TELFORD PREMIUM

AWARDED TO
SIR THOMAS MASON, Assoc. Inst. C.E.,
by
THE INSTITUTION OF CIVIL ENGINEERS,

and presented by him to the

GLASGOW ASSOCIATION OF STUDENTS
OF THE INSTITUTION.

BENJAMIN HALL BLYTH, *M.A., President.*
J. H. T. TUDSBERY, D.Sc., *Secretary.*

SESSION 1914-1915.

SEWAGE-DRAINAGE SYSTEMS

Frontispiece.

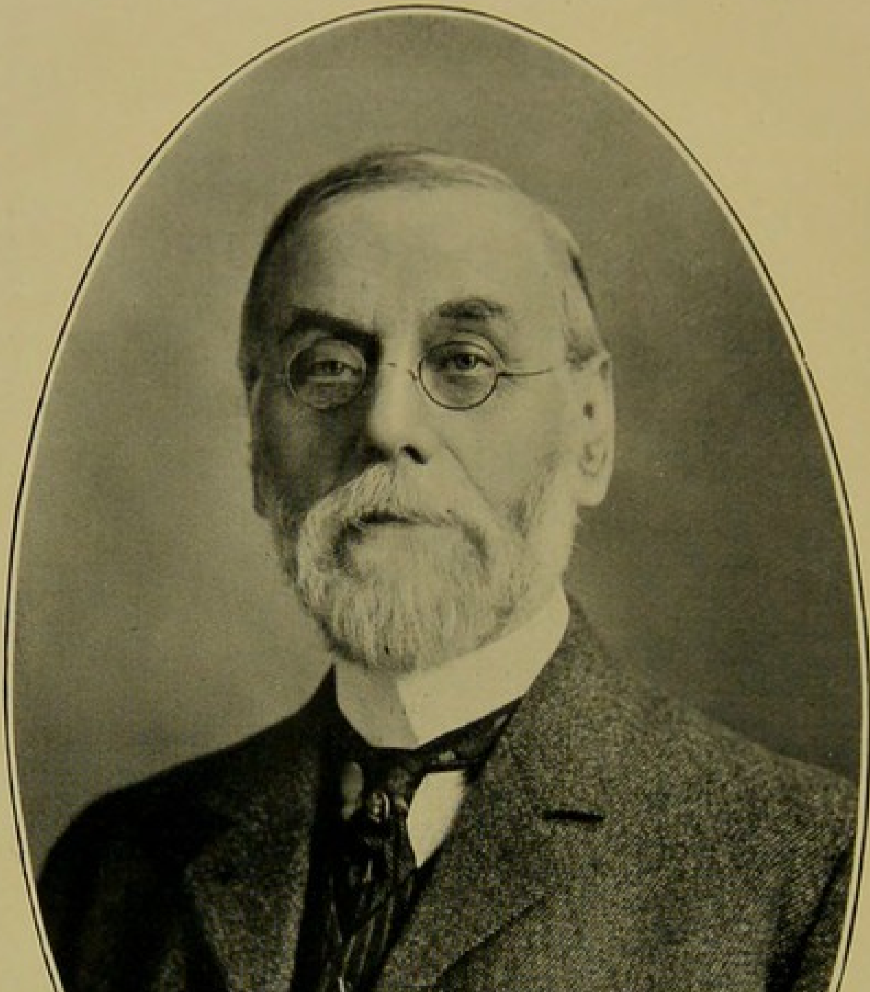

Photo by Maull & Fox

Yours faithfully
Isaac Shone.

THE EVOLUTION OF GREATER BRITAIN'S ANTISEPTIC HOUSE & TOWN SEWAGE-DRAINAGE SYSTEMS OF THE TWENTIETH CENTURY AND AFTER—FOR ALL TIME

With Descriptions of the inherent Defects of the 19th Century Systems

AND HOW TO OVERCOME THOSE DEFECTS
AT
GREAT SAVING OF EXPENSE

In an Address to the President of the Local Government Board, pleading for a Reform of the Prevailing Methods

WITH

EXPLANATORY, ILLUSTRATIVE AND CRITICAL APPENDICES; COPIOUS DRAWINGS AND DIAGRAMS, AND FULL HYDRAULIC, PNEUMATIC AND THERMO-DYNAMICAL TABLES, CORRECTED TO THE PRESENT DATE

BY

ISAAC SHONE

CIVIL, MINING AND SANITARY ENGINEER
PROFESSOR OF PRACTICAL HYGIENIC HOUSE AND TOWN-SEWAGE DRAINAGE, AND DRAINAGE AND SEWERAGE VENTILATION ENGINEERING

MEM. INST. MECH. ENGINEERS; FELLOW OF THE SURVEYORS' INSTITUTION; FELLOW OF THE ROYAL MET. SOCIETY, ETC., ETC.

INVENTOR OF
THE SHONE AUTOMATIC HYDRO-PNEUMATIC SECTIONAL SEWAGE-DRAINAGE SYSTEM; THE SHONE HYDRO-MECHANICAL AND FAN SYSTEM COMBINED, FOR VENTILATING SOIL PIPES, DRAINS, SEWERS, SEPTIC AND HYDROLYTIC SEWAGE TANKS; AND INVENTOR ALSO OF "GREATER BRITAIN'S ANTI-SEPTIC SEWAGE DRAINAGE," AND THE FANLESS AND COSTLESS VENTILATION SYSTEM CONNECTED THEREWITH

LONDON
E. & F. N. SPON, LTD., 57 HAYMARKET
NEW YORK: SPON & CHAMBERLAIN

1914

To my old and much esteemed Friend

LIEUTENANT-COLONEL

ALFRED STOWELL JONES, V.C.

M. Inst. C.E., F.R.S.I., etc., etc.

One of the very first Sanitary Engineering Specialists to recognize the merits and potentialities of my Hydro-Pneumatic Sewage Drainage System, and who has continuously from the date of its inception in 1878 down to the present time retained without intermission the same entire belief in its excellence and utility for the purposes for which it was intended and devised,

I Dedicate this Book

with heartfelt sentiments of affection and regard.

ISAAC SHONE.

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Drainage and Sewerage,

AND

Drainage & Sewerage Ventilation

INTRODUCTION

Errata.

[P]age 317, lines 3 and 2 from foot, *for* col. 1 *read* col. 5
,, 318, top line, *for* col. 1 *read* col. 5
,, 318, lines 3 and 6 from top, *for* 0·3867 *read* 0·6282
,, 318 ,, 6 and 8 ,, top, *for* 0·96675 *read* 1·5705
,, 318, line 7 from top, *for* 1·53325 *read* 0·9295
,, 318 ,, 8 ,, top, *for* 61·33 *read* 37·18
,, 318 ,, 3 ,, foot, *delete* half
,, 319 ,, 4 ,, top, *for* 1·6567 *read* 2·085
,, 319 ,, 5 ,, top, *for* 0·8433 *read* 0·415
,, 319 ,, 6 ,, top, *for* 34 per cent. *read* 16·6 per cent.
,, 319 ,, 7 ,, top, *for* the 17 in. *read* a 16 in.
,, 319 ,, 8 ,, top, *for* 42,700 *read* 20,912
,, 319, lines 23 & 25 from top, *for* 17 in. *read* 16 in.
,, 319, line 3 from foot, *delete* and plan

Page 329, line 1 from foot, *for* $\frac{p_1}{p_2}$ *read* $\frac{p_2}{p_1}$
,, 337 ,, 7 ,, foot, *for* $\frac{\sqrt{2 H^1}}{g}$ *read* $\sqrt{\frac{2 H^1}{g}}$
,, 345, lines 23–25, *for* D *read* D^2, and *for* ρ *read* ρ^2
,, 347, line 10 from foot, *for* col. 16 *read* col. 17
,, 351 ,, 9 ,, foot, *for* 0·5793431 *read* 0·5793431 ρ
,, 351 ,, 9 ,, foot, *for* 0·14984 *read* 0·1931
,, 352 ,, 7 ,, top, *for* 0·8661 *read* 0·8061
,, 352 ,, 2 ,, foot, *for* one-third *read* $\frac{1}{10}$th
,, 357 ,, 4 ,, foot, *for* 4602, 0·0179, 0·185 & 196 *read* 4595, 0·0200, 0·179 & 188 *respectively*

[S]ewage-Drainage Systems, by Isaac Shone.
(*To face p.* xxii.)

of food, as well as of drinking water, and so forth.

There is still, however, one source of preventible disease which is as insidious as any other, and which has not yet received the practical attention it required. It is the purification, as perfectly as can be attained, of our drainage and sewerage systems. This is the subject of the present work, the result of many years' investigation and study. When the published opinions are perused of the numerous authorities of high eminence on this subject, some of which are reproduced in the following pages, and when the almost countless instances are considered of "accidents" and diseases directly traceable to asphyxiation, or poisoning from the gases emanating from drains and sewers (of which a very few examples are given in Appendix VI.), it is hoped that no apology is needed for any honest effort to ameliorate the condition of things referred to, by the proposal of a carefully considered means of obviating or preventing their causes.

So much for the subject of actual preventible disease. Public feeling, however, nowadays is inclined to go a little farther than this. It is hardly satisfied by being told by some analysts of repute that the typhoid bacillus is seldom or never found in sewage (though if we are to trust the careful experimentation of later inquirers that view is a delusion); nor is it essential to be able to prove that every foul smell is a deadly poison. There may be phenomenal individuals whose olfactory nerves are impervious or indifferent to the gaseous products of decomposition; but to the vast majority they are intolerably offensive, and have a sinister influence on weak constitutions or constitutions predisposed to disease. It is therefore the duty of public sanitary authorities to do all in their power to abate, and, as far as possible, to prevent the occurrence of such nuisances in their districts.

The somewhat unusual form in which the matter contained in this volume is presented to the reader, that is to say, the fact that most of its contents are given under the title of Appendices, may, perhaps, require some explanation.

The book is, in essence and in intention, an appeal to the fountain head of authority with regard to the subjects dealt with; it therefore begins with an open letter addressed to the President of the Local Government Board. The information and considerations supplied in the subsequent sections of the work are "appended" to the letter in order to relieve it, to some extent, from controversial details, technicalities, tabular statements, and diagrammatic descriptions. Those sections, however, are an integral part of the elucidations of my views, and most of them are of great importance.

The first Appendix consists of the Paper on the Hydro-mechanical System of Sewer and Drain Ventilation, presented by me to the Association of Municipal and County Engineers*

* Now entitled the Institution of Municipal and County Engineers.

at Liverpool in June 1907, together with some of the discussion and correspondence which followed it. This, of course, being the exposition of the fundamental principles of my proposals, is, perhaps, the most vital part of the whole work.

After the publication of the Paper, however, it became evident, as might have been anticipated, that it is hopeless to expect to convey a perfectly clear and complete apprehension of a new system to the minds of those present at a meeting. There is always a plethora of business to be transacted at such meetings, and the privilege of addressing one of them—especially by one who is not a Member of the Institution—is too valuable to be encroached upon by undue length or minuteness of detail. This will account for the Second Appendix, which pursues the investigation into further ramifications, and reviews various expedients from time to time attempted with the object of rendering sewerage and drainage works innocuous and sanitary.

Appendix IIA consists of a Paper prepared by me for the Congress of the Royal Institute of Public Health, held at Eastbourne in July 1901, and read at that Congress.

The importance of Appendix III. arises in this way. For many years prior to 1898 the sanitary condition of the sewers and drains of the Metropolis had been a source of grievous trouble and anxiety to the various local authorities. Disastrous explosions (not all of them, it is true, attributable to sewer gas), occurred from time to time: and complaints of asphyxiation, sometimes fatal, from poisonous vapours in main sewers were loud and frequent. To remedy this state of things recourse was had to open manhole grids in the streets, which were, as time went on, placed at less and less distances apart. But that system gave rise to a new and ultimately intolerable grievance. From all parts of London complaints poured in to the Vestries and District Boards of offensive emanations from these openings. These bodies in turn appealed with increasing vehemence to the Main Drainage Authorities, first the Metropolitan Board of Works, and then the London County Council. At length, early in 1898, Sir Alexander Binnie, then the Chief Engineer of the County Council, determined upon calling a meeting of the Metropolitan Surveyors and Engineers to confer together upon the subject of the ventilation of sewers. That meeting took place on February 25, 1898. It was preceded, however, by an important meeting of the Association of Municipal and County Engineers on February 18. These two meetings appeared to me to constitute a definite and significant epoch in the history of sewer ventilation, at least as regards the London area. I have, accordingly, printed a full Excerpt from the proceedings of the meeting held on February 18, and following that, the report of Sir A. Binnie to the Main Drainage Committee of the County Council, containing the resolutions passed on February 25, 1898.

The Fourth Appendix is more personal in its inception; but it will be found to be strictly germane to the general subject, and to be of very wide application and of great sanitary importance. It arose from the publication of an able and interesting paper on "The Ventilation of Sewers and Drains," by Mr. R. Read, City Engineer of Gloucester, which was read at the meeting of the Association of Municipal and County Engineers, held at Cardiff in June 1899. The ability, experience, and influence of Mr. Read made it seem impossible to pass over such a studied exposition of views as was contained in the paper referred to. I have therefore reprinted extracts from it which I hope will be sufficiently full and explicit to enable my readers to follow my comments, by which they are succeeded.

Appendix V., Part I., is a description of a drawing showing in one view all the essential parts of the Hydro-mechanical System of Sewer and Drain Ventilation; and Part II. contains illustrations of that system in actual operation.

Appendix VI. is a collection of a few instances of accidents from sewer gas poisoning, and of representations on that subject by local authorities.

Appendix VII. contains a series of Hydraulic, Hydrodynamic, Thermo-dynamical, and other Tables. These have cost in their preparation an extremely great amount of labour and attention, but I shall feel well rewarded for my trouble if they are found, as I believe they are calculated to be, of practical use to the Engineering profession for reference in the course of the performance of their duties. The formulæ upon which the Tables are based are supplied in every instance; and the extremely important Table B is fully illustrated by concrete examples in detail.

Appendix VIII. gives a set of new Hydraulic Tables.

Appendix IX. consists of an Article in the "Builder" for April 28, 1888, by the late John Phillips, C.E., on the "Ventilation of Sewers"; followed by correspondence on the same subject by Mr. Santo Crimp, M.Inst.C.E., Mr. Easton, and others.

Another feature of the book is the very considerable extent to which authorities on the subjects with which it deals are cited and discussed. On this a few observations may be permitted.

In point of fact the sanitary engineers and medical officers whose names appear in these pages are but a small proportion of those who have in one form or other given to the public the results of their experience or experimentation, and their consequent opinions upon the problems relating to the sanitation of sewers and drains and their accessories. The obvious earnestness of these enquirers, as well as their number and eminence, shows at once how serious and how difficult these questions are regarded as being in themselves, and also how widely spread not only in the professions concerned, but among the community at large, is the feeling of their importance.

The able engineers, physicists and bacteriologists, who have devoted their skill and attention to these subjects, show a practical unanimity of opinion as to the gravity of the case. The authors whose views I have cited in the Letter addressed to the President of the Local Government Board might have been added to almost indefinitely had not that been forbidden by considerations of space and the patience of the reader. But while it is thus uniformly recognised that the Water Carriage System of Sewerage and Drainage has, from its inception, brought in its train consequences to which, on high authority, certain zymotic diseases or provocatives thereto have been and are attributed; and whilst, in any case, its establishment in centres of population has given rise to offensive gaseous emanations to an extent which has often aroused public indignation, and even some approach to panic; on the other hand, when the question of a remedy arises we find no such agreement. On this side of the subject, all sorts of different opinions have been expressed, and a multifarious number of expedients and contrivances devised and recommended as more or less sovereign preventives.

I have not abstained from referring to such of these as are, as far as I know, of any serious importance, or have carried with them the influence of eminent authority; and I trust it will be found that I have given a fair and candid account of them, and have not hesitated to give them such credit as I honestly thought their merits called for. On the other hand, the task I have undertaken necessarily involved such unshrinking criticism as I have considered instructive and pertinent.

I now desire to refer to certain personal matters connected with the work to which I have devoted the greater part of an active life. I wish to give utterance to the fact that during that long period, amid many difficulties, disappointments and anxieties, I have made many good and valued friends, and have often at critical moments met with comfort and encouragement—frequently from unexpected quarters. It is hopeless for me to attempt now to deal individually with this topic; as that would involve a reference to many engineering and sanitary officers past and present, and other experts, to a considerable number of members of local authorities, and many more. To all these, before whose eyes these pages may pass, I take this opportunity of expressing my cordial friendship and gratitude for their generous appreciation of my work, evidenced as it has often been by valuable suggestions and advice.

There remain a few to whom I am bound to express my special obligations personally; and the first place among these must fall to my esteemed and honoured partner, Mr. EDWIN AULT.

It was on January 2, 1882, that I took Mr. Ault into partnership; and in announcing the fact in a printed circular letter to my friends and patrons I stated: "Mr. Ault's thoroughness as an assistant and his abilities and straightforwardness have won for him my unqualified confidence and respect."

He was my pupil in the first instance, but after serving his apprenticeship he became my assistant, and acted in that capacity for many years; indeed, he was with me altogether about twenty years before becoming my partner.

Meantime his early industrious and tactful habits led him to study the principles of the various special subjects essential in his profession as a civil and mining engineer and surveyor. Even during his apprenticeship he became an expert draughtsman, and was entrusted with land, railway, metallic, and coal-mining surveying and levelling; and afterwards he, in a modest characteristic manner, utilized some of his leisure in teaching drawing and other subjects at evening classes in Brymbo, in connection with the South Kensington Science and Art Department.

No sooner had Mr. Ault made himself acquainted with my automatic hydro-pneumatic system of town drainage, and had realised that the motor force by which it was to be operated was compressed air, than his loyalty and zeal as an assistant and his anxiety to render himself as useful as possible in its development and propagation were shown in a remarkable way. He promptly undertook the task of studying the laws and principles of thermo-dynamics, so as to be able to apply them practically in connection with works on the Shone system.

He also presented himself at the very first official meeting that was ever held in this country for the purpose of examining Mining Experts, who wished to take advantage of the facilities the Coal Mines Regulation Act of 1872 afforded them, of obtaining certificates of competency to show that they were properly qualified to undertake the important and responsible posts of Colliery Managers. This took place at Wigan, and as the result of the examinations to which he subjected himself on that occasion he in due course obtained the official certificate qualifying him to undertake the management of collieries.

The Mining Engineering Agency, and other appointments held by me prior to our partnership engagement, were by the unanimous consent of all parties concerned transferred to the firm of Shone and Ault, and we have always retained our offices in, and our business connections with Wrexham, where we have reliable representatives (old pupils) professionally trained in and well acquainted with our special work there; and the consequence is that we still have the honour, as a firm, to retain the appointments which I held alone for twenty-seven years—i.e. from 1854 up to the end of 1881.

Thus the total duration of our association together amounts to over half a century.

Looking back to the days when the initial stages of my Sanitary Engineering Reform Work commenced, and reflecting upon the comparative success that has attended my endeavours to render the so-called "English Water Carriage System of Sewage Removal" (to quote Professor Huxley's words) "as reasonably perfect as possible," I am proud to say that I have at all times derived from Mr. Ault's co-operation just that kind of sterling loyalty and engineering skill and energy that were needed to enable me to overcome the difficulties I encountered from time to time whilst pursuing the tasks I set myself to solve.

Mr. Ault was in partnership with me when I began to prepare material for the book I had promised years previously to write on "Sanitary Engineering." It was then whilst I was engaged in describing the House and Town Drainage Ventilation Engineering methods of the 19th Century that I saw the direct and indirect evil effects that resulted from the placing of interceptor traps on house drains, which were only ventilated on the house side of the apparatus; and from that time forward I began to study the general problem of drain and sewer ventilation, with a view to evolve, if possible, a simple and reasonably economical and sanitary system, which could be successfully applied to the ventilation of soil-pipes, gravitation drains and sewers everywhere, irrespective of their sizes, shapes or lengths.

After giving the subject much thought and consideration, I came to the conclusion that the 19th century systems of ventilating soil-pipes, drains, and sewers were amenable to important amendments, which could be effected without making any very material constructive alterations and additions to the existing insanitary regime.

I embrace this opportunity to acknowledge my hearty appreciation of the valuable services of our chief Engineering Assistant, Mr. ALFRED HANSSEN, Assoc.M.Inst.C.E., Past President of the Civil and Mechanical Engineers' Society, during a period exceeding a quarter of a century. Endowed with high abilities and culture, and possessing a thoroughly sound knowledge of his profession, he has ungrudgingly devoted those gifts to the performance of the responsible duties of his office. My partner and I have found his assistance invaluable in our works of designing and superintending the construction of the Shone Drainage and Ventilating systems, and in waterworks and other undertakings.

I also desire to express my sincere gratitude to Mr. T. C. Walrond, A.M.Inst.C.E., etc., who acted for some time as one of our chief assistants, for the valuable help which, in conjunction with Mr. Ault and Mr. Hanssen, he rendered to me in the preparation and completion of the highly technical Hydraulic Tables appended to this book.

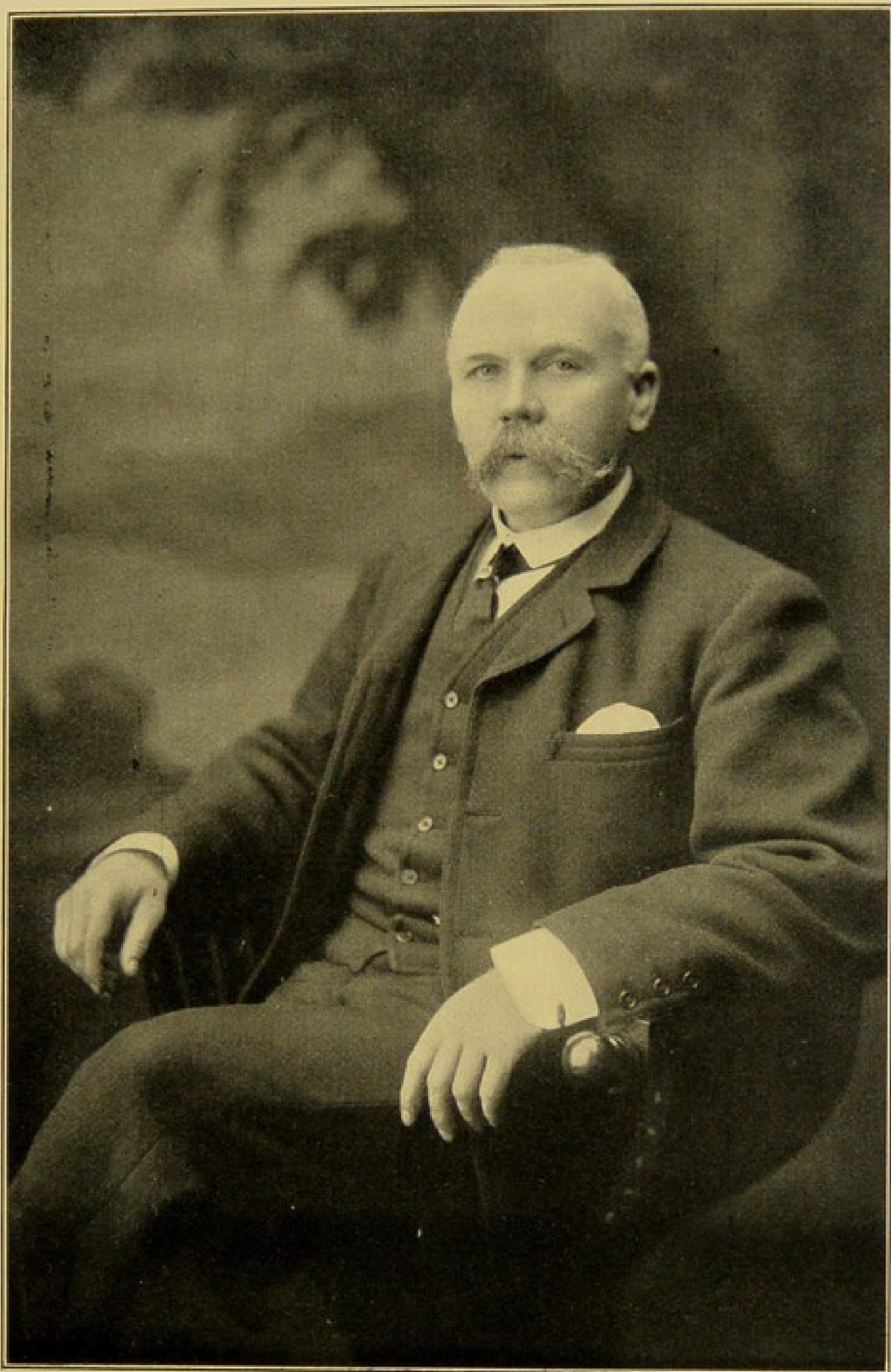
I have referred above to our business connexions in Wrexham, and to our representatives there. Without them the retention and safeguarding of the interests of our clients might have been very difficult. Accordingly we have been served at Wrexham, as assistants for many years, with great zeal, assiduity and fidelity, by two of our old pupils, Mr. J. Price Evans and Mr. John H. Edwards, both Members of the Institute of Municipal and County Engineers. Mr. Evans was a pupil from February 1874 for four and a-half years; he then acted for a year or two as Mining Surveyor to Plas Power and Old Broughton Collieries, and after that for some five years in a similar capacity at the Carson Iron Works and Collieries in Scotland. At the end of that term (viz. in December 1882) he returned to our service, and has been with us since, as our chief representative at Wrexham.

Mr. Edwards became our pupil in 1890, and, after a service of four years under the tuition of Mr. Evans, became our assistant. He is still associated with us and with Mr. Evans, who for eighteen years past has acted as the Engineer for the Wrexham Rural District Council. The loyal services of these two excellent assistants has been a valuable help to their principals.

Engineers and patentees of experience will realise that in modern times, at any rate, the inventing and patenting of any process, device, or combination, is only the first infantine step towards its growth and maturity. Every new process requires thorough testing, and submission to the judgment of those who are competent to estimate its merits, its utility, and its commercial value. It requires, moreover, active support and publicity, and the bringing to bear of such influences as will tend to overcome the apathy and the indifference of the public and the instinctive dread of novelty which is so generally met with in these cases.

Such was the lot to a great degree of the Shone System of Town Drainage. The funds of the small private company which I formed to develop and work it were found to be absorbed sooner than was anticipated, and while much remained yet to be done to place it before public authorities and their engineers in such a practical form as to enable them to appreciate its special claims and merits.

It was in these circumstances that Messrs. HUGHES AND LANCASTER, the well-known firm of Engineering Contractors of Westminster and Ruabon, came forward. Arrangements were made for the transfer to that firm of the powers and interests of the Shone Company, so that they became the sole licensees for the manufacture, sale and use of the apparatus required for operating the Shone System of Drainage. Messrs. Hughes and Lancaster lost no time. They at once applied themselves to the manufacture of ejectors, air-compressing machinery, and all the accessories needed for both. They likewise undertook to supply and fix installations for corporate and other sanitary authorities. This energy on their part rendered the task of bringing the system under public notice much easier and more expeditious than would otherwise have



Yours very truly
John Hughes

[*To face p.* 10

been the case. It enabled experimental or test exhibitions to be made, and arrangements effected for describing and explaining the method to competent judges.

This zeal, amounting almost to enthusiasm, on their part, and based on a firm faith in the sanitary and hygienic virtues of the systems, was exemplified in a striking manner under the following circumstances.

A gravitation drainage scheme of considerable magnitude was proposed to them to carry out as contractors, but, finding that the conditions of it were unsatisfactory from a sanitary point of view, rather than risk their reputation as a firm identified exclusively with work of a high sanitary character, they declined the proposal.

It is a source of real pride to me to add that the enterprise and confidence they then displayed, coupled with their high integrity and business capacity, has been well rewarded.

Their advance in standing and eminence as manufacturing mechanical engineers and contractors has been contemporaneous with, and has, as it were, marched side by side with the growing reputation of the Shone System, with which they, as the practical executants of my patents, are as closely and widely identified as my own firm. They have in the meantime had a large and varied experience in the carrying out of contracts for drainage and water supplies, not only of a special, but also of a general character.

Not only are the foregoing statements true, but it may further be said with full confidence that, in the capacity of contractors and manufacturing engineers of all the multifarious and special works connected with the Shone System of Drainage and Sewerage, they hold a unique position, and one which is, and in my judgment must remain for many years to come, above the reach of rivalry. And the reasons are these: Like all inventions dealing with large and complex works, the Shone System has, from time to time, been found to be susceptible of improvements in a great number and variety of matters of detail, and it has been deemed desirable to protect all these by obtaining letters patent in respect of them. With all such improvements, of whatever description, it need hardly be said that Messrs. Hughes and

Lancaster, as the manufacturers thereof, have always been thoroughly familiar.

It is therefore with pleasure, as well as with gratification, that I seize this occasion to say that such measure of success as has attended the System, since its initiation, is materially due to their able and generous co-operation, and I cannot close these remarks without paying a special tribute to the sympathetic assistance and invaluable, though unpretentious, advice and direction that have always been exhibited by my friend, Mr. John Hughes, the senior partner in the firm, whose portrait I have taken the liberty, without his knowledge or consent, of presenting herewith to the Reader.

To

The Right Honourable JOHN BURNS, *M.P.*,

President of the Local Government Board.

SIR,

As the head of a great department of State—a department which, at least from the point of view of the public health, probably transcends all others in importance, I venture to place before you and to call your attention to the accompanying Papers, bearing upon the momentous question of sanitation Their object and purport are twofold. First, to indicate what in my humble judgment are the causes that are responsible for the existence at this time of day of so much preventible disease, and, secondly, to suggest what I regard as the proper sanitary engineering measures to be taken to remove those causes, or very greatly diminish their evil effects.

2. I had the honour and pleasure of being present on the 19th of May, 1906, at the Meeting of the Incorporated Association of Municipal and County Engineers in the Council Chamber of the Borough of Battersea, when you delivered to the Members assembled a most eloquent, important and encouraging address; and I was exceedingly glad to find afterwards that the official report of your address had been printed on pages 213–220 of Vol. XXXII. of the Proceedings of that Association. Speaking, as you were, in the Metropolis, you rightly and with justifiable pride indicated the vast and growing improvements in the conditions of life which London has seen in the past generation, and stated with perfect truth that the present generation are sincerely desirous of continuing the good work and of achieving, so far as their means and knowledge permit, still more satisfactory results. You also pointed with equal appropriateness to the extremely gratifying progress, from a sanitary point of view, of your own borough of Battersea, where, while the population has in thirty-five years "grown from 54,000 to 175,000," "the death rate in that period has

dropped from 26 to 14 per thousand." You added that, "what is more, infantile mortality has dropped, in ten years only, from 176 per thousand to 131 per thousand." And you concluded your address with a few impressive words of exhortation and encouragement: "I ask you not to lose faith in the greatness of your profession, in your sanitary aims and municipal ideals. If the average ratepayer would only rise to the level of the ordinary engineer . . . we could have in the next generation an average death rate of not more than 10 or 12 per thousand everywhere, and we ought to bring down the infant mortality in poor streets from 200 and 250 to 100. All that is needed is money, and if that money is granted, your profession will endeavour to give value to the ratepayers, and you will add to the comforts, pleasure and well-being of the ratepayers, whose guides, philosophers and friends you are."

Sir, the aspirations to which you then gave expression have long been felt by me, and it has long been my ambition to do what lies in my power, and is within the compass of such qualifications as have been vouchsafed to me as a sanitary engineer of long standing and exceptional experience, towards the realisation of those hopes. If, then, I can trespass upon your forbearance to give a perusal to the following pages, I am sanguine that you will find my observations and suggestions worthy of attention from the point of view of the further and more effective prevention of the causes and incentives to disease, which arise from the defects and drawbacks still existing in the sanitary systems which prevail in various parts of the country.

It is reasonable, however, when a private individual approaches the head of a great Department of State, in the manner in which I am bold enough to do, that he should come with some credentials; that he should furnish at least *prima facie* evidence that he is acquainted with the subject which he proposes for consideration. This will be my apology for inflicting upon you some particulars of my career.

3. I was born on the 30th of April, 1836, at Brymbo, near Wrexham. I was educated partly in private, and partly in public schools. When my school days were ended, my father

placed me as a pupil in the office of Mr. Samuel Jones, the colliery manager to the Brymbo Coal and Iron Co., who was also the mining engineer to the Westminster, Broughton and Ruabon Collieries.*

Whilst I was serving my apprenticeship to Mr. Jones, I was privileged to assist my late grandfather, Mr. Thomas Hughes, who was then, and had been for twenty-one years previously, the local Mining Agent and Surveyor in the Wrexham district to the late Marquis of Westminster, to survey the Westminster Collieries, etc., for royalty and other purposes ; and on the death of my grandfather, which occurred during my apprenticeship, the late Marquis, at a special interview I had with his lordship at Halkyn Castle, did me the honour to appoint me to succeed him in 1854.

This appcintment I also had the honour of retaining during the lifetime of the late Duke of Westminster, and I am proud to state that I still hold it under the present Duke. Thus my grandfather and I have rendered to that ducal house a continuous service extending over seventy-six years.

My marriage took place in 1861, and then it was that I became a ratepaying citizen.

I took offices in Wrexham with the twofold object of conducting my agency business, and of practising my profession as a Civil and Mining Engineer and Surveyor. I continued to reside in Wrexham till 1884, when I removed to London, where I have lived since. While residing in Wrexham, however, I was elected to perform public functions in several capacities, viz. : on the School Board, the Board of Guardians, and finally the Town Council. For some time before, and whilst

* In view of the particular subject of this book, it may be worth while to mention the following facts : The very first piece of work to which my " 'prentice hand " was put in Mr. Jones's office was to make a tracing of a drawing of Struve's patent mine ventilating apparatus, which had just been installed at the Westminster Colliery. I also witnessed the first installation in North Wales (namely, at the Westminster Colliery) of air-compressing machinery for use in mining work, and after my apprenticeship I was present at the inauguration, in the Vron Colliery (with which I was officially connected), of the Goldsworthy steam-jet appliance for ventilating coal mines ; a method which, some readers may remember, was experimentally adopted by the City of London Commissioners of Sewers for the ventilation of some extremely foul sewers in the City during the disastrous epidemic of 1848–9, when 14,137 deaths from cholera alone took place in London —the population of which in 1851 was 2,361,640.

filling these offices, my attention was called to important questions relating to public health. As a member of the Wrexham Corporation I had opportunities of seeing how house and public drainage works were being sanctioned and carried out; and having in my mining engineering acquired a practical knowledge of hydraulics and pneumatics, I soon began to see that there was room for reform in connection with house and town drainage works in particular. This induced me to begin the study of sanitary engineering drainage questions; and I became at the same time an ardent advocate for systematic street improvements and town-planning generally. In 1876 I wrote and issued a pamphlet entitled "Wrexham: its Present Sanitary Condition, with Comments on the Past, and Suggestions for its Future Development and Improvement."

Subsequently I wrote a pamphlet advocating town improvements, which was illustrated by plans and sections to show street, road, and river amendments which I advocated, and copies of that pamphlet were sent to all the officials and members of the Corporation. Some of the improvements therein suggested have since been satisfactorily carried out, though, as invariably occurs, not without opposition.

For these and other services, the members of the Corporation of Wrexham conferred upon me the highest honour in their power by electing me Mayor of the town for 1878–9.

4. The studies I thus pursued, and the practical experience I acquired, of the various methods in use for draining and ventilating metallic mines and collieries, and my knowledge of the different uses to which compressed-air power was put, such as rock-drilling, mine-pumping, hauling and winding, etc., etc., led in the end to my formulating and patenting on the 5th of September, 1878, the Sectional Automatic Hydro-pneumatic System of House and Town Drainage, which bears my name, and which I am glad to think is now widely known in this country and abroad.

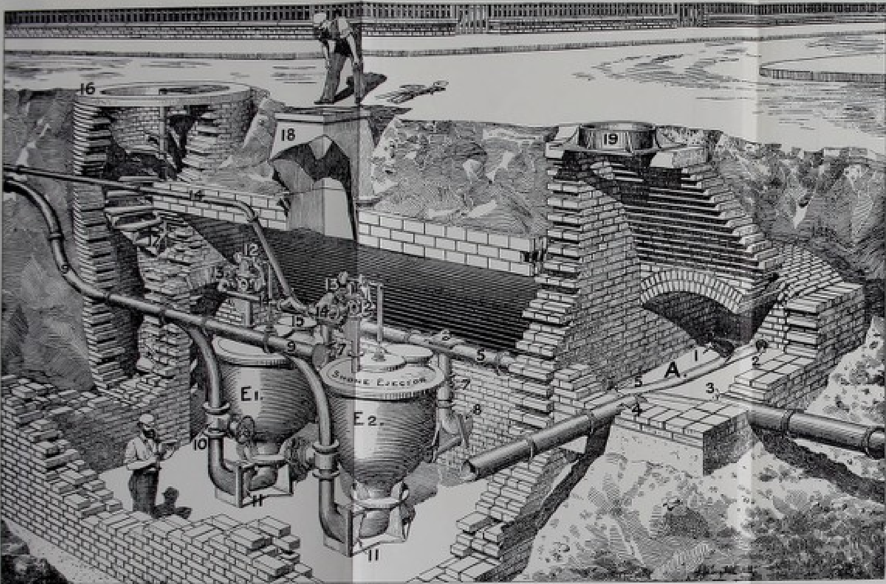
Sanitary Institute, 1878.

5. On the 3rd of October, 1878, I read a paper on that system at the Congress of what was then called the "Sanitary

DRAWING No. 1, Fig. 1.

Being a Sectional Perspective Drawing of a Shone Hydro-Pneumatic Ejector Station in course of construction in Brickwork.

See References on page 17.



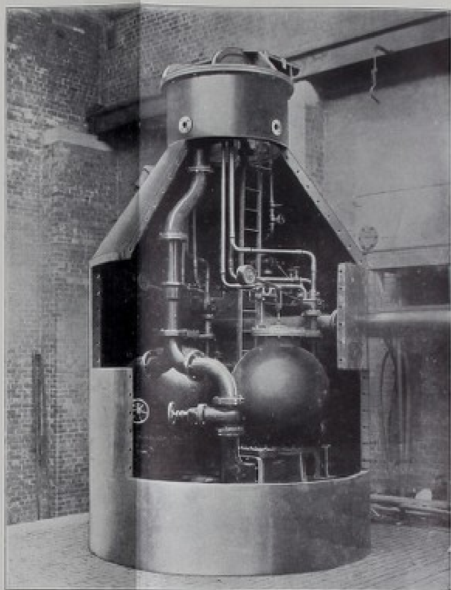
E1. Cast Iron Ejector No. 1.

E2. Cast Iron Ejector No. 2.

1. Stoneware Gravitation Sewer (West).
2. ,, ,, ,, (North).
3. ,, ,, ,, (East).
4. ,, ,, ,, (South).
5. Cast Iron Inlet Pipe from Manhole to Injectors.
6. Cast Iron Inspection Cover.
7. Sluice Valves on Inlet Pipes.
8. Inlet Flap Valves to Ejectors.
9. Cast Iron Outlet Delivery Pipe from Ejectors.
10. Sluice Valves on Outlet Pipes.
11. Outlet Flap Valves on Ejectors.
12. Automatic Gear of Ejectors.
13. Stop Valves on Compressed Air Pipe.
14. Cast Iron Compressed Air Main.
15. Iron Cap on Manhole Entrance to Ejectors.
16. Manhole Entrance to Ejector Chamber.
17. Cast Iron Circular Staircase.
18. Manhole for lowering Gear, etc., down into Ejector Chamber.
19. Entrance to Sewer Manhole Inspection Chamber.

DRAWING No. 1, Fig. 2.

Being a Shone Ejector Station, for Wet Ground or Strata, in Iron Tubbing.



Institute of Great Britain"—which has since changed its name to that of the "Royal Sanitary Institute."

Lieut.-Col. Jones, V.C., M.Inst.C.E., F.R.S.I., etc., the eminent sewage irrigationist, who is employed by H.M. Government, publicly said of that Congress, that it would be specially conspicuous in history because of the fact that it was at that Congress that my paper explanatory of the superiority of the Mechanical Hydro-pneumatic System over ordinary natural gravitation drainage in flat and low-lying villages, towns and districts had been read.

How the Shone System is Operated.

6. To enable you personally to appreciate the fact that it is impossible for engineers to drain flat habitable areas on true sanitary principles without having recourse to mechanical power of some sort, I have prepared a drawing (No. 1, Fig. 1, with full explanatory reference thereof at foot) showing a sectional perspective view of an ejector station in brickwork in course of construction, with two hydro-pneumatic ejectors (E_1 and E_2) placed in position in it. The printed reference will help you to see not only what an ejector station is like, but what the apparatus contained in it and connected with it are like also. You will please suppose that the ejector-station portrayed in the drawing is built in or near to the centre of a flat drainage area, and that it is sunk below the surface of the ground at a point where four streets converge, as exemplified by the plan on Drawing No. 2; and that the ejectors are operated automatically from one single power station by air compressed to any required pressure. Fig. 2 on Drawing No. 1 shows the interior of an ejector station with the various apparatus fixed in iron tubbing, which is preferable to brickwork where the ground is soft and water-logged. (Margin: **Drawing No. 1, Fig. 1.** **Drawing No. 2.**)

By adopting this simple plan, sanitary engineers can always secure, for their gravitation collecting sewers, the gradients which are essential to their being kept in a self-cleansing condition.

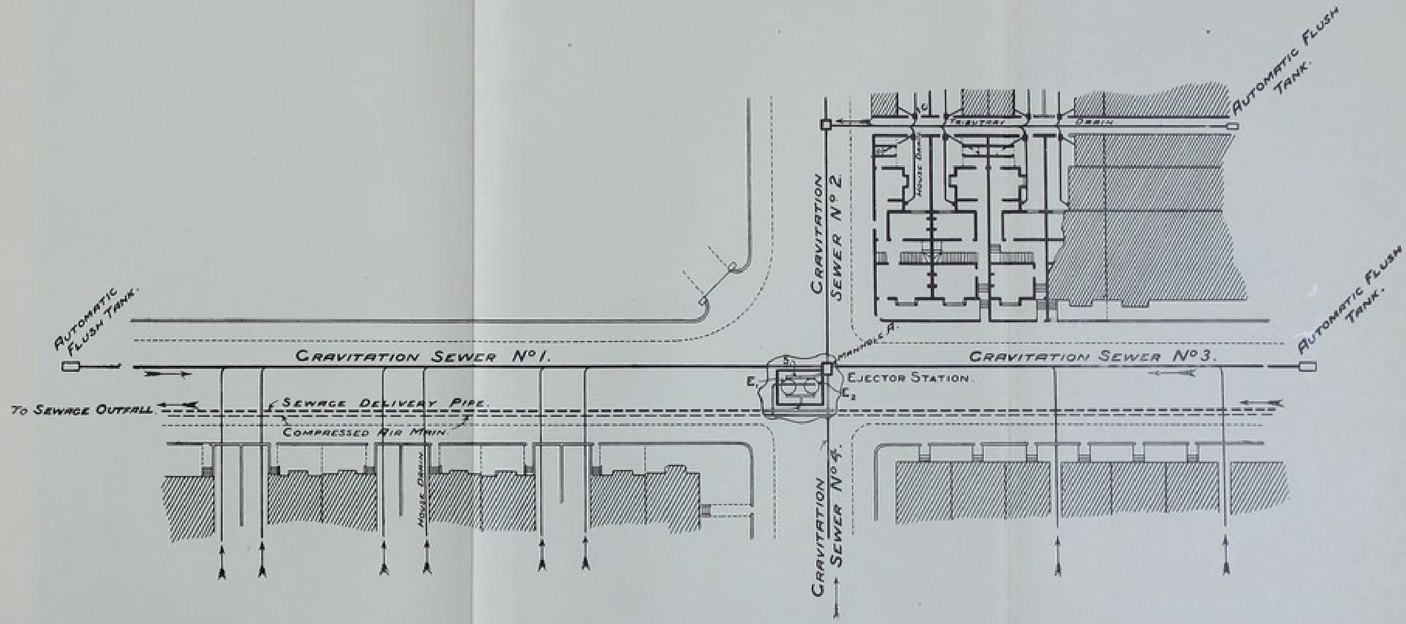
For example, in the manhole marked A, adjoining the ejector-chamber, four separate street sewers (marked in both section and plan 1, 2, 3 and 4) converge. As the crude sewage flows out of each of these sewers into the manhole, it passes along on the inverts of the channels, shown on the floor of the manhole-chamber, and flows into the cast-iron pipe marked 5, and thence into the ejectors. The moment the one or the other of the latter is filled with sewage, that moment compressed air automatically pounces upon the surface of the contents of the ejector, with the result that in half a minute, more or less, the whole charge of sewage is forced out of it, into the cast-iron pipe marked 9, through which it is discharged direct to the point of outfall, wherever that may be.

It is obvious that by the adoption of this plan, flat, low-lying town areas can be divided into as many sewage drainage sections, as may be necessary to insure the laying of self-cleansing sewers within each separate drainage area. To carry out this simple plan, all the sanitary engineer has to do is to take care that the gravitation sewers, which are intended to convey the sewage to the ejectors, shall be adapted to the work they have to do; in other words, that they shall be adjusted in size, and graded so that the sewage discharged into them from the house-drains shall flow freely by gravitation into and through them at a velocity of not less than 2½ ft. per second, which is the minimum velocity universally acknowledged, in England, at least, to be necessary to render drains and sewers self-cleansing.

Its Elasticity.

7. The system thus briefly described is capable of indefinite expansion or limitation, according to the requirements of each case. It operates with equal efficiency, however near or however distant any one ejector station may be from any other, or however near to or distant from the air-compressing station any of them may be, and whether the compressed air is applied to only one or to any number of ejectors in combination.

As examples of the remarkable elasticity thus claimed for the system, it may suffice (out of a great number of cases) to point out that it has been applied and is now in operation, on the one hand, at the Houses of Parliament, at the National Liberal Club, at the New Victoria Station, and at Sir Weetman Pearson's offices in Parliament Street (formerly the Whitehall Club), and the Automobile Club in Pall Mall, etc.; and, on the other hand, it serves from a single air-compressing station


Automatic Flush Tank.
Gravitation Sewer No 1.
To Sewage Outfall.
Sewage Delivery Pipe.
Compressed Air Main.
House Drain
Gravitation Sewer No 2.
Tributary
Drain
House Drain
Manhole A.
Ejector Station.
E_1
E_2
Gravitation Sewer No 3.
Automatic Flush Tank.
Automatic Flush Tank.
Gravitation Sewer No 4.

[Face p. 18.

such large town areas as Eastbourne, Gosport, Norwich, Southampton, Felixstowe, Bombay, Rangoon, Wallingford, and Karachi. It was also applied on a large scale for the drainage and the discharge of the sewage and other waste liquids of the great Exhibition at Chicago, at which the automatic sewage receiving and ejecting stations provided were distributed about, and they numbered twenty-five in all, and the compressed air required to work them was compressed at one air-compressing power station erected in a central part of the building, which was sufficient to compress air enough to eject the waste liquids of a population numbering about 800,000, i.e. if the volume discharged into the drainage system installation there did not exceed on the average 20 gallons per head per day, which it did not.

8. The districts which are specially suitable for treatment by the Shone Drainage System are those which are flat and low-lying, whose natural configurations are adverse to drainage by gravitation, or those which do not possess facilities for disposal of the effluent, without transport or pumping, or both. To emphasize this as part of the subject, and to illustrate its importance, I prepared in 1879 a Hydraulic Table, showing the gradients at which drains and sewers, ranging from 4 to 18 inches in diameter, should be laid so as to render them self-cleansing. The Table also shows the quantities of waste liquids discharged by the pipes running full bore, allowing 15 or 25 gallons per head per day, and specifies the population for which in each case the conditions would be suitable. This Table received the approval and commendation of a number of eminent sanitary engineers, including the late Sir Robert Rawlinson.

9. At a later period, in 1887, I directed the preparation of additional and improved Hydraulic Tables for the use of Municipal Engineers and Surveyors, and Sanitary Engineers generally. They are applicable for reference when designing either house-drainage or town-sewerage works, whether on a gravitation plan or on any system involving the conveyance of sewage under pressure by mechanical means. To these Tables.

were added compressed-air tables, so arranged as to show at a glance what theoretical and practical efficiencies are obtainable from the direct employment of compressed air to lift or force crude sewage to any required height and distance on the Shone Ejector System.

These Tables will be found in Appendix VII. to this volume. They are there described *seriatim*, and the hydraulic and thermo-dynamical formulæ, on which each is based, are prefixed thereto.

A Test Installation.

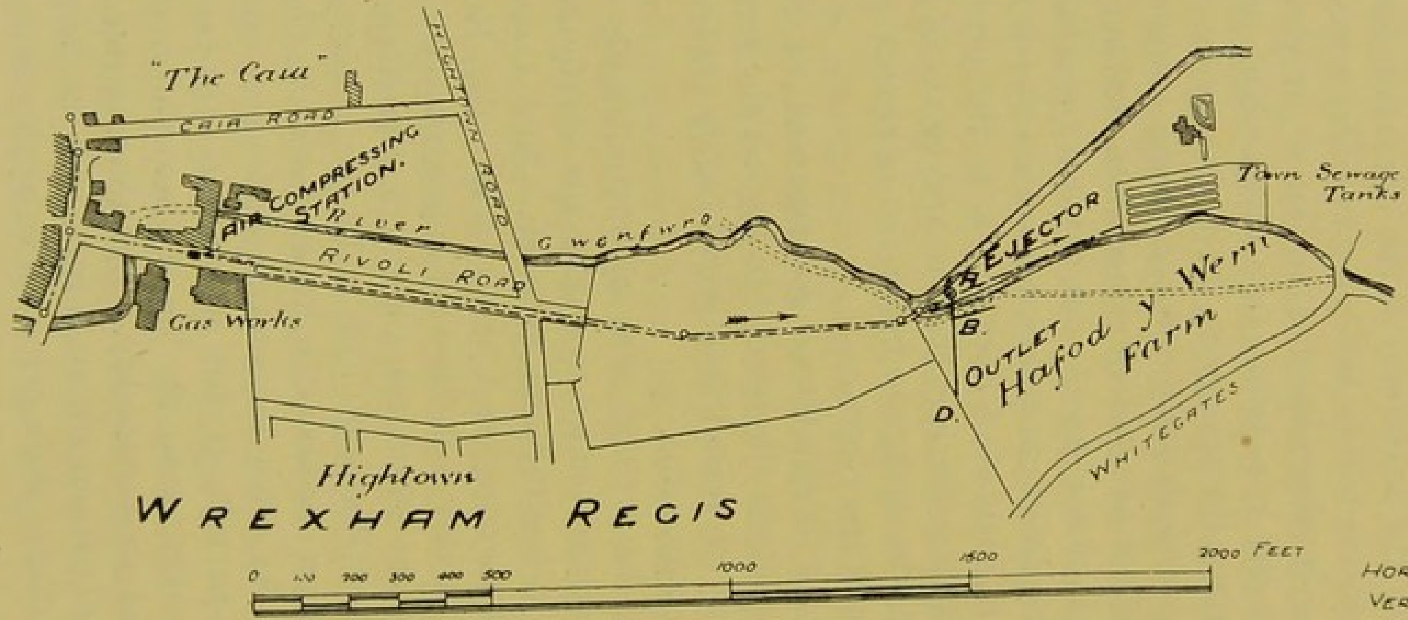
10. In 1878–9, when I was Mayor of Wrexham, by way of giving a practical ocular demonstration to Medical Officers of Health, Municipal Surveyors, Sanitary Engineers and Architects, and the public generally, of the feasibility and working practicability of my system, I sank an ejector station on Lieut.-Colonel Jones's Sewage Irrigation Farm at Hafod y Wern, which he held on lease from the Corporation of Wrexham; and I also had manufactured for my experimental tests an automatic sewage-ejector of 300 gallons capacity, and a small portable 4-h.p. steam engine air-compressor to work it. The ejector was placed at a point a few feet below the main outfall sewer, which carried the Wrexham sewage to Colonel Jones's farm. The air-compressing machinery was placed at the edge of the town 1600 ft. away from the ejector station—the air being conveyed from the compressing engine to the ejector in iron pipes of small bore. I also had constructed and laid a concrete pipe sewer 2 ft. in diameter, which was laid near to, but some 20 ft. above the ejector, at right angles to the iron sewage delivery pipe of the ejector; this latter was made to communicate with the sewer firstly, and afterwards it was extended beyond it up the side of the hill until its outlet end was 35 ft. above the ejector, which was the highest point on Colonel Jones's farm. When these arrangements were complete, the machinery was set to work, and afterwards a part of the rough unscreened sewage, as it passed down the Wrexham outfall sewer, was diverted and turned into the ejector, and was by the latter received and ejected, sometimes into the concrete sewer, and sometimes to the highest point on the farm, where it was utilized for irrigation purposes. The

accompanying Drawing No. 3 shows, by plan (Fig. 1), in what part of Wrexham the experimental works were carried out, and it also shows to scale the relative positions of the various parts of the works described above; and by the section (Fig. 2) it further shows in profile the surface of the land under which the ejector station was sunk, and the concrete sewer and the iron sewage delivery pipes were laid. The object of ejecting the sewage into the concrete sewer was to demonstrate the usefulness of the apparatus for collecting sewage from sewers laid in low-lying building areas, and afterwards ejecting it automatically, as fast or as slow as it was discharged by the population, into intercepting sewers; and the act of ejecting the sewage to the highest point of the farm was intended to demonstrate the extreme convenience and effectiveness of compressed air power when used in conjunction with ejectors to force sewage out of them (whether to low or to high lifts), by direct pneumatic pressure, with one frictionless blow, as it were, instead of pumping it in the ordinary way, and thereby causing the iron pistons and valves of the pumps in contact with the sewage to make ten or twenty strokes per minute for one of the ejectors. Drawing No. 3.

The Duke of Westminster, accompanied by Sir Robert Cunliffe, Bart., did me the honour to inspect the experimental works, and both expressed themselves highly pleased with the working of the apparatus.

His Grace, be it said, was characteristically a devout believer in whatever tended to render the dwellings, whether of rich or poor, healthy and sanitary. And I recollect his presiding at a meeting in Chester, when the Rev. Henry Ward Beecher, a very well-known Congregational clergyman, and minister of the Plymouth Church in Brooklyn, delivered a lecture on the "Waste of Life." In the course of this he mentioned that on one occasion he attended the funeral of a friend's child. As often happens in such cases, some of the people began to talk of the mysterious dispensations of Providence in taking away the life of a beautiful healthy child so suddenly and unaccountably. But the minister said that "Providence had nothing whatever to do with the child's death; it was entirely due to there being rotten apples in the house!"

DRAWING No. 3.



REFERENCE:-

TOWN SEWER SHOWN THUS —·—·—

COMPRESSED AIR PIPE - - - - - - - -

EXPERIMENTAL SEWER ————

FIG. 1.

— PLAN —

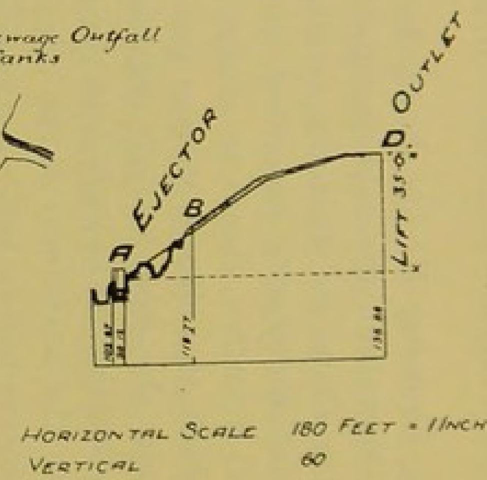


FIG 2

— SECTION —

11. The practical tests described above were carried on at my expense for months, and I had the pleasure of receiving many communications, verbal and written, as to the successful working of this experimental installation, a few of which (together with testimonials from Chicago and Arad) I take the liberty of appending as an addendum.

Glasgow Philosophical Society.

12. The Philosophical Society of Glasgow did me the honour to invite me to read a paper before that Society, which I did on the 26th February, 1880, and which was entitled "Scientific and Sanitary *versus* Unscientific and Unsanitary Sewerage and Drainage, with an Exposition of the New Pneumatic Sewerage System." The paper was well received and discussed, and it was afterwards, with the approval of the Society, reproduced in a modified form and published as a pamphlet by Messrs. E. & F. N. Spon.

Rangoon Works.

12 (*a*). This event had important consequences. The pamphlet fell into the hands of the late Mr. O. D. Clark, the Engineer to the City of Rangoon, who had already in hand a carefully-prepared and well-matured gravitation scheme for the drainage of that town. On perusing my pamphlet, however, he was impressed with the apparent adaptability of such a system to the special circumstances of Rangoon, which is a tide-locked town, practically flat and only a few feet above sea-level. He therefore explained to his Council the advantages possessed by automatic sectional town drainage as compared with ordinary gravitation. The result was that he was deputed by the Municipality to visit England and enquire into the working of the system there. His investigations and reports had the effect of deciding the Council to obtain from my firm, in consultation with him, a project for the drainage of Rangoon on the Shone System. Accordingly the necessary preliminary plans and drawings, together with a report and estimates, were prepared by my firm and in due course submitted to the Municipality, and these were, with some slight alterations, approved by that body and by the Local Government of India.

The estimated cost of the scheme was £187,035 ; but the eventual cost incurred was £175,000, the contractors being Messrs. Hughes and Lancaster.

Rangoon Works opened by the Prince Albert Victor.

A section of the works was formally opened on the 23rd December, 1889, by the late Prince Albert Victor, amidst rejoicings on the part of the Burmese people generally, and of the European and other inhabitants of Rangoon in particular. I must not omit to state here that my partner, Mr. Ault, was really the responsible Executive Engineer in charge of the whole of the works during their construction; and that he did his work well is evidenced by the fact that when, in 1905, new drainage and water-supply extensions became imperative, and were decided upon, he was selected by the Municipality to be the "Special Engineer" to design them. These latter involved the making provision for the drainage and water-supply for quite half a million more people than were provided for in our original drainage project; and therefore the designing, planning, specifying and estimating the cost of such works necessitated much study and hard work and occupied over three years of Mr. Ault's personal time and attendance in Rangoon.

It may be truly said that the adoption of the Shone System of town drainage in Rangoon in 1889 brought about a revolution in the art and science of sewage drainage in the East.

In other words, by the adoption of the system in the chief commercial town in Burma—thanks to the truly progressive spirit and sanitary engineering enterprise of the Rangoon Municipality and the Local Government of India, which were energetically backed by the late Secretary to the Rangoon Municipality, Mr. John Short—the policy of designing and constructing defectively graded and unnecessarily large and costly insanitary sewers of deposit in flat districts, especially in India, was put an end to, as I believe, for all time.

Rangoon, Karachi, and Bombay.

The successful working of the system in Rangoon attracted the attention of the Karachi and Bombay and other Indian Municipalities, and in due course, after consultation with my firm, these municipalities adopted carefully prepared drainage schemes on the system, after such schemes had been approved of by us.

12 (*b*). The preliminary drawings, relating to the first Karachi installation were taken in hand in 1890, but the works, which included six separate ejector stations, were not completed till the beginning of 1895, the Engineer being Mr. James Strachan, C.I.E., M.Inst. C.E., who prepared an interesting paper descriptive of the works for the Institution of Civil Engineers, which was published in Vol. CXXXV. of the "Proceedings." Mr. Strachan designed a second installation on the system before he left Karachi, but as he did not return there, his successor, Mr. James Forrest Brunton, M.Inst.C.E., designed and carried out new extension works on lines similar to those which Mr. Strachan before he left thought were suited to the growing wants of Karachi.

Mr. Brunton also prepared a paper headed "Notes on the Working of the Shone System of Sewerage at Karachi," which was read and discussed at the Institution of Civil Engineers on the 24th January, 1905, which appears in Vol. CLX. of the "Proceedings" of the Institution, and which elicited highly interesting and instructive discussions and correspondence. Mr. Strachan in his written communication commenting on the paper complimented its author as follows: "Mr. Brunton was deserving of the thanks of all sanitary engineers who wished to understand both the practical and the scientific aspect of the Shone System." And the report of the introductory remarks in Mr. Strachan's communication were especially gratifying to me personally, as they read as follows:—

Mr. James Strachan stated that the efficiency-tests which he had caused to be made when he was the Municipal Engineer of Karachi had been very carefully conducted, and that to the best of his knowledge the results were correct. Before advising the adoption of the Shone System in Karachi he had made numerous inquiries as to its mechanical and sanitary efficiency; and this at a time when, as he believed, its merits for water-borne sewerage on sanitary principles were largely under-estimated, and when sanitary engineers who had no practical knowledge or experience of the working of the system alleged that the mechanical efficiencies of the ejector apparatus and their accessories were absurdly low compared with high-class pumping machinery. Then, as now, some engineers were in favour of substituting hydraulic, electric or vacuum power for town and district **Mr. Strachan.**

sectional sewerage works, adhering, however, to the Shone automatic principle. But he had believed then, and still did so, that the compressed-air method, as utilized in the Shone System, if only the works were correctly designed and properly executed and maintained, would always prove to be more economical and better adapted for the automatic and sanitary collection and ejection of sewage within flat or low-lying districts than any of the other systems named.

Visits of Experts to the Wrexham Installation.

On the 19th June, 1879, a meeting of engineers, surveyors, and medical experts and others took place at Wrexham for the purpose of viewing the sewage ejecting works on Colonel Jones's Farm. This meeting was convened under the auspices of Dr. Lory Marsh, and after the inspection, at a large meeting of influential sanitarians held in the Town Hall, the ejector system was, without a dissentient voice, approved of, as may be seen by a reference to the August (1879) number of the "Sanitary Register."

13. Again, on the 21st June, 1879, a district meeting of the Lancashire and Cheshire Association of Municipal and Sanitary Engineers was held in Wrexham under the Presidency of the late Mr. Edward Pritchard, M.Inst.C.E. The works on Colonel Jones's farm were duly inspected and afterwards favourably discussed in the Town Hall by several of the gentlemen who were present, including the President himself, who said, amongst other things :—

"Nothing had been said so far against it, and he was desirous that someone would have raised some abstruse question that would have troubled Mr. Shone, but it appeared to have been so well thought out by him, that, if anything, he had not said quite sufficient in its favour." (*Vide* page 169, Vol. V. of the "Proceedings" of the Association of Municipal and Sanitary Engineers.)

Drainage of Eastbourne on the "Shone" System.

14. In 1880, the experimental works at Wrexham were also inspected by the late Duke of Devonshire's engineering agent at Eastbourne, the late Mr. George A. Wallis, J.P., M.Inst.C.E., who was afterwards the first and the second Mayor of Eastbourne ; by the late Duke's architect, the late Mr. Henry Currey, F.R.I.B.A., and by the then Surveyor of the Local Board of Eastbourne, the late Mr. Charles Tomes, C.E.

15. The visit to Wrexham of the gentlemen named resulted in my being officially requested to prepare a scheme for dealing with the sewage difficulties existing in Eastbourne at that time, in consequence of the main sea outfall sewers failing to discharge either the dry or the wet weather flow of sewage into the sea at all stages of the tides. The first scheme I submitted was adopted. It was one for ejecting 1250 gallons of sewage per minute as a maximum into the sea during high-water spring tides, and I was appointed the engineer to carry it out. The works, after completion, gave so much satisfaction that a second installation, for the drainage of the Devonshire Park property, was decided upon, and executed at the late Duke of Devonshire's expense. The ejector station in Devonshire Park is over two miles distant from the power station. After the first ejector station had continued to work satisfactorily for some time, the question frequently mooted in those days among municipal surveyors, engineers, and others, as to the feasibility of transporting compressed-air power to long distances, without any appreciable loss, was satisfactorily answered in a thoroughly practical manner. From time to time additional ejector stations were added in Eastbourne, and it is no exaggeration to say that thousands of people from all parts of the world, interested professionally and otherwise in sanitary science, have visited that celebrated seaside resort expressly to inspect them.

Compressed Air in Operation.

16. The successful working of the Eastbourne installation attracted the attention of Medical Officers of Health, Municipal Engineers and Surveyors, and Mechanical and Sanitary Engineers. They were enabled to witness for the first time air-compressing machinery doing its work of creating motive power, the field of operation of which was at a distance of 11,200 ft., or 2 miles 213 yards. Three Shone ejectors, at that distance from the air-compressing station, were automatically filled with crude sewage from the gravitation outfall sewer on the town side of the ejectors. Whenever the level of the tide prevented the free flow of sewage by gravitation into the sea, it was diverted into the ejectors by a hand-worked penstock.

These ejectors were designed to receive and eject automatically a maximum quantity of 1250 gallons per minute when high-water spring tides prevailed ; and this they accomplished and more, as was proved by actual tests, to the entire satisfaction of everyone concerned. This latter fact cannot be better evidenced than by stating that to meet the requirements of the increased, and increasing, population additional ejector stations and further air-compressing machinery have been from time to time provided at Eastbourne.

Pneumatic Table E.

17. Now, although when the ejector system was first started all engineers acquainted with pumping could estimate the efficiency of ordinary steam-pumping machinery, it was not so easy for them to estimate the efficiency of a Shone ejector, as the necessary data for that purpose were not then available to them. This circumstance caused me some trouble and anxiety, and, accordingly, to remove this hindrance to my progress out of the way, I decided to prepare and publish Pneumatic Tables to place in the hands of practical engineers which would enable them to observe the natural phenomena that arise from the compression and expansion of air, and would, at the same time, enable them to measure the mechanical effects of applying air compressed to various pressures ranging from 1 to 100 lb. above the normal pressure of the atmosphere, to the work of ejecting sewage by direct pressure, on the Shone System, or for operating ordinary pumps by compressed air instead of steam, or for operating any other kind of machinery which could be driven or worked by compressed-air power.

The figures in these Tables are based upon the well-known Pneumatic Tables of Professor Thurston, which I had extended and improved by adding to them new and important columns. The latter were carefully revised and further improved, and it is gratifying to me to be able to say that in the form in which they are now presented * they constitute a standard for reference not merely for the uses to which my firm have put them, but, as already stated, in connection also with any other mechanical works or operations involving the use of compressed air. I am very sorry they were not pub-

* See Appx. VII. Table E, page 333.

lished in their present form years ago, as I am sure that the opinions which were so freely expressed to my prejudice at the beginning derogatory to compressed air as a motive power were due to a large extent to imperfect knowledge of it, and to the want of familiarity with the application of it in an ejector, which possesses special advantages over the more common processes of pumping by iron piston work, but which advantages could not of course be understood and appreciated at first. In the operation of an ejector, as will be seen by reference to page 17, the compressed air at its full power is automatically made to force the sewage out of it as fast as it is filled, and the friction involved in the motion backwards and forwards of a heavy piston-pump (making perhaps a score of strokes to get rid of as much liquid as the ejector machinery expels in one movement) is thus avoided and saved by the simple frictionless action of an ejector. The result is that with air compressors of good design and make, an even higher degree of efficiency can often be secured by the aid of ejectors than by the use of the best class of steam-pumps, especially for moderate lifts, such as generally obtain in connection with drainage works designed and carried out on the Shone System.

Being anxious to demonstrate to my friends and others my convictions in this connection, in 1878 Mr. Ault, at my request, prepared drawings of and, in conjunction with Mr. Samuel Williams, the present Engineering Manager of the Brymbo Steel and Iron Co., superintended the construction and manufacture of a small automatic double-acting working model of a water ejector, which was made of brass and copper, and which was manufactured for me by the Brymbo Coal and Iron Co.

18. This model I had fixed on the premises of Pentrefelin House, Wrexham, where I lived at the time, and when working it illustrated the principle upon which sewage could be made to flow out of gravitation drains or sewers into ejectors, and forced out therefrom automatically by compressed air applied direct, in the manner described and illustrated in the print copies of the Letters Patent granted to me.

A practical proof of the Efficiency of Compressed Air.

19. But before I had the model made and set to work as explained above, some of my most intimate and valued engineering friends and others in and around Wrexham were doubtful as to whether compressed air could really be depended upon to force water or sewage out of ejectors automatically (whether in small or large quantities) efficiently and economically in the manner originally outlined by me; it then occurred to me that the best thing I could do to convince them that I was right was to demonstrate to them in a thoroughly practical manner the principle upon which it was proposed to discharge sewage into, and to use compressed air to force it out of air-tight cylinders, which are now known by the name of Shone Ejectors, and with this object in view I approached my late friend, Mr. James Sparrow, the proprietor of the Frood Collieries and Iron Furnaces, at whose works air-compressing machinery on a large scale was employed for operating underground hauling and pumping machinery. I asked him to allow me to demonstrate the groundlessness of the views just referred to. He at once acquiesced, and one Saturday afternoon, when there was no work going on, I had one of the large compressed-air receivers, which was used in connection with the air-compressors of the colliery, filled with water. Then a special one-inch wrought-iron pipe was coupled up to a tap of the same bore which was fixed at the bottom of the air receiver to let water condensed in it out of it; and that new special pipe was led up along one arm or side of the wooden pit frame until it reached the shaft of the winding pulley, at which point it terminated in a sharp curved bend. Directly the air receiver was filled with water the compressed air was turned on, and immediately afterwards a copious stream jutted out with great force from the outlet end of the wrought-iron delivery pipe, and it continued to flow out of it until the whole charge of water in the receiver had been ejected, much to the amazement of a few pessimistic friends and others, but to the entire satisfaction of the majority of those present, including Mr. Sparrow and his staff.

20. Apropos of the questions raised at the outset by some

of my friends and others, as stated above, with regard to the economy and efficiency of the then proposed compressed-air water and sewage ejector system, I may mention here the fact that one of the first important installations that was carried out on the system was at Warrington, where two ejector stations, 361 ft. apart, were sunk and successfully worked in what is known as the Latchford District.

The air produced to work them was and is compressed by compressors driven by steam generated in boilers placed at the Warrington Gas Works, which are 3,072 ft. from No. 1, and 5,796 ft. distant from No. 2 Ejector Station. The sewage of No. 2 is lifted over the Latchford Black Bear Bridge to the head of a gravitation sewer, which carries it to No. 1 Ejector Station, and the latter in turn lifts it with other sewage into one of the old Warrington gravitation sewers, which conveys it to its final destination.

The ejecting power parts of these works were severely and absurdly criticized at one of the meetings of the British Association before they were properly completed ; and one of the critics, whose name was not revealed by his confederate—the speaker at the meeting—was referred to as being "the highest" engineering "authority" on compressed-air power, who had arrived at the conclusion, from data alleged to be reliable, that the efficiency of the Shone ejecting plant as applied at Warrington was only 20 per cent. !

Subsequently, however, the confederate of the nameless "highest authority" said this was wrong, as it was only 18 per cent. !

In giving the information by which he arrived at this conclusion he at the same time furnished data which enabled me to calculate from it, on the assumption that his data were right, the real efficiency of the Warrington ejector plant, which I found to be 4½ per cent. only, not 18 per cent. !

The alleged reliable data upon which the so-called "highest authority" on compressed-air power based his estimate of the efficiency of the Warrington ejectors were to the effect that air compressed to 27 lb. above the normal atmospheric pressure of 14·7 lb. per square inch—which is sufficient to force water or sewage to a height, according to Table D, of 62·29 ft.—

was used to eject sewage to a height of 13 ft. 9 in. out of the Latchford ejector, fixed in No. 1 Ejector Station! Whereas, according to the testimony of the Borough Surveyor, Mr. Thomas Longdin, C.E., the air pressure required and used for the purpose was only 6 lb. per square inch. For the public to be told, therefore, in effect, as it was told at a meeting of the British Association, that at Warrington, owing to the employment of a "Shone Ejector," four-and-a-half times more power was used than would be required were ordinary steam pumps substituted for it was, to say the least, on the score of cost, calculated greatly to prejudice the public Sanitary Authorities of this country, and especially their Municipal Surveyors and Engineers and Medical Officers of Health, against the introduction of automatic collectors and ejectors of sewage for the improvement of the existing "English Water-carriage Plans of Sewage removal."

That the eminent engineer who condemned Mr. Longdin's Warrington installation was as sincere as he was confident he was right in what he said must be taken for granted, otherwise he would not have been so indiscreet as to tell the British Association, possibly in the hearing of some of the members of the Corporation of Warrington, that "the man who had laid the ejectors down at Latchford would be glad very soon to remove them."

The Latchford installation was carried out in 1882, over thirty years ago, and they are working to-day as satisfactorily as they did when they were first started, and I prophesy that they will continue so to do as long as the iron of which the ejectors, etc., are made will last, and that may be 100 years or more! So far from slackening in his appreciation of and interest in ejectors by the misleading pronouncements of the eminent civil engineer in question before the British Association, Mr. Longdin actually recommended his Corporation to use ejectors for discharging the contents of the pails that were then and are still used in Warrington for the collection of household wastes on what is known as the "Pail System"; and his recommendations were adopted, with the result that by the establishment of only two ejector depôts, to which the pail contents were carted or waggoned, instead of being carted or waggoned to *one* depot outfall point, where the contents of the whole of the pails were converted into pouderette, a net saving at the rate of nearly £2,000 per annum was effected in cartage cost alone; and as the pail stuff was discharged from the two ejector depôts to the one original outfall depot through iron pipes laid like water-pipes under the streets, the nuisances which arose previously from the cartage of the pail materials through the streets, and which were bitterly complained of at times, but which were said to be unavoidable in practice, were done away with entirely.

20 (*a*). By way of still further emphasizing the untenable character of the unconscionable attacks referred to above and which were made at a critical period in the career of the Shone System—when, in fact, it was practically in its infancy—I beg to reproduce here a copy of a Report which was written by Professor Cawthorn Unwin, F.R.S., M.Inst.C.E., and published some years after the Warrington installation in connection with the drainage of Calcutta :— **Prof. W. C. Unwin on Compressed Air.**

"There are three ways in which the necessary pumping at Stations 1, 2 and 3 can be effected: (1) By separate steam pumping stations; (2) by a central station and electrical transmission of power to the other stations; (3) by a central station and transmission of power to the other stations by compressed air."

Professor Unwin considers each of these methods in detail as to efficiency, convenience, and cost, and comes to this conclusion :—

"I have no doubt at all that for the purpose in view compressed air transmission is cheaper in first cost and cheaper in working than any other mode of transmission. It has also the advantage that it involves only very simple and well-understood mechanical arrangements."

He continues thus :—

"If compressed air is used, two systems are available :—

"(1). *The Shone System.*—In this system air is compressed at a central station by a steam compressor at comparatively low pressure. The compressed air is transmitted by mains to the working point, and there actuates one or more sewage ejectors. The ejectors serve a double purpose. They are reservoirs for collecting sewage, and at

D

the same time they constitute a simple pumping arrangement, without any working parts except a float and a couple of valves. When an ejector is full, it starts into action automatically and pumps the sewage.

"(2). In the system proposed by Mr. Hughes there is a steam compressor at the central station working compound at comparatively high pressure. The air is transmitted in mains and actuates motors which are in hardly any respect different mechanically from ordinary non-condensing steam engines. These motors drive directly centrifugal pumps. To add to the efficiency of the arrangement, Mr. Hughes proposes to reheat the air in a simple reheating stove before use in the motors. This reheating is necessary if much advantage is to be taken of the economy due to expansive working of the compressed air.

"No doubt the second system can be made most efficient or economical of power, and there is no reason why such a system should not work satisfactorily. The motors are quite simple, and would require less attention than an ordinary non-condensing steam engine.

"At the same time, more attendance would be required with system (2) than with system (1), and the amount of machinery required is greater. Looking to the very variably intermittent character of the work to be done in sewage pumping, the automatic action of system (1) seems to me to have advantages large enough to counterbalance a loss of efficiency (waste of power), which in any case I do not think would be considerable. With the Shone System the sub-station would not really require any attendance in ordinary working. The ejectors fill and empty automatically, and in case of choking of a valve an ejector can be put out of action for examination, and the others would at once take up the work. My advice, therefore, is that an estimate should be obtained from Messrs. Hughes and Lancaster for the application of the Shone System to Calcutta."*

Houses of Parliament.

21. Prior to the year 1886 there had been many loud and bitter complaints made by members of both Houses of Parliament with regard to foul and noxious odours in and about the precincts of Westminster Palace. Several successive Committees were appointed to investigate the causes of these nuisances with the view to providing a remedy for them, but

* Mr. A. E. Collins, M.Inst.C.E., City Engineer of Norwich, has repeatedly stated to me that he has had more trouble with their one steam pumping station than with the whole of the seven Shone ejector stations installed in Norwich, with ejectors in duplicate in each.—I.S.

the results were wholly unsatisfactory. At length the evil became so intolerable that on the motion of the late Lord Randolph Churchill another Special Committee was appointed in March 1886 to inquire into the state of the ventilation and the drainage of the Houses of Parliament. This Committee was presided over by Sir Henry Roscoe, and after hearing and considering evidence as to the drainage of the Houses, they recommended the adoption of the Shone System, and I was honoured by the then First Commissioner of Works, the Earl of Elgin, with instructions to design and superintend the new drainage works, which were completed and started at the end of 1886, and have continued to work satisfactorily to this day.

After the drainage works had been in operation at the Houses of Parliament for about five years, another Select Committee was appointed in June 1891 to inquire into the ventilation of the House. The report of this Committee, printed on July 24, 1891, contains the following paragraph:—

22. "The Committee also took evidence as to the system of drainage of the Houses of Parliament which was established in pursuance of the Report of the Select Committee on the Ventilation of the House in 1886, and they find that the system works satisfactorily. The Committee are satisfied that the connection between the Houses of Parliament sewers and the Metropolitan main low-level sewer is so constructed that no backwater or return of sewage, or of sewer gases from the Metropolitan sewer, can enter those of the Houses of Parliament; and the Committee are convinced that no offensive smells or injurious emanations now proceed from the drainage system of the Houses of Parliament, which they are of opinion is as perfect as possible."

Condition of Drainage System up to 1886.

23. Before the improved drainage works of the Houses of Parliament were carried out, the main sewer of the buildings was practically in direct communication with the Metropolitan main sewer, which ran under part of the Westminster Bridge Road and the Thames Embankment. The invert of the Palace sewer where it debouched into the Metropolitan sewer

was about 2 ft. above the invert of the latter, which is 8 ft. in diameter.* The Palace sewer was egg-shaped, and its crown dovetailed into the crown of the Metropolitan sewer, so that when a very small amount of rain fell the waters soon rose to and above the crown of both sewers, with the result that the foul air in the big main sewer of the Palace was forced out of it, as was alleged at the time, into the precincts and environments of the Houses of Parliament.†

Drawing No. 4 of Houses of Parliament Ejectors and Station and Description of Working.

