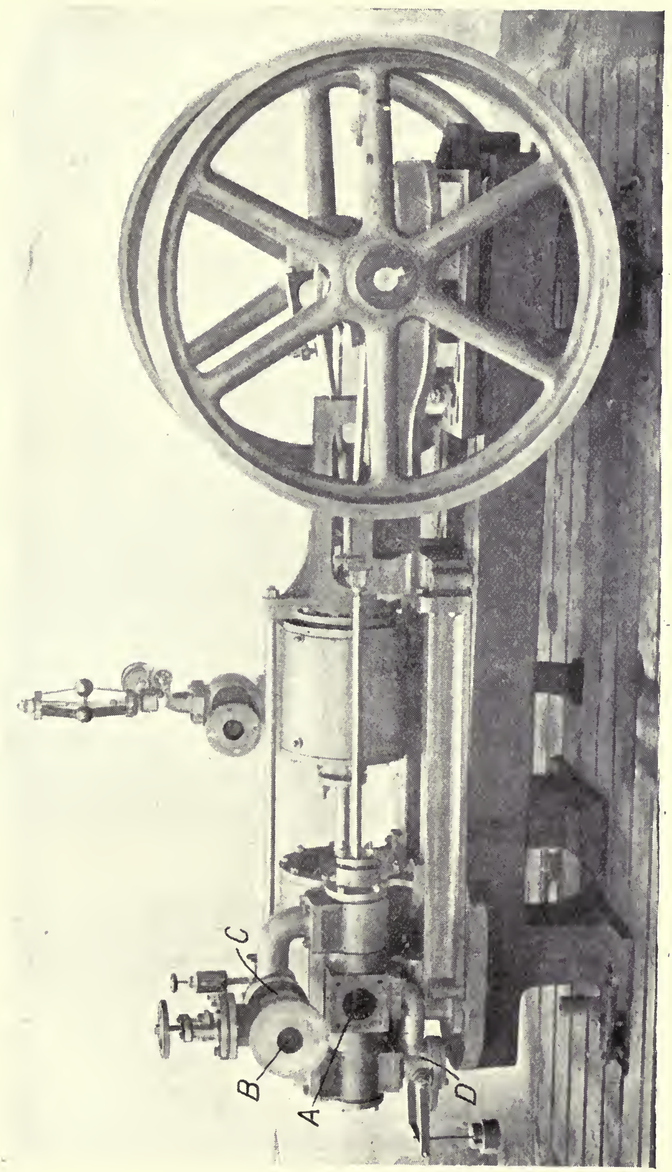


Fig. 607.—James Milne and Son's Compressor.

single-stage steam driven reciprocating compressor (shown in Fig. 607), and manufactured by Messrs James Milne and Son, Limited, of Edinburgh. This apparatus has positively driven piston valves, and the gas compressor is 12 inches by 10 inches. The steam cylinder is also 12 inches by 10 inches. The suction pipe, A, is below the discharge, B, and upon the latter is fitted a non-return valve, C, which permits of the apparatus being shut off in the event of the compressor being out of work.

A by-pass relief valve, D, is fixed upon the suction pipe, A, and

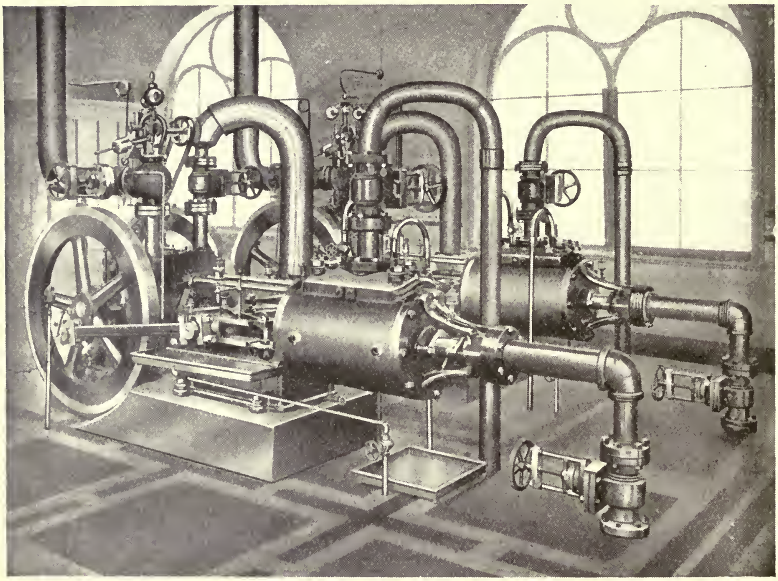


FIG. 608.—The Ingersoll-Sergeant Compressor.

is weighted to open should a predetermined pressure be by any means exceeded upon the discharge main, a quantity of the gas being by this means returned to the inlet of the compressor until the outlet pressure has been reduced to the desired extent.

The apparatus is designed to compress gas to a maximum pressure of 40 lbs. per square inch, working at a speed of 160 revolutions per minute.

Another excellent type of compressor is the series manufactured by the Ingersoll Rand Company, of New York, one of which (shown in Fig. 608) has been put down, in connection with his high-pressure installation, by Mr S. Meunier, of Stockport.

The illustration shows an Ingersoll-Sergeant "straight line" steam driven simple compressor, laid down in duplicate, with steam cylinder of 12 inches diameter and gas cylinder of 16¼ inches diameter and 12-inch stroke, which, at the rated speed of 150 revolutions per minute, would compress 24,900 cubic feet of gas per hour. These compressors are of the piston inlet type, and are fitted with an air ball governor for regulating purposes, and also special intake brackets enclosing the ends of the gas inlets.

One of the most interesting features in connection with the Ingersoll-Sergeant compressor is the arrangement of air or gas valve in the piston. It is probably not too much to say that the whole efficiency of the compressor depends upon the satisfactory working of this valve. The "Sergeant" piston inlet valve has during the last year or two been replaced by the "hurricane" inlet valve. Through the elimination of the guide pins it is possible to increase the circumference of the valve, thus greatly enlarging the effective inlet area, and consequently a greater volumetric efficiency is obtained. The valve is now placed in the piston in a reversed position to that in the former construction, and is held in position by a movable guide plate with perforations round the circumference, so that a double ported effect is obtained. The construction and working of the valve may best be described in the words of the makers:—"The 'hurricane' inlet valve, standard on most of the Ingersoll types of Ingersoll-Rand compressors, is a development of the original piston inlet valve. It retains the 'piston air inlet tube' feature of the latter, but differs in some very important details, resulting in a marked improvement. Each valve—one on each piston face—is a continuous ring of high-carbon, oil treated steel, forged without welds, and turned to a light 'T' section with no holes, slots or weak places. The port is an annular opening in the piston face, of unusual area, and with no obstructions whatever. The bar of the 'T' is the valve face seating over the port. The upright of the 'T' is the guide section sliding on a steel guide plate bolted to the piston face, and made with openings so that the valve is double ported.

"The valves travel with the piston, the one in front closing first by its inertia, and remaining closed under air pressure. The valve behind, as soon as the piston starts, drops back against its stop, making a full opening, maintained until the piston stops, when the valve slides gently to its seat. The inlet valve cannot open until the clearance air is expanded to atmosphere, so there can be no escape of air already compressed. The valve being very light and the travel very short, there is no shock, and practically no wear. When the valve moves it opens full, stays open for the full stroke, and closes instantaneously. Nothing can be more simple and more positive than this valve action.

"The valve is free to turn around its guide ring and does actually turn in operation, never seating twice in succession in the same position, and being thus automatically self-grinding. The removal of any discharge valve on the cylinder exposes the "hurricane" inlet valve, which can be turned around by hand and examined over its entire circumference without removing the cylinder head. There

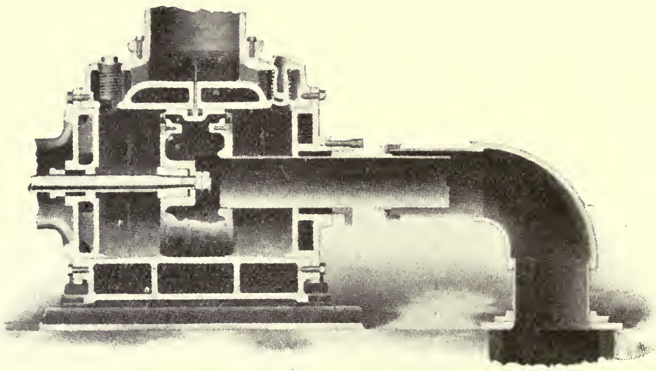
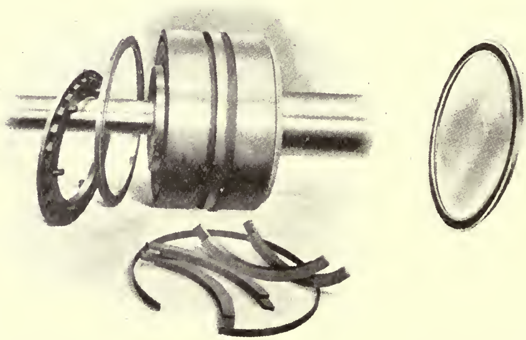


FIG. 609.—Section through "Hurricane" Inlet Air Cylinder, with Cushioned Direct Lift Discharge Valves.

are only two moving parts, actuated solely by momentum and air pressure."

Reference to Fig. 609 shows the "hurricane" inlet valve around the piston rod, between the guide plate and the piston. One of



Piston, with its Component Parts. A Single Valve

FIG. 610.—The "Hurricane" Inlet.

the segmental piston rings is shown in Fig. 610. Nothing about a compressor gives less trouble than the piston rings, which stay in place until worn out. Yet the "hurricane" inlet valve, as shown in Fig. 610, is even more simple than a piston ring.

The intake area afforded by the "hurricane" inlet valve is 12 to 15 per cent. of the total cylinder area. The intake gas enters through the inlet tube, which is constantly cooled by contact with the jacketed cylinder head. The gas piston and valves are cooled by continuous contact with the cold cylinder walls. The gas is admitted in a solid column, and everywhere encounters cool metal. Its temperature cannot be perceptibly raised in the fraction of a second required for the complete stroke.

The use of the "hurricane" inlet valve permits the most thorough cylinder jacketing possible, not only improving the compression efficiency, but resulting in a sustained tightness of all working parts due to better lubrication.

To obviate the possibility of the compressor pulling up dead owing to excess of pressure in the receiver, it is usual to insert a by-pass between inlet and outlet of the compressor. The by-pass is controlled by a pop valve, which is weighted to open at a certain

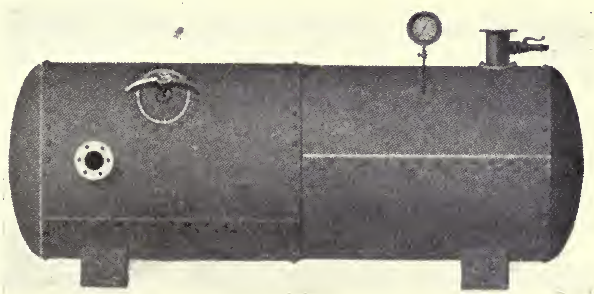


FIG. 611.—Horizonta· Compressed Gas Receiver.

pressure, say about 5 lbs. above the working pressure. When, therefore, the pressure thrown by the gas in the receiver exceeds this amount, the valve opens, and gas is passed again to the inlet of the compressor.

Gas receiver.—For the purpose of acting as a cushion to neutralize the pulsations of the compressor and avoid any oscillation upon the distributing mains, it is advisable to pass the compressed gas into a receiver, the horizontal and vertical forms of which are shown in Figs. 611 and 612.

The receiver, therefore, occupies a somewhat analogous place in high-pressure distribution to that of the gasholder in a low-pressure system; and inasmuch as the gas may be compressed into the receiver at a much higher pressure than it is intended to be supplied at into the mains, the receiver acts, to some extent, as a storage reservoir. The size of receiver necessary to effectually cushion the compressor pulsations very conveniently admits of the double function being performed.

A very effective method of still further neutralizing the pulsations into the receiver is as follows. Take a piece of pipe equal in size to the inlet, and about one-third to one-half the length of the receiver. Perforate this with such a number of small holes as shall in the sum more than equal the area of the pipe. Fix this into the centre of the receiver to act as the inlet pipe, leaving, of course, a short projection upon the exterior to receive the inlet connection. When high-pressure gas is thus introduced into the receiver the pressure is rapidly distributed through the perforations, and the compressor pulsations, broken up into a great number of fine streams, become effectually neutralized.

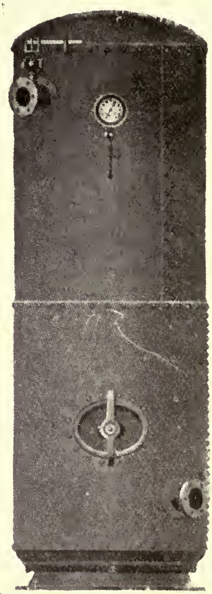


FIG. 612.—Vertical Compressed Gas Receiver.

These receivers are made of the best steel plates, with the side seams double riveted, and are tested to an hydraulic pressure of 225 lbs. per square inch. The preference is usually given to the vertical pattern, on account of the small floor space required.

Another simple and very effective type of anti-pulsator, when working at moderately high-pressure, was described by Mr A. E. Broadberry in a paper on "High-Pressure Lighting" read before the Southern District Association of Gas Engineers and Managers in November 1910. This consists of two lengths of 36-inch cast-iron pipe placed in a vertical position, and connected together by a piece of 4-inch pipe near the bottom. The first is six feet in height, and closed both top and bottom. The second is 12 feet in height, and is closed at the bottom, but open at the top. The gas is discharged into the top of the first pipe. Before starting the compression the pipes are filled with water to a height of about 5 feet 6 inches. The two pipes then form a kind of irregular U tube. When the plant is started, the pressure acting upon the surface of the water in the first tube depresses the level until the pressure is balanced by the rise in the open pipe. A small reservoir of compressed gas is thus formed, the pulsations through which, due to the compressor, are readily taken up and neutralized by the water cushion below it.

Three-Way valves.—One of the necessities of a combined high and low-pressure supply installation is a thoroughly reliable three-way valve. These are not only necessary for the mere control of the different mains, but, being automatic in action, they serve to prevent accident should the high-pressure supply ever suddenly cease from any unforeseen cause. Fig. 613 shows one form of this type of valve. This consists of a pivoted valve gate weighted to withstand less than the high pressure at which the compressors work. The valve, A, which has side flaps, while being a good fit, moves freely in the valve case. By the position of the counterbalance weights, it may be arranged to operate at any desired pressure. The high-pressure gas acting on the flap raises it up to its highest position, cutting off the low-pressure inlet. No communication can be established between the high-pressure and the low-pressure at the same time, and it is found in practice that the valve does not remain in an intermediate position. It is either full up or full down.

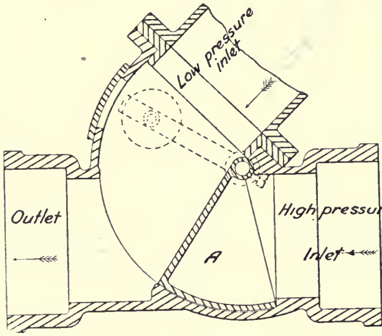


FIG. 613.—Peebles' Three-Way Valve : Flap Type.

Another type of three-way valve is shown in sectional elevation in Fig. 614. This consists of a piston moving freely in a vertical direction, which, according to position, controls one of two sets of ports. In the illustration the piston, A, is shown in the lowest position, thus opening the low pressure to the district. If the high-pressure main is now turned on, the valve, A, will be raised to its highest position, closing the ports B, and opening those at C. Owing to the blind portion of the valve at D, it cannot hang in an intermediate position. It must be either entirely up or right down. It will thus be seen that the valve is automatic in action, and simple in construction.

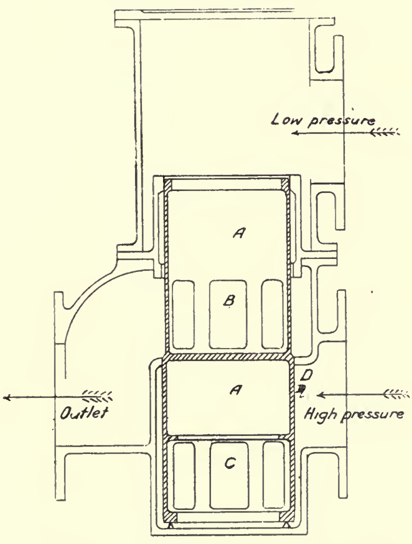


FIG. 614—Peebles' Three-Way Valve : Piston Type.

CHAPTER XXXIV

HIGH-PRESSURE DISTRIBUTORY APPARATUS

It is interesting to note that Mr H. L. Rice, in a paper read before the American Gas Light Association in 1905, states that "for the carriage of gas at pressures not exceeding 5 lbs., cast-iron pipe is successfully used and most favourably regarded. It has also, in a few instances, been used at higher pressures; and specially designed joints are on the market for this work. For pressures of over 5 lbs., however, screw-joint pipe of wrought-iron or mild steel is most generally employed. In the long screw-joint lines expansion sleeves are provided about every 500 feet, and valves are inserted at intervals of perhaps one-half mile, for the isolation and repair of breaks." With regard to this use of screw pipe for high pressures, the author's experience, even when working at such moderate pressures as 8 to 10 lbs., has not been a particularly happy one. When a pipe line has been laid and a small leak shows itself under test at any joint—it is sure to be some distance from the free end—there are no means of making the joint sound but taking the pipes apart and re-jointing again, except, of course, either riveting up or using a Dresser coupling, and either of these should be rigorously ruled out in connection with new work. With all its faults, the lead joint is far superior to the screw from this point of view. As a rule, steel tubes with "rigid" joints are being used in this country for high-pressure mains, a notable exception being the Birmingham 24-inch high-pressure main, which is of cast iron with open cast lead joints.

Main syphons.—In the earliest days of high-pressure gas distribution it was thought that the dehydration of the gas involved in the compressing process would render the use of syphons on the line of main unnecessary; that the question of proper fall might be, if not altogether, yet to a considerable extent, neglected; and that any small quantity of condensation which might possibly be collected could be blown out by the gas pressure through suitably placed plug holes on the line of main. Fuller knowledge has, however, somewhat modified that impression, and it is now generally recognized that drips must be used to ensure free working. The author's own practical experience is, however, that, except for one immediately outside the compressor house, no condensation has been received by any of the other half-dozen syphons on the Leeds high-pressure mains throughout a twelvemonth's working. The type of drip must, of course, be modified to suit the altered conditions. Fig. 615 shows one form of a high-pressure main drip tank, reproduced by permission of the editor of the *Journal of Gas Lighting*, from

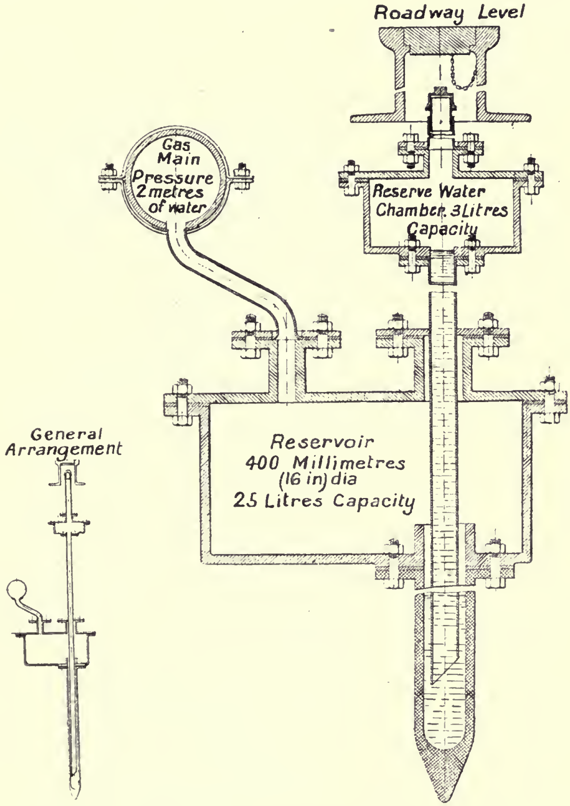


FIG. 615.—French Sealed Syphon for H.-P. Mains.

the paper read by M. D'Aubenton-Carafa before the Société Technique du Gaz in 1908.

Another very good form of syphon for high-pressure mains is shown in Fig. 616, and was described by Mr James Hewett in a paper read before the Midland Junior Gas Association in January 1912. "This is of the through pattern, of cast iron, having socket and spigot ends, and is cylindrical in cross section. The body of the syphon is cast in one piece, and the top consists of a flanged cover-plate. A hydrant valve is provided upon the cover, and a tube attached to the underside of the valve reaches to within an inch of the bottom of the syphon. The top of the tube attached to the outlet of the valve is a few inches below the surface of the highway, and is provided with a 'hydrant' half coupling and cap. The usual box, with cast steel door fitted with safety lock, is fixed above the hydrant valve. Pipes are arranged for access to the spindle of the hydrant valve, and for the protection of the discharging tube. The syphon carts are fitted with a short length of flexible

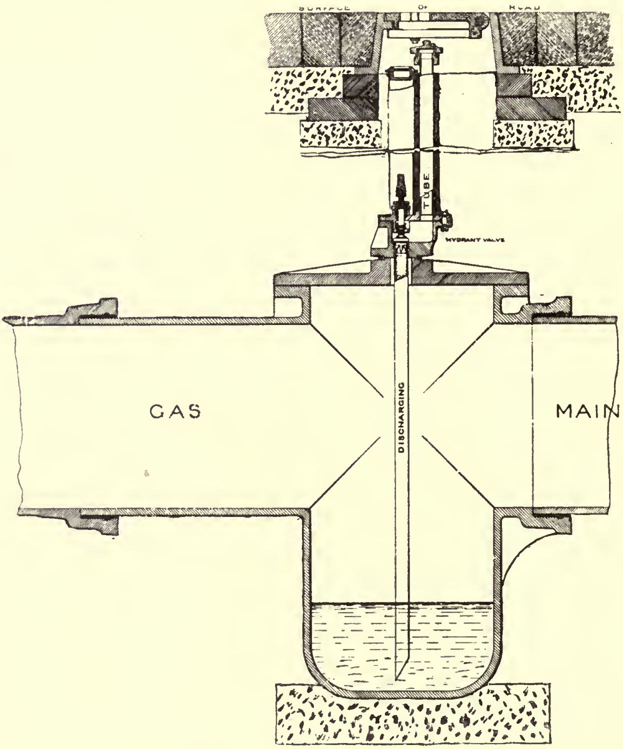


FIG. 616.—Birmingham High-Pressure Syphon.

hose, fitted at one end with a hydrant half coupling. To empty the syphon, the flexible hose is connected in lieu of the hydrant cap and the other end placed in the syphon cart. The hydrant valve is opened, and the contents of the syphon are discharged by the pressure of the gas in the main. After closing the hydrant valve and detaching the flexible hose, any liquid that remains in the tube above the valve is pumped out before the cap is replaced. Isolation valves of full bore, with two parallel discs, are provided in the mains about half a mile apart."

District governors.—When boosting pressures from a high-pressure main into a low-pressure distributing system, one of the first requirements is a thoroughly safe and reliable district governor. Of these

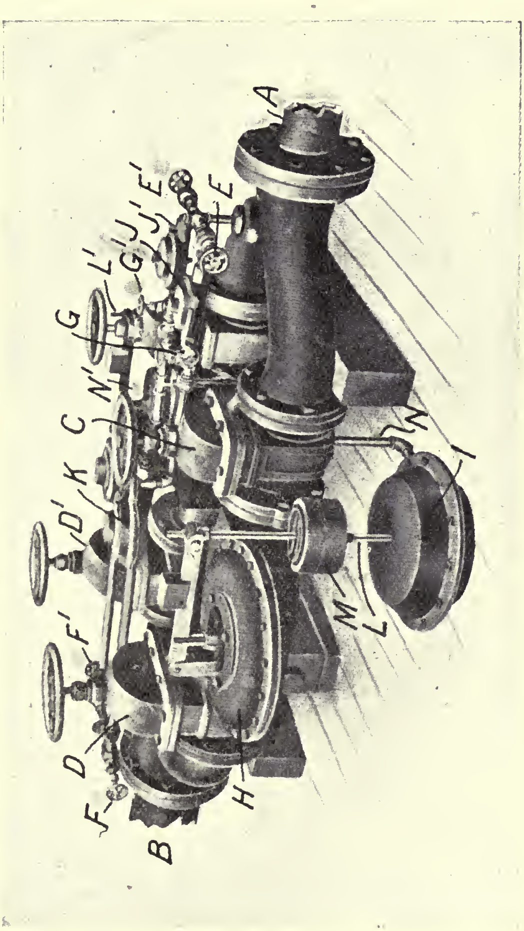


FIG. 617.—Duplicate Set of Johnson-Reynolds District Governors.

there are several now on the market, of which two each of the "diaphragm" and "bell" types may be taken as examples.

The Johnson-Reynolds high-pressure district governor, for which the Bryan Donkin Company are the English agents, is shown in Figs. 617 and 618. The large area of the auxiliary pressure bowl, which

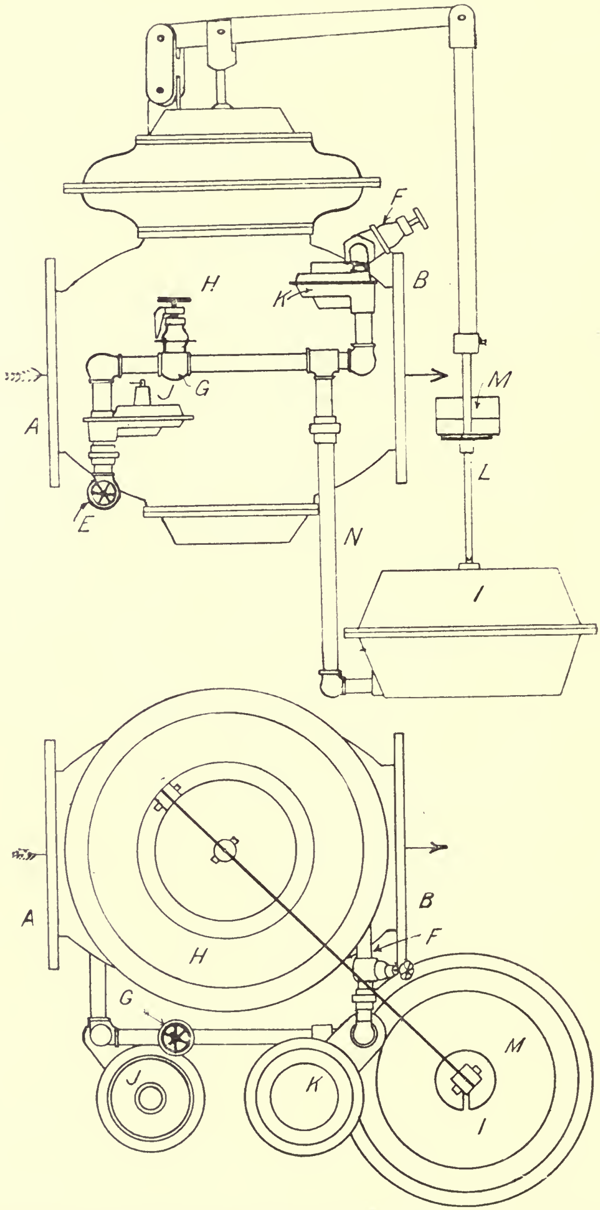


FIG. 618.—Enlarged View of Johnson-Reynolds District Governor without Inlet and Outlet Valves: Elevation and Plan.

influences the working of the main governor, ensures great sensitiveness, whilst the arrangement of supplementary governors to deal with small quantities of gas during times of minimum consumption proves much more satisfactory than any attempt to govern such through a governor primarily intended to deal with much greater volumes could possibly be. The apparatus is perfectly automatic in its action, and readily adapts itself to all fluctuating conditions of demand.

In the illustration, A is the main high-pressure inlet, and B the main low-pressure outlet. C is the high-pressure inlet valve, and D the low-pressure outlet valve. E is the supplemental high-pressure valve, and F the low-pressure supplemental valve. G is the needle valve controlling the supply to supplemental governors, K, and the auxiliary pressure bowl, I. H is the main governor for maximum supply. J is the supplementary high-pressure governor, which is usually set to reduce the inlet pressure to about 10 inches head of water, and K is the secondary governor for dealing with the minimum outflow. L is the connecting rod, by means of which the motion due to the varying pressures in I is communicated to the main governor, H. M are the weights on rod, L, and N the tube connecting the outlet of needle valve, G, to the base of the bowl, I. In Fig. 617 the governor and other parts are duplicated, similar parts being similarly lettered, the second set having the addition of a dash to the letter, and in Fig. 618 an enlarged elevation and plan, without inlet and outlet valves, are shown.

By means of the very ingenious system of secondary valves and governors, any inlet pressure up to 20 lbs. per square inch may be governed down to any number of tenths of an inch on the outlet with great nicety of adjustment under all conditions of working.

It has already been pointed out that the main governor, H, is only brought into action when the consumption is too great for the supplemental governors to deal with it. The flow of gas is then direct through the inlet valve, C, the main governor, H, and the outlet valve, D, into the low-pressure system of mains.