In order to stop up or close the open aerial communication that existed between the Metropolitan and the Palace sewer when the new drainage works were planned, a water- and air-tight dam was built in the Palace sewer, near to its junction with the old Metropolitan sewer, which filled it for 8 ft. of its length; it was built partly of brickwork in cement and partly of concrete in cement. In and through this dam two 12-in. cast-iron pipes were inserted; the lower one can be used to discharge the sewage by gravitation (in the event of any accident occurring to the Ejector Plant), and the other, the higher one, is used to discharge the sewage of the Palace into the Metropolitan sewer by pneumatic pressure. Under the Speaker's Green an Ejector Station was constructed (as per block Drawing No. 4), large enough to hold three Shone Ejectors, one of 500 and two of 350 gallons capacity each. The station was sunk deep enough to permit the sewage of the Palace to flow freely through iron gravitation pipes direct into the ejectors, which, when filled, automatically discharge the sewage into the Metropolitan sewer through a 12 in. cast-iron delivery pipe—which is common to all three ejectors. A short length of the 12-in. delivery main was inserted in the dam, and its outlet is well above the normal level of the dry weather flow of sewage in the Metropolitan low-level sewer. The invert of the latter, at the point where it receives the Palace sewage, is 5 ft. below Ordnance datum, and consequently its crown is 3 ft. above O.D. The normal level of the sewage in the sewer was 1 ft. below O.D. On December 15, 1886, owing to heavy rainfall, the waters in the Metropolitan sewer rose to a height of 9 ft. above O.D., or over 6 ft. above the

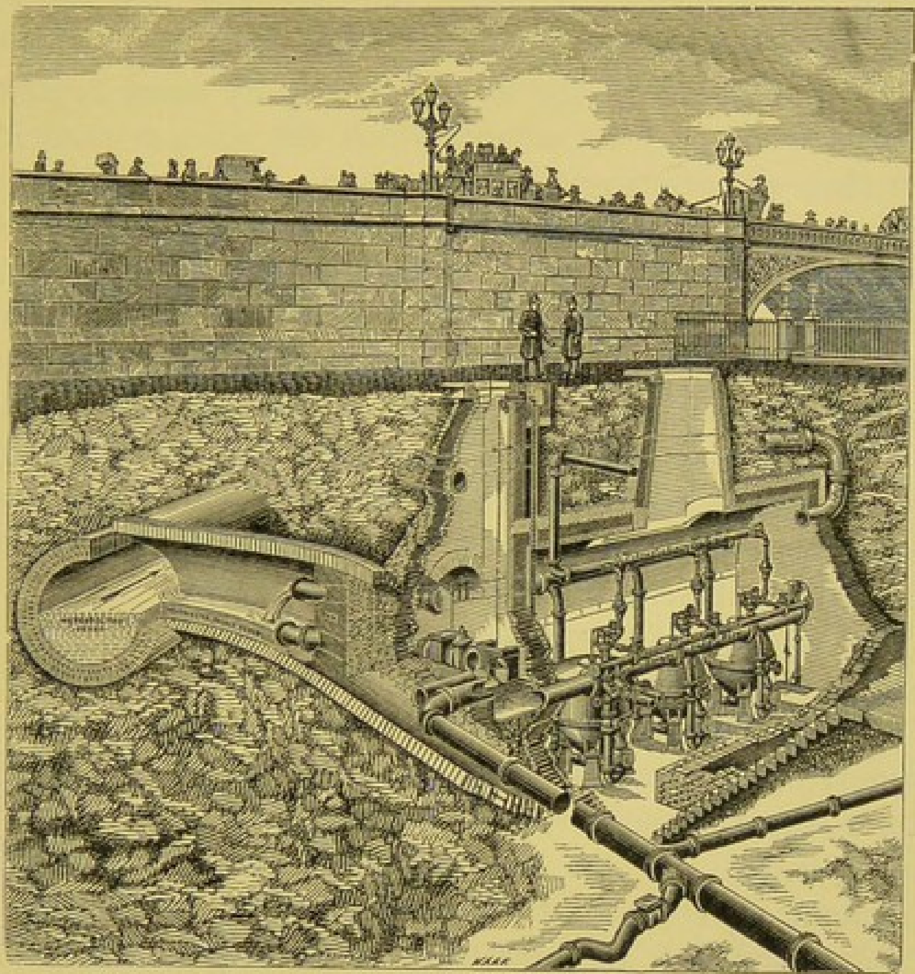
* *Vide* Drawing No. 4.

† *Vide* explanation on Plate I., Drawing No. 4A, which faces page 38.

crown of the sewer, and about 7 ft. above the outlet end of the 12-in. cast-iron pressure delivery pipe of the Palace sewer.

With a head of water, therefore, equal to nearly 10 ft. above the level of the normal flow of sewage in the Metro-

DRAWING No. 4.



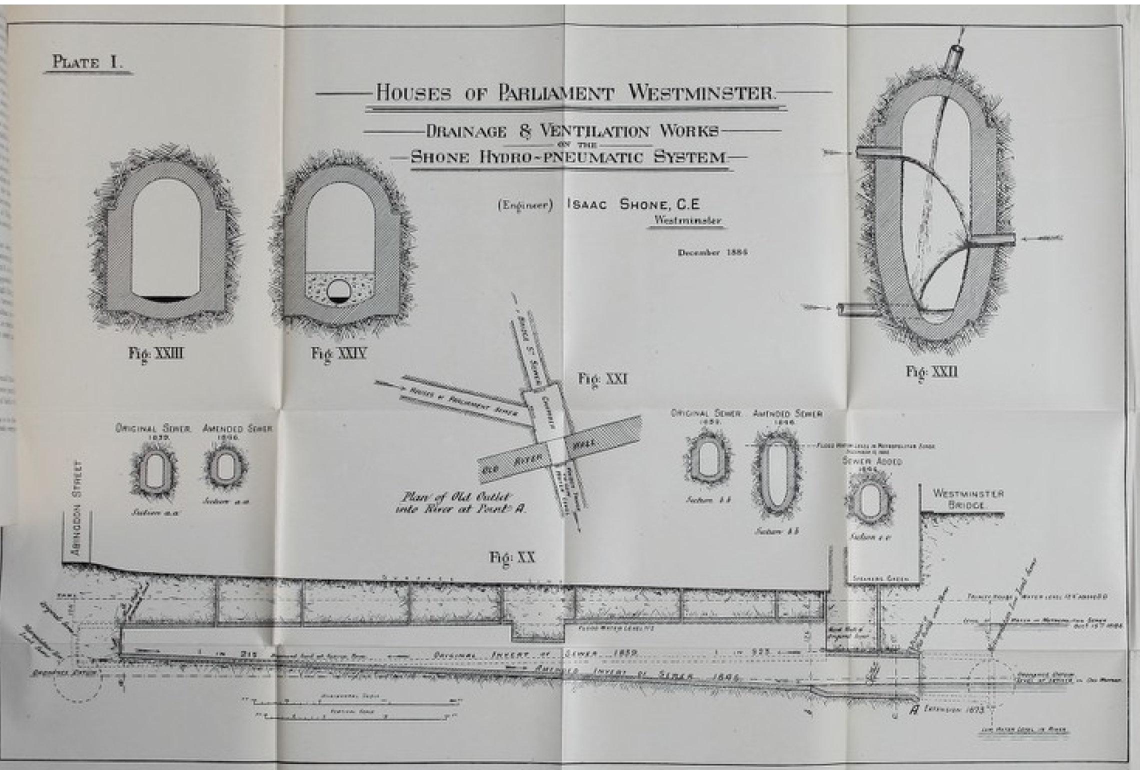
DRAINAGE OF THE HOUSES OF PARLIAMENT: EJECTOR STATION UNDER THE SPEAKER'S GREEN, WITH SHONE EJECTORS.

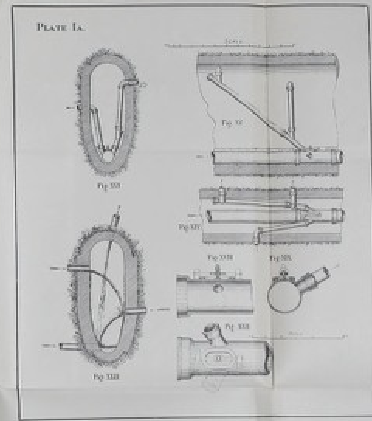
politan sewer, the Palace old sewers were flooded, and consequently, as fast as the storm waters inundated them, so fast was the foul air within them forced out of them into the precincts and immediate environments of the Houses of Parliament. By the adoption of the Shone Ejector System however, the whole of the sewage and rainfall of the Palace buildings was made to flow down the Palace sewers freely in dry and wet weather alike to the ejector station under the Speaker's Green ; and as fast or as slowly as the waters fill the ejectors, so fast or so slowly they are ejected out of them into the Metropolitan sewer. The extraordinarily precarious conditions under which both sewage and rainfall are received and discharged may be gathered from the fact that the dry weather flow of sewage from the Palace sewers, when both Houses of Parliament are in session, is only equal to about one-twelfth of the total volume which the ejectors can eject when they are discharging sewage and rainfall combined, up to the maximum power of the steam-driven air compressors, which supply the compressed air required to work them. The compressors were at first driven by coal-gas, but are now worked by steam generated in large boilers, which are fixed in a central part of the basement of the building. These boilers also supply steam for various other purposes connected with the requirements of the Houses of Parliament. They and the compressors are over 200 yards away from the ejector station under the Speaker's Green.

The Houses of Parliament ejectors form a permanent sewage-gas water seal or trap, as between the Palace and the Metropolitan sewers, which is 12 ft. in depth, and, accordingly, the Select Committee appointed to investigate matters stated in their report of the 24th July, 1891, that they were "satisfied that the connection between the Houses of Parliament sewers and the Metropolitan low level sewer is so constructed that no back water, or return of sewage, or of sewer gases from the Metropolitan sewer can enter those of the Houses of Parliament."*

24. It may be interesting to recall that in 1897, after the system had been at work for eleven years, Dr. Farquharson, M.P., who had been a member of both of the Select Com-

* The SHONE EJECTORS thus became at the Houses of Parliament the largest and most perfect ventilated Hydraulic sewage-gas interceptor traps in the world.





THE INTERIOR OF THE SHONE EJECTOR STATION, AT THE HOUSES OF PARLIAMENT.

REFERENCES TO, OR EXPLANATIONS OF DRAWING No. 4.

☛ The figured drawings on Plates I and Ia are copies of what appeared in a booklet descriptive of the Houses of Parliament main drainage works, written by the Engineer and published in September 1887, and presented by him to each Member of both Houses of Parliament (House of Commons and House of Lords).

Plate I is an historical and technically valuable document, as it was drawn with the assistance and co-operation of the late Mr. John Phillips, C.E., whose knowledge and experience of the Westminster sewers enabled him to advise the Architect of the Houses of Parliament (Sir Charles Barry) to amend the sewers in the manner shown on the longitudinal section (Fig. XX), which shows, amongst other things, that in 1839 the head, or upper end of the original main sewer, was at the northern, and not at the southern end of the Houses of Parliament, and that its invert was then laid at a gradient of 1 in 923. But in 1846 the direction of its invert was reversed, and its gradient was amended at the same time, and made to be 1 in 215. Moreover, in 1873, an additional piece was added to the sewer at its bottom end as indicated on the section. These alterations account for what might be called the phenomenal want of uniformity in the transverse sections of the sewer (shown above, Fig. XXI) after it was amended in 1846. This latter section viewed in conjunction with the transverse section of the tall elliptical piece of sewer headed "Amended Sewer 1846," and marked at the foot section c.c., will show the reader that when the metropolitan sewer was flooded on December 15, 1886, to the extent indicated on the longitudinal section, the water must then have risen in the main sewer of the Houses of Parliament to the level marked Flood-water Level on the amended 1846 sewer, and of course during that interval of time, all the drains debouching into the Houses of Parliament main sewer, below that level line would be flooded with the metropolitan sewer waters, with the result that the foul septic air of such tributary drains would be forced out of them through their several intercepting traps and the chambers in which they were built, whence it would escape up the Parliament drains and soil pipes, etc., into the Parliament buildings.

The transverse section marked Fig. XXII on Plate I is indicative of the way in which the drainage connections were coupled up to the main sewer of the Houses of Parliament before the new works on the Shone Hydro-pneumatic system were carried out, and the sections, etc., on Plate Ia show how the sewage waters, let loose into the sewer Fig. XXII, were harnessed thereafter by being conducted into small pipes debouching into a 15-in. iron gravitating sewer, laid on the invert of the original main sewer of the Houses of Parliament, as portrayed on Figs. XIV, XV, XVI, XVII, XVIII, and XIX, Plate Ia. The drawing Plate Ib shows a sectional perspective view of a group of 3 Ejectors (one of 500 and two of 100 gallons capacity) and their accessories, as they were fixed in 1886 under the Speaker's Green, which separates the North or Clock Tower side of the Houses of Parliament (as illustrated) from Bridge Street. These Ejectors deal effectively, as clearly stated by Sir Henry Roscoe and the Rt. Hon. R. Farquharson on pages 6-8 of this brochure, with the sewage and rainfall waters of the Houses of Parliament, as fast or as slow as they proceed therefrom, and force them into the Metropolitan sewers always irrespective of the heights, even, whether in fact, the sewage and rainfall waters in those sewers rise up to or above the level to which they attained on December 15th, 1886.

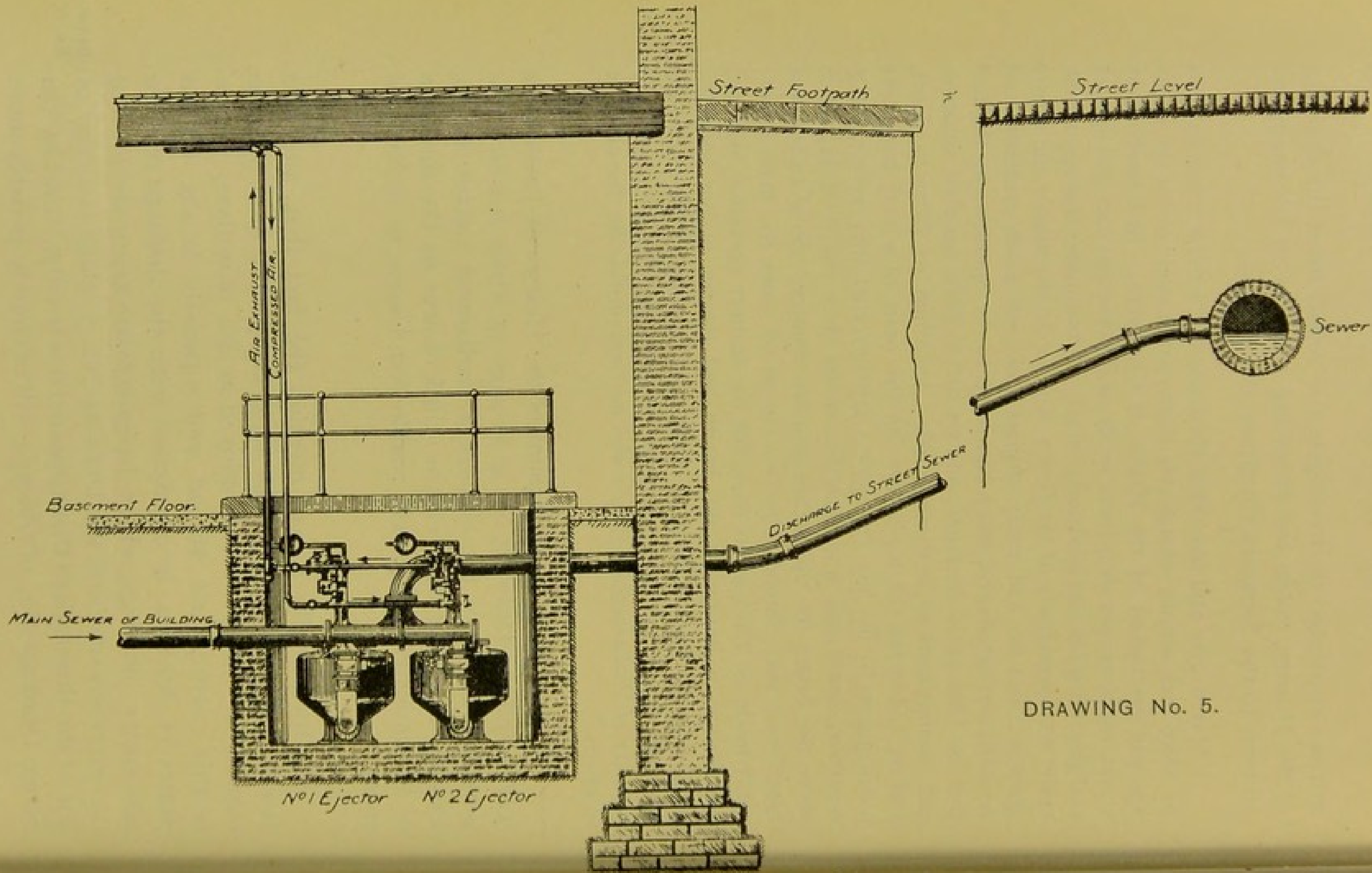
[Face p. 38.

mittees appointed to investigate and report upon the drainage of the Houses, made the following remarks in his inaugural address to the Sanitary Congress at Leeds :—

"May I give you one other illustration? I think it was in 1884 or 1885 that serious complaints began to be made about the drainage and ventilation of the House of Commons. Bad smells were about, members got sleepy and seedy, and influenza came and spread, and grumbling became loud and general. A committee was appointed, under the presidency of Sir Henry Roscoe, to investigate the whole question, and we had many sittings and took much evidence, and rambled through drains, much hampered in our operation by the fact that no plan could be found, and we had to trace out their situation and arrangement as best we could. And then we came to report, and we had to tell the legislators, on the basis of a very important investigation by the late Professor Carnelley, that they were actually breathing sewer gas, and that the sooner they put their House in order the better for themselves and the country. So £10,000 was voted *nem. con.*, Shone's Ejectors cut us off from the main sewer; and I made so bold as to claim for the sanitary operation, national importance in improving the health and temper of our senators, enhancing the quality of their work, and leading to the increased efficiency of our public departments by increasing the administrative capacity of Parliamentary chiefs who are responsible for the conduct of affairs."

The foregoing brief account of the Houses of Parliament works, and the Drawing No. 4, on page 37, which is a sectional perspective view of the Houses of Parliament ejector station, looking from the base of the clock tower in the direction of Westminster Bridge, will enable you, I hope, to understand them.

25. Incidentally I may mention the fact that, after the Houses of Parliament works were completed, quite a large number of ejectors were employed in lieu of ordinary pumps in this country and abroad, and especially in the United States of America, in connection with the drainage of large and costly buildings, whose basements are below the level of the street sewers ; and the Drawing No. 5, which is a copy of **Drawing No. 5.** one of the illustrations that appeared in a booklet issued by the Shone Drainage Co., of Chicago, will exemplify possibly more


Street Footpath
Street Level
Sewer
Air Exhaust
Compressed Air.
Basement Floor.
Main Sewer of Building
Discharge to Street Sewer
No 1 Ejector
No 2 Ejector

DRAWING No. 5.

clearly than Drawing No. 4 does the special practical usefulness of ejectors for the speedy and cleanly collection of the sewage and rainfall of basements, and the equally speedy, cleanly, and automatic ejection of the same therefrom to the public sewers.*

I am indebted to Mr. Urban H. Broughton, C.E., the consulting and executive engineer to the above-named company, for the original drawing, of which No. 5 is a copy.

I may add that early in 1887 I published, through Messrs. E. & F. N. Spon, a *brochure* containing full descriptive matter, illustrated with diagrams and drawings of the leading details of the works, and containing also the Hydraulic Table referred to on page 19. Copies of this were presented to each of the Members of both Houses of Parliament.

The installation, being in the most important building in the British Empire, was extensively, and, I am proud to say, favourably noticed in the public press; and ever since, with the official permission of H.M. First Commissioner of Works, given by ticket, they have been from time to time visited and inspected by thousands of engineers and scientific sanitary experts hailing from all parts of the world.

26. As another illustration of the working of the Shone System, I propose here to explain briefly its adoption and installation at Hampton-on-Thames.

The habitable district within the jurisdiction of the Hampton Urban District Council covers a large area.

An inspection of these lands, on which the houses to be comprised in a sewerage scheme were built and those intended to be subsequently built were situated, showed that they were to a great extent low-lying, unwieldy, and more or less water-logged. It was therefore obviously impossible to drain the district satisfactorily to a single outfall by gravitation alone.

Accordingly the then Local Board decided to adopt the

* In the Houses of Parliament station a glass working model of a Shone ejector was fixed, which is there still, and which has proved an excellent exhibit in assisting thousands of spectators who have witnessed its action to appreciate the simplicity of the working parts of the apparatus.

Shone System, and my firm, in conjunction with the District Surveyor, Mr. J. Kemp, were instructed to design the scheme, and the same was duly submitted and adopted, and in due course received the approval and sanction of the Local Government Board.

The district was divided up into eight sections, in each of which ejector stations in duplicate were provided; and the single compressed-air power station, by which the ejectors were to be worked, was located on the outfall land near where the bacterial beds and the hydrolytic tank now stand, at a distance of 12,500 feet, or over $2\frac{1}{4}$ miles from Hampton Court, where ejector station No. 1 was placed.

The sewers in this drainage scheme are ventilated by the exhaust air from the ejectors in the manner described hereafter.*

It was originally intended to treat or purify the sewage ejected from the various drainage sections or units to the outfall on what was called the "International" System.

That intention, however, was abandoned for the following reason. The "International" System had been in use at Henley-on-Thames for some time, the designs adapted to it having been carried out by my firm at the instance of the Corporation of that Borough. It must at once be fairly admitted that for some time the "International" tanks did their work on the whole without more than what may be called under the circumstances the unavoidable minimum of nuisance. But as time went on they emitted offensive emanations which rapidly became aggravated, and gave dire offence to passers-by along the neighbouring highway, and to many of the residents in the vicinity.

The "International" System having thus failed to give satisfaction at Henley, I considered it my duty to acquaint the Hampton District Council, through their Surveyor, Mr. J. Kemp, C.E., of that fact, and thereupon, as recommended by my firm, a special committee was appointed by the Hampton District Council to accompany their Surveyor on a visit of inspection to the sewage-treatment works at Henley,

* *Infra*, page 47.

as well as to other sewage outfall works. The "International" System for Hampton was thereafter abandoned in favour of what was then called the Dibdin Bacterial Tank treatment. The latter system had been in operation for some time at Sutton before the Hampton Deputation inspected the works there on that system ; and as its influential promoters and advocates declared it to be in every way a most efficient and perfect system, which was in fact declared to be the final solution of the problem of sewage purification, the Hampton Council finally elected to adopt it in lieu of the "International" System.

27. Accordingly my firm, in consultation with Mr. Dibdin and Mr. Kemp, designed triple bacterial beds on the Dibdin system, and these were in due course erected and set to work at Hampton, where they consistently for a considerable time produced satisfactory effluents, as was acknowledged by a large number of home and foreign engineering experts and others who inspected them in operation from time to time.

On the 6th of October, 1900, a paper was read by Mr. Kemp before the Association of Municipal and County Engineers at Hampton-on-Thames "On Sewerage and Sewage Disposal Works," in which he gave a concise account of the working of the bacterial bed system up to that date.

Unfortunately for the bacterial tank methods, as they turned out at Hampton, difficulties neither prophesied nor foreseen soon presented themselves. It was found that the beds were wholly unable to deal with the quantity of sludge placed upon them, but fortunately Mr. Tom Hughes, the manager of the sewage-treatment works there, devised means for arresting sludge and preventing much of it from entering the beds. In fact it was largely due to his practical and intelligent and attentive management that these beds had been able to deal with a strong sewage for something like six years. But as time went on the clogging of the beds increased, and their liquid capacity diminished, until at length the burden of removing the sludge by expensive and offensive manual labour became almost intolerable, and it was seen that some means must be adopted of preliminary treatment.

The object to be aimed at was to pass the crude sewage after being so screened as to be freed from extraneous solid matters, through a sedimentary medium, so as to give the sludge time to settle and be deposited before the effluent liquids were subjected to the treatment of the bacterial beds. With this view, my firm, in consultation with Mr. S. H. Chambers, the present engineer, were asked to advise the District Council. We recommended, with the full assent and approval of Mr. Chambers, that a sedimentary tank should be installed ; and it was an essential feature of this scheme that the tank should be ventilated by hydro-mechanical power, on the identical principle on which the present Hydrolytic Tank is now ventilated, as hereafter described. The plan so recommended was approved by the Council and the tank was accordingly designed, with its ventilating apparatus as just stated, and shown on Drawing No. 6.

Before, however, anything further was actually done, attention was drawn to the new Hydrolytic Tank, which had been designed by Dr. W. O. Travis in conjunction with my partner Mr. Ault, and patented in their joint names ; and as this appeared to present great advantages over an ordinary sedimentary tank, without involving any substantial alterations of principle, or any appreciable increase of expense, the District Council decided to adopt it. The working and ventilation of the Tank are described in Appendix II.*

The downfall of the Bacterial Bed System at Hampton is an eloquent and edifying lesson of the futility of optimism on practical matters until they have been subjected to long and varied tests and trials. It was introduced with every confidence in its infallible and unerring success. All that was deemed necessary was to thoroughly screen the crude material so as to eliminate extraneous matters. The residue was then to be committed to the bacterial beds ; whereupon countless myriads of microbes would come into existence and would devour every particle of organic matter, leaving an effluent practically pure and harmless.

The curious student of this subject who wishes to understand the causes of the inadequacy (to use a moderate term)

* *Infra*, page 169.

of the Bacterial Bed System will find interesting and not unprofitable information in the two published papers mentioned on page 171, together with the following powerful and scientific expositions: 1st, a paper entitled "A Retrospect of Six Years' Treatment of Crude Sewage in Triple Contact Beds, and a Forecast,"* by Mr. T. Hughes, Manager of Hampton-on-Thames Sewage Disposal Works, which was read at a meeting of the Association of Managers of Sewage Disposal Works at Hampton-on-Thames on June 17th, 1905; and 2nd, a paper entitled "Some Interpretations of Sewage Purification Phenomena," by Mr. Sidney H. Chambers, Surveyor to the Hampton Urban District Council, read before the Association of Municipal and County Engineers on October 26, 1907.†

28. The hydro-pneumatic system of sewerage having been thus introduced, in order to render its utility as complete and perfect as possible, there yet remained the problem of making provisions for the adequate ventilation of the public sewers and private house drains to which it was and might in course of time be applied. The necessity for this was evident almost from the first, and the fact had to be dealt with that offensive emanations were found to issue from the drains and sewers. The truth is, and the sooner it is acknowledged the better, that save under a combination of fortunate circumstances, such as are hardly ever realized in practice, no system of sewerage under the "Water Carriage" method is immune from these drawbacks. It must be remembered that the total sewage and waste supplies of any one day in any town or district are not a constant quantity. They are the aggregate of contributions originating in single dwellings and other buildings distributed over the whole sewerage area, and obviously the quota of each of these contributing items is relatively insignificant, and some of them have to travel a considerable distance before reaching the main sewers on their way to the outfall. It follows that the most perfect practicable gravitation system, however well its pipes may be adapted in size and gradient to the calculated ultimate

* St. Bride's Press, Ltd., Fleet Street, E.C.

† Proceedings of the Association of M. and C. Engineers, Vol. XXXIV.

volume to be disposed of, cannot be kept free at all times from deposits and their consequent nuisances. These latter, however, can now by the adoption of the Shone Regulated Hydro-mechanical System of Ventilation be so reduced as to be practically negligible.

What the Hydro-pneumatic sewerage system effected was, in its essence, this:—It furnished to the engineer of a town or district whose geographical, geological and other natural features and circumstances would not admit of its being drained by gravitation alone (unless, perchance, at a prohibitive cost), a method whereby the natural disadvantages just mentioned could be completely overcome, and as good a result in the way of the collection and carriage of its sewage and other wastes attained as if none of those disadvantages existed. But in common with the best gravitation system actually existing anywhere, or which could be conceived to exist, it was liable to the invasion of the local nuisances referred to above.

Now at the time when the Hydro-pneumatic System came into existence practically the only ventilation applied to public sewers was through the perforated iron covers of man-holes, the tops of which were at the street level. The object of this arrangement was to admit fresh atmospheric air to pass into the sewers and to permit the foul sewer air to pass out into the atmosphere. It is plain that when the natural forces which were exclusively relied upon to produce these effects were in anything like equilibrium there would be little or no ventilation at all. And where, as was more often than not the case, the sewers were sewers of deposit, the putrescent air from such deposits would permeate and pollute the whole interior of the sewer. Furthermore, the house-drains were then, as now, furnished with interceptor traps which left the whole of the drain on the sewer side of them unventilated, so that whenever house sewage passed through the drain to the sewer further contributions of foul air would be added to that already seething in the sewer. And in this way, so long as the open street-level manhole vents existed, and so long as the effect of the interceptor traps as designed and laid was to aggravate the evil, as above stated, it was impossible to prevent noxious emanations from passing out of even the best laid self-cleansing sewers into the public streets.

29. With a view to remedy these evils, I devised a plan for removing the gases and of ventilating the sewers by means of compressed air passed through specially designed nozzles. By this arrangement vacuums are intermittently formed at the nozzles which have the effect of inducing air-currents to flow into, through and out of the sewer pipes which discharge sewage into the ejectors.

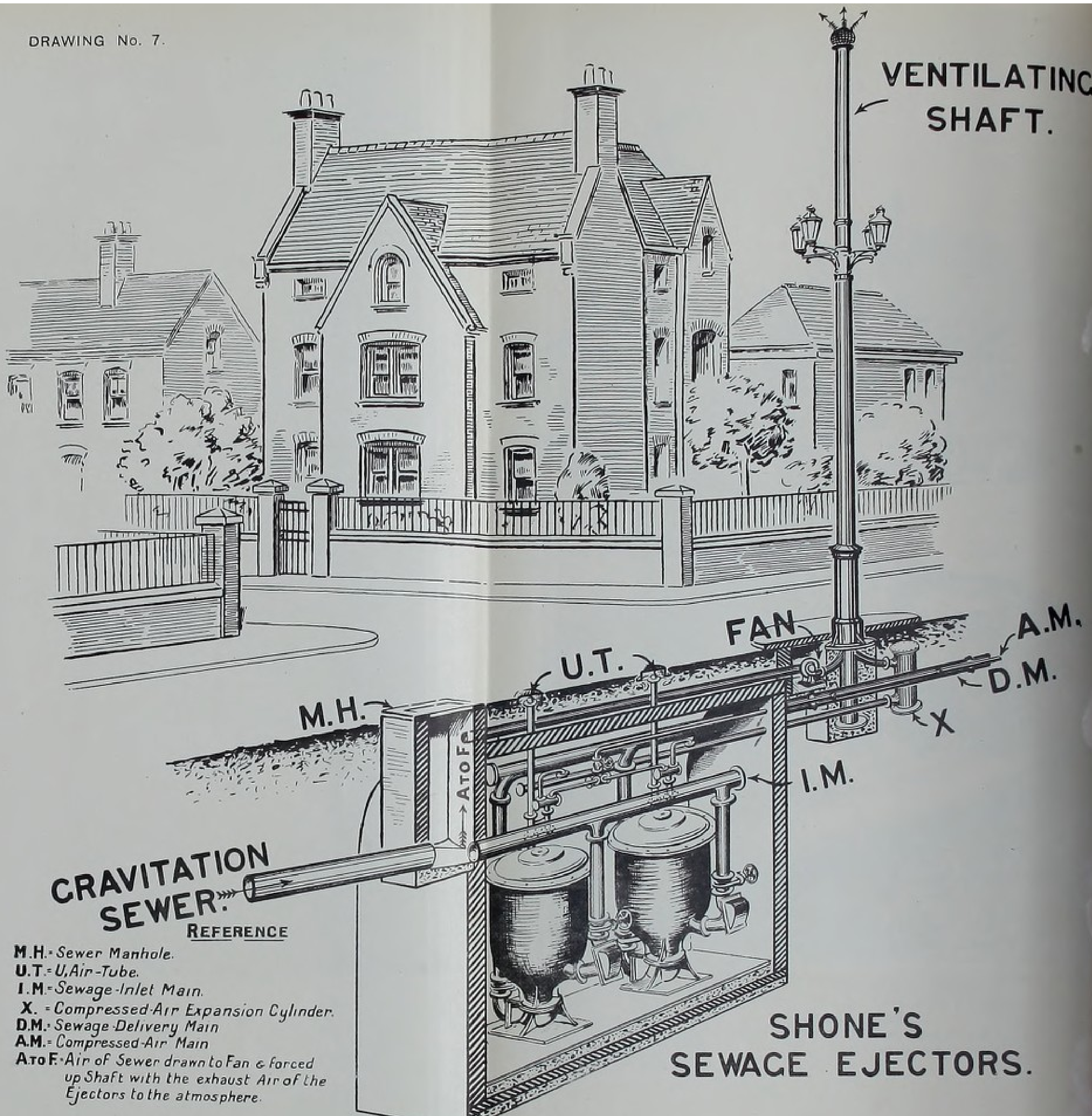
On this plan, therefore, the surplus latent energy stored in the exhaust compressed air, after doing its work of expelling the sewage from the ejectors, is utilized for the purpose of ventilating the sewers.

The system is in use at Wallingford, Henley-on-Thames, Bombay, Hampton-on-Thames, and many other places at home and abroad, and the mode in which it works, e.g., at Henley-on-Thames, will be readily understood by looking at Drawing No. 6, on p. 48, to which proper references are attached. **Drawing No. 6.**

It may be mentioned that originally, especially where the compressed air was under high pressure, there were some complaints that the exit of the exhaust air from the top of the ventilating shaft was accompanied by noise and at times by objectionable odours. We have, however, contrived simple means whereby both these inconveniences are overcome. In fact, I may say that in countries whose climatic conditions are such as obtain in England, the exhaust air plan of sewer ventilation through regulated nozzles when properly designed may now be made to work inexpensively and free from either noise or smell, even when the sewage arriving at the ejector station is only sufficient to keep the ejectors in a state of moderate activity.

30. In addition to the method described above for ventilating sewers by the medium of the exhaust air discharged from ejectors, I suggested in 1888 that the house-drains should be ventilated on the same principle practically. My Patent No. 15203 of 1888 shows by specification and by diagrammatic illustrations a method by which sewers and

DRAWING No. 7.



Face p. 49.]

house-drains and interceptor traps and the drains on both sides of these could be ventilated, either by the medium of the exhaust air from the ejectors (where the Shone Hydro-pneumatic System was in use) or by the direct application of fresh atmospheric air. That patent included special apparatus for ventilating, purifying and disinfecting sewers and drains with various subsidiary devices, which are fully shown and indicated in the diagrams appended to the specification.

Again, my Patent No. 5389 of 1891 had for its object the ventilation of drains and sewers, and the methods prescribed in it for the purpose were fully illustrated by diagrams annexed to the specification.

31. The first occasion of public importance on which I had an opportunity of describing the hydro-mechanical system of sewer and drain ventilation was at the Congress of the Royal Institute of Public Health at Eastbourne in June 1901. The paper I then read was illustrated by various drawings, one being a large cartoon hung on the wall, and substantially the same as the cartoon exhibited at a subsequent meeting of the Institution of Municipal and County Engineers held at Liverpool.

There was, however, this difference. The cartoon used at Eastbourne showed at the lower end of the public sewer and below its invert an ejector station with its ventilating shaft accessories (see Drawing No. 7), but this was left out of the cartoon used at Liverpool, and in its place was shown an underground fan and air-purifying station, on the Hampton principle, as illustrated in Drawing No. 21, opposite page 100. **Drawing No. 7.**

Among the illustrations to my Eastbourne paper were also drawings indicative of the way in which main outfall sewers and their tributaries could be subdivided into as many sections as the exigencies of the sewerage system of each particular town or district demanded, in order to ventilate them all efficiently. A copy of a drawing showing the main underground ventilation and air purification arrangements is that marked No. 8 (opposite to page 50). This drawing is reproduced here for the express purpose of answering engineers who have addressed to me enquiries of the following sort: "How is a sewer to be dealt with if in one or some parts of **Drawing No. 8.**

its length it works fairly well and without causing nuisance, while other parts of the same sewer are insufferably foul?" These eccentricities undoubtedly do occur, especially in old sewers, and the drawing given will suggest to the engineer the most convenient remedy to meet the particular case.

I now pass from what has been mainly historical to the more immediate subject of this letter, and of the several papers which follow it.

Public Health Act, 1875, Sect. 19.

32. For the statutory basis of the sanitary administration now in force in this country we must go to the Public Health Act, 1875 (38 and 39 Vict. chap. 55). Section 19 of that Act provides as follows: "Every local authority shall cause the sewers belonging to them to be constructed, covered, ventilated, and kept so as not to be a nuisance or injurious to health, and to be properly cleaned and emptied." This mandate, though necessarily framed in general terms, is, on the face of it, correctly and exhaustively expressed. And the Legislature, by giving full powers to the Local Government Board to make and issue by-laws in pursuance of the provisions of the Act, laid upon that Department the duty of interpreting that clause, amongst others, in more or less concrete fashion, according to the best engineering and medical skill that could be brought to bear on the matter. The duties thus thrown upon the Board were of the highest responsibility, and, it must be added, of great difficulty.

33. Among the problems which they had thus to solve, the following may be mentioned :—

(*a*) That the processes of flushing and ventilation should be thoroughly efficient, yet should be so conducted as not to cause nuisances in the streets, still less in the houses of the people.

(*b*) That quantities of subsoil water should not be permitted to leak into drains and sewers.

(*c*) That surface and rainwater should, as far as possible, be kept out of them ; and

(*d*) That the initial cost and the expense of maintenance should be within reasonable bounds.

The Board had before them a variety of plans for the

REFERENCE:-

This Drawing with the accompanying reference will be thoroughly understood

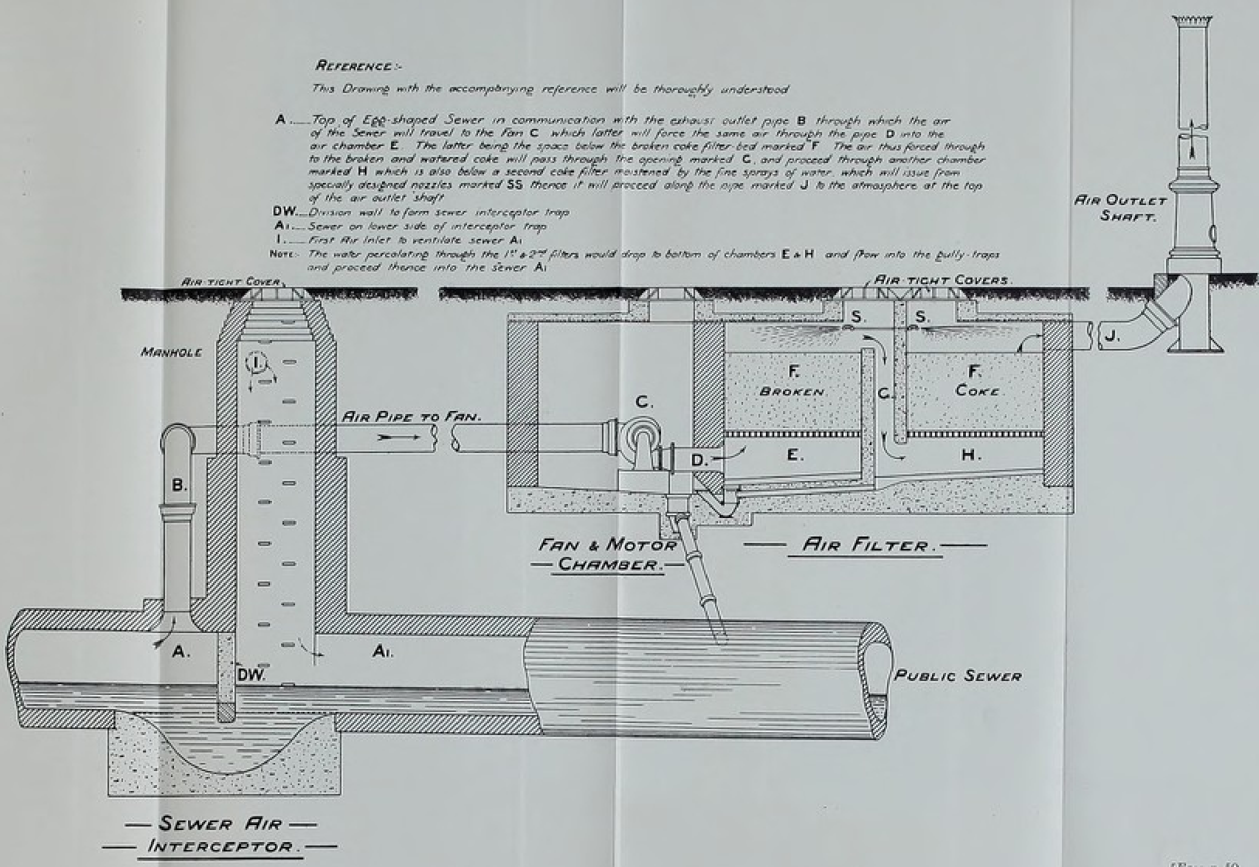
A. —— *Top of Egg-shaped Sewer in communication with the exhaust outlet pipe* **B** *through which the air of the Sewer will travel to the Fan* **C** *which latter will force the same air through the pipe* **D** *into the air chamber* **E**. *The latter being the space below the broken coke filter-bed marked* **F**. *The air thus forced through to the broken and watered coke will pass through the opening marked* **G**, *and proceed through another chamber marked* **H** *which is also below a second coke filter moistened by the fine sprays of water, which will issue from specially designed nozzles marked* **SS** *thence it will proceed along the pipe marked* **J** *to the atmosphere at the top of the air outlet shaft*

DW. —— *Division wall to form sewer interceptor trap*

A1. —— *Sewer on lower side of interceptor trap*

I. —— *First Air Inlet to ventilate sewer A1*

NOTE:- *The water percolating through the 1st & 2nd filters would drop to bottom of chambers* **E & H** *and flow into the gully-traps and proceed thence into the sewer A1*



[Face p. 50.

ventilation of drains and sewers ; and it is not surprising that (as I shall prove was the case) the solution they arrived at was inadequate.

34. That solution (as far as is relevant here) is contained in By-law No. 63 of the Model By-laws, issued by the Board in 1877, and still in force. It runs as follows :— **By-law No. 63.**

"(63) Every person who shall erect a new building shall provide within the curtilage thereof, in every main drain or other drain of such building which may directly communicate with any sewer or other means of drainage into which such drain may lawfully empty, a suitable trap at a point as distant as may be practicable from such building, and as near as may be practicable to the point at which such drain may be connected with such sewer or other means of drainage."

And in Knight's* "Annotated Model By-laws" (p. 116, 2nd ed.) the following *Note* is appended to By-law No. 63 :—

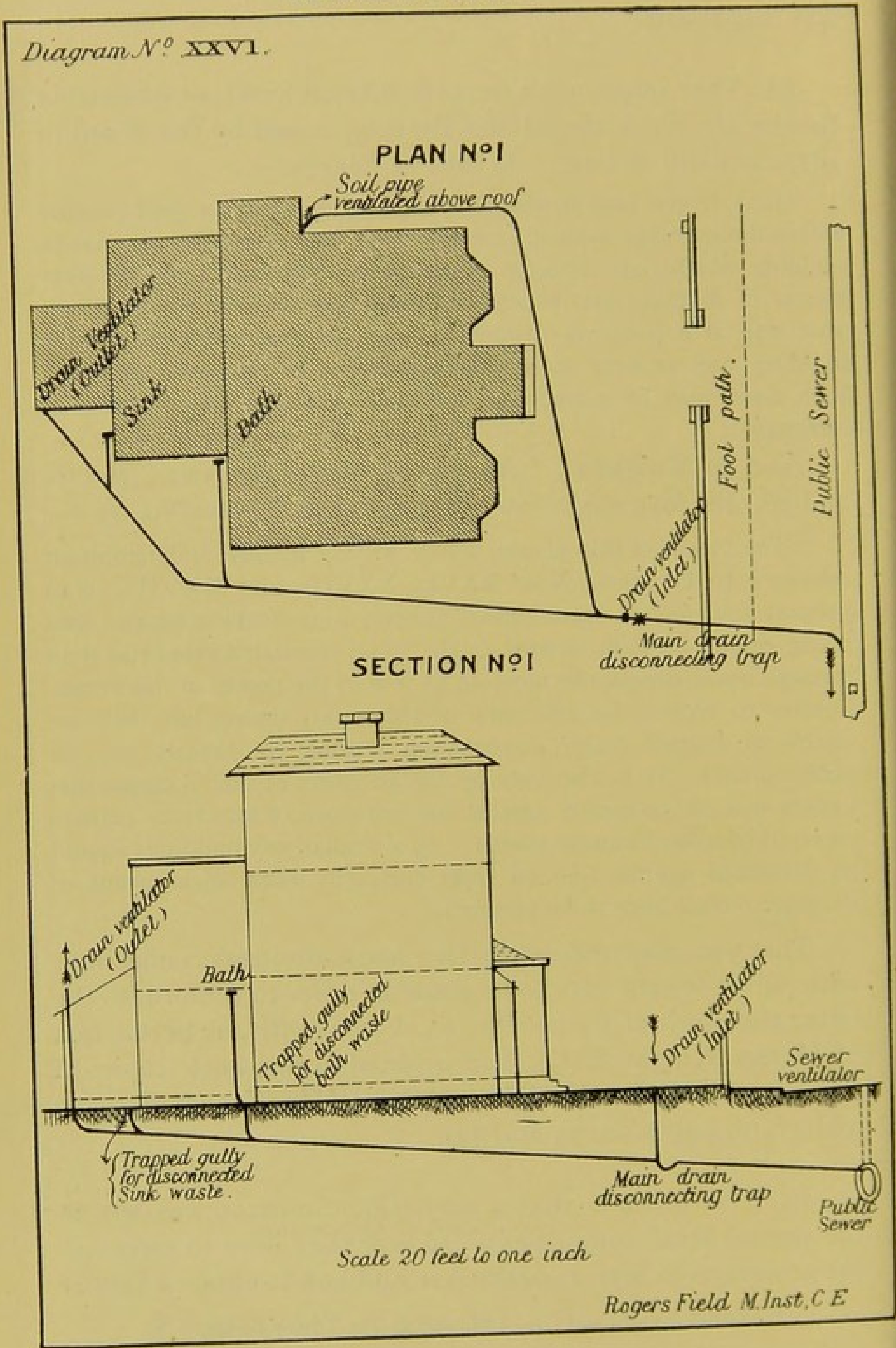
"The object of this clause, which will be readily understood on reference to Diagrams Nos. XXVI., XXVII., and XXVIII., is to prevent foul air, as from public sewers, from making its way into house drains. Public sewers ought to be ventilated otherwise than through house drains, the more so as it is in the power of the householders to ensure the efficiency of their own drains, but they are unable to control faulty construction leading to deposit, etc., in public sewers. It is also only by the adoption of such a clause that houses can be protected against the influence of infectious matters received into the common sewers. In a similar way buildings should be protected against foul air from cesspools when such means of drainage outfall have to be adopted."

That you may understand how house-drainage connections with public sewers were to be made in order to conform to the letter and spirit of By-law No. 63, I have, with the permission of Messrs. Knight & Co., had inserted in this book copies of Diagrams XXVI., XXVII. and XXVIII. (Drawings 9, 10 and 11, on pages 52, 53 and 54). **Drawings 9, 10, and 11.**

35. It is obvious that a very wide discretion was left to the various local authorities as to how they were to carry out the provisions of Sect. 19 of the Act, and how to obtain a proper

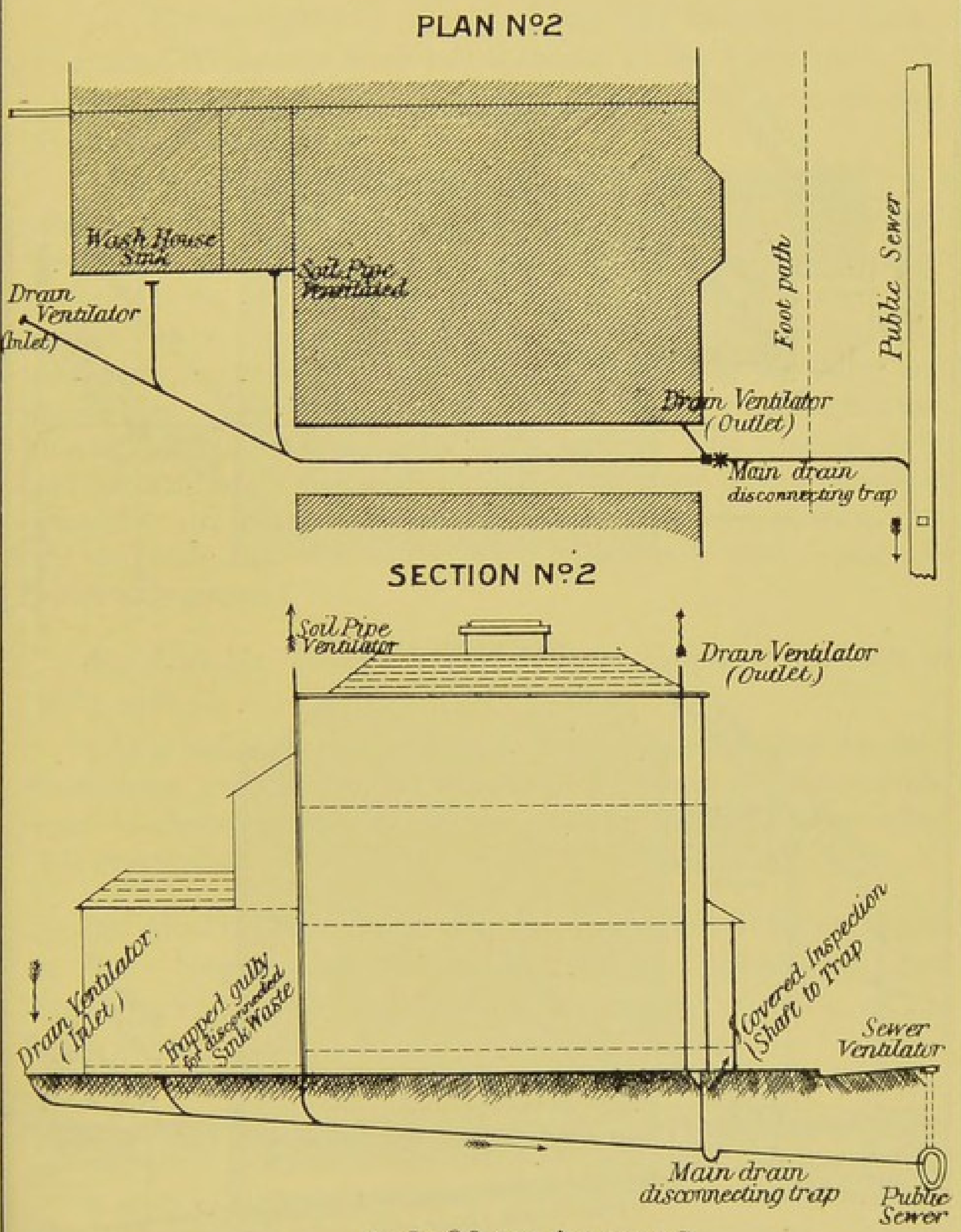
* Charles Knight and Co., Ltd., 227 to 239 Tooley Street, S.E.

HOUSE DRAIN ARRANGEMENTS
DETACHED HOUSES



HOUSE DRAIN ARRANGEMENTS
SEMI-DETACHED HOUSES

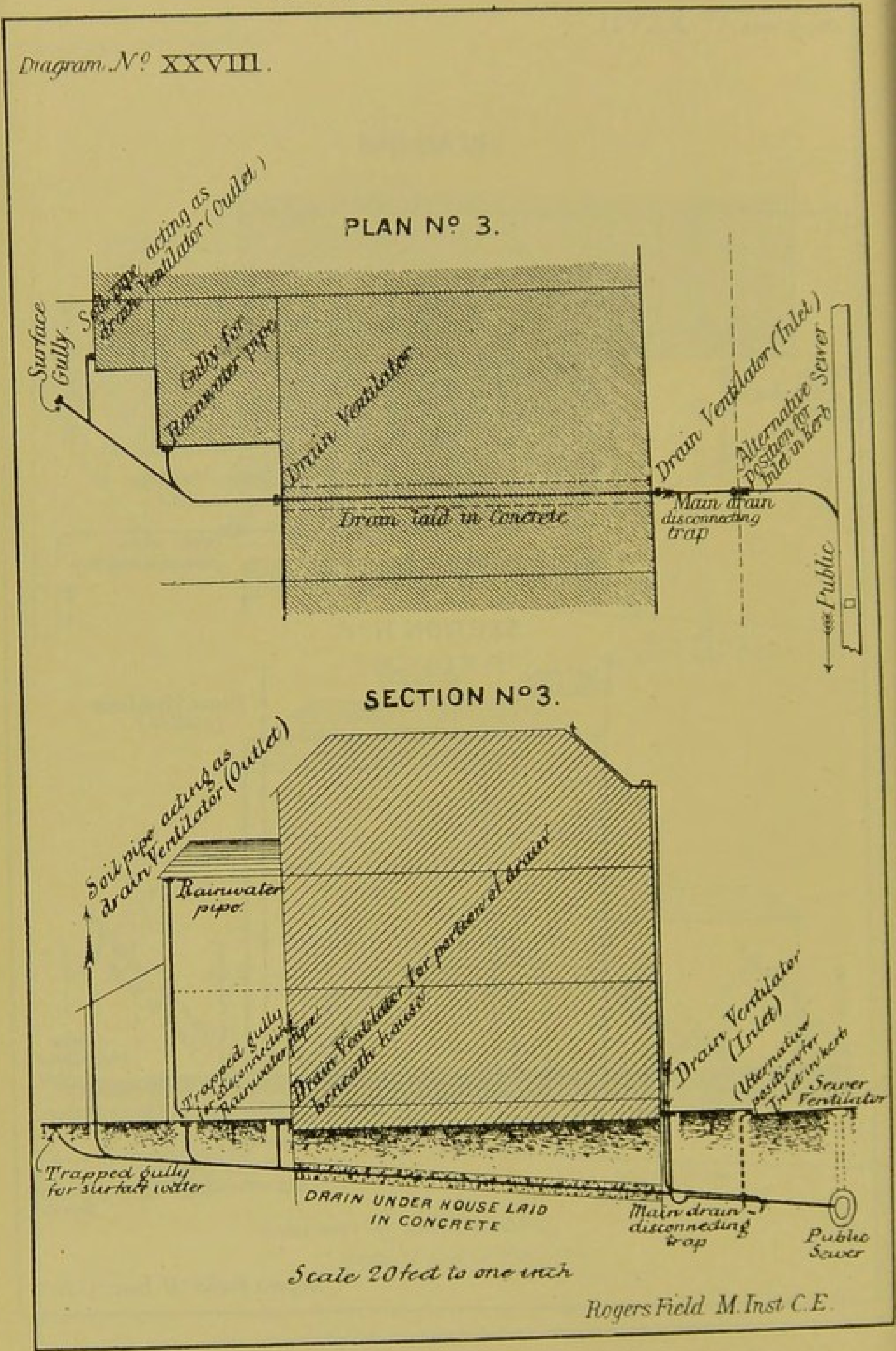
Diagram No. XXVII



Scale, 20 feet to one inch

Rogers Field M. Inst., C.E.

HOUSE DRAIN ARRANGEMENTS
ATTACHED HOUSES



compliance with By-law No. 63. The policy of open ventilation, which had been practised before the Act, was still prevalent, and it was thought sufficient to place in the middle of the streets and over the main sewers manholes with perforated covers.

Evil Results of Open Street Manhole Covers.

36. The adoption of this plan has had lamentable consequences. Warnings were not wanting at an early date. In October 1881, at the Meeting of the Society of Arts, the late Professor Huxley said :—

Professor Huxley.

"Disagreeable and imperfect as the old cesspool system was, it was attended with very little danger as compared with that which waits upon the modern water-sewage system, *if this system is imperfect*; and in fact it is the only possible system in great cities at the present day. It has, however, the terrible peculiarity, that if it is imperfect it becomes the most perfect machinery for distributing the death and disease which may be found in one locality as widely as possible into others, and into the very houses of the people. That I believe to be as absolutely true a statement as any to be found in the records of science of the present day, and therefore it becomes a question, how are we to see that this water-sewage apparatus is what I may call reasonably perfect?"

Mr. G. Laws.

37. And Mr. George Laws, at the Sanitary Institute in 1882, said :—

"As a means of securing that every person passing by shall breathe the greatest possible amount of poisonous gas, this arrangement is almost perfect; but as an outcome of engineering effort it is depressing."

Mr. H. P. Boulnois.

38. Mr. H. Percy Boulnois (who, I am glad to know, is one of your Engineering Inspectors), in his "Municipal and Sanitary Engineer's Handbook," commenting on Sect. 19, has these remarks :—

"The advocates of open ventilation contend that this is completely and satisfactorily effected by making a sufficient number (about one in every 50 to 100 yards) of openings in the crown of a sewer so as to dilute and safely disseminate the foul gases into the atmosphere, and that when this is done no nuisance is caused. If, however, there is any truth in the germ theory of disease, this practice seems fraught with danger *to the unsuspecting passer-by*, and certainly does not always comply with the provisions of the above section of the Public Health Act; consequently, of late years many engineers and sanitarians have agreed that this practice is by no means perfection, but that it must suffice until a better method has been introduced."

Professor A. Bostock Hill.

39. Professor A. Bostock Hill, M.D., D.P.H., in a paper read at the Sanitary Institute Congress in Birmingham in 1898 on "The Construction and Ventilation of House Drains," referring to house-drain interceptor-trap arrangements of the kind referred to, spoke as follows:—

"Under this system, which I regret to say is becoming common in many instances in the Midlands in new property, the following must of necessity occur.

"Each of the siphons on the branch drain holds foul water; in the case of the house having a water-closet, which is the rule at the present time, the trap holds fœcal matter as well. The inlet, which is on the drain just on the house side of the interception trap (and when no water is coming down may act as such), becomes an outlet every time a flush of water is sent down, and the fouled air which the length of the house-drain contained, coupled with the gas which has been given off by the fouled matters in the trap, is discharged into the air in close proximity (in some instances not more than 6 or 7 feet) to the back doors of the houses.

"My experience, then, is that from these so-called inlets, acting frequently as outlets, constant smells from foul gases arise, and I have had ample evidence that the tenants complain loudly of the existing state of things.

"In a close and crowded neighbourhood such a condition of things is undoubtedly bad, even if there is no specially contaminated matter in the drains; but in the case, say, of typhoid fever existing in property drained in this way, it seems to me that even if disinfection of stools had been carried out in the best known possible way, there would be considerable risk of further dissemination of the disease. It is certainly undesirable to store the sewage even for a short time near premises; and I am strongly of opinion that the method which I have described, while no doubt complying with the letter of the law, induces a state of things, from the sanitary point of view, very much worse than the system which it has superseded.

"*I have known instances where, to avoid the odours arising from these so-called inlets in front of the intercepting trap, tenants have on their own account stopped up the opening, and under the circumstances, in my opinion, they are quite justified in doing so.*"

40. Sir Henry Roscoe, in his report to the late Metropolitan Board of Works in 1888, said :— **Sir H. Roscoe.**

"It has next to be considered whether any more satisfactory or less costly means can be devised for effecting the end in view, viz. the prevention of sewage nuisance.

"In my opinion the only other feasible plan is that of aeration. Free oxygen is to be had for nothing, and the cost of pumping air need not be considerable. The adoption of such a plan raises questions which I am not now in a position to deal with, although I believe that this may turn out to be a solution of the problem. At any rate I feel sure that this is a matter well deserving of further inquiry. The rapid purifying effects of aeration on the sewage have been repeatedly observed in my laboratory experiments."

According to the same report, it would appear that the late Board had been spending money at the rate of £40,000 per annum, with a view to reduce to one half some sixty-five cases of complaints of bad smells from the London sewers! At that rate what would have been the expense involved in generally disinfecting and deodorising the whole of the sewers and street gulleys of the Metropolis?

41. Mr. J. Collins, F.C.S., in a paper read before the Sanitary Institute (Trans., Vol. VI. p. 259), said :— **Mr. J. Collins, F.C.S.**

"These (sewer) gases are most noxious—they contain a stinking vapour which is in the highest degree offensive, and which inhaled produces headache, giddiness and nausea. Certain fevers have been directly traced to them. They always include that poisonous product of decomposition, sulphuretted hydrogen. It is obvious that these gases must, by some means or other, obtain egress from the sewers, and they will effect this in the face of the greatest obstacles. They find the smallest vent, they dissolve in water, to be liberated under other conditions; they percolate through the earth, they rise through sink pipes and rain-water butt overflow pipes as surely as they are formed day by day; this, of course, in default of our providing an outlet for them where we may get rid of them with the minimum of evil consequences.

"It is a fallacy of the most dangerous kind to say that sewer gases are no longer hurtful when they are no longer offensive to the sense of smell, for there is no necessary connexion between bad odours and zymotic poisons. There may have been oxygen enough to prevent disease, while there may not have been sufficient to prevent smells which nauseate and cause sickness."

Sir G. Buchanan.

42. The late Sir G. Buchanan, in his report to the Local Government Board on the typhoid epidemic at Croydon in 1875, states :—

"When sewers are small and ill-ventilated they constitute perfectly sufficient means for the rapid distribution of fever infection; and places having such sewers not only show fever rates maintained as high as before the sewers were made, but they may show as smart outbursts of fever as are witnessed where conveyance through water or milk is in question. Croydon itself, after it had made its sewers and before it attempted to ventilate them, had this experience. So in other instances that have come under my personal knowledge, fever has maintained itself after pipe sewers, ill-ventilated, had been made, as in Rugby, in Carlisle, in Chelmsford, in Penzance, and in Worthing; in the last two places breaking out in severe, sudden and diffused epidemics, without there being any question of other distribution than by sewers.

Mr. R. Harris Reeves.

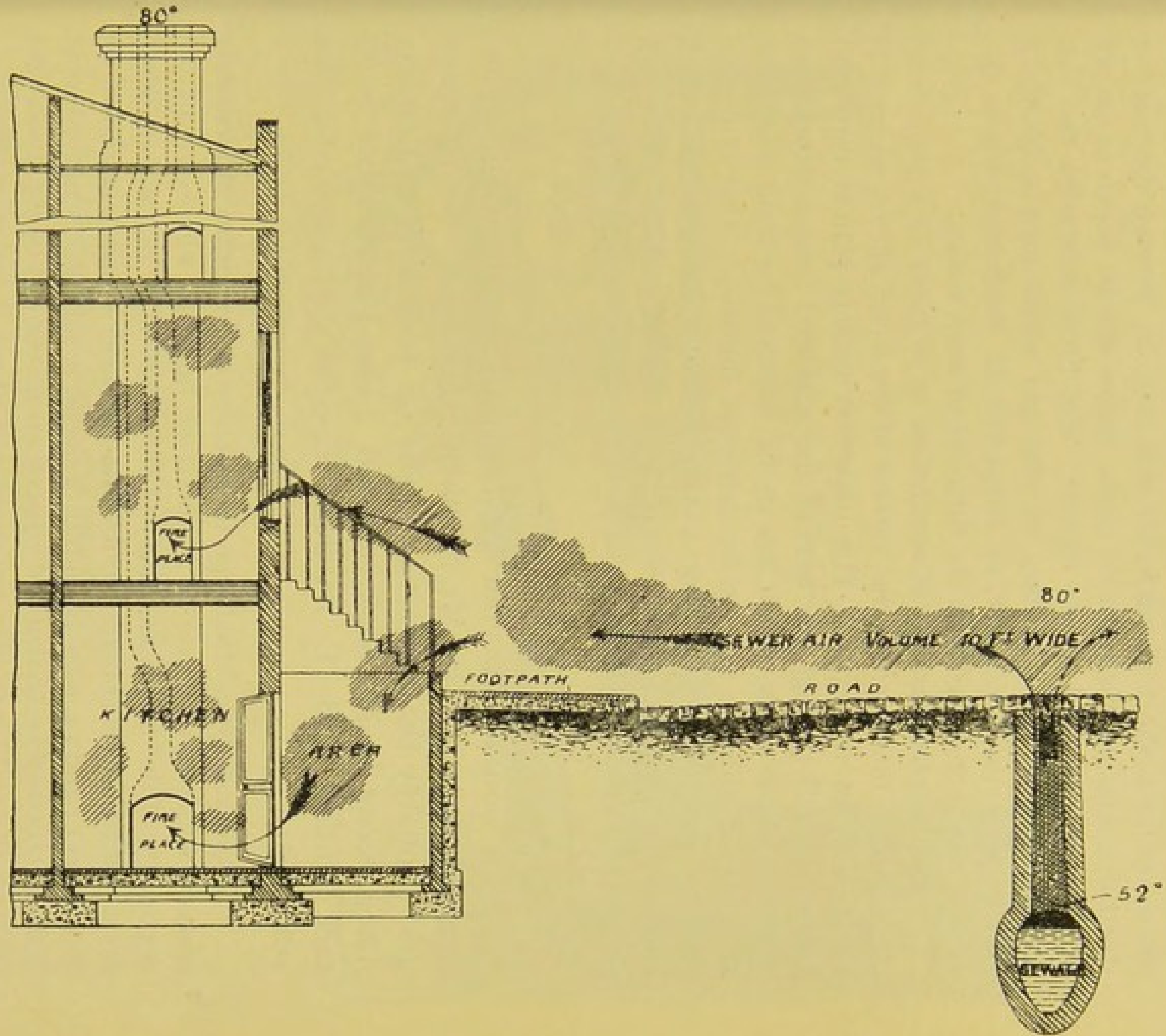
43. Mr. R. Harris Reeves, in his work on "Sewer Ventilation and Sewage Treatment" (Sinclair, Tweedie & Co., London), says (p. 7) :—

"Hitherto it has been the practice to treat sewer ventilation as one subject, and sewage treatment at the outfall as another; but from the results of experiments I have made during the last few years I find that the more perfect the ventilation of the sewers is the less work is involved in treating the sewage at the outfall tanks. In fact the sewage difficulty or nuisance is caused by the sewage having to travel through a stagnant atmosphere in the crown of the sewers, and it is the want of fresh air, or oxygen, in this atmosphere, that is the cause of the nuisance.

"Gases in sewers, especially those at low levels, have as much effect in setting up decomposition in fresh sewage as bad sewage itself."

Mr. Reeves, to demonstrate the inevitable effects which are at times produced by the gaseous emanations from sewers of deposit that are ventilated through holes in manhole covers, fixed at the street level, has inserted in his book a number of drawings, which I consider are very appropriate. A copy of one of these is reproduced here, viz. Drawing No. 12.

Drawing No. 12.


80°
FIRE PLACE
KITCHEN
AREA
FIRE PLACE
FOOTPATH
ROAD
SEWER AIR VOLUME 10 FT WIDE
80°
52°
SEWAGE

Prof. Corfield and Dr. Parkes.

44. Professor Corfield and Dr. L. C. Parkes, in their treatise on "Treatment and Utilization of Sewage" (Macmillan & Co.), have the following observations on sewer ventilation :—

"Connecting the sewers with furnace chimneys has not been found of any avail, for although a great draught may be created in the sewer for a short distance, air will rush in through the nearest street openings, or the traps on house drains will be drawn to supply air for that extracted by the furnace; and there is besides the risk of an explosion from ignition of coal gas which may accidentally find its way into the sewer, as happened at Southwark, where the sewers were connected with the furnaces of soap works.

"The simplest method of ventilation is to carry up a shaft from the crown of the sewer to the surface of the street above, where it is covered by an iron grid. The objection to this plan is that mud and gravel fall through the bars of the grid and form a deposit on the floor of the sewer, which has to be removed by hand labour, or transported with the sewage by continual flushing. This objection can be removed by placing a tray beneath the gratings, which catches the mud, but allows the passage of air around it. This tray should be capable of being removed from the surface of the road."

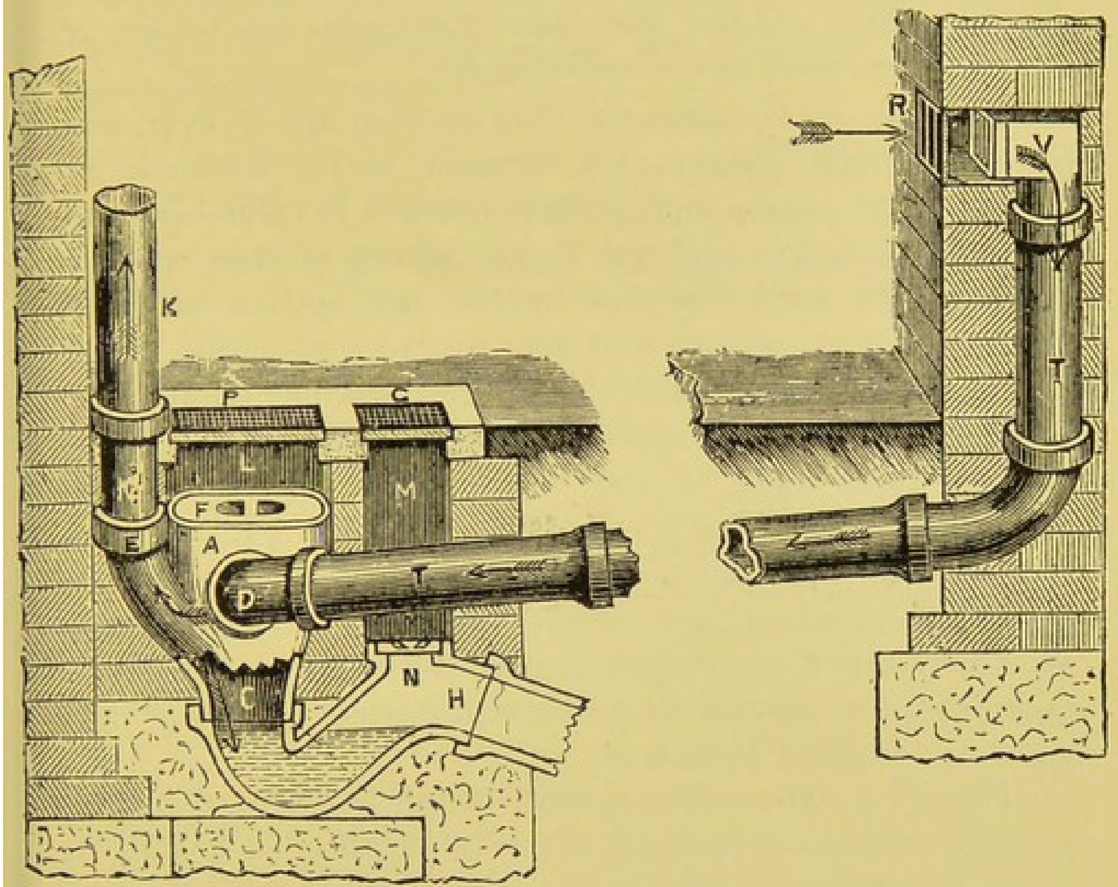
Mr. S. S. Hellyer.

45. I would draw your attention to the following recommendations made by Mr. Stephen S. Hellyer, who is one of and probably the highest authority on plumbing in London. They occur in his book, entitled "The Plumber and Sanitary Houses" (B. T. Batsford, London), at page 180 (6th edition) :—

Drawings Nos. 13 and 14.

"When soil pipes discharge themselves into a drain immediately under a window, or close to a porch or doorway where any of the occupants of the house are likely to stand about, or perhaps sit down for a short time, it is better to fix another kind of trap, as shown on Drawings 13 and 14, with the mouth of the air induct pipe removed some little distance away, so that the vitiated air driven out by the discharges through the soil pipes may not come out where it can give offence.

"If there are no windows or doors near, the foot ventilating pipe need only be taken a foot or two above the connection with the soil pipe, with the end *enlarged* and grated with copper wire, to prevent birds building in it. Then the air can escape out through, or pass into it, according to the needs of the soil pipe. If there is much traffic near this induct pipe, it should be taken up 15 ft. or more



Showing Disconnection of Soil-Pipe.

A. "Soil-pipe Disconnector," but with cover instead of grating.
V. Mica-valve on Mouth of Fresh-air induct.

above the ground level, so as to prevent anyone inhaling the air which would be sent out through this pipe when any of the water-closets were in action."

He also says (at p. 146) :—

"In the *old* way of draining a house the air in the pipes and drains was confined as much as possible, and only allowed to escape in the form of noxious gases through the water seals of the various traps, or the gas holes they had made in the pipes. But *now every waste pipe, every soil pipe, every piece of drainage—whether long or short—has, or should have, a ventilating pipe.*"

To these words, coming as they do from Mr. Hellyer, who by his life-long studies and devotion to his business, by his numerous public and private lectures to plumbers and plumbers' societies, and the Royal Society of Arts, and by his admirable book-teaching, has, in my opinion at least, done more than any other to elevate and perfect the art of sanitary plumbing, I attach the greatest possible importance. They show that in his opinion, instead of the air in sewage-carrying pipes made of iron or lead especially being purposely kept as stationary as possible—preserved, in fact, in a sort of semi-equilibrium condition with the outside air—a plan which some eminent sanitary engineers still advocate, it should be made to circulate within them so as to protect them from the destructive corrosive action of the sewage-gas vapours contained in them.

The preservation of stagnant foul air in drains, therefore, not only is destructive of the life of all metal pipes holding it, but it is destructive also of the life of the people who pay for them.

Dr. Parkes and Prof. Kenwood.

46. This view is supported by the following extract from a recent work by Dr. L. C. Parkes and Professor Kenwood :—*

"There is, however, another disadvantage common to all water-traps, which is that the water may absorb gases on one side of the trap and give them off on the other, so that foul air from the drain or sewer may be given off—only, however, to an inconsiderable extent—into a house, notwithstanding the presence of the trap. The only remedy for such a state of things is the prevention of foul air

* "Hygiene and Public Health," 3rd ed., 1907, p. 110.

accumulations by adequate ventilation. The proper ventilation of drains and soil pipes can only be effected where there is an inlet for fresh air at one end of the system, and an outlet for foul air at the other end. Where there is an inlet, but no outlet, the pipes must be always full of foul air, though not under pressure, for there can be then no renewal of the air in them by the passage of fresh air currents."

At a meeting of the Royal Sanitary Institute, held at Blackpool on March 13th, 1908, on the subject of "Sewer Ventilation and the Interceptor Trap," the following interesting observations were made :—*

47. Dr. F. J. H. Coutts, M.D., B.Sc., D.P.H., F.C.S., Medical Officer of Health for Blackpool, said :— **Dr. Coutts.**

"The simplest plan of dealing with sewer ventilation was, if he might venture on an Irish 'bull,' to have no ventilation at all. This was the solution of the problem in certain towns, such as Bristol and Cheltenham. Of actual methods of attempting to ventilate sewers, the easiest and cheapest was to provide surface level openings in connection, either directly or indirectly, with the manhole. But common sense and actual experience told them that those surface openings were frequently offensive and caused a nuisance.

"Horrocks' experiments also showed them that they were a danger to health, and that disease germs may be inhaled by persons passing over such openings. To his mind the only method of sewer ventilation which can be recommended at present is by means of independent ventilating columns of iron or steel, tall enough to carry all dangerous gases well above all dwelling houses, placed as near the sewers as possible, and with the smallest number of bends. The low ventilator as usually fixed was a danger and would have to be abandoned.

"Sometimes it was fixed in the front garden walls of houses, and where there was a case of typhoid the germ might easily be conveyed to a casual passer by."

48. Mr. J. S. Brodie, M.Inst.C.E., Borough Engineer of Blackpool, said :— **Mr. Brodie.**

"Even usually well-informed people were to be found who were convinced that unpleasantly smelling air or gas issuing from a sewer grating was really not dangerous or injurious to health. Now, what were the simple facts? First, that every year cases were reported of

* See "Blackpool Herald," March 17th, 1908, and "Blackpool Gazette" of the same date.

sewer workmen being poisoned, sometimes fatally, by the escaping gas from the sewers; and for one case reported it was well known that at least twenty were never publicly made known, when the results were not fatal. Secondly, why were those who were responsible for the health of the districts, the Medical Officers of Health, so anxious that houses should be as effectually cut off from the sewer, by means of the intercepting trap, or some equally efficacious arrangement, as the ordinary householder was to keep out burglars? Thirdly, we now had, as the result of recent bacteriological investigations, very good proof that sewer air is 'a nuisance and injurious to health.' If, then, they were of one mind that sewers should be ventilated, the only question that remained was by what method or methods could this object be best accomplished. Surely the exit of foul air from the common sewer, via the private house-drains, to the open air only needed to be clearly stated to carry its own condemnation. Some objected to the trap on account of stoppages, but from the experience of a lifetime he could honestly bring testimony to the fact that in every stoppage coming under his observation one of three causes had been found: an imperfect trap, having practically no gradient or drop, in itself; a good trap improperly laid, with the joints badly made; or a trap of proper construction and well laid, but such utensils as worn-out blacking brushes and similar articles found in it, which should have been put in the house refuse bin and not sent down the house-drain.

"He was of opinion that, until the present method of water-carried sewage was superseded by some greatly improved method, which at present was certainly not within sight, the intercepting trap was a sanitary necessity, and could not with safety be dispensed with."

Mr. Brodie also submitted that the satisfactory ventilation of the common sewers was now practicable at a cost which was not unreasonable, compared with the objects to be accomplished; and that no public sanitary authority was now justified in neglecting their responsibilities in that connection under the Public Health Act.

49. The following extract from a very valuable work on "House Drainage and Water Service," by Mr. James C. Bayles, of New York, throws much light on the hidden and often unsuspected or neglected causes of corrosion and wastage of drain pipes and other drainage appurtenances. The statement therein cited of the observations and views of Dr. Andrew
Dr. A. Fergus. Fergus will be read with special interest, as he traces many cases of typhoid and diphtheria to the same causes:—

"Where there is no danger of an escape of sewer gas to be apprehended, the ventilation of the waste-pipe system of a house would be necessary to prevent the rapid corrosion of lead wastes. The points at which lead wastes soonest wear out and begin to leak are the points at which, in the absence of ventilation, the lighter gases from the sewer would naturally accumulate. I find this is the usual experience of plumbers in this country, and the same phenomenon seems to have attracted attention abroad. At a meeting of the Society of Medical Officers of Health in London, held a short time previous to this writing, Dr. Andrew Fergus, President of the Faculty of Physicians and Surgeons of Glasgow, stated that while the water supply of that city, drawn from Loch Katrine, was so pure in itself and so distributed as to preclude the possibility of excremental pollution, typhoid fever had increased to a startling extent, and as the cause of this disease must be sought either in polluted water or in air poisoned by the gaseous products of decomposition, it was a safe conclusion that the latter was the cause of the trouble in Glasgow. *Reciting many remarkable facts in connection with cases of typhoid fever and diphtheria which had come under his notice, he showed several pieces of 4-inch lead pipe curiously perforated by corrosion commencing from within, and which could only have been caused by the action of sewer gas. These perforations had admitted sewer gas into the houses in which mysterious cases of typhoid and diphtheria had occurred; and as similar perforations were not found in such portions of the pipes as were at any time charged with liquid, they were not betrayed by the leakage of water. Dr. Fergus further said he had found that such pipes as were freely open to the sky by an upcast shaft remained sound nearly twice as long as those in which there was no effective ventilation, but he did not think that a lead soil pipe exposed to the action of sewer gas could be depended upon as sound for longer than ten or twelve years. He also asserted, as the result of careful and intelligent observation, that the usual method of depending upon water-seals in traps allowed sewer gas to diffuse itself through a house 'by a process of soakage,' and that in from half an hour to two hours the foul gases of the sewer and the house drain would have saturated a seal, and thenceforth be freely admitted into the house.** Other eminent and experienced physicians stated that they had reached the same conclusions from observations made in London and other British cities, showing that the rapid corrosion and

Increase of Typhoid Fever in Glasgow attributed by Dr. Andrew Fergus to the influences of Sewage Gas and not to the Water Supply.

Dr. Fergus' evidence of the destructiveness of Sewage Gas within soil and other house drainage pipes.

* The words above which I have had printed in italics are in my opinion most important, and worthy especially of the careful consideration of Medical Officers, Municipal Engineers, Architects, Plumbers, and Building Contractors all the world over.—I.S.

F

perforation of unventilated waste pipes is a matter of common experience on both sides of the ocean."

50. The following observations, taken from addresses given at a meeting of the Royal Sanitary Institute on December 9th, 1904, which was called to discuss the important question of "The Flooding of Basements in London by Sewage," are hardly less pertinent to-day than when they were made.

Prof. Kenwood.

Professor Kenwood said :—

"Those of us who are Metropolitan Medical Officers of Health feel very strongly with reference to this matter of the flooding of London basements with sewage from time to time, and while we must all fully recognise the excellent work which the County Council has done and is doing, we find it difficult to realise why what is undoubtedly the most pressing sanitary need of London was so long practically shelved. The fact that other more attractive schemes, schemes which perhaps appealed more to the general mass of their critics, were meanwhile dealt with, may in some measure explain their neglect, but it does not justify it.

"*If it is not a matter of the first importance to keep sewage and sewage gases out of dwellings, then I don't know what is. It is the first principle of all our sanitary teaching, and it is the greatest lesson of all our public health experience.* The stringent by-laws of the London County Council are very largely designed to guard against this great danger, and the people have been educated to appreciate it."

Sir M. Fitzmaurice.

51. Mr. (now Sir M.) Fitzmaurice, late Chief Engineer to the London County Council, said :—

"Probably some members might help him in a very difficult matter, that was not the entrance of sewage water into sewers, but the exit of gas from the sewers. Considerable complaints were made as to the smells which come up from the ventilators on the surface of the streets, and no doubt it was most objectionable. At the same time, they must remember there was a large army of men at work in these sewers under the streets of London, and unless there was some means of ventilation for these sewers it would be impossible for them to do the work. In some cases he had asked the borough councils to allow him to put up ventilating shafts, perhaps a ventilator of 12 in. in diameter, in order to remedy the smells in the streets. In many cases permission had been refused, and he could only say, as far as he was concerned, he would decline to advise the London

County Council to close any ventilation opening on the surface of the streets unless he would get another to take its place. He was responsible to the Council for the lives of a large number of men; only the other day he had two men pulled out of the sewers senseless from the gas which had developed there. Several times during the last few years they had the men badly burnt through explosions of gas in the sewers coming from different works, such as petroleum works, and so forth. These men must have lanterns, and explosions had occurred in that way. If those present would try to help him in the ventilation of sewers, and get the authorities to allow and give sites for ventilating columns so as to avoid this unpleasant gas coming up to the road surface, they would do something to preserve the lives and health of a large number of men who worked underground in the sewers."

52. The foregoing remarks of Sir M. Fitzmaurice call to mind a very important set of regulations for the safety of men working in sewers issued by the Council of the Borough of Salford through their Engineer, Mr. Corbett, and communicated by him to the "Public Health Engineer," in the number of which journal for the 4th March, 1899, they were published in full.

County Borough of Salford.

Directions for Dealing with Foul Gas in Sewers.

The District Surveyors are requested to hand copies of these directions to their foremen, and to see that the precautions here described are duly observed in all sewer works under their charge.

Whenever men have to go down into an old and foul sewer or cesspool, the following precautions must be taken:—

1st. Open the lids of two adjacent manholes so as to provide a downcast and an upcast shaft; or, if only one manhole is available, and there is no other outlet by an open sewer or vent-pipe, place a wooden tube, about a foot square, down the one manhole for use as a downcast shaft.

2nd. Use one manhole, or the wooden pipe above described as a downcast shaft, by means of a heavy shower of water from a large watering can with a rose jet, or else from a rose jet on a hose pipe from the town's water mains.

3rd. Where there are two manholes near together, use one for the downcast shaft, by means of the shower of water above described; and use the other for the hoisting and working shaft.

4th. Test the air in any shaft before men go down it, by lowering a lighted candle down it. If the light burns dull, even without going out, the shaft must not be entered. Ventilate the shaft as before described and test it again; and do not enter it until a light will burn brightly in it.

5th. Beware of any mixture of combustible or explosive gas in the sewers or their manholes, and if any signs of such gases are found, obtain skilled men and safety lamps from some colliery and let those men direct the work, giving them the help of ventilation, etc., as before described.

6th. When a man has to descend a risky manhole or shaft, he must have a strong rope properly tied about his shoulders so that he could be lifted by it, and the ropes must be kept in hand ready to lift him up if he becomes overpowered by the gas.

When a man has to crawl along a risky sewer he must have a short rope securely tied to his ankles and a rope from it to hand so as to draw him back if he becomes overpowered by the gas.

7th. In case of special difficulty or danger, report the case immediately to the Borough Engineer, so that he may take the responsibility of the work.

JOSEPH CORBETT,
*Borough Engineer.**

TOWN HALL, SALFORD,
January 17, 1899.

53. The following letter is also, in my opinion, well worth your perusal:—

DIRECTIONS TO WORKMEN IN SEWERS.

To the Editor of the "Public Health Engineer."†

"SIR,—The County Borough of Salford's 'Directions for dealing with Foul Gas in Sewers,' published in last week's 'Public Health Engineer,' with Mr. Corbett's covering letter, form a fitting opening for the inevitable annual sewer-gas discussion, more especially as they demonstrate the necessity of a complete change of view on the part of our public health authorities before this important question can receive a satisfactory solution.

"Direction No. 1 says: 'Open the lids of two adjacent manholes, so as to provide a downcast and an upcast shaft,' etc. This is good as far as it goes, but it is one thing to 'provide' a down-

* Similar precautions are recommended by Dr. Parkes and Professor Kenwood in their joint work on "Hygiene and Public Health," and a like code of instructions, but more elaborate and concise, is given by Mr. C. C. James, M.Inst.C.E., late Engineer for the Bombay Municipality, but now the Chief Sanitary Engineer for the Government in Egypt, author of "Oriental Drainage," in his treatise on "Drainage Problems of the East," a work the nominal title of which covers a masterly exposition of the whole art and science of sewerage and drainage.

† Reprinted from "The Public Health Engineer," No. 96, March 11, 1899.

cast and upcast shaft, and quite another to be sure that they will 'act' as such. Sometimes this procedure would be adequate enough, at other times it would not, but men's lives should not be subject to any condition that is not absolute as far as up-to-date sanitary knowledge goes. The remaining directions (Nos. 2 to 7) clearly recognize that No. 1 is not to be relied upon.

"Directions Nos. 2 and 3 suggest a means by which an upcast and downcast movement may be produced, namely, by a shower of water. These directions carry protection very much farther than No. 1, but are still short of sufficient protection. Some sewer fatalities have occurred where the manholes by which the men entered the sewer were perfectly fresh at the time they entered, and the length of sewer they had traversed quite wholesome, but volumes of fatal gases coming in in the meantime from other parts of the sewerage cost the men their lives. Such a case as this is not covered by Directions Nos. 2 and 3, and this is most important, for it is not a usual thing to find the air dangerous throughout a large section of sewerage. The real danger is more often a movable and moving quantity, and a point of the sewerage may be quite safe at one time and dangerous at another, after even a comparatively short interval.

"Directions Nos. 5, 6, and 7 are admirable from the point of view from which they are given, but what a lurid light do they throw upon what the sewerman's lot must be until this point of view be changed.

"Direction No. 6 especially ought to be reprinted in large letters and posted in every council room in the kingdom, until the present state of matters gives place to a better. It reads thus: 'When a man has to descend a risky manhole or shaft, he must have a strong rope properly tied about his shoulders, so that he could be lifted by it, and the ropes must be kept in hand ready to lift him up if he becomes overpowered by the gas. When a man has to crawl along a risky sewer he must have a short rope securely tied to his ankles, and a rope from it to the hand, so as to draw him back if he becomes overpowered by the gas.'

"Mr. Corbett may be regarded in a sense as standing sponsor for these directions, and his known ability and experience only serve to give a more pronounced colour to the gruesome picture which they give of the present practice of dealing with gas in sewers. Is it justifiable that a man should have to 'crawl along a risky sewer' as provided for in this Direction?

"It is not, for the simple reason that it is unnecessary. Let it be understood that I am not criticising these Directions as such. Humane motives are obviously at the back of this endeavour, and such undoubtedly was Mr. Corbett's motive in sending the Directions to you for publication. But I feel bound to insist on this, that no sewers should ever be in a state in which it is necessary for a man to 'crawl along with a short rope securely tied to his ankles, and a rope from it to hand, so as to draw him back if he becomes overpowered by the gas,' that is, probably, with his mouth under the sewage during the process of drawing back. The idea is too revolting, but that such a thing is possible under the present system cannot be doubted, and the County Borough of Salford, recognizing this, have made provision for such an actuality in their Direction No. 6.

"The more widely the real state of matters is known, the sooner, one may reasonably hope, will the proper remedy be adopted. The remedy is a very simple one, namely, to provide for the perfect ventilation of sewers at all times, and under all the varying atmospheric conditions. This, by the Reeves system, has been proved at Sutton, Epsom, and many other places to be a practicable and economical remedy. And not only will sanitary authorities banish all possibility of such special horrors as are contemplated in the Salford Directions by adopting this remedy, but they will thereby insure for their constituents that better health which the purer air they would thus be enabled to breathe in their streets and houses would bring them. There is no more insidious and pernicious de-vitalizer of urban air than the impurities of organic origin which emanate from town sewers, not in summer alone, when they are recognized by their foul smell, but also in the winter, when their presence is not so readily observed,

"Hoping you will find space in your valuable journal for these remarks,—I am, yours, etc.,

WM. BROWN."

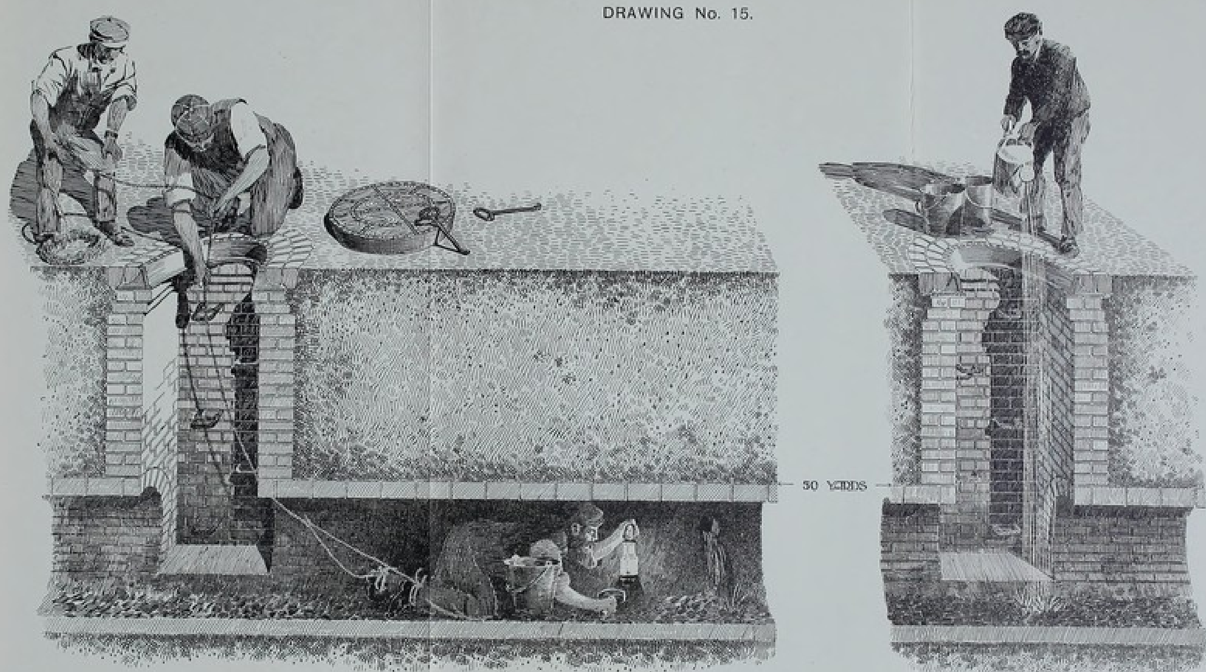
17 Victoria Street, Westminster, S.W.
March 8, 1899.

After the appearance of Mr. Brown's letter a friend of mine, who is an artist but not a sanitary engineer, made a sketch of the kind of service which he interpreted the sewer-men in the employ of the Salford Corporation were expected to render in accordance with the printed directions issued to them by the Borough Engineer, and the following is a copy of it (Drawing No. 15).

It will be seen at once that the sketch illustrates what would take place when foul public sewers had to be treated in the manner suggested by Mr. Corbett's printed directions.

I quite agree with that part of Mr. Brown's criticism of Mr. Corbett's Direction No. 6, which is to the effect, "That

DRAWING No. 15.



Face p. 70.

no sewers should ever be in a state in which it is necessary for a man to 'crawl along with a short rope securely tied to his ankles, and a rope from it to hand, so as to draw him back if he becomes overpowered by the gas,' that is, probably, with his mouth under the sewage during the process of drawing back. The idea is too revolting; but that such a thing is possible under the present system cannot be doubted, and the County Borough of Salford, recognizing this, have made provision for such an actuality in their Direction No. 6."

"The more widely the real state of matters is known, the sooner, one may reasonably hope, will the proper remedy be adopted. '*The remedy is a very simple one, namely, to provide for the perfect ventilation of sewers at all times and under all the varying atmospheric conditions.*'"

I also entirely agree with what Mr. Brown states in that part of his letter which is printed above in italics, at my request; but I suggest that there would be less danger and labour and expense attending works having for their object the inspection and cleansing and ventilation of unventilated sewers of the kind which Mr. Corbett's "Directions" dealt with if County and Municipal Engineers always kept in stock, ready for use, small "Roots' Blowers" or fans, which are light, but substantial and portable, and which can be operated by any ordinary labourer or sewer attendant.

53*a*. These fans have been used for the most part in the past for blowing blacksmiths' fires and cupola furnaces, etc., and they have also been largely used for mine ventilation purposes. They are admirably adapted, in my opinion, for temporarily blowing large or small volumes of fresh street air down manholes into sewers to ventilate them during those times when cleaning or repair works are rendered necessary.

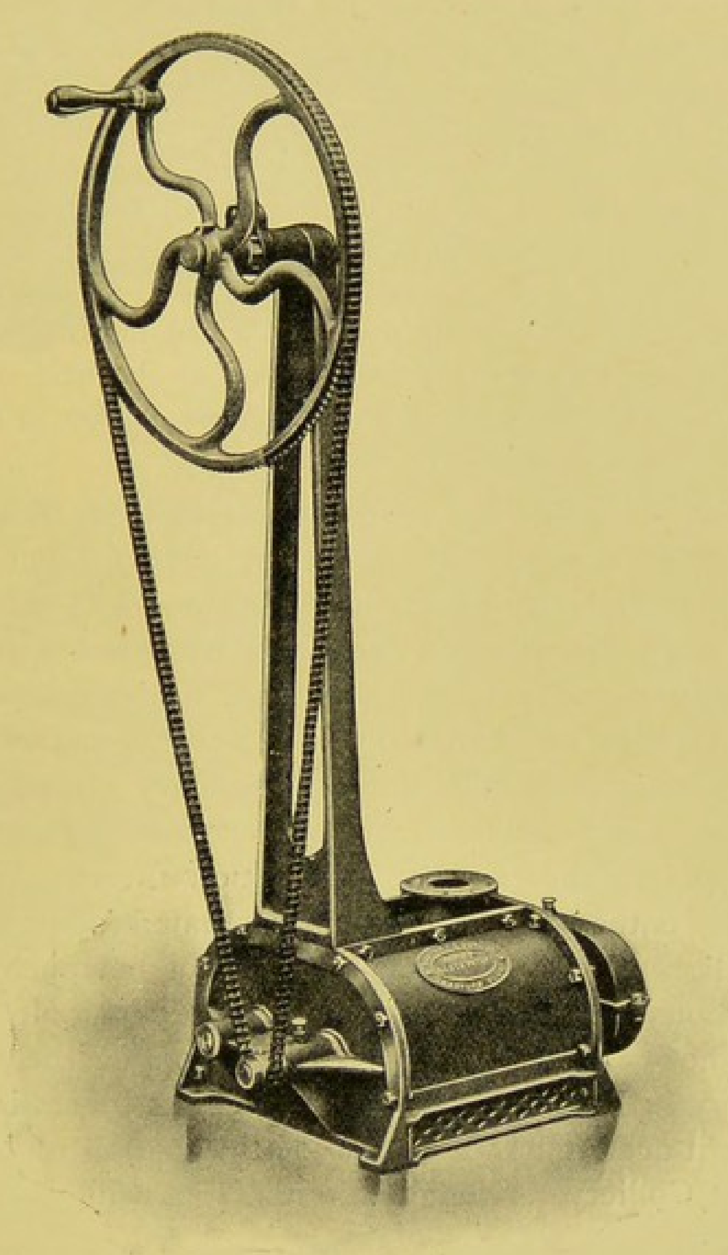
Messrs. Thwaites Bros., Ltd., of the Vulcan Iron Works, Bradford, who are the original licensees for the manufacture of Roots' Blowers, now make for blacksmiths' forges just the kind of blower which, in my judgment, should always be kept in stock, so as to be available to Municipal Engineers whose main sewers are ill ventilated, and rendered in consequence dangerous for men to enter them to cleanse or repair them, without having them thoroughly flushed with air beforehand.

Drawing No. 16.

The blower that would be suitable for general purposes is the one marked "06" in the new numbers, and "4" in the former catalogues of the makers, a block of which is reproduced. This blower will deliver, "with Chain Hand Driving gear," 90 c. ft., or 562 gallons of air per minute, or 5400 c. ft. per hour, into the sewer, via the manhole. This volume of fresh air would enable men to immediately descend into foul-gassed sewers, and work in them as safely, in a sanitary sense, as if they were working in the streets repairing the footpaths thereof.

54. In a book published in October, 1868, by William Mackensie, 22 Paternoster Row, "On Mines and Miners, or Underground Life," by L. Simonin, which was translated from the French and adapted to the then present state of British mining, and edited by H. W. Bristow, F.R.S., there is given on page 164 a full and illustrated description of the way in which some coal mines were originally ventilated in France. The original barbarous methods which were adopted, e.g. for the ventilation of a coal mine at Rive-de-Gier, and which have since been superseded by scientific up-to-date methods, were to a great extent analogous with some of the crude and unscientific methods that we, at the beginning of the twentieth century, tolerate in England in connection with the ventilation of drains and sewers, as is exemplified by the sketch Drawing No. 15. The following copy of what appears on page 164 of the book named will bear out what I say:—

"In some collieries it used to be the custom to light the fire-damp every night. The time is still remembered at Rive-de-Gier, in France, when a man came every evening to set fire to the gas in the mine, to provoke the explosion, in order that the working stalls should be accessible again the next day. Wrapped in a covering of wool or leather, the face protected by a mask, and the head enveloped in a hood like a monk's cowl, he crawled on the ground, before firing the explosive mixture, to keep himself as much as possible in the layer of respirable air; for the fire-damp, being lighter than the



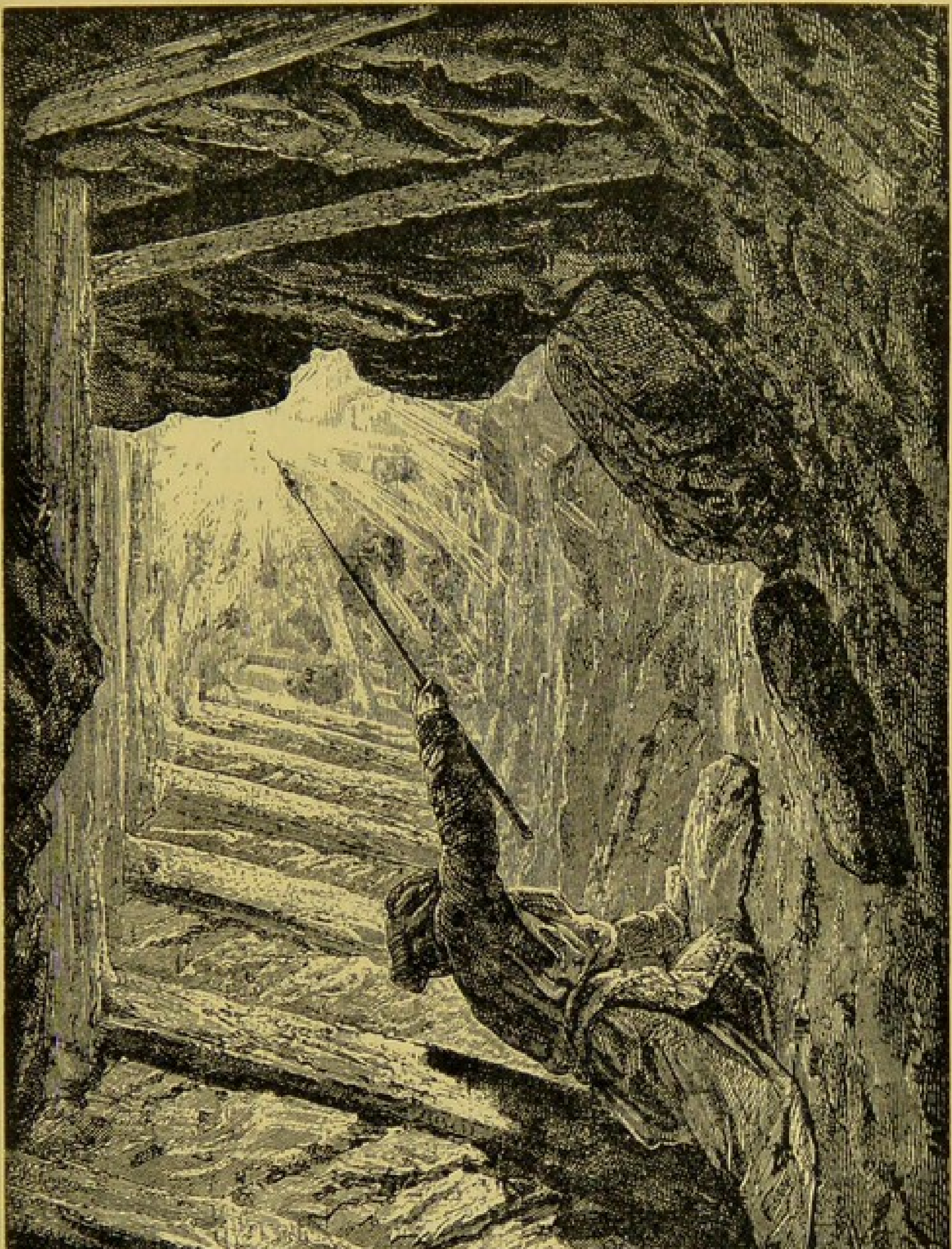
Roots' Blower No. "06."

atmosphere, always ascends to the upper parts of the levels. In one hand he held a long stick, with a lighted candle fixed at the end of it, and he went alone, lost in this poisoned maze, causing explosions by advancing his lamp, and thus decomposing the noxious gas. Having fired any mixture of fire-damp, he naturally changed his position and walked upright, since the carbonic acid produced by the explosion rapidly formed the lowest layer of air. He was called the penitent, on account of the resemblance of his dress to that of certain religious orders in the Catholic Church; and this word seemed at the same time to be dictated by a bitter jest, for frequently the penitent, a victim sacrificed beforehand, was blown away by the explosion, and never returned alive. In other mines this brave collier was called the cannonier. When the fire-damp killed him on the spot, it was said that the cannonier died at his post on the field of honour, and that was all his funeral oration. The same person in English mines bore the expressive name of fireman."

The air of public sewers of deposit of the type represented in Drawing No. 15 (facing page 70), but with closed manhole covers fixed at intervals ranging from 150 to 300, 600 or 900 ft., more or less, and with house drains 20 ft., or so apart on each side of them, discharging sewage into them through unventilated drains, and interceptors of deposit, cannot fail to be full of foul insanitary air which at times becomes explosive, especially when coal gas or petrol finds its way into them. The occupation therefore of men who had to enter and work in unventilated sewers of deposit with lighted lamps or candles cannot be much, if any, less dangerous than the occupation of the "Penitent" of old was, when he was engaged, e.g. in trying to free the Rive-de-Gier Colliery in France of gas every evening, by setting fire to it where it accumulated in some of the roads and working faces of that Colliery, as depicted in the following sketch Drawing No. 17.

Drawing No. 17.

55. The contrast between the original methods described in "Mines and Miners, or Underground Life," and those adopted, for example, at the Ronchamp Collieries in France in the present century for clearing coal mines of their explosive gases, so as to permit the colliers to work in them with safety, is very impressive and very instructive.



Those who desire to form a just estimate of the marvellous improvements which had been attained, should carefully study a most interesting book entitled "The Investigation of Mine Air; an account by several authors of the nature, significance and practical methods of measurement of the impurities met with in the air of Collieries and Metalliferous Mines," * edited by the late Sir Clement Le Neve Foster, D.Sc., F.R.S., and by J. S. Haldane, M.D., F.R.S. The book is divided into three parts, with an appendix.

56. In the previous pages (55 to 67) I have collected observations and criticisms which embody the opinions not only of municipal surveyors and engineers, but also of officers of health, chemists, and other sanitary experts. That those opinions are warranted by experience is probably well known to you; but in order to enforce them by matters of fact, I submit for your perusal as Appendix VI. to this letter a few recent and instructive instances of mischiefs which have arisen from erroneous and deleterious methods of drain and sewer ventilation. To these I have added a very interesting article by Sir Charles Cameron, C.B., which appeared in the "Sanitary Record" of October 24th, 1907.

57. The nuisances which we thus (Appendix VI.) find complained of in all quarters arise from gulleys, surface sewer ventilators and shaft ventilators; and the frequency and intensity of these complaints (which have been regularly emphasized and endorsed by the surveyors and health officers of local authorities) have rendered it necessary in many instances to close down the "ventilators," although this has frequently been done intermittently and capriciously.

It has, however, often been questioned whether this closing down of ventilators, in the absence of any adequate alternative method of ventilation, is not an evasion of the Act, and in any case the practice must be attended with danger.

58. Various expedients have been tried or suggested for meeting the difficulty, amongst others, the placing of ventilat-

* Charles Griffin and Co., Ltd., 1905.

ing pipes in the streets or up the sides of buildings above the eaves of the roof.

59. To this method there are the following objections: it is costly; it requires the consent of the owners of buildings to be applied for, and it is apt to be regarded as an unsightly adjunct to a respectable dwelling-house.* But its essential defect is a sanitary one. By such an arrangement the foul sewer air would ascend the private house drain and proceed direct to the soil-pipe, and up to the top of the latter, where it would have full play to waft itself about the eaves and roofs, and whence it could, and would, enter houses by the chimneys and window or other openings, whenever the relative temperature of the air outside and the air inside the inhabited dwellings favoured its doing so.

60. In your address to the Association of Municipal and County Engineers at Battersea, to which I alluded at the beginning of this letter, you drew a favourable comparison between the British Metropolis and other capital cities. The truth is that we Britishers have the reputation of being a long way in advance of other countries in practical sanitation. And we have been imitated. For instance, on the 8th August, 1894, the Municipality of the City of Paris sanctioned certain by-laws very closely based on those which obtain in England. Thus Art. 15 is as follows:—

Paris By-Law relating to Drain Interceptor Trap.

"Each drain before it passes out of the house is to be provided with a disconnecting syphon, the seal of which shall not be less than 2·75 in., so as to ensure a permanent and air-tight barrier between the house drainage and the street sewer.

"Each disconnecting syphon is to be provided above the bend with an inspection pipe with air-tight cover.

"*The models of these syphons and apparatus are to be submitted to the authorities for their approval.*"†

In this last precaution they are in advance of us.

* "With regard to pipe shaft ventilators . . . . endeavours have been made to erect many others, but I have failed to obtain the necessary consents from the owners of the properties to which the pipes were proposed to be attached."—Mr. Wm. Weaver's Report to the Vestry of Kensington, June 1899.

† From Roechling's "Sewer Gas and Health" (Biggs and Co.).

61. It is now my duty to refer to the provisions of By-law No. 63, which I have cited on page 51 of this letter. The object of this prescription was a most important one, viz. to prevent the foul air of public sewers from gaining access to private house drains, and to a certain limited extent that object has been partially achieved by it in places where self-cleansing drain interceptors and public sewers are the rule and not the exception. But unfortunately the framers of that By-law (No. 63) committed the grave error or oversight of *omitting to provide some arrangement whereby that part of the drain between the interceptor and the main sewer could have been as efficiently ventilated* as that part of the drain that lies on the house side of it.

This defect might, in the opinion of a number of present day municipal engineers, be remedied in the manner shown on Drawing No. 20, on page 97.

62. At the same time, I would again draw your attention to two of the Diagrams referred to in the note to By-law No. 63 in "Knight's Annotated Model By-laws," viz. Diagrams XXVI., XXVII., and XXVIII., of which you will see copies on pages 52–54.

Drawings Nos. 9, 10, and 11.

The lines and arrows shown on the Diagrams are not in the original, but have been so inserted in my copies of them for the following reasons:—

(1) The full lines on Diagram XXVIII. represent a ventilating pipe from the sewer side of the house drain intercepting trap, right to, and above the roof of the house, an arrangement that is now adopted in some towns, but which I consider for the reasons explained in my Liverpool paper, and on page 51 *ante*, most objectionable.

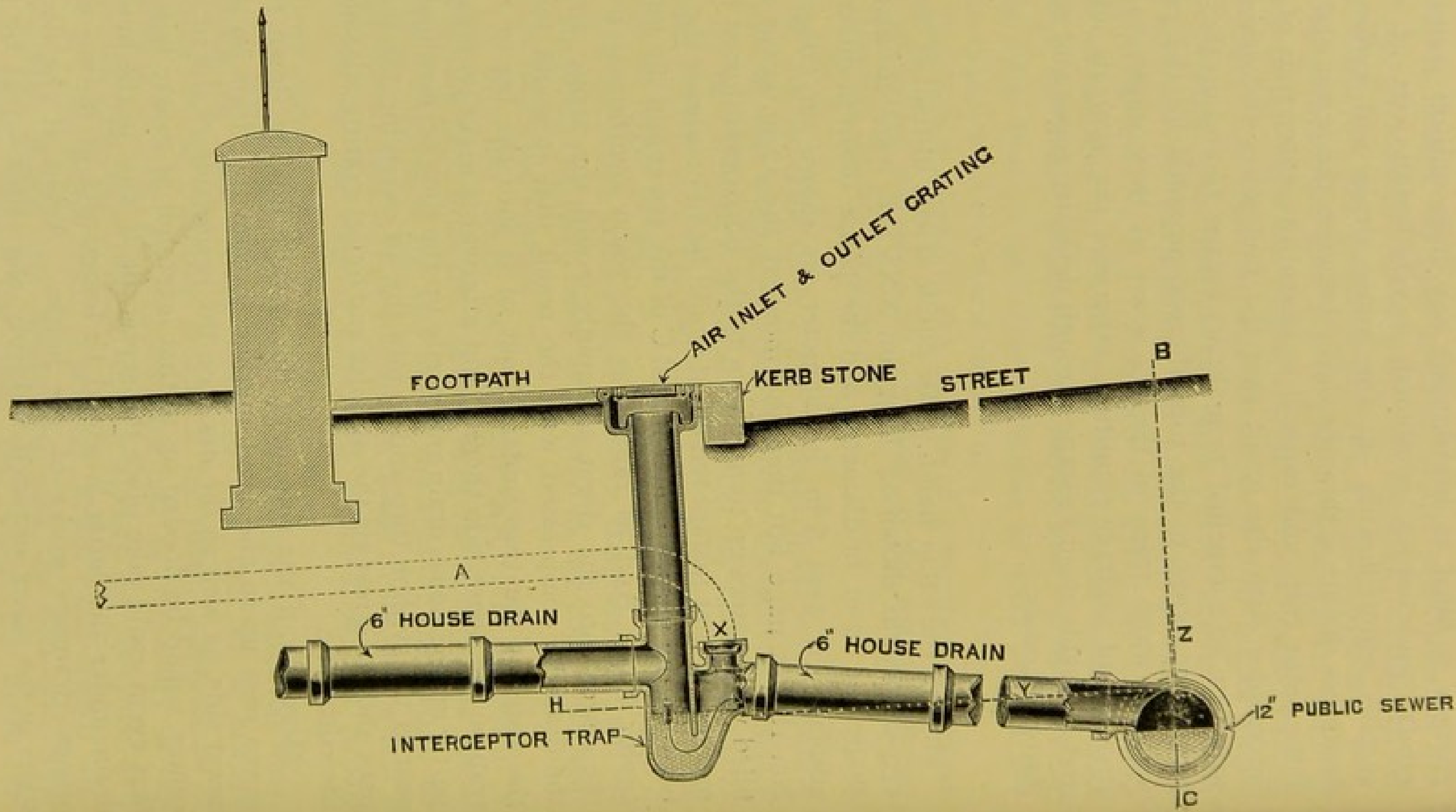
(2) The arrows on both diagrams are somewhat misleading, as they convey the idea that the air is always flowing in the direction indicated by them, whereas, as a matter of fact, the air currents flow just as frequently in the opposite directions; indeed, the air always travels down and not up the house-drain, whenever bath, water-closet, and flush tank waters are discharged into the soil and other waste pipes. And if the sewer into which the drain dis-

charges is filled to overflowing, say from subsoil water, or rainfall and sewage combined, a very small part of such surplus water flowing up the house drain will suffice to compress the air within the drain between the sewer and the interceptor trap, and cause it to unseal the water trap of the interceptor, with the result that the foul sewer and drain air will then be compelled to make its escape to and up the soil and waste pipes, to the tops thereof, provided all the pipes and the water traps of the w.c.'s are as they ought to be, in a sound sanitary condition, otherwise the foul air might and probably would escape through defective pipes and traps into the houses.

63. On the other hand, if the public sewer, instead of being egg-shaped, as shown on Diagram XXVIII., were circular in shape and 12 in. in diameter, and the house drain in question adjoining it were 6 in. in diameter, as shown on Diagram No. 18 (on page 80), then the moment the 12-in. sewer was filled with waters up to its crown to the horizontal dotted line marked Y, that instant the effect would be to compress the air between the perpendicular line B C of the sewer and the interceptor trap. And as rapidly as the water overflowed from the sewer into the drain, so rapidly would the septic air of the drain be compressed, with the result that it would force the water of the trap under X out of it into the leg of the trap on the house side thereof, and afterwards make its escape partly up the house drain and partly up the long perpendicular part of the syphon trap and so into the air overlying the footpath and the street via the air inlet and outlet grating adjoining the curbstone. **Drawing No. 18.**

Moreover, if the volume of the sewage flowing down the sewer rose up to the level marked J, then the drain on the sewer side, as well as the drain on the house side of the interceptor, would be flooded up to that level, but of course before that event could take place the septic air, if any, in the house drain under the letter A would be forced out of it into the private drainage works of the house. Again, if the flood water in the sewer subsided suddenly, the effect would be to

DRAWING No. 18.



cause the water in the interceptor trap to be unsyphoned, and for a short time at least there would be perfect aerial communication between the air of the public sewer and the air of the private house drain and the air of the street.

If, however, the interceptor trap on its sewer side had communicating with it a 4-in. ventilating pipe, marked by dotted lines X to A, the whole of the foul air would then escape via that pipe up to the roof of the house or elsewhere, in which case only the foul air of the house drain on the house side of the interceptor could escape up the perpendicular pipe of the interceptor trap into the street via the air inlet and outlet grating.

The instances given in Appendix VI. of the evils traceable to the defects in question might be indefinitely added to, but your own unlimited access to facts will enable you to form a judgment as to their applicability. There are towns in different parts of the country the whole of whose drainage system, though ostensibly complying with the regulations of your Board, are in reality utterly unsound. There are others where those regulations are disregarded. I will refer especially to one of each kind.

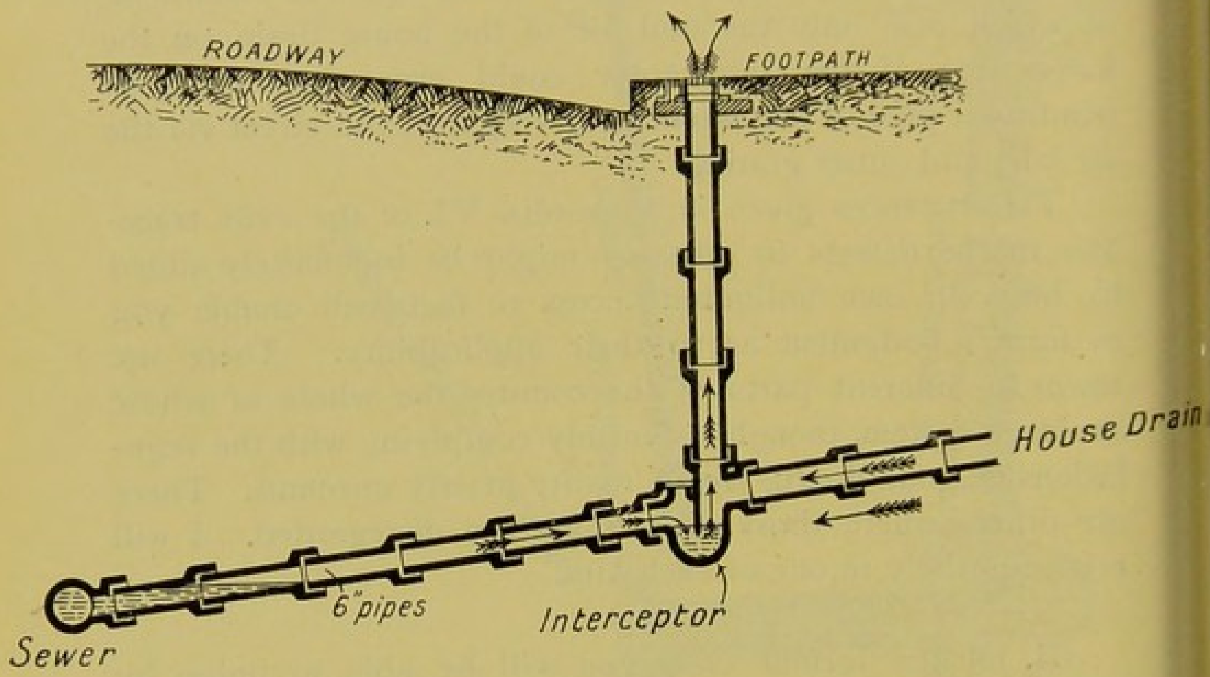
64. Of the former class you will be able to judge by referring to the illustration on the Drawing No. 19, which shows a house connection drainage arrangement as carried out in a town with which I am well acquainted.

The interceptor traps specified and in use in this particular town have water openings of 6 in. instead of 4 in. in diameter, and they contain from $1\frac{7}{10}$ to $1\frac{3}{4}$ gallons, with a depth of water seal of $3\frac{1}{2}$ in. If a 4-in. drain interceptor trap holding about $\frac{6}{10}$ths of a gallon, and possessing a water seal of 3 in. in depth, had been substituted for the larger 6-in. traps of the same design and make, it would have been beyond comparison more sanitary than the present arrangement ; and the initial cost of the smaller sanitary trap would have been about 30 per cent. less.

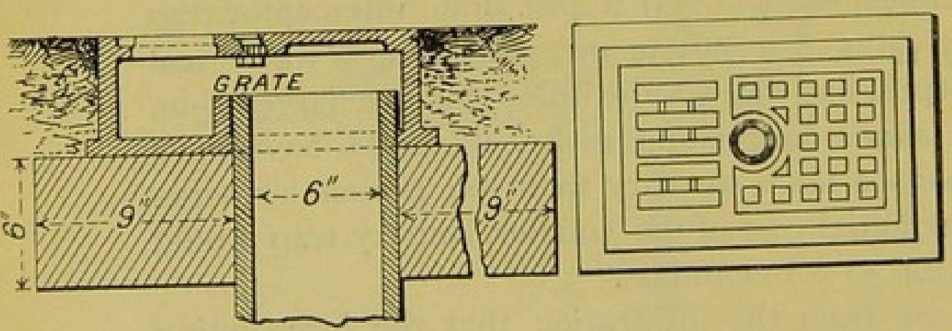
You will see from the illustration that the intercepting trap is fixed under the public footpath pavement, so that the "fæcalised air" of the soil and drain pipes of the houses

HOUSE CONNECTION.

Intercepting Trap and Air-Inlet.



AIR INLET—DETAILS.



and the septic water traps connected therewith must at times be ejected into the faces of the passers-by ; and while it is true that atmospheric air passes into the house drains and the soil pipes at the air inlet openings on the foot-paths, it is equally true that soil and drain-pipe air is forced through each air inlet opening the reverse way whenever closet and bath waters are falling down the soil and other waste pipes into the drain, en route to, and through the intercepting trap, to the sewer.

And as a matter of fact, in the town in question, a serious outbreak of enteric fever occurred shortly after the completion of the new sewerage works, which many of those inhabitants who had to walk on the footpaths of the streets attributed, whether rightly or wrongly it is not for me to say, to the foul drain and sewer air which was emitted into the streets of the town out of the interceptor traps in the manner shown on Drawing No. 19.

65. With the foregoing case permit me to compare the town of Leicester, where for years cases of typhoid had been prevalent, and had been attributed for the most part to badly ventilated sewers. The facts, which are most instructive, are collected and classified by Mr. H. A. Roechling, M.Inst.C.E., in his work entitled "Sewer Gas and its Influence on Health" (Biggs & Co., London). He devotes a table to Leicester (Table II.), showing the mortality from typhoid fever and the number of certificates from 1875 to 1894; and opposite the table is given a diagram showing "Sanitary State of Leicester during the years 1875 to 1886, before and after the Introduction of the Systematic Ventilation of the Public Sewers."

Mr. Roechling divides the whole period 1875–1894 into three smaller periods, according to the treatment adopted in each, and says (p. 207) :—

"1. In the first period (i.e. 1875 to 1880), with badly constructed, very foul and ill-ventilated sewers, the typhoid death rate was highest, viz. 32·2 per 100,000.

"2. In the second period (i.e. 1881 to 1886) of cleansing and ventilating the sewers, the typhoid death rate suddenly went down very considerably, and was lowest, viz. 16·3 per 100,000.

"3. In the third period (1886 to 1894), with new main sewers of good construction and nearly 60 per cent. of ventilating covers closed, the typhoid rate rose again, and was higher than in the preceding period, viz. 17·4 per 100,000, and 17·9 if the years 1895 and 1896 are added.

"4. The increase in the prevalence of typhoid fever in the third period over the second period is still further illustrated by the number of certificates received, the average rate per 100,000 inhabitants for the second period being 100 per annum, and for the third period 130 or 131 if the years 1895 and 1896 are added.

"This increase in the typhoid rates since 1887 is all the more remarkable as since that year the new main sewers and a large number of other sanitary improvements have been carried out in the town; not to mention the general advance in the knowledge and treatment of infectious diseases, and if we look for an explanation of this remarkable fact the thought suggests itself that probably sewer gas had something to do with it.

"In the first period undoubtedly sewer gas did find its way freely into the interior of the houses, forcing the water seal of the traps, as it could not escape either through ventilated manhole covers or soil pipes.

"In the second period the sewer gas, instead of being forced into the interior of the houses, was systematically allowed to escape through the ventilated manhole covers. That this actually did take place is sufficiently proved by the numerous complaints made. It must further be noted that the typhoid death rates in this period decreased about 50 per cent. in spite, as it were, of the very foul accumulations which were removed from the sewers, and which have repeatedly been observed to cause local outbreaks of this infectious disease.

"In the third period the sewer gas was more and more prevented from escaping at the street level by the closing of the open covers, and may have gradually, owing to insufficient ventilation, gained access again to the interior of the houses. In this connection it is very interesting to observe that the Medical Officer of Health reports that in 1893, out of all the typhoid-infected houses, 31·25 per cent. had defective drains, and that in 1894 this percentage rose to 45·18, the defects being discovered by the smoke test. When, therefore, practically for one-third and one-half of the typhoid-infected houses the possibility of the escape of sewer gas into them has been actually proved, it would be wrong to conclude that in the remaining cases sewer gas could not have got into the houses, as underground defects are not always brought to light by the smoke test. It must also be borne in mind that there are many other causes besides sewer gas which may and undoubtedly have been at work in bringing about the fluctuations in the typhoid rates.

"Whatever our opinions on this point may be, the fact remains that in spite of the construction of new main sewers, and in spite of numerous other sanitary improvements, the typhoid rate of Leicester has, since the commencement of the closing of the open covers at street level, not gone down, but on the contrary slightly increased, and this fact should not be overlooked by every thoughtful observer."

66. Since the date, however, to which Mr. Roechling's observations extend, the able Borough Engineer of Leicester, Mr. E. G. Mawbey, Mem.Inst.C.E., a Past President of the Incorporated Association of Municipal and County Engineers, has, to my own knowledge, laboured most assiduously and successfully in abating nuisances arising from sewer air and sewage gas in that town. In his Report to the Joint Highway and Sewerage and Sanitary Committees, dated the 21st July, 1899, after detailing the results of a very great number of tests and experiments, he observes:— **Present system at Leicester.**

"I attach the greatest importance to thoroughly efficient flushing of all sewers in the manner detailed in the Report of September 1894, and also in the Tributary Sewage Report of June 1898. The regular flushing of house and other private drains is of no less importance."

He adds:—

"It will be obvious, from the facts I have laid before you as to the proved efficiency of the shaft system, that my confidence in the recommendations made in my former Reports in favour of ventilation without open grids, combined with ample flushing of the sewers, must since have been materially strengthened, and I therefore now beg to submit the following recommendations for the ventilation of all sewers for the future, from which it will be seen that I am not suggesting any large expenditure for the wholesale closing of open grids and the erection of ventilating shafts in substitution thereof, but rather, that the grid system of ventilating the existing sewers be gradually changed and improved as the necessity arises."

The following were Mr. Mawbey's recommendations, and they were unanimously adopted, and are now in force in the borough:— **Regulations made on Recommendation of Mr. Mawbey.**

"1. That closed manhole and lamphole covers be used in the construction of foul and storm-water sewers in all public and private streets and roads, and that all such foul water sewers be ventilated by high shafts fixed, with the consent of the respective owners, wherever necessary and practicable on houses or other buildings, and where not practicable, by means of standard ventilating shafts on the footways, or other suitable places.

"2. That every public ventilating shaft shall be fixed clear of any windows or chimneys, and arranged to terminate at a height above the level of the ridge of the building on which it is fixed, or nearest to which it is erected.

"3. That the ventilating shafts to be adopted be of the sizes and descriptions recommended in the Report of the Borough Surveyor, dated September 1894, and since adopted as set out in this Report, or of such other sizes and descriptions, and situated at such distances apart, as the Highway and Sewerage Committee may from time to time, on the Report of the Borough Surveyor, determine.

"4. That the Borough Surveyor be authorized to enter into negotiations with the builder and others depositing plans from time to time in future for permission to erect ventilating shafts of the requisite sizes and distances apart, on houses and other buildings in all public and private streets, for the effectual ventilation of the sewers of the Corporation, offering, as an inducement, to make at their expense the connection of the private drain with the sewer, after the necessary excavation has been done by and at the expense of the owner, and in addition to erect the shaft on his property and to pay to the owner for such permission a sum not exceeding £2. These considerations to cover the right of the Corporation, when required, to use the private drain trench, when opened by the owner, for the laying of a separate branch pipe to the shaft. The period for which the above permission shall be granted shall, except in very special circumstances, be not less than two years, after which period the Corporation may be called upon by three months' notice to remove the shaft.

"5. Where a disconnecting trap is fixed on a private drain which does not pass under a building (such trap not being required by the Corporation), the owner shall provide a 4-inch circular ventilating pipe, or pipe of equal sectional area, to be carried up the building from a 4-inch stoneware branch, laid from the drain on the sewer side of the disconnecting trap. The ventilating pipe to terminate not less than 3 feet above the eaves of the roof, and to be clear of all windows.

"6. That the Borough Surveyor be authorized and directed to substitute shaft ventilation for any sewer grid which has, to the satisfaction of the Highway and Sewerage Committee, been proved to be a nuisance, and also to close such grid when the arrangements for the erection of the shaft have been made."

67. Some two years after the date of the above report, I had the pleasure of meeting Mr. Mawbey at the Congress of the Royal Institute of Public Health at Eastbourne, to which I have referred.* He was President of the Engineering Section. It so happened that we had both been retained to read papers, and on the same subject, the Ventilation of Drains and Sewers. Under such circumstances it was but natural that we should exchange our respective views, and I had (as he has acknowledged) the good fortune to impress him with the advantages of my hydro-mechanical system of sewer ventilation, of the practicability of which he had had misgivings. In brief, Mr. Mawbey obtained the sanction of his Committee to the installation of the system (without interceptors) in a small district of Leicester. The works were completed and operations were begun in 1903, and from that time to this they have continued without interruption.

An extremely able and exhaustive paper on the subject was read by Mr. Mawbey at the Meeting of the Association of Municipal and County Engineers at Shrewsbury in July 1904, from which I have ventured to print some extracts in Appendix V.; but I would strongly recommend those interested in the details of the process described to peruse the whole paper as reported in the volume of Proceedings.

68. I have already indicated what I consider the essential defect in the provisions of By-law No. 63, but it by no means follows that I am in favour of the abolition of interceptor traps in house drains. I consider them, on the contrary, indispensable as preventatives of the access of foul and noxious gases from the sewers to the drains and to the houses. In support of this view I would draw your attention to the following observations of Dr. S. Davies, Medical Officer of Health for Woolwich—from the "Local Government Journal," August 24th, 1907—in which, after combating the contention of some

Interceptor traps indispensable.

* *Supra*, p. 49.

sanitarians that the germs of infection are seldom if ever present in sewer gas, he adds :—

Major Horrocks, F.R.S.

"An important paper has recently been read before the Royal Society by Major Horrocks, M.D., F.R.S., in which very different conclusions are arrived at. Major Horrocks carried out a series of experiments, both with specially arranged drain pipes and with existing sewers and drains. Sewage inoculated with the germs of various infectious diseases was introduced into the drainage system, and dishes containing culture mediums were exposed to the gas emerging from the manholes, soil pipes and other exits. Major Horrocks arrived at the following conclusions :—

"1. Specific bacteria present in sewage may be ejected into the air of ventilation pipes, inspection chambers, drains and sewers, (*a*) by the bursting of bubbles at the surface of the sewage, (*b*) by the separation of dried particles from the walls of pipes, chambers, and sewers, and probably (*c*) by the injection of minute droplets from flowing sewage.

"2. A disconnecting trap undoubtedly prevents the passage of bacteria, present in the air of a sewer, into the house drainage system.

"3. An air inlet, even when provided with a mica valve, may be a source of danger when it is placed at or about the ground level.

Dr. Davies.

"These results (continues Dr. Davies) are of great importance, and the care exercised in the experiments, and the scientific status of Major Horrocks, leave little room for doubting that the conclusions he arrives at must be accepted as proved. They also explain the occurrence of certain epidemics of enteric fever which are inexplicable on any other hypothesis. Of course, these results only show the possibility of infection occurring in this way; they do not show to what extent sewer gas is a common source of infection. Under the precautions which are now taken with regard to drainage systems, I believe it is exceptional for infection to occur from sewer gas, but the results of Major Horrocks' experiments show that all precautions must continue to be taken to prevent any unnecessary escape of sewer gas in the neighbourhood of houses." *

69. While, therefore, the interceptor trap, which is the essential feature in By-law No. 63, should on no account be done

* These experiments are also cited by Dr. L. C. Parkes and Prof. H. R. Kenwood in their work on "Hygiene and Public Health, 1907." They have obtained strong corroboration from Dr. F. W. Andrewes, who at the instance of the L. G. B. made with extreme care a series of similar experiments in London. He regards it as now conclusively proved that sewage gives up its bacteria to sewer and drain air.

away with, it remains only to consider whether it admits of such improvement as will, without undue disturbance of existing arrangements and for a strictly moderate outlay, ensure the thorough ventilation of the soil and other waste pipes carrying sewage to the interceptor, and the interceptor itself, as well as the drain which carries the sewage from the interceptor to the public sewer, and lastly, as each house on the line of such sewer, on both sides, would equally be ventilated, it follows that the main sewer itself would also be thoroughly ventilated.

Whatever may be your view of the merits of my plan for remedying the notorious defects still prevalent in relation to the ventilation of drains and sewers, I should not deserve the name of a man of business if I anticipated any great or widespread immediate result from it. I need, however, hardly point out that not only in the Metropolis, but in all the important cities and towns of the country, new buildings are constantly being erected, and the application of my proposals to them involves very little disturbance of existing arrangements.

70. In the spring of 1907 I was invited by the Council of the Incorporated Association of Municipal and County Engineers to read a Paper on the subject of the Sanitary Ventilation of Sewers and Drains at their annual meeting, which was fixed to be held that year in Liverpool. In compliance with that invitation I prepared a Paper, of which the title was "The Defects, and a Solution of the Soil-Pipe Drain and Sewer Ventilation Problems of the 19th Century." This Paper was accordingly presented on the 20th June, and was discussed in considerable detail. The Paper and the discussion were afterwards printed in Vol. XXXIII. of the Proceedings of the Association on pp. 354–384, and they are also reported at length in the "Contract Journal" and in the "Surveyor and Municipal and County Engineer." Its appearance in these journals gave rise to some correspondence.

71. That Paper, together with the discussion and correspondence just referred to (forming Appendix No. I. to this letter), I now propose to submit for your perusal and consideration.

72. It is a characteristic accompaniment, and is part of the history of invention, that whenever a new contrivance calculated to produce great useful effect is proposed, at any rate if the contrivance involves the use of mechanical power, great doubt and uneasiness are felt by those to whose notice it is brought, from the fear of its getting out of order from one cause or another, and thus, however sound it may appear on paper, not answering in actual practice. Such a priori prejudice is perfectly natural and perfectly justifiable within logical limits. It is more excusable in a person who has little interest in the subject matter than in one into whose daily avocations it enters. It is, from another point of view, more or less excusable in proportion to the importance, the utility or the urgency of its object. Where, therefore, the operations to be performed are of general or very wide applicability, and where, further, they are of supreme importance, then it becomes incumbent in a special degree upon those who, whether in a governing or in an executive capacity, have either the right of disposition or the duty of administering the matter in question, to give a serious and unprejudiced attention to any proposal which comes honestly and with proper credentials before them. It is unnecessary to insist on the appositeness of the last sentence to the subject of this book, or to dwell upon the universality of the interests at stake, and the vital importance in its own character of what concerns the maintenance of the public health, and the avoidance or prevention of disease. It is because I am persuaded that these are the views of the municipal authorities of this country, and also of the Engineers and Medical Officers who serve them, that I feel sanguine that these pages will be perused without prejudice and judged on their merits.

I will only add that a number of distinguished Municipal and County Engineers who have avowed their conviction of the soundness of the principle of my plan, have urged me unofficially to lay before you my proposals as the predominant authority in this country on questions affecting the public health. You are well aware of the reluctance of local authorities to entertain undertakings involving change or a new departure. Such reluctance is natural enough, as they are unable to estimate the merits or demerits of what is proposed, and must rely on the recommendations of their Engineer or Surveyor. He in his turn is often deterred from advising anything that implies alteration of system by his reluctance to call for expenditure.

I am also conscious that the limits of a single Paper, such as that which I presented at Liverpool, are necessarily too narrow to fully carry conviction to the minds of busy professional men, whose energies are usually monopolised by the heavy routine of their business. Under such circumstances I have ample reason to be well satisfied with the impression actually produced by the Paper, and with the very large measure of support it obtained. I propose, however, to attach to it certain supplemental matters to which I have from time to time alluded, and to issue the whole in book form, introduced by this Open Letter to yourself as head of the Local Government Board.

The name of your distinguished predecessor, the Right Hon. W. H. Long, is especially associated with a very valuable service, the extinction of rabies. The dog-muzzling regulations maintained during a sufficient period, and coupled with quarantine arrangements as now administered under the Board of Agriculture, have, it may be hoped, stamped out for ever from our country the awful disease of hydrophobia. The number of valuable lives so saved, and the amount of suffering so avoided, may be difficult to estimate, but must be considerable. But it may be safely added that they are almost negligible in comparison with the potential and probable saving of life and prevention of disease which it may be in your power to effect by the institution of a few rational sanitary reforms on some such lines as I have here ventured to define.

I have the honour to be, Sir,

Your obedient Servant,

ISAAC SHONE.

APPENDIX I.

THE DEFECTS, AND A SOLUTION, OF THE SOIL PIPE, DRAIN, AND SEWER VENTILATION PROBLEMS OF THE NINETEENTH CENTURY.

A Paper read before the Incorporated Association of Municipal and County Engineers, at its Annual Meeting in Liverpool, on the 21st June, 1907. By ISAAC SHONE.

73. BEFORE proceeding to deal with the subjects of this paper the author begs to tender to the council of the Incorporated Association of Municipal and County Engineers his warmest thanks for the honour they have done him in inviting him to prepare a paper upon a subject that relates to drain and sewer ventilation—for presentation at this year's annual meeting of the association.

He is aware that the members of this association are eminently practical men, who attend their annual and other meetings to encourage interchange of thoughts and experiences among each other, for the purpose of acquiring knowledge and instruction upon general as well as particular or sanitary engineering subjects—of which latter he ventures, in all sincerity, to say there are none more in need of elucidation at the present time, and certainly none more important, in the whole and varied range of the professional municipal engineer's curriculum, than those which he has the honour in the pages of this short paper, to lay before and to discuss with them.

For the reason just stated—viz., that the members of this association are practical men, having almost every moment of their time and attention continuously devoted to the daily increasing, not to say complex, duties which the sanitary authorities, in whose services they are, impose upon them, it would be out of place for the author to preface the remarks he proposes to make in this paper, with anything approaching to an elaborate history of the evolution in this country, of the drain and sewer ventilation questions.

74. Suffice it to say that, according to a report addressed on March 18, 1858, to the London City Commissioners of Sewers and

to the Metropolitan Board of Works, it would appear that previous to 1830, "the sewers were ventilated by the gullies, which were large open shafts, or shoots, connected with the sewers without traps of any description; they were connected with gratings of large size, the bars of which were farther apart than those at present in use; there were no ventilating shafts rising to the centre of carriageways, nor were there any side-entrances by which access to the sewers could be had. Whatever ventilation took place, therefore, was effected by the gullies, and if a sewer required to be cleansed or examined, the mode adopted was to open holes in the centre of carriageways down to what are technically called manholes, or working-shafts, and perform these operations from these apertures, the shafts being left open a sufficient length of time to ensure ventilation before the men descended, and if there was fear of an accumulation of gas or mephitic vapour, which sometimes was the case near the heads of sewers, but at few other points in them."

Subsequently "a gully trap was devised and fixed in the Pavement, Finsbury, in 1834; and, in 1840, 900 of the gullies had been trapped, with a view to remedy the evil, with the following results: It became apparent, even before that number was fixed, that the sewers were becoming dangerous to workmen to enter, and the gases generated found vent by the house drains (then generally untrapped) into dwellings"; and with a view to try to ameliorate the insanitary conditions, brought about by the gully trap invention, "ventilating shafts, connecting directly with small iron gratings in the centre of the carriageways, were formed: this mode of ventilating was first adopted in the City, and the system of trapping (with numerous modifications in manner) and ventilating the sewers in the centre of the carriageways spread through the length of the metropolis."

But this arrangement again, in its turn, failed to suppress sewage gas, generated in and issuing from the sewers. The gases then escaped into the atmosphere through the hole in the iron manhole covers fixed in the centre of the streets for the express purpose of ventilating the sewers. This simple plan was then, as now, thought by many to be the proper and natural way of ventilating the sewers.

Later on, the General Board of Health was appointed by the Act for the promotion of the public health passed in 1848. This board was reconstructed in 1854, and afterwards, in 1858, it was incorporated into the Privy Council establishment; the late Dr. Simon being retained as medical officer. Among other things, this board prescribed rules and regulations for dealing with the management of sewers and drains. Here is a brief but important extract from the minutes of its transactions: "Make proper provision for the ventilation of sewers and drains in such a manner that there may be a free current of air in them in the direction of the sewage flow"; it also recommended "that the stack pipes should be connected with the sewers without the intervention of traps, in order to assist the ventilation, and there should be no trap between the trap at the inlet and the sewer."

75. These proposals were adopted at Croydon—which was one of the first towns to carry out works of sewerage under the General Board of Health—with the result that some time after the works had been executed, and were in use, an outbreak of enteric fever took place in that town. The Local Government Board, which was formed by Act of Parliament in 1871, was in existence at this time, and accordingly that board deputed one of its inspectors, the late Sir George Buchanan, to report upon the outbreak; and the statements made by Sir George on the subject will, the author hopes, be borne in mind by the members of the association, because they are so transparently sound and correct, from his point of view, as showing the more or less grave dangers which must always attend the act of putting house soil pipes, and drains, in direct communication with public sewers, for ventilation purposes. The following is a copy of the particular paragraph which the author desires should receive special attention and be incorporated in his paper:—

"The air of the sewers is, as it were, 'laid on' to houses; it is arranged that every house drain and every house soil pipe shall contain, up to the very wall of the house and up to the very trap of the water-closet, the common air of the Croydon sewers, not simply charged with impurities it may receive from the particular house, but charged also with any dangerous quality that it may have brought from other houses; for hardly anywhere in Croydon can there be found an arrangement for severing the sewer air from the air of the house drain; so that wherever drain air has entered the house, no matter by how inconspicuous a defect, and no matter whether it has given rise to stink or not, it has been the air of the common sewer."

The plan of ventilating sewers through street surface ventilators was also, as you are all aware, approved of and prescribed by the first chief engineer of the Local Government Board, the late Sir Robert Rawlinson, in his valuable "Suggestions," for the guidance of municipal surveyors and engineers; but the other subsidiary plan, approved of by the General Board of Health, for ventilating public sewers by house drains and soil pipes—as well as by street surface ventilators—the Local Government Board disapproved of, as is evidenced by sec. 63 of the latter board's model bye-laws, which were based on the Public Health Act, 1875, and which were published in "annotated" form in 1877, under the auspices of the Local Government Board, by Knight and Co., the Local Government publishers. Sec. 63 of the bye-laws reads as follows:—

"DRAINS TO BE TRAPPED FROM SEWER.

76. "Every person who shall erect a new building shall provide, within the curtilage thereof, in every main drain or other drain of such building which may directly communicate with any sewer or other means of drainage into which such drain may lawfully empty, a suitable trap at a point as distant as may be practicable from such building, and as near as may be practicable to the point at which such drain may be connected with such sewer or other means of drainage."

The brief history, just given, brings us practically down to the present time; and now the author would ask your indulgence while he ventures very respectfully to criticise in the most friendly spirit possible the drain interceptor trap invention, prescribed by the Local Government Board, as per sec. 63 of their model by-laws.

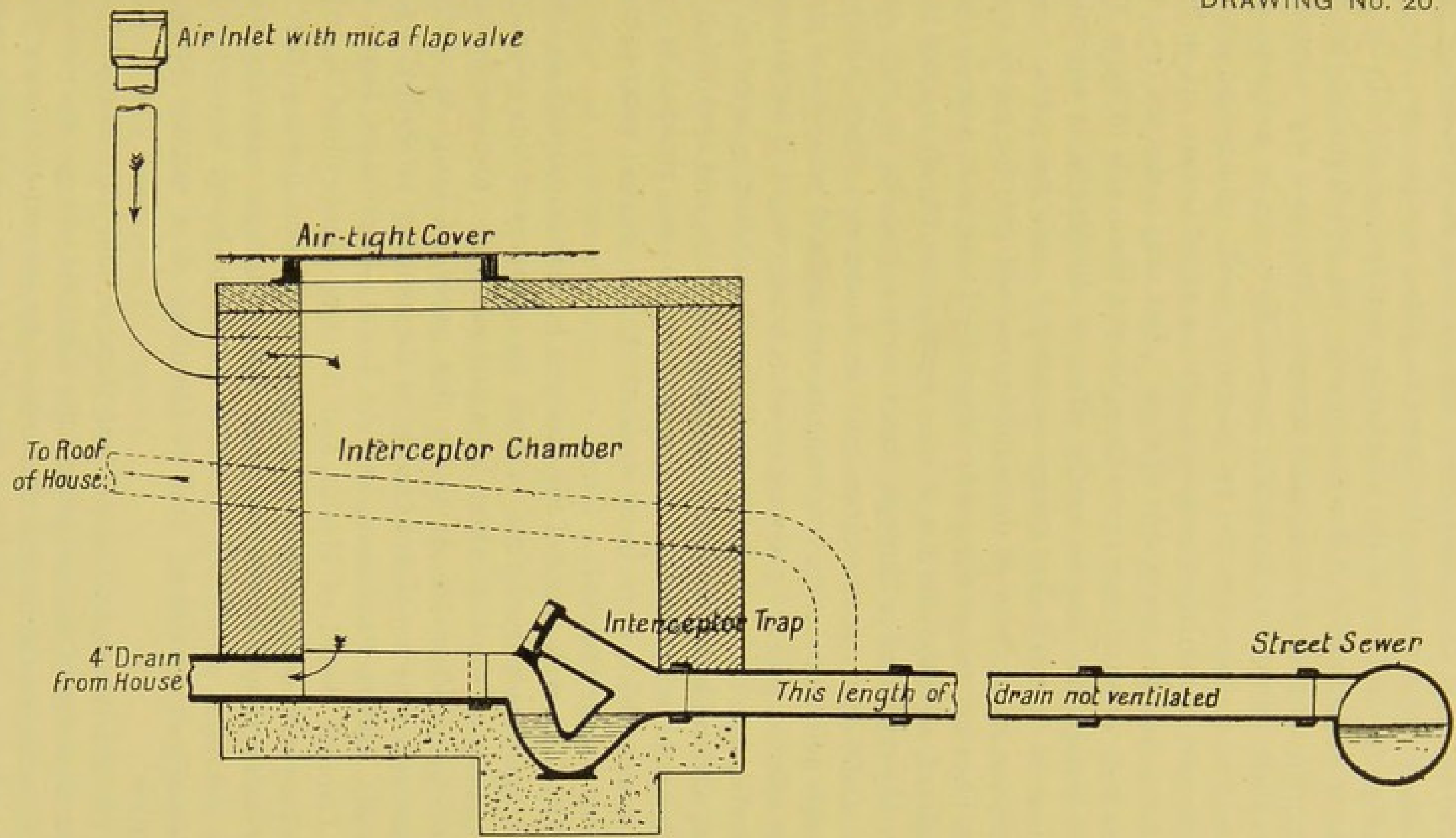
To begin with, he entirely approves of the principle of the apparatus, as it will, when properly designed, answer the purpose for which it was intended. But, unfortunately, its practical action, while performing its functions, as it is now used, is to pollute the air of part of the private house drains and the whole of the air of the public sewers to an enormous extent.

To illustrate what he wishes to say about it, he has had prepared as an exhibit to accompany this paper, the drawing marked No. 20, which shows the manner in which, under the Local Government Board model by-laws, house drains were and are to be connected up to the public sewers; and how the private house drains themselves were and are to be constructed, so as to prevent the foul air from the public sewers entering them. This drawing shows the arrangements prescribed for: (1) Constructing a private air-tight house drain inspection chamber; (2) for fixing in it a hydraulic sewage-gas interceptor trap; and (3) an arrangement for fixing in the inspection chamber a ventilating pipe, having at its upper end a mica flap-valve to admit fresh air from the atmosphere to flow into it, for the purpose of ventilating the inspection chamber and the house drain, soil, and other waste pipes connected therewith.

The mica flap-valve on the air inlet when closed, although intended to prevent the foul air forced by water-closet and other liquids discharged down soil and other waste pipes from escaping into the atmosphere of the house premises, does not always do so effectually, as most of you will be well aware.

The arrangement shown on the drawing has at least one serious sanitary defect: It makes no provision whatever for the ventilation of the house drain on the sewer side of the interceptor trap; and the

DRAWING No. 20.



consequence is that the air in that part of the drain is everlastingly imprisoned in it, and consequently that air must be everlastingly foul. To this obvious insanitary fact must be added another one—viz., the fact that the contents of the interceptor trap (owing to its being too large or capacious, and for that reason not self-cleansing) are too often quite as putrid as cesspool sewage. Thus in a vast number of cases these interceptor hydraulic traps on house drains, and especially house drains which are the recipients of small volumes of sewage, act the part of miniature cesspools, which give off sewage gas on both the house and the sewer side of them. Not only is this the case, but when fresh sewage passes into them, on the house side of them, that fresh sewage has the hydraulic effect of displacing its equivalent volume of cesspool-like sewage entering it, into the public sewer. Moreover, as every house drain thus connected with the public sewer does likewise, and as the public sewer itself may be extremely badly ventilated, as it too often is, it is no wonder that the air emitted from such sewers whether through street surface gratings or high street vent shafts into our streets, or into our houses and other buildings, through defective drains, interceptors, and soil and other waste pipes, gives offence, and is rightly regarded as being one of, if not the most powerful, agents for invisibly poisoning the air that is breathed, the water and milk that is drunk, and the fish, flesh, and fowl which are eaten by the inhabitants of badly sanitated houses, situated in cities and towns which have been drained on the English water-carriage plan of sewage removal.

77. He is well aware of the fact that numerous and various efforts have been made from time to time by members of this association (the names of some of whom he would much like to mention, but it would be invidious to do so, in this paper, at least) to ventilate drains and sewers—if not exactly in the manner prescribed by the late Sir Robert Rawlinson, and the Local Government Board, and the General Board of Health, and the late Metropolitan Board of Works, yet in some such manner or on some such lines, so that the ventilation should be effective, and that sewage-gas nuisances, which now too often invade our houses and streets, should be rendered as reasonably non-existent, and as harmless, in a sanitary sense, as possible.

78. He is also well aware that there is, and very naturally so, a great diversity of opinion among the members of your association as to the relative merits and demerits of the several ventilating plans referred to—e.g. in vol. xxiv. 1897–8, of your association's records of its transactions, there is a very instructive report indeed of an important meeting of the metropolitan surveyors which took place at the Institution of Civil Engineers on February 18, 1898, at which the

subject of drain and sewer ventilation was very fully and ably discussed, but at which the members present failed to agree as to what particular part or parts of the existing orthodox plans of ventilation, or any modifications thereof, should or should not be recommended for adoption by the London County Council.* Some of the members who took part in the discussions at that meeting favoured the plan of adding to the existing number of street surface ventilators, so that they should be placed, say, at about 50 yd. or 60 yd. apart, and that each street surface ventilating opening in the manhole covers should be equal in area to at least 63 sq. in., as recommended by the Metropolitan Board of Works in 1886. It would appear that in this same year (1886) the late Mr. Mansergh advised the adoption of that plan for the ventilation of the sewers of Hampstead. It was contended, and still is, the author believes, by the advocates of the Metropolitan Board of Works' plan of ventilating sewers, that if that plan had only been systematically adopted throughout the metropolis, it would have given almost universal satisfaction, especially if it were supplemented, as its advocates proposed it should be, with an adequate number of high, street-ventilating shafts; air, it was claimed, would then descend into the sewers through openings in the street surface manhole covers, just as air descends into downcast shafts of mines, and afterwards it would ascend out of the sewers through the high, street-ventilating shafts, and back again into the atmosphere. This at least was and is the theory propounded by the advocates of this plan for ventilating sewers by natural means; and to get over the difficulty connected with the ventilation of that part of the house drain which lies on the sewer side of the interceptor trap, it was suggested at the same metropolitan surveyors' meeting that an entirely new or separate ventilating pipe should be laid right away from the drain on the sewer side of the interceptor, up to and above the roofs of the houses, as indicated by dotted lines on Drawing No. 20.

What the author (and his partner, Mr. Ault) think of the proposals just enumerated, and what their views are with respect to the existing drain and sewer ventilation methods as a whole, and what it is suggested should be done to amend them in the future, the author will presently endeavour to explain.

79. The long and varied practical experience acquired in metallic and coal mining and sanitary engineering generally has long since led the author (as well as his partner) to the conclusion that drains and sewers can be better ventilated on the positive down-draught principle, brought about by mechanical means, than they can be by

* See Appendix III., *infra*, p. 222 ; Appendix IV., Part I., *infra*, p. 226.

the up-draught principle, brought about by natural means, which is now almost universally relied upon for this purpose; and, believing this, he has endeavoured to devise a simple, effective, and economical system for ventilating drains and sewers on the principle on which coal mines are ventilated, and he is sanguine that he has succeeded in his efforts in so doing; and in order to enable the members of the association to fully appreciate the difficulties that are inherent in the problem, which he now believes he has solved, he has thought it desirable to deal in detail with the adverse conditions which affect the ventilation of all main and tributary sewers, wherever existent, and to explain how, in his opinion, such conditions can be practically overcome.

80. The new system has been called the "hydro-mechanical" system because, as its name implies, both natural water and mechanical power are employed to work it. The former consists in utilising the cold waters which are discharged from water-closets through the soil-pipes as well as the hot and other household fluids discharged from time to time through waste pipes into drains and sewers for the purpose of creating artificial currents of air to improve the existing natural method of ventilation; and the latter consists in utilising steam, gas, electricity or other suitable power to drive a fan for inducing currents of fresh air to flow down the soil and other waste pipes into the drains and sewers and afterwards to force it out again into the atmosphere, on the principle upon which coal mines are ventilated.

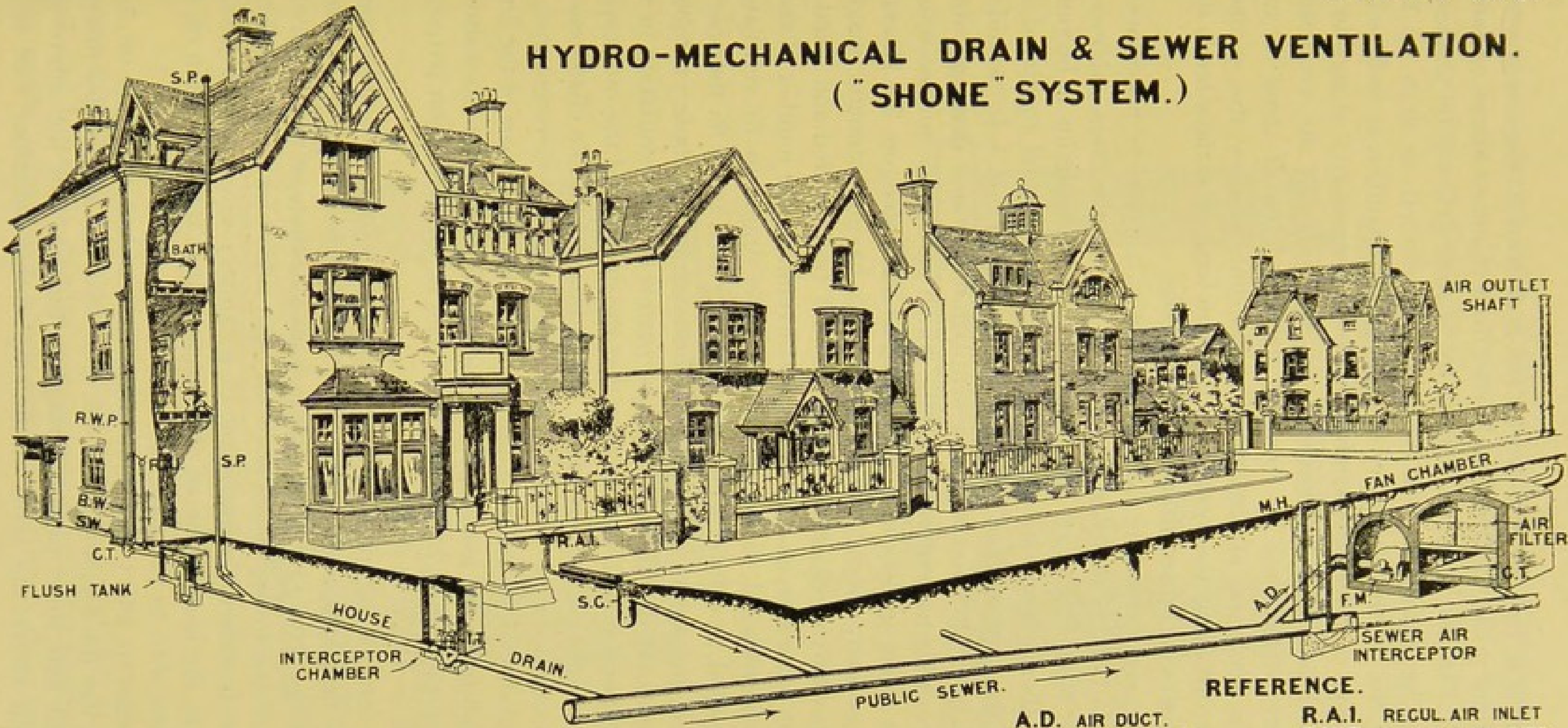
81. That the members of the association may thoroughly understand how the author proposes to apply the principle upon which mines are ventilated to the ventilation of soil pipes, drains and sewers, he has had the large sectional perspective Drawing No. 21 specially prepared, as an exhibit, for hanging on the wall of the room in which this paper will be read: the drawing, of course, is intended to be illustrative only, to demonstrate in fact, as he thinks it does at a glance, in what essential respects the proposed new methods for ventilating soil pipes, drains, flush tanks, interceptors, and sewers differ from those which are now in vogue in this country.