When, on the other hand, the consumption is very small, and falls below a certain point, the main governor, H, is automatically shut off, and the gas required is supplied through the supplemental governors, J and K. The operation is as follows. Assume that the governor, K, is weighted to give a pressure equal to a certain number of tenths water gauge pressure on the outlet. As this is connected directly to the low-pressure system at B, it follows that the pressure at B and at the outlet of K must be equal. Any rise of pressure in B above that which K is weighted to give will therefore cause the latter to close. It has previously been mentioned that the auxiliary governor, J, is usually set to give an outlet pressure of ten inches.

When, therefore, the governor, K, is closed by a sufficient increase of pressure at B, the pressure on the outlet of J is augmented, and this increase, communicated through tube, N, to the bowl, I, causes such motion of the rod, L, as effectually closes the main governor, H. So long, therefore, as the consumption is insufficient to reduce the pressure at the inlet of K below ten inches, the supply is maintained through the supplementary governors, J and K.

When, however, increasing consumption reduces the pressure on the outlet of J to below ten inches, or, in other words, when the

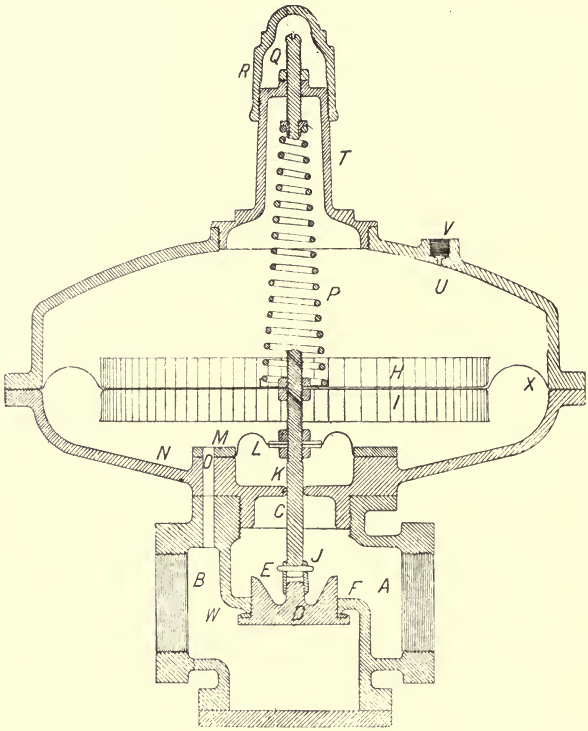


FIG. 619.—2-inch Crawford Sensitive Regulator: Sectional Elevation.

volume of gas required increases beyond the capacity of the supplementary governors, the fall of pressure is immediately communicated through tube, N, to the bowl, I, and by means of the rod, L, to the main governor, H, which is correspondingly opened to restore the pressure necessary in the low-pressure system.

Fig. 619 shows a sectional elevation of a Crawford sensitive governor as manufactured by the Equitable Meter Company, of Pittsburg, Pa., of which large numbers are being used in the United States with every satisfaction.

A is the inlet and B the outlet chamber of the governor. The diaphragm consists of a double metallic disc, H I, to which a flexible diaphragm, X, is attached, the outer edge of which is secured by the flanges of the upper and lower diaphragm chambers.

Supported from the metal discs, H I, is the valve rod, C, which sustains the valve, D. The steadiness and accuracy of working of the valve are very materially assisted and increased by the action of the valve guides, E, which are machined to fit the valve seat, F, as tightly as is consistent with the free action of the valve. The lower flange of the valve, D, carries a composition washer, W, which, when pressed home by the sufficient elevation of the diaphragm, H I, makes with the valve seat a thoroughly sound joint. The valve is securely fastened to the valve rod by means of the toggle joint, J.

For the purpose of ensuring the perfectly vertical working of the valve rod and, consequentially, the equally true alignment of the valve guides, the valve rod is caused to pass through the valve rod guide, K, which loosely fits the rod, C. Between the guide, K, and the main diaphragm, the valve rod carries a subsidiary balance diaphragm, L, the outer edge of which is secured by the clamping ring, M, to the bottom flange of the lower diaphragm chamber, N. This balance diaphragm is of the same area as the base of the valve, D, and being open to the inlet pressure on its under side through the valve rod guide, K, any fluctuation or variation, or irregularity of the inlet pressure from any cause whatsoever, is effectually neutralized, by being made to act upon the valve and subsidiary diaphragm in opposite directions, and thus a perfect balance is maintained.

The outlet pressure is regulated by means of a spiral spring, which is adjustable by the screw, Q, access to which is obtained by the removal of the screwed acorn cap, R. V is a vent in the top of diaphragm case, U, for the upper diaphragm chamber, while the latter is accessible for purposes of inspection by the removal of the screwed hand hole cover, T.

The governor is actuated by the outlet pressure through the controlling tube or port, O. The operation of the governor in actual work will be readily followed from the full description previously given of the working of station governors. The governor is ordinarily constructed to deal with inlet pressures up to 5 lbs. per square inch. It may, however, be made for special requirements to deal with inlet pressures up to 60 lbs. per square inch.

Capacities.—The capacities of the different sizes are shown in the following table :—

With 2 ozs. to 5 lbs. Inlet Pressure.	Water Column Pressure. Inches.	Mercury Pressure. Ozs.	Sizes of Governor.						
			¾″	1″	1¼″	1½″	2″	2½″	3″
Capacity. (C. ft. per hour), set at	½	..	60	75	200	300	500	600	800
,, ,, ,,	1	..	90	120	350	400	900	1200	1500
,, ,, ,,	..	1	150	200	500	600	1200	1500	2800
,, ,, ,,	..	2	200	260	600	800	1800	2200	5000

It has been several times pointed out that a very great deal of pioneer work in connection with high-pressure distribution was carried out in America some years before it was introduced into this country. It was, therefore, to be expected that when English engineers began to work with high-pressure gas they would be more or less dependent upon America for their plant. The introduction of new methods is a rather tedious and slow business in this country, but manufacturers are rapidly rising to and seizing the opportunities for enlarging their business, and are now placing apparatus upon the market which is no whit inferior to the best that American makers can supply.

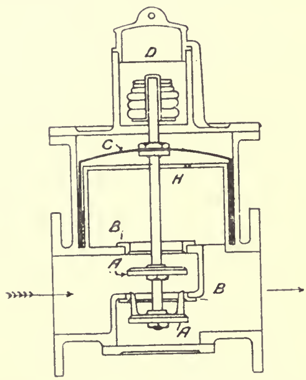


FIG. 620.—Sectional Elevation of Peebles' H.-P Governor.

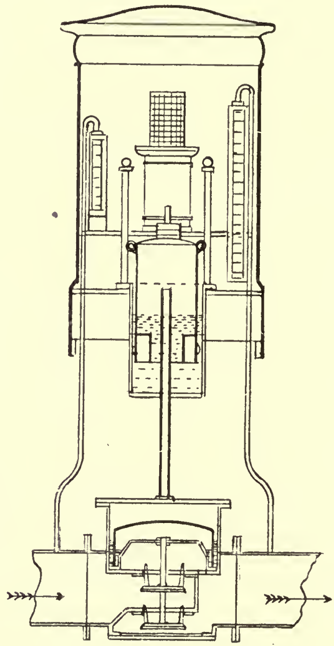


FIG. 621. — Sectional Elevation through Peebles H.-P. Governor for Distance Loading.

Peebles' high-pressure governor.—Fig. 620 shows a sectional elevation through Messrs Peebles' high-pressure mercurial governor.

This may be loaded by weights, as in Fig. 620, or air pressure from a distance, as in Fig. 621. The governor is fitted with double balanced gun metal valves, A, thoroughly ground into their seatings, B. The gas, after passing the port controlled by the valves, flows to the district, and the pressure to actuate the governor passes through a small hole, H, in the metal diaphragm to the under side of the bell, C, which is sealed in mercury. The seal is always made deep enough to seal against the highest inlet pressure which will ever be found on the district; although, as will be seen, it is only the outlet pressure that acts upon the mercury.

The loading is done by weights placed on the top of the bell, through the cover, D (Fig. 620). In the case of loading by air pressure from a distance, the cover is made plain as in Fig. 621, and the air pressure is brought to bear upon the roof of the bell, the valves opening downwards. The air holder may be in any convenient position, such as a cellar, or may be placed in a pillar box as illustrated. Fig. 622 shows an enlarged elevation of the loading arrangement, in which A is the air bell moving in the water tank shown below the pillar box. The bell has a float which will give the necessary power to raise it when the weights are taken off for unloading the governor. For loading, the weights, W, are placed on the crown of the bell, and the air under pressure passes from the port, E, through a pipe to the top of the governor.

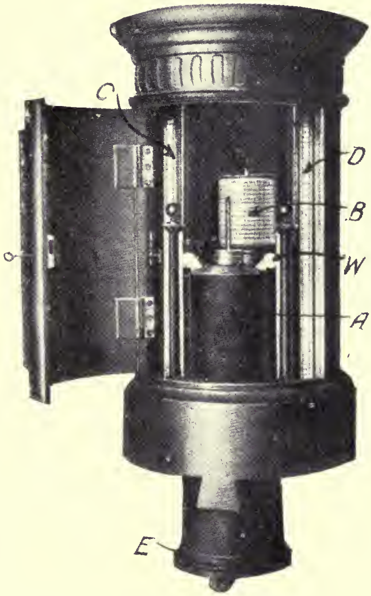


Fig. 622.—Enlarged Section of Peebles' Pneumatic Loading Apparatus.

A pressure recording gauge is shown at B, and inlet and outlet pressure gauges at C and D. The whole is compactly fitted in the pillar box, and takes up very little room on the pavement. The great advantage of this device is, obviously, that the pressure may be altered at any time, even in a busy thoroughfare, without disturbing the street.

Milne's governor.—Fig. 623 shows a mercury governor for high pressures manufactured by Messrs Milne and Son, Limited, Edinburgh. This is of the single-valve type, with compensation chamber formed by a central chamber within the governor bell. The governor is hand loaded with weights upon the bell, access to which is afforded by the removable cover. The bell is actuated from the outlet through the port shown into the outer bell, and the large area of the bell gives considerable sensitiveness to the action of the governor.

In connection with the Newport installation, previously referred to, in order to render it quite impossible for the pressure in the district to rise above a given limit, Mr Canning has introduced a safety seal

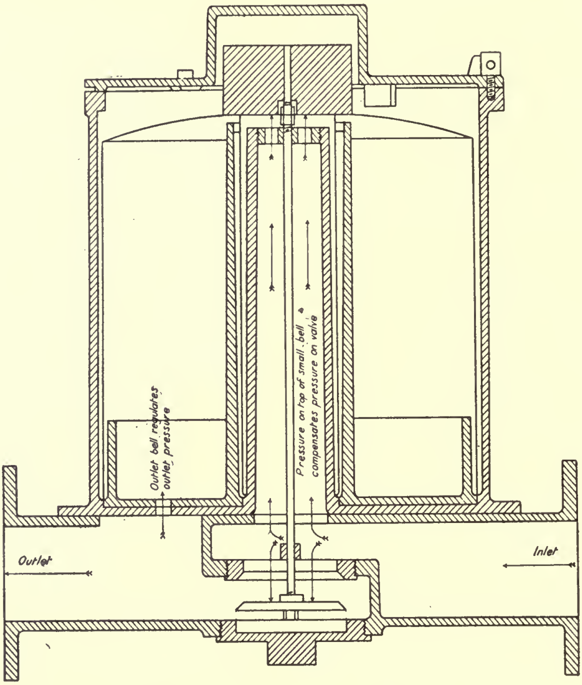


FIG. 623.—Milne's High-Pressure Mercurial Governor.

upon the governor outlet. This is fixed in the base of a lamp column (see Fig. 624) near to the governor pit, and is connected to the outlet main from the governor. In the event of the seal blowing, the gas would escape in safety up the lamp column. The seal pot is so designed that the mercury will run back and form a seal again automatically as soon as the pressure falls below the given limit.

There is, however, a difficulty connected with the use of mercury as a seal for high-pressure governors which fuller experience is revealing. It is one which is met with when mercury is used in other kinds of apparatus, but particularly so when subjected to high pressure as in these governors. It is that small oily vesicles from the gas become intermixed with the mercury, gradually reducing its homogeneity until it becomes pervious to the gas. These oily exudations are most difficult to deal with, resisting all attempts to separate them out. The only method discovered, so far, of dealing with the nuisance is to remove and well wash the mercury with a strong alkaline solution, and then thoroughly clean with a chamois leather. It is then quite fit for use again.

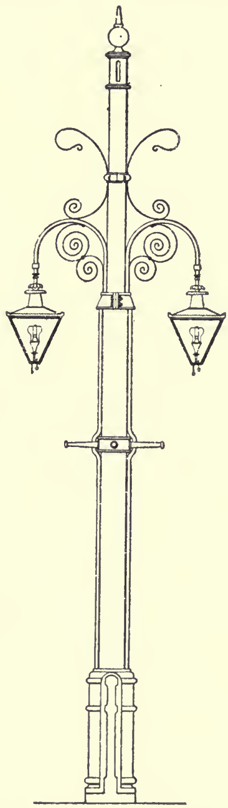


FIG. 624.—Ventilating Column.

In any system of direct high-pressure distribution, by which, of course, is meant the supply of gas at high-pressure direct to the consumer's premises, one of the most important matters is the provision of a simple, sensitive, and reliable governor for the purpose of reducing the pressure in the mains to the extent necessary for measurement and combustion.

Of high-pressure service governors of the diaphragm type, there are now two at least of English manufacture which are capable of giving the best results. The first is that of Messrs Peebles and Co., Limited, a sectional elevation of which is shown in Fig. 625. This is of the compensated valve type, loaded by means of weights inserted through a screw cap cover. The arrangement, adjustment, and method of working of this will be readily followed by comparison with the types previously described.

Short's governor.—A governor which combines some rather novel features is that patented by Mr A. J. Short and manufactured by Messrs J. Stott and Co. of Birmingham, of which Figs. 626 and 627 show a sectional elevation and cross section of base. In the Short governor the loading by means of the resilience of a spring adjusted by a screw, usual in governors of this type, has been completely reversed. As will be seen on reference to Fig. 626 the spring,

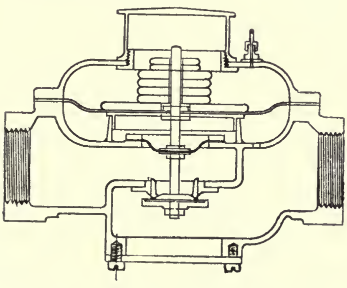


FIG. 625.—Peebles' High-Pressure Governor.

A, while adjustable on removal of the crown cap, F, by means of the screw, H, is in tension, not compression. One advantage of this

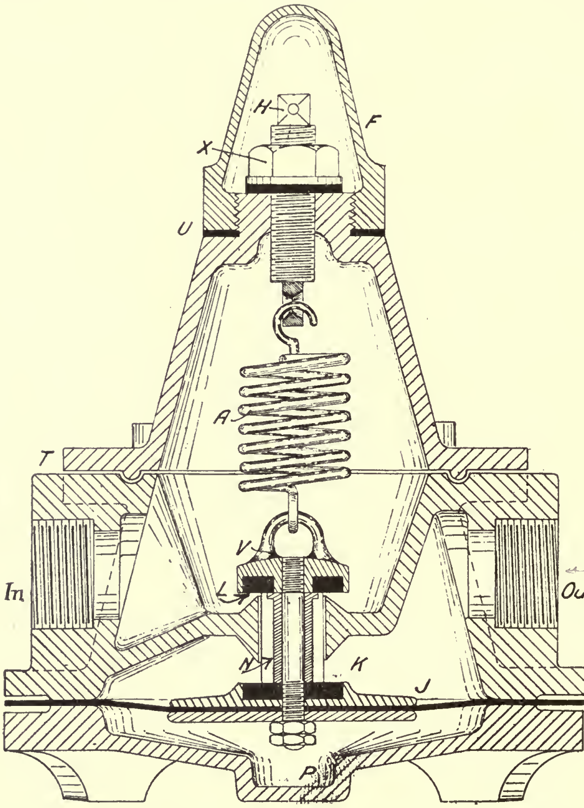


FIG. 626.—Short's High-Pressure Governor: Sectional Elevation.

arrangement is that there can obviously be no possibility of the spring buckling or getting out of true alignment, as there is a tendency

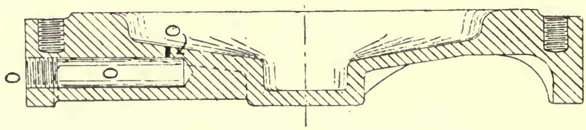


FIG. 627.—Short's High-Pressure Governor: Cross Section of Base showing Air Pin-hole and Vent.

to do when the spring is in compression. The governor, therefore, opens in an upward direction, and the outlet pressure controls the motion of the valve by acting upon the upper surface of the diaphragm, J. As the pressure builds up in the outlet, the diaphragm is depressed, thus closing the valve against the tensile action of the spring, while when the pressure falls in the outlet, the diaphragm rises owing to loss of pressure on its surface, and the valve is lifted by the spring. There is always, therefore, a balance between outlet pressure and the lifting power of the spring. The strength of the spring is regulated by the inlet pressure which it is intended to control. The tension of the spring is, of course, varied by the screw, H, to the particular pressure desired to be maintained upon the outlet.

The valve, V, is of solid cast brass, recessed to receive the leather pad, L, which forms the cut off against the knife edged seating, and N is the solid triangular web guide giving a triple flow through the port, and thus rendering the governor sensitive to fine adjustments.

Free play is secured to the diaphragm by means of the vent, O, the chamber, P, below the diaphragm forming a very effective air cushion, which steadies the diaphragm and neutralizes any possible tendency to oscillation when conditions rapidly vary. It is interesting to note in passing that in calculating the strength of spring required, account must only be taken of the area of the metal disc, not of the full area of the leather diaphragm. The ring of leather outside the disc acts simply as a hinge giving play to the diaphragm.

A critical point to take into account when considering the construction of a high-pressure governor is what will happen should either the leather diaphragm become perforated or a broken pipe occur on the outlet. Either of these contingencies is provided for in the case of Short's governor by means of the auxiliary or safety valve, K. Should the perforation be very small, then the gas would simply leak at port, O. If the perforation permitted more gas to pass than could flow through the vent, O, the pressure on the upper side of the diaphragm would be relaxed, and the tension of the spring would pull the auxiliary valve, K, to its seating and close the port. If, on the other hand, a pipe became broken or a great leak developed on the outlet, then, the controlling pressure being relaxed upon the upper surface of the diaphragm, the auxiliary valve is again closed by the pull of the spring.

The whole can be easily taken apart for inspection, cleaning, or adjustment by means of the series of screws attaching the cone casing to the body of the governor. Unlike most governors the high-pressure gas has free access to the upper portion of the case, and therefore the joints at T and U and X must be especially well made to withstand the inlet pressure. That at T is made by a stout rubber band, clamped in the recess shown, while those at U and X are furnished with good leather or lead washers, according to the pressures they have to withstand, firmly compressed between the two faced surfaces by the adjacent screws and nut. The governor may be fixed in any position, either as shown, or upside down, or any other position most convenient.

The Johnson-Reynolds service governor.—The Johnson-Reynolds service governor is also an excellent type of regulator, admirably designed and adapted for the end in view. It is intended to be used on high-pressure systems supplying direct to consumers, and to reduce the main pressure of any number of pounds per square inch, up to 50, to the number of tenths of an inch water pressure, usually about 20, which is desired at the point of combustion.

Fig 628 shows a section through the service governor, in which A is the gas inlet, and B the outlet. C is a screw by which the spring, H, is adjusted. D is a vent for the upper diaphragm

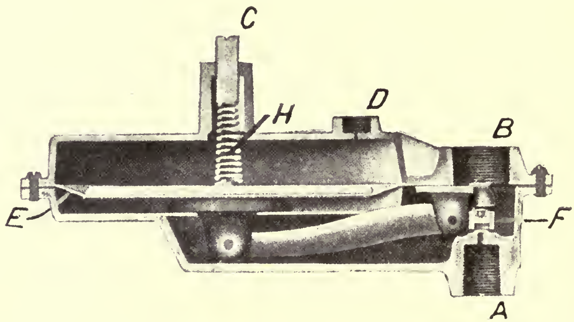


FIG. 628.—The Johnson-Reynolds Service Governor: Sectional elevation

chamber, from which a small tube is carried to the exterior of the premises. E is the flexible diaphragm, and F the valve. The leather face of the valve is countersunk in the soli dmetal, thus ensuring a firm, even pressure when it is brought into contact with the valve seat, and securing a sound cut off.

It will be observed that the diaphragm, E, is perfectly flat, and, therefore, there is little bending and no buckling of the leather. A consequential further advantage is secured in the readiness and thoroughness with which the leather may be oiled from time to time, as may be necessary, to prevent the scorching of the diaphragm by the extremely dry character of the gas when compressed to a pressure of many pounds per square inch. Any oil poured into the vent will travel to every part of the diaphragm, there being no depression or recess for it to lodge in.

The outlet pressures are adjusted by the brass set screw, C, usually to about 2 inches water gauge pressure, but this may be raised by means of the screw by tenths of an inch to a maximum of 3 inches.

In the event of any paint, dirt or grit, or any other foreign substance getting to the governor valve, and thus preventing the free and perfect action of the governor, and especially affecting its power of closing tightly, the pressure upon the meter inlet might build up to an inconvenient and even a dangerous extent. To avoid any possibility of this taking place, the Reynolds mercury seal may be used between the service governor and the meter. The function of this seal is to bring into operation a vent tube for the purpose of relieving any undue pressure at this point.

Fig. 629 shows the arrangement just mentioned. A is the inlet to the governor, and B is the outlet. G is the tee containing the

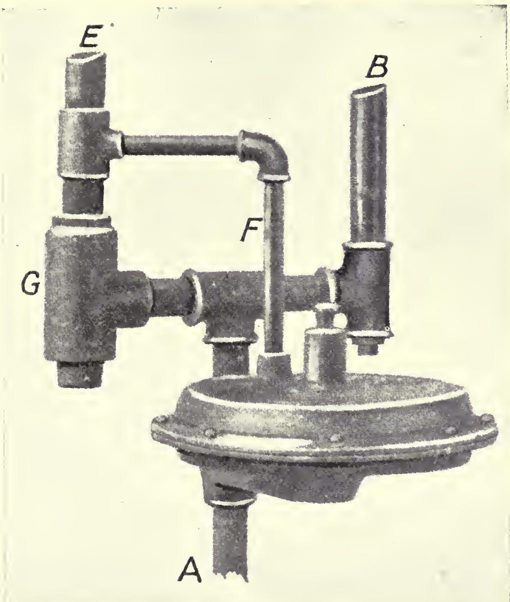


FIG. 629.—Reynolds' Mercury Seal: Elevation.

mercury seal, a section through which is shown in Fig. 630, and E is the vent tube, which is carried to the outside of the premises. F is the small tube connecting the vent in the upper diaphragm chamber of the governor to the tube, E.

For the purpose of preventing any injury to the governor, and particularly to the valve, through any small particles of corrosion falling down into the governor, as would inevitably be the case sooner or later if the outlet of the governor were connected direct into the rising main, the governor outlet is fitted, as shown, with a tee leading into two short lateral pipes which, in turn, connect into two other tees at the bottom of the respective rising pipes, B and E.

Another method of avoiding the dirt difficulty is by slightly rearranging the governor so as to take the outlet from the lower casting. This device has the further advantage that the top of the casting

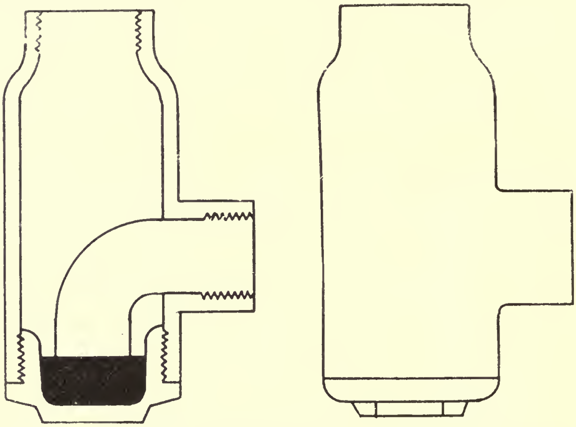


FIG. 630.—Reynolds' Mercury Seal: Sectional elevation.

may be removed, without taking the connections apart, for the purpose of inspection or replacing the valve or oiling the diaphragm.

Improved service attachment.—It is obvious that the means and methods of service attachment which prove fully adequate to the needs of a low-pressure system of distribution will be found much too imperfect for use upon a network of mains in which the pressures maintained amount to many pounds per square inch.

Special series of service clamps for use upon high-pressure distribut-

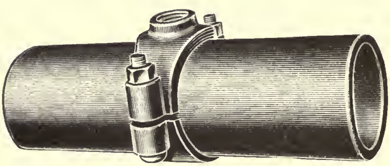


FIG. 631.—Slingsby's Service Clamp.

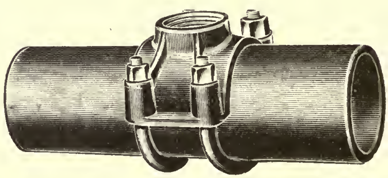


FIG. 632.—Slingsby's Service Clamp, with Double Straps.

ing mains have been devised, those shown being the manufacture of Messrs Walter Slingsby and Co., Limited, of Keighley. Fig. 631 has a single strap, and is used for small services where comparatively low pressures have to be dealt with, while Fig. 632, with its double straps, is intended for use in the case of larger services in connection with mains under much heavier pressures. The double band ensures a much firmer attachment, and prevents the slightest movement of the clamp upon the main. These straps are made of the best soft steel, bent to accurately fit the main. The body of the clamp is of malleable cast-iron, with ribs cast on to give additional strength, the boss being thick enough to give a full deep thread for the service attachment.

The bed of the clamp is grooved to receive a moulded lead ring, as shown in Fig. 633, the ears of which are bent over the sides of the clamp to prevent lateral movement during fixing. When, therefore, the clamp with the lead ring is tightened to the main by means of the straps and nuts, the lead ring conforms to and is firmly bedded upon the main, and makes a perfectly sound joint. It may be noted here that, in making an attachment to a coated steel main, the coating should not be removed at the point of junction, but simply drilled through. The lead ring will bed upon the jute or other coating and make a thoroughly good joint.

FIG. 633.—Moulded Lead Ring.

The various types of fittings adopted for service attachments to high-pressure mains are shown in Fig. 634. The connection at A is made by means of the combined service clamp and tee, D. A male

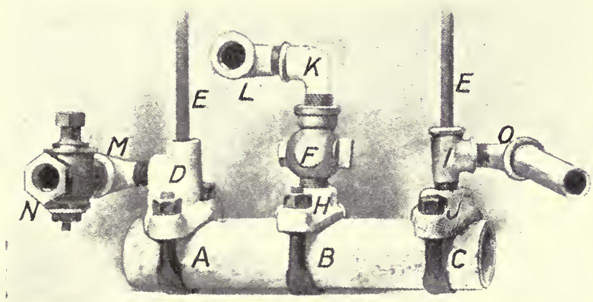


FIG 634.—Three Types of High-Pressure Service Attachments.

and female screwed elbow, M, is screwed into the latter, and in turn is fitted with the high-pressure service cock, N, leading into the service proper. The object of using the elbow, M, which is somewhat foreign to English practice, is to relieve the strain upon the service due to loading or subsidence, to some extent at least, by permitting the elbow to turn slightly in the tee before the breaking point is reached.

In this type of attachment the drilling apparatus is screwed to the top of the tee clamp, and the main drilled through the tee. The upright rod, E, is the shaft of a wooden plug, which is inserted into the main to stop the flow of gas until the service connection is completed. When this has been done the plug is removed, and the tee plugged in the ordinary way.

The attachment shown at B (Fig. 634) is made by means of a Mueller's "Century" pattern service clamp, H, into which a stub pattern high-pressure gas main cock, F, is screwed. The latter is in turn fitted with two male and female elbows, K and L. In this attachment the drilling apparatus is screwed to the main cock, and the main drilled through both cock and clamp, as shown in Fig. 637. This is, of course, done before the elbows are fixed. It is obvious that the use of the double elbows permits of the service being laid in any direction, and at an angle to the main.

The third method of connection, shown at C (Fig. 634), is with the "Century" clamp, J, fitted with a male and female threaded tee, I, into the outlet of which the male and female elbow, O, is screwed to lead into the straight run of service. As in the case of attachment, B, this type of fitting gives a power of universal movement to the service, and the wooden plug is used in a similar manner to that described in connection with method A. In the event of its being

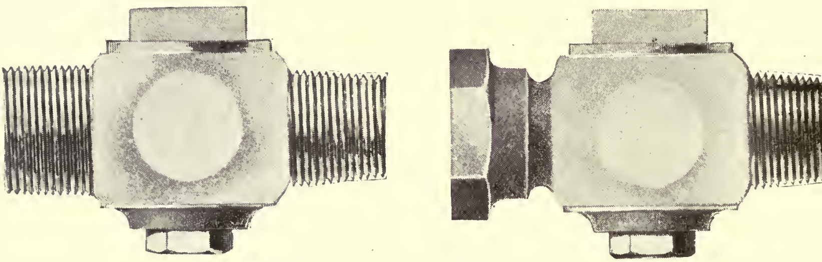


FIG. 635.—National Tube Company's High-Pressure Stub Main Cocks.

necessary at any time to remove the clamp from the main, the wooden plug may be reinserted by removal of the permanent plug from end of tee piece, I, and the clamp lifted over the plug shaft without loss of gas.