Drawing No. 21.

It will be seen from the Drawing No. 21 that the adoption of the hydro-mechanical system of ventilation will practically involve the reversal of the existing methods, but that, notwithstanding this radical change, it can be readily adapted, either to existing old, or to proposed new, drainage and sewerage works, whether such works are on the "dual" or "combined," or on the "separate" system.

The drawing exhibited, however, shows how private house drainage, and how public sewerage works, on the dual or combined system, can be ventilated on the hydro-mechanical system. All that is necessary to be done to set the new system of ventilation in

HYDRO-MECHANICAL DRAIN & SEWER VENTILATION.
("SHONE" SYSTEM.)



REFERENCE.

A.D.	AIR DUCT.	**R.A.I.**	REGUL. AIR INLET
B.W.	BATH WASTE.	**R.W.P.**	RAIN WATER PIPE
C.T.	GULLY TRAP.	**S.C.**	STREET GULLY.
I.T.	INTERCEPTOR TRAP.	**S.P.**	SOIL PIPE.
F.M.	FAN & MOTOR	**S.W.**	SINK WASTE.
M.H,	MANHOLE:	**W.C.**	WATER CLOSET.

DIRECTION OF AIR CURRENT ⟶

operation is to provide and erect a fan and motor at some convenient place, where it can be built and fixed in a chamber above or below ground. The fan can be driven by steam, gas, oil or electrical power. The author, it will be seen, has elected to show on the Drawing No. 21 the necessary fan and motor chamber, as well as the air-purifying or filtering chamber, under the street and alongside an egg-shaped public sewer, because, by so doing, all the ventilating machinery would then be "out of sight and out of mind"; and, moreover, such an arrangement would not involve the sanitary authority installing the system, in the purchase of surface lands that would otherwise be required for the purpose.

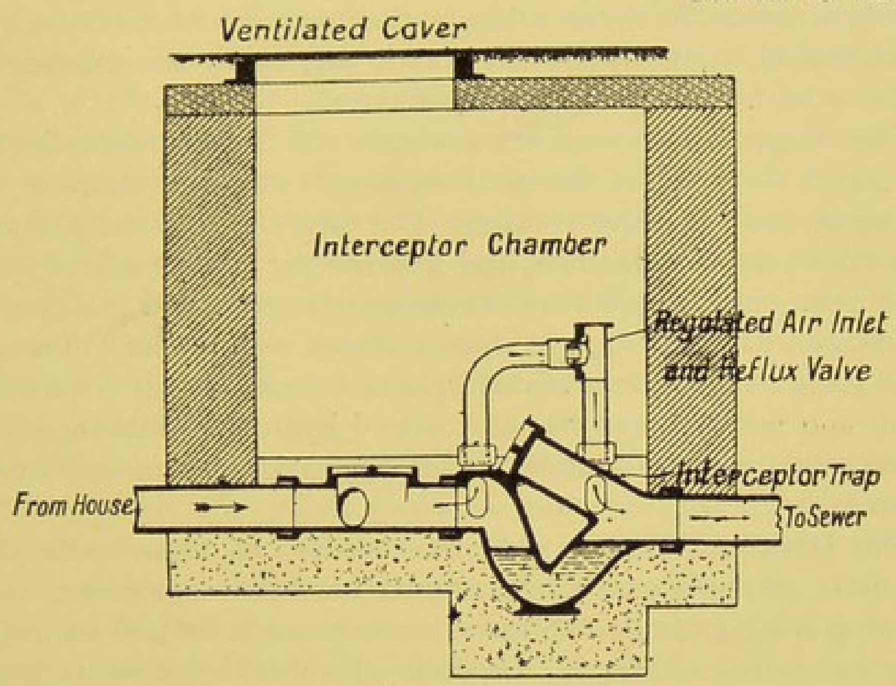
82. Besides providing the fan and motor, it would be necessary to provide and fix as many of the special interceptor traps—shown in Drawings Nos. 22 and 23—as there would be house drains to be ventilated by them; also one or more of the small special regulated air inlets, of the type marked on the Drawing No. 21 "R.A.I.," would be required in connection with the ventilation of house drainage work. Again, in order to ventilate the pipe which carries the surface waters from the street gullies into the sewer, as indicated on the Drawing No. 21, as many special regulated air-inlets, having automatic magnalium reflux-valves attached to each, should be provided and fixed as shown, or otherwise, as may be most convenient; the number of these latter to correspond to the number of gully drains to be ventilated. It is intended, as will be seen from Drawing No. 22, to fix the special ventilated interceptors in ordinary house-drain manhole chambers, having perforated entrance covers, to permit of free ventilation in the chambers; and it will also be seen that the drains and the interceptor traps to be laid on the inverts of the ordinary manhole chambers in question ought to be wholly—as they are shown—covered, and, of course, all should be made air and water tight. That part of the drain pipe which joins the interceptor on the house side of the latter should have a movable airtight cover fixed over it, for inspection purposes, as shown in Drawing No. 22.

The form of the improved interceptor trap itself resembles somewhat the best types now in use; but the improved interceptor shown in Drawings Nos. 22 and 23 differs from all others, in that it not only permits of the sewage water-seals on both sides of it to be ventilated, but, what is extremely important in a sanitary sense, it also permits the air on the house side of it to pass over it into the drain on the sewer side of it, to ventilate it.

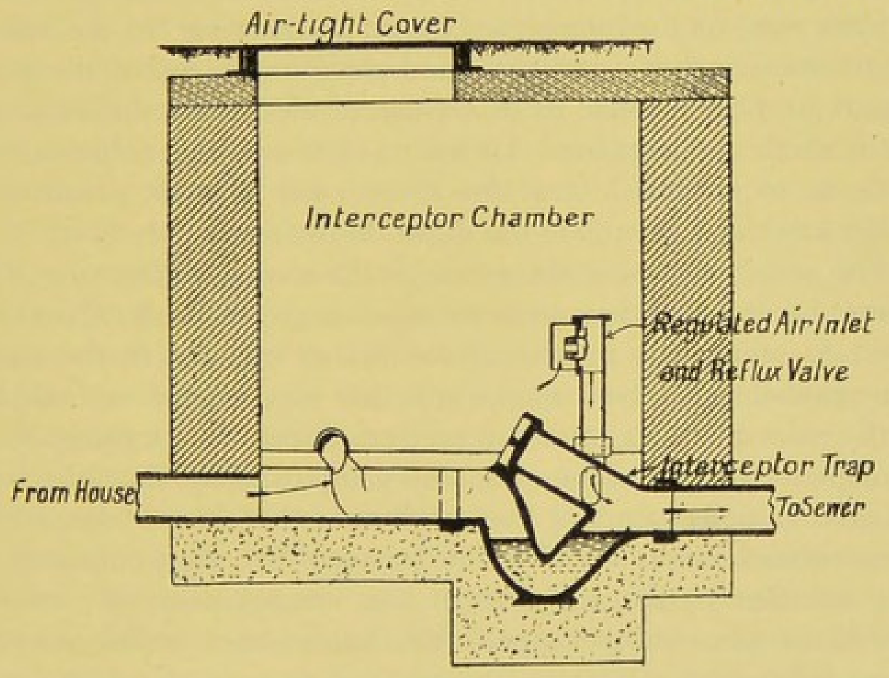
In order to effect this innovation to ventilate the drain on both sides of the interceptor, it will be seen that the author has inserted two small and short pipe openings in the body of the interceptor itself, well above the level of the trap waters on either side of it;

these pipe openings have socket terminals in which are fixed air pipes of the shape and form shown in Drawing No. 22. One of these air pipes—the one which stands perpendicularly in its socket on the

DRAWING No. 22.



DRAWING No. 23.



sewer side of the interceptor—has a special cap piece at its upper end, and to this is fitted a very sensitive and mechanically precise magnalium reflux-valve, which opens freely when the current of air flowing from the house drain is sufficiently strong to compel it to do so; but which, on the other hand, when plenum actions take place in the sewer, instantly closes again. By the aid of this simple sensitive reflux-valve, the foul air of the sewer can be prevented from gaining access to the house drain, on the house side of the interceptor, as effectually, sanitarily speaking, as it can be by the interposition of the water trap of an efficient interceptor.

The hinged valves used are made, as will be seen from Drawing No. 22, in the form of spherical segments, with their concave sides resting against the valve seating. The valves are carefully stamped out of thin sheet magnalium, and ground true to their seatings so as to be quite airtight, and they are accurately suspended from pointed screws, and balanced so as to open and shut with the least movement of air; and as magnalium is very light and strong, and is not oxidised by air and not attacked by sulphuretted hydrogen, carbonic acid or hydrocarbon gas, its durability and uncorrodable character may be relied upon.

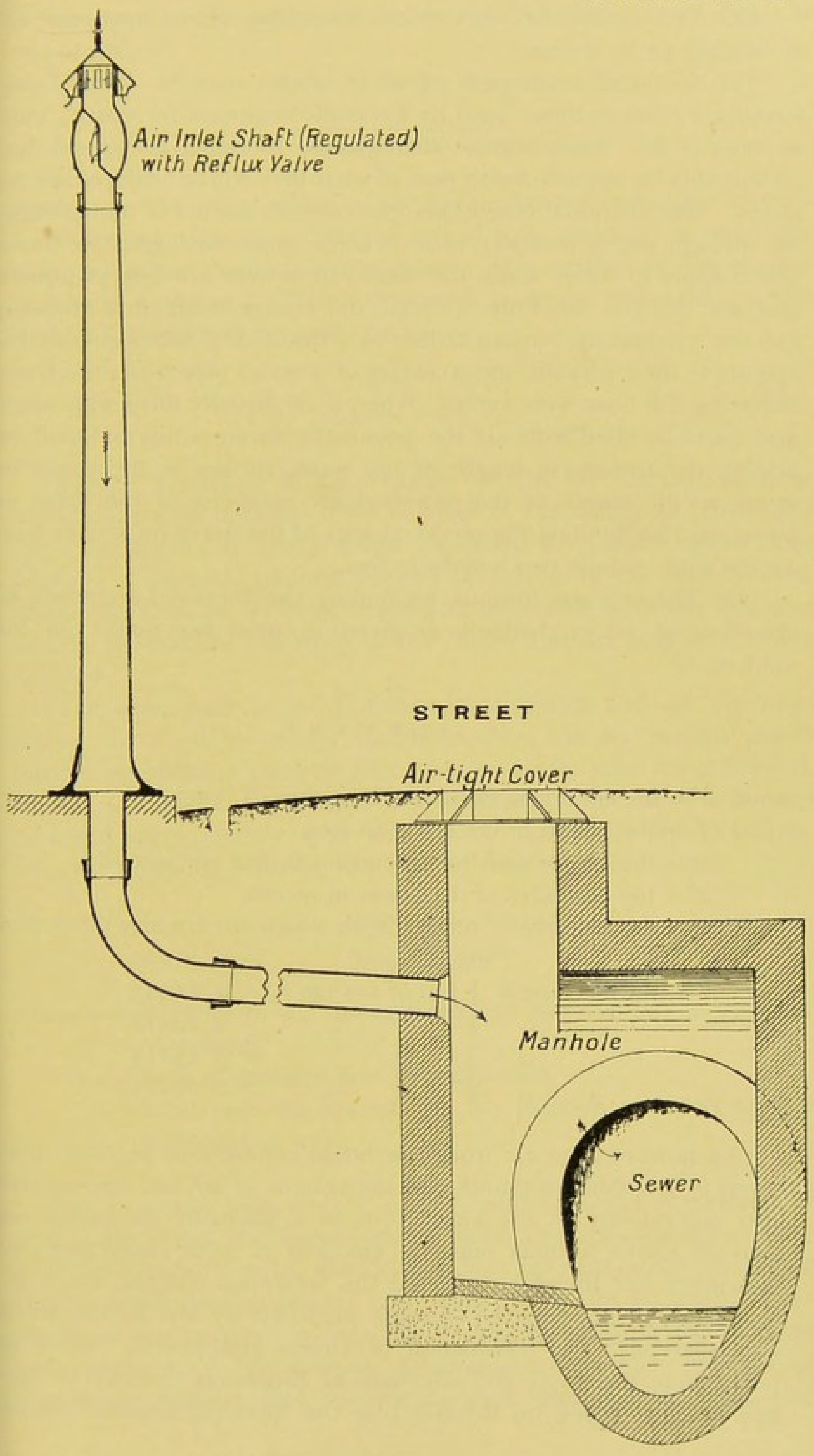
83. Drawing No. 23 is a *facsimile* of No. 22, so far as the shape and make of the house drain manhole chamber is concerned; but in Drawing No. 23 the iron entrance cover is made air and water-tight, and the drains within the manhole chamber which carry sewage from the house to the interceptor are open and semi-circular in shape. The body of the interceptor, too, in this chamber, although hydraulically the same as the interceptor shown in Drawing No. 22, has only one air opening in it; and the hood-piece at the top of the perpendicular air pipe—which is in communication with the interceptor, and in which the regulated air inlet piece and the reflux-valve are fixed—is so designed that the air of the manhole chamber can readily enter it, to ventilate the drain on the sewer side of it.

The author designed the arrangement shown in Drawing No. 23 because he thought that possibly some engineers and others accustomed to seeing the inverts of the drains exposed in the existing open manhole chambers might still like to continue to build them on the principle and after the pattern shown on Drawing No. 20, although, at the same time, probably many of them might be willing and even anxious to adopt the ventilated interceptor apparatus, with its accessories, which are shown in Drawing No. 22, if only they were quite sure that by the adoption of that arrangement they would be enabled to successfully ventilate the house drain on the sewer side of the interceptor. The author thinks it is a great mistake to put the air of the house drain in direct communication with the air of the manhole inspection chamber, because, by so doing, if the air of the drain is foul, the air of the manhole chamber, by the operations of the law of diffusion of gases, will be made foul also; in fact, the extent to which the atmosphere that is within and without dwellings is polluted, by our permitting the air of the drains, soil and other waste pipes to be in direct communication with the air of the manholes with which they are connected, is appalling. Take, for example, the house drain on the left of the interceptor, shown in Drawing No. 20, to be 4 in. only in diameter, and 66 ft. long; and that the manhole at the interceptor is 6 ft. deep, 2 ft. wide, and 3 ft. long; the cubical aerial contents of such a manhole would be about eight times greater than the cubical contents of the drain itself. In other words, by substituting the manhole ventilated from the open air, and the covered drain and ventilated interceptor, shown in Drawing No. 22, for the arrangement which now prevails, and which is shown on Drawing No. 20, the volume of drain air in the immediate vicinity of dwellings would then only be the one-eighth of what it would be otherwise.

84. The same remarks apply more or less to the polluted air of manholes, which is in direct communication with the air of ill-ventilated public sewers, and which is so foul at times that many of the workmen who are obliged to pass up and down them are rendered unconcious by partial asphyxiation, and not a few of them are too often killed outright by it. To prevent these deplorable preventable accidents, all the street manholes (which are built over or on the side of main sewers) that are, or may be, used by the workmen whose business it is to see that the sewers are kept in a proper state of repair, should always be adequately ventilated, either on the lines or in the manner shown in Drawing No. 24 on p. 107, or preferably, **Drawing No. 24.** by converting the gully-drains into air-inlet or down-cast shafts. It is obvious that so long as the present unscientific and unphilosophical state of things remains, the public must continue to put up with the insanitary consequences, while it is equally obvious to the author that if the members of this association recommended their employers to dispense altogether with non-ventilated interceptors of the type shown on Drawing No. 20—i.e., in connexion with all new house and town drainage works—and substituted for it one of the ventilated types shown in Drawings Nos. 22 and 23—preferably the one shown on Drawing No. 22—a most important and far-reaching sanitary improvement, upon existing methods, would immediately result therefrom. Because the soil and other waste pipes connected with the interceptors and drains, and with the sewers as well, would then be ventilated, partly by the air which would be forced by water-closet and bath discharges down the soil and other waste pipes into the drains and sewers, and partly by the air that would flow by gravitation down the soil and other pipes into the sewer, whenever the air in the latter was of a lighter specific gravity than that of the

outside atmosphere surrounding the roofs and the tops of the soil and other pipes. These latter would then act the part of downcast shafts, and the sewers themselves would become the equivalents of upcast shafts, on the principle upon which furnace and fan ventilation is brought about in mines—e.g., if the temperature of the air of the sewer became, as it would do at times, 10° F., more or less, higher than the air of the drain on the house side of the interceptor, then undoubtedly a current of air would be induced to flow from the drains on the house side to the drain on the sewer side of the interceptor. If this latter be 30 ft. long to the sewer, and we treat it as a chimney or upcast shaft of that length terminating in the atmosphere outside and not in the atmosphere inside of a sewer, then the velocity at which the air would flow to the sewer through the regulated air inlet opening of the interceptor would be, allowing 33 per cent. for friction, about 4 ft. per second. If the regulated inlet be circular in shape, and 1 in. in diameter, the volume of the ventilating current would be equal to 1·32 cub. ft., or 8¼ gallons per minute. But, of course, the drain and sewer air conditions here stated are purely hypothetical, and are not on all fours with the conditions that obtain when heated air escapes from steam boiler furnaces into and up chimneys, or when heated air escapes from the like furnaces, placed at the bottom of the upcast shafts of coal mines, into and up such shafts into the atmosphere for mining ventilation purposes. The similarity between the conditions cited, however, is sufficiently approximate to induce the author to draw your attention to them, and particularly to the fact that, under the variable high temperature conditions which are continually occurring in sewers, sensible currents of air could not fail on such occasions to flow into, and help to ventilate, house drains, interceptors and sewers alike. And that such naturally induced currents, supplemented by others, resulting from the falling of water-closet and other waters, down soil etc. pipes, would, if conducted into sewers through drains possessing the apparatus shown in Drawings Nos. 22 and 23, even without mechanical aid, effect improvements upon existing methods which would, as already stated, be of incalculable sanitary value.

But self-cleansing drains and sewers ventilated throughout on the hydro-mechanical system—allied to the natural ventilation conditions just explained—could not fail to render our so-called English water-carriage system of sewage removal as "reasonably perfect," as the late Prof. Huxley, and a host of other eminent sanitarians of the last century, desired it should be, and, as the author is confident it can and will be made to be, sooner or later, and the sooner the better he says, and so, he feels sure, the members of this association and their employers will say so too.


Air Inlet Shaft (Regulated)
with Reflux Valve
STREET
Air-tight Cover
Manhole
Sewer

85. The author will now state something about the work of circulating air in sewers.

The frictional resistances of air in sewers may be found from formulæ similar to those used by hydraulic engineers for water; but, as water is 800 times heavier than air, the frictional resistances for air will only be about 1-800th part of what they will be with sewage or water. The frictional conditions applicable to the act of transporting air through pipes, however, only become quite analogous to those which apply to water when the drains or sewers are free of liquids and are charged full bore with air, the reason being that what we call the "pneumatic" mean radius of a drain or a sewer only corresponds to the hydraulic mean radius of a water pipe when the latter is flowing full bore with water. When it is partially filled with water and partially filled with air the pneumatic mean radius is found by adding the transverse length of the water surface in the drain or sewer to the length of the unwetted arc-perimeter of the drain or sewer, and by dividing the sectional area of the sewer (in square feet) by the sum of these two lengths in feet.

86. The ordinary formula for finding the frictional resistance to the flow of air in channels, as given in most text-books on the subject, is

$$h = \frac{l \times v^2}{52{,}750 \times d \times r_p} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where h = the frictional resistance in inches of water,
l = the length of the sewer in feet,
v = the velocity of the air current in feet per second,
d = the diameter of the sewer in inches,
r_p = the pneumatic mean depth which for circular pipes flowing full bore = 0·25000

If the pipe is $\frac{1}{4}$ full of sewage r_p = 0·21343
" " $\frac{1}{3}$ " " = 0·19571
" " $\frac{1}{2}$ " " = 0·15275
" " $\frac{3}{4}$ " " = 0·08026

As, however, the air from the house connections or other inlets enters at a number of points, and the volume of air, and consequently also the velocity of the air current, is a gradually increasing one, then the above formula must be modified to these conditions; and the author has therefore adopted the following formula, which is a near approximation to the formula proposed by Mr. Edwin Ault in his paper on "The Ventilation of Drains and Sewers," which was read before the Civil and Mechanical Engineers' Society in 1902, and which is based on the fact that the frictional resistance is very nearly equal to the square of the average velocity. The formula is as follows :—

$$h = \frac{l\left(\frac{v_1^2}{6} + \frac{v_1 v_2}{2} + \frac{v_2^2}{3}\right)}{52{,}750 \times d \times r_p} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where v_1 = the initial and v_2 = the final velocities in feet per second.

When the difference between v_1 and v_2 is small, as is often the case, and where the frictional resistance in a number of consecutive lengths of sewers of various diameters is to be calculated, a still simpler formula may be used, viz. :—

$$h = \frac{l \times v_1 \times v_2}{50{,}000 \times d \times r_p} \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Sudden variations in the velocity of the air currents, such as would obtain, for instance, if the volumes of ventilating air proceeding from the smaller tributary sewers exceeded the volume required to preserve a tolerably uniform velocity of current in the main sewers, should be avoided by being regulated, otherwise both the hygienic and the mechanical efficiency of the motor and fan may be sensibly reduced.

The same may be said about sharp bends and all openings having sharp edges, as, for instance, when the air current passes through an ordinary manhole with open invert into the sewer beyond.

87. The power required to move the air by means of a fan can be found approximately, when the size of the delivery pipe is known, from the following formula, which is for fans of good design :—

$$\text{B.H.P.} = \frac{u^3 \times a \times \sqrt{1 + h}}{250{,}000}$$

where u = velocity of air through delivery pipe of fan in feet per second,

a = area of delivery pipe in square feet,

h = total pressure against the fan (suction and delivery) in inches of water.

88. In towns with electric supply, where current for motors is sold at low prices, the electric motor forms a source of motive power which is admirably suited for driving fans for ventilating drains and sewers. It is cheap, compact and reliable, and can be made to run the fan at any required speed. By its aid, therefore, it becomes an easy matter to divide a town up into any convenient number of ventilating districts, and to provide each district with a fan and

motor erected in a small chamber under the street surface, and to deliver the air into a ventilating shaft or elsewhere.

89. The objections made, so far as the author is aware, against the hydro-mechanical system of ventilation are more or less typical of the kind of objections which new things for ages past have encountered in the first instance, whatever the character or intrinsic merits of the new things may have been. For anyone, however, in these pronounced municipal economy days, and especially the inventor of new sanitary things, to undertake to talk of municipal and sanitary engineering reforms, of all subjects, and in the presence, too, of the engineering advisers of the sanitary authorities of this country, is, to say the least, a formidable task; but, nevertheless, the author has not flinched from undertaking it, knowing full well as he does how earnestly desirous the members of the Incorporated Association of Municipal and County Engineers are to acquire the most reliable and best possible information concerning the all-important subjects of drain and sewer ventilation problems. In fact, he is unfeignedly thankful for the privilege which this paper affords him of laying before the association his own and his partner's views as to the ways in which the problems in question can be scientifically and practically solved for all time.

Discussion of Mr. Shone's Paper.

90. Mr. P. Dodd (Wandsworth) said that it seemed to him that Mr. Shone's method was an ideal way of dealing with this complicated question. It appeared to be based on scientific principles, and the only objection that could be brought against it was on the score of expense; but when they considered the number of deaths that occurred as the result of badly-ventilated sewers and drains, the sooner the question of cost was dealt with by those in authority the better it would be for the health and welfare of the community at large. Years ago he had some experience in colliery ventilation, and had also had some experience in drain and sewer ventilation, and the more he studied this hydro-mechanical system the more he was convinced that Mr. Shone had placed before them a practical scheme for solving this difficult problem. Their present method of ventilating drains and sewers by natural means must of necessity be spasmodic, for they depended more or less on the state of the atmosphere, the direction of the wind and other circumstances. In Mr. Shone's scheme there was a regular and constant current of air created irrespective of the conditions of the atmosphere; and instead of bringing the foul air to the vicinity of the houses, as is done at present, it was taken to a point some distance away where

it was filtered and rendered perfectly innocuous before it was allowed to escape to the external air. As they all knew, there were miles of drains in most of their towns between the intercepting trap and the sewer which were not ventilated, and for that among other reasons he was one of those who believed in the abolition of the intercepting trap on the house drain; but in the system before them they were provided with an ingenious arrangement, shown on Drawing No. 22, for ventilating, not only the drain on the house side, but the drain on the sewer side of the trap, and therefore one of the chief objections to the interceptor was got rid of. Moreover, by sealing the drain at the bottom of the intercepting chamber, as shown on Drawing No. 22, the usual air inlet was dispensed with, and the chamber was not liable to be filled with sewage as was the case when the trap happened to be blocked. Another great advantage in the scheme was that it could be adapted to existing sewers and drains without much difficulty and apparently without much cost. If authorities like the London County Council, who had control of the large main sewers, could adopt a scheme of that sort and get rid of the volumes of foul air which were bound to accumulate during the dry-weather flow of the sewage, and which during certain states of the atmosphere were practically stagnant, it would be a very good step in the right direction. In conclusion, he wished to propose a vote of thanks to Mr. Shone for his valuable and interesting paper, and for the elaborate drawings which he had prepared to illustrate his scheme.

91. Mr. William Weaver (London) seconding, said that having carefully read all the papers he had had on the subject, and seen a little of the system, he was of opinion that Mr. Shone had cleverly solved the question of properly ventilating sewers—provided they were made airtight. So far as London was concerned, the root of evil smells were the large main sewers; and the method of the London County Council to get rid of the nuisance was to close up the main air shaft, leaving to the local authorities the task of dealing with the infuriated ratepayers who naturally objected to sewers discharging their gases under their windows. If the County Council could be induced to undertake an experiment on one of their main line sewers, thoroughly test the system, and apply it if successful to the other main sewers of the metropolis, he did not think there would be much left for the local authorities to remedy.

92. Mr. A. E. Collins (Norwich) supported the motion of Mr. Dodd, observing that he looked upon Mr. Shone as the man who, with his ejector, had made the only really fundamental improvement in sewerage since the time of the Romans. Mr. Shone had the advantage over most other people of having lived to see the

fruition of this invention, and he hoped that such might also be the case regarding Mr. Shone's system of ventilation. It would be valuable if the London County Council would try the experiment suggested by Mr. Weaver, and see if they could get the air purer in their long lengths of sewers.

93. Mr. E. G. Mawbey (Leicester) stated that they put down a Shone installation to eighty houses in his town, serving a population of 356. Although he was dead against Mr. Shone on the subject to begin with, he ultimately saw something in the system, and decided to try it. The old idea that mechanical ventilation would (as carried out by Mr. Shone) unseal traps in drains had been entirely swept away; they had found that it was quite practicable to ventilate the drains and keep a steady flow of air away from the houses. They had had a great number of analyses taken of the air both in the old and the new sewers ventilated by manholes and those by shafts, and he could tell them that the carbonic anhydride was substantially and uniformly reduced throughout the system.

94. Mr. A. M. Fowler (Manchester), referring to the system of ventilation introduced by the late Sir Robert Rawlinson, said that at the time he (Mr. Fowler) was engineer to the Corporation of Leeds, Sir Robert was experimenting at, among other places, Worksop. There he had the vertical trays in the shafts made of wire gauze filled with charcoal, the idea being that the sewer air would filter through the gauze and deodorise. But the whole thing was a myth, the charcoal lost its effect, the screens were choked, and it was found that there was no draught whatever through them. He believed that he was not wrong in saying that later on Sir Robert himself saw the fallacy of the ventilators. Of course, the objection to sewer air applied with greater force in large towns than in smaller places from the fact that in the former the sewers were much larger, and in times of dry weather, when the sewage was very low and concentrated, the pipes were very highly charged with sewer air. He did not call it sewer-gas, because they all knew that fresh sewage was comparatively harmless, only commencing to be dangerous when it threw off sulphuretted hydrogen—which it did after a period of about three days. At Leeds he made many connections to mill chimneys. These were a great height, and even with the furnaces down there was a very considerable draught. But although that was the case it was impossible to get a current down a sewer from more than 150 yards. There were, of course, all the gully outlets, which in a large sewerage system one could not expect to get hermetically sealed. But great progress had been made since that time with the subject of sewer ventilation, and he did not think there was much danger to the inhabitants of houses, for they had

got so perfect in the matter of disconnections and vertical columns that one very rarely found any offensive smell near a house. He was always willing to support any scheme that would promote the subject, and for that reason was in favour of the idea of putting down a small installation so as to show if possible to the world that this was a perfect success. That would be the most practical and crucial test that they could possibly have.

95. Mr. T. READER SMITH (Kettering) said that there were many points of difference between mine ventilation and sewer ventilation. In mines there were usually only two openings—a downcast shaft and an upcast—and ventilation was easy until one came to the working faces, where it was largely dependent on sheeting which allowed heavy leakage. It seemed to him that the suggestion that by means of Mr. Shone's system it was possible to ventilate long lines of outfall sewers was very practical, but there were a great many openings along a line of sewer through which air was continually entering, although some of those could, of course, be controlled. The thing resolved itself into a practical consideration of the question: How far would the effort of a fan extend along a line of sewers having these various air inlets? An answer to that would give them some idea as to how many centres of ventilation it would be necessary to establish in a system, and at the same time furnish some indication of the expense.

96. Mr. W. J. STEELE (Bristol) * was of opinion that sewers were intended for the conveyance of the refuse of a community, and contended that the necessity for adopting any special means to pass atmospheric air through a properly designed sewerage system had never been proved. The trend of the discussion at that meeting, like so many others on the same subject, seemed to imply that the adoption of some special means was an axiom, but he ventured to suggest that it was only an assumption based upon conclusions arrived at too hastily. It had been thought that if no means were undertaken, the water seal in the numerous traps would be forced. Had it ever been proved that any large sewerage system was so perfectly airtight throughout, that the air pressure created during a heavy rainfall, or by the rise of the tide at sea outfalls, was so great as to cause the water seal in a considerable proportion of the traps to be broken? If this condition does occur, then most undoubtedly special means should be adopted in Bristol, where a large area of the sewerage system was tide locked twice a day. No special means were adopted in Bristol, and the manhole covers were closed, yet the general and zymotic death rates would compare most favourably with any town of similar size in the country. What would they gain

* See "Bristol" in Appendix vi. page 294, *infra*.

by adopting any system of ventilating their sewers in Bristol? It would be a doubtful experiment, and if they spent the necessarily large sum required, it was a question whether it would do any good, but probably would give ground for very serious complaint, which did not occur under present conditions.

97. Mr. T. CAINK (Worcester) remarked that the foundation of Mr. Shone's system was the assumption that it was necessary to have pure air within a sewer. That, if true, would make the cost of purifying the air a secondary matter. But he agreed with the last speaker, that the assumption was entirely fallacious, and that the whole system, based on that assumption, was fallacious also. The object of sewers, as had been stated, was to convey foul matter. In comparing sewers with mines Mr. Shone had overlooked the fact that one was occupied by persons who had to study their health, and the other by rats and foul matter. The subject occupied him twenty-five years ago, and experiments carried out then showed that it was a fallacy to obtain a circulation of air in a sewer. The effect was to bring into the sewer an increased quantity of foul air. So he was led instead to check the circulation of foul air, and found that all it was necessary to do was to give the sewer such relief as to prevent the pressing of the air through private traps in the drains. In doing that he provided that the air should escape so slowly that it was not observable in an objectionable way. It was obvious that air must escape from a sewer, for every variation in the flow of the water affected it. He thought it was undesirable not to provide means for the escape of the air; while to allow it to escape in a haphazard way was also undesirable. But to assume that it was necessary to provide purified air in a sewer was a fallacy, and any system based on that was a failure.

98. Mr. J. PRICE EVANS (Wrexham) said he had read Mr. Shone's paper, and taken a great interest in it. As a mining as well as a municipal engineer he believed Mr. Shone to be on the right track, but as was the case with every new idea his system was bound to meet with a certain amount of objection. He could not agree with Mr. Steele in his observations because there was always ventilation going down a sewer. He thought the paper was worthy of their serious consideration, and especially of those who were about to lay out a new district. He heartily appreciated the paper, wished Mr. Shone every success, and hoped it would have their careful attention, for the more fresh air they got into their sewers the better it would be.

99. Mr. T. W. A. HAYWARD (Battersea), in a communication on the subject of the paper—which he regarded as most interesting and instructive—said no one would dispute that something ought to

be done in regard to more efficient ventilation. The sewers in our large towns were in many cases nothing more or less than death traps to the men that had to enter them, and any scheme that would remove the dangerous condition of our sewers should be welcomed by municipal engineers. During the summer months of every year, borough engineers in London were inundated with complaints as to smells from sewers, and he quite agreed with the author of the paper that this nuisance should demand greater attention from local authorities than it had hitherto done. Mr. Shone's suggestions were original, and he should very much like to see an experiment tried, on the lines laid down by him, in some of the sewers of the metropolis. The scheme appeared to him to be very carefully thought out. It was simple in construction, and there were very few parts that were likely to get out of order. He should like the scheme better if the reflux-valve on the interceptor trap could be modified in some way, as backpounding was not unknown, and he was afraid the valve might not always act in the way one would desire. The idea of adopting means to draw air into the sewers from the pipes round buildings, and discharging it at a distance from buildings, was very much better to his mind than allowing air to enter into, or escape from, sewers as in the present haphazard manner.

100. Mr. H. GILBERT WHYATT (Grimsby) writes that while congratulating Mr. Shone on the ingenuity of his scheme for dealing with sewer air, he ventures at the same time to disagree entirely with the argument that such a scheme for the ventilation of drains and sewers of small diameter is either necessary or desirable, however necessary it may be in the case of those large sewers into which workmen have to enter daily or periodically. In the extempore remarks made by Mr. Shone when introducing his paper, he quoted several instances of men being overcome by the foul gases, and stated that he had records of a very large number of such unfortunate incidents; but, with regard to the drains and sewers of small diameter, into which it is impossible for men to enter, it is absolutely unnecessary, in the writer's opinion, that they should be ventilated like mines, workshops or nurseries. It is certain that the extensive use of the intercepting trap has considerably increased the foulness of the sewers, partly by retaining quantities of sewage until putrefaction commences, and partly by the interference with the ventilation of the sewers through the drains and ventshafts on private properties. The number of intercepting traps should be reduced to a minimum, one trap to a block of property being all that is necessary; and, in this case, the amount of sewage flows so continuously that no portion remains in the trap sufficiently long for putrefaction to commence.

The present writer cannot think that in the interests of pure air in sewers of small diameter, the air of the towns should be polluted by continuous streams of sewer air extracted by means of a number of fans; and all that is necessary is a sufficient number of ventshafts, acting simply as relief openings in the case of a plenum pressure in the sewer, and discharging the minimum quantity of air that may be necessary to relieve the pressure at a level a few feet higher than house roofs, and, when there is a slight vacuum in the sewer, acting as inlets. One defect in Mr. Shone's scheme appears to be the "very sensitive and mechanically precise aluminium valves" which are fixed in the intercepting chambers. There are very few towns where the sewers are not overcharged two or three or more times each year by a sudden afflux of storm water lasting from a minute or two to a considerable portion of an hour, and after each such rain-storm the whole of these underground valves would have to be taken out and cleaned; for the same reason it would be very inadvisable to put the fan chambers and fans underground. Another objection seems to be the condensation of moisture. There are not many occasions when a manhole, however well ventilated, is opened up, but the ironwork and brick walls are not found to be dripping with condensed moisture, and, although aluminium is both durable and incorrodible, yet this condensed moisture will affect the careful balance referred to. A further objection is the initial cost of the installation and the annual charge for electricity, inspection and maintenance, to which Mr. Shone, perhaps discreetly, makes no reference. The only guide to this which the present writer has been able to find is in a paper by Mr. A. M. Fowler, M.Inst. C.E., past-president of the association, which he read at the annual congress of the Royal Sanitary Institute in Manchester on September 10, 1902. In this he gave the cost of electricity only as £440 per annum for a population of 75,000 (£5 17*s*. 10*d*. per 1000). He mentioned nothing with reference to interest and repayment on the capital expenditure, maintenance or attendance. In these days of "pronounced municipal economy" very few municipal engineers would be able to induce their local authorities to embark upon such an expenditure, or, if successful, the local authority would not be likely, after the first two or three years, to continue such an expenditure as the above figures indicate. Mr. Shone strongly recommends that the length of drain between the intercepting trap and the main sewer should be ventilated, and this is being extensively done in many towns. In Torquay there are over 2000 shafts carried up from the sewer side of the intercepting trap; and the present writer in Grimsby is able to secure this in nearly every instance where a block of houses is erected. In the paper on the subject of "Sewer

Ventilation" which the writer presented to the district meeting of the association when they did him the honour to visit Grimsby on April 23, 1904, among the conclusions which he arrived at, he stated that, in his opinion: (4) The mechanical removal of sewer air by fans is too expensive for ordinary use in towns. (6) That the solution of the problem appears to be the adoption of a large number of reasonably sized ventshafts at frequent intervals (this being practically the adoption of surface ventilation at the level of a horizontal plane a few feet higher than house roofs); the ventshafts to be provided in all cases with rust pockets. (7) That sewers must be regularly and frequently flushed, so that putrefactive matters may be removed before the production of foul gases commences. (8) That the ventilation of the length of drain between the sewer and the intercepting trap should be arranged for and carried out by the person building at the time of the erection of the property.

101. Mr. SHONE replied shortly to the remarks of some of the speakers. He said he had often heard that the Bristol sewers were not ventilated, but he himself always thought that they must be ventilated in some way or other, which only systematic investigators of them could discover and elucidate. Non-ventilated sewers wherever existent could not fail to be a source of danger to the people in whose towns they were to be found. The undulating character or configuration of Bristol doubtless favoured an amount of natural ventilation which had hitherto been unobserved. To cite the Bristol sewers as being worthy to be imitated elsewhere, seemed to him from a sanitary point of view to be most impolitic, not to say a dangerous thing to do, because it was obvious to him, as it would be to others, that if it were wrong (which, of course, it was not) to ventilate the sewers of the twentieth century, then the premier sanitary axioms of the premier sanitarians of the nineteenth century were not only set at nought but rendered absolutely ridiculous. He believed, however, that the nineteenth century methods of dealing with the air of such soil pipes, drains and sewers as were described in his paper were doomed to come to a speedy end in the twentieth century, and those methods he confidently predicted would be superseded by scientific methods devised on the lines indicated in his paper. But most certainly they would not be superseded by the methods which are in vogue in Bristol, where it was alleged the drains and sewers were left to ventilate themselves! Mr. Caink's statement that it was unnecessary to ventilate sewers, because the only living things in them were rats, was not in accordance with everyday practical facts bearing upon the problem. In the sewers of London, for example, there were at times armies of men employed to maintain them in working order; and he knew, as a matter of

fact, that the present chief engineer, acting for the London County Council, had expressed himself publicly as being anxious that some efficient system for ventilating the London sewers—if only for safeguarding the lives of the men who worked in them—would soon be inaugurated. To his certain knowledge many lives had from time to time been lost in ill-ventilated sewers in this country, and only the other day a cheque for 10*l.* was presented at Bow-street by Sir A. de Rutzen to Police-constable William Gough as a reward for his prompt and intelligent action in saving two men from asphyxiation by sewer-gas, emitted from a sewer into a manhole situate in Bethune-road, Stoke Newington. Sewers that were chock full of sewage-gas fed, not only the street manholes connected with them, but every house drain connected with them also, as explained in detail in the paper, and the moment such sewers were surcharged with sewage and rainfall waters above the crown of the drain at the point where it joined the sewer, that moment the interceptor trap on the drain would be unsealed, with the result that the foul sewage-gassed air contained in the house drain would be forced into the inspection chamber and drains on the house side of the interceptor. He himself had seen the interceptor eye-piece of an interceptor forced out of its socket in this way. But as they would gather from the official reports and statistics of the medical officers of health of this country from time to time, the number of men who worked in public sewers, and who sometimes lost their lives in them, was insignificant in the extreme in comparison with the number of people young and old whose health was directly and indirectly prejudicially affected by breathing impure air—rendered so by the mephitic vapours generated in and given off by the ill-ventilated drains and sewers of the present day. By the hydro-mechanical system, it would be seen, it was proposed to abolish street-surface ventilators. It was also suggested that the iron street-lamp-like ventilating shaft or column, shown on his Drawing No. 24 as possessing a regulated air-inlet and reflux-valve terminal piece, could be advantageously dispensed with altogether, and the equivalent arrangement shown in Drawing No. 21, and marked "R.A.I.," should be substituted for it. That was to say, instead of erecting more or less costly iron ventilating shafts in the streets, which many people regarded as unsightly and insanitary nuisances, an equivalent air-inlet and reflux-valve ventilating apparatus could be fixed in the street boundary wall, or in the kerb of the street parapet or footpath, for ventilating the street gully drains and the sewers at the same time, and at one-tenth of the capital cost of the iron columns. Each gully drain thus invisibly ventilated would always be productive of positive fresh air ventilating currents into the sewers. To say, as had been said by

Mr. Caink and others, that the larger the volume of fresh air that was circulated in sewers the larger would be the volume of foul air that would get out of them into the atmosphere of our house premises and streets, was absurd—e.g., if one poured into a vessel containing 1 oz. of pure whisky 3000 oz. of pure water, the 3001 oz. of liquid which the vessel would then hold would not be pure whisky but pure whisky diluted with 3000 oz. of pure water. In the same way if one diluted one volume of sewer-gassed air, which would asphyxiate men working in sewers, with 3000 volumes more or less of normal pure air, the resultant volume could be breathed, as the air of a well-ventilated room was breathed with impunity. With regard to the very practical question put by Mr. T. Reader Smith (Kettering) he desired to say that he hoped presently to supply the necessary replies in book form. In the meantime he might state that two separate egg-shaped sewers, 3 ft. by 2 ft., each to be 2 miles long, or 4 miles altogether, flowing two-thirds full of sewage, and having 1408 house drains, and 282 street gully drains connected to them, and for each connection to contribute ½ cub. ft. of fresh air into them, plus 50 per cent. as an allowance for leakages, could be efficiently ventilated by a fan requiring the one-fifth of a horse-power to drive it and for the motor to use about 8 Board of Trade units of electrical energy, costing, say, 1*d*. per Board of Trade unit, would amount to 8*d*. per day only, or at the rate of about 1*d*. per day per 1000 of the population. The water-gauge vacuum necessary to create, to effect the ventilation, would be under 1 in. at its maximum —i.e., at the fan—and the plenum necessary to force the air through the filter and up the outlet shaft into the atmosphere would be equal to about ½ in., or 1½ in. of water altogether. But at no house-drain interceptor, or street-gully trap, would the vacuum caused by the working of the fan required to ventilate the two separate hypothetical egg-shaped sewers, each to be 2 miles in length and both to converge at or near to the fan chamber, exceed ½ in. of water, and consequently there need be no fear whatever that any of the traps named would be unsyphoned, as Mr. Mawbey's practical experience of the system at Leicester—he was glad to find—had enabled him to testify. Some engineers had drawn his attention to the fact that sewers which were the recipients of both sewage and rainfall at times were inundated, when of course the house drains on such occasions were inundated also, and the sensitive reflux air-valve fixed above the house drain interceptor, as shown in Drawing No. 22, would be liable to be submerged in sewage waters, in which event it had been suggested the reflux air-valve would be disarranged, and would not afterwards—*pro tem.* at least—work properly. But where sewers and drains were liable to be flooded, the air inlet and reflux-valve should be fixed, as it always could be inexpensively fixed, above the highest flood-level mark in the house drain interceptor inspection chamber. He was, indeed, very gratified to find that so many members—four of them being ex-presidents of the association—had taken part in the discussion of his paper, as it was evidence of the fact that they were taking a genuine interest in the subject on which it treated, and which, as he stated at the beginning of his paper, he regarded as one of supreme importance to them especially—none more so; and this truism, in his opinion, would grow upon them all, including the two members who were apparently opposed to sewer ventilation of any kind whatsoever, in proportion to the time they would devote to the study of correct pneumatic principles, upon which alone, the economical and sanitary ventilation of soil pipes, drains and sewers could be universally brought about, whether in this, or any other country, wherever the so-called English water-carriage system of sewage removal was in vogue.

The Hydro-mechanical System of Ventilating Sewers.

TO THE EDITOR OF "THE SURVEYOR."

Sir,

102. As I have neither time nor inclination to enter into any lengthy correspondence on the above, I should be glad if you would kindly insert the following in your next issue as an addendum to the remarks I made at the recent meeting in Liverpool.

In the discussion on this subject, I gathered from the remarks made by Mr. W. J. Steele, Bristol, that the necessity to pass atmospheric air through sewers had never been proved, and he also asked whether it had ever been proved that the air-pressure created during a heavy rainfall was so great as to cause the water-seal in the intercepting traps to be broken.

It seems to me that, apart from other reasons, the large amount expended by the London County Council, borough councils, district councils, and other local authorities all over the kingdom in erecting columns and shafts, and experimenting in other directions for the purpose of assisting, to some extent, the atmospheric air to pass through the sewers, is a sufficient proof of the necessity for something being done in this direction. With regard to the second point raised by Mr. Steele, I know of instances of sealed manhole covers (weighing about 1½ cwt.) on the main sewers in this district having been seen to rise and fall rapidly for several minutes as a result of the compression of sewer air in the manholes caused by a sudden affluxion of storm water into the sewers. If the pressure is sufficient to lift a weight of $1\frac{1}{2}$ cwt., it necessarily follows that it is sufficient to force intercepting traps which contain at most from 20 lb. to 30 lb. in weight of water.

Yours, etc.,
P. DODD.

WANDSWORTH : *July* 16, 1907.

The Hydro-Mechanical System of Ventilating Sewers.

TO THE EDITOR OF "THE SURVEYOR."

Sir,

103. I have to thank you, as I now do, most cordially for inserting *in extenso* in your last week's issue the paper it was my privilege to prepare for and to present to the Incorporated Association of Municipal and County Engineers, on the above-named subject at their annual meeting which was held in Liverpool last month. To get the whole of my paper and all the drawings referred to in it, as well as the salient points of the discussion which arose out of it, inserted in one issue, all those who, like myself, are intensely interested in the subject will highly appreciate.

The two interesting communications which reached you after the day on which my paper was presented and discussed at the Liverpool meeting, the one from Mr. T. W. A. Hayward (Battersea) and the other from Mr. H. Gilbert Whyatt (Grimsby), necessitate, I think, a few further statements from me by way of reply.

(1) The point raised by Mr. Hayward as to the probable effect of sewage floodings in the sewers, upon the reflux air valve within the regulated air-inlet box is, of course, a very practical and very natural one to be raised, especially by engineers in charge of sewers liable to be flooded, as doubtless some of the Battersea sewers are at times. But, as I explained in the statements which form my contribution to the discussion on the paper, the difficulty in all cases can always be readily and inexpensively got over by simply elevating the regulated air-inlet and reflux valve-box above the highest known high-water sewage mark in any and every house drain and inspection chamber, etc. But, after all, the number of cases where special provisions of the kind now suggested are required would form a very small percentage of the whole number of inspection chambers constructed in the towns of England; and therefore it was that I had Drawing No. 21 made to apply to normal and not to abnormal house drain and sewer conditions.

(2) Mr. Whyatt's communication, I confess, astonishes me. He admits that manholes and main sewers in which men are obliged to work ought to be ventilated; but he does not think it necessary, or even desirable, to ventilate drains and sewers of small diameter. But surely the air of house drains and soil and other waste pipes that are in direct communication with sewers, whether the latter be large or small in diameter, which are not ventilated but simply vented, on the principle on which cesspools are vented—which is approximately the principle of Mr. Whyatt's plan for ventilating sewers, or rather, the principle he adopts not for ventilating them, but for not ventilating them—must be foul in the extreme. The sewer air recently accidentally discovered in a manhole in Bethune-road, Stoke Newington, and which was reported in your discussion column last week, is really characteristic of the air of all non-ventilated sewers; and if so it must be characteristic also of the air of every house drain on both the sewer and house side of the interception traps, inserted on the lines of house drains discharging sewage into such sewers. Here is a description which appeared recently in the "Western Mail" of the remarkably insanitary effect of such sewers :—

"RHYMNEY." "*Typhoid, Diphtheria and Sewer-Gas.*"—"Mr. Thomas Jenkins, J.P., presided. The medical officer of health reported that there had been twenty-eight cases of typhoid fever, and three deaths. He had attributed the fever in the upper district to sewer-gas, through insufficient ventilation of the main sewers, although the drains of a large number of the houses were properly ventilated by pipes reaching above the roof. He was still of opinion that sewer gas was the chief cause, and he recommended that the main sewers be better ventilated. Of diphtheria there were twenty cases. Sewer-gas no doubt contributed, but was not the chief cause."

Any hesitation in endeavouring to reform the present methods of ventilation because the suggested improved methods are likely to cost a little more money than the existing methods, which kill more people than all our railways and mines put together do, is, to my mind, very reprehensible, and I am convinced that ere long, the Government of this country will enforce the simple sanitary engineering reforms which are outlined in my paper much sooner than most people who now probably think them premature are aware of.

Yours, etc.,
ISAAC SHONE.

47 VICTORIA STREET, WESTMINSTER,
LONDON, S.W. : *July* 17, 1907.

"THE CONTRACT JOURNAL,"
August 7, 1907.

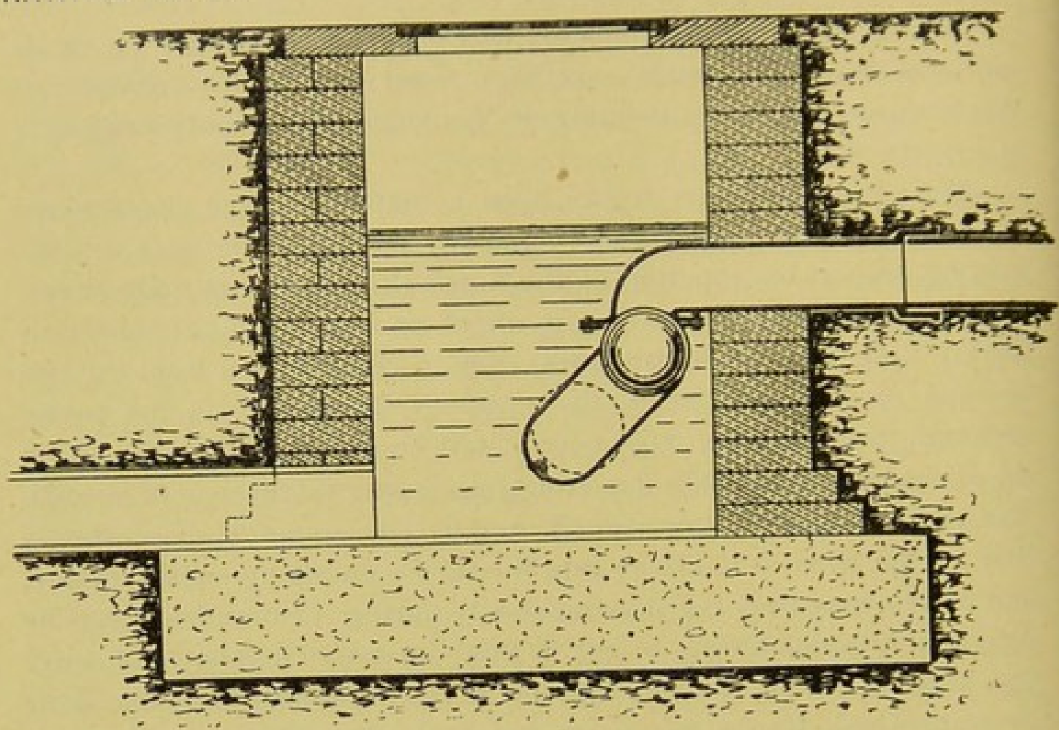
COPY.

Sir,

104. I have read with much interest the report of the paper on soil-pipe, drain, and sewer ventilation read by Mr. Isaac Shone, of Westminster, at a recent meeting of Municipal and County Engineers at Liverpool.

For very many years it has been a matter of keen controversy amongst sanitary engineers as to the advisability of fixing a disconnecting trap at the junction of the house drain with the main sewer. One thing is certain, viz., that it offers no barrier to the sewer air forced back into the house drains, due to compression from the rise of tidal or storm waters in the sewers. Mr. Shone, in his paper, endorses from his own experience a well-known fact, that the air on the sewer side of the disconnecting trap, owing to absence of ventilation, is everlastingly imprisoned, and is consequently everlastingly foul, except when it is driven into the house drains by back pressure, and as this may only occur occasionally during 12 months, it can be imagined how deleterious to health this concentrated essence of sewer gas must be; and it must also be borne in mind that the same pressure which forces this sewer gas back through the intercepting trap will also drive it through the shallower seal of gullies, traps of water-closets, and other appliances. The manufacture of coal gas for illuminating purposes by distillation can only be effected in a closed retort, and sewer gas is similarly produced by imprisoning air in sewers and drains in which sewage not only passes, but is frequently retained until decomposition and fermentation take place. Ventilation on a large scale such as the entire abolition of intercepting traps and the continuation of every soil-pipe above roof-level would undoubtedly prevent the generation of sewer gas by establishing a constant circulation of fresh air within the sewers and the consequent removal and neutralisation of poisonous vapours. But one great difficulty exists in adopting such a system of universal ventilation owing to the great variation in the heights of buildings in cities—as, for instance, a two-story building adjoining one of four or more stories. In such a case the termination of the soil and ventilating pipe at the roof-level of the lower building would possibly discharge in close proximity to the windows of the higher building. Nevertheless, much could be done to improve the state of the air in the public sewers by carrying ventilating pipes up above the roof-level of the many high buildings which are being erected in nearly all large towns. It is, however, of paramount importance to prevent the possibility of air of any kind from public sewers having access under any circumstances into the house drains; and whilst I am not prepared, without better reasons than at present exist, to advocate the

DRAWING No. 25.



total abolition of the intercepting trap, I would strongly advocate that in all cases where the drains are liable to the effects of back pressure previously mentioned, a tidal back pressure ball valve should be fixed in the manhole at the junction of the house drain with the public sewer. The type of back pressure preventing ball valve I allude to, and shown in the accompanying illustration, was invented and patented many years since by the late Mr. George Jennings, and has been most satisfactorily adopted in numerous instances. Its action is most reliable and simple, and, as will be seen by the illustration, the ball is tightly forced into the mouth of the house drain by its being raised by the rise of the tidal or storm waters in the manhole. The hope that my remarks on a matter of universal interest may be considered of sufficient importance to justify you in publishing them is, I trust, an ample excuse for the length of this letter.

Yours, etc.,
(Signed) WALTER JENNINGS.

67 LAMBETH PALACE ROAD, S.E. :
August 1, 1907.

"The Contract Journal,"
August 21, 1907.

Copy.

Soil-Pipe, Drain and Sewer Ventilation.

Sir,

105. I was glad to read Mr. Walter Jennings's letter in your issue of the 7th inst., in which he states that he had perused "with much interest" the paper I had prepared for and read at the "recent meeting of Municipal and County Engineers at Liverpool" on the above-named subject, a copy of which you did me the honour to insert *in extenso* in your issue of June 26 last. The particular statement made in my paper which he quotes in his letter, and which is to the effect that under existing arrangements the air in the drain between the interceptor and the sewer, being everlastingly imprisoned there, must be everlastingly foul, needs correction to make it literally accurate, because, of course, the moment rainfall waters augment the volumes of the normal sewage flow of the drains and sewers sufficiently to close up the aerial opening between the drain and the sewer, the imprisoned air of the drain lying between the sewer and the interceptor is then compressed, and if the inflow of sewage and rainfall continues the imprisoned air will then unsiphon the trap and force itself there-through to the house drain on the house side of it, and it would perform this natural but most insanitary operation before Mr. Jennings's father's excellent device for preventing the flooding of basements, etc., could possibly come into play. On such occasions the imprisoned air of that part of the house drain which lies between the sewer and the interceptor, and which is the "concentrated essence of sewer gas," as Mr. Jennings calls it, would be ejected therefrom into the air of the drain and soil and other waste pipes lying on the house side of the interceptor, and by so doing the whole of the air contained within those pipes would be rendered much fouler and more insanitary, whilst such air was making its escape into the normal internal and external atmosphere of the house drains, etc., than it otherwise would be. As Mr. Jennings remarks, "it must also be borne in mind that the same pressure which forces this sewer gas back through the intercepting trap, will also drive it through the shallower seal of gullies, traps of water-closets, and other appliances." This grave aspect of the danger which attaches to the presence of foul air in house drainage pipes, which if made of iron or lead, rot under its influence, was well stated by the late Sir George Buchanan in his

report to the Local Government Board on an outbreak of enteric fever which occurred in Croydon some years ago. What Sir George stated on that occasion Mr. Jennings will find is quoted in the introductory part of my Liverpool paper. But besides the "concentrated essence of sewer-gas," which Mr. Jennings refers to as being periodically forced into private house drainage pipes when the public sewers are inundated with rainfall floodings, enormous volumes of the foul air of our public sewers force their way at the same time out of them into the atmosphere of the streets *via* manhole covers, vent shafts, and unsealed street gully traps. These unhygienic operations must pollute the air of our towns, and thereby cause increases, as I believe, in the number of hospital patients that would, if investigated, astound the most callous-minded of our citizens. I am glad, therefore, that Mr. Jennings (if only because he is the son of so eminent a plumber as his father undoubtedly was) has perused my Liverpool paper, and that he has, as a consequence of that perusal, expressed what I will call a sympathetic acquiescence in any and every work that tends to bring about a better state of things than now obtains in connection with the ventilation of house drains and town sewers. Another eminent plumber of light and leading—I refer to Mr. Stephen S. Hellyer—in the sixth edition of his book entitled "The Plumber and Sanitary Houses" (published by T. Batsford), states:—"In the old way of draining a house, the air in the pipes and drains was confined as much as possible, and only allowed to escape in the form of noxious gases through the water seals of the various traps, or the gas holes they had made in the pipes. But now every waste pipe, every soil-pipe, every piece of drainage—whether long or short—has, or should have, a ventilating pipe." This is an admirably expressed sentence. But what a ventilating pipe is, from the point of view of some people, may simply mean any pipe that is in communication with waste pipes, drains, and sewers, which permits the influx of fresh air from the atmosphere into them, or the efflux of foul air out of them into the atmosphere, in a perfectly haphazard fashion, in strict accordance with natural laws. But under the influence of natural haphazard-like aerial laws, forsooth, as everybody ought to know, the air within the highest soil-pipe may be made to travel downwards, and escape *via* imperfectly made, and hung, mica flap-valves into the breathing atmosphere of house premises as readily as it can be made to travel down the shortest of soil pipes. So also, were the interceptor removed and the perforated manhole covers in the streets remained, would it, as often as not, travel down high and short pipes alike, and escape at the street level, to the annoyance of the passers-by.

I hope Mr. Jennings will have the leisure to re-peruse my Liverpool paper and the drawings which accompanied it. He will thus see that the hydro-mechanical system of ventilation is based on sound scientific and sanitary principles, which can be readily and inexpensively applied in practice to old, but more especially to all new, drainage and sewerage ventilation works.

Yours, etc.,
(Signed) ISAAC SHONE.

WESTMINSTER, S.W. : *August* 19, 1907.

APPENDIX II.

OBSERVATIONS AND ILLUSTRATIONS SUPPLEMENTARY TO AND FURTHER ELUCIDATING THE SUBJECT MATTER OF THE PAPER IN APPX. I.

108. As stated on page 93, the discussion which followed the presentation of my paper, and the correspondence which appeared in the "Contract Journal" and "The Surveyor and Municipal and County Engineer," together with the private discussions and correspondence which I had subsequently with engineers and others interested in the subjects of the paper, showed clearly that further explanations and drawings were needed to enable those who took part in the discussions and correspondence upon it, to understand it properly. I propose, therefore, in the following pages, to supplement the paper with such additional explanations and illustrations as will enable almost everybody interested in scientific and practical drain and sewer ventilation engineering, to perceive important differences between the past and still existing *quasi* "natural" plans and the proposed hydro-mechanical plan for ventilating drains and sewers.

The historical account that is given in my Liverpool paper of the attempts that were made in the last century for dealing with drain and sewer ventilation problems as they arose from time to time in London itself, is necessarily brief; and for that reason, and because my Liverpool paper is reproduced in this book, I respectfully invite every one who is genuinely interested in sewer ventilation to re-peruse that short historical statement. He will find that the methods and devices for the ventilation of drains and sewers of the Metropolis sixty years ago, were in every essential respect identical with those which are in vogue to-day.

And the same is strictly true of the country at large. During the whole period of over half a century there has been absolutely no organic departure, and no effective improvement. Great ingenuity and perseverance have been manifested from time to time in efforts to solve the problem. We have had in turn the street grating with or without charcoal and other disinfectants; we have had the official interceptor trap; we have had the high ventilating shaft with or without heat in various forms, and we have had combinations of each and all of them. But all these have at best been mere palliatives, and the primary and essential causes of insanitary drainage and sewerage have either not been hit upon or at least have not been effectually removed. The chief reason of this, I think, is the persistent tendency in men's minds to rely upon unassisted "nature." They seem to dwell too exclusively on the *vis medicatrix naturæ*; to imagine that if left alone she will provide her own remedies. They forget that she is a many-sided entity and is subject to mischievous as well as beneficent crises. To avoid the former and enhance the latter she requires to be corrected, guided, regulated, marshalled. The history of all sanitary science is a proof of this. Indeed, it is far too late to raise the cry of "natural remedies." That notion was exploded when the "water carriage" system of drainage and sewerage was established some seventy or eighty years ago in substitution for the cesspool and still more primitive methods of filth disposal which had flourished unmolested for many centuries.

Of course the word "nature" in this connection is used in a popular sense; in reality nature and her laws will never be denied. All inventions and contrivances for lessening or preventing the evils of existence, or for adding to its amenities or comforts, are after all nothing but the application of laws of nature previously overlooked or disregarded, as the wire conductor frustrates the mischiefs of the lightning. And the same considerations apply in the strictest manner to the system of ventilation which I venture to propose. There is, and there can be, nothing in it that is not strictly in conformity with and in pursuance of natural laws. The water-carriage system of sewage removal was a revolution—a right and righteous revolution in itself—but, as experience has proved, it had its initial and inherent dangers. And it is too notorious to require proof that those dangers have to this day never been properly removed. All attempts hitherto made with that object have been more or less abortive; and in many instances have been even mischievous. The air of our drains and sewers, and even the breathable air of our streets and houses, is still often polluted to an appalling extent. How this state of things continues possible, and is indeed caused, will be obvious from the following brief description, which is illustrated by diagrams.

109. Figs. 1 and 2 on Drawing No. 26 show how, according to the "First Report of the Metropolitan Sanitary Commission," which was dated September 24, 1848, street gullies and house drains were permitted to be coupled up to the Public Sewers. **Drawing No. 26**

Fig. 1 is a transverse section of a part of a street showing an egg-shaped sewer under it. This Drawing shows an open hopper-

Drawing No. 26, Fig. 1 like street gully, with an iron grating over it through which the rain-fall waters passed into the gully drain communicating with the sewer. It will be seen that at the lower or outlet end of the gully-drain a flap valve was fixed which was intended to prevent the sewage and the air of the sewer from rising up the gully drain. Originally the street gully drains at their upper ends had no iron gratings even upon them, nor had they flap valves fixed at their junctions with the sewers below. Under the original gully arrangement therefore all kinds of rubbish, stones, sand and mud, etc., were swept from the surface rain water channels of the streets into the sewers below. In this way banks of street debris would accumulate and rise above the sludge deposits on the inverts of the sewers, and dam back the natural flow of the sewage and thereby augment the volume and aggravate the insanitary character of the deposits lying on the inverts of the sewers. The placing of iron bars over the open shoot-like gullies at the street level and fixing cast iron flap valves at the bottom ends of the gully drains, as shown in Fig. 1, were consequently decided improvements upon the original plan. The iron grating openings over the street gully shoots were, however, in the first instance so small that most of the stones that rolled to them along the street channels failed to pass through them, and the consequence was that street channel debris accumulated at and rested on the gully gratings, and thereby greatly interfered with the free flow of the water through them; and this state of things rendered the work of removing the debris accumulations at the street gullies laborious and expensive. For these reasons the gully design, shown in Fig. 2, was substituted for that shown in Fig. 1, and in fact it may be said that the gully design, Fig. 2, is the one that is now and has been in use in the metropolis, with slight modifications, ever since the Metropolitan Commission of Sewers approved of it sixty years ago.

Of course, both the original open shoot-like gully-drain as well as the design shown in Fig. 1, permitted sewage-gas nuisances to arise from the sewers into the streets. But in the past, as in the present, wheresoever noxious sewage-gas nuisances were, or are, detected in the air of streets, the public have always protested against them.

110. The improved gully, Fig. 2, therefore, although sanctioned by the Metropolitan Sanitary Commission, was nevertheless faulty in a sanitary sense, because according to this design, the air within the whole length of the gully drain, from its sewer end to its street end was compelled to remain stationary and foul; so also was the air of the house-drain between the interceptor and the sewer compelled to remain stagnant and foul as long as the original interceptor device remained unventilated.

Again, so long as the sewers themselves were then, as indeed too

DRAWING No. 26.

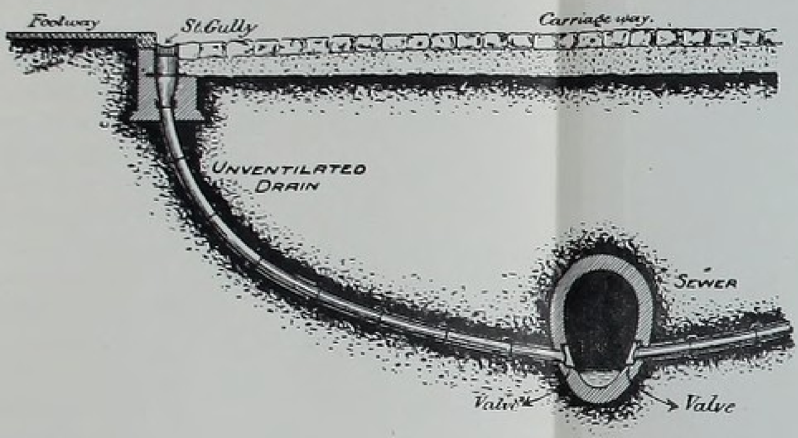


Fig. 1.

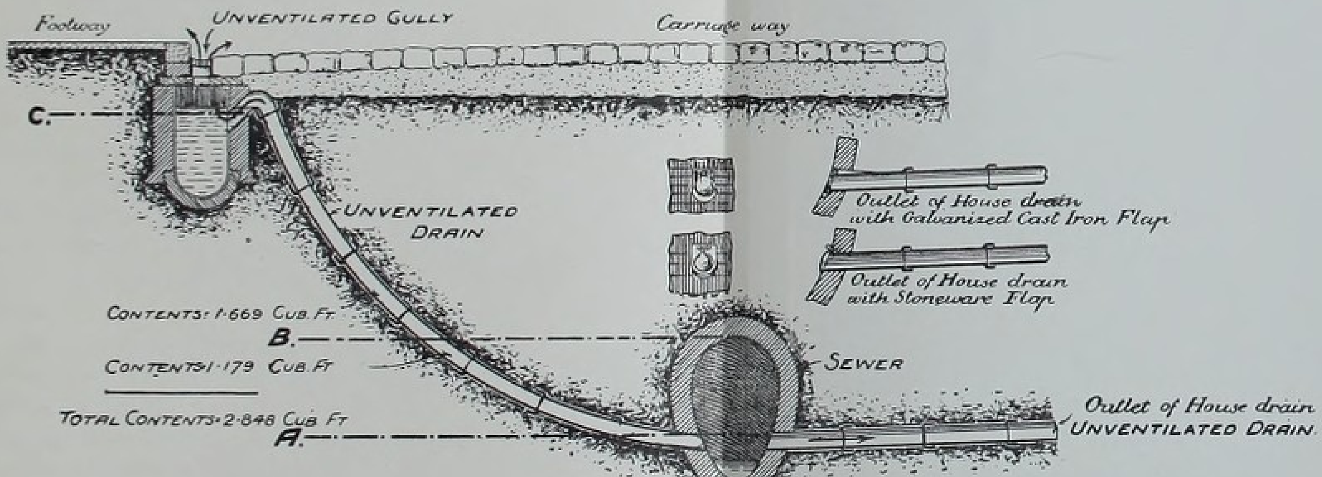


Fig. 2.

many of them are still, badly ventilated, the whole body of the air within them must also be foul and insanitary in the extreme. It is not, therefore, surprising to find that public sewers which are thus unscientifically ventilated, when coupled up to unventilated gully and house drains, give offence to the people who live in the houses built on either side of them—and still more to those who walk over or near to the street gullies placed at the side of the streets; or over or near to the perforated iron covers, which are placed in the centre of the streets over the tops of the sewer manholes.

The conditions being as thus stated, we find it prescribed that sewers should be "naturally" ventilated by placing ventilating openings in the iron covers of street manholes, at intervals of 50, 60, 70 to 100 yards. At the same time it is prescribed that the aggregate sectional area of the ventilating air-spaces in each manhole cover shall be 60 sq. in. (which is about the area of a 9-in. pipe).

In this combination, there is a total disregard of the dimensions, lengths, and gradients of the sewers to be ventilated. These methods, I suggest, are entirely unscientific and must produce many insanitary effects.

111. The force of these statements will be better understood by looking at Fig. 2 on Drawing No. 26. The arrows indicate the way the foul air of the gully and house-drains would be forced out of them, through the street-gully and house-drain interceptors, whenever the sewage in the sewer rose to and above the letter "A." We will assume the gully drain to be 6 in. diameter, and that it is 14 ft. 6 in. long from its lower end at "A," to its top end at "C."

The cubical air contents of the drain between "A" and "C" under those conditions would be 2·848 cub. ft. If the water-seal of the street gully trap was 6 in. in depth, the volume of sewage needed to rise in the gully drain above the level "A," to force air out of the gully into the street as shown by the dotted arrows, would only be about a quarter of a gallon.

The proof of this is extremely simple, as can be demonstrated by the following calculations. Everybody knows Boyle's Law—that with a constant air temperature the volume varies inversely as the pressure or elastic force.

Let us then assume that the normal pressure of the air is equal to 14·7 lb. per sq. in. This is equal to the weight of a column of water 34 ft. or 408 in. in height.

Assuming again, as before, that the water seal of the street gully trap is 6 in. in depth, how much water entering the gully drain from the sewer will suffice to unseal it? In other words, how much water flowing up the gully drain from the sewer will suffice to exert pneumatic pressure enough within the drain containing the

2·848 cub. ft. of confined air between "A" and "C," to make it force or unseal the gully-trap at "C"? On the above data we find that the air must be compressed until its volume is reduced to $2 \cdot 848 \times \frac{408}{408 + 6}$ $= 2 \cdot 807$ cub. ft. Therefore the volume of the water (or sewage) that will suffice to unseal the trap is $(2 \cdot 848 - 2 \cdot 807) = \cdot 041$ cub. ft. Now as a cub. ft. of water contains $6\frac{1}{4}$ gallons, therefore ·041 of a cub. ft. = ·256 or $\frac{1}{4}$ of a gallon . . . . . . (*a*)

Let us now apply this result to our 6-in. drain pipe. One inch in length of a 6-in. pipe has a volume of $6^2 \times \cdot 7854 = 28 \cdot 2744$ cub. in.; each inch in length will therefore hold $\frac{28.2744}{1728} \times 6\frac{1}{4} = \cdot 102$ of a gallon . . . . (*b*)

If now we divide result (*a*) by result (*b*) $\frac{\cdot 256}{\cdot 102} = 2\frac{1}{2}$ in. approximately.

This shows that when the sewage water of the sewer rises $2\frac{1}{2}$ in. up the gully drain the water seal of the street gully will be broken.

Further, if after this event happens, the sewage water in the sewer continued to rise, say up to its crown or the level "B"—then in the interval all the foul air contained in the 6-in. drain between the level "A" and the level "B" will have been forced out of it into the air of the street in the manner indicated by the arrows shown in Fig. 2 on the Drawing.

112. In this way the imprisoned sewage-gassed air of all such street gully drains, and all the foul stagnant air which is imprisoned in the house drains, between the interceptors and the sewers, is always made, as it were, to sit on and pollute the waters of the interceptors and gullies, with the result that by the absorption of the sewage gases contained in such imprisoned drain air, the contents of the interceptors and gullies are too often literally and practically converted into putrid cesspool-like sewage, whose gases in turn emit themselves, more or less potently, into the air of the streets on the one hand, and into the air of the drains and sewers on the other.

113. The following extracts from evidence given in 1858 before a House of Commons Committee on the ventilation of sewers are interteresting in the light of present-day engineering, as compared with that of the middle of the last century.

Colonel Haywood, the chief engineer to the Corporation of the City of London, said: "A down-draught, so complete as to be superior to the diffusive power of the gases, you cannot start with a velocity of less than two miles an hour; and suppose the whole district has been so arranged as to have a sufficient exhaustive power, the mere opening of a water-closet, or the enlarging or the putting in of a new drain into a sewer, or the making a hole a foot square, or a servant taking up a bell trap in a sink, or a sewer man lifting a side-entrance covering, would very much destroy the power of the furnace, and unless you had a gigantic power sufficient to guard against all these casualties, the system could only be a failure."

Sir Joseph Bazalgette, the chief engineer to the Metropolitan Board of Works, gave the following evidence:—

"A furnace ventilating any large district would require to produce a very large volume of air, and to keep up a velocity sufficient to ventilate all the branch sewers, and the drag would consequently be so great through the main that it would force open any house-drain traps or water traps we could form before it would influence the remote branches; but, putting those difficulties out of the question which appeared to us insuperable, we found that the consumption of coal to extract the required quantity of air, supposing that the sewers could be laid out like the channels of mines, would be something enormous."

"I found that the furnace of the clock tower of the Houses of Parliament was supposed to have been connected with the adjoining district to the extent of about a quarter of a square mile, and with about six miles and a half of sewers in length when added together, but that the ventilation had in reality been intercepted by a flap, so that the benefit supposed to be derived therefrom was purely imaginary. Having come to that conclusion, the next thing I directed my attention to was, supposing the whole of the air extracted by that furnace was produced from the sewers, and supposing that all the intermediate channels could be stopped, and that it could be directed from the most remote ends of each of the sewers and distributed over those sewers with the most perfect theoretical accuracy, so as to have a uniform current passing throughout each of the sewers towards that chimney, still the effect upon those sewers would be nothing; and the way in which I prove my statements is this: the total area of the $6\frac{1}{2}$ miles of sewers now connected with the furnace is 713 ft.; the total area of the channel through which the air has to be brought from them is 8 ft., that is, about the 90th part of 713; the air was passing at the rate of 542 ft. per minute through the 8-ft. area. Therefore if I could divide that over the whole district, the velocity in all those sewers would be 6 ft. per minute, or $\frac{1}{15}$ mile per hour. But we have shown already that there exist in the sewers from other causes velocities amounting to 100 ft. per minute and upwards and 6 ft. per minute is, practically speaking, stagnation and not ventilation. Supposing you could obtain theoretical perfection, and all the air produced by this furnace was spread through this district, you would only then get up a velocity of $\frac{1}{15}$ mile per hour, which is no ventilation whatever. But I have gone farther with the inquiry. Whilst we were making our observations on Tuesday, the furnace, being kept up, was consuming at the rate of 8 chaldrons of coke per day: but I will assume that the defective arrangements, that is the chimneys being stopped up, the circuitous connexions, and so forth, necessitated a very much larger consumption of fuel to produce the same effect, than could be produced with better arrangements with a less quantity. I will assume that 4 chaldrons of coke per day, or half the quantity actually used, would produce that current of air, and that when produced it would effectually ventilate the 6½ miles of sewers, which I think I have shown to be impossible; but supposing it were possible, then I find that for 1500 miles of sewers 230 such furnaces would be required, and the cost of the coke at each of those furnaces would be 876*l.* per annum at 4 chaldrons per day, giving a total for the whole ventilation of the metropolitan sewers of 201,480*l.* per annum, upon the consumption of coke, without any labour or incidental expenses. The prime cost of those 230 chimneys and furnaces and establishments I have put down at 2000*l.* a piece; that would give 460,000*l.*, or half a million of money."

"I also visited some of the best ventilated coal mines in the North of England and in South Wales, with a view, if possible, to the application of some more perfect system of ventilation to the London sewers. I entered carefully into the comparative advantages of ventilating fans and furnaces, and into the expenditure of fuel requisite for the extraction of a given quantity of air under various conditions. But whilst it was not difficult to conduct a current of air through the continuous passages of a mine having but one inlet and one outlet, and a tolerably uniform sectional area, I found that such a system could not be applied to sewers. The areas of the branch sewers discharging into any one main sewer are, probably, much more than a hundred times its capacity; therefore, even supposing it were possible that they could be all hermetically sealed at all points excepting the extreme ends, a velocity of current equal to 100 miles an hour (which is next to impossible) would have to be obtained in order to secure a current of one mile per hour in each of the branch sewers. But it is not possible to obtain such a condition of things; and this difficulty lies at the root of all proposed modes of ventilation by extracting the foul gases by furnaces, fans, or such other appliances." *

The following are a few out of many instructive examples of the kind of proposals that were made in the past, with a view to render drain and sewer air as innocuous as possible.

* *Vide infra*, p. 183.