It was soon found in connection with high-pressure distribution that the main cocks ordinarily used upon the low-pressure systems were quite unable to withstand either the strains or pressures involved. A series of high-pressure gas main cocks has, therefore, been placed upon the market both by English and American manufacturers. Fig. 635 is an illustration of high-pressure stub main cocks as manufactured by the National Tube Company, and Fig. 636 shows the locking and thumb gas main cocks manufactured by the H. Mueller Manufacturing Company. These cocks are made of a special red brass alloy, are cast considerably stouter than the ordinary low-pressure cock, and in turning and finishing every care is taken to conserve the strength of material to the utmost extent possible. The plugs are passed through a special process of grinding in, and the keys and bodies are oil polished to ensure closer fitting.

Each of these cocks is subjected to an air test of 150 lbs. pressure per square inch, in addition to the usual hydraulic test, before leaving the works, so that their perfect soundness under the highest gas pressure may be ensured.

These cocks are made in three sizes, *i.e.* $\frac{3}{4}$-inch, 1-inch, $1\frac{1}{4}$-inch,

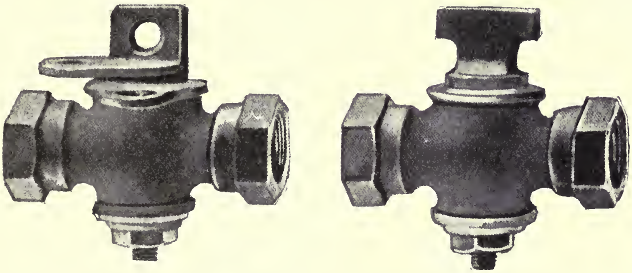


FIG. 636.—Mueller's High-Pressure Locking and Thumb Gas Main Cocks.

each size of cock having a clear opening through the plug equal to the next lowest size of tube. The $\frac{3}{4}$-cock, would, therefore have a full $\frac{1}{2}$-inch opening, the 1-inch cock a full $\frac{3}{4}$-inch opening, and so on.

Improved drilling apparatus.—Just as special attachments have had to be devised to surmount the difficulty of making and maintaining sound service attachments under high pressures, so a similar necessity in regard to working upon a main under these conditions has led to the provision of special apparatus for drilling mains, preparatory to service laying.

Fig. 637 shows a sectional elevation, of the high-pressure gas drilling machine of the H. Mueller Manufacturing Company, of Decatur, Ill. This machine is constructed to drill through tee and clamp, where used either in the separate or combined forms, as in C or A in Fig. 634, or through high-pressure main cock and clamp, as shown in Fig. 637, where these are used. In the event of neither tee nor cock being used, a short piece of tube may be screwed into the clamp to accommodate the drilling apparatus.

It will be observed that in this machine the thrust is an absolutely central one, and there is, therefore, not the slightest danger of the drill wobbling, with consequential injury to either the main cock or fittings. The thrust is applied by means of the feed wheel, W, and the two tension rods, E and F, terminating in the yoke, Y, which engages the collar Z, of the boring bar. The thrust is ultimately conveyed, by means of the various pieces composing the socket in which the drill works, to the service clamp. At P in Fig. 637 a packing ring is inserted in the recess provided between the screwed upper end of the stuffing nut nipple, H, and the back of the body stuffing box, I, which, being compressed tightly around the drill spindle, keeps the whole system absolutely gas tight after the main has been pierced until the drill can be withdrawn sufficiently to allow the stub cock to be closed. The drill is operated by the ratchet handle, the taper peg attached to which is used to remove the drill from the drill shaft.

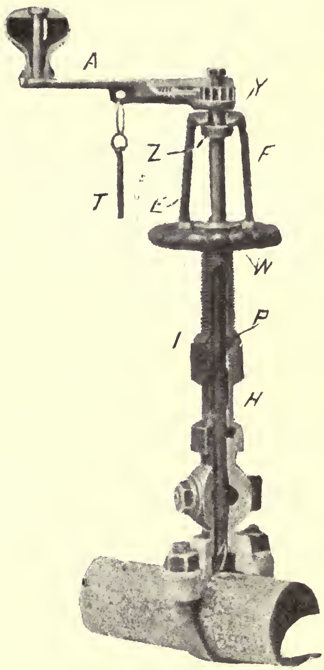


Fig. 637.—Mueller's High-Pressure Gas Drilling Machine: Section.

For drilling cast-iron mains a stronger apparatus is necessary, and that manufactured by Messrs E. Pass and Co., of Denton, Manchester is very suitable for the purpose. This is shown in Fig. 638 and consists of a combined drilling machine and slide valve, and may be used indifferently for either gas or water mains. The drilling machine is of the usual direct feed, central thrust type, and itself calls for little comment or description.

The peculiar feature of this machine is the circular slide valve, shown partly in the bonnet immediately above the main. When the hole has been drilled and tapped, the drill is withdrawn by means of the feed screw until it is above the level of the gate of the valve. Then the slide is revolved into the closed position by means of the square-headed shaft shown, after which the upper portion of the machine may be taken off and the drill removed.

A special interest attaches to the very simple device for service attachment, which allows for the stoppage of the gas whilst the connection of main to service is being made. This is shown in enlarged section in Figs. 639 and 640, and consists of an internally threaded space nipple, within which is screwed a stop plug. On the removal of the drill after the closing of the valve, this nipple, together with the loose head, is placed in the bottom of the feed shaft, the upper portion of the machine placed in position again, the valve opened, and the connecting nipple screwed tightly into the main. When this has been done the drilling machine and valve may be removed altogether, the gas now being stopped by the internal plug within the nipple.

In the sectional elevation (Fig. 639), the stop plug is shown screwed into the nipple. When the service has been connected a screwed rod sliding easily within a square shaft is inserted through the special cap, and the former screwed into the plug. A locking boss at the upper end prevents the inner rod moving in an upward direction without the square shaft, when once the former has been screwed into the plug. When, therefore, the rotatory motion is reversed, the square rod shaft

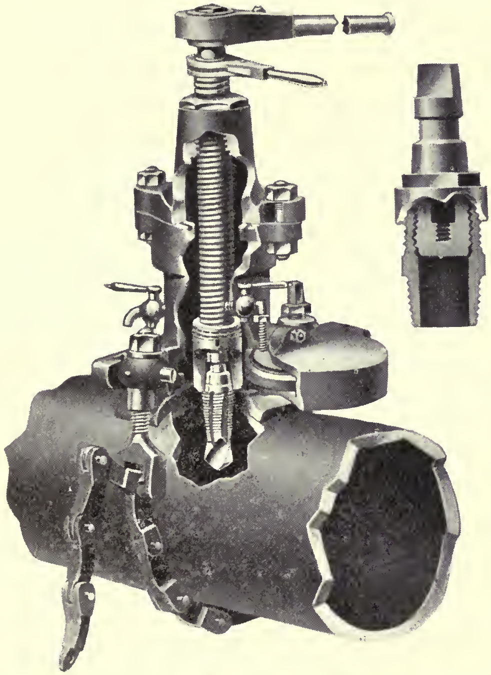


FIG. 638 —Pass' Under-Pressure Drilling Machine.

engaging with the squared recess in the plug unscrews it from its lower position. When free there the plug is lifted and screwed into its final position in the head of the tee, as shown in the part sectional elevation, and the free gas way to the service is left quite clear. The top is then secured by the brass cap, which is attached by means of a bayonet joint. The top of the tee and the inner surface of the cap being truly faced, the attachment is quite sound.

The small taps shown just above the slide valve are for use when the machine is being used for drilling water mains. They are intended to introduce water from the main into the upper portion of the machine before the valve is closed, so as to reduce the shock which would otherwise take place when the valve gate was reopened.

Fig. 641 is interesting as showing at a glance the full arrangement of service and meter connections, the various parts of which have been considered in detail. The service attachment is of the type C (Fig. 634), and there is a Mueller main cock under the foot-path, access to which is obtained by means of cover plate and shaft. There are also a high and low-pressure gas main cock upon the inlet to the meter upon either side of the regulator, so that each section is under perfect

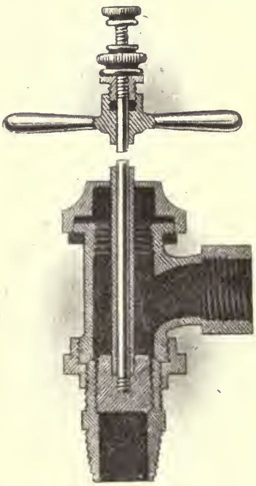


FIG. 639.—Pass' Service Attachment for H.-P. Mains: Sectional Elevation.

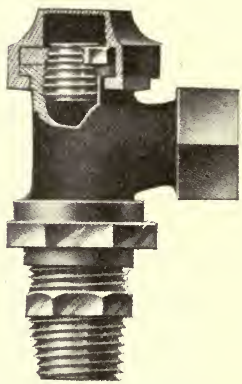


FIG. 640.—Pass' Service Attachment for H.-P. Mains: General Elevation

control. The arrangement of the seal and vent pipe and vent from regulator is clearly shown, and needs no further description. Fig. 642 shows the slightly different arrangement of the National Tube Company, of Chicago.

High-pressure gas meters. — One of the difficulties encountered by any undertaking when commencing to supply high-pressure gas is that of registration. Obviously the meters used in low-pressure distribution would be far too weak to stand the stresses incidental to high pressures. A stronger meter must, therefore, be used.

It would be perfectly easy by very considerably strengthening the case and possibly altering somewhat the usual form, and stiffening up the internal working parts, to construct a dry meter which would withstand the high pressures and accurately measure the gas under the conditions. It would involve, however, using very strong skins

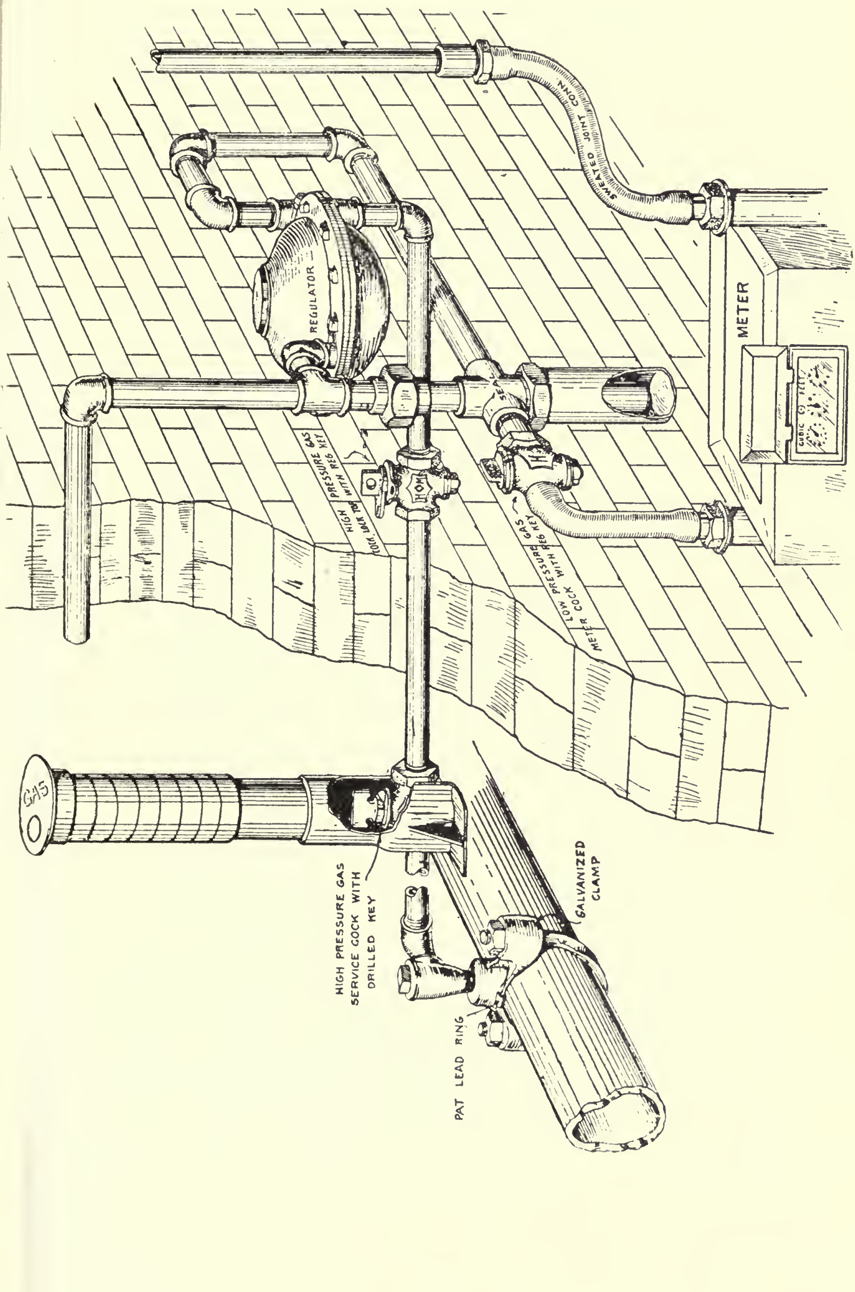


FIG. 641.—Mueller's Complete High-Pressure Service Connections

for the diaphragms, and here at once we are met with a serious difficulty. The Sale of Gas Act requires that every meter must receive the inspector's stamp, and that the stamp must only be affixed if the meter works correctly—within certain narrow limits—at 5-tenths pressure. Now, it is obvious that a diaphragm strong enough to stand heavy pressures cannot be expected to be sensitive enough to register correctly at that very low pressure.

With the wet meter there is no such initial difficulty to overcome. It is only necessary to suitably and sufficiently strengthen casing and working parts, remove the float, and ensure the meter against shocks, and the meter in somewhat its present form may be adapted to its purpose.

Seeing that the volume of a gas is inversely proportional to the pressure applied to it, and that prices are based upon a low

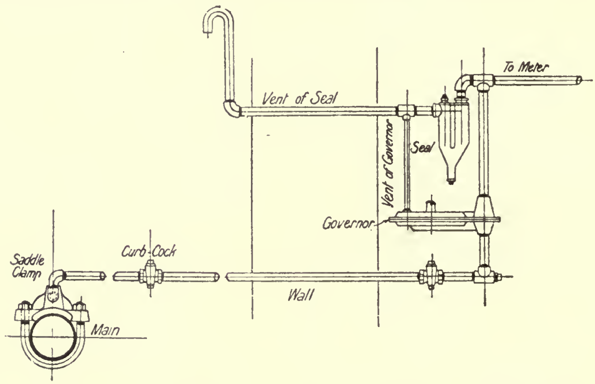


FIG. 642.—National Tube Company's Complete Service Attachment.

pressure supply, it is obvious that some means of taking into account the lessened volume at the higher pressures must be adopted. This may be done in various ways. A correction of the volume of gas registered to the pressure at which it is ordinarily supplied may be made, or an increased price may be charged proportional to the decrease in volume of the gas at the higher pressure. It would, of course, be perfectly easy to introduce a modification of the index gearing to give the same result, but this method is prohibited by the requirement of the Sale of Gas Act to test the meter at a pressure of 5-tenths. But apart from this, the practical utility of such a device would depend on pressures remaining constant, while in actual working they would probably vary. Then, apart from the normal variations in the mains, one of the advantages of a high-pressure gas supply is that it admits of consumers being supplied with gas at the pressure which best suits their requirements. Putting the two things together it would, therefore, be not only necessary to have meters of differing capacities as at present, but also meters of the same capacity geared differently for different pressures, a multiplication of type which would prove very inconve ient and practically unworkable.

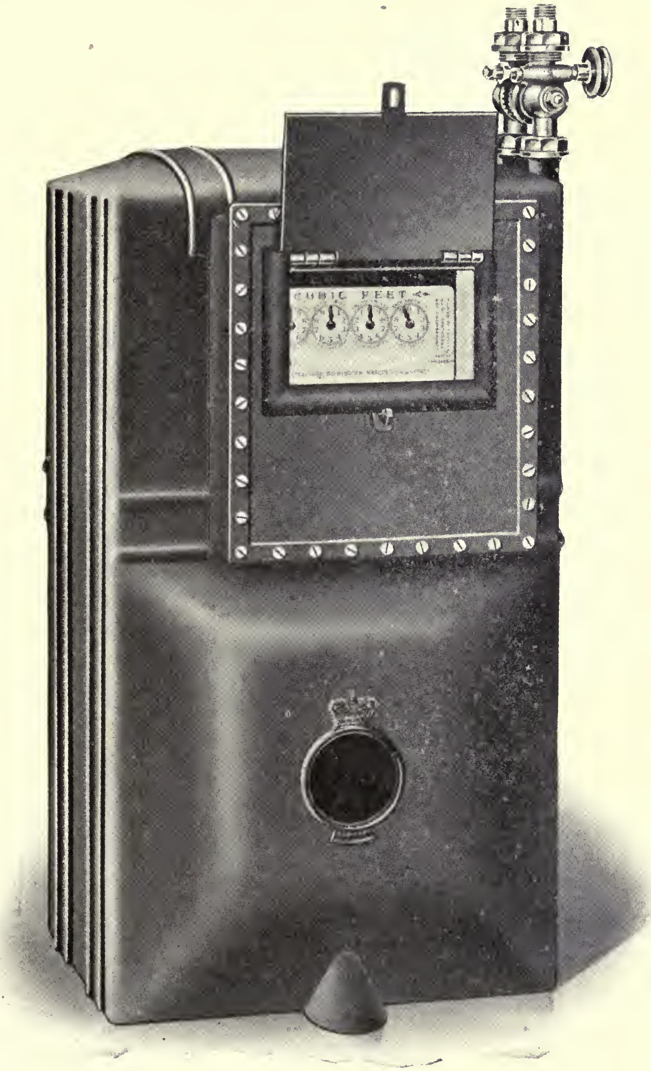


FIG. 643.—Parkinson's Moderate High-Pressure Dry Meter.

These difficulties have been overcome by Messrs Parkinson and W. & B. Cowan, Limited, in their patent high-pressure meters (shown in Figs. 643 to 646) by the adoption of a variable index gearing working in connection with a sealed aneroid chamber which, as in the

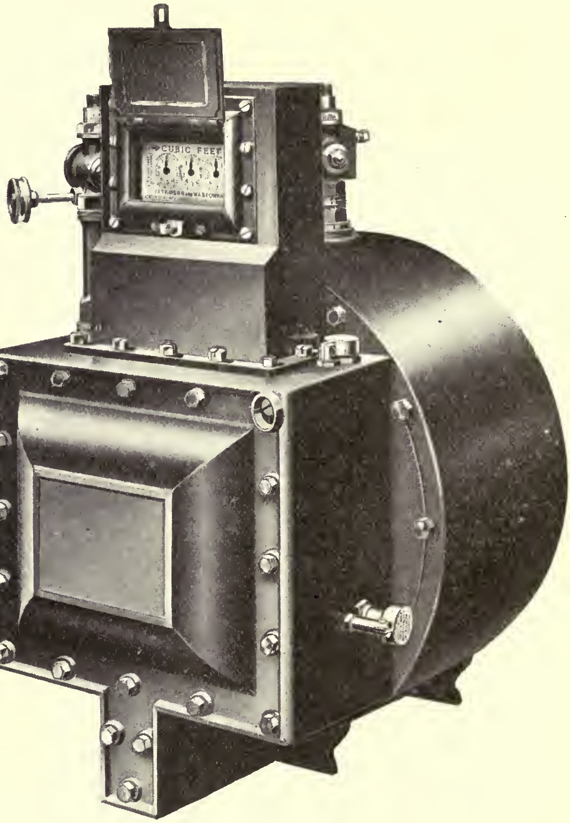


FIG. 644.—Parkinson's Moderate High-Pressure. Wet Meter.

case of pressure gauges and registers, gives increased movement proportional to the pressure applied. The registration being correct at normal pressure, the meter complies with the requirements of the Sale of Gas Act, whilst at higher pressure the aneroid comes into operation and adjusts the registration to high-pressure conditions.

Mention has already been made of the necessity of protecting the meter from sudden shock, such as would occur in turning on and off at the meter in the way usual under ordinary conditions. This is provided against in Messrs Parkinson's meter by connecting the outlet and inlet cocks together by a patent device shown in Fig. 646, which ensures that both cocks shall be opened or closed by the same action and at practically the same moment. As a matter of fact, the inlet cock is in this device opened slightly in advance of the outlet, but both are actuated very slowly in order to avoid internal strain. The device is very simple, and consists of a spindle carrying two worms, each of which engages with a cogged head of the plug of the cock. Each cock is actuated by the one movement of the spindle, which is provided with an end wheel for the purpose. In order to facilitate the application of this simple device, the inlet and outlet of the dry meters are brought together side by side, as shown in Fig. 643. In the wet meters, the relative positions of inlet and outlet are also varied somewhat from those of the ordinary low-pressure meter.

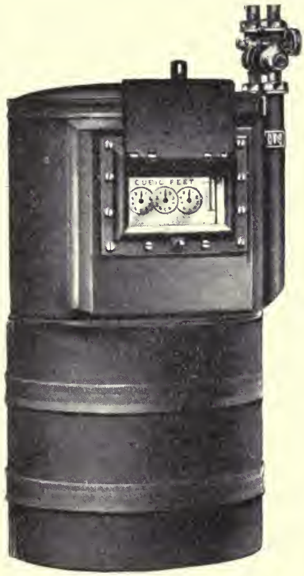


Fig. 645.—Parkinson's High-Pressure Dry Meter.

In the wet meter, special precautions against unauthorized persons tampering with the filling or overflow plugs are taken by either sealing or locking.

The meters are made in both wet and dry types for moderately high pressures and for high pressures, the difference being one of added strength, and, of course, extra cost in the case of those designed for the higher pressures.

Summary of various points.—In concluding this section, it may not be amiss to gather up a few of the points of a general character which emerge as a result of the discussion of, and extended experience with, compression and transmission of high-pressure gas. These are as follows :—

(*a*) That all compressors, and the machinery driving them, should be duplicated. In duplicating, it is well to have the compressors of differing capacities. The one most adapted to the needs of the moment may then be run, and consequently each may be run more nearly at full load.

(*b*) That, notwithstanding the many fears which have been expressed, and the limited information as to loss of illuminating and calorific power in compression which is available, the experience, so far, is that this loss is practically a negligible quantity.

(*c*) That the practical effect of compression is to very considerably dehydrate the gas.

(*d*) All sharp turns should be avoided ; easy curves and long sweeps should be adopted, with Y-tees rather than those branching at right angles.

(*e*) All curves and bends should be properly backed, or gyrations

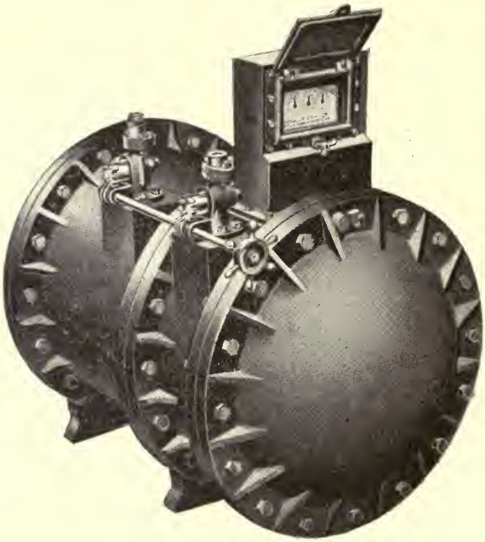


FIG. 646.—Parkinson's High-Pressure Wet Meter.

somewhat like those of a garden hose left to itself with a good head of water on it may be obtained.

(*f*) That each consumer's governor should have a safety pipe attached, so that in the event of any accident to the governor the high pressure in the main should not be thrown upon the consumer's fittings. As an alternative, an automatic cut off may be substituted, so that any excess of pressure would have the effect of shutting off the supply entirely.

(*g*) That this governor should have a valve opening of sufficient diameter to maintain the supply in the event of the pressure in the mains falling considerably below the normal, owing to any accident to compressors or other apparatus at the works.

(*h*) That although smaller sizes would be fully adequate to transmit the quantity of gas required, in practice it is inadvisable, in view of the strength necessary to withstand the inevitable strains to which any distributing system is subjected, to use smaller sizes than 2 inch for mains and ¾ inch for services.

(*i*) That as a result of the dehydrating of the gas, the stoppage of the service pipes by frost is of very rare occurrence.

(*k*) That another result of freeing the gas from moisture is to make the use of wet meters very inadvisable, owing to the avidity with which the dry gas absorbs water from the meter.

(*l*) That the mains should be of sufficient capacity to store half an hour's maximum consumption, if compression tanks are not used.

(*m*) That where compression storage tanks are used, these may either be concentrated at the works or placed at "delivery points" and made part of the distributory system.

(*n*) That the supply being automatically governed, there is not the risk of sudden fluctuations of pressure on consumers' services, such as may happen in large areas under a low-pressure system, at times of sudden and partial gloom or fog.

CHAPTER XXXV

HIGH-PRESSURE LIGHTING AND HEATING

HITHERTO we have dealt with high-pressure gas simply in relation to public lighting or the private lighting of the exterior of buildings. But this, of course, is only a part—an important part truly, but still only a part—of the field which high-pressure gas is already occupying, and will increasingly occupy in the near future. The domain of lighting for large roomy interiors, of halls, workshops, mills, factories, and railway stations, where fairly large units of light must be employed, was thought but a few years ago to have been lost to gas for ever. Imagined by many to be even now the peculiar and exclusive preserve of electric lighting, this service is being rapidly recovered by means of high-pressure gas.

In addition to the sphere of lighting, high-pressure gas is calculated to meet a real demand as a fuel for industrial heating purposes. The manufacturing processes requiring high, accurate, reproducible, and controllable heats are many and increasing. A fuel which may be concentrated or diffused, applied to any imaginable condition, position, or circumstance, and capable of giving a very wide range of temperatures, is an absolute necessity of modern industrial production in a great many trades. None satisfies the demand so well as high-pressure gas.

It is, of course, quite impossible to deal with these various applications of high-pressure gas in any great detail here. A single chapter of a book covering such a wide range of subjects as must be dealt with under the title of *Distribution of Gas* is altogether inadequate for such a purpose. It may, however, be well just to glance briefly at a few of the things which are being done in the field of high-pressure lighting and heating.

Lighting of spacious interiors.—The satisfactory lighting of lofty and spacious interiors, such as large halls, has perhaps always been one of the most difficult problems confronting the gas engineer. The conditions which must be met are very onerous. What are they ? The light itself must be extremely diffusive and suffusive, the need being for good general illumination. Shadows and sharp contrasts must be avoided, as must also the distressing effect of glare. The lights must be placed high above the line of sight, and, whilst the floor space is adequately lighted, a portion of the light must be available for relieving the gloom of the upper portion, roof, and crosstrees. A lighting scheme which left the ceilings in partial darkness, or which, by means of reflectors designed to throw the whole of the light rays emitted from any source of light in a downward direction, introduced a horizontal plane of sharp contrasts at the level of the light source, above which all was gloom and below which all was lighted more or less brilliantly, would be extremely objectionable, and even distressing. There must, therefore, be a sufficient quantity of light available either directly or by reflection to relieve the darkness of the upper portion of the hall.

The new type of ornamental screen adopted by Messrs Keith and Blackman (shown in Fig. 647) is admirably adapted to meet these requirements. The circular screen round the globe not only adds to the ornamental character of the lamp, but by diffusing the light and allowing a sufficient proportion to pass in an upward direction relieves the upper portion of any hall or room in which it may be used of the objectionable gloom to which reference has been made.

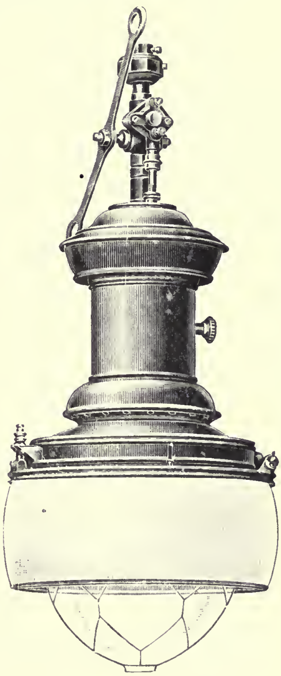


Fig. 647.—Keith High-Pressure Lamp with new Opal or Ground Glass Screen.