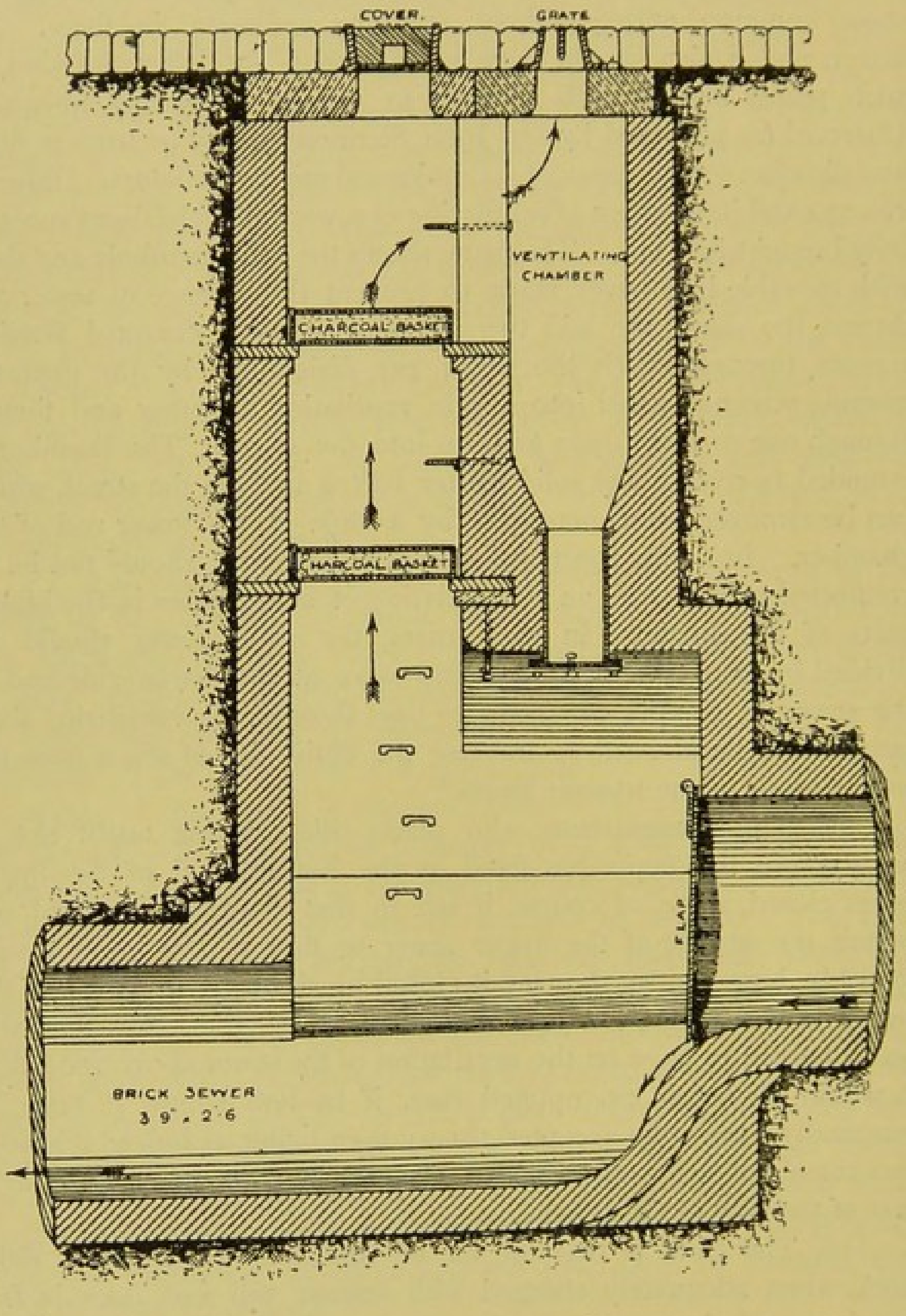
114. The late Sir Robert Rawlinson in his admirable book (corrected to 1878) entitled "Suggestions as to the Preparation of Plans as to Main Sewerage and Drainage and as to Water Supply" (page 4) states:— **Sir Robert Rawlinson**

"Street sewers should be capable of conveying all sewage to some common outlet, without retaining sediment in them. All sewers and drains should have arrangements for full ventilation, at such points and in such manner as not to cause any nuisance. Charcoal (as proposed by Dr. John Stenhouse) may be used to filter and disinfect sewage gases, at manholes and other ventilators. Drawing No. 27 exhibits a system of ventilation of sewers which has been successfully brought into use. The figure shows the usual manhole and shaft with movable iron cover made to prevent the passage of sewer air. **Drawing No. 27** Across the shafts are laid two or more movable charcoal filtering screens, through which the sewer gas, disinfected by the charcoal filtering screens, passes into a side ventilating chamber and thence through one or more open gratings into the street. The chamber is intended to receive any solid matter falling in from the street, which can be removed when necessary by a slide at the lower end of the chamber. In a hilly town the system of sewerage should not be so connected as to permit an accumulation of sewer gases in the higher parts of the district. In such cases, the main sewer should be divided by steps or falls, with a flap-valve at the discharging end of the sewer to compel the gases to pass through the ventilating shaft rather than be allowed to traverse the entire line of sewer from the lowest levels to the summit levels."

115. The draughtsman who made this drawing ought not to have shown the flap-valve fixed at the bottom end of the upper sewer closed, since, of course, if left in that condition it would not permit the sewage of the upper sewer to flow to the lower sewer. Possibly, however, by showing it closed he thought the theory of the author of the design, Dr. John Stenhouse, as to the effect the valve was intended to have on the ventilation of the sewer above and below it, would be better exemplified than if he had shown it open, or practically open—the accepted theory then being, as indeed it is now, that the air of steep sewers always travels in a direction opposite to that of the flow of the sewage.

116. The truth is that the air of steep sewers in active daily work, when adequately charged with sewage will and does in fact mostly travel down, not up the sewers. It is drawn down by a dragging power exercised upon it by the rapid flow of the sewage with which it is in contact in the sewers. Moreover, sewers having sudden drops in their inverts under such conditions as are represented on the Drawing, would greatly accelerate the flow both of the sewage

DRAWING No. 27.



and the air in their passages from the upper to the lower sewer. The experimental tests recorded in the late Mr. Santo Crimp's paper which is partially reproduced herein on pages 144 to 148, and the tests recorded in Mr. Read's paper on Sewer Ventilation, which are given in Appendix IV., Part I., and commented upon in Appendix IV., Part II., demonstrate in a simple and practical manner that ascensional ventilation against the sewage flow of the sewers could not take place under such conditions as are represented in the Drawing now under consideration.

Sir J. Bazalgette also, in his report on the Ventilation of Sewers of London, recommended "that charcoal filters be fitted to such ventilating shafts as may be the source of annoyance."

117. Mr. Baldwin Latham in the second edition of his valuable book on "Sanitary Engineering" (published in 1878 by E. and F. N. Spon, London) described a number of patented devices, including his own, for using charcoal to purify the air of sewers; and he alludes to the "Evil of unprotected Sewer Ventilators" and states that "there is always a danger in some towns arising from the fact that children will play over or near the open sewer ventilators." He quotes from a report addressed by Dr. Tatham, the Medical Officer of Health of Salford to a Joint Committee of Health and Building Departments of the Corporation as follows:—

118. "Dr. Tatham explains at the commencement that his enquiries into the subject have been occasioned by serious complaints from medical gentlemen and others, that the practice recently adopted by the Corporation of opening sewers into the narrower streets of the Borough by means of untrapped manholes, had been followed by results most disastrous to the inhabitants where such communications existed"; and, referring to Croydon, Mr. Latham also states:—

"There is not any town that does not use charcoal in its ventilators, in which the ventilators are not the subject of constant complaint, as creating nuisance. It is well-known that in many cases charcoal has been reintroduced into some of the sewer ventilators, in consequence of the complaints as to the nuisance *and danger of the unprotected sewer ventilators.* Experience goes to prove that charcoal ventilators will prevent any nuisance arising from an open sewer ventilator.

Consequences attending removal of charcoal from ventilators at Croydon

119. "During an epidemic of typhoid fever at Croydon in 1875 and 1876, the charcoal was removed from the ventilators, but after it was removed no abatement occurred in the fever, which continued until the springs had risen in the early part of the year 1876, and then and not till then did the epidemic disappear. The experience of fever again at the usual period in the rise of the water in the

springs in 1876 and 1877, shows that the cause is not in sewer air; but, on the other hand, since the removal of the charcoal from the sewer ventilators, Croydon has not been more healthy; *in fact, there have been a greater number of deaths from diphtheria, croup, and other kindred diseases in the district since the charcoal was removed from the ventilators than was ever known at any previous period.*"

Complaints of nuisance at Croydon

"Table No. 60 shows this very clearly, and this increased death rate from these diseases has been combined with a greater number of complaints of the nuisance of the open ventilators. In fact, since the removal of the charcoal more complaints have been made in a single week of the nuisance of ventilators than occurred in the whole previous ten years, during which time the charcoal was in use. Here then we see nuisance increased, and no sanitary benefit accruing, simply because somebody has said that charcoal, however good in itself, impedes ventilation, and the consequence has been that at Croydon, as elsewhere, charcoal has again been put into some of the ventilators complained of as creating a nuisance, and the only means of remedying the evil."

TABLE NO. 60.—SHOWING THE DEATHS FROM DIPHTHERIA AND CROUP IN CROYDON BETWEEN THE YEARS 1869 AND 1877.

Year	Estimated Population of District	Number of Deaths from Diphtheria	Diphtheria Death Rate per 1,000	Number of Deaths from Croup	Croup Death Rate per 1,000
1869	51,755	5	0·096	11	0·212
1870	54,075	3	·055	9	·166
1871	55,663	0	·000	5	·089
1872	56,356	4	·070	2	·035
1873	57,099	8	·141	12	·210
1874	60,792	4	·065	13	·213
1875	63,000	7	·111	5	·079
1876	64,500	26	·403	19	·294
1877	66,000	43	·651	24	·363

120. The statement that during the typhoid epidemic of 1875–6 the charcoal was removed from the ventilators would seem to imply that the charcoal at any rate did not prevent the epidemic; and the further statement that after its removal no abatement occurred in the fever hardly carries us much farther, as that removal might, if charcoal had really been a preventive, have been followed by an aggravation of the mortality.

One thing, however, is perfectly clear that the air in the Croydon sewers must have been extremely foul at the times to which he refers, as was undoubtedly the case when Sir George Buchanan reported upon them in the terms stated at page 58 of this book.

The following passages from the same work embody the general views of Mr. Baldwin Latham on the question of sewer ventilation.

"The conclusion arrived at by persons well acquainted with the working of a system of sewers is almost unanimous with regard to the inapplicability of a system of mine ventilation applied to sewers, while all agree that there may be some special cases in which a partial adoption of such a system may be attended with advantage." *

121. Mr. Latham formulates what he describes as the essential points to be kept in mind in the ventilation of sewers and drains. They are the following: "(1) That the system shall be simple in its operation and not likely to get out of order, and that it shall be independent of uncertain mechanical aid. (2) That it shall admit of the expulsion of all sewer air and the supply of fresh air at all periods. (3) That the escaping gases shall be so diluted with atmospheric air as to be rendered harmless, or that they shall be destroyed or arrested. (4) That the system shall not impede natural ventilation. (5) That it shall not be costly in execution or maintenance."

122. Mr. Latham pronounces himself in favour of "ventilation of sewers by means of shafts communicating with the crown of the sewer, and terminating about the centre of the roadway, which has been carried out in London and many other places." "This system," he says, "when ventilators are provided in sufficient number and furnished with materials for absorbing and destroying the escaping gases, is decidedly the best system that can be adopted."

By "materials for absorbing, etc., the escaping gases," Mr. Latham probably refers to charcoal trays as above alluded to.

Mr. J. Bailey Denton on Mr. Latham's charcoal system

123. Now the late Mr. J. Bailey Denton in 1877, in his excellent book on "Sanitary Engineering" (published by E. and F. N. Spon, London), states on page 214: "Mr. Latham too had patented a ventilator, and there can be no doubt that benefit may be derived from its use in certain cases, but such instances I believe to be few. The efficacy of charcoal depends so much upon its being kept free from dust and in a dry condition, that its purifying functions when used in connection with sewers soon cease to have any effect. Where, therefore, aeration can be gained by a manhole and lamphole openings at regular and frequent intervals throughout the sewerage system, with occasional shafts for ventilation only, aided by private ventilating outlets above dwellings, recourse to charcoal is undesirable. It is in fact so often an evil rather than a benefit, that as a rule charcoal should be discarded from sewerage systems. In this view there is now a very general concurrence amongst engineers."

"Mr. Jones, the Town Engineer of Ealing, says that his experience of charcoal trays and cages is not at all favourable to their use,

* *Vide infra, p.* 183.

unless the charcoal is very frequently changed. When closely packed, the layers do not act as ventilators; when loose, the charcoal has but little effect upon the gas, and when charged with moisture is, so far as gas is concerned, valueless."

"Mr. (now Sir James) Lemon, the Borough Engineer of Southampton, says, 'I have come to the conclusion that charcoal trays in ventilating shafts are of no use, and have decided to abandon them.' In another letter he adds 'that the use of charcoal stops the outflow of impure air and does more harm than good.'"

"Mr. Pritchard, the Engineer of Warwick, says that he has removed the charcoal from existing manholes and substituted open ventilation, adding that he looks upon the system as the only perfect one of ventilating sewers."

"Mr. Coghlan, of Sheffield, says, 'I do not find it necessary to use charcoal trays in manholes, and certainly have never used any. Unless they have careful attention, and the charcoal is constantly replaced, they become no better than a wet blanket.'"

"Mr. Buckham, the Engineer of Ipswich, says, 'he does not approve of fixing charcoal in the ventilating shafts of any system of sewerage.'"

"Mr. Banks, the Borough Engineer of Kendal, says, 'I used to use charcoal in all my ventilators, but it is practically more injurious than having none in at all. I found that unless we changed it frequently, in the course of two or three days it got so damp and clogged from our constantly damp atmosphere, that the passage of sewage gas through it was completely stopped, and it acted as a bung to the only outlets of air from and the inlets into the sewers.'"

124. To these authorities I may add that of Mr. Wm. Weaver, M.Inst. C.E., late Borough Surveyor of Kensington, whose great experience as a municipal engineer is unquestionable. Speaking of experiments in sewer ventilation made in Kensington, he says, "a considerable number of patent charcoal ventilators have been fixed, on the assumption that the foul gases would be deodorised in passing through cages of charcoal broken into small pieces. It was found on experience, that this course was practically equivalent to closing the ventilators; for the charcoal, however frequently renewed, became useless so soon as saturated with moisture; the first heavy rainfall, moreover, had the effect of clogging and stopping up with mud the meshes of the grating."—*Report to the Vestry of Kensington*, Sept. 24, 1889, pp. 4–5.

125. Mr. Denton also quoted what appeared in the late Colonel Waring's book on "Sanitary Drainage of Houses and Towns" about sewer ventilation. That gentleman wrote: "The principle of the ventilation of a sewer is practically the same as that adopted by

builders for the prevention of dry-rot. The fungi which cause this rot in timber cannot produce their germs in a current of air, and if a sufficient number of ventilating openings are made, communicating with each other, the action of the wind from one side or the other will cause a sufficient current. So in a sewer a continuous movement of the air in one direction or the other carries away and dilutes sewer gases, and if they contain germs of organic disease capable of infecting the human blood, these are believed to be destroyed by the oxidation or otherwise."

"A safe sewer always has a current of air passing through it, and if it contains sewage matters at all, these also must be in constant motion. On this incessant movement of the air and the liquid must we rely for our only security. A solution of sugar in water, remaining stagnant, and protected from a free circulation of air, will enter into a vinous fermentation. If well ventilated and agitated no such fermentation takes place. It is asserted that the excrement of a typhoid patient, continually agitated in contact with fresh air and a fair admixture of water, passes through a series of complete chemical changes with no injurious product; but if allowed to remain stagnant, if not freely exposed to the air, or if it gain access to human circulation before a certain oxidation, it will, like a ferment, reproduce itself, and give rise to the conditions under which it was itself produced. Motion and aeration are therefore needed to prevent infection, which is sure to be generated when typhoid evacuations are confined and stagnant. Unventilated and badly constructed sewers are sure agents for the propagation of the disease when once it has taken root."

126. On the subject of sewer ventilation, Mr. J. W. Adams, the Chief Engineer to the Board of City Works of Brooklyn, has the following observations in his treatise on "Sewers and Drains for populous Districts":—

"Dilution by fresh air if it does not destroy the seeds of disease brought by sewer gas . . . has a tendency to interrupt and render harmless their action on human organisms, providing that the sanitary surroundings are otherwise rendered favourable."

"Heat is an important element in all ventilation, and owing to the intermittent introduction of hot and cold liquids into sewers, and the heat generated by decomposition, is extremely variable in its extent and effects, daily creating expansions and condensations with the changing currents of air due to their action."

"The difference of temperature between the external atmosphere and that within the sewer is a force always at work tending to effect this ventilation; and if allowed free action, it will accomplish all that is needed."

"The effort to ventilate sewers, either by special machines or chemical reagents have been more conspicuous in the older cities of Europe, where the existence of narrow streets and mixed systems of small and large sewers render the imperfections of ventilation more obvious and more difficult to remedy. Of the efforts to remove foul gases from the sewer by exhaustion, that by means of fans driven by steam power seemed to promise success (to its projectors), but on trial it proved otherwise; so also has the method by means of shafts with furnaces below. The attempt has been made to utilise the chimneys of manufactories to this end, but unsuccessfully; also to lead all the products of combustion in dwellings and factories through the sewers to large chimneys, and thus to draw off all foul gases; but all these efforts appear to have been based on the erroneous supposition that the principles of mine ventilation could be applicable to sewer ventilation, whereas the varying position and extent of openings in the branches may become so great that neither by the method of forcing or exhausting could power be had sufficient to effect ventilation in sewers save at a very great expense of fuel."

"Special pipes have been laid from the sewers up the external walls of buildings in hopes of effecting a natural ventilation, and a screw-ventilating apparatus has been affixed to pipes so placed with a view to extract mechanically the gases within. It has been suggested to use the lamp-posts as ventilators, and also the street gas-posts—the combustion of the gas day and night, it was claimed, would effect ventilation. The steam-jet has been proposed, fully tested, and abandoned."

Mr. Adams disposes of all these proposals in a summary manner by saying that the proposers "lost sight of the enormous velocity which becomes necessary in one part of a system of sewers, in proximity to the power employed in order that the velocity requisite for efficient ventilation should be extended to the outer boundaries."

He goes on to say that "the failure of mechanical expedients to remove the gases after they were formed led to the adoption of various chemical ingredients for their destruction, or to prevent their accumulation in the sewers." He mentions carbide of iron, lime, chlorine, sulphurous acid, and charcoal. Of this last he says, "charcoal placed in trays within the manholes and renewed from time to time has had quite a run in England, but it is no longer recommended, save by the patentees of the contrivances for its use; and the difficulty in the way of a practical supervision and preservation in working order, of this as well as other chemical appliances, has led to their disuse, save under exceptional circumstances, and would prove of little practical benefit in our cities."

Having thus with equal complacency condemned all mechanical appliances and also everything in the nature of chemical neutralisers or preventives, Mr. Adams arrives at the conclusion that the sewers will ventilate themselves by the simple expedient of constructing manhole shafts on the street mains at intervals of not less than every 100 ft., and instead of a solid cover at the level of the street, close the opening of the manhole by a cast-iron perforated cover or grating, and require the openings therein to be freed from ice and snow in the winter months. If the openings in the covers be made properly, as shown in Figs. 46 and 47, the refuse of the street traffic will not close them at other seasons. This, and the connection of the waste-pipe from the dwelling being made without a trap of any kind, as also the rain-water leader from the roof being untrapped, as shown in Fig. 71, will enable the sewers to *breathe* and ventilate themselves at all times.

127. Reference has already been made (*see* Appendix I. pp. 98–99) to the Conference of Metropolitan Surveyors which was held at the County Hall on Feb. 25, 1898; and to the resolutions passed on that occasion. Appendix III., Part II., contains Sir A. Binnie's report of the Proceedings.

Drawing No. 20 contains a representation of a ventilating pipe carried up from the sewer side of the interceptor, in the manner recommended by Resolution No. 3; the pipe in question being in dotted lines and marked V.P. No. 2. The inherent dangers and doubtful efficiency of such an arrangement for attaining the desired object (namely, the ventilation of that part of the house-drain which lies between the interceptor trap and the sewer, and the ventilation of the public sewer itself) has been indicated before (*see* Letter, p. 78). It is also obvious that the supplying and fixing of such a pipe would entail expense to the house owner to an extent depending on circumstances (say from 5*l.* to 20*l.* or more), in addition to the cost of the ordinary access chamber, interceptor trap, etc., which he had doubtless flattered himself were all that were wanted to render his house drainage perfectly sanitary.

As far as I have been able to ascertain, the Resolution in question has been a dead letter, and no provisions enforcing it are to be found in the Drainage By-laws of the London County Council.*

The Council, however, have from time to time during the past seven or eight years, in response to innumerable complaints from all quarters of London of foul emanations from street gratings, erected a large number of high ventilating shafts in the streets and elsewhere at a total cost of a good many thousands of pounds.

In the meanwhile, the adoption of the ventilating arrangements

* See Mr. Blair's remark, Appendix IV. Part II., p. 244.

described in this work * would render both the pipe and the high street shafts advocated by the metropolitan surveyors unnecessary.

128. The late Mr. Santo Crimp, M.Inst.C.E., prepared a paper (No. 2395) for the Institution of Civil Engineers, which was accompanied by four diagrams and which gives the results of his "Experiments on the Movements of Sewer-air at Wimbledon, 1888."

The paper appears on pages 383–391, in Vol. XCVII. of the minutes of the Proceedings of the Institution of Civil Engineers; and is full of evidence to show that the author tried in a most painstaking and laudable manner to ventilate by mechanical means certain drains and sewers in Wimbledon that were complained of as being offensive, so that the smells arising from them should, if possible, be located and put an end to. The nature and character of the investigations which Mr. Santo Crimp initiated and carried out, with a view to trace the cause or causes of the smells complained of, can be best understood and appreciated by my giving the following liberal quotations from his paper, together with copies of the diagrams which accompanied it. He began the paper by stating that "In consequence of some unexpected results having followed the adoption by the author of certain measures, to be described later, having for their object the localisation of sewer-air, he was induced to investigate the question at some length."

129. "One of the three main outfall sewers at Wimbledon provides for the collection of the sewage from the most hilly portions of the district, and frequently complaints were received as to the foul gases escaping from this outfall, which for a considerable length is constructed under a comparatively level road much used by pedestrians. The branch sewers, for the most part, are at right angles to the main sewer, and pass up hills with gradients varying from 1 in 8 to 1 in 100."

130. "As the outfall was so frequently complained of, the dwellers in the higher parts of the district, not unnaturally, thought that they might be prejudicially affected by the gases supposed to be generated in the outfall below. The complaints having been considered, the author advised the trapping-off of each branch from the main outfall. This work was carried out, and immediately above the siphon-trap employed an air-shaft was brought to the surface, in order to admit of fresh air entering the sewer."

"The traps were placed in the brickwork of each manhole, thus allowing the removal from them of any obstruction, should such occur. The air-shaft, in several cases, terminated near the footway crossings, and was provided with a ventilating cover." (Drawing No. 28, Fig. 1.)

* *Infra*, p. 246.

DRAWING No. 28.—MR. S. CRIMP'S EXPERIMENTS.

Fig. 1

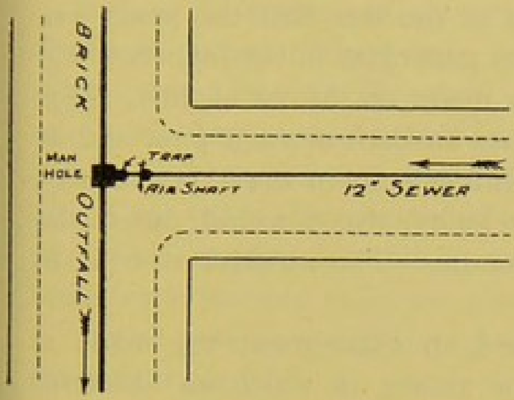


Fig. 2

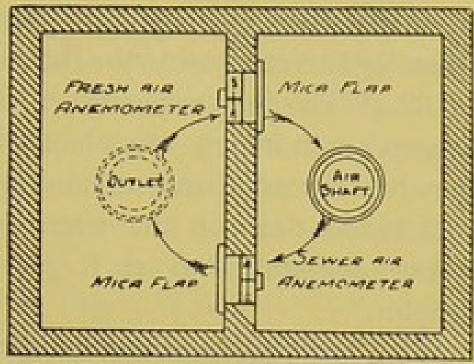


Fig. 3

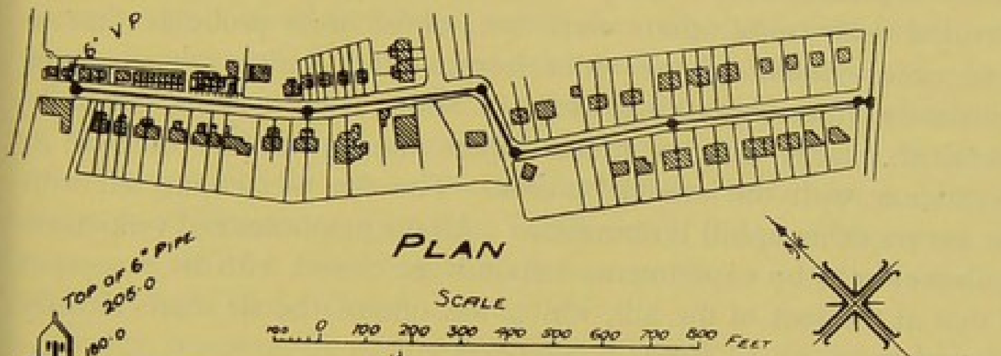
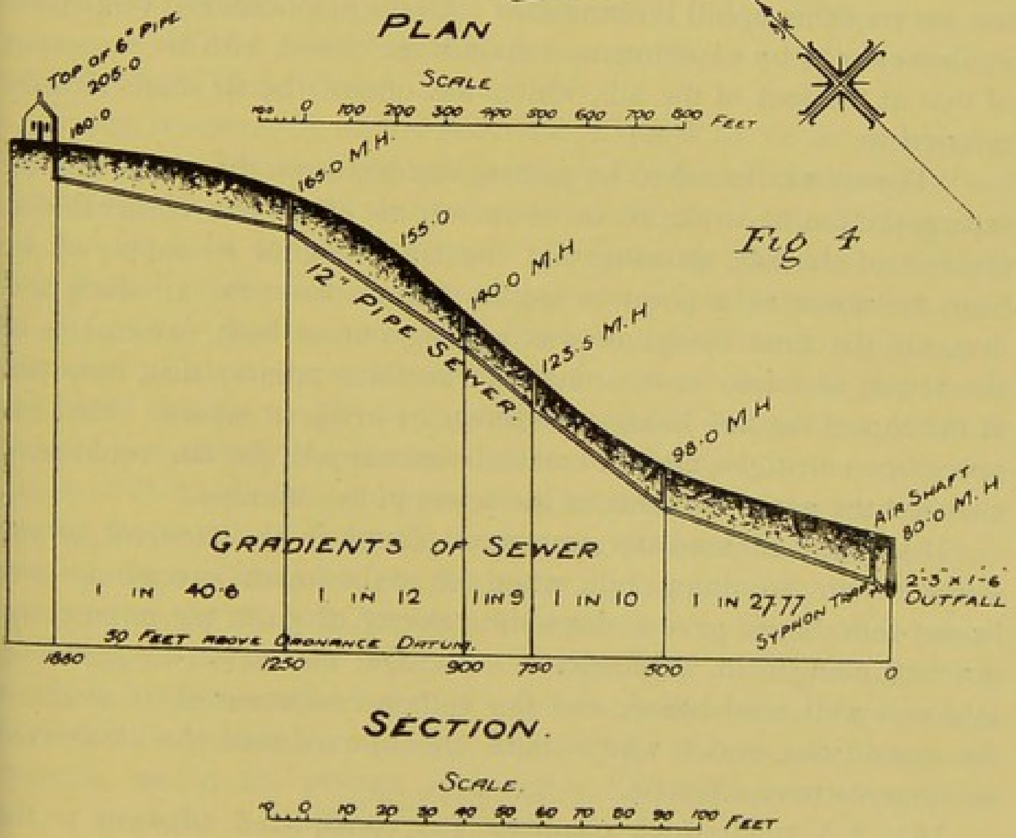


Fig 4



131. "During the hot weather which occurred soon after the carrying out of the work, it was found that the sewer air frequently poured out of the air-shafts, showing first that the air was often passing down the sewers, and secondly, that the complaints with regard to the outfall were most probably due to the fact that the sewer was frequently the receptacle for the gases generated in the branches."

132. "The first experiment was made on the 1st of July, 1887, when an anemometer was placed in an air-shaft at 12.30 p.m. and at 7 p.m. had recorded an average downhill velocity of 104 ft. per minute; at 9 a.m. on the 2nd the average velocity, also downhill, due to the 14 hours amounted to 42 ft. per minute. The air-shaft is 6 in. in diameter."

133. "About the date mentioned, an experiment was made at Wimbledon by Mr. Fewson and the author, in which an 'Electrolyser,' in conjunction with a 'Capell' fan was employed. The capacity of the fan was 18,000 cub. ft. per hour; the length of 12-in. sewer operated upon was 620 yards; the street gullies were connected with a separate drain; many houses draining into the sewer were provided with traps, others were not, whilst it is probable that in some cases—those of the older houses—the drains act as sewer ventilators; the conditions were, in short, such as are generally prevalent, except in new streets where the houses are drained in accordance with the model by-laws. The fan was connected with the sewers at its uphill termination. All the manholes and ventilators on the sewer to be experimented upon were closed, with the exception of that at the foot of the hill, which was one of the air shafts already referred to.

"The air was found to be passing steadily down the sewer, and on setting the fan to work as an extractor, no effect was observable at the foot of the hill, showing that the fan procured its supply of air from the sewer at a point or points remote from the air shaft, and that, for the time being, air was passing out at both extremities of the sewer, and into it at some intermediate points; that, however, at the top of the hill being withdrawn by artificial means. Had the sewer been air-tight, and all connections trapped, the fan would have changed the aerial contents of the sewer in five minutes."

134. "An anemometer was next placed in the air-shaft of the sewer of an adjoining hill, when an experiment extending over twenty-four hours gave a downhill velocity of 52 ft. per minute, the air-shaft being 6 in. in diameter. The fact that sewer-air passes up sewers is well established, and the author endeavoured to ascertain the conditions under which both the upward and the downward movements were effected."

135. "A small brick chamber was constructed adjacent to the

air-shaft of the sewer experimented upon by Fewson's apparatus; a central division was built, provided with two openings; each opening was furnished with a mica valve, but on opposite sides of the wall (Fig. 2)."

136. "An anemometer was placed in each opening and all the sewer-air passed through one, whilst all the fresh air entering the sewer passed through the other. Two self-registering maximum and minimum thermometers were employed in the sewer, one for ascertaining the temperature of the sewage, the other, that of the sewer-air. This latter was suspended in the sewer at a point distant about 250 yards from its downhill termination. A plan and section of the sewer experimented upon are given in Fig. 3."

"The general results have been placed in a tabular and in a diagrammatic form."*

137. "With regard to temperature, the close approximation of the average temperature of both sewage and sewer-air to the mean temperature of the ground at a depth of 10 ft. (the depth of the sewer), and the periods of the year at which the maximum and minimum are respectively attained, prove that the earth, with which the sewer is surrounded, is the principal factor in effecting changes of temperature; when it is considered that in the case of branch sewers, of which a complete main-drainage scheme chiefly consists, the whole of the exterior of the sewer is in intimate contact with the soil, whilst but a small portion of the invert is subjected to the influence of the sewage, it will be conceded that the proposition is quite consistent with the facts of the case."

"The temperature of the ground at a depth of 10 ft. varies with the seasons. The summer heat is slowly conducted downwards, and the maximum is reached about the end of August; as the temperature of the air falls on the approach of winter, so the heat stored in the ground is given up, and the minimum is reached about the end of February. The exact periods at which the extremes occur naturally depend upon the weather. Now an examination of the Table will show that the range of temperature of both sewage and sewer-air follows very closely the changes in the temperature of the earth at a depth of 10 ft.; the maximum monthly temperature of the air occurred during the month of August; the sewage attained its maximum temperature in September, whilst the sewer air is practically of the same temperature during both August and September. The coldest month was February, and the minimum temperature of the sewage was reached in that month; but this was principally due to the fact that considerable quantities of snow fell during that month, which on thawing cooled the sewage appreciably. The sewer-air was at its

* *Infra*, p. 148; Drawing No. 29.

lowest temperature in March, the effect of the cold February being very manifest."

"Incidentally, it may be mentioned that the highest temperatures recorded were: of the sewage, 63° in June, and of the sewer-air 61° in August; whilst the lowest readings were: of the sewage, 33° in February, and of the sewer-air, 39° in the same month.

"The temperature of the sewer-air was higher than that of the atmosphere during the first four and last four months of the year, the range being from 1° above in April, to 8·4° above in October; it was lower than that of the atmosphere during the months of May, June, July, and August, the range varying from 1·35° in July and August to 3·45° in June."

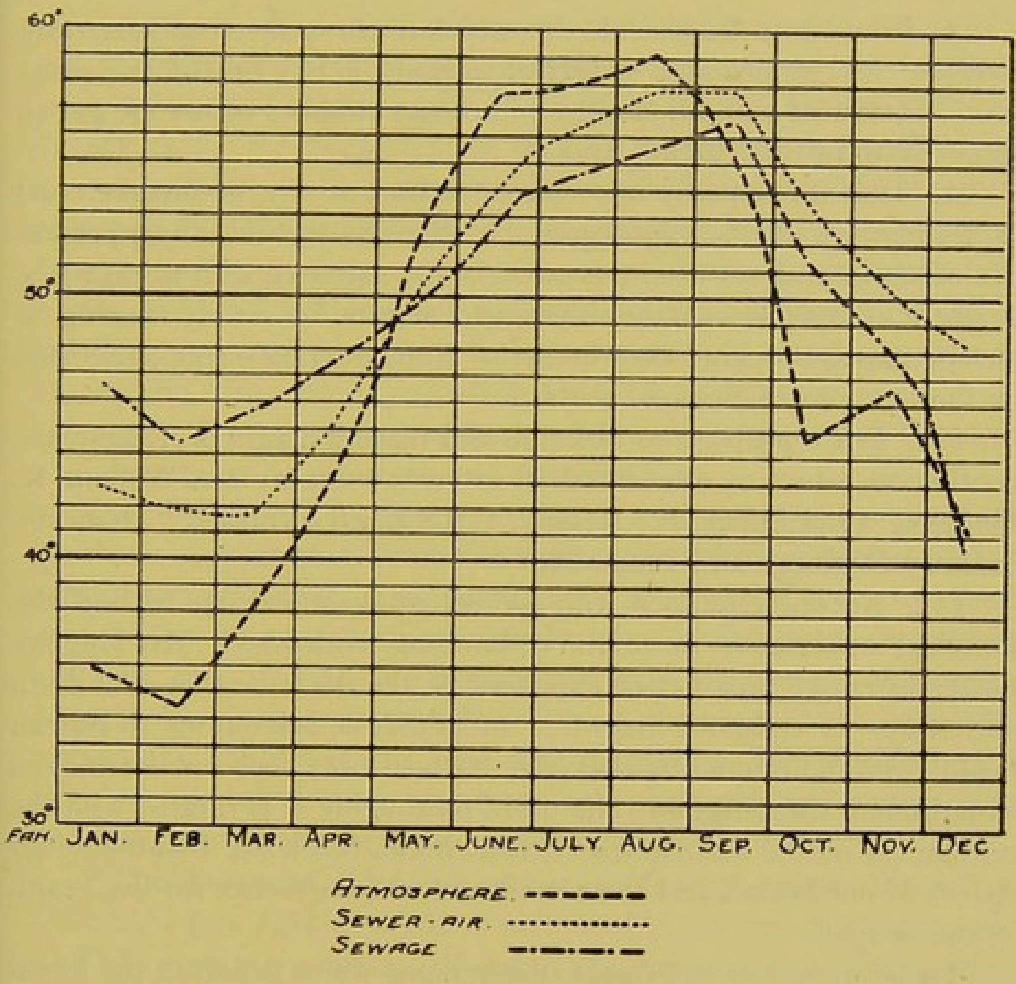
138. SEWER-AIR EXPERIMENTS, WIMBLEDON, 1888.

Month	Temperature Air	Temperature Sewer Air	Difference	Temperature Sewage	Number of Days		
					Up	Down	Both
	Deg.	Deg.	Deg	Deg.			
January .	35·75	42·70	+6·75	46·30	13	12	8
February.	34·75	42·30	+7·55	44·75	19	29	19
March .	38·50	42·10	+3·60	45·41	13	27	11
April .	43·50	44·50	+1·00	47·60	19	30	19
May . .	52·00	49·20	−2·80	50·10	11	26	11
June . .	57·70	54·25	−3·45	53·90	3	27	3
July . .	58·00	56·65	−1·35	54·80	2	28	2
August .	59·10	57·75	−1·35	55·65	4	27	4
September	55·80	57·70	+1·90	56·70	5	20	5
October .	44·70	53·10	+8·40	51·25	3	12	1
November	46·40	50·65	+4·25	48·30	5	26	5
December	41·00	48·85	+7·85	40·60	..	9	..
Means .	47·26	49·98	..	49·61	Totals 97	273	88

139. I am of opinion that the reason why the recorded numbers of the down currents were so much in excess of the number of the up currents—the former being 273 to 97 of the latter—was that, the gradients at which the 12-in. sewer experimented upon was laid were too steep to permit of any positive ascensional ventilation taking place while even the minimum daily flow or sewage was being discharged into it. Gradients of 1 in 40·6, 1 in 12, 1 in 9, 1 in 10, and 1 in 27·77, for a 12-in. sewer, are certainly steep. If the sewage flowing down the steep parts of the sewer was sufficient in volume to charge it to a depth of 2 in. only, which it was apparently, as stated by Mr. Crimp, even then the velocities of the sewage on each of the gradients given and figured in Fig. 3, Drawing No. 29 would be abnormally high, and would be in fact about 4·30, 7·90, 9·10, 8·66 and

5·20 ft. per second respectively, and of course such abnormal sewage velocities would be sure to have the effect of dragging the air from the upper to the lower end of the sewer, as recorded in Mr. Crimp's paper. Moreover, as the two self-registering maximum and minimum thermometers used to ascertain the temperature of the sewage and the air of the 12-in. sewer were fixed at the point on the section marked by me with an asterisk, which it will be observed is practically on the steepest part of that sewer, the recorded temperatures would

DRAWING No. 29.—MR. S. CRIMP'S EXPERIMENTS (*continued*).



be more or less misleading, as evidence of what obtains in sewers laid at suitable gradients and working under normal conditions.

Mr. Crimp stated that the fan used for the purposes of his experiments was a "Capell" one, and that it could exhaust 18,000 cub. ft. per hour, or 300 cub. ft. per minute out of the sewer. This volume if extracted out of a 12-in. sewer with 2 in. depth of sewage in it would travel at a velocity of 6·4 ft. per second; but no tests appear to have been recorded to show that the fan drew 300 cub. ft. per minute of air out of the sewer, and afterwards discharged that volume up the fan shaft, into the atmosphere. Nor is it stated in the paper that the velocity of the fan wheel was sufficient to produce a vacuum that would have the effect of causing a current of air to flow up the 12-in. sewer, at a velocity of 6·4 ft. per second, in the face and, as it were, in spite of its meeting with a sewage flow current travelling in the opposite direction at an average velocity of about 7 ft. per second.

140. The foregoing review of the investigations and proposals of some of the most eminent sanitary engineers of the latter half of the nineteenth century, seems beyond question to justify the following conclusions:

(1) That it is impossible to circulate air and to satisfactorily ventilate foul drains and sewers of deposit on any one of the plans above described without causing inordinate volumes of sewage gas to be generated within them; and

(2) That it is equally impossible (at least at any permissible cost) to destroy in a satisfactory degree the offensive and insanitary properties of drain and sewer air, once it is impregnated with sewage gas, before it escapes out of the drains and sewers, by simply trusting to the spontaneous operations whether of Nature acting direct or assisted by the medium of charcoal trays.

141. I now propose to describe and discuss a plan of house-drain ventilation, which is advocated in an able work by Mr. William R. Maguire, Assoc.Inst.C.E., Ireland, C.S.S.I., etc., entitled "Domestic Sanitary Drainage and Plumbing."

142. No one equipped with the scientific knowledge of, and the practical experience in sanitary plumbing work which Mr. Maguire possesses could be a better exponent of the doctrine that foul drain and sewer or cesspool air, when breathed, is deleterious to human health, and consequently that the farther away such air is removed from human dwellings and the more thoroughly it is diluted with the normal air of the atmosphere before it can reach the breathable air spaces of our houses and their environments, the better for the health of the people.

These were, beyond doubt, the reasons which actuated the Local Government Board in prescribing that where, in the absence of sewers, cesspools have to be constructed they must, in the first place, be properly ventilated, and in the second place they must be at a prescribed distance (practically at least 50 ft.) away from the dwellings to which they appertain. And it can only be the same identical principle which has induced Mr. Maguire, who is well aware that the so-called air-inlets and air-outlets (whatever be the quality of the house-drainage work to which they are attached) become as often as not transmuted into recipients for foul and noxious air and gas, to recommend that such inlets and outlets should be removed as far away as possible from the inhabitable parts of buildings.

Drawing No. 30, shows a simple typical example of the orthodox 19th century plan of removing w.c., bath, and sink wastes, and roof rainfall waters from houses into public sewers; and how the latter and the street manhole connected therewith were and are still ventilated naturally, by means of small openings in the iron covers placed over sewer manholes at the street level, of which the one marked H is an illustration. It also shows to what extent the present up-to-date house-drain pipes, etc., conveying liquid wastes into the sewers are, and are not, ventilated. Moreover, the drawing shows, in outline at least, in the opinion of Mr. Maguire, as stated on pages 172–3 of his valuable work, the present approved plan of ventilating house-drainage work by natural means could or ought to be still further improved. Briefly stated, his suggestion is that an additional independent air-pipe should be provided and fixed between the house-drain inspection chamber from the point marked E to, say, the point marked F, which latter is just above the ridge of the roof of the hypothetical house whose drainage and drainage-ventilation arrangements are shown on the drawing. Mr. Maguire's reasons for making this suggestion are clearly and concisely expressed in his book as follows :— **Drawing No. 30**

143. "The ventilation of house drain and branches and manhole chambers must be thorough and constant."

144. "The best method is to carry a 4-in. cast-iron or, better still, lead vent-pipe or shaft from the drain or manhole chamber in front area, direct and straight as possible, up the front of the house to the roof. Here it may stand up straight, surmounted by an ornamental extractor top, or it may be surmounted by a mock rain-water hopper-head, if there be a parapet, a bend being turned in at the back of the hopper and continued as a pipe of same bore, as vent shaft along the slope of roof to the ridge where the vent-shaft may end vertically just an inch or two over the ridge, or with an extractor top."

"The sweep of the wind up the roof from either side will act effectually as a natural exhaust, and create a suction in the vent-shaft which is very serviceable. If the vent-pipe be of heavy lead, it may be carried up under the roof, and out through the ridge."

"There is no use whatever in providing an outlet vent-shaft on any drain unless you also provide a corresponding inlet through which some colder, and therefore heavier, column of air may press in and drive the lighter air in the vent-pipe upward."

"If you open a hole in the bottom of the open top vent-pipe or in the manhole chamber connected directly with it in front area, you have ventilation at once. The air flows in and up the vent-shaft. However, it is not the vent-shaft we want to ventilate, but the house-drain and the soil-pipe; consequently if we go to the upper end of the soil-pipe in the rear of the house, and open an inlet there, we shall probably find the air flowing in down the soil-pipe along the drain through the manhole chambers, and up the main vent-shaft a constant current day and night, and every time that water is sent down the soil-pipe the ventilating current of air is accelerated on its beneficial course."

"Now, whether the air will take the course indicated, or whether it stays still, or whether it annoys us by coming back the opposite way, depends (if we leave out of consideration the sucking action of the extractor top on the vent-shaft) on the relative condition of the column of air in the vent-pipe at the front of the house, and in the soil-pipe at the back of the house. If both pipes are of equal height, then the air, being warmest, on the sunny side of the house, will have expanded and become lighter, and so surely as the heavy side of the balance weighs down to earth and sends up the lighter scale, so surely and on the same principle precisely (the universal attraction of gravity) will the heavier column of air send up the lighter column. It will be well therefore to arrange your inlet-pipe as low as possible, and in the coldest position, shaded from sunshine, and your outlet extractor vent-shaft as high as possible, free from all blow-down action of the wind, and in as warm a corner as you can find for it, avoiding all needless bends."

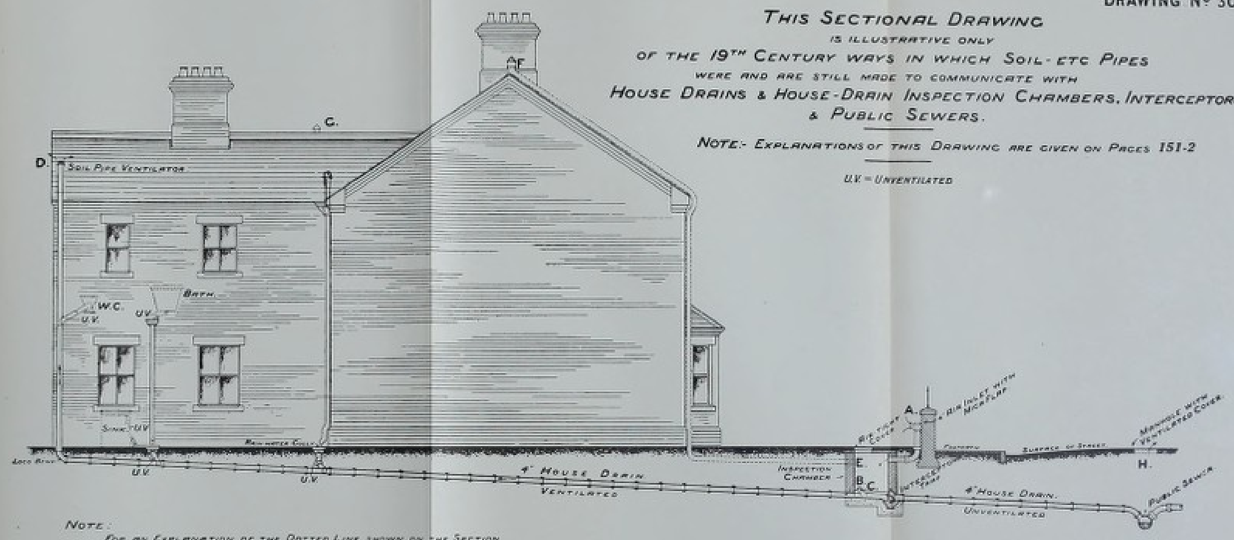
145. Mr. Maguire, of course, knows that like himself many of the leading British House Drainage engineering experts have for some years past specified and provided the additional ventilation pipe suggested by him, when planning drainage works for first-class houses and other buildings; and certainly where expense does not stand in the way, or is not a formidable hindrance to the carrying out of "reasonably perfect" methods for ventilating house-drains, by the best possible so-called "natural means," his proposals as explained and illustrated in his book are well conceived. At the same time I cannot help thinking that his proposals, if applied for instance to the main drain of the kind of house we are now discussing, would be equally effectively carried out, if he omitted to provide and lay the extra air-pipe between the inspection chamber E, and the point marked F, which latter is just above the ridge of the roof, and trusted say to the main, and subsidiary drain shown as debouching into the manhole or inspection chamber, at the points marked B and C acting as air-inlets, and their terminals shown at the points marked D and G acting as air-outlets, because, by adopting such arrangements, practically speaking, the same additional and safe up and down air circulation currents within the drains, which Mr. Maguire explains would result from the insertion of the air-pipe

DRAWING Nº 30.

THIS SECTIONAL DRAWING IS ILLUSTRATIVE ONLY OF THE 19TH CENTURY WAYS IN WHICH SOIL- ETC PIPES WERE AND ARE STILL MADE TO COMMUNICATE WITH HOUSE DRAINS & HOUSE-DRAIN INSPECTION CHAMBERS, INTERCEPTORS & PUBLIC SEWERS.

NOTE:- EXPLANATIONS OF THIS DRAWING ARE GIVEN ON PAGES 151-2

U.V. = UNVENTILATED

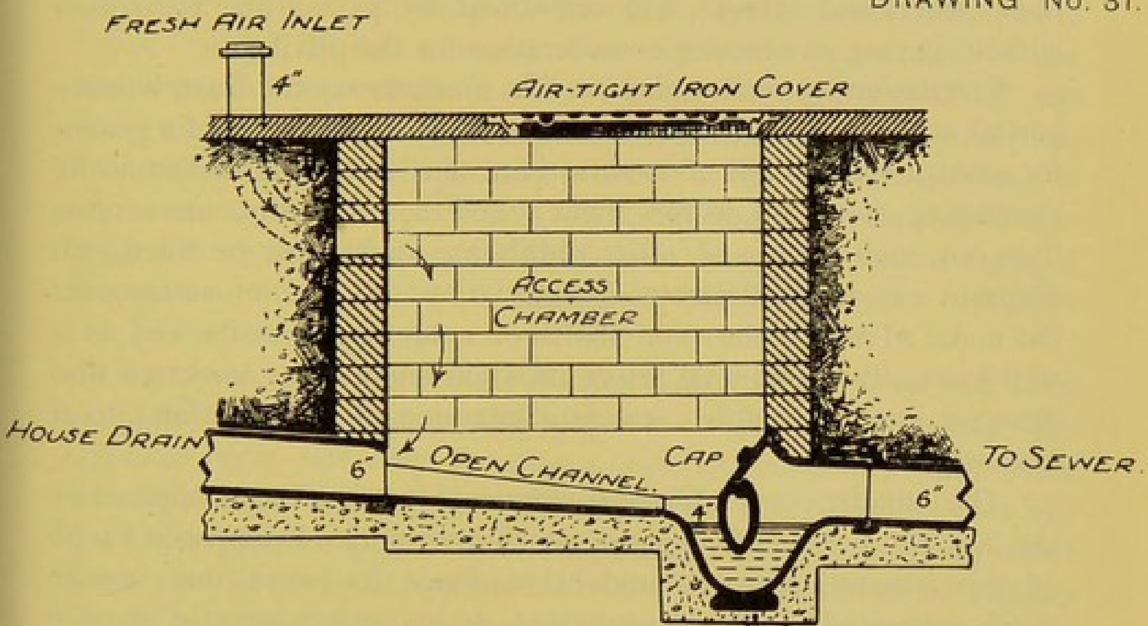


NOTE:
FOR AN EXPLANATION OF THE DOTTED LINE SHOWN ON THE SECTION BETWEEN THE LETTER "A" IN THE INSPECTION CHAMBER & THE LETTER "B" PLACED NEAR TO THE RIDGE OF THE ROOF OF THE HOUSE. SEE PAGES 152, 153

[Face p. 152.

between E and F, would or ought to result also in making the drains marked B and C in the inspection chamber act as air-inlets, and their terminals, marked respectively D and G, as air-outlets. The principal air inlet marked A which is placed outside the inspection chamber, on which is fixed a mica flap valve, would feed the inspection chamber and the two air inlets B and C with fresh air, and thus they would be made to act the part of two distinct low level air-inlets for two high level air-outlets, marked respectively D and G, in which case of course the owner of the house would save the cost of providing and fixing the special air-pipe from E to F. Such a pipe including its terminal, fixed, would probably cost in heavy lead 10*l.*, and in heavy cast iron 4*l.*

DRAWING No. 31.



MANHOLE INTERCEPTING CHAMBER, WITH FRESH-AIR INLET.

146. Now, if instead of providing one of Mr. Maguire's special ventilating pipes, an arrangement such as is described hereafter at page 246 were fixed on the main drain, all the improved ventilation which Mr. Maguire's plan could bring about would be obtained without it; with the further all-important advantage that the drain between the interceptor and the public sewer would be ventilated at the same time.

147. The ventilation of that part of the house drain that lies on the sewer side of the interceptor seems to have escaped Mr. Maguire's attention; at any rate he makes no provision for it, as a glance at his "access chamber," of which Drawing No. 31 is a copy will at once show. This of course is not surprising, as at the date when his book was published—1896—the Hydro-mechanical system had not yet been invented; and moreover probably he, like all other professional **Drawing No. 31**

plumbers, would regard the ventilation of that part of the main drain of the house as being outside the province of his employers.

I have entered at some length into the views expressed in Mr. Maguire's instructive work for the purpose of affording some additional matter for comparing the relative sanitary efficiencies of different house drainage ventilation systems with each other and their relative estimated costs.

148. The modern plan for ventilating unventilated sewers is to ventilate them through the medium of iron pipe columns resembling gas-lamps which like the latter are erected for the most part in the public streets, but a certain percentage of them are erected alongside of buildings, sometimes with and sometimes without the sanction of their owners and tenants, and sometimes by paying and sometimes without paying any money consideration for the privilege.

Ventilation by such a plan as this must, to say the least, be very partial at best. It partakes in fact more of the character of a system for venting foul air out of sewers than of a system for scientifically circulating fresh air within them; and consequently, more often than not, such street and other ventilating shafts must be filled with stagnant air which destroys by oxidation the interior surfaces of the metal of which the pipe shafts or columns are made, and as is well known the same foul sewer air when breathed by workmen who descend into the public sewers containing it is often fatal to it instantly.

The exhaustive scientific and practical investigations conducted by the late Dr. Fergus of Glasgow, which are referred to at pages 64–66 of this volume, afford abundant evidence to prove that sewage gases generated within ill-ventilated drains and sewers of deposit have the two-fold prejudicial effect of rendering air within them capable of destroying the metal of which they are made, and thereby shortening their duration often to the extent of one-half, and further of impairing the health of those who unconsciously breathe it.

149. The arrangements shown in Drawing No. 30, giving the special ventilating pipe suggested by Mr. Maguire, would probably be regarded by most experts in house drainage and in house drainage ventilation as being reasonably perfect and as illustrating the natural principles upon which the best class of house drainage work of the 19th century has been carried out and amended up to the present time.

I hope to be able, however, to show in the following pages how the present methods of ventilating house drains and sewers can be improved by the addition or adaptation to them of the whole or part of the Hydro-mechanical System described herein.

150. To enable me to do this satisfactorily, it is highly important that I should recall to the notice of the reader some well-established

facts concerning the properties of air and gases, particularly in their relation and application to the process of ventilation. These are essential elements and conditions of the problem which in the past have been far too much disregarded or left out of sight. Even at the present day many sanitary committees and their official advisers seem disposed to resist any regulated mechanical system of ventilating their sewers and drains.

There are now, however, I have reason to believe, a good many who are well aware of the inherent deficiencies of the prevalent expedients, and who recognize the superiority of the principle of mechanical ventilation over unassisted Nature. But in this, as in all similar cases in the past, the old story is heard.

There is not unnaturally a fear of the typical ratepayer, who is "very careful of the economy that does not economise, of the parsimony that starves where a broad generosity would nourish," and who grumbles at any fresh expense, no matter how it may be justified. There is also a disposition in one quarter to await the issue of a trial in another; the fact being ignored that the proposer of the improved method has no jurisdiction to carry out experiments of this class on a large scale, and must therefore depend on the initiative of a public authority.

The same was originally the case with colliery owners. They clung to natural ventilation till they were forced to learn that fiery collieries were not only dangerous, but unworkable at any price without artificial ventilation and without the use of protectives like the Davy lamp. They have consequently had to resort to either furnace or fan power to ventilate their collieries. And thus the colliery viewer and mining engineer of the present day has necessarily to know more of the weights and pressures of air and gases under different conditions of temperature and so forth, than is considered essential to municipal surveyors and engineers.

151. It is easy to find the weight and pressure of any given volume of atmospheric air at any time by reference to a barometer, since the weight of a cub. in. of mercury is 0·4908 lb. When the height of the mercury column in the glass tube of the barometer is therefore equal to 30 in., the weight of the atmosphere will then be equal to $30 \times 0{\cdot}4908 = 14{\cdot}72$ lb. per sq. in., which is generally regarded in this country as the normal pressure of the atmosphere. If, however, the mercury column rises 1 in. higher (i.e. to 31 in.) this indicates that the pressure or weight of the atmosphere has increased from 14·7 to $\frac{31 \times 14{\cdot}7}{30} = 15{\cdot}109$ lb. per sq. in.; and conversely, should the mercury column fall 1 in. (i.e. to 29 in.), the meaning is that the weight or pressure of the atmosphere is reduced to 14·21 lb. per sq. in.

152. Again, it is well known that air at 32° F. (the freezing-point of water) expands the $\frac{1}{491}$ part of its volume when it is heated 1° F., the coefficient of dilation for 1° thus being = $\frac{1}{491}$ = 0·00203. The corresponding centigrade expansion due to the addition of 1° of heat on the centigrade scale is = $\frac{1}{273}$ = 0·00366.

153. Again, the densities or weights of gases or vapours are proportional to their atomic weights; and according to Avogadro's Law, equal volumes of all gases, under the same conditions of temperature and pressure, contain the same number of molecules. To find the weight of a gas in pounds per cub. ft. at 32° F., multiply half the molecular weight of the gas by 0·00559. For instance (since the molecular weight of carbon is 12 and that of hydrogen 1) 1 cub. ft. of marsh-gas (CH_4) is equal to $\frac{12 + 4}{2} \times 0{\cdot}00559 = 0{\cdot}0447$ lb.*

154. Further, according to the law of gaseous diffusion demonstrated by Graham, gases diffuse themselves amongst each other at velocities inversely as the square roots of their densities. If d equals the density of a gas, air being unity, and v equals the volume of gas which diffuses in the same time as 1 volume of air, then $v = \sqrt{\frac{1}{d}}$.

The density of hydrogen being 1 and that of air being 14·44, the velocity of diffusion of hydrogen as compared with that of air will therefore be as $\sqrt{14{\cdot}44} : \sqrt{1}$; or as 3·8 : 1. To put this concretely, while 1 volume of air is passing through a porous septum, 3·8 volumes of hydrogen will pass through the same porous septum.†

155. The law just stated, however, applies to gases diffusing under normal atmospheric conditions. The gases of which the atmosphere consists, when they are in a state of quiescence and left undisturbed for some time, say, in wells, sumps, or cesspool pits sunk in porous strata, and when they contain it may be abnormal volumes of carbonic acid together with other gases, which are heavier than air, will not diffuse themselves exactly according to Graham's law, but will rather separate themselves from each other mechanically under the influence of the law of gravitation, the volume of the heavier gases, e.g. the carbonic acid gas, occupying the lower, and the volume of the lighter gases occupying the higher zone of the pit or well containing them. Similarly the air of tunnels and sewers which are not ventilated must be in an insanitary condition, and dangerous to inhale, more especially the sewers of deposit which are practically unventilated.

156. It is well known that long ago, after careful and elaborate tests, it was found that 459·2 cub. ft. of air, at a temperature of 0° F.,

* Kent's "Mechanical Engineer's Pocket Book," p. 479.
† See Newth's "Inorganic Chemistry," 10th edition, p. 83.

when the atmospheric pressure was equal to 30 in. of mercury, due to the density of 32°, weighed exactly 39·76 lb. avoirdupois; or 39·76 ÷ 30 = 1·3253 lb. per mercurial inch.

157. Adopting this datum, we can compare the weight of a cub. ft. of water with that of a cub. ft. of air. For the weight (W) of a cub. ft. of air at any temperature in F. degrees, and at any barometric pressure, can be calculated from the following simple formula, which is given in an excellent treatise by W. Fairley, Ph.D., F.G.S., on the "Theory and Practice of Ventilating Coal Mines," and is as follows:—

$W = \frac{1 \cdot 3253 \times B}{459 + t}$, B being the height in in. of the mercury column of the barometer, and t being the temperature in F. degrees indicated by the thermometer.

158. For example, a cub. ft. of air at the standard pressure and temperature of 62° F. and 30 in. of mercury respectively weighs $\frac{1 \cdot 3253 \times 30}{459 + 62} = \cdot 076313$ lb. And as a cub. ft. of water at the same temperature and pressure weighs 62·355 lb., it follows that water is, bulk for bulk, $\frac{62 \cdot 355}{0 \cdot 076313} = 817 \cdot 095$ times heavier than air.

159. Hence, a given volume of air will issue out of an air receiver or compressed air-pipe under a pressure equal to 1 ft. of water head, at a theoretical velocity of $8 \cdot 025 \times \sqrt{817 \cdot 095} = 8 \cdot 025 \times 28 \cdot 585 = 229 \cdot 4$ ft. per second.

160. And the same calculation proves also that the velocity of the flow of air through an orifice or tube is $\sqrt{817 \cdot 095}$ or 28·585 times as great as that of water under the same conditions. And, once more, if the pressure be only = 1 in. of water-gauge (the temperature being still 62° F.) then the theoretical velocity of the issuing air would be $8 \cdot 025 \times \sqrt{\frac{817 \cdot 095}{12}} = 66 \cdot 2$ ft. per second.

161. By the aid of the following formula we can also calculate approximately the velocity at which atmospheric air at any other barometric pressure and temperature would flow through the by-pass pipes, from the drain on the house side to the drain on the sewer side of the interceptor.

The formula is as follows: $V = 8 \cdot 025 \sqrt{\frac{(t - t^1) \times L}{491}}$; t being the temperature of the heated drain air, t^1 the temperature of the outer air, L the length in feet of the drain sewer or shaft containing the heated air, and V the resultant velocity.

Let us apply this formula to the conditions represented on Drawing No. 32. The temperature of the outside air overlying the tops of the soil-pipes A and A[1] and the roof of the house shown on that Drawing is taken hypothetically as being 60° F., and the temperature of the air of the drain on the sewer side of the interceptor, is given as being 69° F. Let us further assume that the house-drain on the sewer-side of the interceptor is 30 ft. long. Under the conditions stated therefore, $V = 8{\cdot}025\sqrt{\frac{9 \times 30}{491}} = 5{\cdot}95$ ft. per second, which corresponds very nearly to the velocity of the flow of air through an orifice which has a vacuum on the sewer side of it equal to $\frac{1}{100}$th part of an inch only of water. Or, to take a stronger example, if the temperature of the heated drain air exceeded that of the outer air four times as much as in the preceding example, i.e. by 36° F., then the velocity at which the outer air would flow through the ventilating orifices into the sewer would be in this hypothetical case *twice* as great as it would be with the drain air at a temperature of 9° F. above the atmosphere, as the following calculation will show: $V = 5{\cdot}95 \times \sqrt{\frac{36}{9}} = 11{\cdot}93$ ft. per second. Or, again, if the drain containing the heated air was four times longer, i.e., 120 ft. instead of 30 ft. long, the temperature being 69°, the theoretical velocity of the air neglecting friction would then be also *twice* as great as it would be were the length 30 ft. only, i.e. $V = 5{\cdot}95\sqrt{\frac{120}{30}} = 11{\cdot}9$ ft. per second.

It will be seen that in the foregoing calculations the drain between the interceptor and the sewer has been treated as if it were a chimney or an upcast shaft of a coal mine, or as if it were an iron ventilating column or shaft 30 ft. high, erected in the public street, for the purpose of ventilating the public sewer below.

162. The aerostatic pressures by the aid of which coal mines are ventilated whether by furnace or fan power vary as the depth, but in the case of furnace ventilation they also vary as the difference between the temperature of the inflowing ventilating air of the downcast and that of the outflowing heated air of the upcast shafts, and the quantity or velocity of the air varies as the square root of the depth and also the square root of the difference between the temperature of the air in the upcast and the downcast shafts. The statement just made and the foregoing calculations demonstrate important physical facts which for the reasons already stated are more familiar to mining than they are to municipal surveyors and engineers, viz., that the efficiencies of furnace ventilation installations, in coal mines especially, are dependent upon the degree of heat applied to the air by the furnaces, and the height or depth of the upcast shafts employed to bring about the ventilation required in each case. That in fact while the efficiency of mine furnace ventilation varies directly as the depth, the fuel consumption per horse-power varies inversely as the depth, as is clearly

The Shone Hydro-Mechanical System.

For ventilating
Soil-Pipes, House Drains, Interceptors, and Public Sewers.

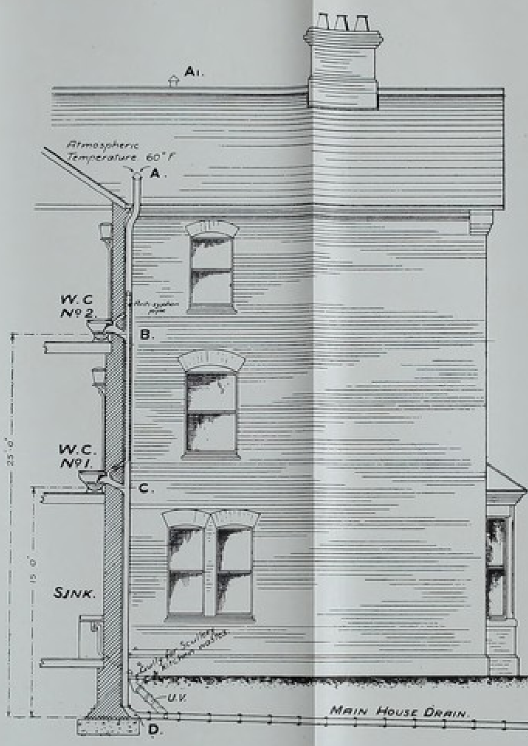


Fig. 1.

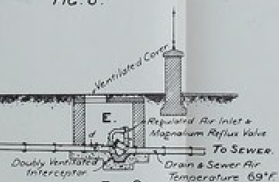


Fig. 2.

— Reference to Fig. 1. —

A....... Ventilated Soil-pipe for main drain
A1....... do do tributary do d
B. C..... Levels from which W.C. discharges begin to fall down the Soil-pipes
D......... The "Loco" bend for accelerating the flow of the W.C. discharges through the House-drains
E......... Inspection or Access Chamber

Fig. 3.

— Reference to Fig. 3. —

Sketch-drawing of a 4" Improved doubly-ventilated Interceptor, containing 60 gallon & having 3" water seal. The body of the apparatus a, a, a, is made of Stoneware, (in this case) but the bye pass pipes b, b1 and the flanged socket-piece b2 and valve-box piece C containing the Magnalium Reflux Valve, and the pipe b3 are all made of Cast Iron.

[Face p. 158.

explained in the valuable and instructive book on "Mining" by Professor Arnold Lupton, M.Inst.C.E. F.G.S.*

163. He gives on page 209 a short table, which shows at a glance that the efficiency of furnace ventilation varies, according to the orthodox theory, directly as the depth, and the fuel consumption inversely as the depth; and in view of the fact that the coal-gas plan of heating iron pipe columns or shafts in public streets for ventilating public sewers has been and still is adopted in many places, I venture to reproduce here a copy of that table:—

Shaft . .	250 ft. deep . .	fuel consumption per H.P.	96 lb.
,, . .	500 ,, . .	,, ,, ,,	48 ,,
,, . .	1000 ,, . .	,, ,, ,,	24 ,,
,, . .	1500 ,, . .	,, ,, ,,	16 ,,
,, . .	2000 ,, . .	,, ,, ,,	12 ,,
,, . .	3000 ,, . .	,, ,, ,,	8 ,,
,, . .	4000 ,, . .	,, ,, ,,	6 ,,

From this table, it will be seen that a furnace used to heat a hypothetical coal mine upcast shaft 4000 ft. deep, with a consumption of about 6 lb. per h.p. per hour, would, if it were only 250 ft. deep, consume 96 lb. of coal per h.p. per hour, which is 16 times more than would be used, if the mine had been 4000 ft. deep. Mr. Lupton also shows that a coal mine, whose downcast and upcast shafts were 1000 ft. deep each and the temperature of the downcast shaft was 50° F. and the temperature of the upcast shaft 130° F., the volume of the ventilating air at 50° F. moved under these conditions was estimated to amount to 100,000 cub. ft. per minute, while the pressure causing the ventilation was equal to 10·61 lb. per sq. ft., or 10·61 ÷ 5·2 = 2·04 in. on the water gauge; and the power exerted was reckoned to be equal to 32·15 h.p., with a coal consumption of about 24 lb. per h.p. per hour.

164. Evidently, therefore, furnace ventilation, whether it be employed to ventilate abnormally deep coal mines or shallow sewer ventilating shafts on a large or a small scale, must be far more expensive than ventilation by fan power.

In the above investigation we have (following Mr. Lupton's lead) taken 100,000 cub. ft., as the unit of quantity of ventilating air to be dealt with. But obviously in practice it would neither be admissible hygienically nor possible in an engineering point of view to exhaust so large a volume as 100,000 cub. ft. of air per minute out of the sewers and drains of any town either by furnace or fan power, and to convey that quantity to one upcast shaft and force it into the

* Longmans, Green and Co.

atmosphere untreated as if it were merely the vitiated air from a coal mine. This, however, in no way affects the law involved.

165. In my Liverpool paper I stated that the frictional losses due to the flow of air and water through pipes were proportional to their respective densities. And I supplied formulæ for finding (1) the total resistance due to friction to the flow of air in pipes measured in inches of water head, and (2) the horse-power required to move the air by means of a fan for ventilation purposes. I now propose to give a few examples to show how the calculations can be made in accordance with the formulæ.

A few comments on the formulæ and on their practical application will not be out of place.

166. The primary law that, as between liquids and gases, the friction varies as the density, is admitted on all hands. But as between one gas and another of different densities there has been no such agreement. And coming concretely to the case of free air as compared with compressed air, we find among the authorities an extraordinary difference of opinion.

167. For example, D'Aubuisson's formula takes no account of the density of the air. A table of the loss of pressure by flow of air in pipes, given by Mr. Cornut in a paper on "Compressed Air Machinery," adapted to English measures and weights by Mr. D. K. Clark in his "Manual for Mechanical Engineers," gives the losses by friction for pipes of various diameters and for various initial velocities, but does not state the absolute pressure. Again, Mr. Hawksley, in Vol. XXXIII. page 55 of the Proceedings of the Institution of Civil Engineers, stated as the result of varied experience, that the formula put forward by him for the flow of water in pipes may be employed also for the flow of air in pipes. And accordingly Mr. Clark has made the necessary calculations to obtain the corresponding formula for the flow of air, making no allowance, however, for the density or degree of compression of the air. Once more, Mr. Box in his admirable treatise on Heat (2nd Edition, page 116) gave a formula for calculating the head or difference of pressure of a given volume of air, steam, or gas at the two ends of a pipe of given diameter and length, and gave on page 117 a table in illustration. Here also the degree of compression of the air is disregarded.

168. On the other side we have the very high authority of Dr. Pole, whose conclusions on the laws of the friction of fluids in motion through pipes are probably the clearest and soundest ever published, and I have much pleasure in reproducing them here.

1. "The friction of a fluid upon a solid is independent of the hydrostatic pressure to which the fluid is subjected. Thus the

friction of water passing along a pipe under a pressure of 100 lb. per square inch, is no greater than if the pressure were but 1 lb.

2. "It is proportional to the area of the rubbing surface. Thus the friction of water in passing along a pipe 100 ft. long will be twice as great as if the pipe were only 50 ft. long, or if the circumference of a pipe be doubled (the length remaining the same) the friction will be double in like manner. If, therefore, L = length of a pipe, and C = its circumference, the friction will be proportional to L × C.

3. "It varies with the velocity, but in what exact ratio does not appear to be well determined. As a simple rule, however, near enough for practical purposes, the friction may be assumed to vary as the square of the mean velocity with which the bodies move upon each other, or as v^2. Thus if the velocity of water passing along a pipe is doubled, the friction will be increased four-fold, and so on.

4. "It may be assumed to be proportional to the specific gravity of the fluid, or will vary as the weight of 1 cub. ft. of the fluid. The friction does not appear to be dependent in any other respect upon the nature of the two substances in contact, providing only that the fluid be in a state of perfect fluidity, and that the surface of the solid be so smooth as not to offer obstructions to the passage of the fluid along it."

The leading authorities, as I have said, are agreed that the principles which determine the frictional resistances to the passage of water or sewage through pipes are applicable with practical accuracy to the passage of air also; subject, of course, to the different densities of water and air.

169. The volume of water or other liquids discharged through short pipes, tubes or orifices of small bore, as is well known, may be augmented or diminished according to the shape given to their inlet and outlet ends. The discharging efficiency of a tube or pipe whose length is from 1½ to 2½ times its diameter is about 0·81 of the full bore discharge of a long pipe; but the discharging efficiency of an orifice in a thin plate, is only equal to about 0·615 of that of a long pipe which is full of the liquid discharged by it.

If it is true, as is agreed both by those who would abolish the interceptor trap and by those who favour its retention, that the more thoroughly sewer air is diluted with atmospheric air the less harmful will be the result, it follows that the less vitiated air is admitted to the house drains above the interceptor, the better will be the consequences in a sanitary point of view.

170. Considerable misapprehension has for years existed in the minds of many sanitary experts upon the real causes of the inefficiency of the traps attached to waste pipes and drains, and as a **Current Fallacies**

consequence, the true remedies which can alone be relied on to produce sound sanitary conditions have not been brought to light.

(*a*) For example, it has been said that a current of air in a sewer-drain or soil-pipe travelling at a velocity of 4½ ft. per second will unsiphon any trap with a 2-in. seal. Were this the case it would be impossible by any regulated method of aeration to ventilate sewer-drains or their accessories on the Hydro-mechanical System. But such a statement cannot be based either on adequate experimentation or on an acquaintance with pneumatic laws.

(*b*) Another fallacy which was started many years ago and is constantly being reiterated even to the present day is the suggestion that a street gully trap, or a house drain trap or any other trap is liable to be easily unsealed by evaporation; it has even been said that this may occur after a few hours of dry wind or hot sun. It is difficult to conceive how any sanitary expert can have arrived at such a conclusion who has given any study to the ascertained scientific laws which govern the evaporation of liquids at varying temperatures. But such a doctrine, repeated as it is with confidence in quarters which carry authority, is so dangerous an impediment in the way of practical sanitary progress that I feel bound to deal with it in some detail.

171. The rate of evaporation with different liquids and at different temperatures is given by the late Mr. Thomas Box, in his excellent "Practical Treatise on Heat" (5th Edition, Spon) as "proportional to the difference of the elastic forces of the vapour of the liquid at the given temperature of that liquid, and that of the vapour actually present in the ambient air."

The formula he employed was: $R = (F - f) \times 378$; where R = the rate of evaporation in grains per square foot per hour with the air perfectly calm, F = the force of the vapour of the given liquid at the temperature of the ambient air, as distinguished from that of the liquid itself, which may be lowered by evaporation, and f = the force of the vapour of water actually present in the air as indicated by the hygrometer.

Mr. Box made a series of experiments on the rates of evaporation of different liquids, namely water, alcohol, benzoline, and ether, by exposing them to perfectly calm air at natural temperatures in a vessel suspended by a delicate balance.

It is only necessary here to cite the results obtained by him with water, and it may at once be stated that the experimental results with water correspond exactly with the formula above given, from which is calculated the table appended hereto, which will be found on page 144 of Mr. Box's book.

"With water, 30 grains were evaporated in 620 minutes, or

30 × 60 ÷ 620 = 2·9 grains per hour from a vessel $3\frac{1}{16}$ in. diameter = 7·366 sq. in. area, which is equal to 2·9 × 144 ÷ 7·366 = 56·7 grains per sq. ft. per hour. The mean temperature of the ambient air was 60° and the wet-bulb hygrometer 55°, showing 71 per cent. of saturation."

It will be seen that the above result (56·7 grains per sq. ft. per hour) corresponds to that found by the formula $R = (F - f) \times 378$; F (the elastic force of vapour of water at 60°) being = 0·518 in.; therefore, with the wet bulb at 55°, showing humidity 0·71, f = 0·518 × 0·71 = 0·368 in.; so that the formula gives $R = (0{\cdot}518 - 0{\cdot}368) \times 378$ = 56·7 grains per sq. ft. per hour, or the same as by experiment.

The following is Mr. Box's table :—

EVAPORATION AT NATURAL TEMPERATURES AND WITH AIR IN DIFFERENT STATES OF DRYNESS.

Temperature of the Air and Water	Humidity of Air : Saturation = 100							
	Dry	30	40	50	60	70	80	90
	Grains Evaporated per Sq. Ft. per Hour in Calm Air							
Deg.								
32	69	48	41	34	28	21	14	7
42	101	71	61	51	40	30	20	10
52	147	103	88	74	59	44	29	15
62	211	148	127	106	84	63	42	21
72	298	209	178	149	119	89	60	30
82	426	298	256	213	170	128	85	43
92	570	400	342	285	228	171	114	57

"The rate of evaporation of water varies very much with the humidity of the ambient air." This will be seen by the table; e.g., at a temperature of 62° of the air and water, the following are the successively decreasing amounts of evaporation as the degree of humidity of the air increases :—

HUMIDITY OF THE AIR : SATURATION 100.

Temperature of the Air and Water	Dry	30	40	50	60	70	80	90
	Grains Evaporated per Sq. Ft. per Hour in Calm Air							
Deg. 62	211	148	127	106	84	63	42	21

On the other hand, the amount of evaporation increases, with a given degree of humidity, as the temperature increases. For instance, if the wet bulb shows a humidity of 70 per cent. we should have, under the table, the following amounts of evaporation at successive temperatures:—

Temperature. Deg.	Grains Evaporated per Sq. Ft. per Hour	Temperature. Deg.	Grains Evaporated per Sq. Ft. per Hour
32	21	72	89
42	30	82	128
52	44	92	171
62	63		

It will further be observed that the increase of amount of evaporation is not in the exact proportion of the rise of temperature, but the amount augments, not only actually, but at an augmented rate, with each increase of temperature. This phenomenon becomes specially important in relation to the drainage of tropical districts.

172. By applying the principle upon which the foregoing calculations were made to the conditions which obtain in connection with the evaporation of interceptor-trap waters in this country, we shall be able to estimate approximately how long it will take before the whole of the water in the interceptor trap will be evaporated down to the unsealing line of the trap.

Let us assume that the water seal of a 4-in. interceptor is 3 in. in depth; the depth of the water-seal is the same in each leg of the trap, then its surface area on the house side as well as on the sewer side will be = 12·57 sq. in.

Now, the weight of water contained in a 4-in. pipe 1 ft. long is $4^2 \times 0 \cdot 34 = 5 \cdot 44$ lb. And as the depth of the water-seal is 3 in., the weight of water to be evaporated will be $5 \cdot 44 \times 0 \cdot 25 \times 2 = 2 \cdot 72$ lb. And since 1 lb. avoirdupois is 7000 grains, before the water-seal can be broken $2 \cdot 72 \times 7000 = 1940$ grains must be evaporated.

The volume of water in the interceptor in question is, therefore, $12 \cdot 57 \times 3 \times 2 = 75 \cdot 4$ cub. in.; and as the number of grains in 1 cub. in. of water is 252·286, it follows that there are $252 \cdot 286 \times 75 \cdot 4 = 19022 \cdot 36$ grains in weight of water in the trap.

Now Mr. Box's tests showed an evaporation of water at the rate of 56·7 grains per sq. ft., which equals $56 \cdot 7 \div 144 = 0 \cdot 39375$ grains per sq. (or cub.) in. per hour.