Then, again, the units used must be readily controllable for lighting and extinguishing from a convenient centre, at will. This is one of the points in which for a long time gas was without power of effective competition with its great rival. Recent inventions in distance lighters, and special apparatus for meeting the requirements of the case, have quite robbed electric lighting of its much vaunted superiority in these respects. High-pressure gas is now able to compete on quite equal conditions in these important details. On the one hand, we have the admirable distance controller of Messrs Keith and Blackman, fully described in a previous chapter. On the other, there are the electric ignition devices of Dr Rostin of the Telephos Company, and of Messrs Keith and Blackman, both of which are giving very good results.

Examples.—As practical examples of the brilliant lighting results obtained from high-pressure gas we may take two recent installations. The first of these is that at the Festival of Empire Exhibition at the Crystal Palace in 1911, the lighting of which was carried out by means of Keith and Blackman's high-pressure inverted lamps. These to the number of twenty-two, two rows of eleven, are suspended at a height of 27 feet above the floor level, from the upper gallery, and spaced about 48 feet apart. Each lamp contains two burners of 1500 candle-power, a total for each lamp of 3000 candle-power. In place of the usual globe, each lamp is fitted with a hexagonal screen supported on the outer edge of the ordinary shades, as shown in Fig. 648, which gives a beautifully soft and suffusive light. The side courts under the galleries are lighted by eighteen 1500 candle-power lamps similarly fitted. The lamps are controlled by Keith's automatic lighters, and are lighted up by simply starting the compressor, the pressure after being raised to a certain point opening the disc valve described on p. 619.

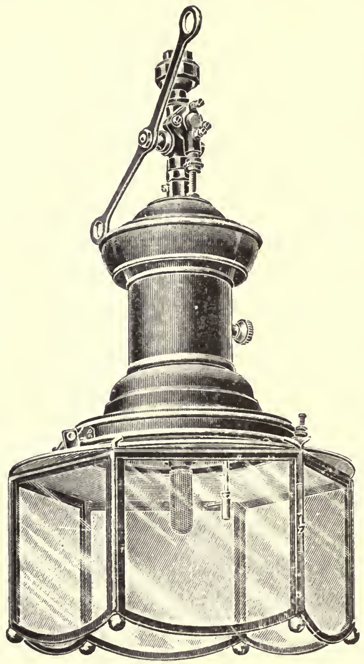


Fig. 648.—Keith High-Pressure Lamp fitted with Hexagonal Screen.

The second example is that of the Alexandra Palace, where gas was installed in 1909 for the purpose of lighting the central hall and the skating rink. Fig. 649 is a reproduction of a photograph of the central hall, which is lighted up by four lamps of 1500 candle-power, those at the side being of 500 candle-power. These lamps are fitted with shades similar to those at the Crystal Palace, the usual globe being dispensed with. The lighting is controlled in seven groups of lamps from central switch boards in the compressor house. Upon the supply pipe for each group as it leaves the compressor a diaphragm governor (Fig. 650) is fixed, from which a small pipe is run to the $\frac{3}{8}''$ gas cock at the switch board. When the cock is turned off, no matter what the pressure at the inlet of the governor, only low-pressure gas can pass to the lamps for the supply of the pilot lights. When the compressor is running and the cock is turned on, the governor is put out of action and high-pressure gas passes to the lamps. The lamps are fitted with the Keith automatic controller. A further improvement has been recently introduced in the Keith control cock with governed internal by-pass. This combines the functions of governor and switch, in a simpler, handier and cheaper form.

Fig. 649.—View of Lighting of Central Hall, Alexandra Palace.

Rostin controller.—The distance controller of Dr Rostin is a very ingenious device, depending for its primary working on wave pressure, and for its ignition upon the electric resistance of a platinum wire. Fig. 651 shows a longitudinal, and Fig. 652 a part sectional elevation of the apparatus. The object of the device is to turn on the gas to the by-pass and ignite it simultaneously with the turning on of the gas to the main burners.

To attain his object, Dr Rostin employs a flexible diaphragm, A, which works within the two concave plates, D and E. The object of so enclosing the diaphragm is to prevent excessive strain upon it, by giving it the support of the strong plate at the point of maximum travel, and also to prevent trouble in the event of any slight perforation or fault in the diaphragm developing in use. The diaphragm is brought to rest upon the bottom of the two plates by means of a weight or spring.

The rod, F, is attached to the diaphragm in such a way that when the pressure is admitted to the under side of the diaphragm and the latter is lifted, the rod, F, is lifted with it. To ensure perfect freedom of motion the lower end of the rod works in the oil chamber, H.

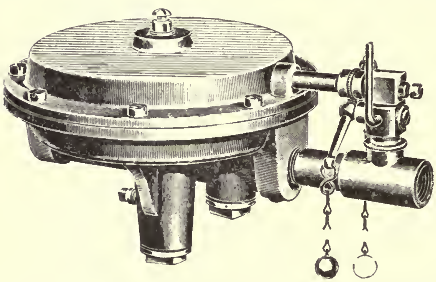
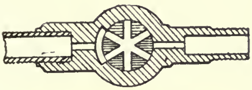


FIG. 650.—Keith's Diaphragm Governor for Distance Control.

As the rod, F, rises it is met by the weighted hinged lever, L, to which is attached the balanced pawl, I. The rod, F, therefore, in rising lifts the lever, L, which actuates the pawl, I. This pawl engages in a series of notches on the ratchet wheel head of the plug of the by-pass cock in such a way that when L is lifted the pawl turns the cock round through one division. The lever is prevented from lifting too far, and so throwing the cock out of precise position, by the adjustment screw, J. By means of the series of diaphragm, lever pawl, and ratchet-headed cock, the mere turning on of the gas to the main burners by admitting gas pressure to the under side of the diaphragm is caused to turn the by-pass cock on.

The method of ignition is equally simple. Upon the face of the ratchet head of the by-pass cock is fixed another wheel, K, which is hexagonal in shape, and is attached to the plug of the cock and revolves with it. In the casing of the controller is fixed the contact rod, P, which is insulated from the casing. This is fixed at such a height that the wheel, K, in revolving causes the hexagonal points to make contact with the rod, P, and so closes a circuit. From the contact rod, wires are led connecting up a battery with a platinum wire fixed at the head of the burner. As the wheel, K, and rod, P, complete the circuit, the platinum wire becomes incandescent, ignites the gas at the pilot light, which in turn ignites the gas issuing from the main burner.

The full range of travel of the diaphragm is such that the pawl, I, in its motion not only turns the by-pass gas on, but, continuing its movement, turns it off again. This will be understood by reference to the section through the gas cock. The arrangement



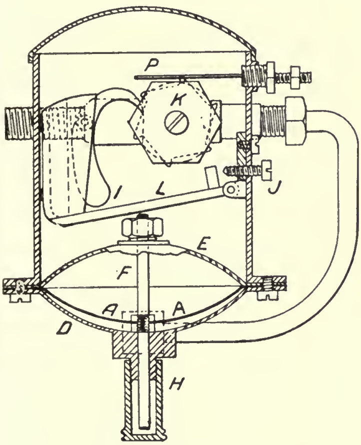


FIG. 651.—Rostin Controller: Longitudinal Section.

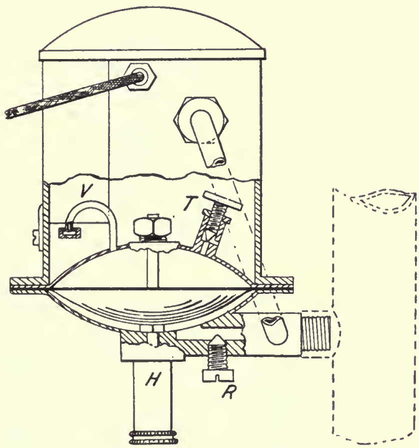


FIG. 652.—Rostin Controller: Part Sectional Elevation.

of lever and pawl is so designed as to turn the cock one-sixth of a revolution. It will be seen, therefore, that starting from the position shown, one-sixth of a revolution opens and closes the gas way again.

It is obvious that gas pressure admitted suddenly beneath the diaphragm would cause such a rapid movement through the full cycle that the ignition device might not have time to act. A retarding action, therefore, becomes necessary. For this purpose the passage of gas to below the diaphragm is restricted by the screw, R, by which the flow of gas can be adjusted to any speed. In the case of high-pressure gas even this may not be sufficient. A second screw T (Fig. 652) is therefore introduced into the upper concave plate which regulates the exit of air from above the diaphragm, so that this contained air is caused to act as an air cushion against too rapid action of the diaphragm.

Provision is made for the rapid replacement of air to the concave chamber after the operation of the instrument by means of the non-return valve, V.

Engineering workshops.—Take now another type of internal lighting, that of large engineering workshops. In this case we need (*a*) good general lighting, and (*b*) local lighting for lathes, drilling machines, work benches, and so forth. In this case the conditions are are altogether different from those of the Crystal Palace. In place of the open area and clear floor space, we have machinery of all kinds, whilst the floor space is littered with ironwork in all stages of manufacture. The requirements, therefore, are for well diffused lights, absence of shadow, and absolute steadiness. The electric arc lamp, with its continual flickering, its concentrated lighting, and consequent deep shadow, is the very worst possible type of illumination for an engineering shop.

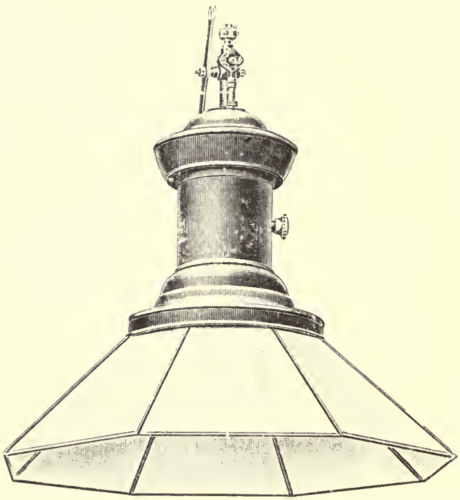


FIG. 653.—Keith High-Pressure Lamp fitted with Conical Opal Reflector.

In addition to the essentials previously mentioned, it is obvious that for the general lighting the units must be of high illuminating power. They must be placed very high in order to avoid the travelling crane usually at work in such shops. The light which best meets all the severe requirements of the case is undoubtedly high-pressure gas. Either a Keith lamp with the ordinary standard reflector as shown in Fig. 536, p. 623, or one fitted with the new conical opal reflector, shown in Fig. 653, are eminently suited to this purpose. The use of the conical opal reflector allows of the usual globe being dispensed with, as it forms an effective draught screen. By permitting a quantity of light to pass upwards, it also tends to prevent the sharp contrast in degrees of illumination to which reference has previously been made.

Not long ago the author was taken round his workshops by the head of a large engineering works in Leeds. In every shop the previously existing arc lamps had been displaced by high-pressure gas, with magnificent results. The shops were brilliantly lighted, the light was splendidly diffused, and there was a complete absence of shadow. Although the floor space was crowded with ironwork in various stages of making-up, there was not the slightest excuse for tripping. Every stumbling block was clearly seen, and consequently easily avoided. Accidents to workmen, which before

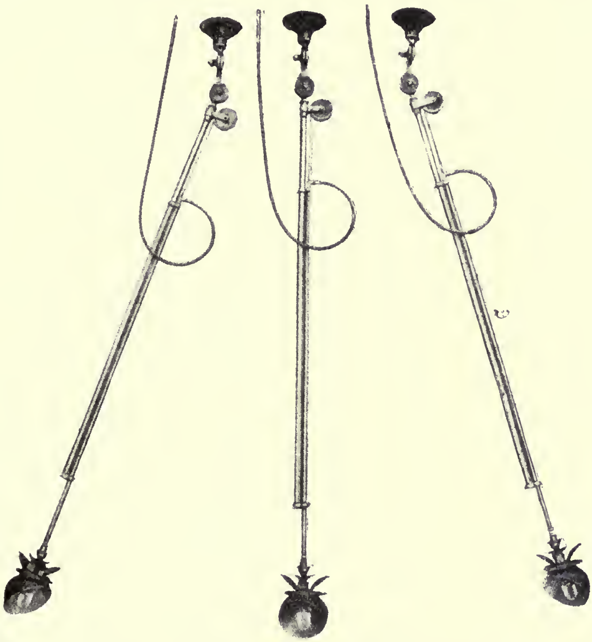


FIG. 654.—The "Perfect" Adjustable Pendant.

had been very common, are now almost unknown. The importance of this in these days of "employers' liability" needs no emphasizing. In addition to the lighting of the machinery and fitting shops, the author found the high-pressure lamps being used with considerable success under the most adverse circumstances. In the moulding shops, with all the dust incidental to that kind of work, high-pressure lamps were being used without globes or shades of any kind, without an inordinate expenditure for mantles. In another shop, similarly exposed and unprotected mantles were working in a steam and dust laden atmosphere, and although here the maintenance account was rather heavy, the illumination is far superior to that obtained under the previous electric light system.

Amongst other cases may be mentioned a large engineering works where over 1000 Keith high-pressure lamps have evicted electric lighting, while in another, well known to the author, the high-pressure system is being gradually extended after an experience of several years. In still another case, that of a large engineering works now in course of erection, after fully considering the pros and cons in the light of the experience of others, the firm have decided to fit up entirely with high-pressure gas. It is an old adage that the proof of the pudding is in the eating. The unbiassed judgment of the firms quoted constitute undoubtedly a splendid testimonial to the advantages of a high-pressure gas supply. They desire the best light at the cheapest rate, and, along with others, they are under no doubt as to how it can most readily be obtained.

For local lighting at lathes and machines, the Docking adjustable pendant is an exceedingly handy arrangement. It has been specially designed for this direct and local lighting duty. It is mounted, as seen in Fig. 654 on a ball-bearing friction-head which gives it a perfectly resilient motion, and, being free from any jerky movement, enables it to be moved quickly without breakage of mantles. It is perfectly counterbalanced by means of a spring reel, there being no friction whatever when it is extended. The light is concentrated on the object required, and therefore the maximum of light is obtained at a minimum of cost. The light is screened from the workman, and directed where needed by the parabolic reflector.

Weaving sheds.—The case of a weaving shed similar to that shown in Fig. 655 may be taken as an illustration of another type of lighting of large, roomy workshops.

Here the requirements are quite different from those of an engineering shop. There is very little need for local lighting. What is required is exceptionally good general lighting of a reliable, efficient, and steady character. The machines are placed so close together that the illumination must be practically uniform. It must be so well diffused that each part of the machine is well illuminated, and consequently under continual observation. Small repairs and adjustments are frequently required, and the light must be sufficient to allow of these being made at a moment's notice. The light must be so thrown upon the fabric being woven that any fault is immediately detected. The almost innumerable threads coming from the spools to feed the machine are continually breaking and have to be jointed up again, so that not only the front but the back of the frame must receive good illumination. Every spindle, spool, guide, and thread must be well lighted, so that spools may be replaced as they become emptied and broken threads reconnected. Lastly, the lights must be so placed as to throw no shadow upon the work either from other machines or from the weaver herself. This means in practice that they must be placed immediately over the gangway between the fronts of the machines, at such a height and so spaced that the very minimum of shadow is thrown, and those—where there are any at all—from the

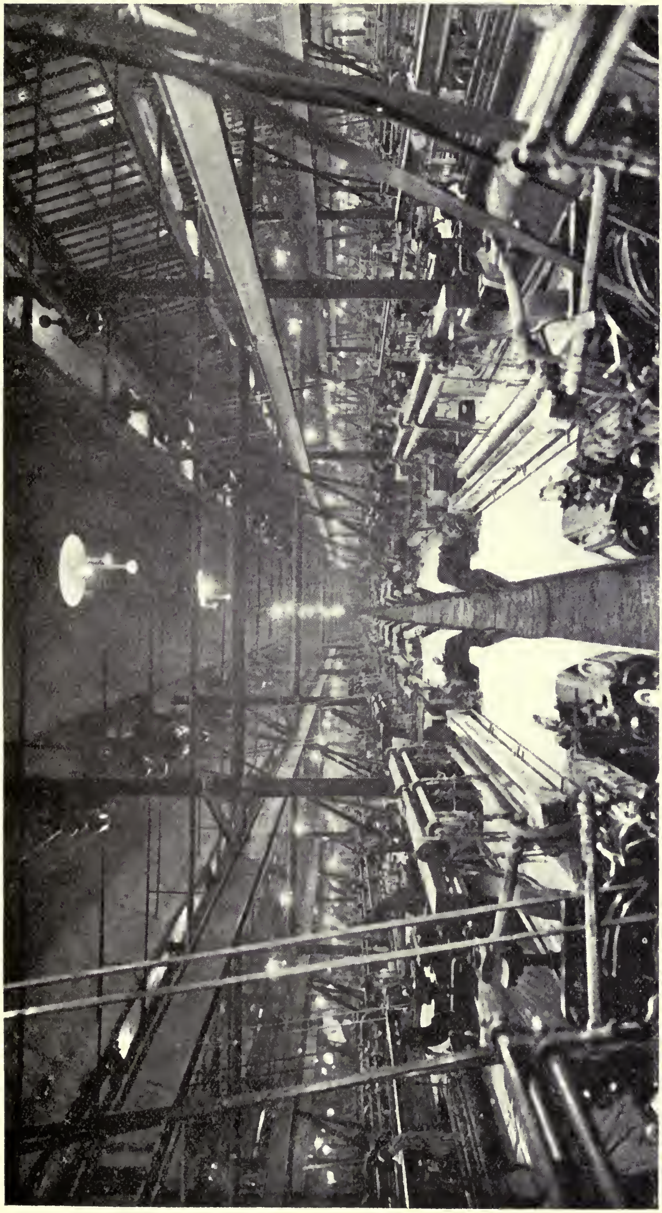


FIG. 655.—Shed of Rochdale Co-operative Society.

weaver are thrown upon the "walk" and not on either machine or fabric. These conditions are admirably met by the comparatively close spacing of the 80 c.-p. Keith lamps by which the shed is lighted.

Spinning sheds.—Much of what has been said respecting the lighting of weaving sheds applies to the lighting of spinning sheds also. The conditions are, however, so far different as to necessitate some modification in the type of lamp required. Lamps for use in spinning sheds must be so constructed as to afford the least possible surface for the collection and accumulation of fluff and dust, which might under conceivable circumstances lead to risk of firing.

The paper on "High-Pressure Gas for Textile Mills" read before the Textile Society of the Manchester School of Technology by Mr Chas. Walton, in August 1910, is full of practical information on this aspect of high-pressure lighting, but reference here can only be made to one item. At the close of the paper the author gives the actual cost of twelve months' working with different classes of light. The electric current was generated at the mill, as it was found much cheaper to generate than buy. The working results were as follows :

Flat-flame gas . . .	5.410	pence	per c.-p.	per year.
High-Pressure gas . . .	0.812	,,	,,	,,
Osram lamps (generated current)	1.830	,,	,,	,,

The author significantly adds :—"The difference is sufficient, I should think, to entice the most conservative business man."

Printing works.—We have considered, in the four cases mentioned above, types of interior high-pressure lighting which require good general illumination, and good general supplemented by local lighting points for particular kinds of work. We come now to another class, namely, one in which a strongly concentrated light is required. In such cases, where fine work of any kind is done, the requirements are of a most exacting kind.

We may take as an illustration the composing room at any printer's establishment. Fig. 656 shows a reproduction of a photograph of the composing room of the Solicitors' Law Stationery Society, Limited. What is required in such a case is obvious. It is a strong, pure white light, of a mild character, absolutely steady and thoroughly reliable. The light should be thrown upon the formes and type racks by means of suitable reflectors, thus affording a maximum of light upon the type, just at the point where it is most required, while at the same time affording such a measure of general illumination as shall relieve any tendency to undue contrasts or spottiness which would be distressful. The lights should be placed above the line of sight, and so disposed that discomfort to the workman is entirely avoided.

The illustration shows how well the smaller high-pressure lighting units of 100 or 150 candle-power may be employed to meet the conditions, and the splendid illuminating effect obtained. In such a

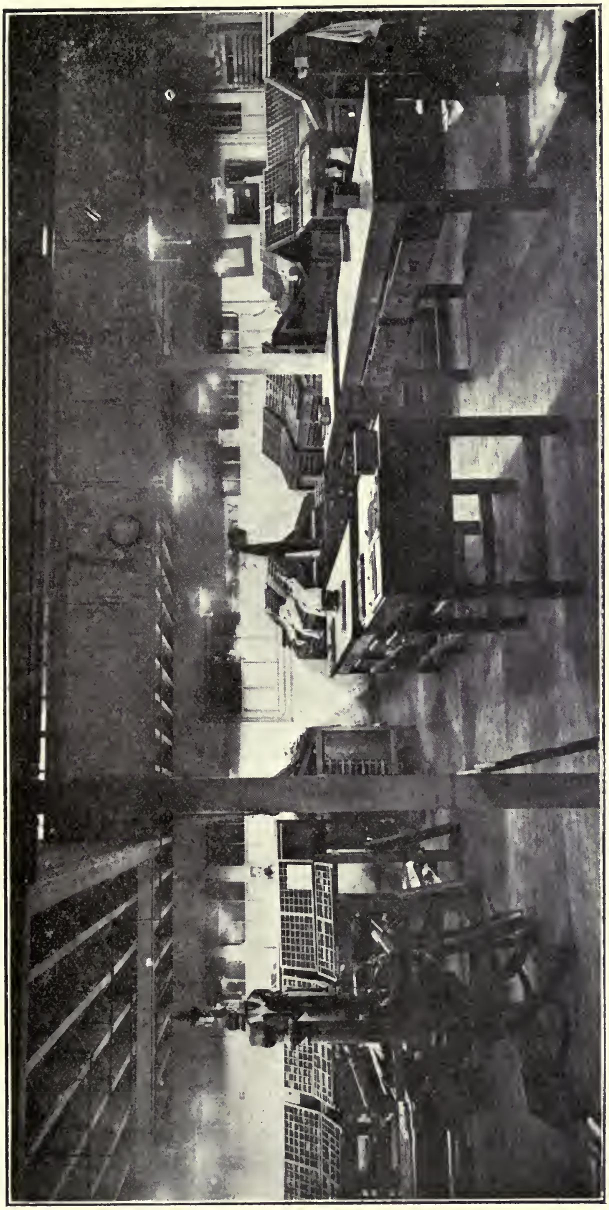


Fig. 656.—Composing Room of the Solicitors' Law Stationery Society, Ltd.

case as this, the lamps may be fitted with a deep shade, set at an angle of 45° or thereabouts with the horizontal, so as to focus the light on the formes, as shown in Fig. 657. As will be seen from the polar curve, these shades so reflect the light as to give the rays of maximum intensity in a vertically downward direction from the burner, while still allowing sufficient to pass obliquely to avoid the appearance of spottiness and give an efficient general illumination.

Laundries.—The enormous advantages which gas possesses as a fuel have been previously referred to in this volume. In few industrial operations, however, does its special advantages stand out more clearly than in its application to laundry purposes. Here they are pre-eminent.

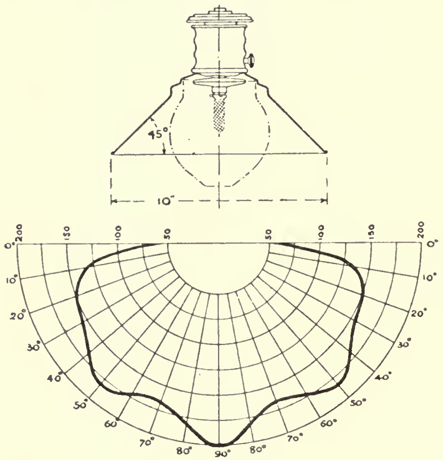


Fig. 657.—Keith 150 Candle Power, High-Pressure Lamp, fitted with deep shade, showing polar curve.

Consider for a moment exactly what is required. The essentials are a source of heat which is absolutely clean, which is uniform, which can be regulated at will, which when once regulated or adjusted is unvarying, which is mobile, and may be rapidly moved over a limited area without interfering in any way with the production of heat or its intensity, which requires no flue of any kind, which may be applied in any number of units in apartments occupied continuously by human beings, and which requires no fetching or carrying of fuel, or clearing away of ash, dust, or dirt. Finally, the source of heat must be cheap itself, and capable of application to cheap apparatus. Every one of these requirements are admirably met in high-pressure gas.

Fig. 658 shows a general view of the Sutton Model Laundry, and Fig. 659 a view of the ironing room at the Innisfail Laundry, Childs Hill. The whole interior is admirably lighted by 100 candle-power high-pressure Keith lamps. For service of this kind, the lamps should be fitted with a shallow shade, such as that shown in Fig. 660, making an angle of 15° approximately with the horizontal. When so fitted, they give a light of very even distribution, as seen by the polar curve, and are eminently suited for the general lighting of roomy apartments with comparatively low ceilings. The ironing room is fitted with high-pressure gas irons connected by flexible

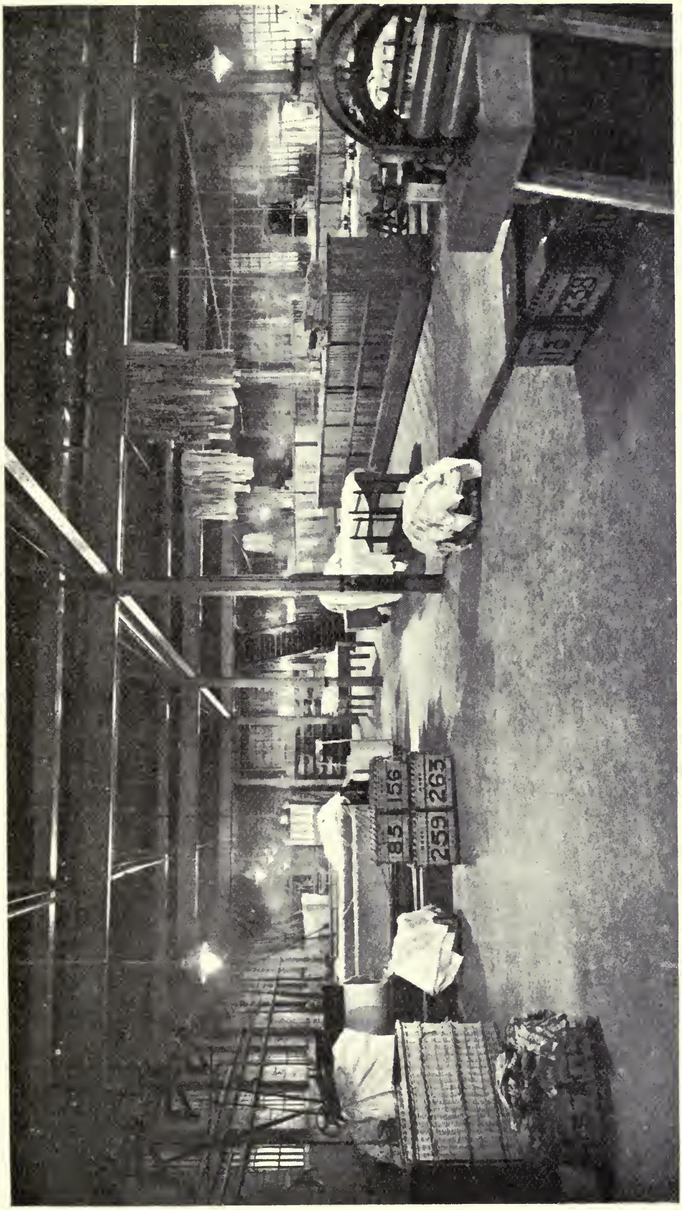


Fig 658.—Sutton Model Laundry: General View

Fig. 659.—Innisfail Laundry Ironing Room.

metallic tubes to a main running down the centre of the bench. The necessary mobility is obtained by swinging the flexible tube from the roof, which gives all the movement required for the purposes of ironing. A comparatively small quantity of gas is required to maintain the heat of the iron, there is a complete absence of smell, and the whole arrangement conduces to the comfort and facilitates the work of the operator.

One great advantage of these high-pressure gas irons is that they are absolutely "fool proof." With low-pressure irons, one of the great difficulties met with is in the interference with the gas and air adjustment on the part of workpeople in order to alter the heat of the iron in accordance with the requirements of the moment. The consequence is that the adjustment is seldom correct, gas is wasted, incomplete combustion takes place, and the air is more or less contaminated.

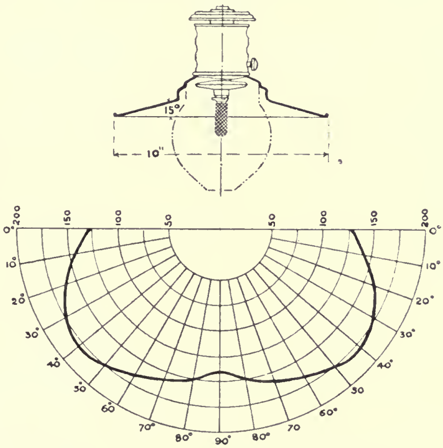


Fig. 660.—Keith 150 Candle Power, High-Pressure Lamp, fitted with shallow shade, showing polar curve.

In the Keith system the adjustment is made once for all by the engineer, and when made it cannot be altered by the operator. A special cock is fixed upon the supply pipe which gives three distinct controls: maximum heat, moderate heat, and gas shut off; and the adjustment is correct at each position. Each iron is fitted with a by-pass, so that gas may be economized when the iron is out of use for short intervals without the trouble of lighting up afresh each time.

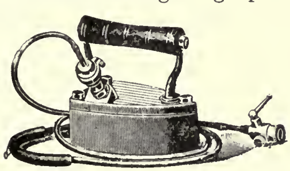
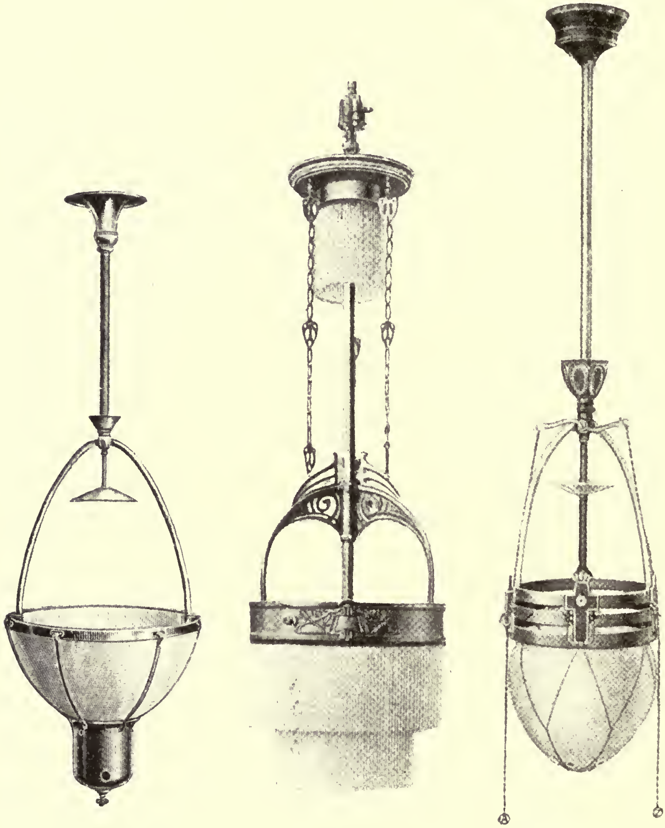


Fig. 661.—Keith H.-P. Gas Iron.

Lighting less roomy interiors.—For the lighting of interiors of a less roomy character than those previously described, high-pressure gas is increasingly making its claim felt. These include such cases as stores, shops, and other similar establishments where a good, pure, well diffused and cheap illuminant is an absolute necessity. These stores also frequently require fittings of a more ornamental character than the strong plain designs suitable for factory and workshop purposes.

The ornate series of " Pharos " high-pressure air-gas lamps placed upon the market by the Welsbach Light Co., Limited, are admirably adapted to meet this requirement. Fig. 662 shows a few of these types of lamps, which may be obtained in almost any kind of finish



High-Pressure Gas Lamp. High-Pressure Air Lamp. High-Pressure Air-Gas Lamp.

FIG. 662.—" Pharos " Lamps.

to suit the particular purpose for, and surroundings in which, they are to be used. The open bowl form of globe gives excellent lighting effect through reflection from ceilings, whilst at the same time ensuring a mild, well-diffused light direct from the lamp itself. The fringe in the middle lamp of the three adds a highly artistic appearance to a very ornamental lamp.

It cannot be too often or strongly emphasized that high-pressure gas is in a very advantageous position in relation to its great competitor for this class of lighting. The competition here is with the metallic filament lamp, and, as has already been pointed out, light for light, these lamps are many times more expensive than high-pressure gas. Cheapness alone will be quite insufficient to capture this field of lighting for gas. But when to cheapness can be added efficiency, purity, steadiness and grateful character, together with central and efficient control, the advantages become so overwhelming that we may confidently look to a great extension of gas lighting for these purposes in the near future.

High-pressure gas for industrial purposes.—The near future will also probably witness very great developments in the use of high-pressure gas for innumerable industrial purposes, for which the experimental and practical work which is being carried out in Birmingham and other industrial centres is now paving the way. There is here a vast and fruitful field waiting to be occupied and worked by the gas engineer, which will bring an abundant return for the skill and energy which may be put into it. At present the soil is almost virgin, but as its possibilities become more and more realized the application will become increasingly marked.

What is it that the manufacturer requires, in the various smelting, annealing, tempering, refining and other such industrial processes as carried on to-day ? First of all, the fuel employed must be capable of giving an extremely wide range of temperatures. These temperatures must be absolutely under control. They must be regular and uniform. They must be reproducible at will.

In each of these particulars, except the first, a solid fuel fails to meet the requirements of the case. Undoubtedly a very wide range of temperatures may be obtained with a solid fuel. But they are certainly not under complete control. They cannot be varied at will. If in a solid fuel furnace the temperature becomes too high or too low, it cannot be immediately rectified. It is impossible to maintain an absolutely uniform heat. Every time the fuel is replenished there must be a cooling of the furnace. The amount of fuel added may not always be alike. The draught may vary, or the quality of the fuel may vary from day to day. Continual variations between a maximum and minimum temperature must be always taking place. And for these amongst other reasons it is practically impossible to reproduce any set of conditions, and therefore of results, with certainty. And in many processes certainty is absolutely essential.

Contrast now with this the advantages which a high-pressure gaseous fuel offers. In the range of temperatures afforded, high-pressure gas compares favourably when burnt under suitable conditions with the best of solid fuels. The control is perfect. The temperature may be varied at will by simply regulating the supply.

This can be done instantaneously. The heats may be kept absolutely regular and uniform. When any required temperature has been attained, the quantity of gas necessary to maintain it may be determined and continuously supplied. If that is done, then regularity and uniformity are bound to follow. And lastly, any desired temperature may be reproduced at will. If it is found that a certain quantity of gas of a certain calorific value, issuing from a jet of known dimensions and character at a certain pressure, and consumed under a certain set of conditions, develops a certain required temperature, then, seeing that with high-pressure gas each factor and set of conditions are under absolute control, they may be repeated with certainty and the temperature reproduced with exactitude. These great advantages would be quite sufficient to compensate for considerably increased cost of fuel if that were necessary. But even here the balance of advantage lies clearly with high-pressure gas, as is established by the very definite figures given by Mr E. W. Smith in his paper read before the Institution of Gas Engineers in 1911 relating to the work done by the Birmingham Aluminium Castings Company.

"The cost of melting in the new furnaces, week in and week out, and including wastages, dinner-hour losses—when furnaces are running at half heat and no metal is being poured—works out at 12s. per ton. On a single day's melt, under good conditions of working, this figure is halved. The average rate of melting is 100 lbs. in half an hour."

The advantages are neatly summed up by Mr Smith in the following paragraph :—"The manager states that by using high-pressure gas instead of coke the labour costs are halved ; the cost of melting is more than halved ; the amount of metal melted per pot is much increased ; there is less oxidation of the metal during the melt owing to the presence of a reducing atmosphere throughout the furnace ; the method is much cleaner ; there is no carting of ashes ; there is no stoking up ; heats are easily and simply controlled ; and there is a more even alloy. As a result of careful tests by experts, it is found that the tensile strength of the alloy is increased ; there is a saving in the rebuilding of the linings when the inner one is worn out ; and lastly, the new method is much better for, and much preferred by, the furnace men." Such a testimonial from an unbiassed practical worker using a comparatively new process is a very high commendation indeed.

High-pressure burners.—The construction of the burner for use with high-pressure gas in a crucible furnace varies very considerably from the ordinary low-pressure high-power burner, with which long use has made everyone engaged in the distribution of gas perfectly familiar. These, in single and duplex form, are shown in Figs. 663 and 664. The great difference is, of course, that the high-pressure burner has no mixing tube. The high-pressure jet or nipple is brought to the mouth of a conical opening into the interior of the furnace, through which the air for combustion is induced at a considerable velocity by the issuing stream of gas. The exact position of the nipple in relation to the conical throat is a matter of extreme importance, as on this depends the quantity of air induced.

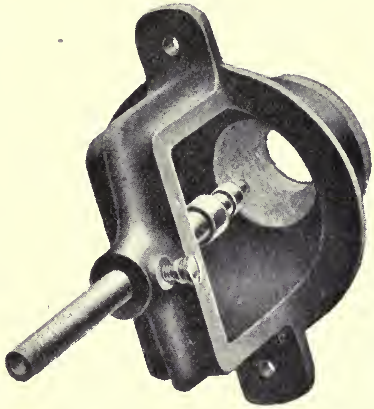


Fig. 663.—Single High-Pressure Furnace Burner.

Furnaces.—Then the gaseous mixture is not introduced centrally and from the bottom of the furnace, but at the side and tangentially. The effect of this is to give a rotatory and spiral travel to the gaseous mixture during the process of combustion. The portion of the furnace in the same horizontal plane as the burner being first heated, the temperature gradually creeps up until the whole furnace is thoroughly incandescent, a process which takes about ten to fifteen minutes.

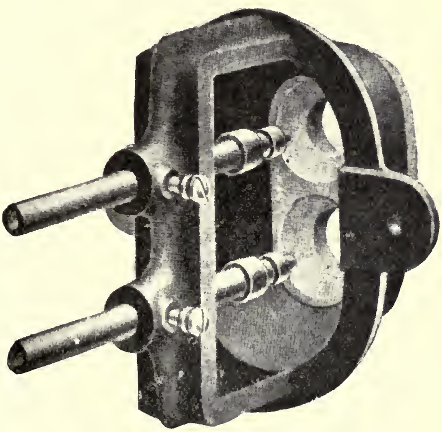


Fig. 664.—Double High-Pressure Furnace Burner.

Another interesting and important point is the relation of the size of the furnace to the size of the contained crucible. It has been pointed out in quite another connection that if the best results are to be obtained, the incandescent mantle of a burner or the radiant in a gas fire must fit the flame. The same thing obtains in a high-pressure crucible furnace. The annular space between the exterior of the crucible and the interior of the furnace must be such as to "fit" the "flame" or stream of gaseous fuel undergoing combustion.

And the last striking difference is this. When the gas is first turned on and ignited, and whilst the furnace is cold, the combustion takes place in the form of flame in the usual way. But as the furnace becomes heated up all flame disappears, and all that can be seen are

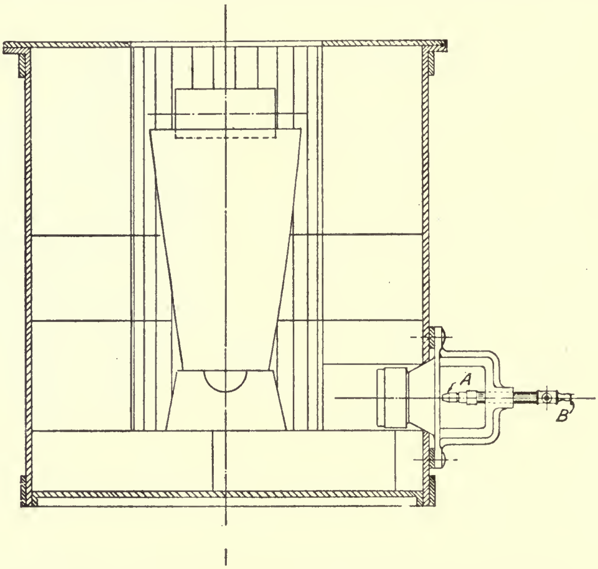


Fig. 665.—Vertical Section High-Pressure Gas Furnace.

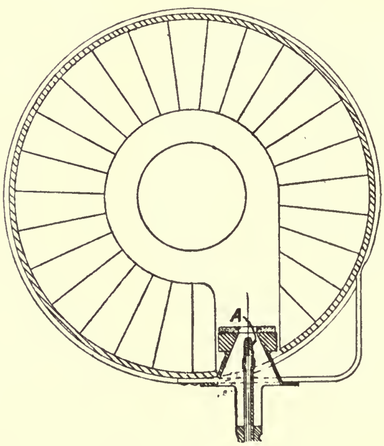


Fig. 666.—Horizontal Section High-Pressure Gas Furnace.

the glowing surfaces of the furnace and crucible bathed in a sea of incandescence. Perhaps it was this appearance which most impressed the author when in 1911 he first saw the high-pressure furnaces at work at the Birmingham Aluminium Castings Company's works.

Fig. 667 shows one of the very excellent series of crucible furnaces for high-pressure gas which have been introduced by the Richmond Gas Stove and Meter Co., Limited. These are made in a wide range of powers, and are designed for the melting of gold, silver, copper, brass, aluminium, etc. They are adapted for pressures of from 5 to 15 lbs. per square inch. The sliding cover and extended top plate are designed to facilitate the work of the furnace, the ingots being placed upon the top, while access is obtained to the crucible by simply sliding the cover aside.

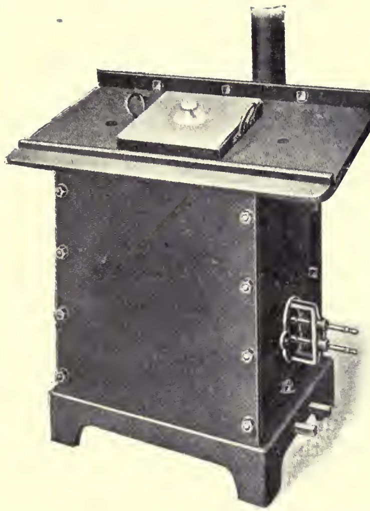


Fig. 667.—Richmond's High-Pressure Gas Crucible Furnace.

Fig. 668 shows one of Messrs Fletcher, Russell and Co.'s latest furnaces for high-pressure gas. It is arranged as a tilting furnace, and is adapted to the melting of all kinds of metals up to a temperature equal to the melting point of steel, or 2500° F. They are made in all sizes up to a 400 lb. crucible.

Fig. 668.—Fletcher, Russell and Co.'s Tilting Crucible Furnace.

For all kinds of blowpipe work high-pressure gas is rapidly superseding the air blast blowpipe in use at present. One of the handiest types of blowpipe is the Smith-Walter (shown in Fig. 669), which is specially designed for use with high-pressure gas, and was described by Mr E. W. Smith in his Institution paper in 1911. In this the high-pressure gas is connected to both tubes, in the one being delivered at high velocity in the usual way with a high-pressure jet, while in the other the gas is expanded by being passed through the larger tube and issues practically as a low pressure supply. "It was found that by leaving the latter turned slightly on, so that a small flame was obtained round the jet, when the high-pressure gas was turned on from the jet, this small flame acted as a concentric by-pass, with none of the disadvantages of the orthodox form of pilot light. When the maximum stable flame had been obtained from the high-pressure jet, the low-pressure supply could be turned on and the size of the flame increased—it being non-luminous, partially luminous, or luminous—depending on the velocity of the gas coming from the high-pressure jet." Both supplies are readily under control, the low-pressure by means of a small lever within reach of the thumb, and the high-pressure by means of the large lever shown, which is gripped in the hand.

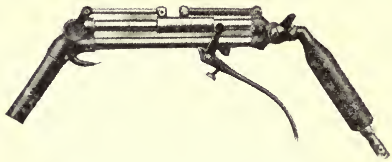


Fig. 669.—The Smith-Walter High-Pressure Blowpipe.

Mr Smith found a blowpipe of this type to produce a flame at least 100 per cent. better than a flame of the same gas consumption obtained from the usual type of air blast blowpipe.

CHAPTER XXXVI

UNACCOUNTED-FOR GAS

THE question of "unaccounted-for gas" is one of the most important which has to be considered by the distributing engineer. Should this account be allowed to become unduly inflated, the splendid results which may be obtained by carbonization in the retort house may be largely neutralized, and that which should go to swell the profits of an undertaking be dissipated to a very great extent. A leakage of gas from the distributing system is not only so much direct loss to the undertaking, but is also a nuisance, inasmuch as the subsoil becomes impregnated and discoloured, and vegetable life may be rendered impossible in the immediate vicinity. It may also become a very possible source of danger, by percolating through the ground into adjacent premises, with results to property, health, and even life itself, which may entail a very considerable outlay upon the undertaking. The leakage from a distributory system is therefore (*a*) a dead loss to the undertaking; (*b*) a nuisance to the community; (*c*) a possible source of danger to the public, entailing (*d*) a considerable expenditure in making good damage and injury caused by the leakage.

The unaccounted-for gas of an undertaking is the difference between the total of that registered by the station meters and the sum of the quantities registered by the consumers' meters. In other words, it is the difference between the quantity of gas made and the quantity of gas sold. In cases where the gas used upon the gasworks, depôts, distributing stations, etc., is not supplied through meters, the quantity used in this way must be estimated and deducted from the difference between the total quantity of gas made and that sold before the leakage account can be made up. Generally an allowance of 1, $1\frac{1}{4}$, or $1\frac{1}{2}$ per cent. of the quantity of gas made is assumed, as a rough approximation, under this head.

Fallacious method of comparison.—The unaccounted-for gas of an undertaking is usually stated in terms of percentage of gas made. It is obvious, however, that for purposes of comparison this method of stating the result obtained is unfair and fallacious. If two undertakings be taken, one of which supplies an area which is densely populated and has a large consumption in proportion to the mileage of mains, and another in which the conditions are the reverse, it is at once apparent that, other things being equal, the undertaking whose area of supply is wide and straggling must inevitably have the largest leakage account. In the one case, 100 miles of mains only may be necessary to supply the same quantity of gas as the straggling character of the district may render the employment of 150 miles of mains necessary for in the other. So long as there is leakage at all, if there are two undertakings whose distributory systems are equally sound per mile, that one with the greater length of main will, naturally, have the greater loss, although the output of gas may be approximately the same in both cases. Therefore, by stating the total loss in percentage of gas made an undertaking with a long distributing system in proportion to the gas sold will inevitably be prejudiced in comparison with another having a more compact system, and this from causes which are altogether outside the control of the management.

It would appear, therefore, to be a much fairer basis of comparision to state the unaccounted-for gas in terms of loss per mile of main. If this principle were adopted, many undertakings which show a heavy leakage account when stated in the usual way would be found to come out with much more favourable figures, whilst, on the other hand, some whose percentage loss is small would be shown to have a comparatively large loss when stated in terms of loss per mile of main. Appended is a list showing the results obtained by applying this principle to some of the more important gas undertakings of the United Kingdom.

The figures are derived from *The Gas World Analyses of Municipal Gas Accounts for* 1910-1911, and *Analyses of Gas Companies' Accounts for* 1910, which are the latest figures available.

It is seen at a glance how fallacious, for purposes of comparison, is the usual method of stating the unaccounted-for gas in percentage of the make. For instance, the Gas Light and Coke Company and the Brentford Gas Company show almost identical losses in percentage of make. But the loss per mile of main is 731,282 cubic feet in the case of the former, while the latter, although 0.1 per cent. heavier in the percentage, has a loss per mile of only 472,123 cubic feet. Again, the South Metropolitan Gas Company shows a loss per mile of main of 307,028 cubic feet, and the Edinburgh and Leith Gas Commissioners slightly less, or 293,080 cubic feet. But whereas the former is only 2.9 stated in percentage of make, the latter, with less loss per mile, runs to 6.2 per cent. on make.

Although, in the opinion of the author, the statement of unaccounted-for gas per mile of main is an advance on the percentage method, it must not be assumed that the figures given in the foregoing table are final and conclusive as to the relative soundness of the distributory systems of the undertakings quoted. For instance, it does not necessarily follow because the Commercial Gas Company has more than twice the unaccounted-for gas per mile of main that Bradford has that the mains of the former are twice as leaky as those

Gas Undertaking.	Miles of Mains.	Gas made. Thousands of Cubic Feet.	Gas Sold. Thousands of Cubic Feet.	Gas Sold per Mile of Main. Thousands of Cubic Feet.	Unaccounted-for Gas. Percentage of Make.	Unaccounted-for Gas per Mile of Main. Cubic Feet
The Gas Light and Coke Company .	2,466	27,123,618	25,014,949	10,144	6.6	731,282
South Metropolitan Gas Company	1,243	13,123,012	12,593,478	10,131	2.9	307,028
Manchester Corporation . .	948	5,659,844	5,416,013	5,713	3.2	193,457
Birmingham Corporation . .	798	8,042,087	7,583,853	9,504	4.3	436,326
Newcastle-on-Tyne Gas Company	765	3,351,927	2,998,487	3,919	9.0	395,522
Sheffield Gas Company . .	586	3,812,036	3,648,440	6,226	3.4	225,416
Bradford Corporation . . .	451	2,138,002	2,004,042	4,444	6.3	297,029
Edinburgh Gas Commissioners	436	2,044,182	1,895,266	4,347	6.2	293,080
Brentford Gas Company . .	438	3,083,061	2,830,571	6,462	6.7	472,123
Bristol Gas Company . . .	365	2,777,798	2,547,863	6,980	7.8	546,249
Nottingham Corporation . .	391	2,088,463	2,006,425	5,132	3.9	209,816
Commercial Gas Company . .	290	3,516,414	3,261,968	11,248	5.7	695,517
Salford Corporation . . .	290	1,685,506	1,540,812	5,313	7.0	409,248
Leicester Corporation . . .	286	2,112,668	2,010,183	7,028	4.1	302,164
Oldham Corporation . . .	230	1,454,503	1,359,606	5,911	5.4	339,730

in Bradford. That may or may not be true, but the inference would be unwarranted if made simply from this table.

Essential factors for fair comparison.—If it were desired to institute close comparisons, it is obvious that much more detailed information as to local circumstance would be necessary than is at present accessible. As a first step, the so-called leakage account would have to be analyzed to ascertain exactly what loss is sustained under each of the six heads discussed later. Then, having found the loss due to leaky joints, for instance, we should need to know the lengths and sizes of the mains in each undertaking, so that the total length of jointing surfaces of the whole of the system might be determined. Other important factors are the number, length, and size of the services of the undertaking, and the pressure at which gas is supplied. For instance, it would obviously be unfair and inaccurate to compare a mile of 6-inch main at a pressure of 2 inches, and without a single service attached, with a mile of 12-inch main at a pressure of 4 inches to which, say, 250 services were attached, as simply one mile of main in each case. The other factors mentioned must be brought into the calculation if a fair comparison is to be made. But public information on these matters is altogether lacking ; and even if it were available, such a detailed investigation is not within the scope of the author's present purpose.

How the unaccounted-for gas is built up.—It has already been suggested that only part of the quantity of gas unaccounted for actually leaks away through the distributory system as escaping gas. Assuming that the water-line of the station meters at the gasworks is properly looked after, that the meters register correctly, that the quantity registered is duly corrected for temperature, that the gas registered is duly received into the gasholders, and also that the latter themselves are perfectly gas-tight, the so-called leakage account is built up as follows, viz :—

1. Loss due to making connections for extensions and repairs of the distributing system.
2. Loss due to leaky pipes and joints.
3. Loss due to inaccuracy of consumers' meters.
4. Loss due to condensation in mains.
5. Loss on public lighting account due to imperfect working of lamp governors.
6. Loss due to the difference between the temperature at which gas is sold, and that to which it is corrected (if at all) at the gasworks.

It may be advisable to take these six points in order.

Loss due to working.—It is inevitable, even with the best tools, the most up-to-date methods, and the most careful management and over-sight, that there must be some slight loss of gas in consequence of the work necessitated upon live mains, in extensions, repairs, and renewals, and in connecting services. There can be little doubt that this minimum has often been largely increased by the astonishing carelessness of the ordinary run of workmen. The practice of workmen heating their ladles of lead in a flame of gas issuing from a hole cut for the purpose in the main, or gasfitters heating their soldering irons by lighting the gas at the service end, may be exceptional, but it is certainly typical of avoidable waste which is frequently allowed to take place even to-day. It should, however, be the aim of all who can influence the matter to reduce this quantity to the lowest possible figure. And this can only be done by persistent attention to small and petty details as work is carried out. The leakage account of a gas undertaking is not made up, as far as the particular point now under notice is concerned, of a comparatively small number of large losses, but by an infinite number of small ones. The relatively small avoidable loss at each working operation, when multiplied out over the thousands of such carried out in the course of every twelve months, makes a surprisingly huge total. Therefore, workmen must be made to understand that any loss of gas, however apparently trivial in itself, which can possibly be prevented when making connections, is waste, and should and must be avoided. Only those who have experienced it can form any idea how very careless and indifferent some workmen may be on this point. Continual watchfulness is imperative on the part of the management to correct this tendency.

Leakages.—The question of leakages from faulty pipes and joints has been fully discussed in a previous chapter, and need not be further elaborated here, except to emphasize again the importance of a regular and systematic inspection of the services and service mains, in which by far the greater amount of such leakage takes place.

Registration of meters.—With respect to the loss due to inaccuracy of registration of consumers' meters, this is a matter which calls for the greatest watchfulness and care on the part of the meter inspectors and their superintendents. The loss may be greatly checked and reduced by efficient work in this department.

Inaccuracy in registration may arise from any one of several causes, of which imperfect water-lining of wet meters is one of the most common. The increase in the cubical capacity of the drum if the water-line is allowed to fall below the true level, and the consequential importance of due attention being given to the water-lining of wet meters, have previously been noticed in the chapter on wet meters. In addition to slow registration due to the before-mentioned cause, wet meters may, under certain circumstances, cease to register altogether, whilst still passing gas. This may, of course, occur at any time during the period in which any current account has been built up. If such has been the condition of the meter throughout the whole period from one inspection to another, the fact reveals itself to the inspector immediately he compares his reading with that of the previous inspection. But if the meter has only ceased to register during the last few weeks of the period between the inspections, the matter is not quite so easy of detection. Any exceptional differences in the account as compared with that covered by the corresponding months of the preceding year should at once be investigated, and if no sufficient explanation is forthcoming, the meter should be tested to ascertain whether it is still registering correctly or not.

Another point of great importance is to make absolutely sure that no wet meter is being worked at a rate exceeding its normal capacity. It has already been pointed out, when treating of wet meters, that the effect of this is to increase the capacity of the measuring chamber. In testing a 3-light wet meter to determine the extent to which this may take place under working conditions the author found that the meter when passing 18 cubic feet of gas at a pressure of 5-tenths was perfectly correct, but that when the inlet pressure was increased to 3 inches and the consumption increased to 36 cubic feet per hour, the meter registered $1\frac{1}{2}$ per cent. slow.

The water-line, too, of large consumers' wet meters in cylindrical cases, working without float, should be watched very carefully. In some makes of meters a depression of the water-level by about $\frac{3}{4}$-inch to 1 inch would permit of small quantities of gas passing through the centre of the drum without registration. The same thing may also happen to small consumers' meters working with a float, if the latter should stick, or if the float valve does not shut the gas off tightly.

The correctness of registration of dry meters should also be kept continually under review. If there is any leakage between the measuring chambers, due to fault in the leathers or the joints, or imperfectly fitting valves, quantities of gas may be passed through the meter unregistered. It is a good plan to allow sufficient time for the inspection, say once in six months, to enable the inspector to apply a rough and ready test to the dry meters in his district as well as to water-line the wet ones. This may be done by lighting one burner upon the premises supplied and ascertaining by observation of the small dial that the meter registers this small quantity. If sufficient gas is passed unregistered to maintain one burner, a second should be added, and, if necessary, a third, or more, until a point is reached at which the meter commences registering. A dry meter will often register when passing gas at a rate approximating towards its full capacity when it may pass very much smaller quantities without registration at all. The result of the test will, of course, suggest the remedy to be applied.

Assuming that, from any of the causes referred to, consumers' meters are to any serious extent registering slowly, the proportionate effect would be much greater in summer than in winter. The aggregate of the small consumptions of the summer months is much larger relatively to output than in the winter months, and if small quantities of gas are being passed without registration the percentage effect is much greater in the one case than in the other. Probably this is the reason why the percentage of unaccounted-for gas in some instances has been noticed to be greater during the months of low consumption than when consumption is heavy.

In this connection there is another point also to be considered. The provisions of the Sale of Gas Act permit a maximum range of variation from true measurement of 5 per cent., of which 3 per cent. shall be against the gas undertaking and 2 per cent. against the consumer, or a balance of 1 per cent. against the undertaking. In estimating the leakage proper, as distinguished from unaccounted-for gas, it would appear only fair to make some allowance on this account, say of $\frac{1}{4}$ to $\frac{1}{2}$ per cent.

Condensation in mains.—The extent to which condensation in the distributory system affects the unaccounted-for gas will be, of course, dependent upon the thoroughness with which the gas is condensed upon the gasworks, the differences of temperature it is subjected to in the gasholders and the distributing system, and the area of the mains in comparison with the quantity of gas passing through them, or, in other words, the velocity of flow of the gas.

Some time ago the author kept a series of records as to the quantity of condensible constituents which were taken out of the syphons on the distributing system in his district, and was somewhat astonished to find that the average daily aggregate was approximately 1100 gallons, for the four winter months. This was from a distributing system containing at that time over 900 miles of mains.

Except, perhaps, for some little moisture the gas might pick up from the water in the gasholder tank, the whole of this quantity would be passed through and measured by the station meters in the form of gas or vapour. A gallon of pure water at 60° Fahr. would give 213 cubic feet of vapour. Several samples of the liquor drawn from the syphons were taken and vaporized to ascertain the quantity of vapour given per gallon of liquor. The following results were obtained :—

In the first experiment one gallon of liquor at 60° Fahr. gave 175 cubic feet of vapour. The second gave 157.2 cubic feet per gallon, and the third 150.9 cubic feet of vapour per gallon of liquor, or an average over the three experiments of 161 cubic feet. The difference in the results obtained was probably due to the difficulty in obtaining any two samples exactly alike as to their relative quantities of water and hydrocarbons, although great care was exercised to mix the liquids as thoroughly as possible before weighing.