At this rate it would require $19022 \cdot 36 \div 0 \cdot 39375 = 48310$ hours (or 2012 days) of continuous drought before the whole of the water in the interceptor could be evaporated. And to evaporate 2 out of the 3 in. in the depth of the seal of the trap would require two-thirds of that time—namely, 1342 days—and to evaporate 1 in. would take 670 days. And to give an instance more suitable to a tropical climate, suppose the temperature of the ambient air to be 82°; then, as shown above, the rate of evaporation would be 128 grains per sq. ft. per hour. But even then it would require 9511·18 $\div \frac{128}{144} \times 2 = 21400$ hours (approximately) = 992 days to evaporate the whole, and 594 days to evaporate 2 in., and 296 days to evaporate 1 in. of depth of the interceptor.

So long, then, as the depression in the water-seal due to vacuum caused by the working of a fan does not exceed 2 in., there would always remain 1 in. of water in the trap as a water-seal to prevent the sewer air from getting into the house drain on the house side of the interceptor. There is thus no need for any apprehension of any speedy evaporation in the interceptor.

It has been suggested as an objection to ventilation by mechanical means that you never can be sure that your gullies and drain and other pipes or conduits are really water-tight. Should they fail you, will there not sooner or later be leakages and escapes which if they do not annihilate, will at least diminish the efficiency of your ventilating apparatus?

There is at first sight some colour for this apprehension. There cannot be a doubt (and engineers all over the country will testify to this) that in a great many towns and districts the pipes and gullies are not properly water-tight. And here by water-tight I of course do not mean the degree of non-porosity required and found say in a hydraulic power main which has to stand the test of a pressure of from 700 to 1000 lb. on the square in. A gully or a sewer or a drain is never under any conditions subjected to a pressure calling for any such resisting power. But relatively small as is the density required in them, they only too frequently, as we all know to our sorrow and indignation, fail to rise even to that standard. If this state of things were of the nature of the case and inevitable, we must despair of ever getting our sanitary appliances cleanly and healthy. But is this so? Let us examine the question a little more closely.

173. To begin with I suppose that every consulting engineer, and every municipal engineer specifies, as a matter of course, that all gullies, pipes, etc., shall be "water-tight"; and with equal regularity they are doubtless sold and delivered as being water-tight.

But with the experience that so many of us possess, we should not be satisfied with this. Sewerage appliances for the most part, are hidden underground, and when they once get there they are apt to be forgotten, unless and until they make their existence known, if not by an outbreak of disease, at least by offensive odours.

Now, it is surely easy enough in these days to procure stoneware pipes sufficiently impervious to withstand an internal water pressure equal say to 2 or 3 lb. per sq. in.

This standard would prevent any appreciable leakages of sewage waters and would satisfy the requirements of the hydro-mechanical system; because, *a fortiori*, it would enable them readily to bear an *external* air pressure equivalent to 3 or 4 in. on the water gauge above atmospheric pressure. Of course it follows that every care must be taken to ensure their being properly jointed together when laid in their trenches.

I suggest that the manufacturers of stoneware pipes should be subjected to the responsibility of guaranteeing the imperviousness of pipes by reference to a scaled test. My experience leads me to say that first class firms would welcome the inauguration of reforms calculated to be practically effective in safeguarding the interests of the public health.

Even then I would further suggest that the pipes should be put to the requisite test before being put down.

Then there should be periodical supervision and examination. And the supervision should not be restricted to the public sewers, but should be extended to house drains by obtaining, if necessary, powers to visit at reasonable times private manholes.

The above suggestions will I think be greatly strengthened by the following extracts from the able work of Mr. W. R. Maguire, to which I have already referred.

174. "That interceptor traps are required on the lines of drain, at some point before they reach the houses, is now generally admitted. If interceptors choke, the fault lies in their over-large size, bad form, defective fitting, or insufficient flush combined with the total neglect of observation on the part of the householder. There are now several forms of interceptor, which, in 6-in. and 4-in. sizes, will clear every time an ordinary flush is used, nevertheless they should be fixed and arranged so that they can be easily inspected, and so that any serious stoppage will reveal itself at once on the surface. The fact that the drainage of all the houses in the streets o higher levels must pass by the mouth of your house drain, and that possibly the drainage is further polluted by the drainage from fever hospitals, which also discharges into the public sewers, ought to afford sufficient reason for the importance of placing intercepting sewer-gas traps on private house drains. Their absence frequently allows infectious diseases to spread from house to house; indeed without interception and thorough ventilation a system of supply for conveying infected drain air into houses exists, similar to that adopted by the waterworks for the purpose of supplying pure water, the only difference being that in the case of polluted sewer air the pipes are 9 in., 6 in., and 4 in. in

diameter, instead of $\frac{1}{2}$ in., and the supply is unrestricted. Householders can have any amount of dangerous sewer air, but pure water must be very carefully and sparingly used, or the water inspector will cut off the supply at seven days' notice!"

"The diameter of interceptors frequently corresponds with the diameter of the drain. Place a 9-in., a 6-in., and a 4-in. interceptor of one of the best forms side by side for comparison. You observe the necessarily large, clumsy, unmanageable dimensions of a 9-in., and the handiness of the 6-in. and 4-in. traps for manipulation, and you can at once see that no ordinary house-flush of 2 or 3 gallons of water would clear the larger trap, and consequently that foul deposits would be likely to remain, decomposing dangerously, and finally will choke the trap and drain unless a flushing tank is in use to discharge large bodies of water at intervals through the drain and trap. The need of these interceptors affords a very strong reason, therefore, in favor of 4-in. and 6-in. drains over 9-in. The traps are now used very generally, even when the house drains are of larger diameter. The 4-in. trap retains 1 gallon; * the 9-in. trap retains 6 gallons."

"Intercepting chambers should be placed in the open areas in front of every house, easy of access, and furnished with air-tight iron covers and abundant ventilation."

"It might be a fair question for consideration whether the sanitary authority or the householder should provide this chamber, but it should be the duty of the sanitary authority to lay the drain from the public sewer in a straight line into the area in every case, also providing and fixing a uniform intercepting sewer-gas trap on the house end, with a splay junction to enable the outer drain to be cleared; while the building of the chamber, together with the house drain and branches, at the house side of the interceptor should be the duty of the householder."

175. I desire here to refer to one matter of detail which my limits of time prevented me from explaining at Liverpool. I refer to the flush tank shown on Drawing No. 21 (No. 4 in the paper). A friend, himself a distinguished sanitary engineer, expressed the opinion that such a tank as there placed appeared to him unnecessary, in view of the sizes of the houses, the apparently sharp inclinations of their drains, and the close proximity of the former to the public sewers. He is quite correct; a flush tank in the position indicated would not be required, for example, in connexion with large houses abutting on the streets, especially in some parts of London where the water supply is on the average about 35 gallons per head per day. But where houses whether large or small are set back a long

* In the 4-in. trap of the hydro-mechanical ventilation system, only $\frac{3}{5}$ of a gallon is retained.

way from the public streets and roads, their drains, in order to be kept permanently in a self-cleansing sanitary condition, require to be well and frequently flushed. To make this clear, I submit a Drawing (No. 33, which is Drawing No. 2 extended) and on which is shown a house set back a considerable distance from the public sewer; where accordingly the main drain connecting the house drainage with the sewer is provided with an automatic flush tank in conformity with the requirements of the case.

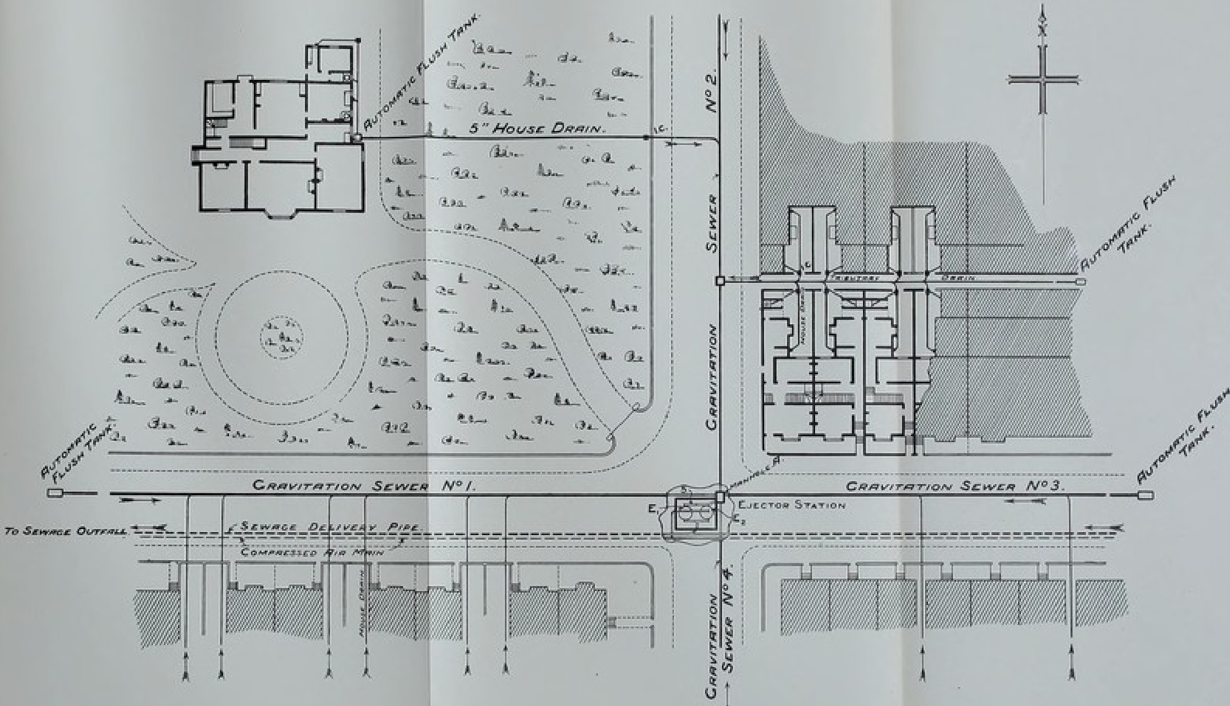
176. In another part of this volume * are given instances of complaints and protests made by metropolitan local sanitary authorities of the intolerable nuisances caused by emanations from the main sewers of the metropolis. While such complaints have been practically universal over London, perhaps there is no district which has expressed itself more constantly and more vigorously than the one which embraces the boroughs of Greenwich, Lewisham, Deptford, and Woolwich—the reason being possibly that in the areas especially which are in the vicinity of Blackheath and Woolwich Common, there are a number of superior middle class residences. It appears that new large main sewers have recently been constructed or are in course of construction in that district. As practically the only method proposed to be adopted for the ventilation of these sewers is that of surface ventilators, a great many of the residents have protested with much vehemence against that system; and in accordance with these complaints, a conference of representatives from the four boroughs above named was held in 1907, at which resolutions giving expression to the objections entertained were passed, and pressing the London County Council to adopt "some other and less objectionable method of ventilation." A number of alternative plans for effecting the ventilation of the sewers were submitted for the consideration of the County Council; among them being a proposal which obtained very considerable local support for the ventilation of the whole length of the sewers by means of coke furnaces.

There was also submitted to that body a draft scheme for the ventilation of the sewers by the use of mechanical power. Both these suggestions as well as the other alternatives were rejected, and the method of surface ventilation by perforated grids on the street level was adhered to. Whether this determination was come to solely as a question of expense, or whether the notion is still entertained that that mode of keeping the public sewers free from asphyxiating gases is efficient and at the same time innoxious to the inhabitants, it is impossible to say.

177. I endeavoured, in my Liverpool paper, to make clear what I regard as the only scientific and practical way by which sewers and drains can be effectively ventilated. But it is still found in a greater

* Appendix VI.

DRAWING Nº 33.



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or lesser degree, and under conditions with which most municipal sanitary engineers are acquainted, that notwithstanding the purification of the effluent sewage gases by their admixture (whether by natural or mechanical means) with large quantities of atmospheric air, objectionable smells are still very perceptible. Before these can be eliminated and satisfactory results obtained, the present orthodox house and town sewage drainage conditions must be amended. In order, however, to demonstrate to the members of the association how this important additional sanitary service could be satisfactorily effected I introduced the air-filtering arrangements shown in Drawing No. 23 of my Liverpool paper (page 100). The limits at my disposal precluded me from giving a detailed description of those arrangements at the time, and I now propose to supply that omission.

The easiest way to do this, as it seems to me, is by giving a brief explanation of the system by which the hydrolytic tank at Hampton-on-Thames is ventilated; bearing in mind, however, that the special filtering process there applied on a thoroughly practical scale, is in principle equally applicable in the case of all drains and all sewers.

The simple working parts of the installation in question are illustrated in plan and section on Drawing No. 34.

It will be seen that the hydrolytic tank air is drawn from it through an 18-in. pipe A, by means of a fan B, which is driven by a steam engine C, and is or was originally discharged up the outlet shaft D into the atmosphere. The air of the tank and the covered channels connected therewith, is admitted into them through various regulated openings, which are in direct communication with the atmosphere, and the volumes of air thus drawn by the fan from the atmosphere flow over the surface of the liquid in the tank and in the connected channels direct to the fan B and thence up shaft D into channel D1 and through the wetted coke E into the atmosphere. At first the top of the shaft D was left open to the air, in the expectation that the high degree of aeration which the effluent gases had undergone would prevent all smell whatever, and such was indeed to a very great extent the case. Nevertheless, on rare occasions in certain conditions of the atmosphere, unpleasant odours could be perceived.

To get rid of these slight and intermittent smells the top of the outlet shaft was closed down in the manner shown on the Drawing, and the effluent air was then diverted and made to pass direct into the air space D1 that is below the wetted coke filter E, through which it escapes into the atmosphere and is thus rendered not only innocuous, in the ordinary sense, but is absolutely sterilised, that is, incapable of supporting any pathogenic bacilli whatever.

This filter E is 3 ft. deep, 8 ft. 1½ in. wide, and 12 ft. 9 in. long, and consists of broken coke, which is kept damped and moist by fine sprays of fresh water, amounting in the aggregate to about 14 gallons per hour, or 336 gallons per day, when about 2000 cub. ft. per minute of hydrolytic tank air is being treated by it.

178. The hydrolytic tank began to work in November 1904, and has practically carried on its functions from that time to the present with most satisfactory results.

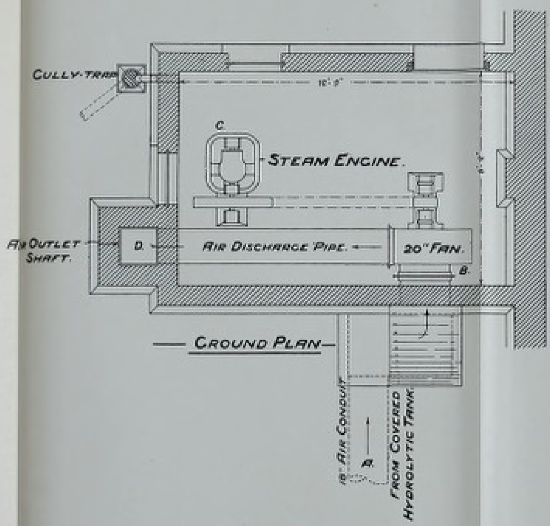
During that period a very great deal of bacteriological and chemical experimentation has been conducted under the direction of Dr. Travis. He has been able to demonstrate the presence in sewage in large quantities of suspended solids and colloidal matters, and to eliminate the same therefrom. He has also arrived at the conclusion that too much importance has hitherto been attached to the liquefactive factor of sewage resolution, that operation being mainly already performed in the processes of digestion. The more active the bacterial operation is, the less will it be a liquefaction and the more will it become a gasification.

Further, the bacterial action, and consequently the evolution of gas, is intensified as the temperature rises. This was proved by the following experiments. The same sewage sludge was kept in sealed bottles for one hundred days, under varying temperatures, and in such a manner that the sewage gas evolved from the sludge could be readily separated and measured. One set of bottles were kept under ordinary temperatures varying from 50° to 75° F., while another set were subjected to heat varying from 86° to 95° F. The results over the period referred to were that the quantity of gas evolved at ordinary temperatures averaged 4·38 volumes of gas per diem from 100 volumes of sewage; while at the higher temperatures there was as much as 31 volumes of gas evolved from 100 volumes of sewage sludge.

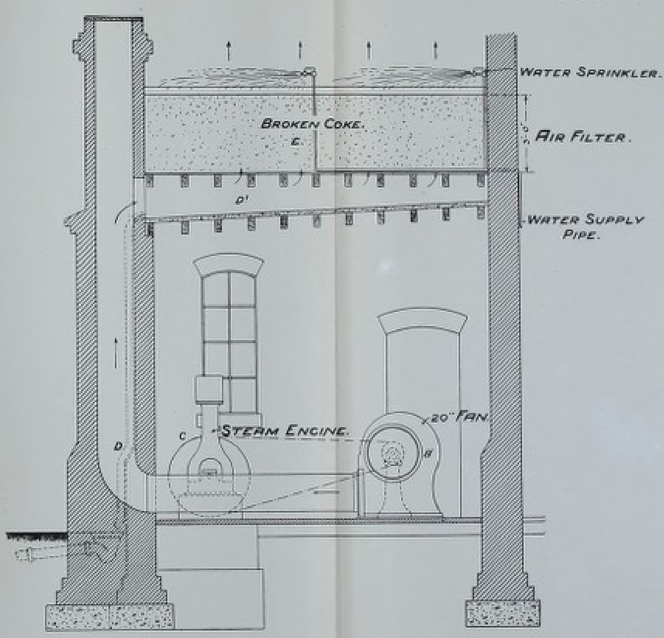
In an ordinary sewer there would not of course be any such active gasification, as it is not so much the sewage itself that is gasified as the sludge which adheres to the sides and bottom, where the bacterial action takes place.

It is, therefore, not strictly accurate to express the amount of gas formed as a percentage of the sewage flow, inasmuch as it greatly depends upon the temperature of the sewage and the condition of the sewers. Dr. Travis, however, finds in practice that the volume of sewage-gas generated in the Hampton hydrolytic tank averages about 6 per cent. of the sewage flow.

The conclusions arrived at by Dr. Travis, as stated above apply, of course, to the English climate and temperature, and to absolutely septic sewage enclosed in a tank, and not to the sewage flowing in



GROUND PLAN



SECTION

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such drains and sewers as have been laid at Hampton. In hot climates, or under less perfect drainage and sewerage conditions than those which obtain at Hampton, the evolution of sewage gas, in drains, sewers and hydrolytic or other tanks alike, would inevitably be much greater.

The details of these prolonged and exhaustive investigations and their scientific and practical results will be found in very interesting forms in two published papers; the one a paper by Colonel A. S. Jones, V.C., M.Inst.C.E., and Wm. Owen Travis, M.D., read before the Institution of Civil Engineers in January 1906, and entitled "The Elimination of Suspended Solids and Colloidal Matters from Sewage"; and the other by Wm. Owen Travis, M.D., read on May 3, 1906 before the Civil and Mechanical Engineers' Society, and having for its title "Some Observations relating to Bacterial Tank Operations."

179. The air filtering operations which have been conducted at Hampton as experimental tests have turned out as satisfactory as could at any time have been anticipated; yet admirable as the results obtained have been it is not contested that by the use of the very finest and most modern spraying and filtering devices those results may be rendered still more perfect; the principle remaining the same.

We now prescribe, therefore (as the result of the experience thus gained), that the volume of the coke filter should be equal to about one-fifth of the total volume of the polluted air exhausted per minute out of hydrolytic tanks or sewers (as the case may be); and that the quantity of fresh water playing on the coke filters should be equal to (but should not exceed) about 10 gallons per 1000 cub. ft. per minute of the vitiated air to be purified. The Hampton experiments have also proved that a greater depth of coke filtering material in proportion to its superficial area than in the Hampton filter would tend to the further enhancement of the purifying effect.

Personally, although I believe I am endowed with a full average of olfactory sensibility, I am quite unable to detect any odour, even a musty one, arising from the filter. But, just as the presence of smell does not necessarily indicate poison, so, on the other hand, the absence of smell may nevertheless be consistent with unhealthy elements. This subtle question belongs to the province of the biologist and the chemist. And, as I am neither the one nor the other, I requested Dr. Travis to investigate the chemical effects of the operations connected with the ventilation and purification of the tanks, with the special object of ascertaining whether they have beyond question rendered the air issuing from the filter into the atmosphere innocuous. Dr. Travis has very kindly complied with my request, and has forwarded to me the subjoined statement which I have great pleasure in recording.

180. "The object of the filter is to remove the foul-smelling products prior to discharging the exhausted air into the atmosphere.

"This is brought about as follows :—

"The impure gases and volatile substances are first dissolved or removed by the water passing through the filter, and are subsequently oxidised, and retained, or evacuated, as solid matter. The effect is aided, and made more complete, by the large area of wet surface presented by the material, which permits of efficient contact between the air and the water. The quantity of liquid distributed, and the size of the filter particles are important factors.

"For, if the water be in excessive amount, the matters brought into solution are washed away, prior to being oxidised; whilst if the particles are too large, the air will pass through with insufficient contact.

"The efficiency of the operation has been demonstrated by frequent examinations of the material of the filter, and of both the entering and issuing liquid and air.

"The material of the filter has been found to have accumulated a considerable amount of deposit, which contains as an average of the samples submitted to analyses, 0·57 per cent. of sulphur and 0·62 per cent. of organic nitrogen. The sulphur is the expression of the oxidation of the sulphuretted hydrogen, dissolved out of the air by the water, whilst the organic nitrogen has been deposited as solid matter, either directly, or from the solution of volatile and other organic impurities.

The average analyses of the water sprayed over the filter, and of the water passing from it, are as follows :—

—	Solids			Nitrogen		Oxygen
	in Suspension	in Solution	Ammonia-cal	Albuminoid	Nitric	Absorption
Influent . .	nil	29·0	nil	0·007	0·18	0·07
Effluent . .	9·4	49·0	0·21	0·032	0·06	0·20

"There is thus a marked difference in the character of the two liquids. The solids in suspension in the effluent, when separately analysed, are found to consist of 76·4 per cent. inorganic matter, largely composed of fine grit washed from the material, and 23·6 per cent. organic matter, of which 2·5 per cent. are sulphur. The ammonical nitrogen in the effluent arises from the ammonia compounds removed from the air. The increases in the albuminoid nitrogen, and in the oxygen absorption, are caused by the organic matter removed, which has, at the same time, reduced the nitrates in the wash water.

"Finally, these effects have profoundly influenced the character of the air leaving the filter. For there is now no evidence of malodorous air, and only the faintest indication of a musty odour on the filter itself. Whereas, formerly, when the gases passed either directly into the atmosphere from the open channels, or indirectly through the fan, with a large volume of atmospheric air, there was a definite nuisance, which was perceptible at some distance from the point of origin, and was the subject of complaint, yet an analysis indicative of the quality of the air which issued out of the open top of the shaft at that time gave only carbonic acid 4·6 parts per 10,000; hydrogen sulphide a trace."

181. There has been recently published an able work on the "Ventilation of Public Sewers," by Mr. J. S. Brodie, M.Inst. C.E., Borough Engineer of Blackpool, in which he refers to and describes a number of different plans and methods of sewer ventilation past and present.

With reference to the hydro-mechanical system he makes the following observations:

"Messrs. Shone and Ault's hydro-mechanical system of sewer ventilation is based on scientific principles, which have been and are in successful application in the ventilation of mines. It is perhaps not too much to say that by this system only has the solution of the double problem of sewer and house drain ventilation been solved. It will probably be objected that the first cost of this system renders it impracticable on financial grounds. The answer to this is that no just comparison can be made unless the absolute efficiencies of a so-called 'cheap' system and a perfect one are taken into account.

"It may also be pointed out that the first cost of this system appears, *at the present stage*, to be more apparent than real, and that when confidence in the system has been established, *it will be found that much of the apparently costly devices in the interceptor traps and chambers will be saved in less expensive house drain and other plumbers' work in connexion therewith.*"

The importance of the last two statements can hardly be exaggerated, and is emphasized by the fact that Mr. Brodie supplies a table headed "Comparative summary of costs of various systems of sewer ventilation."

182. A superficial survey of such a table would attract attention

mainly to the relative degree of *cheapness* of the different "systems"; while, on the other hand no amount of study of it could convey any adequate notion of the relative values *inter se*. This can only be arrived at by assigning some standard by which each can be scientifically and practically judged.

I submit that the proper and only standard for a comparison of the relative initial and maintenance costs of different proposals for the ventilation of sewers and drains is to determine the amount and the character of the ventilation work to be performed and the true sanitary efficiency thereof.

183. In this connexion I am tempted to quote what in my opinion is the best exposition of Sanitary Engineers' duties and responsibilities that I have ever read, I refer to the view expressed by Mr. E. S. Philbrick, author of an excellent work entitled "American Sanitary Engineering," * and which are as follows: "One of the most harassing experiences which the sanitary engineer has to meet with arises from the difficulty in deciding off-hand, as to the relative merits of the thousand devices which an army of inventors have brought to his door. The only way to meet such questions is to be sure that you are thoroughly grounded in the governing principles, viz., the laws of nature, whose aid you wish to avail yourself of in reaching your end. It is the part of folly for anyone to seek to accomplish his ends if his processes are not in perfect harmony with physical laws. It is not only a wasted effort, but serves to bring into discredit, by its failure, the cause of education itself. The greater opportunities we have for acquiring knowledge, the greater is our responsibility for making the best use of it, and the greater the disgrace if we act on imperfect information, and are led astray by false lights. It is from considerations of this sort that we are led to appreciate the dignity of this profession, and its possible value to society when disgusted, as at times we may be, by the petty annoyances of its minor details, the bigotry of men who have seen and studied only one little spot in the great field, and the ignorance, or want of light yet existing upon many points which are yet obscure.

"It is here, as in many other walks of life, that we should be careful to keep the attention fixed upon fundamental principles, as the foundation upon which all human effort must rest."

184. It is far from my desire to depreciate the merits of those who have applied their talents and their energies to the mitigation of the evils arising from insanitary house drainage and town sewerage works. These evils are so universal and so intense, that he who designs any method for their removal or even abatement, however partial it may be, or however it may fall short of completeness in

* "The Sanitary Engineer," New York, 1881.

other respects, richly deserves, in my opinion, all the reward he may obtain for any genuine service he may render to the public in this direction.

I therefore wish it to be clearly understood that any criticisms which I may deem it right to offer upon the results of the efforts of other workers in this most important department of the public weal, are on no account to be read as implying that such palliative measures should be cast aside as useless. On the contrary, the evils arising from sewage gas nuisances are so wide-spread, so various, so persistent and formidable, that any abatement of their mischievous effects, however incomplete or intermittent it may be, is to be welcomed, and estimated at its due value.

It is, however, not the less true that the only means of arriving at a remedy for the evils in question, which shall be at once permanent and universally applicable, is to get at their original causes, and to remove these. To the same extent in respect of physical health, as hygiene tends to supersede drugs, so in respect of sanitation will the removal of the primary causes of insanitary conditions do away with their baleful results.

The limits at my disposal preclude me from entering seriatim into a discussion of all the methods collected by Mr. Brodie, but there are two of them as to which I think some comments may not be out of place.

185. The first is the ventilating lamp patented by Mr. J. E. Webb, which is in use in connexion with some of the sewers of Blackpool and elsewhere, and is operated by coal-gas. By this arrangement it is claimed that the temperature of all the air exhausted from the sewer by the lamp is raised to 550° F. so as to destroy all the micro-organisms contained in it before it is discharged into the atmosphere.

It is impossible not to admire the ingenuity of this plan, and therefore I do not desire to say a word in derogation of its capability to produce the results claimed for it by its inventor.

But in a matter where the demand is unlimited, because every living person in the country regards sanitation as a necessity of life, we must judge any plan for securing that blessing, not alone by its efficiency under local conditions, but by its practical value if it were applied universally as its promoter desires it should be. And in this point of view, everyone will agree that two very essential elements are efficiency and cost.

186. Let us therefore consider how the system in question if applied everywhere with sufficient guarantees of its universal efficiency would work out in point of costliness compared with, say, the hydro-mechanical system of ventilation.

Suppose, for example, 2000 cub. ft. of air per minute have to be heated from, say, 60° F. to 550° F. This means an increase in heat of 490°.

Now 2000 cub. ft. of air at a temperature of 60° will weigh approximately 153·8 lb.

Every degree (F.) of heat added to a lb. of air requires the expenditure of 0·2377 thermal unit.

Therefore, the heat required to raise 153·8 lb. (i.e. 2000 cub. ft.) of air from 60° F. to 550° F. is $153 \cdot 8 \times 0 \cdot 2377 \times 490 = 17913 \cdot 6$ thermal units.

The heating value of coal-gas is represented by 628 thermal units per cub. ft. So that the number of cub. ft. of gas required per minute to raise the temperature of the air from 60° to 550° F., is $17913 \cdot 6 \div 628 = 28 \cdot 6$ cub. ft. Assuming that this consumption is constant throughout the year, we get the following result.

Gas required per annum :—

ft.		min.		days		cub. ft.
28·6	×	1440	×	365	=	15,032,160

which at 2*s*. 4*d*. per 1000 cub. ft. (the price at Blackpool) would cost 1753*l*. 15*s*. per annum.

The foregoing calculation is made to the best of my judgment from the published description of the method by which the Webb lamps are operated, and is based on the assumption that that method is capable of being as universally applied, and with the same efficiency as far as is compatible with its nature, as the hydro-mechanical system. Upon no other supposition that I can suggest can a fair comparison, or indeed any useful comparison, be made on the question of cost.

187. Unfortunately in this case we are faced by a primary difficulty which greatly frustrates, if it does not render impossible, the investigation, not only of the cost, but of the real efficiency of the system. No particulars are supplied as to the amount of sewer air which the apparatus can exhaust from the sewers, and treat as above described. For example, if I ask how many cub. ft. of sewer air per minute can a Webb lamp with a consumption of, say, 1000 cub. ft. of gas per hour extract and deodorize, I find no materials given for answering that question.

The four Webb lamps at work in Blackpool may be taken, I presume, as typical instances. They supply a total length of sewers of 1·85 miles, and have 316 house connexions. Thus, at the rate of five people per house, they supply a population of about 1580.

The average cost per lamp was, it appears, 29*l*. ; and the net cost per annum of the four lamps was 66*l*. 7*s*. 10*d*., or 16*l*. 11*s*. 11*d*. per lamp. Worked out at so much per mile, the first cost would be 58*l.*, and the annual cost 33*l.*

But what is the precise meaning of these figures? They represent the expense incurred in obtaining a certain amount of very useful deodorization; but what that amount is there are no means of determining.

One thing, however, seems clear. The Webb system, as established at Blackpool, deals only with the air of the public sewers, and does not ventilate that part of the house-drain which is between the interceptor and the sewer, nor the surface gully drains between the street gullies and the sewers.

187*a*. The second ventilation system referred to in Mr. Brodie's book is that which bears the name of Mr. R. Harris Reeves. This system is described by Mr. W. J. Dibdin, F.I.C., F.C.S., etc., formerly chemist and superintending gas examiner to the London County Council, in his important work on the "Purification of Sewage and Water," in the following terms:—

"Some time back Mr. Harris Reeves took up the idea suggested by the use of manganate of soda and sulphuric acid for the temporary deodorisation of the London sewage, pending the opening of the outfall precipitation works, and constructed a convenient arrangement of earthenware, by means of which a solution of manganate of soda was constantly prepared, and to this was added, as it flowed over a porcelain capsule, strong sulphuric acid, the action of which not only converted the cheap manganate of soda into the permanganate, but by the heat set up by the action of the acid, evolved vapours of permanganic acid, probably one of the most powerful deodorants we have.

"This system appears to have been tried at various places with marked success for the purpose of dealing with special ventilators which have been found to be a nuisance. In one case nine manholes were so treated, at a first cost of 112*l.*, and an annual working expense for manganate of soda and sulphuric acid of 20*l.*, the labour being performed by the ordinary staff without extra cost. Equally satisfactory results appear to have been obtained elsewhere, but it is evident that the cost of this system is against its general adoption for all manholes, however suitable it may be for special cases."

187*b*. Mr. Reeves' apparatus has been placed before the public in two different forms, which may be called for convenience the original system, and the 1908 system respectively. The essence of that system was that it was a method of deodorization, operated mainly, if not entirely by chemical deodorants, and not in any ordinary sense a ventilation system. Its intention, as described by Mr. Brodie, was "to produce artificial oxidation of the sewer air, before it escapes into the outer atmosphere, by means of apparatus, placed in specially prepared sewer manholes, the other manholes being closed with air-tight covers. Two chemical-ware vessels were placed in a recess formed in the manhole. The larger vessel contained a specially prepared mixture of dry manganate of soda (called 'Reevezone'), and the small vessel contained strong sulphuric acid. These chemicals were caused to mix continuously, the result of their reaction being the formation of sulphuric acid gas, oxygen gas, permanganic acid, and soda sulphate. These gases purify the foul air they come in contact with, whilst the oxidizing solution falls into the sewer, and has a beneficial effect on the sewage." Such, as far as can be gathered from the somewhat meagre details supplied, is broadly speaking the mechanism of the original Reeves' system.

In 1908, however, a new type of apparatus was introduced. This seems to have no specific designation other than "Reeves' 1908 Type Sewer Ventilator." Of this type, Mr. Brodie says, "The principle upon which this improved ventilation works, is the prevention of sewer gas being made by keeping up a continuous flow of saturated air through the sewer, and *rendering unnecessary the work of deodorization*. It falls, therefore, more properly under Chapter III." *

How far this may be the case I am unable to judge, but I will assume that the deodorizing operation is still performed in the new apparatus.

187*c*. Mr. Reeves has published a table "showing the amount of oxygen produced and details of work done by Reeves' 1908 Type Sewer Ventilator." I have very carefully examined this table, and I am bound to confess that its most essential features present mysteries in chemical science and practical mechanics which are beyond my comprehension altogether. I have not space to copy the whole table, but the following is a sufficient description of it:

Column 1 gives a series of temperatures of the air in the sewers from 50° to 60° F., by increments of 1°.

Column 2 gives the weight of the air in grains per cub. ft. at the several temperatures.

Column 3 contains only one number, viz. the volume of chilled and saturated air passing through the apparatus per day, i.e. 144,000 cub. ft.

Columns 4 and 5 give respectively the weight in grains per cub. ft. of the oxygen and of the nitrogen of the air. The sum of these two columns equals of course column 2.

Column 6 gives the "weight in grains of additional amount of oxygen gained by saturation per cub. ft."

Column 7 gives the "amount of oxygen gained per day."

Column 8 gives the cost per day of working the 1908 Type

* Chapter III. deals with Ventilation by Natural Air Currents.

Ventilator with "Walton Manufactured Chemicals." This cost is 0·263 pence.

Column 9 gives the quantity of water consumed in gallons per day "for motive power and chemical saturation of air in ordinary sewers." This quantity is 200 gallons costing (at 6*d.* per 1000) 1·2 pence.

Column 10 gives the cost of repairs, maintenance and attendance, viz. 0·1641 pence.

Column 11 gives the initial cost per mile of sewer (5 ventilators to one mile) complete with water meter. It is 60*l.* to 79*l.*

The weights given in column 2 are sufficiently correct for practical purposes. So also are those given in columns 4 and 5. But it is when we come to consider columns 6 and 7 that our difficulties begin.

In order to show this, I subjoin a copy of columns 1 to 7 of the table for three of the eleven given degrees of temperature. I neglect columns 8 to 11 as irrelevant for the present purpose.

Temperature of Air in Sewers	Weight in Grains per Cubic Foot	Volume of Chilled and Saturated Air passing through Apparatus per Day	Weight in Grains of Oxygen per Cubic Foot	Weight in Grains of Nitrogen per Cubic Foot	Weight in Grains of Additional Amount of Oxygen gained by Saturation per Cubic Foot	Amount of Oxygen gained per Day, Troy Weight (*sic*)
1	2	3	4	5	6	7
Deg.	Grains	Cubic Feet	Grains	Grains	Grains	Tons cwt. lb.
50	546·82	..	114·8322	431·9878	6·3903	1 8 70
55	541·5	144,000	113·575	427·785	5·2731	1 8 40
60	536·28	..	112·6188	423·6612	4·1769	1 8 15

Referring now to column 6, it gives the number of grains of oxygen obtained by saturation per cubic foot. This oxygen is, of course, extracted from the saturated air as it passes through the apparatus or from the water employed in the chilling process; in either case it is measured per cubic foot.

Now column 7 purports to give the gross weight of oxygen gained per day. It is headed "Troy weight" by some odd blunder, but is given in tons, cwt. and lb. How now can the results given in column 7 be reconciled with those of column 6? Calculated out on the basis of column 3 they are altogether inconsistent.

Thus, at 50°, the table gives a gain of 6·3903 grains. Multiply this by 144,000: result, 920203·2 grains. Divide by 7000: result, 131·46 lb. avoird.; or 1 cwt. 19½ lb. approximately, and not 1 ton 8 cwt. 70 lb. as given in Column 7.

Similarly, at a temperature of 55° a gain of 5·2731 grains per cub. ft. gives for 144,000 cub. ft. a gain of approximately 108½ lb. avoird. and not 1 ton 8 cwt. 14 lb.; and lastly at 60° a gain of 4·1769 grains per cub. ft. gives for 144,000 cub. ft. just under 86 lb. avoird., and not 1 ton 8 cwt. 15 lb., as stated in column 7.

The apparent incongruity shown by these calculations at the very least requires explanation. The table expressly purports to show the amount of oxygen produced and the work done by the apparatus; and surely these should be so expounded for the information of responsible Municipal Engineers as to enable them to understand and test them.

Should there be any occult element of calculation which has escaped my observation, I shall be glad to have it pointed out.

I have not had the advantage of seeing Mr. Reeves' apparatus in actual work, but I have carefully perused illustrated descriptions of it which have been published. I am of opinion that the apparatus with its accessories can be easily fixed in specially made underground chambers or in manholes suitably prepared for its reception. By its action currents of air from the thoroughfares are induced to flow into sewers through openings in the iron manhole covers containing the apparatus. Further, I have no reason to doubt their effectiveness for the suppression (temporarily or permanently) of sewage-gas nuisances issuing out of the covers of manholes in inhabited streets; and they are calculated to be a real boon to residents in such streets who, finding those offensive emanations intolerable, petition the local sanitary authority to have them removed.

While, therefore, within the limits thus stated I very gladly admit the utility of Mr. Reeves' system, I am bound to add that I consider that its effective application to long lengths of foul sewers of large dimensions, assuming always that it can do the amount of work claimed for it, would be found to be prohibitive on the ground of cost.

In addition to the table previously referred to, Mr. Reeves gives a "Table showing the amount of water passing through meter-nozzle per 24 hours at various pressures." According to this table, Mr. Reeves claims that he can, by the aid of his patented apparatus, and by using 150 gallons only of water per day from a street water main subjected to a pressure of 30 lb. per sq. in., induce 144,000 cub. ft. or 900,000 gallons of normal street air to flow into the sewer, down each manhole at the top of which his apparatus will be fixed. This is done by forcing the 150 gallons of water, after being chilled, into the manhole which is in communication with the sewer to be ventilated, through a nozzle at the rate of 1 pint in 1 minute and 12 seconds throughout the day of 24 hours. The theoretical velocity at which the water would issue out of a nozzle under the conditions stated would be (neglecting friction) about 67 ft. per second. He claims to be able at the same time to inoculate every gallon of the 900,000 gallons of fresh air thus induced to flow into the sewers per day with the vapours of his deodorants, before the whole volume of chemicalized air is made to flow into and through the sewer to be ventilated by it.

It will simplify our calculations perhaps if we assume that the volume of chilled water to be used per day, is equal to 180 gallons exactly; then, as there are 1440 pints in 180 gallons, and 1440 minutes in a day, the water used in Mr. Reeves' apparatus under such conditions would be exactly equal to 1 pint or 0·125 of a gallon per minute. Again, as each apparatus discharges 144,000 cub. ft. of chilled and saturated air into the sewer through the manhole or chamber in which it is fixed, it follows that the effect of forcing 0·125 of a gallon of chilled water per minute through Mr. Reeves' special nozzle, is to induce a current of air equal to 144,000 cub. ft. per day to pass through the sewer. It also follows from the same data that 1 gallon of water at 30 lb. pressure, in passing through his apparatus will produce and discharge into the sewer $= \frac{144{,}000 \times 6\frac{1}{4}}{180}$ = 5000 gallons of ventilating air per day. And as the proposal is to employ five separate apparatus to every mile of sewer to be ventilated by the system, it will be evident that $5 \times 150 = 750$ gallons of water at 30 lb. pressure per sq. in. will be required per mile per day, which would be = 0·01092 h p. per minute. Thus if the system were employed to ventilate a sewer say of 15 in. in diameter, 1 mile long, and if that sewer had at its upper end a manhole fitted up with the Reeves apparatus, 100 cub. ft. of air per minute ought to descend that manhole—which for convenience we will call No. 1 —into the sewer. We will further assume that the manholes possessing the Reeves apparatus are equidistant from each other— that is that they are $5280 \div 5 = 1056$ ft. apart, as may be hypothetically illustrated by the accompanying Drawing No. 35. Apparatus No. 2 would contribute another 100 ft., making the volume which would pass between Nos. 2 and 3, 200 cub. ft.; No. 3 would add 100, making the volume passing between Nos. 3 and 4, 300 cub. ft.; No. 4 would add 100, making the volume passing between Nos. 4 and 5, 400 cub. ft.; and the volume that would pass from No. 5 manhole (which is at the end of the first mile) to No. 6 would be 500 cub. ft. per minute. The effect of thus adding increments of 100 cub. ft. of air at each manhole would be to cause the air to travel along a sewer 15 in. in diameter charged one-third full of sewage to flow between Nos. 2 and 3 at 230, and between Nos. 3 and 4 at 345, and between Nos. 4 and 5 at 460, and between Nos. 5 and 6 manhole the velocity would be 575 ft. per minute respectively.

Under such conditions the power that would be necessary to cause the air to flow between manholes Nos. 2 and 3, would require to be 8, between Nos. 3 and 4, 27, between Nos. 4 and 5, 64, and between Nos. 5 and 6 it would require to be 125 times greater than

DRAWING No. 35.

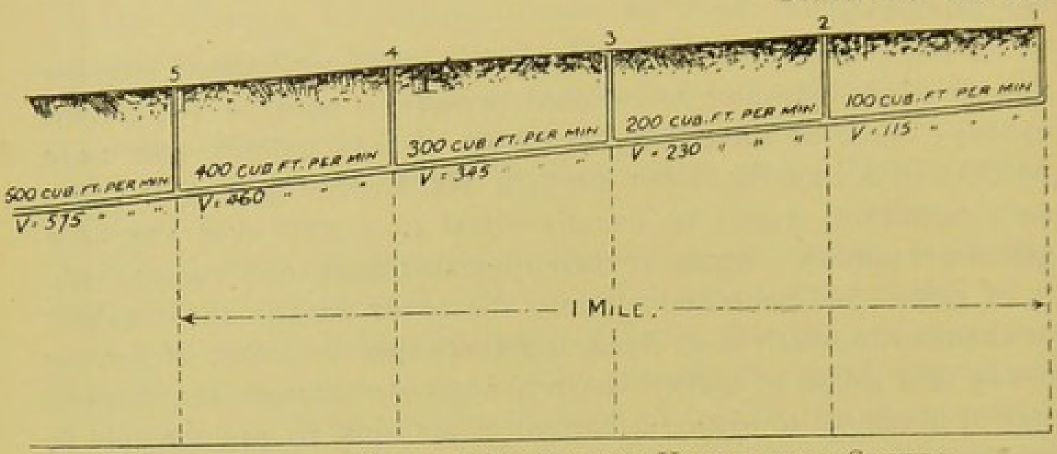


ILLUSTRATION OF REEVES' SYSTEM FOR VENTILATING SEWERS. APPLIED TO ONE MILE OF 15" SEWER.

would be required to propel the air along the first of the five sections of the sewer, i.e. between manholes Nos. 1 and 2. The total h.p. required to propel the air under the conditions stated above will be about 0·109 h.p. or about 10 times greater than the power necessary to expend in order to create the water-motive force used to bring about the ventilating results claimed by Mr. Reeves.

The table in question, however, might very advantageously have been made more explicit. Read horizontally (i.e. from left to right) it shows that the greater the quantity of water passing through the nozzle per day the more rapidly it passes through. For instance, at a pressure of 30 lb., whereas 150 gal. pass through at the rate of 72 seconds per pint, 300 gal. will pass at the rate of 36 seconds per pint, and 600 gal. at the rate of 18 seconds per pint.

These phenomena can only be accounted for as far as I am able to understand them, on the assumption that the nozzles are successively of gradually increasing diameters. This, however, is not stated. But when the table is read vertically, the natural inference is that the same nozzle is referred to as acting under the successively increasing pressures. If this is the meaning of the table, then I suggest that the results are not in accordance with hydraulic law. For example, by the table, a nozzle delivering under 30 lb. pressure 150 gal. at 72 seconds per pint, will (if I interpret the table correctly) deliver 225 gal. in 48 seconds at a pressure of 60 lb.

Now 150 gal. at 72 seconds per pint equals 125 gal. at 60 seconds per pint. And 228 gal. at 48 seconds per pint equals 281 gal. at 60 seconds per pint.

But pipes of equal diameter discharge liquids in the ratio of the square root of the pressure; so that when (as in this example) the pressure is doubled the volume discharged at 30 lb. should be multiplied by $\sqrt{2}$ to obtain the volume discharged at 60 lb. pressure; that is to say a nozzle discharging 125 gal. per day at a pint per minute under 30 lb. pressure will discharge $125 \sqrt{2} = 176 \cdot 6$ gal. per day at a pint per minute under 60 lb. pressure and not 281 gal.

188. Now the hydro-mechanical system, properly designed as herein prescribed, will not only ventilate the public sewers, and all the private house-drains, on both sides of the interceptor trap, but also all the street gully drains whatever their number. By its aid, the gully drains can be made to carry to the public sewers regulated increments of fresh air to ventilate them, and the air, after passing down the soil pipes into and through the drains and sewers, can be further purified before it is discharged back into the atmosphere as is done at Hampton and described on page 41 (ante); both operations —i.e. the ventilation and the purification—are based on scientific principles which are entirely new, but which it will be found can be easily and inexpensively applied to the ventilation of the drains of private houses and public buildings, and also of the drainage and sewerage arrangements of towns and villages of whatever size.

189. A perusal of the opinions (some of which are quoted above) * of Sir Joseph Bazalgette and other eminent Engineers, English and American, on the question of sewer ventilation shows that, in the middle of the nineteenth century, the most influential sanitary engineering authorities were agreed in the opinion that sewers could not be ventilated on the principles applicable to the ventilation of mines. Their view was that so soon as either furnaces or fans were set going to exhaust air from the sewers by vacuum power, the water-seals of house drain and gully drain interceptors would be at once unsealed. And it was also considered (and in this case correctly) that if house drain and street-gully drain interceptor traps were dispensed with when fans or furnaces were employed to ventilate the drains and sewers, the volumes of sewer and drain air to be extracted would be so enormous as to necessitate the use of huge power which would render mechanical or furnace ventilation absolutely prohibitive on the score of first and annual cost.

The consequence was that any idea then entertained of applying the principles of mining ventilation to that of sewers was abandoned.

The fallacy involved in this most unfortunate conclusion was that those distinguished authorities assumed as a finally demonstrated fact that the power or pressure of the air exhausted from the atmosphere and induced into the sewers, could never by any possibility be so

* *Supra*, pages 132 *seqq.*

controlled or regulated as to ensure the safety of the water-seals of house and street gully drain interceptors.

190. It is, however, an unquestionable fact, founded on scientific principles and now established in practice, that it is not only possible but easily and economically practicable to regulate and control the air pressure at will, so as to meet the specific requirements of each particular case. And such control can be exercised with or without the use of the house drain interceptor trap.

In my opinion, however, the easiest and most perfect as well as the most economical way to regulate both the volume and the pressure of the ventilating air supply is to employ interceptor traps designed on the principle shown on Drawings Nos. 22 and 23. Only so much air approximately should be extracted from the atmosphere and made to circulate in drains and sewers as will suffice when it enters the soil and other waste pipes into the house drains and passes through the small air-pipes of the house drain interceptor trap into the sewers, and along these to the fan—to dilute and render harmless the volume of sewage gas given off by the sewage in its transit to the outfall.

191. It is known by experience that the amount and character of sewage gas arising from sewage in its transit to the outfall varies considerably according to the quality, condition and temperature of the sewage in any given place at any given time. Consequently, the amount of atmospheric air dilution which would under one set of conditions be sufficient to render the sewer air practically inodorous and innocuous, would under other conditions require to be added to to produce an equally satisfactory result.

192. I have shown elsewhere on the basis of analyses made by Dr. Letheby, which were laboratory trials, that when the gas evolved from putrid sewage is diluted with fresh air to the extent of half a cubic foot per minute, the sewage gas will be so diluted that its volume will be to that of the air as $\frac{1}{43200}$. Now a fan working on the hydro-mechanical system with a capacity to exhaust 4 gallons of air per minute would pass in a day (1440×4) = 5760 gallons of atmospheric air through the house drain into the sewer. But 5760 gallons = 922 cub. ft. per day = 0·64 of a cub. ft. per minute, or more than was assumed in the example just given; so that the degree of dilution would be much greater than $\frac{1}{43200}$. Further it must be remembered that normally the sewage so aerated would be fresh sewage and would be under aeration from the moment it passed through the soil pipe; which, of course, involves a still higher degree of dilution.

193. I may mention that at Leicester, where the hydro-mechanical system has been at work for seven years, although the fan is placed on the footway of a comparatively narrow street, in the vicinity of and opposite to good houses occupied by artisans, no complaints have

been made either of offensive emanation or of any other inconvenience. Yet the volume of air exhausted from the sewers and discharged up the fan shaft amounts to about 900 cub. ft. per minute.

194. This furnishes, I submit, a fair practical illustration of the fact that, provided the sewer air before being allowed to escape into the atmosphere is approximately as pure as the atmosphere itself, it will produce no harmful effects.

The facts just stated will no doubt be accepted as sufficiently re-assuring in many quarters, especially where strict economy is essential. But I have admitted elsewhere that notwithstanding the high degree of dilution arrived at by the action of the fan, causes of complaint may at rare intervals and under unusual conditions occur—that is to say, such as must always exist in connexion with foul drains (and drain interceptors) or sewers of deposit. Therefore, arrangements are provided for a final process of purification through the medium of the coke filter shown in Drawing No. 4 of my Liverpool paper, and numbered 21 in this book, and fully described at page 101 *supra.*

With these introductory observations, I will now describe by way of illustration the application of the hydro-mechanical system to the ventilation of the soil-pipes, house-drains, street-gully drains and public sewers of a district containing, say, 1000 houses, with a population assumed as 5000.

195. To enable the reader to understand readily how that operation would be effected it is desirable to assign hypothetically a given area as the *locus in quo.*

We will therefore assume that the whole of the 1000 houses above referred to can be drained to the centre of one of a number of flat, or partly flat and partly undulated automatic drainage sections. Such an arrangement is described above, at par. 6, and is shown in perspective section on Drawing No. 1, Figs. 1 and 2, and in plan on Drawing No. 2. There is a full reference also to the various parts illustrated in Drawing No. 1. However, for my immediate purpose it may be useful to go partly over the ground again.

It will be seen that the four main gravitation sewers converge at a manhole marked A on both section and plan, which manhole is sunk under the surface of four roads or streets, where they cross each other at right angles. The sewage discharged by each of the four sewers flows into the manhole A and then passes by gravitation through the pipe figured 5, into the two ejectors E_1 and E_2 which are fixed in the ejector station. These eject it automatically under direct pneumatic pressure to the outfall, through the iron sewage-delivery pipe 9. It should not be overlooked that the gravitation sewers, etc., shown and numbered in Drawing No. 1 are shown and numbered correspondingly on the plan No. 2. Moreover the sewers represented in Fig. 1, as converging to the manhole A, are of the pattern prevalent in the early part of the last century, and are in their higher reaches connected with house drains, on which unventilated interceptors of deposit are fixed.

Now to ventilate the four main sewers and their tributaries and all the house-drains joined to them, as well as the soil-pipes of the district represented, all that would be necessary to do to ventilate them by fan power would be to fix on the line of each house-drain a ventilated interceptor of the type shown on Drawing No. 32, and also for ventilating the gully-drains an arrangement of the class illustrated in the Drawing No. 35, on page 182, should be fixed.

In Drawing No. 2 there is indicated by the letter B the situation where a fan and motor and a sewer-air purifying filter could be fixed, below ground or on the surface; placed in such a position that they could be utilised to ventilate the sewers only, or would equally efficiently ventilate all the soil pipes, drains, gully drains and sewers in combination throughout the entire system, as is shown on Drawing No. 35 on page 182, where it will be found fully described.

196. I have referred elsewhere to the admirable treatise on "Sewer Gas and its influence upon Health" by Mr. H. A. Roechling, and I venture here to produce in a graphic form certain extremely significant and instructive sanitary facts reported by him with regard to the city of Berlin.* They will be found in Appendix X. of the book, which is appositely entitled "Influence of Sanitary Works upon the Mortality from Typhoid Fever."

Mr. Roechling says: "It might not be out of place to make a few remarks here on the presence of typhoid fever (typhus abdominalis) in Berlin before and after the systematic sewering of the town, as the statistical material at our disposal appears to have been collected with the greatest care."

197. He gives a table showing the number of deaths in Berlin from all causes and from typhoid fever between the years 1854 and 1890; and he also gives diagrams marking the years in which various sanitary improvements were commenced or carried out there.

He observes as follows: "It will be seen that there has been a very steady decline in the typhoid mortality since 1856 when the waterworks were opened, but that this decline has become considerably more rapid since the commencement of the drainage works in 1875."

It is by no means contended that to this reduction in the death-rates only the water supply and drainage have contributed.

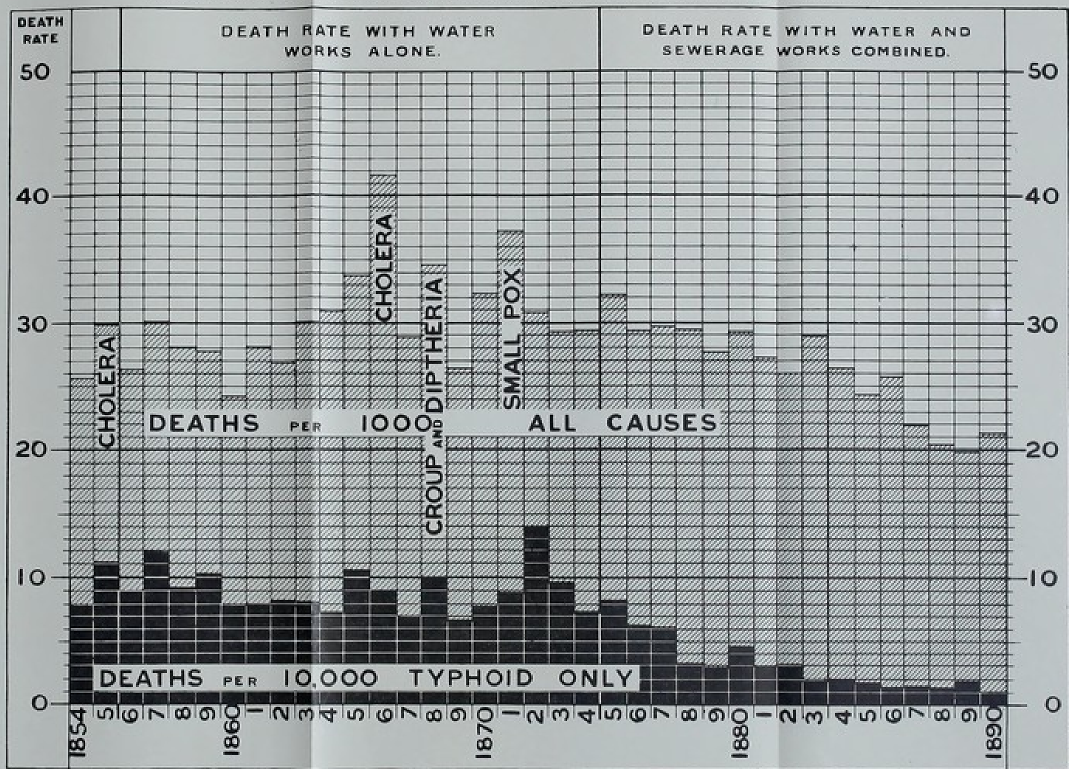
* Th. Weyl: "Die Einwirkung Hygienischer Werke auf die Gesundheit der Städte mit besonderer Rücksicht auf Berlin," 1893.

DRAWING No. 36.

BERLIN

B

TABLE SHOWING MORTALITY FROM ALL CAUSES AND FROM TYPHOID 1854 TO 1890



[Face p. 186.

On the contrary, no doubt, a great many other factors have added their quota, but I think we are perfectly entitled to say that amongst the beneficial influences at work, sewerage and water supply occupy a most prominent position."

198. I have taken the liberty of exhibiting the above-mentioned results in Drawing No. 36.

PROPORTIONS PER 10,000 INHABITANTS OF THE DEATHS FROM TYPHOID FEVER.

Year	Population	Number of Deaths from Typhoid Fever	Proportion per 10,000 of Typhoid Mortality to Population
1854	429,390	342	7·96
1855	432,685	483	11·17
*1856	442,040	397	8·98
1857	449,610	536	11·92
1858	458,637	426	9·29
1859	474,790	490	10·32
1860	493,400	371	7·52
1861	547,571	440	8·04
1862	567,560	467	8·23
1863	596,390	488	8·18
1864	633,279	459	7·25
1865	657,690	693	10·53
1866	665,710	599	9·00
1867	702,437	485	6·90
1868	728,590	725	9·95
1869	762,450	518	6·79
1870	760,000	596	7·84
1871	825,937	732	8·86
1872	864,300	1,208	13·98
1873	900,620	859	9·54
1874	932,760	691	7·41
†1875	966,858	805	8·33
1876	995,470	623	6·26
1877	1,010,946	612	6·05
1878	1,039,447	326	3·14
1879	1,069,782	296	2·77
1880	1,122,330	506	4·51
1881	1,138,784	340	2·99
1882	1,175,278	355	3·02
1883	1,212,327	221	1·82
1884	1,250,895	241	1·93
1885	1,291,359	214	1·66
1886	1,337,171	181	1·35
1887	1,386,562	193	1·39
1888	1,439,618	188	1·31
1889	1,495,151	290	1·94
1890	1,548,279	143	0·92

* 1856, opening of Waterworks.
† 1875, sewerage of town commenced.

APPENDIX IIA.

PAPER READ AT EASTBOURNE, 1901.

Copy of Paper read by the Author's partner, Mr. Ault, on July 30, 1901, *at the Eastbourne Congress of the Royal Institute of Public Health, on " The House and Town Drainage Systems of the Twentieth Century," by Isaac Shone, C.E., M.Inst.Mech.Eng., F.S.I., and F.R.Met.S., etc.*, 47 *Victoria Street, Westminster, S.W.*

199. The Author desires to say at the outset that he greatly appreciates the honour which the Council of the Institution of Mechanical Engineers conferred upon him in nominating him one of their delegates at this Congress, as he believes that Institution to be one of the most valuable mechanical engineering institutions of the world at the present time.

October 3, 1878, was a red-letter day to the Author, as on that date he first introduced to the notice of the British public the automatic hydro-pneumatic sectional system of town drainage, which bears his name, by reading a paper describing it at the Stafford Congress of the "Sanitary Institute of Great Britain." By the aid of that system—which has been greatly improved in detail and as a whole, thanks to the hearty co-operation and enterprise of the licensees and manufacturers of the various apparatus required to operate it, viz. Messrs. Hughes and Lancaster—sanitary engineers can always establish in the flattest and lowest tide-locked building areas small and properly graded self-cleansing drains and sewers. That system, perfect as it was and still is, so far as the hydraulics of the sewerage problems are concerned, nevertheless lacked one thing of great importance in a sanitary sense; and that was that there were no provisions made other than those approved of by the Local Government Board in their model Bye-laws for the ventilation of the drains and sewers connected with it. This one insanitary blot, however, appertained not only to the self-cleansing drains laid on the ordinary dual system of sewerage by which sewage and rain-waters are separated, but to the ordinary combined system of town drainage as well.

Thanks to the foresight and the enterprise of the then Local Board, guided chiefly by the genius of Eastbourne's first and second mayor, viz. the late greatly missed and sincerely lamented Mr. G. A. Wallis, M.Inst.C.E., and the former respected surveyor—now the consulting engineer—Mr. C. Tomes, it was at Eastbourne, 21 years ago, that the first sewerage installation of the Shone system, on a thoroughly practical scale, was established; and the Author is glad to note, from the report of the Medical Officer of Health, Mr. W. J. Willoughby, M.D., for last year, that Eastbourne has not only not suffered by the working of the system during that long period of time, but that it stands out prominently still as a splendid object-lesson to other seaside health resorts to copy, in so far as its vital statistics are concerned, as the following figures will show :—

Years	Number of Deaths	Death-rate	Death-rate excluding Deaths of Visitors	Death-rate of England and Wales
1890	485	14·38	12·92	19·5
1891	468	13·21	12·51	20·2
1892	505	13·58	11·67	19·0
1893	576	14·76	12·79	19·2
1894	430	10·49	8·59	16·6
1895	521	12·40	10·71	18·7
1896	454	10·43	9·10	17·1
1897	399	8·96	7·91	17·4
1898	494	10·85	10·20	17·6
1899	566	12·04	11·34	18·3
10 years average	490	12·11	10·87	18·3
1900	501	10·22	9·31	18·3

And now the Author is truly proud to add that this is also a red-letter day to him, for he hopes to demonstrate publicly at this important Sanitary Congress for the first time how the drain and sewer ventilation problems—which have hitherto been considered and treated, apparently, by the highest engineering authorities, as if they were unsolvable and would remain so for all time—have been solved absolutely, reasonably, successfully, upon sound sanitary and scientific and economical principles; so that the one insanitary blot referred to may now be considered to have been practically wiped out, and, consequently, henceforward sanitary engineers will not only be able to institute self-cleansing drains and sewers, under all conditions of surface configuration, but they will also be able to ventilate alike new and old drains and sewers in a thoroughly efficient manner.

200. To secure what the Author considers to be reasonably and practically perfect drainage on English lines in connection with all future work, he suggests :—

1. That where sewage irrigation is in use or proposed the dual system of drainage should as far as possible be insisted upon to the extent, at least, of excluding all rain waters, other than those which fall upon the roofs and curtilages of buildings, from the sewage drains and sewers.

2. That the rain falling upon all surfaces other than roofs, etc., should be removed by small open channels or shallow drains or conduits, either direct to natural water courses or to storm-water filters, for purification, preparatory to its being delivered to its final destination, wherever that may be.

3. That all public sewers and principal house-drains should be designed in accordance with hydraulic rules, so that when they are charged one-fourth full of liquid, the latter shall flow, when, e.g., a water-closet discharge takes place, at a *minimum* velocity of 2½ ft. per second.

4. That all tributary house-drains should be designed in such a way as to cause the sewage therein to flow, if they were charged full or half-full, at a velocity 50 per cent. at the least greater than the minimum laid down for the like purpose for cleansing public sewers, i.e. at a velocity of 3·75 ft. per second.

5. That no ordinary principal house-drain should be smaller than 4 in. or larger than 6 in. in diameter, even for that of a mansion.

6. That provision should be made for periodically flushing all house-drains which are longer in length than 1½ times the radius of the inclination at which they are laid. For instance, a 4-in. drain should be laid at a gradient of 1 in 30 to cause sewage, flowing full or half-full therein, to flow at a velocity of 3·75 ft. per second, and when the length of such drain exceeds (30 × 1½ =) 45 ft., provision should be made, supplemental to w.c., bath and rain-fall discharges to flush it.

7. That all house-drains should have suitable and sanitary ventilated interceptor traps fixed somewhere on their lines, to prevent

the air of the public sewer escaping into the house-drains, and ascending there-through, into the atmosphere overlying the roofs, etc., of the buildings to be drained.

8. That the inlet and outlet branches of the trap should be of the same bore as the drain, but the lower part of the trap ½ in. less, and that the water-seals should be 3 in. in depth.

9. That all subsidiary house-drains should not be less than 3 in. or more than 4 in. in diameter.

10. That all the principal and subsidiary house-drains and all the soil and waste pipes connected therewith should be ventilated, either by natural or mechanical means, in as perfect a manner as possible.

11. That the house-drains on the sewer side of the interceptor trap should be ventilated by the system adopted for the ventilation of the public sewers.

12. That all the drains which carry surface waters from road and street gullies into public sewers, should be ventilated in a similar manner to those given under 11, and that, in both cases (11 and 12), the air should be admitted to the drains in the direction of the flow of the sewage, but should be prevented from flowing in a reverse direction from the sewer, *via* the drain, into the atmosphere of the road or street or house premises—that the ventilating air should be compelled to travel downwards in the direction of the sewage flow, and that it should only be allowed to make its exit again into the atmosphere at one point, *via* a ventilating shaft suitable for the purpose.

201. The general arrangements indicative of the way in which house and town drainage, and of the way in which house-drain and public sewer ventilation works, of the 20th century should be carried out on the lines of and in accordance with the foregoing suggested rules, are shown upon the large diagram placed upon the wall and which is almost self-explanatory. It will be seen, for instance, that it is proposed to utilise not only the rainfall, but all the w.c., bath and sink waste discharges, for flushing the drains and interceptor traps, and the public sewers. The flush tank to be used will resemble a properly ventilated interceptor trap, and it should be automatic in its action.

A house containing, say, 5 people, discharging 30 gallons per head of sewage into the drains during the day, would if such sewage were turned into a flush tank of, say, 10 gallons capacity, cause the latter to fill and empty 15 times a day; but during heavy rain—equal, say, to 1 in. per day falling on roof and other surfaces, equal to 500 sq. ft. per house, and assuming 75 per cent. of the rainfall to reach the drains as it fell—would cause the flush tank to be filled and emptied 34½ times a day.

These figures are given merely to show that whilst almost every sanitary engineer is crying out to-day for more water for drain and sewer flushing purposes, he overlooks and neglects to catch in a systematic manner, the supply of rainfall and sewage-waters which are allowed to run literally to waste, instead of utilising the whole of them for flushing purposes.

It will be noticed that the Author has shown, upon the diagram, Shone's Ejectors for the collection within and the ejection out of the flat section district, represented as being dealt with on the automatic Shone System. But the introduction of the ejectors for the purpose is not compulsory, as it is open to other Sanitary Engineers to substitute ordinary pumping plant driven by steam, oil, gas, water or electricity if they so prefer.

It was a convenience to show an ejector station on the drawing in connexion with the ventilation arrangements, because, in sectional drainage, the ejector station is the place to which all the sewage of each section is brought; it represents, therefore, the pumping station in a scheme where the whole or part of the sewage of a town is brought to one low point, or the outfall, in a purely gravitation scheme of sewerage. The ejector station on the drawing, therefore, may be taken as representing the converging point or points of the sewage of a town, whether the sewage be brought to one point or outfall, as in towns on sloping or undulating ground, or to several points, as in flat areas, having sectional drainage; the converging point or points, to which the sewage is brought, being also the point or points to which the air is brought in the author's proposed method of ventilating drains and sewers by mechanical means.

It will be convenient to state shortly some leading principles which should be considered when devising a method of ventilating drains or sewers.

1. Some mechanical means must be resorted to for producing currents of air in drains and sewers, because the movements and densities of the atmosphere are too variable, and ordinarily too feeble in force, to be depended upon, for the production of natural and efficient ventilation. This has been shown over and over again by tests of the flow of air in sewers carried out by various engineers, notably by the present President of the Incorporated Association of Municipal and County Engineers, and who is I am glad to find President of the Engineering section of this Congress, viz. Mr. E. G. Mawbey, M.Inst.C.E., at Leicester, and by the late Mr. Santo Crimp, M.Inst.C.E., at Wimbledon. The author may state here *en passant* that he proposes to publish a book in which will be found an epitome of the tests and opinions of all the leading authorities in connection

with drain and sewer ventilation, and in which Mr. Mawbey's good work in Leicester will be described and illustrated.

2. The air entering sewers must be controlled, so that each length of sewer can obtain its fair quota or share of the ventilating current available.

If this is not done, the air-opening nearest to the fan will admit more than its fair share of the ventilating current, in which case the sewers furthest away from the fan would have less than their fair share of current.

3. The air should always if possible be made to pass through the sewers in the same direction as that of the flow of the sewage.

4. The outlet of the air from the sewer should be at as few points as practicable, and should be well above the surface in order that it may be quickly diffused within the atmosphere.

The fewer places provided for exit the better, since at each a mechanical means of producing air currents must be provided, and the fewer of these the more economical the expenditure of power. Having a constant flow of air through the drains and sewers, without stagnation, it would follow as a natural consequence that any gases evolved from the sewage would be constantly diluted and oxidised, and hence there should be no nuisance at the exits if these are placed high up in the air.

As to the volume of air which should be passed through a given sewer, Mr. Mansergh, President of the Institution of Civil Engineers, has given it as his opinion that if a sewer has its air renewed 46 times a day, it is quite sufficient for the purpose of ventilation. The volume of air necessary or desirable for ventilation must, however, be dependent on the circumstances of the case; a strong sewage, having comparatively large proportions of organic constituents, would, no doubt, give off larger volumes of gas than a sewage weak in organic constituents. Again, a stale sewage, such as has been travelling slowly through non-self-cleansing sewers, will be more actively decomposing and yielding gases than a fresh sewage travelling quickly through self-cleansing sewers.

Let us assume that the air permitted to enter each house drain is half a cubic foot per minute; this will be equal to $\frac{1440}{2} = 720$ cubic feet, or 4500 gallons of air per day. The volume of sewage (dry weather flow) would be, say, 30 gallons per head from 5 persons, or 150 gallons per day, in which case the volume of air would be $\frac{4500}{150} = 30$ times that of the sewage. Assuming the drain to be 4 in. diameter and 50 ft. long, the 720 cubic ft. of air would be equal to renewing the air of the drain 165 times a day, as compared with Mr. Mansergh's requirement of 46 times a day.

Under the conditions of a constant current of air, always flowing through the drains and sewers in one direction, the volume of air assumed for each house is a generous allowance; but still it is a volume which could be easily dealt with by mechanical means, and would prove a vast advance on the present uncontrolled, and therefore inadequate, ventilation of drains and sewers which is in vogue, more or less, all the world over.

202. In order that you may have before you a practical illustration of what working cost would be involved in the application of the system, the author will take the case of a part of a large sewerage district, drained on the separate system, the works of which were designed, and have been executed under the supervision of his firm as engineers. The sewers of this district are shown [by Plate II.] to converge to an ejector station E S; the arrows alongside the lines of sewers indicate the direction of the flow of the sewage, and also of the air in a mechanical system of sewer ventilation. The letters A B indicate the heads of two of the branches or lines of sewers, and by an inspection of the figure it will be observed that these two lines of sewers, A C to E S and B C to E S, are the longest of the whole group, and therefore the ruling lines for arriving at the head required for producing ventilation.

The two lines referred to are of equal length, and consequently it is only necessary to calculate one of them to ascertain the required head. The thinner lines on the figure represent 7 in. and the thick lines 9 in. sewers.

It will be the more useful for our purpose to consider this example for the reason that the population served by the sewers is a dense one—about 250 per acre. The population of the district is almost exactly 5000, and is fairly evenly distributed over the area commanded by the sewers. Taking 30 gallons per head per day as the contribution of sewage from the population and for the one half to flow into the sewers in 400 minutes, we should have a total maximum flow of

$$\frac{5000 \times \frac{30}{2}}{400} = 187 \cdot 5$$ gallons per minute, divided into three streams at the E S, of which the one (from the west) would be $93\frac{1}{2}$ gallons and each of the other two (from south and east) $46\frac{3}{4}$ gallons per minute.

The formula used for calculating the air friction in the pipes is that given in D. K. Clark's "Manual of Rules, etc., for Mechanical Engineers," which is as follows:—

$$h = \frac{lv^2}{156{,}800\, d}$$

where v = velocity in feet per second.
h = head in inches of water.
d = diameter in feet.
l = length in feet.

The formula given is for pipes charged full bore with the flowing air, and, reducing the formula to apply to pipes running, say, three-quarters full of air, their diameters being reckoned in inches, becomes :—

$$h = \frac{lv^2}{11{,}050\,d}.$$

The head to overcome the friction of the air for the line of sewers A C to E S [shown in Plate II.], calculated from this latter formula, is given in detail in the accompanying Table I. Other columns have been added to the Table—

Col. 1. Refers to particular sewers shown on Plate II. and described in text.
„ 2. Diameter of sewer in inches.
„ 3. Length of sewer in feet.
„ 4. Number of persons served by the sewer.
„ 5. Volume of air in cub. ft. per second flowing into and along the sewers, assuming half a cub. ft. for each house connection per minute, or 0·1 cub. ft. per head. The figures in this column, therefore, represent the number of persons contributing sewage to the sewers; and this number can be arrived at thus : $N = x \frac{0 \cdot 1}{60}$, where N = the number of persons contributing to the sewer, and x = the volume of air in cub. ft. per second flowing into and along the sewers.
„ 6. Velocity of the flow of air in ft. per second.
„ 7. Head in inches of water necessary to produce the velocities given in column 6.

From the Table it will be seen that the last length of sewer C to E S has passing through it 13·31 cub. ft. of air per second, or (13·31 × 60) = 798·6 cub. ft. per minute. This is from the western side of E S. The same head, given in Col. 7, would, of course, act upon the group of sewers to the East and South of E S and draw at least an equal volume of air therefrom or a total of (798·6 × 2) = 1597·2 cub. ft. of air per minute, to be drawn through the fan at a pressure equal to 0·72 inch of water head; and as one inch of water head is equal to a pressure of 5·2 lb. per sq. ft., the actual pressure would be (0·72 × 5·2) = 3·744 lb. per sq. ft., and the actual power required for drawing the air would be $\left\{\frac{1597 \cdot 2 \times 3 \cdot 744}{33{,}000}\right\} = 0 \cdot 18$ H.P. only.

TABLE I.—Showing head in inches of water, necessary to draw air along the line of sewers A C to E S, assuming that the volume of air amounts to 0·5 cubic foot per minute from each house connection or 0·1 cubic foot per head per minute.

Reference Letters to Length of Sewer	Diam. of Sewer in Inches	Length of Sewer in Feet	No. of Persons contributing to Sewer	Volume of Air in Cubic Feet per sec.	Velocity of Air in Feet per sec.	Head to Produce Velocity in Inches of Water	
1	2	3	4	5	6	7	
A to C	7″	510	325	0·542	2·53	0·042	0·139
	7″	135	418	0·697	3·26	0·018	
	9″	72	832	1·387	3·91	0·011	
	9″	195	1250	2·083	5·87	0·068	
C to E S	9″	310	2500	4·167	13·31	0·581	
		1222				0·720	

The mechanical efficiency of such a small motor and fan would of course be very low, as it would take as much or perhaps more power to turn the motor and fan than to move the air. Responsible makers, however, are prepared to supply the necessary plant for doing the work named above, using half of a horse-power at the motor. Under these conditions, assuming electricity as the source of power, costing threepence per B.T.U.,* the annual cost of the power would be 9855 pence, or 41*l.* 1*s.* 3*d.* per annum, for ventilating a length of street sewers equal to 1·7 miles, as well as the house drains connected thereto and the sewers and drains accommodating a population of 5000, or less than one-fifth of a penny per house per week.

It will be found (see Table I.) that the head on the length of the sewer C to E S is $\left\{\frac{0 \cdot 581}{0 \cdot 720} \times 100\right\} = 81$ per cent. of the total head, and this indicates a case where an ovoid sewer would have the

* Since the above was written the cost of electric energy has very greatly diminished, and bids fair to diminish still more.

advantage over a circular one, as regards the flow of both sewage and air. The quantity of sewage to be conveyed by this length of sewer is, as stated above, $93\frac{1}{2}$ gallons per minute, and for a 9 in. circular sewer, with a standard velocity of $2\frac{1}{2}$ ft. per second, the sewage would occupy a depth of 2·52 in., and the gradient necessary would be 1 in 147 to produce this velocity. The sectional area available for the air-way is 0·34 sq. ft., and the flow of air being 4·167 cub. ft. per second (see Table) the linear velocity of the air is $\left\{\frac{4\cdot167}{0\cdot34}\right\} = 12\cdot25$ ft. per second, requiring a head to produce it of 0·492 in. of water.

If we substituted an ovoid sewer, 1 ft. 6 in. × 1 ft. for the 9 in. pipe, the $93\frac{1}{2}$ gallons of sewage per minute would occupy a depth of 2·9 in. and require a gradient to produce a velocity of $2\frac{1}{2}$ ft. per second of 1 in 148, giving slightly better conditions, as regards the flow of sewage, in the ovoid as compared with the circular sewer. The area of the air way in the ovoid sewer would, however, be 1·05 sq. ft., and the velocity for 4·167 cub. ft. per second would be $\left\{\frac{4\cdot167}{1\cdot05}\right\} = 3\cdot97$ ft., as against the 12·25 ft. per second in the circular pipe The head for friction of air would be approximately in the inverse ratio of the squares of the velocities, in the two cases of the 9 in. circular as compared with the 1 ft. 6 in. × 1 ft. ovoid sewer, and, therefore, the head for friction in the latter would be about $\left\{0\cdot492 \times \frac{3\cdot972^2}{12\cdot252^2}\right\} = 0\cdot052$ in. of water instead of 0·581 as given in the Table I., showing the very great reduction of head for air friction, resulting from the substitution of an ovoid for a circular sewer under such circumstances.

A great advantage of controlling the flow of air in the ventilation of drains and sewers, and causing the air to travel in the same direction as the sewage, is that in case of any evaporation of water from a trap on the house-drain (in consequence of continued disuse) the forcing of a trap from any cause, or the opening of any accidental communication to the house-drain or sewer, air would always be drawn towards the sewer through such opening, and, therefore, to the fan and the proper outlet into the atmosphere. In case of any repair, or new connection, or the examination of any of the sewerage arrangements, necessitating the temporary opening of a communication to the sewer—through which a large volume of air would be admitted to the detriment of the ventilation of the sewers on the farther side of such opening, reckoning from the fan—it would be an easy matter for the time being to close the connection to the sewer while the temporary work was being done, and thereby allow of the ventilation of the rest of the drains and sewers being carried on in the normal course.

In the many cases where rainfall is admitted to the sewers, they would be more fully charged with sewage when rain occurred than during dry weather flow, and therefore the area of the air-way would be reduced. This is no detriment to the ventilation as the more diluted the sewage becomes, the less is the evolution of sewer gas and the less air is needed for ventilation. Should the sewers become completely filled with liquid, say, from an intense fall of rain, there is then, of course, no need for any ventilation and it would, under such circumstances, be automatically stopped *pro tem.*, owing to there being no air-passage available in the sewers. When the inflow of rain waters ceased, and air-ways were again available, the fan of course working continuously would again draw air through the sewers as before. A simple arrangement of a self-acting relief valve in the fan chamber, weighted so as to open at say a water head of 1 in., could be arranged to admit air direct from the atmosphere in order to prevent, at any and at all times, a water head above that pressure being produced in the sewers by any accidental restriction of the air-way, from the racing of the fan or any other cause. This would effectually prevent the forcing of intercepting or other traps.