If, then, we take this quantity as being approximately correct for the whole of the liquor removed from the street syphons, a very simple calculation will show how so-called leakage may be inflated from this cause. If we multiply 161 (vapour per gallon) into 1100 (quantity of liquor removed per day from syphons) into 120 (number of days in November, December, January, and February) we get a total of 21,252,000 cubic feet for the four months. Assuming that the amount of condensation in the remaining eight months of the year is, roughly, equal to that for the four months quoted, we shall have a total for the year of 42,504,000 cubic feet of gas registered by the station meters, but unaccounted for owing to condensation in the street mains.

Public lighting.—There can be but little doubt that if the public lighting is not very closely watched, and especially where it is not in the direct charge of the gas undertaking affected, there may be a very great aggregate loss to the latter through (*a*) the imperfect action of lamp governors, and (*b*) the failure on the part of the lamplighter to strictly observe the stated time for lighting and extinguishing the public lamps.

The latter is a cause which may particularly operate in the summer months. The proper time for commencing to light the lamps falls so late in the evening that there is a tendency, especially if the weather is dull or gloomy, to anticipate the time-table somewhat. And as during the same period, the lamps should be extinguished in the very early morning, when the superintendence is usually comparatively slight, there is a serious probability that the stated times are not invariably rigidly adhered to. The same causes do not, of course, operate to anything like the same extent in the winter as in the summer months, but even then there are frequently departures from the time-table which, when the variation is multiplied out over a great number of lamps, constitutes a very serious loss to the undertaking. If in an area in which there are 20,000 public lamps there is an aggregate departure from the time-table of half-an-hour per week, including lighting and extinguishing, against the undertaking, and it is assumed that the lamps average a consumption of 4 cubic feet per hour, the loss to the undertaking would total to upwards of 2,000,000 cubic feet per annum.

The lamp governors, too, require a considerable amount of care and attention to maintain them in perfect working order. Even the best varieties are liable occasionally to stick and get out of order, and pass more gas than they are set to give. It is, therefore, a wise precaution to have a certain quantity of governors, taken indiscrimately from different districts, brought in annually to be tested.

In one large town known to the author, where this course was taken some few years ago, the results of the tests of over 1100 lamp governors, taken haphazard from various districts in the town, showed that the lamp governors passed an average excess of 8.85 per cent. of gas at a pressure of 15-tenths. When the pressure was increased to 20-tenths the excess quantity of gas passed by them rose to 14.57 per cent. The net result over the whole area of supply was to inflate the so-called leakage by upwards of 14,500,000 cubic feet of gas per annum.

Relative temperatures at station and consumers' meters.—The effect of great differences between the temperature at which gas is registered at the works' meter and that at which it is sold must be most marked on the amount of unaccounted-for gas.

In connection with many gas undertakings it is usual to take hourly observations of the temperature at which gas is measured by the station meter at the gasworks, and correct the registration to 60° Fahr. But this is not universal by any means. Many do not correct the station meter registration at all. Some correct to 55° F., others to lower temperatures still. Some correct to a definite relation to the atmospheric temperature. In two cases known to the author, the gas made has to travel very long distances underground before being measured at all. This great lack of uniformity in ascertaining the very basal factor of the problem destroys to a very large extent the value for purposes of comparison of the various analyses published. But whatever the correction made, if the gas were measured at the consumers' meters at that temperature there would be no loss due to shrinkage of bulk. It is found, however, that such ideal conditions do not exist in practice. In passing through the distributing mains the gas is cooled, and it may be measured at the consumers' meters at a temperature far below that to which it is corrected at the works.

There is another very important point in connection with this problem of unaccounted-for gas which is very commonly overlooked. It is the shrinkage in bulk which may go on in the passage of the gas from the station meters to the gasholders, which is proceeding during storage there, and during transmission to the station governors, due to change of temperature. The table on p. 782 shows to what extent this takes place in works producing nearly 3000 million cubic feet of gas per annum. If this quantity were corrected to 60° Fahr. and sent out at the temperature shown, the result would be that in the months of heaviest consumption the unaccounted-for gas might total as high as 3.5 per cent. on the make before a cubic foot of gas had left the gasworks. It is seen at once what an anomalous position this is, to talk of 3.5 per cent. of leakage which is really shrinkage of bulk upon the works.

Determination of unaccounted-for gas.—This brings up the further question whether on the whole it is a good plan to take the station meter registration as the datum line from which to calculate the unaccounted-for gas. A far better method would be to take the temperature hourly at the governors, and, for the purpose of ascertaining the unaccounted-for gas only, correct the "make" to the average temperature of the gas passing out to the district. The difference between the station meter registration so corrected and the sum of the registrations of the consumers' meters would be the unaccounted-for gas for which a distribution department might fairly be held responsible. As a result of long experience and experiments extending over many years the author has come to the conclusion that, speaking broadly, the station governor temperature and the temperature at which gas is measured at the consumers' meters do not vary at any one time more than a very few degrees Fahr. If this is so generally, then the calculation of the unaccounted-for gas as suggested must always be far more satisfactory because of this equality of temperatures of "make" and "sale."

The opinion just expressed as to the similarity of temperatures at station governors and those of the "sale" is strikingly confirmed as far as temperatures of transit are concerned by the particulars as to ground temperatures given in the presidential address of Mr William Millhouse, Assoc. M.Inst.C.E., at the anual meeting of the British Association of Waterworks Engineers at Scarborough in July 1906. In his address Mr Millhouse says:—"I have taken records of the temperature of the ground (at Scarborough) at a depth of three feet below the surface for some years, and find it varies between 40° and 60° Fahr." The actual readings are given in the following table:—

Month.	1903.	1904.	1905.
	Deg. Fahr	Deg. Fahr.	Deg. Fahr.
January . .	43 to 41	43 to 41	41 to 40
February . .	41 ,, 43	41 ,, 40	40 ,, 41
March . . .	43 ,, 44	40 ,, 42	41 ,, 42
April . . .	44 ,, 44	42 ,, 46	42 ,, 45
May . . .	44 ,, 48	46 ,, 51	45 ,, 51
June . . .	48 ,, 53	51 ,, 54	51 ,, 57
July . . .	53 ,, 55	54 ,, 60	57 ,, 60
August . . .	55 ,, 54	60 ,, 58	60 ,, 59
September . .	54 ,, 53	58 ,, 56	59 ,, 56
October . .	53 ,, 50	56 ,, 51	56 ,, 48
November . .	50 ,, 45	51 ,, 45	48 ,, 44
December . .	45 ,, 42	45 ,, 41	44 ,, 43

It must, of course, be conceded at once that the average depth of gas mains is not so great as 3 feet, and by so much some allowance must be made. The figures could not be taken exactly as they stand as an indication of the temperature which gas attains in passing through a distributing system.

It is obvious, however, that, being nearer the surface, the gas mains would be liable to greater fluctuations of temperature. During the winter months the temperatures would probably range lower than those given by Mr Millhouse, while in the summer time they would generally prove higher. These conclusions have recently received ample confirmation in the investigations of Mr J. W. Napier, of Alloa. In an address at the annual meeting of the Waverley Association of Gas Managers, in June 1912, Mr Napier gives the result of his investigations into the temperature of the gas in the street mains as follows :—

	Maximum Deg. Fahr.	Minimum Deg. Fahr.	Average Deg. Fahr.
January	40	35	37
February	44	36	39
March	43	37	39
April	46	39	44
May	59	47	50
June	65	54	59
July	68	56	61
August	65	54	59
September	58	51	54
October	59	45	50
November	49	38	44
December	44	36	39

If, therefore, the quantity of gas registered by the station meters is uniformly corrected to 60° Fahr., and has, in its passage to the consumer, to pass through a network of mains at anything like the temperatures shown either in the Leeds or Alloa tables, it is apparent that there must be a very considerable shrinkage of bulk in transit. There is bound, therefore, to be a great difference, in these circumstances, between the aggregate registration of consumers' meters and that of the station meters, due to this cause alone.

The results thus deduced from the tables given by Mr Millhouse and Mr Napier receive ample confirmation from observations which the author has himself made. A careful record, extending now over eight years, of the temperatures at which gas was passed through the station governors at the Leeds gasworks, and also of the temperature at which gas was registered at his own residence, gives most interesting results. The gas meter in the latter instance is fixed in quite an ordinary position, such as is usual in residential property, and under similar conditions in every way to thousands of other meters in the city. The average of the daily results noted for the four years 1908 to 1911 are given in the table on the next page.

It is shown by the table that in the four years 1908-1911 there were only two months in 1908, one in 1910, and two in 1911 when the gas passing out through the station governors reached the temperature of 60° or above, and ten months only in the four years when the temperature at the consumers' meters was 60° Fahr. or over. Four of these ten were in the wonderfully warm summer of 1911.

	1908.		1909.		1910.		1911.	
	Gasworks Governor.	Consumer's Meter.	Gasworks Governor.	Consumer's Meter.	Gasworks Governor.	Consumer's Meter.	Gasworks Governor.	Consumer's Meter.
	Deg. Fahr	Deg. Fahr.	Deg. Fahr.	Deg. Fahr.	Deg. Fahr.	Deg. Fahr.	Deg. Fahr.	Deg. Fahr.
January	41	39	43.0	41 .0	42.8	40.8	43.6	41.2
February . . .	43	45	42.3	41.6	42.9	42.4	44.0	42.8
March . . .	42	43	41.8	41.6	41.1	47.1	44.2	43.6
April	44	46	48.1	52.1	47.9	49.0	47.7	47.4
May	53	58	51.5	55.9	50.8	56.3	54.8	58.8
June	58	62	55.4	56.4	58.6	63.2	58.2	62.2
July	61	65	58.2	61.5	58.8	61.8	62.7	67.6
August . . .	60	59	59.6	58.8	60.0	60.0	63.8	65.4
September . . .	58.1	58.9	56.5	57.1	56.4	58.5	58.6	61 1
October . . .	56.4	56.2	54.3	52.9	54.1	54.1	52.0	51.0
November . . .	49.8	46.9	47.8	44.5	44.7	40.0	47.4	45.1
December . . .	45.0	42.1	44.2	41.3	46.7	44.7	44.6	44.2

Probably half the total output of most gas undertakings is sent out during the four months November to February, inclusive. A reference to the table shows that in 1908 the temperature through the station governors during those months varied from an average of 49.8° to 41°; in 1909 from 42.3° to 47.8°; in 1910 from 42.8° to 46.7°; and in 1911 from 43.6° to 47.4°. During the same months the temperature at the consumers' meters varied from 39° to 46.9° in 1908; from 41° to 44.5° in 1909; from 40° to 44.7° in 1910; and from 41.2° to 45.1° in 1911. When we remember that gases expand or contract, approximately, 1 per cent. for every 4.9° rise or fall in temperature, a simple calculation will show to what an enormous extent the amount of unaccounted-for gas is inflated by the difference in temperature between works' meter (corrected to 60° Fahr.) and the consumers' meters. Mr Napier, in the address to which reference is made, puts the average temperature of the gas in the mains at 47° Fahr. The author's experience in Leeds gives a rather lower average—45° Fahr. The figures mean that where, under these conditions, the gas registered at the station meter is corrected to 60° Fahr., the unaccounted-for gas due to this shrinkage in bulk is alone approximately 3 per cent. It would, of course, be a great mistake to generalize too freely from limited data, but there can be no doubt that the basis upon which the leakage account is determined needs very careful reconsideration, in order (*a*) that some discrimination may be made between real and paper leakage, and (*b*) that the leakage account of different undertakings may be tabulated upon some basis which is a really comparable one as between one and another.

CHAPTER XXXVII

FUSION AND ELECTROLYSIS

THE tremendous growth, during the past decade, of electric traction, particularly as applied to the tramway systems of our towns and cities, has introduced a new source of danger to the distributing mains and services of the present-day gas undertaking. The reference is, of course, to the fell evils of fusion and electrolysis, perils of such a character as to deeply impress the imagination and fill with some amount of dread those who have given the subject the consideration its importance deserves.

The consequences which may result from the insidious attacks of this stealthy foe are beginning to be generally realized in this country. It is only a year or two ago, however, that anyone who ventured to raise his voice in warning against the evil impending was ridiculed as fanciful and as being oppressed with a fear of something which, while theoretically possible, had little of a substantial character.

The report of the American Gas Light Association Committee on Electrolysis proved, however, very clearly the potentialities of the situation. It is, of course, admitted that, under the regulations and control of the Board of Trade, the tramways of this country are laid down in a much more substantial manner than are most of those in the States, and consequently the danger to be apprehended in this way is considerably reduced. There is nothing in this country which can compare for a moment with the condition of things which this report reveals. In one place, actual tests made showed a loss of metal on a single service pipe of over 1 lb. in a month. In another, differences of potential of 10 volts were commonly found, at one point reaching as high as 35 volts. Well-defined pittings have been discovered on an 8-inch main within six weeks of the pipe being laid new. In five years from the time at which it was laid new, pittings to the depth of 0.45 inch were eaten in a 12-inch pipe; and a length of 200 yards had to be taken up and replaced. These are a few instances culled at random from the report.

It must be recognized that as certain causes have led to certain results in the States and on the Continent, the same causes will inevitably lead to the same results here. If across the water these results are brought about in a comparatively short space of time because the escaping current is considerable, the same results are likely to occur here, although the time required to produce them may be much longer, as the escaping current is much smaller in quantity. In other words, the result obtained is the product of the amount of electricity operating multiplied into the length of time during which it operates, and consequently, if one of the factors be varied, the remaining one will be varied proportionately, but the final result will remain unaltered.

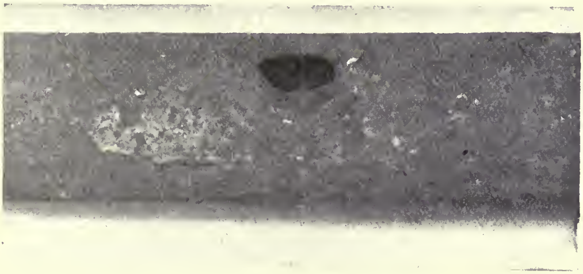


FIG. 670.—1-inch Service Pipe Fused by Tramway Cables at Leeds.

But even in this country the question of damage from stray currents has for a long time now been removed from the region of conjecture into that of proved fact. For a long time gas engineers were challenged to produce a single instance of their pipes having been injuriously affected by these stray currents. Whilst ten or twelve years ago we could only urge the possibility and even probability of injury taking place, it is to-day unfortunately true that

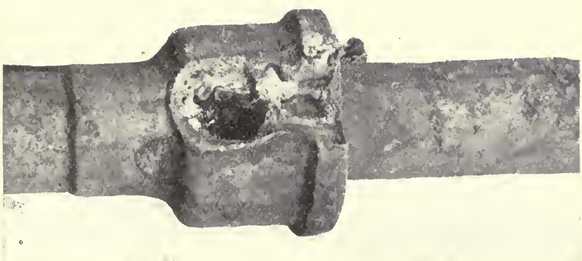


FIG. 671.—2-inch Main Fused by Electric Cables at Darwen.

evidence is surely, if but slowly, accumulating that the evil so long feared has begun to make its presence felt.

Two different kinds of electrolytic damage.—In considering this subject, it must be remembered that there are two totally distinct ways in which gas pipes may be injured by escaping electric currents, viz., by fusion and by electrolysis. Photographs of several recent cases of the former are shown in Figs. 670 to 675.

Fusion is caused by an electric cable in which the insulation has become imperfect, either through the worsening of some original defect, or in consequence of some accident in the immediate vicinity

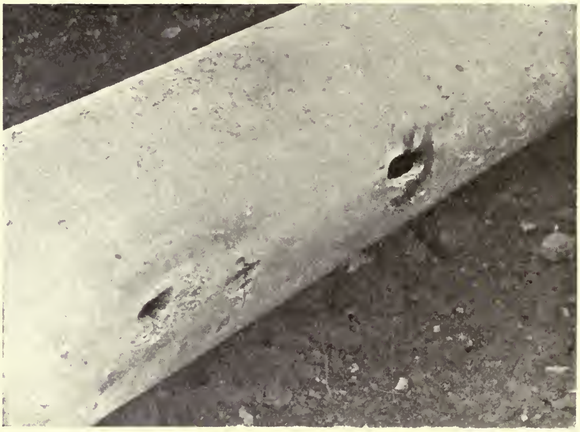


FIG. 672.—12-inch Main Fused by Electric Cables at Bradford.

of or in actual contact with a gas main. In every cable there is an outgo and return, insulated from each other by paper or other insulation of high resistance, the whole being sheathed in lead.

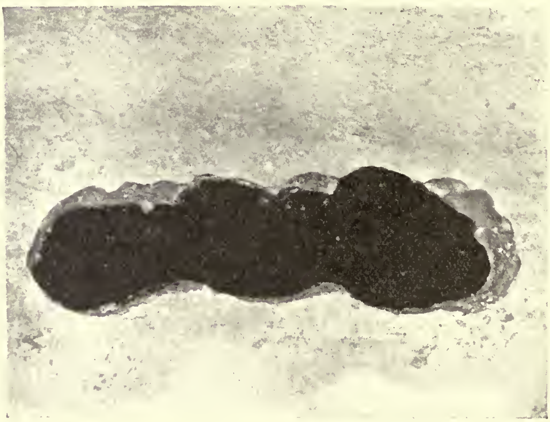


FIG. 673.—18-inch Main Fused by Electric Cables at Bradford.

The return is at earth potential. When the insulating sheath is damaged, and moisture obtains access to the paper insulation, the insulation is destroyed, and an arc set up between the outgoing cable of high potential and the return at earth potential. This develops great heat, and burns everything in the neighbourhood of the arc. In addition to this, there may be a second arc set up between the outgoing cable and any pipe in the vicinity, which becomes a second return for the time being. Any gas main which is unfortunate enough to be placed near such a faulty cable may be damaged by (*a*) the effects of the heat generated by the arc, of which the two wires are the terminals, or (*b*) by an arc of which one terminal is the gas main itself.

The injury to the wall of the pipe will, of course, vary in extent according to the strength of the current, the time over which the arc is continued, and the material of which the pipe is composed.

The damage done is, therefore, immediate, is strongly marked, is readily traced to its source, and cannot possibly be mistaken for

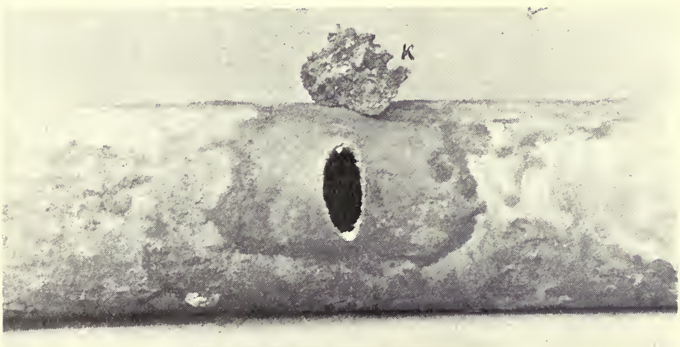


Fig. 674.—14-inch Main Fused by Tramway Cables in Leeds.

injury caused in any other way whatever. It may be caused either by alternating or direct electric currents.

Figs. 674 and 675 show the latest example of this kind of injury coming under the notice of the author. A 14-inch main laid in one of the principal thoroughfares of Leeds was crossed at right angles by an electric light cable. Both were under a concreted roadway paved with wood blocks. A bad escape of gas was reported by the Tramway Department, and on opening up the roadway the pipe was found in the condition shown in Fig. 674. The mass of metal fused out of the pipe is shown at K. Fig. 675 shows on a larger scale the fused ends of the 5-inch wrought-iron pipe in which the cable was laid, and which was completely melted away for a distance of about 18 inches where it crossed the gas main. The experience of breaking through a concreted and paved roadway with such an escape of gas going on immediately below is one which the author is not at all desirous of having repeated.

The only way of preventing this kind of injury, assuming, of course, that the cable is perfectly insulated in the first instance, is to keep the electric cables and gas mains at such distances apart as is necessary to prevent the formation of an arc between them.

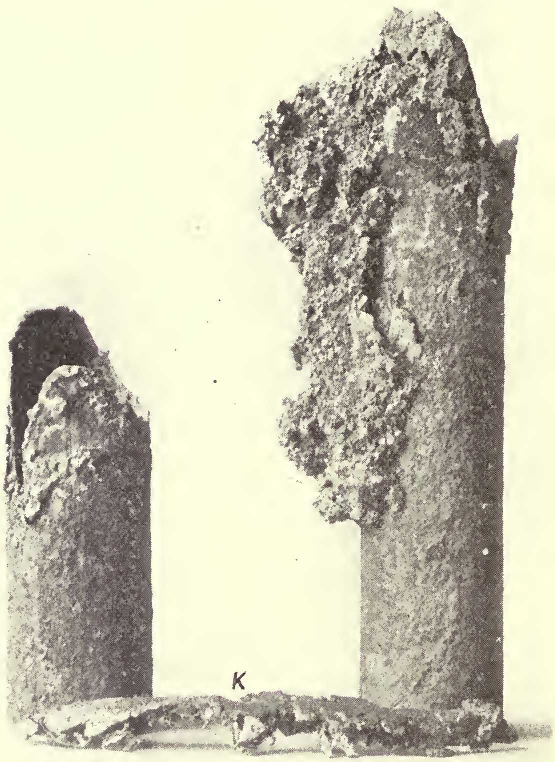


FIG. 675.—Fused portions of 2-inch Wrought-Iron Tubing, to larger scale, in which the Tram Cable was laid.

In the crowded condition of the subsoil of our large towns, however, this has, unfortunately for our distributing systems, become a matter of extreme difficulty, and sometimes an absolute impossibility.

There are, however, usually some redeeming features to be found even in the worst kind of occurrences, and this is no exception to the general rule. It is certainly fortunate that no fault in an electric cable of such dimensions as to cause fusion can possibly take place without the fact becoming immediately known at headquarters. It constitutes a very serious interference with the proper working of the system. In other words, the cable affected cannot perform its ordinary duty with leakage of such a serious character going on, and the generating station is at once made aware of the unusual conditions. Self-interest is, therefore, at once brought to bear to locate and remedy the fault. This cannot, of course, be done without discovery at the same time of the fact that fusion of the gas main has taken place. The gas undertaking, is, therefore, not left in the position of having to discover, in the ordinary way, by the smell of the leaking gas or, more sharply still, by some resultant explosion, causing considerable damage to property and injury to life, the fact of fusion having taken place, but is at once notified by the electric department, and is consequently enabled to take immediate steps to prevent serious accident ensuing.

Working of tramways.—With regard to the second kind of possible damage to a gas distributing system from stray electric currents, the question loses the features of simplicity and directness, and becomes, by comparison, somewhat involved and complicated. To form any idea as to how this danger arises, a rudimentary acquaintance with the general working of an overhead trolley tramway system is necessary.

The electric current for such a system is, of course, generated at the central power station or stations. From thence it is carried to the overhead trolley wire, and passes down the trolley pole to the electric motor on the car, and then back again to the generating station by means of the rails, as shown by the arrows in Fig. 676, the rails being supplemented in large undertakings by a system of return feeders.

If, then, the rails were perfectly insulated, assuming that were possible, as the outgoing wires are, the whole of the current sent out would return to the generating station again by means of the rails. But as they are not, it is found in actual practice that part of the current leaves the rails and returns either as earth currents or by means of some metallic conductor, such as gas or water mains which may be embedded in the subsoil in the vicinity. As a matter of fact, the current generally divides itself between the three, if no additional facilities of a special character are provided for these return currents.

For the purpose of keeping this leakage within the narrowest possible limits, tramway engineers take special precautions to make and maintain extremely good electric connection between the rails themselves, so as to reduce as far as possible the resistance of the rail system to the flow of the return current, and also provide auxiliary paths for the return current, apart from the rails.

This is done in three ways, namely :—

(*a*) By bonding the rails together with fish plates having the same sectional area as the rails themselves, or, better still, by welding the successive rails together by means of the "Thermit" joint, so as to approximate as closely as possible to the ideal of a continuous rail.

(*b*) By supplementing these with suitable copper conductors, connecting not only successive rails, but also, at intervals, the parallel tracks.

(*c*) Where *a* and *b* are insufficient to keep down the difference of potential to the extent desired, return feeders consisting of insulated cables are used to draw off the current from the rails and conduct it directly back to the generating station.

(*d*) Lastly, in conjunction with these, a negative booster may be employed at one or several suitable points, to suck back the current to the power house, in much the same way as a gas-works exhauster draws the gas away from the retorts.

The current straying from the tramway rails will, of course, always divide itself proportionately to the amount of resistance in the various paths open to it on its return journey. Having found a path of low resistance in some contiguous gas or water main, a great portion of the stray current may proceed by this route, as shown in Fig. 677, until one of two things happens. If the joints along the line of pipe are very good, and offer but a comparatively slight resistance to the flow of the current, the latter will travel to the neighbourhood of the generating station, where it will either pass back to its legitimate conductor, the tram rail, and thence to the station, or it may pass away through some pocket of the subsoil of relatively good conductivity, back to the earth plate and to the negative pole of the generator.

If, on the other hand, in a line of main which otherwise proves a fairly good conductor, there happens to be a few joints which, by reason of the electrically imperfect contact of the jointing materials, offers a comparatively high resistance to the current, and assuming that such a joint or joints happen to coincide with a pocket of moist earth, particularly if of a saline character, the current may leave the main at this point to resume its return journey by its original route—the tram rails—as per sketch (Fig. 678).

Or, as another alternative, if the earth conditions favoured that course, part of the current might pass round the joint, through the earth, entering the main again on the other side of the joint, to resume its homeward journey once more by means of the main it had temporarily left. This process has come to be known as "jumping the joint," and is shown diagrammatically by the arrows in Fig. 679. Professor Ayrton found that as high a proportion as one-third of the current travelling by the main may jump the joint in this way.

In view of these various alternatives, it is obviously possible for the current to pass and repass between rail and main several times in the course of the return journey along an extended tramway route, should the conditions be favourable to that course.

Were it possible for the electric current to enter and leave a gas

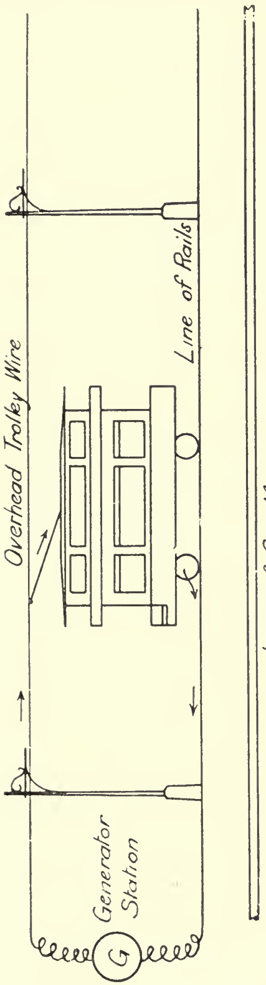


Fig. 676.—Sketch Showing Direction of Electric Current Through Car.

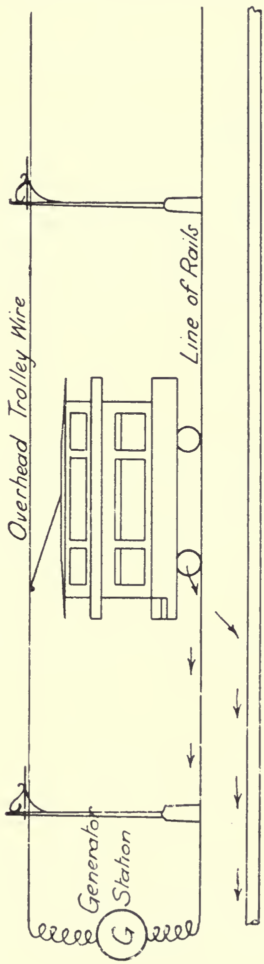


Fig 677.—Sketch showing Return Current dividing between Rail and Mains.

main in a perfectly innocent and innocuous manner, there would, as far as the author is aware, be no very great objection on the part of gas undertakings to its selecting this course. In its entrance to and its travel along the line of main the current is perfectly harmless. It is in leaving the main that injury is caused.

Some illustrations.—Exactly what occurs will be readily understood by reference to a very familiar industrial operation. In the electro-plating of articles, the latter are attached to the negative terminal of a battery, termed the cathode, and a bar of silver to the

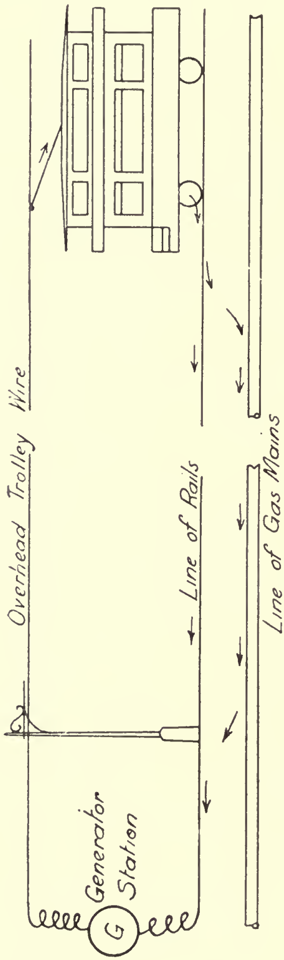


FIG. 678.—Sketch showing Return Current leaving Mains again to Rejoin Rail.

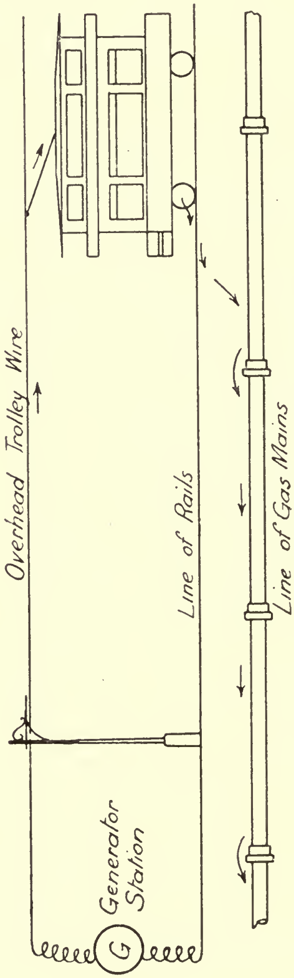


FIG. 679.—Sketch showing Return Current Jumping Joints.

positive terminal, called the anode, and both are immersed in a bath of a suitable character. When a current is caused to pass through the circuit, part of the silver is removed from the bar at the positive terminal and deposited upon the article to be silvered at the other terminal. Substitute, in imagination, the gas main for the silver bar at the positive terminal and the tram rail or earth-plate for the negative terminal, and a portion of moist, saline or sewage contaminated earth for the bath, and the conditions are reproduced with sufficient accuracy for the purpose of illustration. The current leaving the gas main takes a portion of iron from the body of the pipe, forming ferrous salts. As this operation proceeds the pitting of the pipe, in consequence of the more or less continuous removal of these

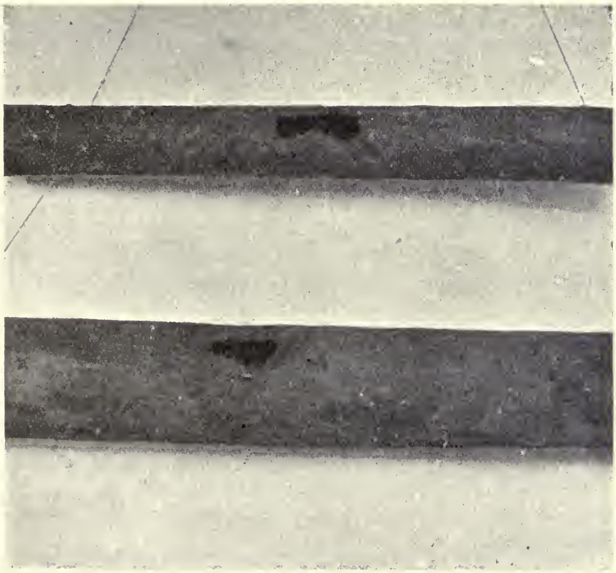


Fig. 680.—Copy of Photograph of ¾-inch and 1 inch Service Pipes eaten through by Electrolytic Action.

small particles of metal, slowly but surely assumes a grave aspect, until, if continued long enough, the wall of the pipe becomes completely eaten through, as shown, in the case of service pipes, in Fig 680.

In his paper on the "Destruction of Gas Pipes by means of Electricity," read before the Gas Section of the Engineering Congress at Glasgow in 1901 [*The Gas World*, 21st September 1901], Dr W. Leybold, of Hamburg, used the following simple illustration of the process of electrolysis of iron. He says:—"The process is easily shown if a current of electricity is passed through a thick glass pipe, closed at both ends by sheet-iron plates, and filled with sand soaked in a solution of chloride of sodium. The sand at the positive pole becomes of a green colour as it sucks up the protoxide of iron which is formed. By degrees a yellow rust is produced, through the admission of air. The same effect is produced by a solution of chloride of ammonia, gypsum, and carbonate of lime, in such organic salts as are always found in the earth, and also of a watery solution of earth."

The quantity of the metal thus removed is, of course, proportional to the current density operating at the affected spot. It has been estimated by Professor Sylvanus P. Thompson that one ampere of current will remove about 15 grains of iron from the rails per hour, or, flowing continuously, is capable of removing about 14 lbs. of iron per annum. American scientists have placed it as high as 20 lbs. per ampere per annum.

In an appendix to the exceedingly interesting and able paper on electric tramways, read before the Institution of Civil Engineers in 1902, by Messrs C. and B. Hopkinson and Talbot, Mr Bertram Hopkinson, B.Sc., states that " the iron is eaten away at the rate of rather over 1 grain per ampere-hour, or about 1.3 millimetres per ampere-hour per square centimetre."

In the case of gas mains the current, of course, always leaves the main upon the exterior of the pipe, and the damage is an external one, but in the event of current travelling by a water main " jumping the joint " the opposite of this takes place. Water is a good electrical conductor, and it is found that the current will leave one side of the joint, pass through the water contained in the pipe, and again resume its journey by the metal of the pipe upon the other side of the joint. The pitting in such a case would obviously take place upon the internal surface of the pipe, and would not be discovered until the pipe was eaten away sufficiently to allow the water to leak through. It has been found that a difference of potential of $\frac{1}{6}$th volt is sufficient to cause this jumping.

It is obvious that those pipes lying within a short distance of the power station or the locality of the return feeders, where the latter are used, and where the difference of potential between main and rail is the greatest and the direction of flow is from main to rail, are in the position of most danger. The areas where these conditions obtain have been termed the danger zones. It must not, however, be assumed that those mains which are negative to the tram rails are therefore immune. It is quite possible that they, in turn, may be brought near some other metallic underground structures to which they are electrically positive and current pass from the main to these. In that case electrolytic corrosion would be set up at the point or over the area from which the current left the gas main, just as in the danger zone area.

The injury which may be wrought upon a gas distributory system in the danger zone is not by any means covered by the pitting and removal of iron from the wall of the affected pipe. It has been pointed out by Professor Dewar that " there is a secondary deleterious effect upon the life of the pipe in the increased natural corrosion caused by the current making the surface of the iron more easily attackable. There was a double attack on a pipe when it was electrolytically affected." There is (*a*) the direct electrolytic action, which, in turn, leaves (*b*) the pipe more susceptible to ordinary corrosion.

Endeavours made to minimize evil effects.——Endeavours have from time to time been made to minimize these effects in two ways. First of all, an attempt to cloud the issue has proceeded along the line of multiplying out the amount of loss of metal over the exterior areas of considerable lengths of mains, and showing that the amount of metal lost would, after all, be infinitesimal in comparison with the weight and the thickness of the pipes. But such an argument is founded upon the entirely fallacious idea that if a current is flowing through a line of pipes it will discharge itself equally from the whole area of the pipes it is travelling by. That is precisely the opposite of what really takes place. The condition of the outer shell of the metal of a line of pipe varies very considerably in different places. Some parts are corroded, others comparatively clean. The soil surrounding the pipes also varies very greatly from place to place, in the degree of its conductivity. The difference of potential will be much greater at one point than another. The current will always take the line of least resistance, and this means, in actual practice, that the current will be discharged from a comparatively restricted area, if not from a single point. The difference in the damage wrought between discharge from the whole exterior surface of a line of main and from a very restricted area is obviously enormous.

In an appendix to the paper previously mentioned, Mr B. Hopkinson, after referring to the fact that if the currents are evenly distributed over the surface of the pipes their density will be too small to cause appreciable corrosion, goes on to say :—" It is asserted that, in consequence, corrosion can only occur if the stray currents are concentrated on small areas of pipe. Now, concentration can occur in two ways. There may be a highly conductive stratum of soil, which, so to speak, picks up the stray current from the surrounding earth and focusses, say, 0.5 ampere on a square metre of pipe surface. But the current will not generally be uniform over that square metre. Microscopic examination of a polished steel anode bedded in clay, which was allowed to dry slowly during the passage of a small electrolysing current, showed that, roughly, one-half of the surface was unattacked, doubtless owing to bad electrical contact with the clay, which had shrunk away from the plates. Over the other half the current density was, of course, double the average for the whole plate ; and this half was accordingly pitted to double the depth inferred from consideration of the average current."

The second line of argument which has been taken by those who have desired to minimize the possible ill effects of stray currents upon gas distributory systems has been to urge that the quantity of iron removed by the action of small currents of low density is not, in practice, anything like so great as might be anticipated by a consideration of the usual laws of equivalents governing such cases. Against that view we find Mr Hopkinson stating, in the appendix already referred to, that his "experiments have convinced him that, with current densities of 0.4 ampere per square metre and upwards, the loss of weight of an iron electrode in a weak solution of common salt is the same as though the equivalent of ferrous salts were formed, certainly within 1 per cent. This is equally the case with electrodes bedded in moist clay. There would be nothing subversive of accepted

FIG. 681.—Plaster Cast of Pitting on 8-inch Main.

theories if the contrary were the fact; but the author does not believe it to be so."

A single ounce of fact, however, is worth pounds of theory in such a case. The casts taken of pitting on mains now working (shown in Figs. 681 and 683) will be sufficient to convince open minds that the action is a very serious one.

Board of Trade Regulations.—In consequence of an agitation upon this subject in the early 'nineties, a Joint Committee of both Houses of Parliament, after hearing a considerable amount of such evidence as was then available, requested the Board of Trade to formulate a series of regulations under which electric tramways might be permitted to work. These, of course, were framed for the purpose of affording, amongst other things, a full and sufficient protection to the various gas and water authorities whose interest might otherwise be prejudicially affected. The principal points of interest to the gas

FIG. 682.—Negative Wax Cast of Electrolytic Pitting on 14-inch Cast-Iron Main.

FIG. 683.—Positive Plaster Cast of Electrolytic Pitting on 14-inch Cast-Iron Main.

engineering profession are naturally those governing the arrangements for the return currents. These have been extracted from the general body of regulations, and are as follows :—

Regulations made by the Board of Trade under the provisions of Special Tramways Acts or Light Railway Orders authorizing lines on public roads ; for regulating the use of electrical power ; for preventing fusion or injurious electrolytic action of or on gas or water pipes, or other metallic pipes, structures, or substances ; and for minimizing, as far as is reasonably practicable, injurious interference with the electric wires, lines, and apparatus of parties other than the company, and the currents therein, whether such lines do or do not use the earth as a return.

Definitions.

The expression " pipe " means any gas or water pipe or other metallic pipe, structure, or substance.

The expression " current " means an electric current exceeding one-thousandth part of one ampere.

Regulations.

5. (*a*) When any part of a return is uninsulated it shall be connected with the negative terminal of the generator, and in such case the negative terminal of the generator shall also be directly connected through the current indicator hereinafter mentioned to two separate earth connections which shall be placed not less than 20 yards apart.

(*b*) The earth connections referred to in this regulation shall be constructed, laid, and maintained so as to secure electrical contact with the general mass of earth, and so that an electromotive force not exceeding four volts shall suffice to produce a current of at least two amperes from one earth connection to the other through the earth, and a test shall be made at least once in every month to ascertain whether this requirement is complied with.

(*c*) Provided that in place of such two earth connections the company may make one connection to a main for water supply of not less than 3 inches internal diameter, with the consent of the owner thereof and of the person supplying the water, and provided that where, from the nature of the soil or for other reasons, the company can show to the satisfaction of an inspecting officer of the Board of Trade that the earth connections herein specified cannot be constructed and maintained without undue expense the provisions of this regulation shall not apply.

(*d*) No portion of either earth connection shall be placed within 6 feet of any pipe except a main for water supply of not less than 3 inches internal diameter which is metallically connected to the earth connections with the consents hereinbefore specified.

(*e*) When the generator is at a considerable distance from the tramway the uninsulated return shall be connected to the negative terminal of the generator by means of one or more insulated return conductors, and the generator shall have no other connection with earth ; and in such case the end of each insulated return connected with the uninsulated return shall be connected also through a current indicator to two separate earth connections, or, with the necessary consents, to a main for water supply, or, with the like consents, to both in the manner prescribed in this regulation.

(*f*) If the current indicator cannot conveniently be placed at the connection of the uninsulated return with the insulated return, this instrument may consist of an indicator at the generating station connected by insulated wires to the terminals of a resistance interposed between the return and the earth connection or connections.

Fig. 684.—Electrolytic Pitting on 4-inch Cast-Iron Main.

The said resistance shall be such that the maximum current laid down in Regulation 6 (*i*) shall produce a difference of potential not exceeding 1 volt between the terminals. The indicator shall be so constructed as to indicate correctly the current passing through the resistance when connected to the terminals by the insulated wire before mentioned.

6. When the return is partly or entirely uninsulated the company shall in the construction and maintenance of the tramway (*a*) so separate the uninsulated return from the general mass of earth, and from any pipe in the vicinity; (*b*) so connect together the several lengths of the rails; (*c*) adopt such means for reducing the difference produced by the current between the potential of the uninsulated return at any one point and the potential of the uninsulated return at any other point; and (*d*) so maintain the efficiency of the earth connections specified in the precedi g regulations as to fulfil the following conditions, viz :—

(*i*) That the current passing from the earth connections through the indicator to the generator or through the resistance to the insulated

FIG. 685.—Electrolytic Pitting on 3-inch Cast-Iron Main.

return shall not at any time exceed either two amperes per mile of single tramway line or 5 per cent. of the total current output of the station.

(*ii*) That if at any time and at any place a test be made by connecting a galvanometer or other current indicator to the uninsulated return and to any pipe in the vicinity, it shall always be possible to reverse the direction of any current indicated by interposing a battery of three Leclanchè cells connected in series if the direction of the current is from the return to the pipe, or by interposing one Leclanchè cell if the direction of the current is from the pipe to the return.

In order to provide a continuous indication that the condition (*i*) is complied with the company shall place in a conspicuous position a suitable, properly connected, and correctly marked current indicator, and shall keep it connected during the whole time that the line is charged.

The owner of any such pipe may require the company to permit him, at reasonable times and intervals, to ascertain by test that the conditions specified in (*ii*) are complied with as regards his pipe.

(7) When the return is partly or entirely uninsulated a continuous record shall be kept by the company of the difference of potential during the working of the tramway between points on the uninsulated return. If at any time such difference of potential between any two points exceeds the limit of 7 volts, the company shall take immediate steps to reduce it below that limit.

Are the regulations stringent enough ?—The question as to whether these regulations are efficacious in affording the protection they were intended to ensure is one upon which very considerable doubt has been expressed, not only by gas engineers, but even amongst electricians of the highest eminence and authority in their profession. Several very stiff battles have been fought out in the Parliamentary Committee rooms upon this subject. It should be remembered that in 1893, when these regulations were first formulated, there were only some five or six electric tramways running in this country, and consequently there was little experience to draw upon. At the present time there are hundreds of such at work. As, therefore, experience of the practical working of these systems has been extended, and as, on the other hand, evidence of positive injury to gas and water pipes has slowly but surely accumulated, it is beginning to be generally felt that the regulations must be made much more stringent, if they are to be effective for the purpose for which they were designed.

Take the 7-volt regulation, for instance (Regulation 7). There is no limitation of length through which the maximum fall of potential allowed shall operate. It is not only conceivable but extremely probable that a fall of potential which might be perfectly harmless if taken over a tramway route three or four miles in length would bear an absolutely different character if taking place over a route half a mile in length. This regulation should evidently be much more strictly defined.

The other regulations are equally unsatisfactory from the point of view of a gas undertaking. The indicators attached to the earth-plates at the negative pole of the generator are altogether illusory if regarded as registering the whole amount of leakage from the rails. They may indicate with great exactitude the current returning by the earth-plate, but the two things are not identical by any means. It has already been pointed out that under favourable conditions it is possible for current to pass and repass between main and rail several times on its journey, and finish the concluding portion of its travel by means of the rail after all. In such a case none of the current which had thus strayed would be registered by the indicator.

Again, with regard to the 1.5-volt regulation, the idea that a limitation of difference of potential to this amount as a maximum confers immunity upon gas mains has been strongly challenged even by eminent electricians. It has been found that electrolysis of a serious character may and does take place with a much less fall of potential. In communicating the results of his experiments, Mr B. Hopkinson states that the 1.5-volt rule "was perhaps originally based upon an idea still prevalent, that serious electrolysis cannot take place if the potential between pipes and rails is less than that required to decompose water—about 2 volts. The author finds, as others have very likely found before, that this idea is erroneous.

Steel plates were bedded in moist clay containing a fractional percentage of salt, and a pressure of 0.22 volt was maintained between them. The resulting current density was about 0.4 ampere per square metre, and the anode lost weight to a corresponding extent. With a larger cathode the same current density on the anode could be maintained with even a lower potential. On tramways the rails are the cathode, and the current density over their great surface is always less than 0.4 ampere per square metre. However, it may be asserted that dangerous corrosion can always take place with an electrolytic fall of potential between pipe and rail of 0.25 volt. Consequently the Board of Trade rules safeguard pipes only in so far, as by reason of the resistance of the soil, they limit the current density."

Fortunately, or unfortunately, perhaps, would be better, we are not now limited to theoretical calculation. The question has entered the stage of d monstration. The author has carried out some hundreds of tests on the distributory system of the undertaking with which he is connected. In not a single instance were the Board of Trade regulations being transgressed, yet instances of undoubted electrolytic damage have been found. (See Figs. 652 to 657). All these have occurred within limits of working which were supposed to secure absolute immunity from damage.

In the report of the German Electrolysis Commission, published in 1904, it is stated that at Strassburg, with a difference of potential from main to rail varying from 0.2 to 1 volt, the water company have experienced considerable injury to their mains from electrolysis.

Assuming, in view of the considerations which have just been urged, that whilst the Board of Trade rules and regulations may be successful in largely reducing the amount of stray currents which might otherwise travel by gas mains, they do not by any means confer immunity from serious injury from the quantities of current which still may choose this route for their return, the question arises: Can any maximum be fixed which would afford the requisite safety to these underground structures?

This is pre-eminently one of those points upon the elucidation of which much work of an experimental character will have to be undertaken, and the practical effect of the working of tramways upon the distributory systems of gas undertakings keenly scrutinized and carefully tabulated before anything like a definite and final opinion can be pronounced. The materials for such are certainly not forthcoming at present. It has been said, with a great deal of truth, that the difference of potential should be kept at the very lowest possible point without introducing an abnormal or prohibitory expense in the construction of the tramway system. But obviously that of itself does not take us very far. It is self-evident that an expenditure of £200 or £300 upon return feeders, or a moderate multiple of that sum for the duplication of them where necessary, is a small price to pay for the absolute protection of the gas and water mains contained in the roadways of our cities ; and by the employment of these there appears to be little difficulty in reducing the maximum difference of potential, where the main is positive to the rail, to something like one-third of the maximum allowed by the Board of Trade regulations.

It is certainly instructive to find in this connection that, however lax municipal administration may be in many American cities in this matter, there is at least one which enforces a considerably higher standard than our own Board of Trade.

Atlanta city's regulations.—Three of the rules enforced by the City Council of Atlanta, N.J., upon their tramway company are as follows :—The company shall so confine its current to the metallic return circuit, which it shall provide, as to comply with the following conditions :

(*i*) The maximum difference in potential between any part of the metallic return circuit and any water or service pipe, or other metal conductor not intended as a part of such return circuit, shall not at any time exceed ¼ volt.

(ii) The difference in potential between any two points upon the metallic return circuit within a distance of 200 feet from each other shall not at any time exceed ¼ volt.

(iii) The current passing along any water or service pipes or any other metallic conductor not intended as a part of said return circuit shall not at any given time and point exceed one ampere.

German Electrolysis Commission's rule.—The rules compiled by the German Electrolysis Commission include the following as to the difference of potential to be allowed between main and rail, from which it will be seen that only under rare circumstances should that difference exceed 1 volt, and that the maximum permissible might be fixed at much under that quantity. The rule reads as follows :—

(3) The difference of potential in the rails is not to exceed a certain prescribed amount. The precise maximum figure for each place must be settled according to local conditions, and will be governed by the nature of the soil, by the difference between the highest and lowest potential found in the mains, by the resistance between the points where highest and lowest potential are observed, and by the position of the mains in relation to the rails. In special cases the maximum permissible figure may be varied in different sections of a tramway system. Provisionally, this maximum may be taken as 1 volt ; the figure being the mean of readings extending over 10 minutes at time of full load.

Maximum permissible current density.—As far as the author is aware, the only English electrician of eminence who, while admitting that the regulations under which tramways are now working do not, under all conditions, render the gas mains immune from electrolytic attack, has at the same time attempted to formulate any rule, the observance of which would reduce such danger to an absolutely negligible quantity, is Mr B. Hopkinson, in Appendix II. to the paper which has several times previously been referred to. After pointing out that the best way of protecting pipes from electrolysis is to limit the current density at which any stray currents shall leave them, Mr Hopkinson goes on to say :—" It is necessary to begin by fixing a maximum permissible current density. A fair limit is probably 0.5 ampere per square metre." Assuming that the ordinary law of electro-chemical equivalents holds good in the case of electrolysis of gas pipes, " such a current, if continued throughout a tramway year of 7000 hours, would corrode a pipe to a depth of 0.5 millimetre. If this depth be fixed as a maximum, the mean will, of course, be a good deal less ; and an ordinary pipe 5 millimetres thick may be expected to last 15 or 20 years at least." But in the absence of any reliable data as to what extent differences in the conductivity in the earth surrounding the pipes may induce a concentration of the current leaving the pipe to a small area, such a rule " can be dealt with only by the use of a factor of safety. Assuming that the maximum current density in any area, such as a square metre, is not more than five times the average, the current density rule must be so far amended as to read that the average current density over such an area must not exceed 0.1 ampere per square metre."

Mr Hopkinson's experiment on a model track.—In attempting to supply an answer to the question whether, with a difference of potential of 1.5 volts, the current density would be sufficient to corrode the pipe, Mr Hopkinson gives particulars of a most interesting experiment he carried out with a model installation. " The author has experimented on a piece of model track consisting of four $\frac{3}{4}$-inch T-bars bedded in concrete, and resting on sand moistened with a one per cent. solution of common salt, the whole being on 1-tenth scale. It was found that the resistance between the rails and the pipe, 0.4-inch in diameter, laid parallel with them and just below the centre of the track, would be about $37\frac{1}{2}$ ohms per metre. The resistance in a full-sized track made with the same concrete and soil would be the same. Thus a difference of potential of 1.5 volts would cause a current of, roughly, 0.04 ampere per metre from a 4-inch pipe to the rail, which corresponds with a current density at the pipe's surface of about 0.125 ampere per square metre. This is just outside the danger limit ; but in actual practice it is considerably reduced by the fact that much current goes past the pipe, thereby raising the apparent resistance between pipe and rail. Some soils, such as clay, have a higher conductivity than the sand used in the model ; but, on the other hand the resistance of the concrete in the model is probably less than in an actual track. With a pipe more than 4 inches in diameter the resistance between pipe and rail is slightly less, but the surface of the pipe is much greater, consequently the current density is much less ; probably in any actual instance it is not far from inversely proportional to the size of the pipe. This indicates a possible substantial improvement in the 1.5 volt rule, viz., to make the maximum permissible potential between pipe and rail depend upon the size of pipe—say, by allowing 0.2 volt per square inch of the diameter of pipe. The rule would then be usually a sufficient protection, except in cases where the distribution of soil is such as to focus currents on small areas. The 1.5 volt rule as it now stands seems barely stringent enough to protect small pipes laid in clay or other highly conductive soil." It follows, therefore, if 0.2 volt per inch of diameter of the pipe should be considered the maximum difference of potential allowable, that gas pipes of 7 inches diameter and under which lie adjacent to any tramway system which is worked at near the limit allowed by the present Board of Trade rules may be subjected to dangerous corrosion.

"In the foregoing experiments the pipe was parallel with the track, as will usually be the case. It will sometimes happen, however, that a pipe will cross the rails at right angles and close beneath them; and it seems probable that under such conditions the current density where the pipe crosses may attain a dangerous value." The seriousness of the latter statement may be gauged at once by the reflection that within the danger zone of every electric tramway system there must be scores at least of services crossing the rails at right angles and at very short distances below the bed of the track, and which are, therefore, in very convenient positions for discharging any stray currents which may be travelling in the distributing system, back again to the rails, and in which it is admitted that "the current density may attain a dangerous value."

Mr Trotter's experiments.—It has generally been considered that there is no liability to electrolysis from the action of alternating current. But in the course of an address[1] in which some very interesting experiments are published, Mr A. P. Trotter, of the Board of Trade, states:—"He had felt that it was not likely alternating currents would be free from corrosion; and, taking two pieces of lead pipe, one of which was on the table, he had buried them in moist earth in a box, and had subjected them for a month to an alternating current, from Deptford, of 1 ampere. The two pipes had faced each other, about 4 inches apart. A thick white crust of what he thought was carbonate of lead had formed. It was an interesting fact that the patch was definitely limited, showing that at less than a certain current density, or difference of potential, no corrosion took place. He had used lead because, the electro-chemical equivalent of lead being higher, the product of the action was of larger amount than with iron; and further, it was an insoluble white crust which could easily be seen. Recently, Mr R. Mordey, in reply to the discussion upon his paper, had suggested that the experiments made by G. Mengarini showed that alternating currents at a less density than

[1] *Transactions of the Institution of Civil Engineers*, 1902.

4 amperes per square inch would not cause corrosion by electrolytic action. He had measured the area of the pipe affected, and had found it to be about 40 square inches; so that about $\frac{1}{40}$ ampere per square inch had produced the effect shown. After Mr Mordey's remarks, he had thought it would be well to make some experiments to ascertain whether there was any critical current density below which no corrosion might be found. He had already tried many experiments on lead wire in the Board of Trade laboratory with continuous current, in attempting to find such a point; but he had not found it. In his experiments he had not used clay or gravel, but simply ordinary damp soil. Chemists, he believed, gave the name 'humus' to the active principle of soil which was supposed to attack the lead. He had started the experiment with alternating current at 83 periods per second, and with the current density at which he had left off in the previous experiment, namely, $\frac{1}{40}$ ampere per square inch. Taking four lead plates, each 4 inches square, he had painted them with varnish, with the exception of square spaces in the middle. [See table below.]

"By the end of a month a thick white incrustation of lead had formed on Nos. 1 and 2 and a thinner coating on the larger plates, the corrosion being apparently proportional to the current density. With continuous current the corrosion would probably have been about double." Such experiments as these appear to prove conclusively that electrolysis may take place with alternating currents, but that the current density necessary to produce that action is much greater than in the case of direct current. Another point of interest is that, in the case of the lead tubes, the discharge was not spread equally over the pipe, but was more or less concentrated at a well defined patch, thus following the practice observed in connection with direct current electrolysis.

Plate No.	Unvarnished Portions of Surface.		Current Density.	
	Front.	Back.	Ampere per Square Inch.	Amperes per Square Metre.
1	$\frac{1}{2}$-in. × $\frac{1}{2}$-in.	1-in. × 1-in.	Front $\frac{1}{40}$	9.7
			Back $\frac{1}{160}$	38.7
2	2-ins. × 2-ins.	2-ins. × 2-ins.	$\frac{1}{640}$	2.42
3	3 ,, × 3 ,,	4 ,, × 3 ,,	$\frac{1}{1440}$	1.075
4	4 ,, × 4 ,,	4 ,, × 4 ,,	$\frac{1}{2560}$	0.605

Precautions to be taken.—The minds of gas engineers have naturally been much exercised to discover, if possible, what precautions should be adopted in order to protect their distributory systems from these insidious attacks by stray currents. Unfortunately we are almost helpless in the matter ; but there are a few steps which may be taken with the object of ascertaining what is actually going on.

The first of these is obviously to obtain a plan of the tramway system, upon which not only the routes taken but position of generating station and each of the return feeders should be marked.

A thorough and systematic series of tests should then be undertaken for differences of potential as between mains and rails, and the points where such differences exceed, say, 0.25 volt, main to rail, should be carefully plotted upon the plan. In this way the danger

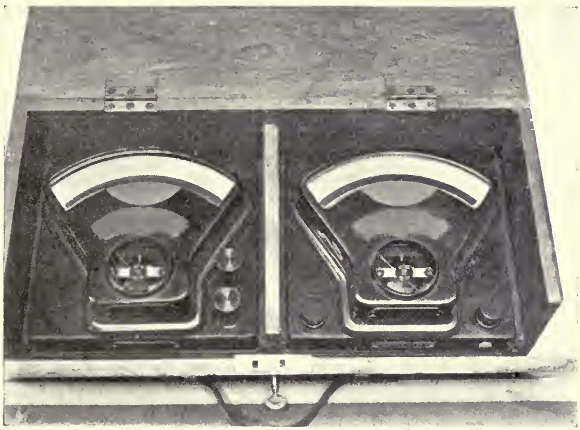


Fig. 686.—Weston's Direct-Reading Set of Portable Volt-Meter and Am-meter in Box.

zone or zones will be localized, and the degrees of danger due to the character of the subsoil will be fully ascertained. Incidentally, it will also be discovered how far the tramway is being worked within the maximum limit allowed by the Board of Trade.