It should be borne in mind that in a system of sewers laid down to carry away storm waters, as well as sewage proper, the diameter of the sewers would be relatively larger than that given in Table I., and therefore, during the dry weather flow of sewage only, the air-ways would be larger, and the friction of the flowing air, as well as the head to produce the flow, would be less relatively than in the case tabulated. On the other hand there is no doubt that during the dry weather flow in a combined system of sewerage, the conditions favour a more energetic evolution of sewage gas owing to the more sluggish movement of the sewage, but in consequence of the greater sectional area available for ventilation purposes in such a system, the volume of air admitted at each house-drain may be considerably increased, without requiring a greater head for moving the air through the sewers than that given in the Table.

Where an engineer has before him the designing of a sewerage scheme *de novo*, it would be an easy and comparatively inexpensive matter to put down, say, for some of the main sewers, ovoid, instead of circular sewers, which would have the advantage of furnishing the smaller section—of course properly graded—for the flow of sewage and the relatively larger section (as compared with circular sewers) for the flow of air. By judicious adaptation of the form and size of the sewers to the work of conveying sewage and air, an almost unlimited supply of the latter, for ventilation, could be passed through the sewers, without requiring an unreasonable head for drawing it through them.

The example of sewerage ventilation which has been given refers to a case where the Shone system with its small pipes has been established; but the same method can be just as readily applied to an ordinary gravitation system of sewers, which may, if necessary or desirable, be divided up into sections by means of an inverted syphon trap or the ventilation may be produced by a single fan, at or near the outfall, as circumstances may direct. What is necessary to be borne in mind is that the difference of pressure between the outer atmosphere and the air in any part of the sewer shall not exceed 1 or 1½ in. of water head so that the water seals of all traps shall be secure against being forced by the action of the fan.

203. As regards the method of controlling the entrance of fresh air into the sewers, this is shown [by Plate III.]. The inspection chamber may be built near to the boundary of private property which it serves and on the side of the street along which the public sewer is laid. The house drain being finally led from the inspection chamber and connected with a sewer. To the inspection chamber all the sewage discharges of the house are brought in the usual way, delivering at the chamber into a channel leading into the interceptor trap. The upper end of the house-drain is supposed to be in free communication with the atmosphere, by means of a pipe, carried up above the house roof. To the drain, on the sewer side of the interceptor trap, two branches are attached or formed, one for cleansing purposes (by means of rods), which is closed normally with a stopper as shown. The other branch is for the purpose of ventilating the drain leading from the interceptor trap to the sewer, and to this branch is connected a valve chamber, by means of a short piece of pipe. The valve chamber is in two divisions, the lower one being in communication with the drain, and the upper one being in communication with the atmosphere.

On the lower division of the valve chamber are attached two valves, V_2 and V_3, for the purpose of admitting air from the inspection chamber to the drain. One of these valves, V_2, is a light one and is capable of being restricted as to its passage of air. The other valve, V_3, is a larger cne, and is a relief valve made of such weight that it will open when a pressure equal to 1 in. of water head exists in the inspection chamber.

In normal working the small light valve, V_2, only comes into operation, allowing a regulated quantity of air to pass from the inspection chamber to the drain, and thence to the sewer. The purpose of regulating this valve is to prevent an excess of air passing into the drain and sewer at any one point, so that in mechanical ventilation the useful effect may be distributed throughout the whole lengths of the sewers and their connections as already explained.

The regulation of the volume of air, admitted through the valve V_2, may be accomplished in several ways. A simple and cheap method is that shown [in Plate III.]. This consists of an ebonite plug fitted into a socket or screwed on in front of the valve, the plug being bored through its length with a hole of suitable diameter, the plugs nearest to the fan having smaller, and those furthest away having larger holes, so that greater resistance is offered to the air passing the valves as they are nearer to the fan.

On the upper division of the valve chamber is fixed a light valve, V_1, opening towards the inspection chamber, and from the valve chamber a pipe is carried to any convenient place above ground, so as to admit of fresh atmospheric air, through the valve V_1, to the inspection chamber. On the top of the pipe admitting fresh air a protecting cap is fixed, with one side open, but covered first, by a fine wire gauze, for the exclusion of dust, etc., and second, by a hood for the prevention of casual interference or damage. The hood is formed in such a way that the air enters from below.

A similar valve chamber, but combined with the fresh air admission cap and hood, is shown by dotted lines fixed in the boundary wall, and which is connected with the drain from a roadside gully. The valves are similar to V_2 and V_3, and are for the purpose of admitting a regulated supply of fresh air to the drain leading from the gully to the sewer; the valve V_3 being the relief-valve, to prevent any excess of vacuum in the drain, beyond, say, one inch of water head.

With mechanical ventilation of sewers by means of a fan, etc., it is evident that a constant flow of air can be maintained in the sewers and branch drains up to the interceptor traps and gullies, by the inflow of air from the inspection chambers, through the regulated valve V_2. It is also evident that the inflow of air through those valves can be regulated to any desired extent (even to blocking up entirely the admission of air through the valves), thereby securing a ventilating current throughout the whole length of sewers and drains connected with the fan. It is further evident that, by the admission of fresh air through the cap and hood, *via* the valve V_1, into the inspection chamber, a constant supply of fresh air is provided for passing through the valve V_2. We have thus a complete means provided for the passing of a constant current of air through the whole length of the sewers and the branch drains connected thereto, right from the heads of the sewers, from the boundaries of private properties, and from the heads of the gully drains down to the outlet shaft wherever that may be placed, the current being always in one direction, and normally of the same volume and density.

Should abnormal conditions arise through any blockage in the pipes, or any openings for repairs, etc., the relief valve V_3 may come into action if the pressure or rather vacuum amounts to one inch of water head, or where a sewer or drain is broken into, and the air in such cases is drawn from the atmosphere to the drain or sewer, and in the direction of the fan and outlet shaft. The only result of such abnormal conditions would be that the efficiency of the ventilation of the sewers and drains on the upper side (that furthest from the fan) of the accidental opening would be interfered with and possibly stopped for the time being.

As regards the house drains on the upper side of the interceptor trap, where the house sewage is collected into a flush tank every time the latter discharged its contents, air would be driven down the drain to the inspection chamber, and should its pressure in the chamber rise to one inch of water gauge, the valve V_3 would open and allow the excess of air to go down the drain to the sewer. When the discharge of the flush tank ceased there would be a free way for fresh air to pass into the inspection chamber, *via* the inlet valve V_1, and thence up the house drain and the vent pipe connected therewith, to the outer atmosphere above the roof of the house. This ventilation is of course quite separate and distinct from that of the public sewers and the branch drains below the interceptor traps, and is confined entirely to the private drains belonging to the house itself.

In the event of there being no mechanical ventilation of the public sewers, the effect of such a flush as has been described would be to send air into the inspection chamber, and thence through the valve V_2 to the drain leading from the interceptor trap to the sewer, thereby ventilating this part of the house drain at every discharge from the flush tank without forcing the seal of the interceptor trap.

Although the above description of the ventilation apparatus has taken some time, it will be observed that the arrangement as a whole and in each detail is as simple as it well could be, and with the exception of the fan and motor there is nothing about any of the details but what could be readily fixed and attended to by a workman of ordinary intelligence.

204. In conclusion, the author would refer to the question of the disposal of sewage at the outfall. The last decade of the nineteenth century witnessed the establishment on a practical scale of a method of purifying sewage by natural agencies, which bids fair to completely revolutionize the practice of sewage disposal. Whether the biological treatment of sewage will be as complete a success in all cases as its many enthusiastic advocates expect must be left to the experience of the twentieth century. The author's experience goes to show that

more complete oxidization of organic impurities has been attained by this treatment than by any previous treatment on a practical scale, and further that the *bête noire* of the sanitary engineer and local authorities—the accumulation of sewage sludge—has been almost completely obviated by the new method of dealing with sewage at the outfall.

It appears to the author, however, that while much thought and ingenuity have been expended in devising and constructing sewage disposal works, there has not in many cases been that continuous attention paid to the every-day working of the disposal works which is absolutely necessary to success, whatever method of treatment of the sewage is applied.

The demands of the Local Government Board have not been conducive to success in the matter of sewage disposal, and it appears to the author that definite rules as to the required purity of effluent should be formulated which fix a maximum beyond which no local authority should be obliged to go in the treatment of its sewage, this maximum to be reduced, in relation to the purity of the stream into which the effluent would be discharged, down to a fixed compulsory minimum of purity.

The mode of treatment should be left to the local authority and its expert advisers, subject to its being shown to have a reasonable chance of success, and the Local Government Board or some other Government authority should have a continuous watchful care over the daily working of the treatment in order to guard against negligence and carelessness. If these suggestions were acted upon there would be, in the author's opinion, a very great improvement in sewage disposal, and in the purity of our streams and rivers in the twentieth as compared with that of the nineteenth century.

APPENDIX III.

PART I.

EXCERPT FROM THE PROCEEDINGS OF THE INCORPORATED ASSOCIATION OF MUNICIPAL AND COUNTY ENGINEERS.*

(The meeting at which these Proceedings took place was held at the Institute of Civil Engineers, Feb. 18, 1898, to discuss the proposed Conference of Metropolitan Surveyors called to consider the question of Sewer Ventilation.)

205. The CHAIRMAN † then introduced the question of "The proposed conference of Metropolitan Surveyors called to consider the question of sewer ventilation." He said : I was very anxious this question should be brought before the Association, because this day week (the 25th of February) the surveyors, and, I understand, some of the medical officers of the metropolis, will meet in conference under our President (Sir Alexander Binnie). It is very essential, if possible, we should agree upon some broad views on this particular subject. The question is a very vexed one, and it is almost impossible to be able to generalise or lay down rules that will apply to all districts alike ; what, for instance, would apply to Shoreditch will not apply to Hampstead, and so on. That is our difficulty in coming to any decision ; but we are all very anxious that some practical result should come from our meeting on Friday next. We want to guard against such a trouble as we were put to by the 1891 Public Health Act, when, owing to the influence of our friends the medical officers of health, a little clause was put in as to snow clearing, which has turned out to be totally impracticable. It is possible some of the medical officers will

* Vol. xxiv. 1897–1.

† C. H. Lowe, M.Inst.C.E., Vice-President.

promulgate theories with which we as surveyors will probably have very little sympathy, although, of course, we are all actuated with a wish to do what is best for all London. I think, possibly, there is no district in London, certainly no suburban district, which has given more attention to this question than my own. We lie particularly high, and the theory was started that we were suffering unduly from the up current from the main sewer of London. That theory was started in 1877, and was backed up by complaints both sentimental and real. I do not think anyone here will dispute my statement, that one would rather deal with twelve real complaints than with one sentimental complaint. Upcast shafts were tried with and without gas, with patent revolving cowls as extractors, and open mouths without any cowls. We tried numerous plans to get rid of this sewer air. Our main lines of sewers were dealt with by placing reflux traps or flaps to prevent the up-draught from London, and we went so far as to siphon some of the sewers. This thing went on until 1886, when, as we were still troubled by complaints, the Vestry called in Mr. Mansergh, one of the highest authorities of the present day, to advise them on the whole matter. Mr. Mansergh went thoroughly into the matter and examined many of the sewers of Hampstead, and reported they were generally in excellent condition, properly laid, with ample falls, and the only thing he could suggest, as the final result of his report was, that there was a little more automatic flushing required, and that there certainly should be more open ventilation. Mr. Mansergh recommended open ventilators in the roads, with gratings of sixty square inches superficial open area, and that the ventilators should not be further apart than sixty yards. Since that time the Vestry has pretty well followed out Mr. Mansergh's recommendations. They have spent a large amount of money, 2000*l.* or 3000*l.*, in supplying automatic flushing tanks, and in providing an additional number of ventilators in various parts of the district. After carrying out these works, and upon careful examination and testing, we think we have discovered the source of the frequent complaints: and it is a curious result to notice, that complaints are much more general in the districts where the modern system of house drains has been established under the new by-laws of the London County Council, than in the districts where the old system of drainage remains, and the sewage matter is at once taken direct to the main sewer and not held in suspension in traps, examination chambers and the like. We have localised the complaints so far that we are in a position to say that the manholes and the intercepting traps do not properly clear themselves. There is a certain amount of sediment left nearly at all times, which is not discharged for a considerable period, possibly for some days, and in some cases it may be even for weeks. In some cases, where the siphon becomes virtually blocked, the solid matter accumulates, and there is practically a high-water mark round the brickwork in the chambers showing where it has stood. The men working in the sewers say that from eight to eleven in the morning, when the housemaids are generally busy cleaning out the whole of the bath establishments, etc., in large houses, the smells which are given off in all directions in the sewers are so abominable that they are almost unable to stay in them. We have thus been able to so far fix the complaints as to be able to suggest to householders and builders that really what is required on their drains is simply extra means for keeping clean and flushing. The waste water preventer is an abomination, as there can be no proper flush of the pan or closet. You want to supplement that by flushing the drains themselves at frequent intervals by means of flushing tanks constructed at the highest points of the house-drainage system. My board has gone carefully into the matter, and arrived at the conclusion that the proper plan is to flush the sewers regularly well where required, and also to provide additional open ventilators; and I may say that where the complaints have been dealt with recently in that way, and extra ventilators have been put in, the complaints have ceased to be made. The additional ventilators no doubt diffuse the sewer airs, and so lessen the effect on any given spot; and, as a consequence, we are not troubled with so many complaints. The old drains in my district, as in other parishes, are being remedied as fast as they can be, and I have no doubt, if we go on as we have been doing, increasing the ventilation of the public sewers, and can induce owners of property to increase the flushing of the private house drains so as to keep them clear, we shall find there are fewer complaints of smells from open ventilators in the streets. As far as the Hampstead district is concerned, the death rate has not gone up, which is pretty conclusive proof that the steps now being taken are in the right direction. If we can possibly come to some consensus of opinion as to what is the best thing to be done, it will fortify and strengthen our influence very much when we come before the Conference on Friday next. Personally, I have not much confidence in conferences, because we do not generally come to very practical conclusions ; but I do hope we shall so thrash the subject out to-night as to help us to arrive at some practical result. Mr. Weaver has furnished me with a copy of his report on Sewer Ventilation, etc., in which he states that, in his opinion, the introduction of intercepting traps is the cause of all the trouble. In favour of free and open ventilation, I see Mr. Weaver quotes two very high authorities on the subject, viz. Dr. Simon, late Medical Officer to the Privy Council, who assured him that he was strongly in favour of free diffusion of sewer air, as against its concentration in the sewers ; and also Dr. M. Kirchener, of Stuttgart, who in 1816 wrote as follows : "A distinction is drawn between sewer air and sewer gas, and it is pointed out that the latter can only form in sewers which contain dead air, and in other places where effective ventilation is wanting. In well-constructed sewers the contents pass away freely and rapidly without undergoing putrefaction, and the air in such sewers is in no way *unhealthy*. The house drains and soil pipes are much more likely to engender evil smelling and injurious gases than are the sewers." I do not consider that pipe ventilators put up in my district have been by any means a success. I have rarely found any satisfactory action going on in the pipes ; no doubt these pipes are an easy way for the surveyor to get out of a difficulty. He receives a complaint of smells from an open ventilator, which he blocks up, substituting for it a pipe ventilator, and often the only result is that additional pressure is put on the nearest surface ventilator. So far as my district is concerned, the upright pipe ventilators have not been generally a success, either with or without gas, or with or without cowls.

Mr. J. P. NORRINGTON: I want to have it stated distinctly whether the practice of putting in additional surface ventilators has stopped the complaints?

The CHAIRMAN: Yes, it has stopped the complaints.

Mr. PRITCHARD: In many cases?

The CHAIRMAN: Yes.

206. Mr. WEAVER: I should like to inform the meeting how the matter comes before them this evening. During the autumn of last year, my esteemed colleague the medical officer of health of Kensington presented his annual standing dish to our sanitary committee, of the stinks in the parish. He does that regularly once a year. (Mr. PRITCHARD: They all do.) I was called upon to reply to the remarks which he made to the sanitary committee, and I told the committee I was fully sensible of the debt of gratitude I owed to the medical officer for giving me an opportunity to make some remarks upon an evil which he had so largely contributed to create. I think the growing complaint of smells in the public highways, without doubt, are in a large measure to be attributed to the advance of sanitation in the houses. I informed my committee that if they desired me to go fully into the matter, I would give them a report on the subject, as I had done in previous years. The result was I gave the report dated the 18th of October of last year. One suggestion in that report was that I recommended my Board to send a communication to the London County Council, asking them to call a conference of the various metropolitan surveyors to thrash out this question, assisted by the Chief Engineer of the Council, Sir Alexander Binnie. The communication was accordingly sent to the London County Council, and it was promptly acceded to by the Council, with the result that Sir Alexander Binnie has appointed this day week at Spring Gardens for the metropolitan surveyors to meet and confer with him. At the same time the medical officers of health have, I think, in some districts, been appointed as delegates to the meeting. Well, you will clearly see if there is an equal number of medical officers and of surveyors at that Conference, if there is any very great

diversity of opinion amongst the surveyors, they will be entirely outvoted and sat upon by the medical officers, who will have, I should say, a pretty solid unanimity of opinion upon the subject. The medical officers in their language will say: make each house perfect, and let the public authority deal with the public sewers. That is very good in theory, and it shifts the burden of responsibility entirely off the shoulders of the medical officers to the shoulders of the surveyors. It was with a view to this Conference thrashing out the subject, and arriving at something like unanimity amongst ourselves, that the Council and the District Secretary thought it advisable to place it on the agenda paper for this meeting, so that if possible we might thrash it out and adjust any differences amongst ourselves. When siphon traps began to be introduced into London, I ventured to express the opinion, and supported it in a paper which was read and discussed for two evenings before the Medical Officers' Association, that the introduction of siphon traps into main house drains was bad in theory, and would have a bad result in practice; and the subsequent experience which I have gained since reading that paper has only tended to confirm the opinion I then expressed. It seems to me that smells in the street increase in direct proportion and ratio to the reconstruction on modern principles of house drains. In former years each house in a measure aided to get rid of the smells in the sewers, whereas now each house strives to shut off all connexion with the sewer air, and thrusts its smells under the nose of its neighbour. I think each house drain ought to aid in the diffusion of the smell it helps to create; that the drains of the houses and the sewers in the public highway should all be treated as part of one system, like the veins and arteries of the human body, dependent upon one another and assisting one another. In view of this Conference next Friday, I have taken the liberty of sending to each of my metropolitan brethren a copy of the report I have presented to my Board, and in a circular letter, which I have sent with that report, I have asked you to consider the views I have put forward, and if, after consideration, you can support the resolution which I propose to move at that Conference, or something like it, it is possible our opinion may have some weight at the Conference; otherwise, if there are forty of us there, and we have about thirty different opinions, our views will have very little weight with the authorities. Of course, as you know, under the present statute, each drain is required to be ventilated; but in modern practice the ventilation of a drain is only partially carried out, as the ventilator only ventilates that portion of the drain between the intercepting traps in the front and its termination at the higher end. I maintain that only a portion of the drain is ventilated, and that the length of drain between the sewer and the intercepting trap is not ventilated in any way. If the County Council under its new by-laws insists upon an intercepting trap in the front of each house, I propose that a ventilating pipe shall be carried up on the sewer side of the interceptor. If there is no intercepting trap, then of course the ventilator at the end of the drain would answer all practical purposes. There is one other point which I do not refer to in my printed report, but is included in the resolution which I wish to move, that where an intercepting trap is placed on the main line of a house drain, a flap trap should not be fixed on the outlet of the drain, except in special cases where directed by the local authority; that would be in such cases where there is a risk of flooding, so as to prevent back flow from the sewer. At the present time, on an average, I unstop about twenty drains a week, and almost the unvarying report of the sewer men is that the siphon trap is choked with grease, or that there is an accumulation of fat behind the flap trap, which the flow of the drain, owing to its being so diminished in force by passing through the interceptor, has not had sufficient power to force into the sewer. In a great number of cases, at the request of the owners, I have removed the flap traps altogether, or fastened the flaps up to the sewer. To meet the further evil which exists where interceptors have been fixed on the drains throughout a district, I propose that the local authority be armed with powers to carry ventilating pipes up buildings wherever they deem it necessary for the ventilation of the sewers. I fix a number of these pipes annually, as directly I receive a complaint of an offensive ventilator, I enter into correspondence with the owners and persons interested in the property in order to get the necessary permission to carry up a pipe, and perhaps, after writing half-a-dozen letters, I get some to consent, and others refuse ; in about 50 per cent. of the cases I meet with success, and in the remaining 50 per cent. my efforts are fruitless, and the street ventilator has to remain, or an order is made to close it up. With regard to one point touched upon by Mr. Lowe, and emphasized by Mr. Norrington, that the multiplication of ventilators leads to a cessation of complaints, that is not quite my experience. In some cases it does lead to a discontinuance of complaints, but in many other cases I have found the complaints are visionary ; and very often the existence of a ventilator opposite a man's house is sufficient ground for him to complain of its existence, and not because there is any smell therefrom. I have several recorded cases in my books where I have quietly closed ventilators underneath, and have received stronger complaints after they have been so closed, and I know of several surveyors who have had similar experiences. I should look to a multiplication of ventilators to lead to a multiplication of complaints. Then the increase of ventilators at the street surfaces would lead to a lot of road sweepings being forced down into the sewers, and forming little dams on their inverts and retarding the flow of sewage. Of course, buckets could be placed underneath to catch these sweepings, but that means extra trouble to empty the buckets, particularly where you have many miles of roads to attend to. I think the simpler plan would be to make each house put up a pipe. At Buenos Ayres, which I consider has one of the most perfect systems of sewerage and drainage, each house is required to carry up a ventilating pipe from the sewer side of the interceptor ; at Torquay, likewise, a place where you go if you want to prolong your life, the pipes are carried up the fronts of the houses. I do not wish to occupy too much time, but I would impress upon the metropolitan members this important fact. I want, if possible, that the surveyors of the different authorities in London should have some little voice in the guidance of the affairs of London, and we can only obtain that by pulling together. If we can go to that meeting next Friday fairly unanimous, I think we shall do some good. I do not recommend the adoption of special ventilating columns, of which there are several in the market; these columns all mean extra expense, and I always endeavour to keep down the rates rather than increase them. In this particular matter I think the duty of the householder is to help in getting rid of the smells which the householder creates, and not that the public rates should be burdened either by the erection of columns with gas burning or with exhaust fans, because whatever effect they had upon the sewers, they would certainly have the effect of increasing the rates.

207. Mr. J. P. NORRINGTON: I am afraid I am not going to show that unanimity which Mr. Weaver has assured us is so desirable, as I do not agree with him on this matter. I was very pleased to hear from Mr. Lowe that his Board had adopted the advice given them by Mr. Mansergh, and had constructed surface ventilators about 60 yards apart. That was the recommendation of the Metropolitan Board of Works in 1886, and it was afterwards emphasized by them about 1887 in a report which Mr. Weaver refers to in his report to the Kensington Vestry. On page 10, paragraph 10, of Mr. Weaver's report, the recommendations are quoted as follows: "That the surface ventilators to the recently constructed sewers have ordinarily been placed at a distance of from 50 to 60 yards apart, with air openings in the gratings equal to 60 square inches, and that the number and size of many of the ventilators on other sewers in the Metropolis should be increased." Then the recommendation goes on to say, "That the amount of ventilation afforded by large special ventilating shafts is in no way commensurate with their cost, and that the adoption of such shafts, with or without fire heat, or the connexion of sewers with factory shafts, can only be adopted in very exceptional circumstances. Where shafts with fire are used, the sewer gases should be allowed to pass into such shafts over, as well as through the fires, otherwise the amount of ventilation afforded will be very much limited." Some time ago I made experiments as to the value of ventilating shafts, and the facts I ascertained were unfavourable to their use. I wish to urge the surveyors who are present to make experiments for themselves before attending the Conference on Friday next, and I think that if such experiments are made my

opinion will receive a great deal of support. The figures I propose to lay before the meeting are the result of tests made by myself in 1894, and they were published in the 'Surveyor' of December 28, 1894. My attention was called to the matter by the report of the Borough Surveyor of Leicester, which appeared to me to be one with which I could not agree. The tests were very carefully made, and the result of a trial of 26 surface ventilators was that without any exception they acted more or less vigorously, the average result being that 43 cubic feet of air per minute, or 2580 cubic feet per hour, passed in or out of the sewers. I examined at the same time, and under the same conditions, 12 ventilating shafts, some of which had been erected by the London County Council and some by my Vestry. I am sorry to say of those shafts only three showed the slightest movement. In two cases I considered that the air in the sewer was under pressure, and the shafts were acting as a kind of safety valve. But in any case only three acted, and the net result was that only 4·25 cubic feet of air per minute, or 255 cubic feet per hour, passed through them; I call that a very insignificant and deplorable result.

Mr. WEAVER: Where did you put your anemometer?

Mr. NORRINGTON: At the top of the shafts, and I made a special arrangement to protect the anemometer so that the wind had no effect upon it, and that there should not be the slightest doubt about the figures. I could not help feeling that the whole of the money spent on the construction of these shafts—some of them cost as much as 20*l.*—had been utterly wasted. It is a common practice among surveyors, where they receive complaints of surface ventilators, to erect shafts, and in my opinion their erection is nothing more or less than a sort of subterfuge. You check the ventilation of your sewers—but you appease the clamour of the people who complain. I do not think it is worthy of us as engineers. We are, however, all sinners alike, it is only a question of degree; and the County Council are perhaps as bad as anyone in this respect. The method adopted by the Hampstead Board of increasing the number of surface ventilators is undoubtedly the proper one, and, although recommended in

1886, it has never been fairly tried by the London County Council, for none of their sewers have ventilators 60 yards apart, the distance being usually 200 or 300 yards, consequently you have 300 yards of sewer full of more or less offensive gas, and directly there is a little pressure in the sewer a very strong smell arises, and complaints are the result. I do press this meeting to consider whether we ought not to revert to the original recommendations and practice of engineers. I do not say that all shafts are useless, but I do say that the ordinary shaft which is not assisted in any way is useless. We know that shafts have been erected with gas-jets burning inside, and no doubt the gas burning will create a current of air—but at Hereford two of these even gave very little result. They cost each of them about 7*l.* 13*s.* per annum, and the result was 12 cubic feet per hour. What is the use of that as a result? Even Mr. Weaver admitted he did not consider these shafts of any very great value, and that they simply had the effect of causing the complaints to cease. I still hold the opinion which I set forth on December 28, 1894, that it is advisable for engineers to collect and publish more data for the purposes of comparison as to the efficiency of shafts before closing the surface ventilators. It is the ill-ventilated sewers which cause complaints to be made of the surface ventilators, and I strongly advocate that it is desirable to add to rather than diminish the number of surface ventilators until some better means of ventilation can be obtained.

Mr. READ: I should like to ask Mr. Norrington if the 12 ventilating shafts he mentions were in the neighbourhood of the 26 surface ventilators.

Mr. NORRINGTON: Yes, sir; in the same neighbourhood and some on the same sewer.

208. Mr. READ: That being so, I do not think he could expect any other result, because the outlets must be in excess of the inlets if there is to be any ventilation at all, and they must be arranged and proportioned to agree with the action of the sewer. We are all agreed that ventilation is a necessity which cannot be avoided, because if you do not provide the means of ventilation a sewer will ventilate itself. The whole difficulty

appears to me to have been created by the dictum of the Model By-laws of the Local Government Board, issued in 1877, which say that drains must be independently ventilated from the sewers, which means that the sewers must be ventilated by the authorities and the house drains must be ventilated by the owners. In order to divide these two systems of ventilation, the Model By-laws provided an intercepting trap. That intercepting trap, to my mind, is the cause of all our difficulties. It paralyses the ventilation; you cannot ventilate in that way successfully. The popular idea of ventilation is that the more ventilation you give, the more stinks you let out, but that is not so. The stinks are governed by the condition of the drain or sewer. These intercepting traps put an obstruction into a 6-inch drain 8 inches deep. What is the effect of this? You lose a large amount of the fall in the drain and largely destroy its efficiency. The difference of level between the outlet and the inlet of these interceptors has been increased from nothing up to 4 inches. The better class of intercepting traps have now a difference of 4 inches between the outlet and the inlet; but they are put in regardless of the amount of fall available in the drain above them, and the result is that the water trickles in at one end of the trap and trickles out at the other, and leaves nearly all the solids behind. That is proved by the experiments of the Sanitary Institute in 1894, a very extensive report of which is given in vol. xiv. of their Transactions. They laid down a full sized 6-inch model drain 50 feet in length, with a fall of 1 in 40, with a closet pan and flush at the top, and having an intercepting trap at the bottom, and the average of 300 discharges through that drain was that 26 per cent. of the solid matter was left in the trap with a 3-gallon flush, and 37 per cent. with 2 gallons. If this is so in a model drain laid above ground, and in a laboratory experiment, what can be expected to be the result in the case of the hundreds of drains laid underground? Why, you are providing a manufactory of sewer gas in every drain that is laid with an intercepting trap. That intercepting trap is no safeguard to the house. The true safeguard to the house is the soundness of the drain—of course, if the drain is not sound the intercepting trap, instead of being a safeguard, is a danger, because it provides the gas which is to poison the household. If the drain is sound—and we have now means of testing drains by the smoke test and otherwise, so that they can be made sound —it does not matter what you pass through it. If the drain is outside the house then there is even less reason for putting in an intercepting trap. Ventilation itself does not produce the nuisance, it simply calls attention to a nuisance. The effect of these intercepting traps is that when a lot of drains are run into a sewer, and each drain is trapped, they are supplying the sewer with sewer gas, and no amount of flushing which the authorities can do in the sewer will get rid of it, because directly the flush ceases the drains will again pour in sewer gas. The initial point of flushing should be the head of the drain at the water-closet or gully: and the whole of the flushing that goes through the drain is then available for flushing the sewer afterwards. If the drains are laid as they ought to be with good falls, and if the sewers are laid with good falls—and I contend that the sewers are generally the better of the two, for they are laid by experts, and the drains perhaps by labourers—you get a good result; and in the absence of interceptors you get the sewer and the drain acting together, ventilating the whole system in the most natural and perfect manner, and reducing the sewer gas to harmless sewer air. To my mind ventilation must consist of both inlets and outlets, and you cannot have a proper system of ventilation without it. The inlets should be small and at the road level, and the outlets large and numerous above the roofs; their action would then be constant in one direction. The proposition of putting in larger road surface ventilators for sewers is a very old one. It was made by Mr. Mansergh in connexion with the Gloucester sewers in 1877. Mr. Mansergh recommended the surface ventilators to be 60 yards apart, and they were made so, and have been so ever since, but nevertheless we have complaints of sewer smells from time to time, the same as you all have. The remedy for defects of sewers and drains is reconstruction and flushing combined with free ventilation properly applied, but if you depend upon ventilation alone I am afraid you will not be able to remedy the evil.

209. Mr. P. DODD: I should like to ask whether the ventilating shafts experimented on by Mr. Norrington were ordinary iron pipes, and how long they had been erected, because ordinary iron pipes which have been fixed for some time are liable to become choked with oxidation. I should also like to ask whether connexion with the manholes was made in the form of a bell mouth, as it is generally admitted that the pipes should not be of the same diameter throughout. If, for instance, a 12-inch pipe were fixed at the manhole and gradually reduced to 6 inches, I think a much better draught would be obtained.

Mr. NORRINGTON: In all cases where a shaft was erected the nearest manhole was closed, because the shaft was erected in consequence of the complaints of the manhole. The surface ventilators I made the observations upon were on the same system as the shafts. The shafts in some cases were fairly close to the surface ventilators, and in others a good distance away. With reference to the construction of the shafts, the results I obtained were so astounding that I took the trouble to re-open them to determine if there was any stoppage, and I can assure Mr. Dodd that I found no obstruction whatever in any of them. Whether the shaft was a 6-inch or a 4-inch one, I put a 9-inch pipe from the nearest manhole to the bottom of it.

Mr. DODD: I think all iron ventilating pipes should be galvanized or glazed inside, otherwise, as I have stated before, they become completely blocked at the bottom of the pipe with iron rust in about two years' time. I quite agree with Mr. Weaver, where interceptor traps are insisted upon, in having a ventilating pipe for each house on the sewer side of the trap. If not, miles of drains between the sewers and the trap would remain unventilated. Also the street surface gratings ought not to be sealed, because it is desirable to get as many openings to the sewers as possible, in order to promote as much as possible the circulation of air through the sewers and the ventilating pipes.

210. Mr. W. N. BLAIR: I want to give some more figures rather in contradiction to what Mr. Norrington has said. They are also facts: some of them taken some years ago. These

figures were taken at Bootle in 1892. We had there an outfall sewer, with manholes and ordinary surface covers about 100 yards apart. This sewer received the effluent from the gas-works, it was very foul indeed, and was tide-locked twice in the twenty-four hours. Therefore the whole volume of air displaced by the tides was forced up the sewer out of the manholes on to the carriageways. We had so many complaints that the Corporation felt they must do something to try to relieve the difficulty. We therefore put up one of Holman's sewer ventilating columns, and after that had been working some time I found that it was passing 2430 cubic feet per hour, the velocity in the shaft being 235 feet per minute. On another occasion I tested the same column, and the test showed that it was passing 2640 cubic feet per hour with a velocity of 260 feet per minute. This was done at a cost of 10*l.* or 12*l.* per annum for gas. We then put up some plain 6-inch pipes—heavy rain-water pipes—tarred inside and out, and in one we got a result of 2626 cubic feet per hour on one occasion, and on another occasion 1492 cubic feet. With another plain 6-inch shaft we got 2520 cubic feet per hour, and with a third one 2356 cubic feet per hour; so, if you take them on the average, we got quite as much result from a 6-inch plain pipe of 35 feet height, as we get from a Holman column, which cost us 12*l.* a year for gas. Let me give you another set of figures taken in London. The northern end of my district rises to 430 feet above Ordnance datum, the greater part of the rise, about 230 feet, occurring in a distance of about half a mile. The gradient of the road is about 1 in 10 or 11, and the sewer, which is 3 feet 6 inches by 2 feet 6 inches, follows the same gradient, and, being connected with the main drainage system of London, you might naturally expect to find a considerable amount of smell coming from the ventilators on that sewer. That has been the case, and it has been flapped off. First of all, I cut that sewer into three lengths, with a sheet of india-rubber about ½ inch thick, with light battens fixed on the rubber to prevent it buckling up. A short distance below each of these flaps I got in a pipe connexion up to a building near the road, and erected a plain shaft in two cases, and in a third case connected on to an existing Holman's ventilator. With regard to that, I got very different results from the former test. In November 1893, during 15 minutes—it was, by the way, connected with a 12-inch pipe with bell mouth—there was absolutely no movement in the anemometer. Then I proceeded to take out the furnace, the plates and things, but leaving on the top gear, the cap and the lamp, and on the next test I got a result of 10,096 cubic feet per hour.

Mr. WEAVER: Was the lamp alight on the top?

Mr. BLAIR: There was no heat at all in that case. With the same conditions existing at the bottom, and the cap and lamp off the top, all clear, with no heat, we got 16,290 cubic feet per hour, and with similar conditions, but with gas-jet lighted at the bottom, 19,320 cubic feet per hour. That is a difference of one-sixth with the use of gas costing 12*l.* a year. After all that I reinstated the column in its normal condition, with everything in at the bottom, the cap and the lamp on at the top, the gas-jet alight, and tried the result with the anemometer—it was nil. With regard to the two plain pipe columns I have not any figures, but I can say, speaking from observation in the sewer—where you can easily see whether you have a good current or not—that I have often found a very good current coming out of those pipes, and although they are at the summit of a section of sewers with a gradient of about 1 in 11, I have on some occasions found the current going down the ventilating pipe and coming out of the surface ventilators. But even in that last condition there is certainly no nuisance in that road, where formerly there was a terrific nuisance. I do not think it matters which way the air moves, if you can only get it to move freely. I am very much in agreement with Mr. Weaver, but I think there is very little prospect of getting compulsory power to require owners of property, without any consideration for the architectural aspect of their houses, or the effect which might be produced upon their letting value, to put a ventilating pipe up in front. In nine cases out of ten they would have to put the pipe up the front of the house to ventilate on the sewer side of the interceptor. That is what we want, but we shall not get it. The introduction of the siphon trap has undoubtedly interfered with the ventilation of the main sewers. But we must remember for what purpose, and under what conditions, the siphon was introduced. It was introduced with the object of shutting off the gas in the main sewers from the house drain, because at that time house drains were not to be relied upon as to being either gas or water-tight. Now we can rest assured that drains constructed under the modern requirements of almost any corporation's by-laws are both air and water-tight, there can be no harm in allowing the air from the sewer to pass through the ventilation pipe provided for the ventilation primarily of the drain. At the same time, I think there are many of us who would hesitate to have a drain passing under our houses to ventilate a public sewer. Where the drain is in a garden no one need hesitate. There is one other consideration which should come in at this point, that is, that no connexions with any drain so constructed as to ventilate a sewer should be allowed within the house. Many of us here know how slight is the seal of some gullies, and how the discharge of a closet will cause pulsation in the trap of any gully. Sometimes you will see the water oscillate up and down perhaps an inch in extent. Such action might unseal the gully, and if the gully were within the house, that would admit the air of the sewer into the house. Therefore, where gullies are necessary inside a building, I say most emphatically that the drain into which those gullies discharge ought not to be used as a ventilator for the sewer. But there are many cases in which drains might, without any harm, be so used if the owners could be persuaded to allow it. But there is something in the point Mr. Weaver mentioned, although he put it down to statute; it is a by-law which requires every person to ventilate the whole of the drains of his premises, but by trapping off by a siphon you may have a length of drain, perhaps 40 feet, which is not ventilated. I think the owner should be required by the by-law to ventilate that portion as well as that which is above the siphon, and therefore to that extent we are justified in asking the owner to provide an additional ventilating pipe for the portion of the drain below the siphon. That would ventilate the sewer, and at the same time it would leave the house drain free from any risk which there might be if sewer air were passing through it. As to the first suggestion Mr. Weaver makes in his report—that "it shall be compulsory on the owner of the premises to carry up a ventilating pipe not less than 24 square inches in sectional area from the sewer side of the interceptor up the front, side, or back of the house, to the satisfaction of the local sanitary authority"—there comes in the difficulty as to the position. The defacement of the property would no doubt influence many people in resisting any such order. With regard to the complaints of manholes on the surface of the streets, while I am a strong believer in them, at the same time I quite sympathize with Mr. Weaver's views of them in such a district as Kensington, where there are so many macadam roads. No doubt a great amount of grit and sediment does get into the sewers through these manholes, and causes a deposit of the very material in the sewage which afterwards begins to ferment and give off the smells which cause so much trouble. The suggestion to put buckets in the sewers at these places only leads to further trouble; those who are supposed to empty the buckets do not always do it, then they spring their hangers, and fall to the bottom and cause a bigger block in the sewers than ever. Where you have liability to get macadam and grit into the manholes, as, for instance, after covering the road with new macadam, it would be desirable to keep the buckets in, but I would not keep them there permanently.

211. Mr. Weaver: I think the only way to test the feeling of the meeting, so as to enable me to put my resolution next Friday at the Conference at the London County Council, is to put my resolution to the vote. I shall not move that resolution next Friday unless I feel it commends itself to my brother surveyors. I therefore move, that it is desirable that, in connexion with any interceptor hereafter fixed on a main house drain, it shall be compulsory on the owner of the premises to carry up a ventilating pipe not less than 24 square inches in sectional area from the sewer side of the interceptor up the front, side, or back of the house, to the satisfaction of the local sanitary authority.

Mr. Blair formally seconded the proposition.

Mr. NORRINGTON : I think Mr. Weaver deals rather with the fringe than the main lines of the subject. I will propose that the Council be recommended to carry out the recommendation of the Metropolitan Board, as contained in section 10, page 10, of Mr. Weaver's report, viz. "That surface ventilators be placed every 50 or 60 yards apart in existing sewers." That has never been tried by the Council, and until it is done I do not consider that the principle of surface ventilation has been given a fair trial. I would start with that: though any further addition to the ventilation of the sewers will be in the right direction.

Mr. A. SOUTHAM : I shall have pleasure in seconding that.

Mr. WEAVER : You say that the remedy for complaints of smells from sewers should be sought in the direction of the multiplication of open grids in the road surfaces.

Mr. NORRINGTON : I say that is one remedy, perhaps the best remedy.

Mr. WEAVER : That must be taken as an amendment. If you go in for pipe ventilation you must reduce the number of the street surface ventilators.

Mr. NORRINGTON : I decline to put it as an amendment. I say the first thing to do is to ventilate the sewers. The Metropolitan Board have recommended surface ventilators, and it is our duty to ask their successors to carry out that recommendation.

The CHAIRMAN : It appears to me that you are trying to ventilate the sewer through private property. I do not think many of the local authorities would advocate this arrangement. The proper course is for the drain to be in such proper working order as to clear itself at all times, and then for the local authority to be responsible for the sewer and its ventilation at the point where it connects with the drain. I do not think the local authority could rightly call upon private owners to ventilate the public sewer; this plan would need additional legislation.

Mr. W. A. DAVIES : I take it that between the sewer and the trap there is a certain length of drain unventilated, and the pipe is suggested to ventilate that portion of the drain.

Mr. WEAVER : I touched upon it as part of one system. It is absurd for the householder to create a smell and give it to the surveyor to get rid of in the public sewers. I say, help to get rid of the common evil you help to generate. I think it is the simplest plan of getting rid of the evil.

Mr. DODD : I should like to recommend that both resolutions should be put together to the meeting.

The CHAIRMAN : I do not see why you should not carry both resolutions.

The propositions of Mr. Weaver and Mr. Norrington were then put to the meeting and carried unanimously.

Mr. WEAVER : I have a further resolution to propose, "That the local sanitary authority shall be empowered by statute to carry up any building sewer-ventilating pipes." If the sense of the meeting is that that power might be exercised prejudicially in certain cases, that might be corrected by giving the owner of the property the right of appeal to the London County Council, but I may point out that the interest of the local authority is not to disfigure good buildings, and depreciate their rental value, but to improve the same.

Mr. BLAIR : I cannot second Mr. Weaver's proposition, because I consider it has already been dealt with.

The CHAIRMAN : Had we not better rest as we are, and not attempt to force the hands of the County Council further?

Mr. WEAVER : I am prepared to withdraw this resolution.

The resolution was then, by leave, withdrawn.

PART II.

THIS contains a copy of the letter addressed to the Main Drainage Committee of the London County Council, on March 24, 1898, by their then Engineer, Sir Alexander Binnie, when he was President of the Incorporated Association of Municipal and County Engineers, reporting the resolutions passed at the conference of Metropolitan Engineers and Surveyors, held at the County Hall on February 25, 1898.

COPY.

LONDON COUNTY COUNCIL.

VENTILATION OF SEWERS.

212. *Report by Engineer as to the result of a conference of Engineers and Surveyors of the several Vestries and District Boards of the Metropolis.*

To the Main Drainage Committee.

In accordance with the instructions of the Committee I issued two circular letters to the engineers and surveyors of the various vestries and district boards in the county, inviting them to a conference on the subject of the ventilation of sewers, with a view to some uniform system being adopted if possible, for dealing with complaints of offensive emanations from gratings connected with both local and main sewers.

In response to the invitation a meeting was held at the County Hall on Friday, February 25, at which upwards of 40 of the gentlemen invited were present. A list of those who signed the attendance book, together with the names of the districts represented by them, is appended hereto.

The discussion on the subject of the ventilation of sewers occupied a period of over two hours, and resulted in the following resolutions being passed, namely :—

212A. (1) That the closing of sewer ventilators in response to complaints increases the general evil, the diminution of which is to be obtained by the multiplication of the ventilators at regular frequent intervals.

(2) That in connexion with any interceptor hereinafter fixed on a main house drain it is advisable to carry up a ventilating pipe from the sewer side of the interceptor, up the front, side or back of the house, to the satisfaction of the local sanitary authority, and that the outlet drain from the interceptor shall not be flap-trapped in sewer, unless required by the local sanitary authority.

(3) That pipe ventilators up buildings, or otherwise where possible, should always be adopted, in addition to surface ventilation.

It will be observed that the general result of the conference has confirmed the action of the committee and the council in recent years, and the remedy for sewer emanations is to be looked for from the maintenance of more frequent ventilating openings, both at the street level and by means of pipes carried up houses and other buildings.

I would suggest that, as the meeting was a very representative one, this report be printed, and that copies be sent to each member of the council and to the engineers and surveyors of the district boards and vestries in the Metropolis.

(Signed) ALEX. R. BINNIE,
Chief Engineer.

SPRING GARDENS, S.W.:
March 24, 1898.

APPENDIX IV.

EXTRACTS FROM A PAPER BY MR. R. READ, M.INST.C.E., AND COMMENTS THEREON.

PART I.—THE EXTRACTS.

This Appendix contains important extracts from the paper entitled "The Ventilation of Sewers and Drains,"* which Mr. R. Read, M.Inst.C.E., the City Engineer of Gloucester, prepared for the annual meeting of the Municipal and County Engineers, held in Cardiff, June 29, 1899, and reported in Vol. XXV. of the Proceedings of the Association.

The following are the extracts referred to :—

213. (*a*) "The most ordinary method of ventilating sewers is by ventilating the manhole and lamphole covers at the surface of the street at intervals, which commenced in the early days at about 300 yards apart, and were gradually made more numerous until some engineers put them as close as 40 yards apart, the idea being that the nearer the approach of the sewer to a continuous open cutting the better.

"These distances have since been modified until they now vary from 60 to 100 yards apart. During the last twenty years in some towns the street gratings have been closed, and vertical shafts erected against houses have been substituted for them, and in other towns combinations of street surface ventilators and shafts above houses have been used. Other forms of ventilation have been tried, such as connections to factory chimneys, or small gas furnaces, and gas lamps, and systems of deodorising sewer gas by means of charcoal and other chemicals have been tried in addition to or in substitution for the ventilation."

214. (*b*) "If a sufficient number of shafts are erected against houses between each pair of road surface ventilators, all the road surface ventilators will then be converted into inlets, and the shafts into outlets, and the ventilation will be constant in one direction,

* Although Mr. Read's Cardiff paper was read fourteen years ago, yet Mr. Read's views have not since undergone any change.

because there is always more motion in the outer air at the top of a ventilating shaft, say, 30 ft. above ground, than there is at the ground level sufficient to create an up-current in the shafts, each set of which are practically isolated, and supplied with air by the manhole on the upper side of them acting as an inlet, this arrangement being the only one which harmonises with the several forces above described. The only way to get a sufficient number of shafts to produce this result, is to use every house drain as a ventilator by abolishing the intercepting trap."

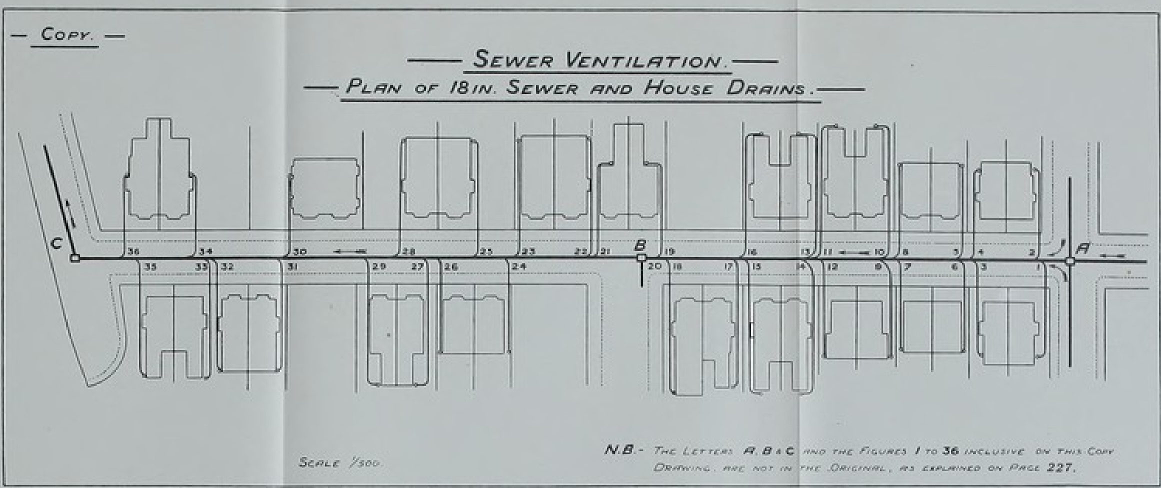
215. (*c*) "This useless obstruction (i.e. the interceptor trap) to the flow of both sewage and air was invented by the late Mr. W. P. Buchan of Glasgow after the illness of the Prince of Wales in 1871, and they were introduced into the model by-laws issued by the Local Government Board in 1877, thereby placing an obstruction from 8 in. to 10 in. deep in the flattest part of every house drain, consisting of about three gallons of stagnant sewage weighing about 30 lb., which cannot be entirely cleared with a six-gallon flush, notwithstanding that the improved forms of trap have from 2 in. to 4 in. difference of level between the house and the sewer ends of the trap. They are practically cesspools for manufacturing sewer gas, fouling both the drains and the sewers."

216. (*d*) "At the Westminster District Meeting of this Association, in February 1898, an important discussion occurred upon the subject of sewer ventilation, with a view to deciding the course of action to be taken by the Metropolitan surveyors at a conference which had been arranged between them and the medical officers of health to the London vestries. At this district meeting two propositions were discussed: the one to increase the number of the road surface ventilators, by placing them every 50 yards apart on the sewers; and the other to pass a law compelling every building owner in future to provide a shaft in the front of his house, to ventilate the drain on the sewer side of the interceptor; and after considerable discussion both propositions were carried,* and at the conference afterwards held, Sir Alexander Binnie in the chair, the shaft proposal was adopted for recommendation to the London County Council.† The author took part in the commencement of the discussion, but was unfortunately obliged to leave early to catch his train, and takes this opportunity of pointing out that the two propositions are somewhat destructive of each other, because the ventilation will take place in the direction of the line of least resistance; and if you increase the number and area of the road surface gratings in proportion to the

* See Appendix I., page 99; Appendix III., Part I., *passim*.

† See Appendix III., Part II.

DRAWING No. 37.*



Face p. 227.]

* This Drawing is marked Fig. 4 on the drawings which accompanied Mr. Read's Paper.

outlet shafts above the houses, you weaken the velocity and get a liability to stagnation or reversal of current, owing to its feebleness; that is to say, the greater the number of shafts between each pair of man-holes the stronger is the initial velocity of the air entering the manhole gratings, especially if the latter are kept small within reasonable limits, and a strong initial velocity at the road surface inlet is necessary to enable the current to reach the furthest outlet shaft between the two inlets."

217. (*e*) "To take an ordinary example in a suburban district: in a distance of 100 yards between a pair of manholes, it is possible to have fifteen houses on each side of the street, and if each house drain were ventilated by a 4-inch soil pipe carried up above the roof, the sum of their outlet areas would be $12\frac{1}{2}$ sq. in. by $30 = 375$ sq. in., and these would all be drawing air in at the upper manhole, having, say, 36 sq. in. of surface grating openings, or a ratio of more than 10 to 1 in favour of the shafts being outlets; and a velocity of, say, 1 ft. per second discharging from thirty outlet shafts, would cause the air to enter the 36 sq. in. of manhole grating at the road surface (with a velocity of not less than 10 ft. per second), without any allowance for friction through the pipes.* There is no occasion for alarm at this proposition, as the popular idea that the more ventilation the more sewer gas is entirely wrong, because the more perfect the ventilation the less sewer gas is formed."

"The proposal agreed to by the London Conference increases the number of ventilating shafts to be provided by the house owner while retaining the intercepting trap, and is a compromise which does not strike at the root of the evil. The owner is more likely to consent to abolish the trap, as it would be less expensive to him, and, in the author's opinion, more beneficial both to the owner and the community at large. The soundness of the drain should be tested when the trap is taken out, especially if the drain passes under a house."

218. (*f*) "Drawing No. 37 (Fig. No. 4) shows a plan of a main trunk sewer 18 in. diam. The manholes ventilate 36 sq. in. area of opening, and the existing shafts against the houses are shown in red,† the shafts shown by blue spots are additional ones which are necessary to complete the author's scheme of ventilation."

"The velocity of the sewage is about 3 ft. per second when flowing one-third full, and with a light wind and a fine day the author has measured currents of air passing down the sewer at the rate of 100 to 140 ft. per minute, and then go on again. This pulsation, of

* I entirely agree with this statement of Mr. Read's, as I have explained in my letter to "The Surveyor" of July 17, 1907, vide page 121.—I. S.

† The coloured lines and circles referred to are not reproduced here.

course, was due to the effect of the wind, as there are in the length of sewer under test only three 6-in. and six 4-in. shafts, not sufficient to keep a constant current in one direction, but sufficient to prevent its being reversed, as during the whole test the manholes never acted as outlets, and on testing the sewer by pumping smoke from an eclipse machine into the upper manhole, it came out of all the shafts, and did not come out at any manhole until the smoke was in excess, when it came out at the lower manhole, not a particle going up the sewer against the flow of the sewage."

PART II.

COMMENTS OF THE AUTHOR ON MR. READ'S VIEWS AS EXPRESSED ABOVE.

219. Both the quality and the statistical character of the information supplied in Mr. Read's paper throughout is essentially interesting and practical, and in my opinion, well worth investigating and dissecting in more or less detail. It contains and explains practical data on which he has formulated certain theories, which have led him to propose a plan of his own for ventilating drains and sewers without using house-drain interceptor traps, of which apparently, he is an uncompromising opponent. And as it is of vital importance to every British Municipal Surveyor and Engineer to avoid associating himself with any schemes for ventilating soil pipes, drains and sewers, which are calculated to be a menace, and not a benefit, to public health, I venture to hope that the time I propose to devote in the following pages, to the consideration and discussion of some of those parts of Mr. Read's paper that are here reproduced, will be appreciated by all who wish to adopt in future, the most efficient sanitary system possible for ventilating drains and sewers.

220. (*a*) * This extract clearly and accurately describes what has been done in the nineteenth century, and what is still being done in the twentieth century in connection with what is known as the work of ventilating drains and sewers by natural means.

But obviously the effect of constructing ventilation manholes, e.g. at 50 instead of 300 yards apart, would be to multiply their

* *Supra* par. 213.

number and therefore their cost sixfold, to say nothing of the serious increase in the expense of maintenance and supervision. Whereas I contend that by installing the hydro-mechanical system far more efficient ventilation could be obtained even though the manholes were 300 yards apart, and with their surface ventilators absolutely closed, than can be obtained by the plan of trusting simply to a number of perforated street surface ventilating manhole cover openings, however numerous these may be, since the latter only permit the street air to flow into the sewers, and the foul air to flow out of them at random, under the influence and by the operation of natural inconstant laws.

The disposition or bias which has (as Mr. Read rightly remarks) led engineers and others of late years to favour almost open sewer ventilation, so "that the nearer the approach of the sewer to a continuous open cutting the better," is to be deprecated because it is indefensible on hygienic and economic grounds. The better plan is to adhere to and try to perfect the present system as much as possible by discharging all domestic sewage, in the first instance, into sound soil and waste pipes, and afterwards into sound self-cleansing house-drains and public sewers; and if these cannot always be efficiently ventilated throughout by natural means, then they should be ventilated by mechanical means, and the effluent air purified and rendered innocuous.

Surely such a plan as this, for draining sewage by natural gravitation, and ventilating the drains and sewers by mechanical means, would be better than constructing and exposing in our roads and streets open cuttings having within them ever varying volumes of more or less slow moving sewage-waters, and having also ever varying volumes of putrid sewage sludge-deposits clinging to their sides, and resting on their inverts.

Of course, sewage-gas nuisances arising from sewage within covered drains and sewers vary in volume and quality largely as the temperature conditions of the atmosphere within and without the drains and sewers vary; but these natural alternations would have the effect of immeasurably increasing and aggravating the character of the existing offensive insanitary nuisances in our streets and roads—if the sewage from which they are emitted were allowed to run or meander in open ditches or channels. Such an arrangement would indeed be violating both the principle and the letter of section 86 in the Model By-laws of the Local Government Board, which makes it imperative upon householders whenever they build cesspools to sink them at considerable distances away from their dwelling houses, and that the minimum distance away therefrom should not be less than 50 ft.; whereas the result of taking off the tops or crowns of septic street sewers so as to make them into open cuttings would be to practically convert every non-self-cleansing sewer into an elongated street cesspool, which, of course, would be intolerable.*

221. (*b*) The act of making the air-inlets in manhole covers overlying public sewers small in comparison with the air outlets prevents the air from taking the line of least resistance, and is simply subversive of the principle upon which ventilating air-currents are induced to flow into and out of drains and sewers, whether by natural or artificial means.

If Mr. Read's theory were correct, that is to say, if it were founded on sound hydrostatical principles, the problem of efficient drain and sewer ventilation would be very readily solved.

But unfortunately, his theory is as unsound from a scientific point of view, as it has been repeatedly shown by experience and proved to be in practice. This I proceed to show.

In the first place, in order to draw drain and sewer air out of the soil pipes, as Mr. Read proposes, there must be at the top of each soil-pipe some aspirating power at work, resembling in its action the exhausting power of furnaces or fans which, when at work, create vacuums into which air rushes at velocities proportionate to the vacuums induced by them. The winds of heaven, which are ever inconstant, blowing over the tops of soil pipes which are on the same level plane, would cause equal suction action to take place in each, and consequently there would then be little or no ventilation work going on. But in calm weather no effective natural ventilation currents could be induced to flow into the sewers through small ventilating openings in manhole covers at the street level, and afterwards into and along Mr. Read's trapless drains, and finally into and out of the soil pipes at the tops of the latter.

222. In support of these contentions, I cannot do better than quote from the admirable work of Dr. W. Shaw, F.R.S., entitled "Air Currents and the Laws of Ventilation."

(1) "Whatever the motive power may be, if the flow is to be maintained, the working agent must be in continuous operation, the wind must go on blowing, the fire that warms the flue must be maintained, the engine driving the fan must be kept at work. All this means continuous expenditure of energy, continuous work, whether it is separately provided and paid for or not. Moreover, if the ventilation is to be steady and maintained, if the flow is to be definite in amount, the agent, whatever it is, must work steadily and the work that it does in any given time must be equally definite in amount."

(2) "The head required to maintain a flow through a given

* Vide Dr. Andrew Fergus' evidence on the subject of Septic Sewage Channels or "burnes" on page 65.—I. S.

resistance is proportional to the square of the flow, and the resistance is inversely proportional to the square of the area of the aperture, i.e. inversely proportional to the fourth power of the linear dimensions for thin plate apertures of similar shape."

"These complicated algebraical laws may seem to be altogether out of place in dealing with an everyday subject like ventilation. They are, however, unfortunately the laws to which ordinary ventilation is subject, and the complexity which they represent is the complexity of real life. It must be allowed for if the practice of ventilation is to be fully understood. Neglect of these laws of numerical relation accounts in a great measure for the failure of ventilation appliances. To take a simple application; if all the apertures for ventilation are doubled in linear dimension, other things remaining the same, the flow is increased fourfold, but to increase the flow fourfold, the aperture remaining the same, the head must be increased sixteenfold."

223. In the second place the head, or aeromotive force, which produced the ventilation in Mr. Read's 18 in. gravitation sewer was not due to the fact that the level of the air inlets at the street manhole cover was 30 ft. more or less below the level of the tops of the soil-pipes through which the ventilating air, after passing into the sewer and drains, made its exit back again into the atmosphere; nor was it due to the fact that the sectional areas of the soil-pipe outlets in the aggregate, exceeded the sectional areas of the inlet openings in the manhole covers in the ratio of ten to one. It was due more to the rapid flow of the sewage in the sewer than to anything else. In fact in the absence of some aeromotive force produced by a fan, or by the heat of the sun raising the external and internal temperatures of the soil-pipes, or, in the absence of storms of wind blowing over the tops of the soil-pipes, the outlets of these would become air-inlets and air-outlets alternately. Besides, the act of reducing the areas of the air-inlet ventilating orifices in street manhole covers to one-tenth of the areas of the air-outlets of the soil-pipes, assuming, as is conjectured by Mr. Read, that the suction power at the tops of the soil-pipes is real, and not hypothetical, and that it will remain constant, so far from increasing the volume of the ventilating air-current tenfold, would have the contrary effect—that is to say, it would have the effect of decreasing the volume of the ventilating air-current one-hundredfold, as compared with what it would be if the aggregate areas of the inlets and outlets were equal. As Mr. Shaw clearly shows, in the second extract given above, when ventilating apertures are doubled, the flow of air is increased four-fold, and conversely, when the apertures are reduced one-half or one-tenth, the flow is thereby reduced four-fold or one-hundredfold accordingly.

Thirdly, the following calculations based upon Mr. Read's data will demonstrate the fact that it is wrong to assume that if a current of air is made to travel through his inlets at the street manhole covers at a velocity of 10 ft. per second, it will suffice to cause it to travel along the line of least resistance, and at the same time to divide itself equably, so to speak, in the sewer, so as to enable each of the thirty 4-in. hypothetical soil-pipe outlets to discharge their respective volumes of ventilating air into the atmosphere at a velocity of 1 ft. per second. He states, for instance, that the area in the aggregate, of the openings in the street manhole covers overlying his 18 in. sewer, is equal to 36 sq. in., which corresponds very nearly to the area of a circular pipe whose diameter is about $6\frac{3}{4}$ in. What the average sectional area of the manhole into which his ventilating air is made to flow I am unable to give, but I will assume it to be equal to the area of a pipe 24 in. in diameter; in which case the ventilating air-current passing into the sewer through the openings in the street manhole cover at the stated velocity of 10 ft. per second, would be immediately reduced, when the same air travelled down the manhole to the sewer, to $10 \times \left(\frac{6\frac{3}{4}}{24}\right)^2 = 0\cdot790$ ft., or to $9\cdot48$ in. per second.

Fourthly, Mr. Read states that the depth of the sewage travelling at the rate of 3 ft. per second on the invert of his 18-in. sewer, was equal to one-third of its diameter, i.e. to 6 in.; in which case the sewer must be laid at a gradient approximately of about 1 in 278, and the aerial section of the sewer above the sewage would then be equal to $180\cdot2$ sq. in. or $1\cdot251$ sq. ft., and that the velocity at which the ventilating air would flow down the sewer from the point marked "A" on Drawing No. 37, to the first house drain connection marked by the figure 1, would be $= 10 \times \frac{36}{180\cdot2} = 1\cdot998$ ft. per second. At this point 1, according to Mr. Read's theory, one-thirtieth of the total volume of the air that would pass through the opening in the street manhole cover in the sewer, viz. $\frac{36 \times 10 \times 60}{144} = 150$ cub. ft. per minute, would turn away from the main current in the 18-in. sewer at an angle of about 135°, and ascend the house drain firstly, and the soil-pipe secondly, in the direction opposite to that of the flow of the sewage, till it escaped out of the tops of each of the thirty hypothetical soil-pipes, back again into the atmosphere, at a velocity of about 57 ft. per minute! That is to say, at each of the nineteen house drain connections with the sewer between the manholes A and B, a volume of air equal to $\left(\frac{150}{30}\right) = 5$ cub. ft. per minute would be abstracted from it by each of the nineteen house drains, shown on the plan between the letter A and the drain figured 19.

If the air inlets were represented by a pipe 1 in. in diameter, and the air outlets by a pipe 10 in. in diameter, instead of being 36 sq. in. and 375 sq. in. in area respectively—which latter are nearly in the ratio of 10 to 1, as stated by Mr. Read—the 10 in. pipe would discharge $10^2 \div 1^2 = 100$ times more air than the 1 in. inlet pipe, i.e., if the velocity was the same in each pipe. But according to the laws which govern the flow of gases and fluids as these have hitherto been interpreted—*vide* Table C, par. 297—so long as the pressure required to move the air is constant, the discharge of a 10 in. pipe will be $\sqrt{10^5} = 316{\cdot}3$ times more than a 1 in. pipe.

Box in his work on Heat describes the losses which arise from passing steam through pipes as follows: "the pressure lost in discharging a fixed volume of steam varies inversely as the fourth power of the diameter of the orifice, for this reason: the area of a circular orifice, and consequently the velocity of efflux with a fixed quantity varies as d^2, and as the pressure varies as V^2, the ratio becomes $d^2 \times V^2$, or more simply as d^4. For instance, if in any particular case we reduced the diameter to one-half, the area would be reduced to one-fourth, therefore the velocity necessary for a fixed quantity must be increased in the ratio 1 to 4, and the pressure to generate that velocity, in the ratio 1 to 4^2 or 1 to 16, so that with diameters in the ratio of 1 to 2, the pressures are in the ratio 1 to 2^4 or 1 to 16." Whatever volume of ventilating air, therefore, Mr. Read elects to discharge at the outlet ends of his ventilating pipes, the pressure needed to apply at their inlet ends in order to secure the delivery of the volumes required at their outlet ends must be in the ratio of 1 to 10^4, i.e., it would have to be 10,000 times greater than would be necessary if the ventilating air were passed through a pipe which was 10 in. diameter throughout its entire length!

I venture to think that when Mr. Read formulated the plan he described in his Cardiff paper, for general adoption, for ventilating sewers, drains and soil pipes, he omitted to take the foregoing amongst other important aspects of the problems he essayed to solve into consideration.

And the daily experience of engineers and other careful observers confirms the conclusions of science. Nor could any better evidence of this be found than that of the eminent engineers who took part in the discussion on Mr. Read's paper.*

Substantially the same conclusion is arrived at by Mr. William Brown (the writer of the excellent letter printed on pages 68 *seq.*) in a lucid article he wrote some years ago on "Sewer Ventilation: the High Shaft Fallacy," which appeared originally in "The Public Health Engineer." He points out that "a high shaft rising above the

* *Infra*, par. 213 *seq.*

street level is subject to the same laws of aerostatics, as one terminating at the street level; and also that for all practical purposes both are equally subject to the same forces which affect or interfere with the air currents in a sewer apart from these laws, such as the varying level of the sewage and the discharges from branch drains."

Mr. Brown reproduces a series of tests made with ventilating shafts and manhole gratings at Fulham by Mr. Norrington and at Sutton (Surrey) by Mr. Greatorex, which I have not space to reproduce here, but which show not only the entire unreliability of high-ventilating shafts for producing air currents in drains and sewers, but also the capricious character of their operation as outlets or as inlets.

Mr. Brown's view on the general subject of sewer ventilation is that to the utmost possible extent recourse should be had to natural oxidation, and where this is inadequate or impossible the deficiency should be made up by artificial oxidation. In this I entirely agree with him, and this is the problem which I have attempted to solve.

224. (*c*)* As stated in my Liverpool paper I entirely dissent from the views of those who are in favour of abolishing the house-drain interceptor trap, because I regard it as being a sort of scientific safety valve apparatus, which, when properly designed, and made of sound vitrified stoneware or cast iron, or any other suitable material, cannot fail when in practical use to render the important services which its inventor intended it should. I am aware that much has been said and written from time to time in the past on lines similar to those adopted by Mr. Read against that apparatus. The objectors, however, have always appeared to me to exaggerate quite unconsciously the points which they urged against it while under-estimating the real intrinsic hygienic value of the apparatus.

I am entirely at one with Mr. Read and many other objectors up to this point—that the kind of interceptor he refers to and is familiar with is unsuitable for the purposes intended; and especially when such interceptors are fixed on the lines of the main drains of small houses, whose sewage discharges are inadequate to preserve them in a self-cleansing condition. Under such circumstances Mr. Read is justified in describing them as "practically cesspools for manufacturing sewage-gas, fouling both the drains and the sewers." But this serious indictment is only true of interceptors which are unduly large and practically unventilated. I maintain that in principle the interceptor trap is absolutely sound, and its operation most beneficial, provided that its design, capacity, and functions are conformable to what is required of it.

* *Supra* Appendix IV., Part I., page 226.

225. In pursuance of these views, I have, in Appendix I. on page 103, presented illustrations of improved forms of interceptors which could be used in connection with the Mechanical System of Ventilation, and which meet practically the requirements just referred to. Those illustrations and the lettered and figured skeleton-like interceptor, shown in elevation on Drawing No. 38, which is to be found opposite to page 236, together with the descriptions given of them, will doubtless be read with interest by Municipal and Sanitary Engineers generally. **Drawing No. 38**

It will be observed that the Drawing No. 38 is of a 4-in. trap having a $1\frac{1}{2}$ in. cascade drop, but with a water-seal 3 in. in depth, yet holding only 0·6 of a gallon, or about one-fifth of the contents of ordinary 6-in. interceptors. The hygienic value of the small interceptor may be perceived by drawing the following comparison between it and the larger one.

If a family of five persons living in a small house, whose water-supply and consequently its sewage discharges did not exceed on the average 15 gallons per head per day, and if on the main drain of such a house an interceptor trap holding 3 gallons of sewage were fixed, the total dry-weather volume of sewage that would then be discharged through it in a day of 24 hours would only be sufficient to renew the contents of the interceptor $\frac{5 \times 15}{3} = 25$ times; whereas the same total volume of sewage passing into the smaller 4-in. ventilated interceptor would be sufficient to renew its charge $\frac{5 \times 15}{0 \cdot 6} = 125$ times, in a day of 24 hours, and consequently the water contents of the latter could never give off dangerous sewage-gas nuisances so long as the fan ventilation continued and the houses using the interceptor apparatus were occupied.

226. Again, it is well known that the friction due to the passage of water or sewage through pipes is at its minimum, for any given unit of length, when the pipes are straight, and the water or sewage conveyed by them is in what is termed "train"; and that it increases as the square of the velocity and as the number and the character of the changes in the direction of the pipes increase, for any given unit of length. The friction in fact, for short lengths of such house drains as we are now discussing, is made up of three parts: (1) the friction due to what is called "velocity at entry," or *vis inertiæ*; (2) the friction due to the passage of the water through any given length of straight pipe; and (3) the friction consequent upon either vertical or horizontal deviations from the straight line in the pipes.

I will assume that the gradient at which a straight 4-in. house-drain pipe should be laid, in order to secure a self-cleansing velocity of 3 ft. per second, when the pipe is full or half full of sewage, is 1 in 65; and that it will discharge when so laid 98 gallons per minute. But the discharges of sewage wastes through drains into and out of interceptors are never continuous, but always intermittent. To force continuously through a 4-in. interceptor 98 gallons, the water contents of such an interceptor would be renewed $98 \div 0{\cdot}6 = 163{\cdot}3$ times in one minute; and the water head H, necessary to produce the velocity at entry, may be calculated from the formula given on page 22 of Box's "Practical Hydraulics" (7th Edition) as follows:—

$$H = \left(\frac{98}{4^2 \times 13}\right)^2 = 0{\cdot}222 \text{ ft.} = 2{\cdot}66 \text{ in.};$$

and the friction due to the act of passing sewage through the 4-in. *ventilated* interceptor—which is drawn and figured in detail on Drawing No. 38, at the rate of $\left(\frac{98}{60}\right)$, or $1{\cdot}63$ gallons per second, can be calculated from the rules given on page 282, in the 24th Edition of Molesworth's "Pocket Book of Engineering Formulæ," as follows:—

For knees, such as the first angle marked A in the same Drawing, the formula is as follows:—

$$H = 0{\cdot}0155 \times V^2 \times K.$$

For bends such as those marked A_1 and A_2 at the bottom and outlet end of the trap, the formula is:—

$$H = 0{\cdot}0155 \times V^2 \times \left(\frac{A}{180} \times L\right).$$

In these formulæ the notation is as follows:—

H = head of water in feet.

V = velocity of flow of water in feet per second.

K = coefficient for knees depending upon the angle A, as ascertained from the curve marked K, on Drawing No. 38.

L = coefficient for bends, depending upon the proportion $\frac{r}{R} = \frac{\text{radius of bore of pipe}}{\text{radius of curvature of bend}}$, as shown by the curve marked L on the same Drawing.

The curves K and L have been drawn by plotting the values given by Molesworth's formulæ in the form of a diagram, so as to find all the intermediate values between those given by him.

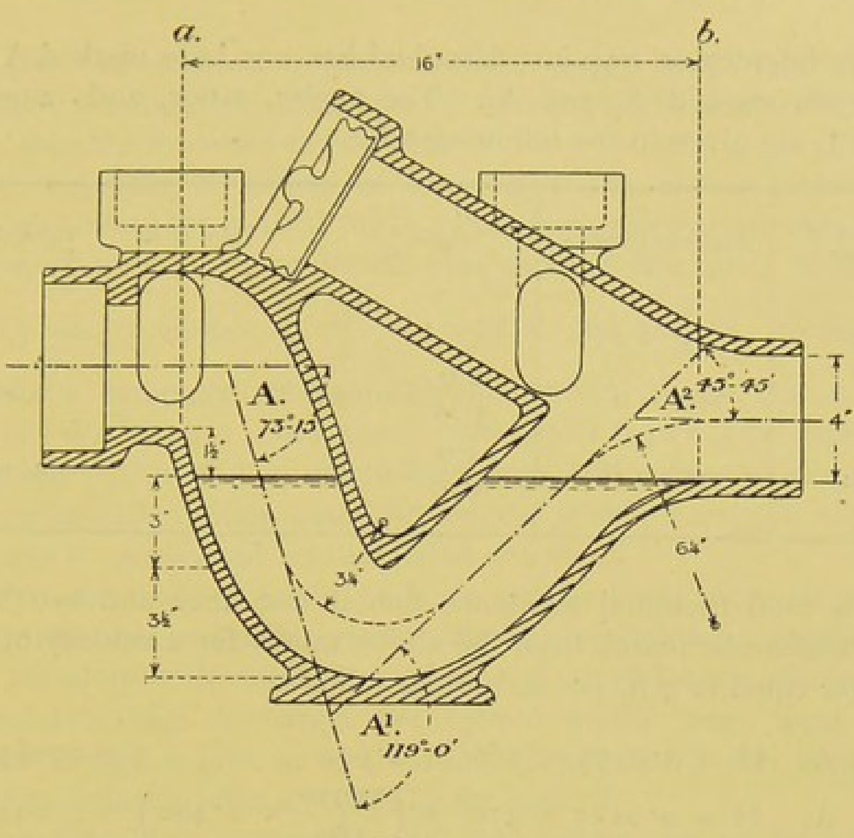

a.
b.
16"
A.
73°15'
A².
45°45'
4"
1½"
3"
3½"
3¼"
6¼"
A¹.
119°0'

FIG. 1.

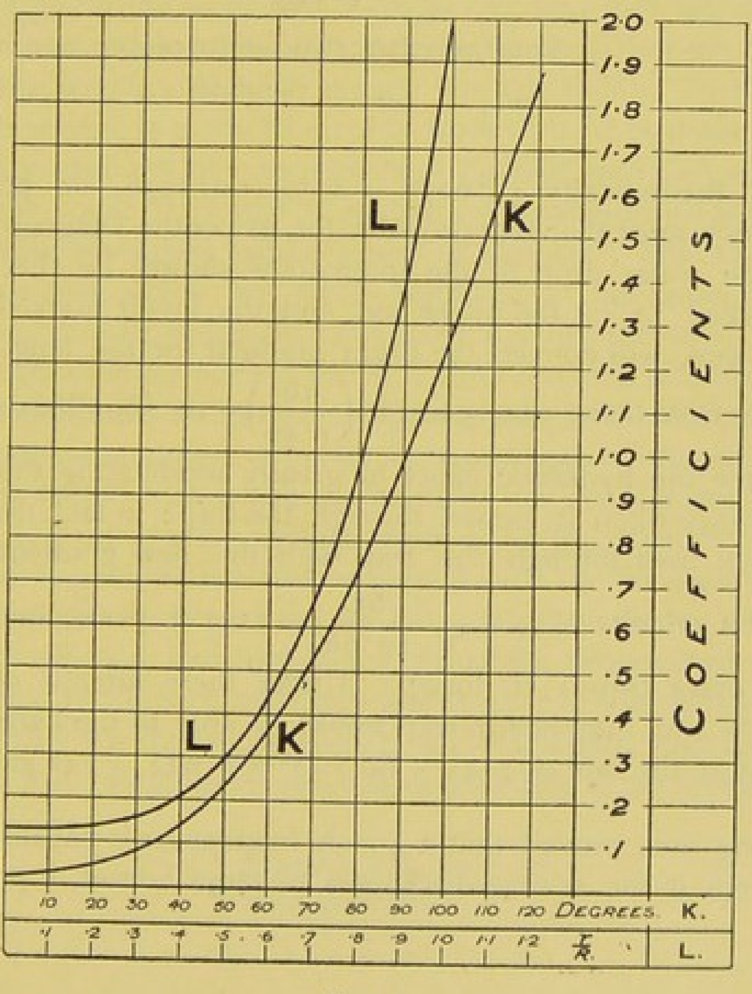

L
K
L
K
COEFFICIENTS
2·0
1·9
1·8
1·7
1·6
1·5
1·4
1·3
1·2
1·1
1·0
·9
·8
·7
·6
·5
·4
·3
·2
·1
10 20 30 40 50 60 70 80 90 100 110 120 DEGREES. K.
·1 ·2 ·3 ·4 ·5 ·6 ·7 ·8 ·9 1·0 1·1 1·2 r/R. L.

FIG. 2.

The interceptor trap just described has one knee marked A and two bends marked A_1 and A_2. The angles, ratios, and values of K and L are given in the following table :—

Position of Angle	Angles in Degrees	Ratio $\frac{r}{R}$	Value of K	Value of L
A	$73^\circ - 15$	..	0·600	..
A_1	$119^\circ - 0$	$\frac{2{\cdot}0}{3{\cdot}25} = 0{\cdot}615$	..	0·480
A_2	$45^\circ - 45$	$\frac{2{\cdot}0}{6{\cdot}56} = 0{\cdot}305$	..	0·165

The total frictional resistance due to one knee and two bends can therefore be found, from the above values for a velocity of flow of water equal to 3 ft. per second, as follows :—

$$\text{For A} \quad H = 0{\cdot}0155 \times 3{\cdot}0^2 \times 0{\cdot}600 = 0{\cdot}08370$$

$$\text{,, } A_1 \quad H = 0{\cdot}0155 \times 3{\cdot}0^2 \times \left(\frac{119{\cdot}0}{180} \times 0{\cdot}480\right) = 0{\cdot}04427$$

$$\text{,, } A_2 \quad H = 0{\cdot}0155 \times 3{\cdot}0^2 \times \left(\frac{45{\cdot}75}{180} \times 0{\cdot}165\right) = 0{\cdot}00585$$

$$\text{Total resistance in feet of water} = 0{\cdot}13382$$

$$\text{,, ,, inches ,,} = 1{\cdot}6058$$

which is, theoretically $(1{\cdot}6058 - 1{\cdot}5) = 0{\cdot}1058$, or practically $\frac{1}{10}$ of an inch more than that provided for, as per the Diagram No. 38.