How to make tests.—These tests may be very easily made. Perhaps the best instrument for the purpose is a Weston's portable direct-reading volt-meter, with index-reading up to 10 volts by gradations of $\frac{1}{10}$ volt. The terminals of this volt-meter (shown in Fig. 686), are connected up to the main and rail, respectively, by insulated wire, and readings noted. Care must be taken to ensure absolutely good electrical contact between wire and main and wire and rail. The connection should not be made to lamp service, valve, syphon, or other similar portion of the distributing system ; all such are liable, from one cause or another, to give very misleading results through bad contact. It is much better to dig down to the main itself, and get a direct connection with it. The best and most reliable plan is to drill a small hole in the main, into the newly cut and clean threads of which the cleaned threads of a short piece of stopped tube may be screwed, to the other end of which the connecting wire is soldered. The tram rail must be well cleaned where contact is desired, as also the wire terminals at the volt-meter. Indications of the current density at each of the places tested may be secured by the use of a Weston's direct-reading am-meter, shown in Fig. 686. These should always be taken, and may vary very considerably for the same difference of potential. The difference of potential may be low in a large pipe while the quantity of current passing may be comparatively high. The author carries his volt-meter and am-meter side by side in a single box, with a lifting lid and dropping flap front, the partition between the two being partially removed to allow of the connections being easily made. In making a test, it is only necessary to remove the terminal wires from the volt-meter to the am-meter, or *vice versa*, to obtain both sets of readings.

When other large pipes lie in the proximity of the gas main under examination, tests for differences of potential should always be made between these and the gas mains. The latter may be negative to the rail, but positive to other mains in the vicinity. The importance of this lies in the fact that current received from the rail may be passed on to the neighbouring main, and a possible danger zone go undetected.

If we wish to measure absolutely the quantity of current that is carried by a main, a rather different method must be adopted. This is the test applied to one of the large mains in Leeds in 1903, and is also fully described by Professor Ganz in his paper read before the American Gas Institute in 1907. By means of a very delicate milli-volt-meter, the difference of potential between two points on the same main, say some 100 to 200 feet apart, is taken. The drop of potential divided by the resistance of the pipe in ohms gives the current passing, in amperes. The resistances are given in a paper by Mr Maury, on "Surveys for Electrolysis and their Results," read before the American Waterworks Association in 1903, as 0.00144 ohm per pound-foot for cast-iron and 0.000181 ohm per pound-foot for wrought-iron. The resistance of pipe per foot is found by dividing the foregoing figures by the weight of pipe per foot. A table of these resistances worked out is given in the lecture by Professor Ganz.

Inasmuch, however, as these resistances are for continuous and homogeneous lengths of pipes, and such a length as has been suggested must contain many joints, allowance has to be made for the resistance offered by these. In the case of a main newly laid, where all the joints are tightly caulked, it would be necessary to test only a single joint, as the resistance of each would be approximately equal. But in an old main, the resistances of the joints vary considerably. A series of tests carried out by the author some years ago showed that there was a great difference between joints apparently equally tight. These joint resistances may be many hundred times as great as that of an equal length of plain pipe. It would obviously be a costly and inconvenient business to test all these joints separately; and, consequently, it is better to measure the difference of potential between two points upon the same pipe as far apart as possible. This is a much more delicate business, but one which completely eliminates the factor of joint resistance.

Results of tests.—By the time our survey has been completed and posted upon the maps, we shall have obtained three items of information, without which further progress is impossible. We shall know whether, and to what extent, the tramway is being worked within the Board of Trade regulations; we shall have ascertained the area within which current may leave the mains to return to the generating station; we shall also know the points of greatest danger within the danger zone, and, consequently, the area within which

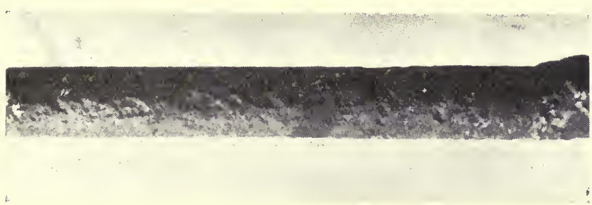


Fig. 687.—2-inch Steam Tubing used in Experiment.

most careful watch should be maintained for any evidence of electrolytic damage. Now, assume for a moment that this careful scrutiny of the pipes—as, from time to time, repairs are carried out or pipes are uncovered in the course of other excavations—reveals distinct evidence of electrolytic damage. We shall, of course, be met by our electrical friends with the denial that the damage done is due to the suggested cause, and the assertion that it is owing to the ordinary corrosion which is continually going on, quite independently of tramway working. The question then arises: Are there any clear and indubitable signs by which we may differentiate between electrolytic and ordinary corrosion? It is, of course, impossible to label a current; but the author thinks that, both directly and indirectly, we may be able to distinguish between the two.

First of all, what are the signs by which electrolysis of our pipes may be recognized directly? In order to confirm his own observations of suspected pipes, the author carried out a test upon a perfectly sound and good piece of 2-inch steam tube. It was buried in a box containing dry loamy soil, and the latter saturated with distilled water. A current of $4\frac{1}{2}$ amperes, average, was passed through the pipe for 288 hours; at the end of which time the pipe was removed from the box. This is shown in Fig. 687. On examination, it was found that along the pipe the pitting was very general, with some shredding of the fibres of the pipe. There were two principal pit-marks of an irregular oval shape, attaining a maximum depth of ¼ inch. There was the characteristic blue discolouration at first, changing to a brown oxide tint after a short exposure to the air. The shredding was most marked near the end of the pipe, and the pitting was greatest on the side turned to the negative terminal. The direct evidences are, therefore :—(*a*) A bright bluish discolouration, which rapidly turns brown on exposure to the atmosphere. (*b*) Pitting, more or less localized, upon an otherwise sound piece of pipe, developing in time to the complete perforation of the wall of the pipe. (*c*) In the case of wrought-iron tubes, a considerable amount of shredding may accompany the pitting. (*d*) Whereas in ordinary corrosion the worst portion is usually the underside of the pipe, electrolytic corrosion is frequently worst at the upper side. (*e*) In the case of cast-iron pipes, the iron is so reduced that it may be easily cut with a knife. Frequently the form of the pipe is maintained, and the damage can only be ascertained by very careful examination. In one case chemical analysis of the pipe showed no less than 22.3 per cent. of graphite and only 49.7 per cent. of iron ; whereas a good new pipe should contain 92 per cent. of iron and only 3 per cent. of graphitic carbon.

These direct evidences may be very materially supported by others of an indirect character. At a suitable number of points within the area of greatest danger, sheet lead plates, 9 or 10 inches square, may be buried in pairs. One of the two must be attached by wire and soldered joints to a lamp or house service. The second plate should be simply buried in the earth, some 12 or 15 inches distant from the first. In the event of any stray current tending to leave the pipes near one of these points, the wire connection and lead plate form an excellent path to earth, and inasmuch as the same amount of current corrodes lead much more rapidly than iron, in about the proportion of 7 to 2, the effect of electrolysis upon the lead plate will be comparatively well defined. The second plate is buried in the earth to ascertain the degree of corrosion due to the unaided action of the earth and any salts that may be present. If periodical examinations of these reveal traces of increasing corrosion on the connected plate, of which there are no traces on the loose one, it is evident that the corrosion cannot be due to the natural action of the earth, as, if it were, both plates would be equally affected. It can only be due to escaping current, since that is the only factor present in the one case which is absent in the other. Should both be similarly attacked, then it follows that the corrosion is not due to current, for the same reason.

To sum up, if we have at any point a difference of potential in which mains and services are positive to the tram rails, which is accompanied by corrosion conforming to the peculiarities noted above, and the whole of which is supported by the testimony of the lead plates, we shall have a body of evidence that no amount of partisanship can set aside. The special point to which our efforts should be directed is to bring pressure to bear upon the tramway undertakings to keep their rails below earth potential. This may be done by the provision of a sufficient number of return feeders and negative boosters. This provision is, however, not obligatory under the Board of Trade regulations, which really govern the situation. These prescribe the maximum beyond which the undertaking may not go; but no mention is made of any minimum. Now, as many if not most, electric tramway undertakings belong to the local authorities, it is possible, with clearly proved instances of damage in our hands, to bring such pressure to bear in the direction indicated as they would be quite unable to withstand; and any modifications introduced on the lines owned by local authorities would soon be made compulsory for any possible intractable private company. Where both tramways and gas undertaking are owned by the local authority, of course, the matter is much simplified. No authority would tolerate its property in one department being destroyed by the working of a second concern under its own control.

It is interesting to note that at one point in Hamburg where previously the difference of potential had risen as high as 5 volts, the provision of additional return feeders had reduced the difference to a maximum of 0.45 volt. In another case within the knowledge of the author, the provision of return feeders reduced the difference of potential, where at one point it ran originally as high as 1.3 volts, to 0.25 volt.

It has already been pointed out that unless the Board of Trade rules are transgressed a gas undertaking is practically at the mercy of the tramway companies. By that, of course, is meant that they have no power of protecting themselves. Various suggestions have from time to time been made with a view to minimizing possible danger, but each has been discredited after trial.

German Commission's rules.—Two of the rules drafted by the German Commission on Electrolysis deal with precautionary measures which are within the competence of a gas undertaking to carry out, and are as follows:—

(11) *Distance between Rail and Gas or Water Fittings.*—The shortest permissible distance between a tram rail and such gas or water fittings (hydrants, stop-cocks, and the like) as are in metallic contact with the mains and approach or reach the surface of the road is 1 metre. If it is impossible to keep the fitting at such a distance from the rails, it must either be removed altogether, with its accessories, or the electrical connection between it (*e.g.* any surface plate lying in the tramway) or the upper layer of earth and the mains must be broken by means of brickwork, jacketing tubes of earthenware, or other appliances.

(12) *Precautionary Measures.*—For a distance of at least 1 metre on either side of the outermost rail, mains which pass underneath the tram

lines are to be insulated, or they must be run inside jacketing tubes that are in good electrical contact with the mains. Where mains which are liable to exhibit differences of potential that are not negligible in quantity approach or cross one another they should be brought into good electrical contact.

These suggestions are, however, likely to be somewhat costly to carry out, and it should surely be the business of the tramway electrician to reduce his stray currents to the points of harmlessness, in the way which has been previously pointed out, rather than put previous users of the subsoil to such gratuitous expense.

Metallic connections between rail and main.—The sugggestion has also been made that if a good metallic connection is made from main to rail at the point where the difference of potential between them is greatest, and the main is positive to the rail, the current would choose this path, and there would be no electrolytic action set up. There can be no doubt, however, that such a provision would certainly lead to two very undesirable results. First of all, greater quantities of current would be induced to return by the gas mains, and secondly, the evil previously referred to of the current "jumping the joint" would be proportionately intensified. We are not, however, left to theory or conjecture in this matter. The plan has been tried at Dundee of connecting the water main to the negative bar of the tramway switchboard, but was discontinued, as it was found that, so far from being any protection, the connection actually proved detrimental to the main.

New Jersey experiments.—This plan of bonding has also been tried extensively in connection with the water mains in New Jersey. At six suitable points in the danger zone, bonding strips were attached to rail and main. Notwithstanding this, however, it was found that, except in the immediate vicinity of the connections, the water mains were permanently positive to both rails and ground, the difference of potential rising to as much as 4 or 5 volts.

In some places pipes were found eaten away to as much as 50 per cent of their thickness. Of 51 tests, the pitting varied from 2 per cent. to as much as 100 per cent. In one case where the pipe had been eaten through it had been in use for only five years. In another serious damage had been done in four years. The result of the whole extended trial was summed up in the recommendation that "connection should not be allowed between electric railway returns and water mains, except as a temporary expedient to reduce the rate of corrosion at a certain point."

It is interesting, too, to notice that the German Commission strongly condemn any such plan, as the following extract from their rules shows :—

(10) *Connections between Mains and Rails* :—Metallic contact between the gas or water mains and the rails, or the return conductors, or the

negative pole of the dynamo must not occur. Such connections bring the mains into parallel with the rails or the return leads, and encourage destructive action at all places (joints) in the mains where the contact is imperfect.

Insulating the joints.—Another plan which has been strongly advocated is the insertion at intervals of non-conducting joints. These may be made by the placing in the line of main of a flanged joint made with a bedding of properly vulcanized rubber or fibre. In such a joint the bolts must also be covered with thick rubber tubing, and the bolt heads and nuts bedded in the same material. Joints made in this manner have been successful in some American cities in materially reducing the large currents travelling by means of the gas and water mains, but whether they are applicable to English conditions is rather doubtful.

The practical effect of introducing an insulating joint upon a line of main somewhere about the middle of the length, one portion of which is electrically positive and the other negative to the car track, has been found by Mr F. P. Stearns, chief engineer to the Metropolitan Water and Sewage Board of Massachusetts (see *American Engineering Record*, 29th July 1905), to be as follows :—

1. To stop the direct flow of electricity along the pipe line at the point where the joint is set, and to reduce considerably the amount of electricity flowing along other parts of the pipe line.
2. To lower the average potential of the pipe line on the negative or power station side of the joint.
3. To raise the average potential of the pipe line on the positive side of the joint.
4. To maintain a difference of potential of several volts between the positive and the negative sides of the joint, and to produce conditions tending to increase electrolytic action at that point, unless the joint is carefully located in dry ground.
5. To cause a new distribution of electrical conditions, under which the two sections of the pipe line become similar to the original line, with one portion of each positive and the other negative to the car tracks, so that the number of positive areas is increased by one for each joint.

Rosa and M'Collum's experiments.—The recent research work of Messrs E. B. Rosa and Burton M'Collum in connection with the Bureau of Standards, the results of which were communicated by them to the American Gas Institute at their annual meeting (see *The Gas World*, 20th January 1912, pp. 70-1) is the last authoritative word on this subject of insulating joints. Although the experiments are still being pursued the investigators have felt justified in reporting that cement joints have so high an electrical resistance as to be practically insulating. Their conclusions as far as insulating joints are concerned are as follows :—

(*a*) Where insulating joints are properly used, the pipes do not, as a rule, have a very strong tendency to discharge current into the earth.

(*b*) Insulating joints, rightly used, can be made very effective in minimizing electrolysis.

(*c*) Those who have had the most experience with insulating joints up to the present time, regard them as economical, and entirely practical from a mechanical standpoint.

(*d*) Insulating joints should be carefully made to ensure permanent insulation.

(*e*) Insulating joints should not be confined to positive areas, but should be installed in all places where there is any considerable potential gradient parallel to the pipes, and should be installed with sufficient frequency to prevent any considerable current from flowing in the pipes, and so that a dangerous potential difference cannot occur across the joint.

(*f*) The effective resistance of a joint depends not alone on the resistance of the joint proper, but also on the resistance of the leakage path in parallel with the joint. For this reason, the effective resistance of a joint increases very slowly with increase of length; so that short joints are practically as effective in reducing flow in pipes as very long ones.

(*g*) Long joints give a much more uniform distribution of leakage current, and hence less rapid deterioration of the adjoining pipes, than do short joints; so that in special cases, where it is necessary to have a high drop of potential across the joints, a long joint is to be preferred.

(*h*) If pipe lines containing insulating joints are connected to mains not so insulated, the insulating joint immediately adjoining the uninsulated line will, as a rule, be subjected to higher differences of potential than elsewhere. This is particularly true if negative feeders are connected to the uninsulated main. For this reason, the use of insulating joints and negative feeders on the same pipe system is not to be recommended.

(*i*) Where insulated and uninsulated systems occupy the same territory, and where it is necessary to have metallic contact between them, as inside buildings, an insulating joint, placed between the point of contact of the two systems and the point where the insulated system enters the earth, will be of great value in preventing current from flowing from the uninsulated into the insulated system.

These conclusions of the American investigators and the evidence by which they are supported are undoubtedly important and valuable. They are the result of much painstaking and laborious research work. If we were laying our distributing systems out *de novo* there is much to guide and assist us. But unfortunately they do not carry us very far in relation to our existing systems, totalling to hundreds of miles in length, and laid in the thoroughfares of our busy towns. Even if we assume that the remedy is perfect, how is it to be applied, say, in Leeds, with nearly 1000 miles of mains interconnected in all directions over an area of 40 square miles without incurring an appalling expense? Surely the wiser, cheaper, and more equitable plan is to request the electrician to keep down the potential differences until they become innocuous.

Protective coatings.—Many experiments have been made in the endeavour to discover a protective coating for pipes liable to electrolytic action, but so far without success. Paints have been proved useless because, so far, no one has been able to produce a paint that is absolutely moist proof. Cement coatings both inside and outside the pipe have been tried but fail from a similar reason. When moist the coating has a low electrical resistance, and current may readily leave the pipe line.

One firm of repute in this country, Messrs Alexr. Wright and Co., Limited, claims to render pipes immune by means of a metallic coating. A deposit of lead to any reasonable thickness is electrolytically deposited in a pure state upon the interior and exterior of steel or iron or other pipes. The deposit may be either a mere skin coating or may be increased to any depth up to $\frac{1}{4}$ inch. The author has had no experience with these pipes, but the standing of the firm commands respect for any claims they may make for their goods or processes. But assuming that pipes may in this way be thoroughly and permanently insulated, this again does not assist us much with regard to our existing pipe system. Such a process is obviously inapplicable to pipes already in the ground, and after all these are what we are principally concerned about. New mains and pipes are almost wholly laid in the outskirts of our city areas, and there the danger is negligible.

Encasing pipes.—It has also been urged upon gas undertakings that they should lay their service pipes within the danger zone in troughing, and encase them in insulating material. This, again, is a remedy which obviously cannot be applied to an existing system without very great expense. Moreover, as it is clearly impossible to apply the remedy to the whole of the mains and services within the area, the result would probably be merely to change the point of danger. If current travelling by a system of mains cannot discharge itself at one point it must at another, and the evil would, therefore, merely be transferred from the service to some point in the main.

APPENDIX

Tables showing the Discharge of Gas, in Cubic Feet per Hour, through Pipes of Various Diameters and Lengths, at Different Pressures.[1]

By Thomas G. Barlow. Extended by Thomas Newbigging, M.Inst.C.E.

Reprinted from Newbigging's *Handbook for Gas Engineers and Managers*, by permission of Mr Newbigging.

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	20.7	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	108.6	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	75.7
1.0 ,,	328.8	232.3	189.8	146.5	119.9	103.2	84.2
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

[1] It should be clearly understood that the pressures referred to in these tables are the differences between initial and final pressures ($P_1 - P_2$).—W. H.

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	476.6	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	428.2	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 ,,	1,287.9	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 ,,	1,335	1,090	943	770	667	545	421
0.3 ,,	1,628	1,335	1,172	943	819	667	516
0.4 ,,	1,882	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	731
0.8 ,,	2,666	2,177	1,882	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	1,202
2.0 ,,	4,702	3,839	2,965	2,102	1,713	1,482	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	906
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	2,748	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	1,880	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	4,929
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	9,380	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	11,350	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	45,351	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 ,,	59,216	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	31,450	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	39,000	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	32,010	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	34,300	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	306,724	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	10,000
Quantity Delivered with 0.5 in. pressure	234,000	166,000	135,000	117,000	105,000	86,000	74,500
0.6 ,,	257,380	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	128,300
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	10,000
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	171,285	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	428,000	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 tables by 0.6325 (the square root of 0.400) and dividing by the square root of the specific gravity of the other gas.

The quantity of gas discharged at any other pressure may be ascertained by multiplying the quantity indicated in the tables by the square root of the new pressure and dividing by the square root of the original pressure.

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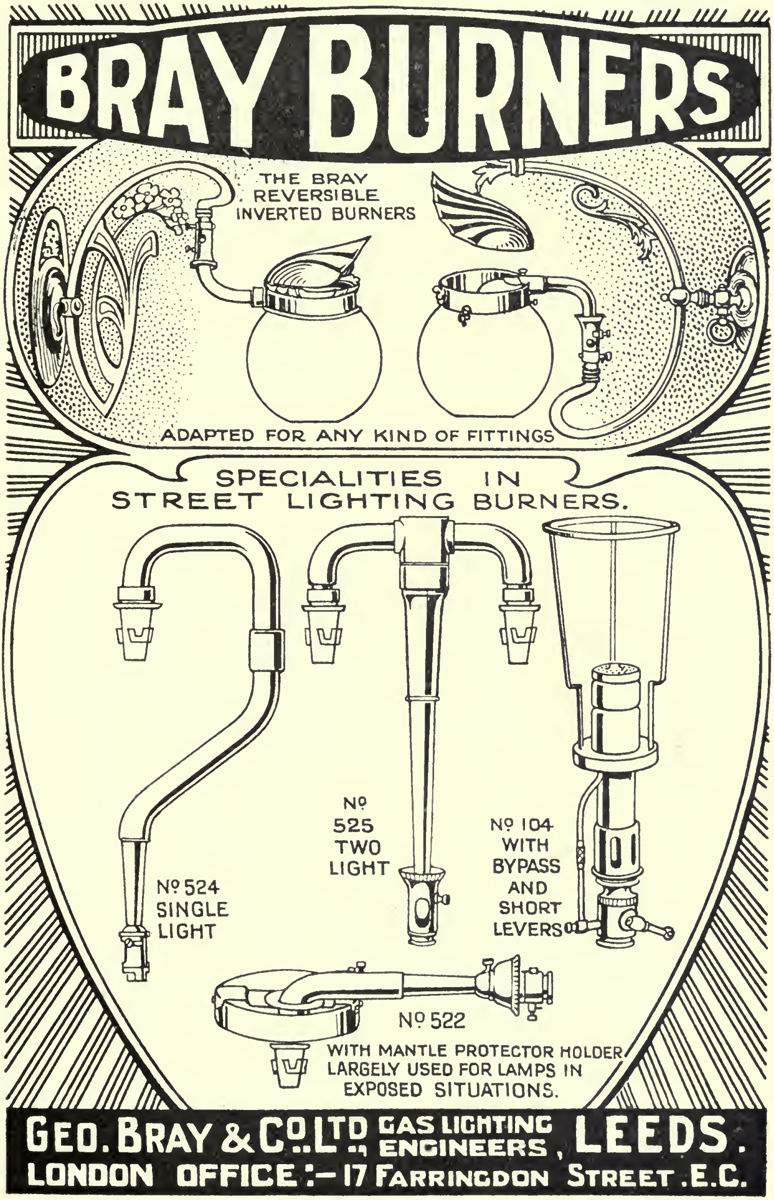

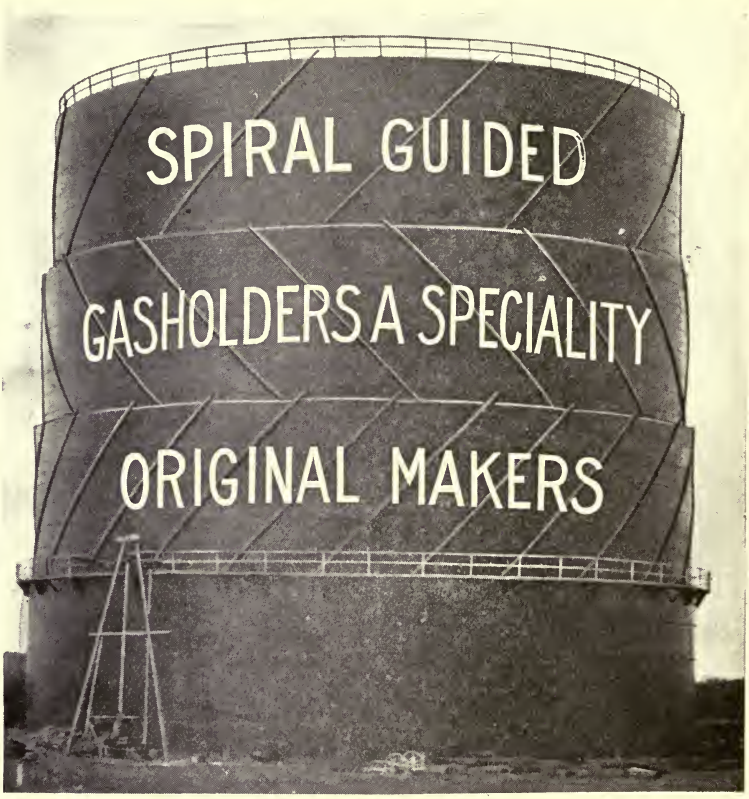
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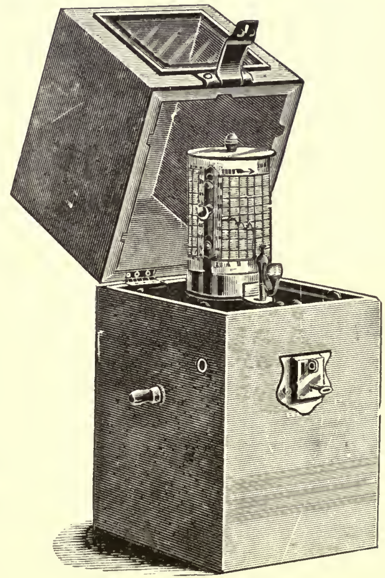

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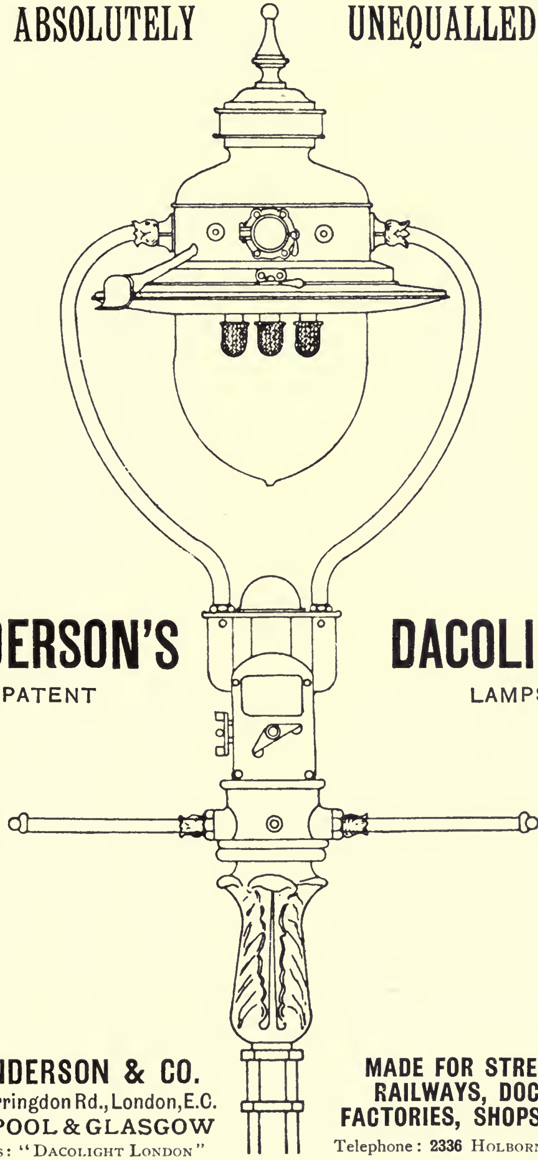

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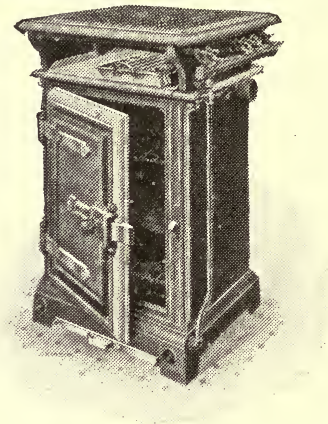

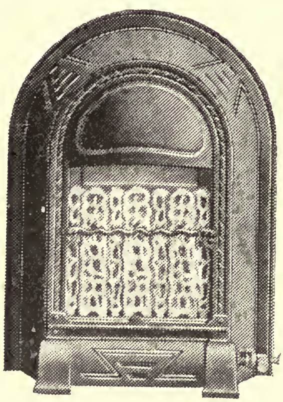

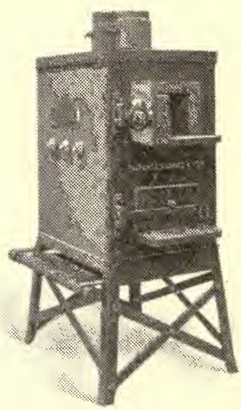

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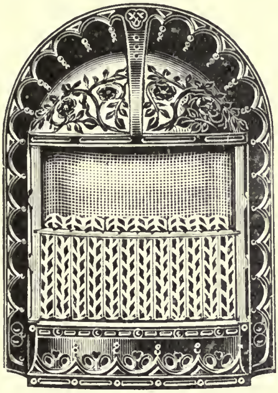

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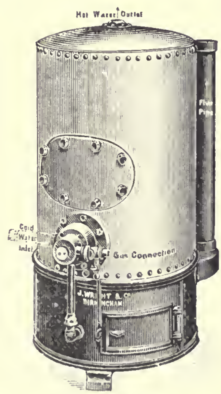

THE "SUN."