But the water drop of the interceptor shown, i.e. between its invert marked "*a*" at the upper end, and the invert marked "*b*" at its lower end, will convert the drain gradient for the length of the interceptor from being 1 in 65 to 1 in $\left(\frac{16}{1{\cdot}50}\right) = 10{\cdot}66$. This alteration would have the hydraulic effect of greatly accelerating the velocity of the sewage when it passed through the trap: in fact the sewage would then pass through the trap with the new gradient of 1 in $10{\cdot}66$ at a velocity of $3 \times \sqrt{\frac{65}{10{\cdot}66}} = 7{\cdot}41$ ft. per second (i.e. for an interceptor trap 1 ft. long). Under these altered conditions therefore a 4-in. interceptor trap would be able to discharge sewage through it at the rate of $7{\cdot}41 \times 60 \times 4^2 \times 0{\cdot}034 = 242$ gallons per minute.

Having thus proved that a 4-inch interceptor is capable of pass ing through it the sewage-discharges of large houses, I propose to show also, the practical objections which apply to all interceptors, which are too large and capacious for the important sanitary services which they are intended to perform.

For example, if, instead of inserting a 4-in., a 6-in. interceptor were substituted for it, then the 1·133 gallons per second of sewage, discharged by the former, would pass through the latter at the reduced velocity of $3 \times \sqrt{\frac{4^5}{6}} = 1 \cdot 088$ ft. per second; as may be verified by reference to the Table C*, which shows that a 6-in. pipe will discharge 2·7562 times more water than a 4-in. pipe, and conversely the velocity at which the 1·133 gallons per second could pass through the former, would be reduced from 3 ft. to $(3 \div 2 \cdot 7562) = 1 \cdot 088$ ft. per second, as calculated above.

What the velocity would be when 90 per cent. more or less of sewage reaching and passing intermittently through 6-in. interceptors fixed on more or less long main drains of small houses whose total maximum sewage discharges per second would range from mere driblets to half a pint, or a quart or two, at most, I will leave the reader to estimate what it would be for himself.

The foregoing statements and calculations prove conclusively what Mr. Read states is the effect of employing interceptors which are too large for the work they have to do: i.e., they act the part of small permanent cesspools of deposit, and as such they must seriously impede the free flow of fresh sewage through them. In this way in fact fresh sewage is made to eject in front of it its equivalent volume of putrid sewage out of interceptors of deposit, into the unventilated part of the house-drain that is in direct communication with (it may be) a badly ventilated public sewer of deposit. The 18-in. public sewer, however, which Mr. Read described in his paper as the one in connection with which he conducted his experimental investigations is hydraulically perfect, which is the exception and not the rule. Hence the extreme inadvisability of dispensing with even unventilated house-drain interceptors everywhere, regardless of the condition of the public sewers with which the house drains are connected.

227. (*d*)† It is quite evident from what Mr. Read states under this heading that he was not in accord with the decision arrived at at the conference referred to; for he states in his paper, referring to what took place at that conference, "that the proposal agreed to by the London conference increases the number of ventilating shafts to be provided by the house owner, while retaining the intercepting trap, and is a compromise which does not strike at the root of the evil.

* Appendix VII., page 327.
† *Supra* page 226.

(*e*) The owner is more likely to consent to abolish the trap, as it would be less expensive to him, and in the author's opinion more beneficial both to the owner and the community at large."

That is to say, the majority of house owners who do not understand what constitutes the difference between efficient and inefficient house-drainage works would doubtless favour the adoption of the plan which appeared to them to be the less costly, regardless altogether of sanitary considerations. These were the views which Mr. Read entertained when he wrote his paper, and he was evidently sanguine that his plan of ventilating sewers, drains and soil-pipes by abolishing interceptors altogether would be sooner or later generally adopted; because he says that "the soundness of the drain should be tested when the trap is taken out, especially if the drain passes under a house." I agree with this statement as to the making of all drains sound, but even if they were all made of gun-metal, as perfectly as gun barrels are made, they would then only all the more perfectly convey the foul air of ill-ventilated public sewers of deposit into possibly defective soil-pipes, in direct communication with defectively trapped w.c.'s, etc. In this way sewage-gas escapes into our houses and is turned on to the roofs and other parts of the environments of our houses. The better, and in the long run by far the most economical plan is to devise mechanical or other means whereby currents of fresh atmospheric air may be induced to flow down every soil-pipe into the drains and sewers, so that the sewage gases arising from the exposed surfaces of the sewage in its transit from the houses and buildings to the outfall, may be swept away therefrom and conveyed invisibly and innocuously with the sewage itself away from our houses and public streets to some point or points of outfall for treatment.

228. (*e*)* A copy of the plan here referred to is shown on Drawing No. 37. But the ventilating shafts which are fixed against the houses placed on the original plan are not shown on that drawing, nor are the letters A, B, and C on the lines of the sewer, and the figures indicative of the number of house-drains connected with it shown on the original plan either, and for these reasons they could not be shown on the plan which appears in Vol. XXV. of the Proceedings of the Incorporated Association of Municipal and County Engineers.

The reproduction, however, of the plan as it appears in that volume with the addition of the letters and figures will enable the reader to understand the methods which Mr. Read proposes to adopt for ventilating drains and sewers.

What he states about the velocity of the ventilating air flowing

* *Supra*, page 227.

down the 18-in. sewer and the non-appearance of smoke at all but one, and that the lowest of the manhole covers, is just what I should expect would happen, but on the other hand I do not think that the appearance of smoke at the tops of the soil pipes is by any means conclusive evidence to prove that Mr. Read's theories with respect to drainage ventilation are correct or otherwise.

The smoke which was seen issuing out of the tops of the ventilating soil-pipes was of course due to the operations of natural laws which, by their action, created aeromotive forces enough to expel some of the smoke generated in the sewers for the purposes of Mr. Read's tests out of them. But without knowing much more about the drains and sewers, with which the soil-pipes were connected, than is revealed in Mr. Read's paper, it would be presumptuous for me to pretend to define the exact causes of the movements of the smoke within them. I will only say that the rapid flow of large volumes of sewage waters in sewers results in the air being compressed by the momentum action of the moving waters within them, when the flow is suddenly retarded by sharp turns in the sewers altering the direction of the flow; or in consequence of deposits diminishing the sectional area of the main sewer or its tributaries; these and other natural actions would have the effect of creating plenum power enough to expel the smoke into the atmosphere, in the manner described by Mr. Read; and moreover, as smoke is lighter than sewer air, sensible quantities of it would naturally ascend through and with the air to the tops of the highest points in the sewerage works, on the principle on which balloons float in air.

The issuing of smoke at and out of the tops of Mr. Read's ventilating soil-pipes, must not, therefore, be regarded as supporting his theory that air at the street level, after descending into the sewers below, will also, on the same principle, ascend therefrom *via* the drains to the tops of the soil-pipes—if only the air-inlet openings into the sewers at the street level are made smaller in area in the aggregate, than the areas in the aggregate of the soil-pipe openings.

While explaining the example he gives in his paper in support of this theory, he was led to suggest that the areas of the air-inlets in street manhole covers, in the aggregate, should be equal to about one-tenth of the areas, in the aggregate, of the tops of his 4-in. outlet soil-pipe shaft, as, apparently, by ventilating the 18-in. public sewer shown on his plan in this manner, he discovered that the street air entered it through the small openings in the manhole cover, marked A on the accompanying copy of his plan, at a velocity of 10 ft. per second. Now the question is, what was the natural power of the aeromotive force which produced and brought about the movement of the ventilating air?

229. (*f*)* As already stated on page 233, Mr. Read gives the total area of the small inlet holes in the manhole covers as being 36 sq. in., and the total areas of the tops of the thirty 4-in. outlets as being 375 sq. in.; the area of the inlets was thus about one-tenth of the area of the outlets as stated by him. But for convenience of calculations I will assume the area of the inlet openings in the aggregate to be equal to that of one pipe of 6 in., and the total area of the thirty outlet pipes to be equal to that of a pipe of 21 in. in diameter; then on these assumptions the velocity of 10 ft. per second, at which the air would pass through the 6 in. pipe, would theoretically, after it entered the 21-in. pipe, attain a velocity of $10 \times \left(\frac{6}{21}\right)^2 = 0{\cdot}8163$ feet, or a little under the velocity of 1 ft. per second, which Mr. Read assumed would be the final velocity at which the ventilating air would pass out of the tops of his thirty hypothetical ventilation soil-pipe shafts into the atmosphere.

A uniform ventilating velocity of 10 ft. per second, which Mr. Read apparently would not object to if it could be proved to be necessary for sanitating drains and sewers efficiently, could only be obtained by making the ventilating pipe of one uniform bore or diameter throughout its entire length, from its inlet to its outlet end, which of course is impossible in town drainage ventilation, and consequently the foregoing calculations prove that Mr. Read's proposals to reduce the sectional areas of the air-inlets to one-tenth of the sectional areas of the air-outlets, so far from augmenting the volumes of the air required for the ventilation of soil-pipes, drains and sewers, by natural means, must have the contrary effect.

Moreover, the important fact must not be overlooked, that if the sewage flowing on the invert of an 18-in. sewer (or one of any other size) travelled too slowly to be able to induce ventilating currents of air to follow it, as is always the case where the sewers are laid at flat non-self-cleansing gradients, then, instead of there being lively natural fresh-air currents entering the sewers through the street manhole cover openings, as was the case with Mr. Read's 18-in. sewer, the chances are that there would be, on the contrary, oftener than not, foul air-currents flowing out of such sewers into the air of the streets and elsewhere.

230. Mr. Read's paper was followed by an interesting discussion from which I reproduce a few extracts.

Mr. Mawbey said: "I have tried hard for some years to lay down some general rule, to devise a regular system, but I have found under certain local conditions or varying conditions of temperature,

* *Supra*, page 227.

when all the grids were closed with only one exception, and all the ventilating shafts along the sewer were open, but notwithstanding all those outlets for sewer air, we found that the one manhole was also acting as an outlet."

Mr. J. A Angell, the District Surveyor of Beckenham, gave particulars of a ventilation system established in a small isolated portion of that district. There all the surface grids were closed, and ventilating columns varying from 13 to 25 ft. in height were placed on the footways at intervals of about 150 ft. Each ventilating column takes the place of a lamp column, lanterns being attached to a bracket fixed on the column. This system was applied to 300 houses with a population of 1500 persons; "and," said Mr. Angell, "the result has been altogether favourable." And he further stated that "the system of sewer ventilation by shafts and columns is now about to be extended to the entire district, when all the surface grids in the district will be closed."

Assuming that this has now been completed, it would be very interesting to know the cost incurred, bearing in mind that Beckenham is a high-class residential district.

Mr. Angell fully corroborates what Mr. Mawbey had observed on the unreliability of the behaviour of inlets and outlets when these are left to the spontaneous action of the atmosphere. He stated that "Mr. Mansergh made extensive anemometer experiments in connection with our Beckenham sewer, but, so far as I personally could ascertain, no definite theory could be deduced from the results. . . . Whilst on occasions the grids acted as inlets, and the columns as outlets, subsequently precisely the reverse action was set up."

It may be mentioned that at Beckenham the dual system of drainage is in operation.

Mr. W. H. Blair, Borough Engineer of St. Pancras, reminded the meeting of the conference of metropolitan surveyors, which had been held in London a year previously, and cited the resolutions which had been practically unanimously passed at that meeting. (See *supra*, Appendix III., Part II.)

Mr. Blair continued: "These recommendations, I think, summarise the views of a good many speakers to-day. They do not contain the condition which Mr. Mawbey advocates of abolishing the surface ventilator altogether, but they do admit the principle that high ventilating pipes should be adopted wherever available. But in London that is our difficulty. Instead of getting refusals in 5 per cent. of the cases, we may get consent in 5 per cent., so for hundreds of yards we might not get a single consent. This leaves us with nothing but the open grid." Later on Mr. Blair drew attention to the fact that after the above conference had been held, etc. that what you have calculated to come about does not occur at all, but often exactly the reverse." "To be perfectly frank, I must admit that both with the ventilating shafts and the street grids you will at times get them acting the reverse way." "We had a case the London County Council had issued by-laws for the metropolis, and that in these "they have completely disregarded our practically unanimous recommendation."

I will refer to one more observation of Mr. Blair. He said, "I have a sewer in which I have spent hours at different times. Its gradient is about 1 in 15, its maximum gradient is 1 in 9. That sewer used to give us a great deal of trouble, because it goes to the highest part of the parish, and is directly connected with the main metropolitan sewers—consequently there used to be a very strong smell from the ventilators. We disconnected it from the lower length of main sewer, with a flap of ½-in. sheet rubber. The normal flow of water was about 2 in., but at heavy rains it would run 18 in. in depth.

"At a gradient of 1 in 13, 18 in. of water comes down like a water-chute, and I have been down the sewer with 6 in. of water when it has been unnecessary to move your feet, as the force of the water carried you along. But even there with that terrific velocity, I have very often found the air travelling in a different direction to the water, though it is not always so. Taking it to be the natural tendency of sewer air to rise, being lighter than atmospheric air, it was always assumed with that sewer that the sewer air would rise to the top of the hill and escape at the ventilator at the highest point."

He adds: "At a distance of about 250 yards we had another air flap and a 9-in. ventilating pipe carried up a building, and we closed all the ventilators with the exception of two, one at the lower end of each length of the sewer, and while we generally got a continual draught of air up the sewer, we found occasionally that the air was going in at the highest pipe and out at the lower one. Therefore you see you are dependent upon a variety of circumstances; but I believe that which mostly affects the current of air in sewers is the direction of the wind on the surface."

231. The discussion from which the foregoing extracts have been taken appears to have given Mr. Read considerable satisfaction, but an examination of the opinions expressed in it does not show much enthusiasm in favour of the scheme which he propounded, regarded as a practical method to be generally recommended for adoption. It is indeed somewhat surprising that many of the important observations made should not have had some effect in diminishing Mr. Read's confidence in the perfection and infallibility of his plan.

In particular the supposed principle upon which he so implicity relies, that shafts erected against houses between road surface ventilators will always act as air outlets, and the road surface ventilators will always act as air inlets, was completely refuted by the extensive, varied, and thorough-going practical experience and experiments of no less than three of the eminent engineers who took part in the debate, as the above extracts will show. These gentlemen are unanimous in declaring from actual trial, that so long as such an arrangement is left to the spontaneous operation of nature, no definite theory can be deduced from the results; and that it is impossible to foresee when the very opposite effect to what was anticipated will not take place, the supposed outlets being turned into inlets, and *vice versâ*.

Again, with regard to the interceptor trap, Mr. Read by no means succeeded in converting his hearers to the view that it is necessarily the "useless obstruction" he describes it as being. On the contrary several of the speakers strenuously advocated its retention, although one or two would give to the engineer the option of retaining or excluding it according to circumstances.

Mr. Read glories in the fact that he has been a vigorous and consistent opponent of the interceptor trap ever since its initiation. Persistence of repetition and energy of statement may possibly point rather to rooted prejudice than to a judicial conclusion founded upon careful and deliberate examination.

Surely, in the course of the last quarter of a century Mr. Read has been confronted with sufficient evidence to shake in some degree his confidence in the soundness of his conviction of the universal uselessness of the interceptor. Notwithstanding the admitted defects in the type of interceptor hitherto in use, their excessive size and undue water-capacity, their inferior material, their defective method of laying, and the fact that they are so placed in the drain that the portion of the house drain between the interceptor and the public sewer is unventilated (all which defects are perfectly and even easily remediable); nevertheless their essential function as a safety-valve to prevent the access of foul sewer gases from the sewers into houses has convinced numberless sanitary engineers of the necessity of their retention. These were the reasons why the Local Government Board under the advice of their engineers have prescribed the trap; and why local town authorities throughout the kingdom for the most part have made it a part of their drainage by-laws.

As recently as March 1908, at an important meeting of the Royal Sanitary Institute, held in Blackpool for the express purpose of discussing sewer ventilation and the interceptor trap, after every objection to the latter had been fully and minutely considered, hardly a voice was heard in favour of its abolition.

APPENDIX V.

PART I.

DESCRIPTION OF THE SHONE HYDRO-MECHANICAL SYSTEM OF SEWER AND DRAIN VENTILATION, DRAWING NO. 39.

232. THE object of this drawing is to show the adaptations of the hydro-mechanical system to existing sewer and drain installations. By consulting it engineers will be able to judge how simple and comparatively inexpensive those adaptations are; and it is confidently hoped that the accompanying description of their structure and *modus operandi* will satisfy all that they are calculated to remove for ever the defects in the existing arrangements, which have hitherto defied all efforts to get rid of or counteract them.

Fig. 1 shows, in section, a house-drain inspection chamber, containing a ventilated interceptor trap; and Fig. 1A shows, in plan, the pipes and other arrangements connected therewith. The principles governing these latter arrangements are in conformity with those that are applied at the present time to high-class modern house-drainage works. That is to say, adequate provision is made for ventilating the drain on the house side of the interceptor trap on the present approved orthodox plan. But here, as explained in the Liverpool paper,* the house-drain on the sewer side of the interceptor will be ventilated also.

Fig. 1B is a section of the same interceptor chamber, and will be seen to be identical with Drawing No. 22 on page 103, in my paper.

Fig. 1 differs from Fig. 1B in this respect alone. In the latter the air-inlet and reflux valve are situated in the interceptor chamber and are therefore below ground, while in the former they are, by a prolongation of the vertical pipes, placed above the ground level, and are intended to occupy a position similar to that now commonly occupied by the mica-flap opening in the prevailing system. The

* *Supra*, Appendix I., pars. 79–84.

two arrangements are merely alternative, but their functions are practically identical.

233. Figs. 2 and 2A are transverse sections showing an ordinary street gully *in situ*.

234, 235. Fig. 3 shows an egg-shaped public sewer to which are connected the ventilated house-drains and ventilated gully-drains illustrated respectively in section by Fig. 1 and by Figs. 2 and 2A, and in plan by Fig. 1A and Fig. 4.

236. Fig. 5 illustrates, with the aid of Figs. 2 and 2A, how the street gullies and the water contained in them are to be ventilated at the points marked *a* and *b* on the latter figure, and how the street gully-drain itself is to be ventilated.

Fig. 2A shows (1) how the street air will always be in contact with the contents of the street gully at the points *a* and *b*; and (2) how the street air will flow into and ventilate, firstly, the gully drain trap water and the gully drain itself, and, secondly, the public sewer.

Fig. 3A shows what in my opinion ought to be done at the crown of every egg-shaped or circular public sewer, in order to facilitate and render perfect the ventilation of it on the hydro-mechanical system. The bottom of every new street manhole, erected on the lines of public sewers for inspection purposes, should be made to form the crown of the public sewer, in such a way that the brickwork or concrete wall of the latter should be made to dovetail, as it were, into the walls of the former. And further, an iron manhole inspection cover (air and water-tight) should be substantially fixed at the crown of the sewer, as indicated by the letter *c* on Fig. 3A.

Thus, by reference to the several figures from 1 to 5 in this drawing, a clear understanding will be obtained of the arrangements proposed for ventilating new house and street gully-drains and sewers on the hydro-mechanical system, and also for adapting existing drains and sewers to that system.

237. I may here advert to one of the objections made to the hydro-mechanical system, which is the following:—

It is said that, if you place in an ordinary house-drain inspection chamber a ventilated interceptor trap of the type shown in Drawing No. 22 of my Liverpool paper (page 103) the sensitive reflux magnalium valve, fixed at the top of one of the two vertical by-pass air pipes would be thrown out of order, or rendered inoperative, whenever sewage waters flooded the house-drain, whether on the house side or on the sewer side of the interceptor.

A very little consideration will show that any such contingency is physically impossible. In other words, whatever floods may occur at any time, the physical conditions would make it impossible for any flood waters to rise high enough in the vertical by-pass air-pipes to interfere with the normal working condition of the magnalium reflux valve.

For, assuming the normal pressure of the atmosphere to be 14·7 lb. on the square inch, and also assuming Boyle's law, already alluded to, to be correct, it follows that to double the pressure of any air that may be at any time in the by-pass air-pipes and valve box by water power, would require a water-head of $(14{\cdot}7 \times 2{\cdot}31) = 33{\cdot}957$, say 34 ft.

Now in Fig. 1B in Drawing No. 39, the line XX drawn across the interceptor shows the position graphically, that is to say it would require a head of 34 ft. of water to raise the flood waters up to the line XX.

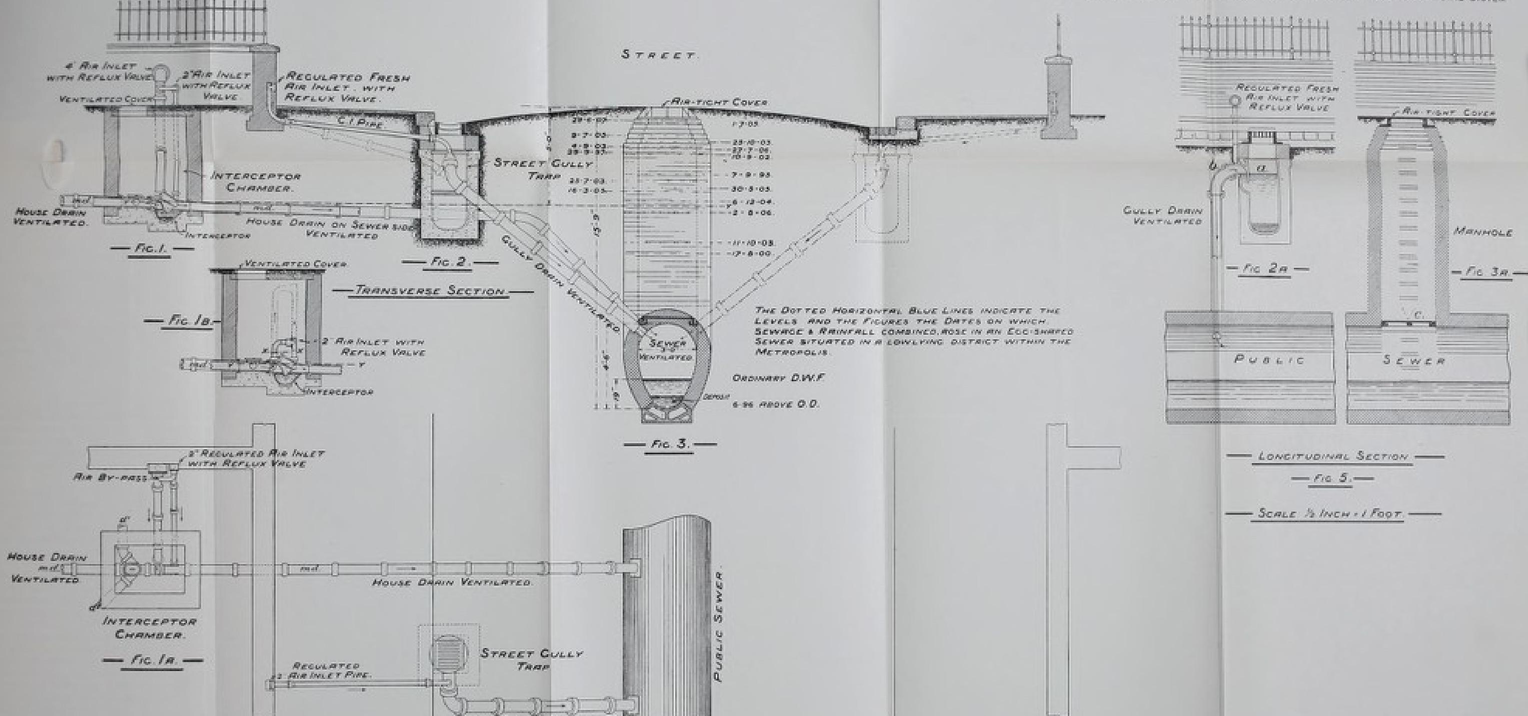
It is thus obvious that under the most adverse conditions which could obtain in practice the mechanical parts of the ventilated interceptor can never be inundated with sewage or flood waters, so long as the interceptor-trap piece and the pipes connected to it (shown in Fig. 1B) are of sound material and are jointed together in a proper workmanlike manner.*

Under these conditions, the flooding waters could only fill the main drain marked *m.d.* on Fig. 1 and Fig. 1A, and also the drains marked d^1 and d^2, till they overflowed the tops of yard gullies, etc. But they could never interfere with the functions of the reflux valve.

For instance, take Fig. 3, which is a section to scale of an egg-shaped public sewer in a low-lying district in the metropolis. The horizontal lines on the diagram above the sewer indicate the various heights to which storm waters rose on the several dates marked on both sides of the diagram. The highest of these, it will be seen, occurred on June 29, 1907. On that day the water rose to a height of 15 ft. 3 in. above the invert of the sewer, and within 6 in. of the tops of the street manhole cover. Even in this condition the height of the water above the crown of the drain at the interceptor trap would not exceed 4 ft. And it must be borne in mind that even that water would be in the pipes and could not escape into the inspection chamber Fig. 1.

* In ordinary cases the body of the ventilated interceptor with its special inspection eye-piece and the drain-pipe inspection-piece would be specified to be made of the best stoneware, but for large first-class houses they would doubtless be specified to be made wholly of heavy iron. But in any case, all the by-pass air-pipes connected with the interceptor should be made of iron, and preferably of the best galvanized iron; and all should be specified to be fitted and jointed together in the soundest manner possible.

DRAWING No. 39.—THE SHONE REGULATED HYDRO-MECHANICAL AND NATURAL SYSTEM



PART II.

EXAMPLES OF THE APPLICATION OF THE HYDRO-MECHANICAL SYSTEM OF VENTILATION; AND SUGGESTIONS TO ENGINEERS IN CONNEXION THEREWITH.

Extracts from the Paper entitled "Experiments on Shone's System of Sewer Ventilation at Leicester," read at the Annual Meeting of the Incorporated Association of Municipal and County Engineers at Shrewsbury, in July 1904 *by Mr. E. A. Mawbey, M. Inst. C.E., Borough Engineer of Leicester.*

"In July 1902 the Highway and Sewage Committee of the Leicester Corporation entered into an arrangement with Messrs. Shone and Ault to instal a small district with Shone's system of drain and sewer ventilation (according to Shone and Ault's patents), for the purpose of carrying out experiments in order to test its practicability and efficiency, together with the working expenses involved therewith.

238. "The district dealt with is shown upon Drawing No. 40. The area under the influence of the system is 2½ acres, and comprises portions of one of the modern built-up parts of the borough. The streets are 40 ft. wide. The carriageways are paved with 3-in. by 5-in. granite setts, and the causeways with concrete flags. It includes eighty six-roomed houses of artisan class, at a rental varying from 17*l.* 10*s.* to 19*l.* 10*s.* per annum, and having a population of 356, with an average of 4·45 persons per house.

"The total length of foul-water sewers ventilated is 297 yards constructed on the separate system, the storm-water sewers being quite distinct and receiving the rain water from the streets and front roofs only.

"The private drains operated upon comprise a total length of about 583 yards. They are mostly 6 in. in diameter, with 6-in. branches to the water-closets, and 4 in. branches to the sink wastes, constructed with ordinary stoneware socketed pipes. Rather more than half are jointed and filleted with Portland cement. The remaider have clay puddle joints. In both cases each joint is surrounded by a band of clay puddle 8 in. wide.

"Inspection chambers are provided at the principal junctions of these drains, and are constucted in 4½-in. brickwork in hydraulic lime mortar, and covered with stone slabs also bedded in hydraulic lime mortar.

"There are no intercepting traps on any of these private drains.

"To the eighty houses, there are twenty-seven of these ventilating pipes. The proportion of ventilating pipes varies from one pipe per house to one pipe to six houses.

"It is only fair to this system of ventilation to say that part of the sewers and drains, viz. from the manhole near the fan to the junction of Wilberforce Road, comprising roughly about two-thirds of the area, has been submitted to a water test. There was a head of water of 3 ft. 8 in. at the manhole at the junction of Wilberforce Road, and it was found that the leakage amounted to 7 gallons per minute. No doubt this would have been increased if a greater head had been put upon the drains.

"Perhaps it ought also to be mentioned that the system of clay jointing of private drains has been abandoned for seven and a half years, and the system of cement jointing adopted, and with the clay band around the socket.

"It will thus be seen that this system of sewer ventilation has not been applied to an ideal water-tight set of house-drains.

239. "The section of sewers experimented upon is trapped off from the adjoining sewers at the outfall end by a siphon trap, constructed in the manhole on the 3 ft. by 2 ft. brick sewer, and at the flushing manhole near the fan and at the manhole in Wilberforce Road, at the junction of Equity Road, by shutting down the flushing penstocks.

"At the upper end of the system, a fan and motor chamber is constructed of 9-in. brickwork in cement mortar, 6 ft. 6 in. long by 3 ft. wide, built under the footway opposite the flushing manhole, as shown on the cartoon. In this chamber is fixed a 15-in. sirocco fan driven by an electric motor working at 700 revolutions per minute, the current being supplied off the electric lighting cables at 200 volts.

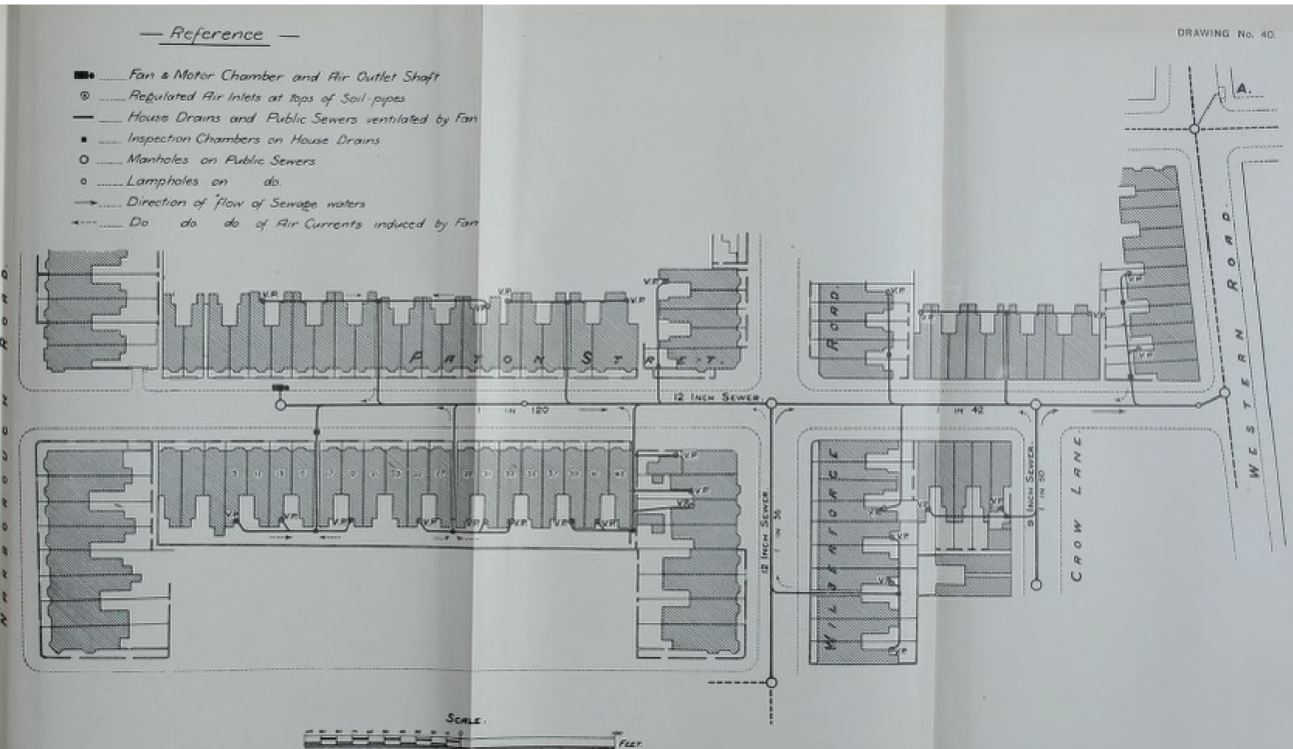
"Connexion is made between the flushing manhole and the fan by 18 in. stoneware socketed pipes.

"On the footway at one end of the chamber is erected a 9 in. circular steel ventilating shaft 40 ft. high. In the first instance, however, a 6 in. shaft was erected and a number of experiments carried out with this, but later on it was advantageously replaced by the 9 in. shaft.

"The fan is connected to this pipe by means of a zinc air discharge pipe, tapering in size from 7 in. to 9 in. diameter.

240. "The main features of the arrangement are that the existing private ventilating pipes, or soil pipes, as the case may be, are

DRAWING No. 40.



[Face p. 250.

provided with suitable regulated fresh air inlets, so that the entire lengths of soil pipes and drains should be swept by the ventilating current into the public sewer, and drawn thence to the main extraction shaft, the volume of fresh air drawn in through these ventilating pipes to be sufficient not only to draw away the foul air through the drains from the vicinity of the dwellings in the direction of the flow in the drains, but so to dilute it that it can be safely discharged through the main extraction shaft into the open air above the level of the houses, rendering it impossible for there to be any escape of dangerous foul air into or around the dwellings, the volume of air being properly proportioned and controlled according to the number of houses and volume of sewage discharged in the drains.

"The most important feature is the constant and uniform drawing away of the soil pipes and drain air from the dwellings and workplaces of the people, thus preventing it finding access thereto.

"It will be gathered that at Leicester this installation is applied to a district where the intercepting trap is not in use. The author will not go into the question of the merits or demerits of this trap, except to refer to the fact that it is now very largely dispensed with; but, as in some towns, it is largely used in accordance with the requirements of the model by-laws of the Local Government Board, this description will not be complete without referring to the application of this system in combination with the intercepting trap. The author can, therefore, say at once that the system will be as equally applicable and effective in combination with it as without it, the chief difference being that the regulated air inlet will be fixed at the intercepting trap, and will still draw the fresh air supply through the soil pipes and drains, and also, which is very important, will on its way ventilate that portion of the drain between the trap and the sewers.

"The actual working expenses are practically confined to the cost of the electric current consumed in driving the motor. The repairs and maintenance could not be a serious matter, and the attention required is obviously very small.

"After these experiments, the author formed the opinion that not only was the sectional area of the inlets too small, but that the sectional area of the extraction shaft was also too small to obtain the best results from the motor and fan, and in consultation with Messrs. Shone and Ault, it was decided to first experiment on the extraction shaft only.

241. "An experiment was then carried out by disconnecting the fan from the extraction shaft, and delivering the air at the street level. This at once not only resulted in discharging nearly four times the volume previously discharged through the 6 in. shaft, viz.

998 cub. ft. per minute measured in the 18 in. branch leading to the fan, but increased the air admitted through the twenty-seven inlets on the private ventilating pipes from 31·17 cub. ft. per minute to 105·55 cub. ft. per minute, representing 1·5 cub. ft. per minute of air per house, at an average velocity of 99·27 ft. per minute, against 29·3 ft. per minute previously obtained, and every one of the inlets was found to be acting at such a velocity as could be recorded by the anemometer.

"In order to maintain as far as possible this increased efficiency, a 9-in. extraction shaft was then substituted for the 6-in., and the fan connected therewith, and tests were made with a result that 741·9 cub. ft. per minute were extracted through the shaft at an average velocity of 1264 ft. per minute; and a total volume of 74·59 cub. ft. per minute was admitted through the twenty-seven inlets on the ventilating pipes at an average velocity of 70·2 ft. per minute through the anemometer, representing an average volume per inlet of 2·76 cub. ft. per minute, or an average per house of 0·94 cub. ft. per minute, which is more than twice the quantity of fresh air admitted into the inlets when the 6-in. diameter shaft was in work.

"At this point of the experiments, viz. in November last, the author felt satisfied that this was a practicable and efficient system of sewer ventilation, which would be thoroughly reliable at all seasons of the year, as before referred to; but the consumption of electrical energy and, of course, also the cost thereof, was in the author's opinion too great for the number of houses dealt with.

"The author felt sure that this could be remedied by largely increasing the areas of the inlets, so that by decreasing the resistance, the greater volumes of fresh air would flow in, and a much less proportion be derived from underground sources, where the resistance must be greater.

"A great number of experiments of this description were then carried out, and the total area of the twenty-seven inlets has ultimately been increased from 10·278 sq. in. to 75·258 sq. in. or to 89 per cent. of the area of the 9 in. diameter extraction shaft.

"The result was that 752 cub. ft. per minute were discharged by the shaft at an average velocity of 1284 ft. per minute; and a total volume of 324·53 cub. ft. per minute (or nearly half the total volume discharged by the extraction shaft) was admitted through the twenty-seven inlets on the ventilating pipes at an average velocity of 226·2 ft. per minute, representing an average volume per inlet of 12·02 cub. ft. per minute, or an average per house of 5·23 cub. ft. per minute. All the inlets were acting.

"The quantity of fresh air admitted through the inlets being now vastly greater than was required for the eighty houses, it was clear that this small fan was capable of dealing with a much greater district. The author, therefore, decided to connect up, by lifting the penstock in the manhole near the fan, the sewers of the adjoining Narborough Road district, and regulated this penstock until the volume of air drawn from the ventilated area was reduced by about one-half. The actual volume extracted from the adjoining district was 421 cub. ft. per minute, and the total volume from the Paton Street district 473 cub. ft. per minute.

"A total volume of 190·01 cub. ft. per minute was then admitted through the twenty-seven inlets on the ventilating pipes at an average velocity of 143·4 ft. per minute, representing an average volume per inlet of 7·04 cub. ft. per minute or an average volume per house of 3·22 cub. ft. per minute. All the inlets were acting.

"This reduced the proportion of current consumed to six units per twenty-four hours per eighty houses.

"As, however, the volume per house per minute was still much in excess of that necessary for ventilation, the penstocks for the respective districts were adjusted so that a volume of 746 cub. ft. per minute was drawn from the adjoining district, and the volume from the Paton Street district was reduced to 142 cub. ft. per minute.

"This is a remarkable advance on the results first obtained, when the total volume entering the twenty-seven inlets was only one-ninth of that delivered through the extraction shaft.

"This means that the air in the private drains was changed with air drawn direct from the atmosphere, 502 times per twenty-four hours, or about once every three minutes, whilst the air in the ventilated sewers was, roughly speaking, changed 309 times per twenty-four hours, or once every four and a half minutes.

"Mr. Shone contends that ½ cub. ft. per house per minute, with an average of 5 persons per house, is ample for efficient ventilation, as against the 1·73 represented by this expenditure of current. Under these circumstances, the air in the private drains would be changed 145 times per twenty-four hours, or approximately once every ten minutes. The current consumed would be reduced to 2*l.* 7*s.* 4*d.* per thousand population per annum (at 1*d.* per unit), which equals 0·57*d.* per head per annum.

"Respecting the fresh air inlets, these experiments convinced the author that in consequence of the varying local conditions wherever this system may be applied, it was impossible to theoretically calculate and determine the most efficient area of opening required for the individual inlets, and that a terminal should be so designed that after fixing it could be adjusted to admit the volume required—this being ascertained in each case by an anemometer test. Messrs.

Shone and Ault have devised a terminal to meet these requirements, a sample of which is now submittted.

"Although no large intercepting sewers have been at present experimented upon at Leicester, the author sees no reason to doubt that equally satisfactory results would be obtained by the application of the system thereto, and if some other of our members takes this up, it would be desirable that he should apply it to a section of sewers of this character.

242. "When this system was first propounded by Mr. Shone, the author had serious misgivings as to its practicability, but was nevertheless so impressed with a paper read on this system at Eastbourne, at the Congress of the Royal Institute of Public Health, when he was President of the Engineering Section, that he felt it was well worth submitting to a practical trial, and it is only after very exhaustive and practical investigations, extending over a period of at least two years, that he has felt at all justified in expressing any definite opinion thereon.

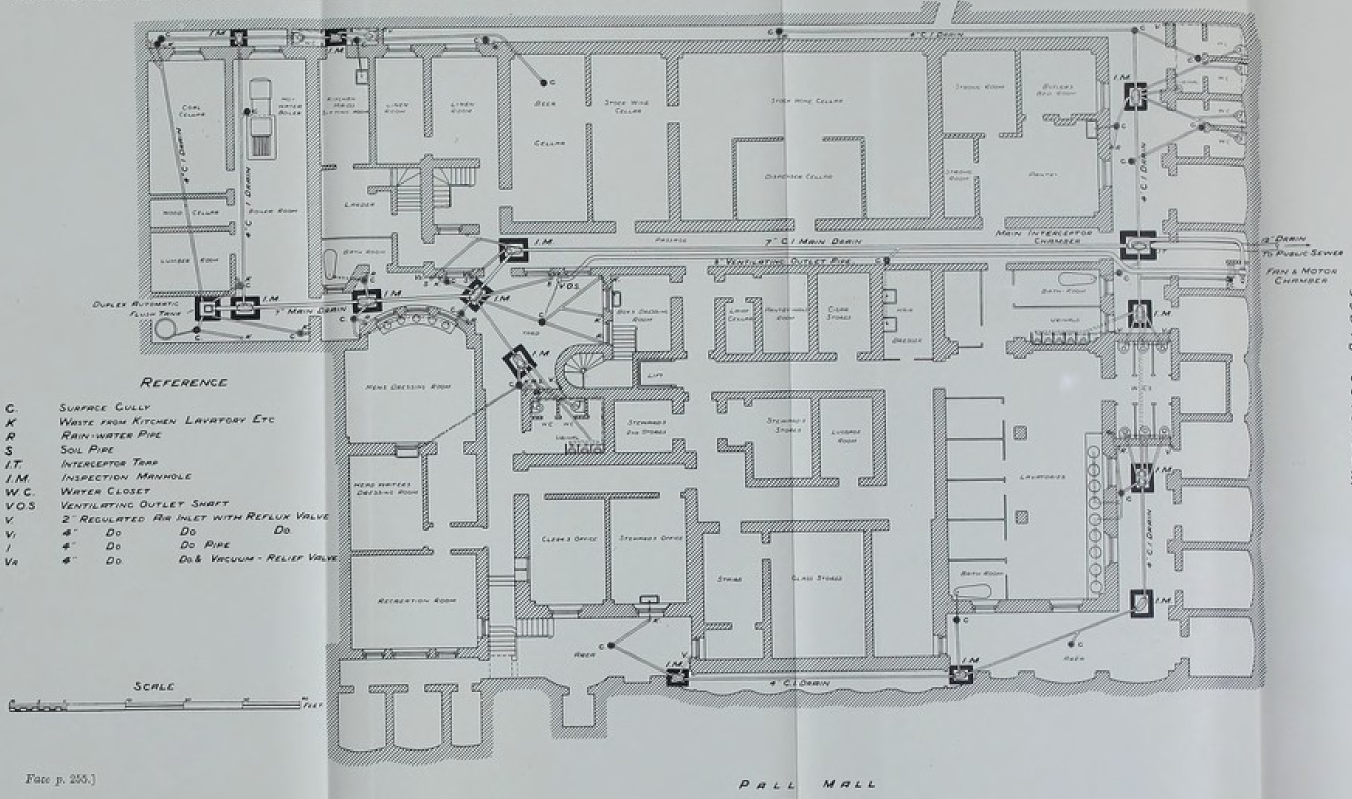
"The author is, however, now able to say that the soil pipes, drains and sewers have by this system been satisfactorily and uniformly ventilated for the period referred to, under the varying conditions of the atmosphere and of the air within the sewers, and that this has been effected without any siphoning out of any of the traps in connexion with the house drains. In fact, the vacuum in all parts of the system has been too small to be registered by a water gauge, although many attempts have been made to obtain readings.

"The experiments certainly go to show that, by the Shone system, a sufficient quantity of fresh air direct from the atmosphere can be supplied into, and circulated through, soil-pipes, drains and sewers, to dilute the air therein to any extent that may be necessary, and, according to the results obtained in this practical test, at a cost, which, having regard to the importance of efficient ventilation, cannot fairly be considered to be prohibitory."

In the course of the discussion Mr. Weaver said:

"If Mr. Shone can show us how we can create a continuous flow of fresh air through the sewers, he would hand his name down to posterity as the benefactor of all large towns; and, personally, I should very much like, if I could, to put up an installation on a brick sewer in my district so that I could make up my mind whether it could be adopted in some of the brick sewers of London, which daily become more foul owing to the clamour of the public against street ventilation."

DRAWING No. 41 SHOWING THE DRAINAGE AND VENTILATION OF THE UNITED SERVICE CLUB.



Face p. 255.]

Description of the Drainage and Ventilation of the United Service Club in Pall Mall.

243. The drainage and the ventilation of the drainage arrangements of this Club were designed and carried out by my firm, and are shown on the basement plan Drawing No. 41.

On reference to that drawing it will be seen that the main drain at its upper end commences near the boiler-house on the west side of the building, and extends along the central area and passages to the main interceptor chamber at the lower end, whence it proceeds to the public sewer under Waterloo Place. This drain, from its upper end to the main interceptor, is 7 in. in diameter, and is laid at gradients of 1 in 78 and 1 in 65, which have the effect of causing the sewage, when the drain is full or half-full, to flow through it at self-cleansing velocities of 3·50 and 3·83 ft. per second respectively.

All the tributary drains are 4 inches in diameter, and are laid, for the most part, at a gradient of 1 in 48, which is sufficient to cause the sewage to flow through them at a self-cleansing velocity of 3·47 ft. per second, i.e. when they are charged full or half-full with sewage.

The drains throughout are made of cast-iron socketed pipes, which are embedded in cement concrete, and the inspection chambers are lined with white glazed bricks; the inverts of the chambers being of cast-iron with air-tight access covers, bolted down on same.

244. The bath, sink and other waste pipes discharge over surface gully traps in the areas, and from the gullies the drains are laid and carried wherever possible, in straight lines direct to the nearest inspection chamber; this arrangement allowing bends to be fixed inside the chambers at the junctions with the main drain.

The soil pipes in every case discharge directly into inspection chambers.

At the head of the 7-in. main drain a duplex automatic flushing tank of 75 gallons capacity is fixed. This tank acts the part of a self-cleansing grease trap, because it receives the grease and other waste fluids of the kitchens, etc., and which are utilized (instead of costly potable water) to flush the main drain thoroughly many times a day from its head to the main interceptor trap; and as its contents, 75 gallons, are discharged in less than half a minute, the volume that passes through the main interceptor, when the tank is in action —plus the dry-weather flow of the ordinary drainage volume—is sufficient to ensure a self-cleansing velocity also within the 12-in. iron gravitation outlet sewer which lies between the main interceptor and the public sewer under Waterloo Place.

The ventilation of the soil and waste pipes, and the flush tank, as well as the main and tributary drains, is effected by means of a $7\frac{1}{2}$-in. sirocco fan, which is driven by an electric motor, both of which are erected in a small chamber close to the main interceptor, as shown in plan on the Drawing No. 41. The fan and motor run on the same spindle, and make about 1000 revolutions per minute, so that a vacuum equal to about a quarter of an inch of water is created which has the effect of inducing currents of fresh air to flow through regulated air inlets inserted in or connected with the various types of ventilating pipe-terminals, as illustrated on the Drawing, just as if they were the equivalents of so many down-cast ventilating shafts of a mine. By these simple arrangements, each regulated air-inlet supplies its quota of fresh air to ventilate the whole of the main and tributary drains alike; and all the ventilating air currents travel to the fan in the direction in which the sewage flows; and, as fast as the ventilating air is exhausted from the drainage system of the Club, into and through the fan, it is propelled away therefrom into an 8-in. iron delivery pipe, which carries it to a point in the central area marked "V. O. S.," whence it ascends perpendicularly up to its outlet end, which is well above the roof of the Club.

The total volume of ventilating air which is thus drawn into and forced out of the fan amounts to about 1250 gallons per minute, and the power required to drive the motor that is used to run the fan is equal to about one-tenth of a b.h.p., and the electrical energy expended costs only about 3*d*. per day of 24 hours.

From the foregoing description it will be seen that this Club furnishes an excellent practical example to show how the whole of the drainage arrangements of one building, however small or large and complicated it may be, can be efficiently ventilated hydro-mechanically, independently of, and without interfering in any way with the ventilation of the public sewers, into which the sewage of the building is discharged.

APPENDIX VI.

A FEW INSTANCES OF COMPLAINTS OF FOUL EMANATIONS FROM DRAINS, AND OF ACCIDENTS THEREFROM.

THE following cases are extracted from the columns of the Press during the past ten years. They are obviously typical of numberless incidents of the same kind which have occurred in every part of the United Kingdom ; and it is safe to say that they might be paralleled by similar occurrences all over the civilised world.

245. SEPTIC TANK BLOWN UP.

The septic tank at Sheringham blew up at about four o'clock yesterday afternoon, killing two men and injuring several others seriously. Three fishermen who were sitting on the top were blown down the slip-way. Boats that were standing upon the top were lifted clean into the air, and three were blown to pieces.—*The Daily Express*, May 2, 1903.

246. THE SEWER FATALITY. COUNCIL EMPLOYÉ'S TERRIBLE DEATH. HEROISM IN FOUL ATMOSPHERE.

[From *The Surrey Comet*, Aug. 13, 1904.]

The fatal disaster, as reported in our Saturday edition, in which an employé of the Surbiton District Council, John Thomas Moore, met with his death, while inspecting a sewer belonging to the Council, was inquired into by the Coroner, Dr. M. H. Taylor, J.P., at the Assize Courts, Kingston, on Saturday evening.

Mr. F. J. Bell, Deputy-Clerk to the Surbiton Urban District Council, watched the proceedings on behalf of that authority, and Mr. S. Mather, Surveyor, was also present.

The Coroner said the jury had to enquire into the case of a man employed by the Surbiton Urban District Council in connection with sewer work, and who was found in an unconscious condition, from which he could not be resuscitated, at the bottom of a manhole. It was for the jury to say whether his death was brought about by accident, and whether sufficient precautions were taken by the District Council to safeguard their employés.

Mr. Bell, in intimating that he represented the Surbiton District Council, observed that he should be pleased to give every information he possibly could to throw light upon the very tragic and regrettable occurrence. The deceased was an old and very much respected servant of the Council, who desired to express their regret at the unfortunate accident.

Harry Moore, a lamplighter, living at Bonner's Hill-road, Norbiton, identified the body as that of his father, who was 49 years of age. He had been in the employ of the Surbiton District Council for the past twenty-three years, his work being mostly in connection with the sewers. He was quite experienced in his work.—The Coroner: Did you ever hear him complain of suffering from the effects of foul air in the sewers?—Witness: No, I had never heard him say so.—The Coroner: He was a man in fairly good health, wasn't he?—Witness: Yes, sir.

Mr. William Edward Mott, a sanitary engineer, residing at Maple-road, Surbiton, deposed that at about half-past eleven o'clock on Thursday morning, he was cycling along the High-street, Kingston, when he saw a man standing by the side of an open manhole. Witness pulled up at the premises of a cycle maker near by, and remained for a short time in the show-room talking to the proprietor, when suddenly he heard some shouts, and on running into the road he was told that two men were down the manhole drowning. He ran across to the manhole, and after taking some deep breaths he leant over the opening in order to ascertain the state of the air, to see if it was safe to venture down. Mr. J. Wilcox came up and volunteered to descend to the assistance of the men, but witness advised him not to do so, explaining that there was too much foul gas in the sewer to permit anyone to go down with safety. Some men ran to the riverside for boat-hooks, and witness, seeing Dr. Townshend Chambers passing on his motor-car, asked him what was best to be done under the circumstances. The doctor replied that he would drive into the town and obtain some oxygen, and while he was gone endeavours were successfully made to rescue the men by means of the boat-hooks, and Dr. Chambers, assisted by some police-constables, succeeded in resuscitating one of the men.—The Coroner: When you looked down the manhole which way were the men lying?—Witness: I could see very little. I saw one man lying beneath the water. The other man seemed as though he had slipped. He was lying in a collapsed heap, but with his face out of the sewage. —Coroner: When the first man was brought up did you see the position the other man was in?—Witness: No, I did not. In reply to further questions from the Coroner, witness said he was acquainted with the nature of drains, and knew that foul gases sometimes accumulated in sewers.—Coroner: Even supposing the sewer is well ventilated, is it advisable for a man to go straight down?—Witness: No, I should think it would be risky to go down into a sewer at all without taking the cover off another manhole. The men should wait, while the cover of another manhole is removed, and allowed to remain off some time.—Coroner: What about Mr. Wilcox?—Witness: He said he would go down, but I advised him not to, as I did not think he could remain down long enough to secure a rope around the men. Besides, boat-hooks had been sent for. But he went down. A rope was tied round him, and he placed a handkerchief over his mouth. His feet reached the bottom of the sewer, and then he called out to be drawn up again, as he could not stand it.

Mr. Joseph Wilcox, butcher, of High-street, deposed that at about half-past eleven o'clock on Thursday morning he was in his shop, when he heard a commotion in the street. When he reached the manhole the second man, Wild, had gone down to Moore's assistance. Wild reached the bottom of the sewer, and stooped to lift Moore out of the drain. He held him for a second or two, and then relaxed his hold and fell back with a groan, in a state of collapse, against the side of the drain. There was a chain or rope hanging from above, and Wild stretched out his arm as if to clutch it, but directly he touched it his hand fell helplessly by his side. No one seemed to know what to do to assist the men, who appeared to be dying below. No suggestions were made, so witness volunteered to go down and endeavour to effect a rescue. Mr. Mott was there, and after examining the air in the drain he pronounced it dangerous for anyone to venture into, and advised witness not to go down. Witness, however, decided to descend, and after having a rope secured around him he went down, but when he got to the bottom he become dizzy and felt suffocated. He remembered nothing more until he found himself on the top again. There was a peculiar smell in the sewer, added witness, and he could not breathe there at all.—The Coroner: You did your best to save the two men.—Witness: I did try to, sir.—Coroner: Did the air make you sick?—Witness: No, but I kept retching.—Coroner: You are all right now?—Witness (cheerily): Yes, sir.—Mr. Bell: The District Council desire me to thank Mr. Wilcox for the plucky efforts he made to save the two men.

P.C. Liebermann stated that on Thursday morning he was called to the manhole, around which a crowd of people had collected. When he arrived, Mr. Wilcox was just being drawn out. Some boat-hooks were procured, and Wild was hooked by the belt and brought up to the surface. He showed signs of consciousness, and Dr. Chambers attended to him. Moore was afterwards brought up in the same way, and witness, with P.C.'s Elliott and Lovelock, used artificial means of respiration in an endeavour to resuscitate him. Witness understood the methods to be employed, as he was acquainted with First Aid. After an hour's hard work, Dr. Chambers pronounced life extinct, and the body was removed to the mortuary, and Wild was conveyed to the Surbiton Cottage Hospital. On recovering consciousness, Wild said that he heard Moore cry for help, and he descended the manhole to his assistance, but he was overcome by the foul air. Wild was still in hospital.—Coroner's Officer: He is going on very well.—In reply to Mr. Bell, witness said that deceased was lying in the sewer with his face upwards, but under water.

Mrs. Palmer, of 54 High-street, Kingston, was next called, and deposed that at 10.45 on the Thursday morning in question, she saw the deceased and Wild take the top off a manhole in the road near her shop. She had seen them do the same thing many times before, but they had never descended into the sewer immediately. They had generally stood by some time. On this occasion, however, one of the men went down within five minutes from the time the trap of the manhole was removed. The other man remained on the top. Shortly afterwards witness heard someone call out for a ladder, and then one of the men was brought into her shop. It was Wild. He was attended to by a doctor and some policemen, and other people, and the police worked very hard in their attempt to bring the man round.—In reply to questions from the Coroner witness repeated that the deceased did not wait long before descending into the sewer. Usually the men remained talking together for a considerable time before going down.

Thomas H. Whitewick, road foreman to the Surbiton District Council, and residing at Tolworth, stated that deceased had been under him for the past six or seven years. He was employed in repairing the roads and in attending the sewers, in which work he was well experienced.—The Coroner: Have you any general instructions from the Council as to precautions to be observed in the inspection of sewers?—Witness: Yes sir. The men are required to take the manhole covers off some considerable time before going down.—Coroner: How are you to know what time is sufficient to enable the foul air to escape?—Witness replied that if the men were not satisfied that the air was clear, they tested it with a light, which was lowered into the sewer. If the light remained burning it was safe for them to descend. The quicker it was extinguished the more dangerous was the state of the air. Without using that test, the usual time occupied in clearing a sewer of its foul air was about ten minutes. —Coroner: Is it customary to have another manhole open?—Witness: They had instructions to have two open; three if possible.—Coroner: These instructions are received from the Surveyor?—Witness: Yes. Coroner: Can you say that Moore was acquainted with these instructions?—Witness: Yes, sir. Continuing, witness said that on the morning of the fatality he saw the deceased and Wild at work at a manhole opposite St. Raphael's Roman Catholic Chapel in Portsmouth-road. Deceased was down the manhole, and witness asked him how he was getting on, and he replied "Very well indeed."—Coroner: What was he inspecting at the time?—Witness: The depth of the silt. Deceased, the witness proceeded to relate, came to the surface and witness instructed him to go direct to the Kingston Sewage Works, to ask the people there to keep the sewage down; then to take the depths in the manhole under the railway bridge, and afterwards to work his way back. Witness then left the men, and cycled out to Hook and back to Tolworth, where he was told of the occurrence at the Town's End sewer, and having some apprehension that the man who had been suffocated must be Moore, he went down to the spot and found that his misgivings were unfortunately correct.—Coroner: With regard to Wild. Inspecting sewers was also his occupation?—Witness: Yes.—Coroner: Did he know of the precautions that had to be taken?—Witness: Yes.—Coroner: When these men go down into the sewers is there anything else they do?—Witness: They always carry a life-line.—Coroner: Deceased should have attached it to his body?—Witness: Yes.—Coroner: Was this rule of a life-line one of the regulations of the District Council?—Witness: Yes, and it should have been used.—Coroner: Have you any reason to believe it was not used on this particular occasion?—Witness: It was not used. Witness proceeded to read a list of the articles with which deceased was furnished upon leaving the depôt to commence his work. A life-line was included in the list. In reply to the Coroner, witness remarked that for the sake of ventilation and protection, other manholes were usually opened when the men were at work in the sewers.

Mr. S. Mather, Surveyor to the Surbiton Urban District Council, bore out in evidence, all that had been said by the road foreman in respect to the instructions given to the men and the precautions they were required to exercise when engaged on sewer work, and he put in a plan showing the position of the manhole in the section of the sewer where the accident occurred. After explaining the details of the plan to the jury, the Surveyor said that had the cover of a neighbouring manhole been removed before the men descended into the sewer, the accident might not have occurred. It was very difficult to get the men to carry out the regulations. They were instructed to carry life-lines which were supplied by the Council, and the men knew where they were kept. Deceased was a very competent and steady man, and on account of the objectionable nature of the work upon which he was engaged his wages were increased, and he was kept specially for the work.—Coroner: Is there no special time for the manhole covers to be off before the men descend?—Witness: I don't think they should be off less than twenty minutes or half-an-hour.—Coroner: There is no inclination to rush these men in their work?—Witness: No, sir. On the contrary, I myself have rebuked them before now for unduly hurrying. Witness added that he had a theory that the two men hurried because it was getting near their dinner-hour, and they wanted to get the job finished so as to partake of their meals-—A Juror asked why the sewer was not ventilated.—Coroner (to witness): Do you say that the sewer is not properly ventilated?—Witness: It is not efficiently ventilated. We have done all that we can possibly do in the matter. I think an objection was made by the Kingston Corporation when the Surbiton Council wished to more efficiently ventilate the sewer.—Mr. Bell observed that he had endeavoured to look up certain correspondence on the matter, but he had not succeeded in doing so. On one occasion he remembered the Council wished to put in an extra manhole, but they were refused permission to do so by the Kingston Corporation. He forgot for the moment on what grounds the objection was made.—Mr. Mather: It was practically an absolute refusal. We are quite at the mercy of the Kingston Corporation in respect to this sewer. Having to run a sewer through their district we have to accept their terms. Mr. Mather added that the sewer extended from the boundary of the two districts to the Sewage Works, and was 5795 ft. in length.—Coroner: Do you think that if this sewer had been ventilated the same as those in Surbiton the accident would not have happened?—Witness: Oh, no I would not like to say that.—Coroner: The men would have been quite safe had they carried out their instructions?—Witness: Yes. If Moore had had a life-line, it would have been held by his mate. Coroner: You think it was more their fault than the fault of the sewer?—Witness: I think I must admit it was so. In reply to further questions Mr. Mather said that no matter what kind of ventilation deceased had been in, the accident might have occurred had he failed to have taken the precautionary measures laid down.—By a Juryman: It was a rule that deceased should test the sewer with a lamp.—Coroner: So it would have been his own fault if he had not got a lamp?—Witness: Yes, it would have been his own fault.

Dr. Townshend Chambers, of Uxbridge Road, Kingston, told the Coroner that on the previous Thursday morning, as he was driving along the High-street, Kingston, in his motor-car, he noticed a group of people standing in the centre of the road around an open man-hole, and, remarking to his chauffeur that something appeared to be wrong, he slowed up. At the same time he was told by the witness Mott and a policeman that two men were down the sewer, and it was thought they were dead. Witness looked down the manhole and saw the head and shoulders of one of the men, and he gave instructions for them to be got out as quickly as possible, while he drove into the town for some oxygen. Wild was first got out of the sewer, and was carried into the garden at the rear of Mrs. Palmer's shop. Dr. Donald was there, and looked after the man, while witness went to attend to Moore, who had also been got out. He was alive when he was brought to the surface, but very far gone. Artificial respiration was employed by the police, who did their work very well and laboured very hard, but without avail. Witness returned to Wild and administered oxygen, and in about a quarter of an hour he recovered consciousness, and looking round exclaimed "Where am I?" He was then sent to the Surbiton Cottage Hospital. Witness did not administer any oxygen to Moore. It would not have been any use doing so, as they were unsuccessful in promoting respiration by artificial means. Witness thought at the time, and his theory had since proved correct, that Moore's condition was caused by fluid and not by foul air. Witness had made a post-mortem examination of the body, and found a long and deep gash on the cheek, which had been caused before death, probably when the man lost consciousness and fell forward. Death, he was of opinion, was due to asphyxia from drowning. In reply to the Coroner, the doctor said there was every symptom of poisoning from foul air.

The Coroner summed up briefly. The first thing the jury had to do, he said, was to find the cause of death, and in that they would no doubt agree with the doctor. With regard to the precautions taken to safeguard the men, the jury had heard the evidence of Mr. Mather and the road foreman, who told them that strict rules were laid down, and that deceased had been in the employ of the Council for a great number of years, and was a thoroughly competent man. Mr. Mather had made a plausible suggestion which threw light upon the deceased descending into the sewer so soon, and that was that his dinner-hour was approaching, and he was getting hungry. The Coroner thought the jury had better leave the question of the ventilation of the sewer to the Surbiton Council and the Kingston Corporation. Had the sewer been ventilated according to Mr. Mather's ideas, it was impossible to say whether the deceased would have exercised the precautions laid down.

The jury, after retiring, returned a verdict of "Death by misadventure," and added as a rider that they were of opinion the Surbiton District Council had made all provision they reasonably could for the safety of the deceased, who, however, did not avail himself of the opportunities offered in respect to the use of a life-line, etc. On the face of the evidence, they considered that the long length of sewer from the Kingston boundary to the Sewage Works should be more efficiently ventilated. The jury added that they desired to commend the actions of Messrs. Wilcox and Mott, and P.C.'s Liebermann, Elliott and Lovelock, considering that by their energy and promptitude, superintended by Dr. Chambers, one man's life was saved, and they desired that the Coroner would bring the conduct of the three constables to the notice of the Commissioner of Police. They further wished to thank Mrs. Palmer for her very great kindness in the case, and in conclusion they expressed deep sympathy with the widow and family of the deceased.

The Coroner remarked that he fully agreed with all that the jury had said. What the people mentioned had done was excellent in every way. Mr. Wilcox, who risked his own life, was especially deserving of very great praise. (Applause.)

Mr. Bell said he very heartily concurred in the jury's commendation of the great pluck shown by Mr. Wilcox, and the valuable services rendered by the others.

The Coroner: The action of these gentlemen is in marked contrast to the conduct of two men at Barnes the other day. A crippled boy appealed to them to save a young boy who had fallen into the river, but all they remarked was, "Let him go down," and walked away.

The Funeral.

Amid every token of respect the funeral of the late John Moore took place on Tuesday afternoon at Kingston cemetery, and was attended by the majority of the District Council officials and employés, the latter preceding the cortege from the deceased's residence in Cadogan-road. The coffin was covered with beautiful wreaths, including one from the Council officials, while the deceased's comrades sent an everlasting wreath to be placed upon the grave. At the express wish of the widow the whole of the funeral service was held at the graveside, on account of the large assembly of friends. This was conducted by the Rev. J. H. S. Taylor, and was of an impressive character. The undertakers were Messrs. Seth Curtis and Son, of Cleveland-road.

Letter from the Coroner. To the Editor.

Sir,—In the notice of the above published in to-day's issue of your paper, the name of Wild, the man working with the deceased man Moore, is not mentioned. I regret this omission, as Wild is deserving of the greatest praise for his efforts to save the life of his comrade. It came out in the evidence that, when he saw Moore overcome by the foul air at the bottom of the manhole, he went down at once, without waiting to take the least precaution, and endeavoured to rescue him. It was only by the help of the bystanders at the surface who witnessed Wild's efforts, and saw him overcome in turn, that he was fished out in an unconscious condition and resuscitated. When commenting on the case I failed, through inadvertence, to dwell upon Wild's plucky efforts, and I would now repair that error. We are justly proud of the soldier who risks his life to save a comrade, and we are pleased to see him rewarded by the highest honour which can be conferred on a soldier. The action of the soldier is usually performed in the heat of battle, when men's blood is up, whilst the conduct of Wild was under far different circumstances, and far different surroundings. Which is the braver act?—Yours faithfully,

M. H. TAYLOR.

Tudor-house, Twickenham: August 10, 1904.

[∴ Dr. Taylor cannot have read our report very carefully. So far from the name of Wild not being mentioned, it occurs eleven times in the evidence, which was reported fully on account of the importance of the case.—*Ed. S. C.*]

The circumstances under which an employé of the Surbiton District Council lost his life last week, in the outfall sewer which runs through Kingston to the Sewage Works, are reported fully in another column. Unhappily, as is so often the case in dangerous occupations, there seems to be no doubt that the man lost his life through neglecting to take the most ordinary precautions to ensure his own safety. The life-line provided by the District Council for his use was left on the top of the manhole; the lamp which would have given warning of the presence of the deadly sewer gas was not lighted; and the cover of the next manhole was not removed, so that there could be no current of air to drive out the poisonous fumes. Consequently the jury had little difficulty in coming to the conclusion that no blame rested upon the District Council or its officers for the unfortunate fatality. The deceased's companion, Wild, who went to his rescue, and Mr. Joseph Wilcox, who courageously descended the manhole after both the sewer men had been rendered insensible, narrowly escaped with their lives, and the commendation of their conduct by the Coroner and jury was well deserved. Happily, in this country, there are never wanting brave men and women who, at a moment's notice, are ready to respond to the cry of distress, and to risk their own lives in the effort to save the lives of their fellow-creatures. On the question of the ventilation of the sewer there will doubtless be divergence of opinion. The jury expressed the view that it should be more efficiently ventilated, and the officials of the Surbiton District Council sought to cast the responsibility for its lack of ventilation upon the Kingston Town Council. The fact is that sanitary engineers are by no means agreed on the question of sewer ventilation. It is generally held that house drains should be well ventilated; but as to main sewers we have heard competent engineers say that they would like to keep them, if possible, hermetically sealed. They argued, and with a good deal of force too, that the proper place for sewer gas was in the sewers, and that if it were allowed to escape it would in all probability work mischief. It is well known that diphtheria and other zymotic diseases are traceable to the presence of sewer gas; and there are few problems more difficult than the provision of a perfect system of sewer ventilation. To this fact the Surbiton District Council and its officials cannot be strangers, for when they attempted to introduce a system of sewer ventilation some years ago on Surbiton Hill, it occasioned a great outcry amongst the residents, and the utmost difficulty was experienced in securing sites for the ventilators.—*Surrey Comet*, August 13, 1904.

247. Five men were badly burned yesterday by an explosion of gas in a sewer in Spa-road, Bermondsey.—*Daily Mirror*, December 21, 1906.

248. Two men were at work on Friday last (April 20, 1906) at Sutton, near Birmingham, when an explosion occurred. Both were badly injured, the windows of the houses in the vicinity shattered, and the sewer grating lid hurled a distance of 40 yards, several pedestrians having narrow escapes.—*Surveyor*, vol. 29, p. 466.

249. Sewermen Rescued in Southwark.

Four sewermen of the L.C.C. were in a sewer under Great Suffolk-street, Southwark, at 2.30 to-day, when three of them were overcome by sewer gas. The fourth man managed to reach the ladder and scramble up into the street, where he gave the alarm by calling the fire-brigade. A number of firemen from the Southwark headquarters, with apparatus for such emergencies, proceeded to the scene, and succeeded in rescuing the three men, two of whom were in a very serious condition. The men were taken to Guy's Hospital. —*The Westminster Gazette*, August 7, 1907.

250. Poisoned by Sewer Gas.

The Surveyor reported to the Roads Committee that one of the Council's employees, Driver William Olding, contracted illness whilst clearing out the sewerage tank at the Swan Street Pumping Station on the 31st January, and died on the 8th February, the medical certificate showing that death was due to poisoning by sewer gas and other causes, and that he had communicated with the Insurance Co., who sent one of their Inspectors to Torquay to investigate the matter with him, and he now awaited the Company's report. At a subsequent meeting the Surveyor reported that he had received a communication from the Insurance Co. in this matter, enclosing cheque for 75*l*. made out to the widow as full compensation so far as they were concerned under the policy, and that after consulting with the Town Clerk he had handed the cheque to Mrs. Olding, who had signed the special receipt sent by the Company. After considerable discussion as to whether any further compensation was due from the Corporation, it was resolved that the further consideration of the question be taken at the next monthly meeting.

Councillor Pike moved the acceptance of the minutes of the Roads Committee, with the exception of those having reference to the proposed Torwood Mount widening.

Councillor Kenny seconded, and the minutes were accepted.—*The Torquay Times*, March 9, 1907.

251. Explosion at Sewage Works. Councillor's Narrow Escape.

"An extraordinary explosion of sewer gas occurred on Friday night at the Little Hulton District Council's Sewage Works, near Walkden, the roof of a tank 40 yards long, lined with brick and concrete, being blown away. Mr. John Kilburn, a member of the Little Hulton District Council, and two daughters were standing close by, and Mr. Kilburn was blown into the tank. A young man named James Eckersley, living close by, ran to the spot, and leaning over the edge of the tank with a hoop succeeded in pulling Mr. Kilburn out in an exhausted condition. Eckersley was almost overcome by the gas, and was in danger of being pulled in when another man named Heyes came to his assistance. It is thought that the throwing down of a lighted match may have caused the explosion."—*The Manchester Guardian*, April 6, 1907.

252. Overcome by Sewer Gas. Narrow Escape of Six Men in Southwark.

Half-a-dozen sewer men had a very narrow escape from a terrible death in Southwark yesterday afternoon, and were only saved by the active intervention of the members of the London Fire Brigade.

The men were working from a manhole at the corners of Southwark Bridge-road and Great Suffolk-street, when they were overcome by sewer gas. The manhole was open at the time, and the first intimation that people above had that anything was wrong below, was the fact that a lad, who had been peering down the manhole, fell back into the street overcome by the fumes.

The alarm was quickly raised, and contingents of firemen from the adjoining station and Whitefriars were soon present with smoke-helmet appliances. Exciting scenes followed. The firemen descended into the sewer, and cheers were raised as the six men, one after the other, were brought to the surface. One poor fellow was so completely overcome that he had to be dragged to the manhole by ropes.

The men were removed to St. Bartholomew's Hospital, and all, with the exception of one, had sufficiently recovered by the evening to proceed home. Thomas Ansett, belonging to Catford, is still detained in the institution.—*The Tribune*, September 1, 1907.

253. Defective Drains. Ipswich House Owner to pay Damages. Widows at Law.

At the Ipswich County Court on Thursday, before his Honour Judge Eardley Wilmot, Mrs. Ellen Eliza Gunn, widow, sued Mrs. Harriet Maria Seager, widow, of Ipswich, for £100 damages under the following circumstances:—The plaintiff claims, as administratrix of the personal estate and effects of Fenn Robert James Gunn, deceased, on behalf of herself (the said F. R. J. Gunn's widow), the infant child of the said F. R. J. Gunn, and Pamela Gunn, the mother of the said F. R. J. Gunn, for compensation under the Statute 9 and 10 Vic., chap. 93, for the loss of the said F. R. J. Gunn, by reason of the negligence and default of the defendant in letting to the said F. R. J. Gunn, a dwelling-house, known as 43 Cobbold Street, Ipswich, which the defendant represented to be fit for human habitation and to be equipped with proper and safe drainage, thereby inducing the said F. R. J. Gunn to enter into occupation of the said premises, with his wife and family, and thereby occasioning the loss of the said F. R. J. Gunn and his child through poisoning by sewer gas owing to the faulty drainage of the said premises. The plaintiff also claimed rescission of the lease of the house, which had been entered into for three years. Mr. W. Rowley Elliston (instructed by Mr. J. W. Aldous) appeared for the plaintiff, and the defendant was unrepresented. Mr. Elliston stated that Messrs. Turner and Turner had been acting for the defendant, but they had given notice to the defendant that they had ceased to do so.

Mr. Elliston first called Mr. Herbert Wright, auctioneer and valuer, to prove formally that the house was under the value of £500, as there had been a question of jurisdiction raised. He then proceeded to outline the case briefly, stating that the claim was brought under Lord Campbell's Act, and the facts revealed a shocking state of things, and a very sad state of things, because the defective nature of the drainage of the premises at 43 Cobbold Street, led to the death of the plaintiff's husband, Mr. Fenn Gunn, who was a working tailor, and also led to the serious illness of the plaintiff herself. Indirectly, also, they contributed to the death of plaintiff's child, which was weakened in health by the poisonous sewer gas in the premises. There was, however, no claim in respect of the death of the child. In July last year Mr. Gunn took the house from the defendant, but the first thing he said to her in the negotiations was "Are the drains satisfactory?" He had previously moved from another house on account of the bad state of the drains, so that he was on his guard. Mrs. Gunn was present at the negotiations and could tell the Court that her husband would not go into the question of the house at all until Mrs. Seager assured him that the drains were quite in order. Mrs. Seager had for a year or two lived in the house herself, so that she might be expected to know. When they went to look over the house the question of drainage was again raised, and Mrs. Seager said, "You need have no fear of the drains, they are quite all-right." They moved in in August, the lease being signed on August 20, and very soon after Mrs. Gunn noticed an unpleasant smell in the lower rooms. Mr. Gunn thereupon wrote to Mrs. Seager, saying that for the last few days the basement was quite unbearable owing to very bad smells, which he believed to be due to sewer gas, and asked her to give the matter her attention, as the house was unfit to live in.

His Honour said that he did not remember a case of the sort before.

Mr. Elliston said that it was brought under Lord Campbell's Act, and the section said that wherever the death of a person was caused by the unlawful act, neglect, or default which would, if death had not ensued, entitle the party damaged to maintain an action, then the other party shall be liable as if the dead person had himself brought the action in life.

His Honour said that there was no implied warranty that an unfurnished house was fit to be occupied, but he supposed the plaintiff relied on the reckless statement made by Mrs. Seager.

Mr. Elliston said that was exactly how he should put it.

His Honour said he took it there was no ground of negligence.

Mr. Elliston said that he should put it that Mrs. Seager was reckless in her statement, not caring whether it was true or false, knowing that the plaintiff's husband would act upon what she said.

His Honour said that he did not recollect a similar case.

Mr. Elliston said that he could not refer His Honour to a case in the books, but he was told that there was a few years ago a similar case at Birmingham Assizes, where the family of an Alderman of Birmingham recovered damages for his death on the ground that he was poisoned by sewer gas. The man being dead, there was no other way except under Lord Campbell's Act by which they could recover damages.

His Honour said that Mr. Elliston might take the case shortly, as the defendant was not present or represented, and he would give judgment in his favour. It would then be for the defendant, if she was not satisfied, to show cause why the judgment should be set aside.

Mr. Elliston said that with regard to furnished and unfurnished houses there was authority for the contention that in regard to a vital matter, such as drainage, the house should not be a death-trap.

Mrs. Gunn, widow of the late F. R. J. Gunn, said that she knew from her husband's books that her husband's earnings were 114*l.* a year nett. She bore out her counsel's statement as to the facts. Her husband enquired particularly about the drains of the house, and Mrs. Seager said they were quite all right. After they moved in she noticed a smell in the basement, and her husband wrote her the letter that had been read. Mrs. Seager came to see them, and said that she had noticed a smell when she lived there, but that it was nothing to do with the drains. Witness's husband used to work in a place at the bottom of the garden, but he burned his foot, and being advised not to go out of the house, he took up his quarters in the basement. He was a heavy smoker, and did not appear to notice the smell, but shortly afterwards he was taken ill, and was removed to the Hospital by the doctor's orders. Her husband was her sole support.

Dr. Heath, medical attendant to the Gunn family, said that in

January 1907 he was called upon to attend the deceased on account of a slight burn. As a result of this accident, Mr. Gunn had to work in the house, and developed typhoid, which he attributed to sewer gas, which was present in the basement room where he worked. Witness had no doubt that it was sewer gas, after he had entered the room. On the 9th of February he communicated with the town authorities, and the Medical Officer of Health ordered the house to be closed. The deceased was removed to the Fever Hospital, where he died. Witness was satisfied that his death was due to illness brought on by sewer gas. He was satisfied that the man's death was due to poisoning by sewer gas. He saw the drains when they were opened, and never saw drains in a worse state.

Judgment was given for the plaintiff for 100*l.*, and costs, and the rescission of the lease was formally granted.—*East Anglian Daily Times*, September 20, 1907.

254. Sewer Heroes Rewarded.

In the Eaton Rural District Council Chamber at Slough yesterday, Richard Grantham and Albert Stevens were presented with the bronze medals and certificates of the Royal Humane Society for bravery. On descending a sewer at Burnham, near Slough, a man named George Bowler was overpowered by gas, and succumbed to its effects. Grantham in endeavouring to rescue him, was also overcome. Stevens then went down, and after displaying great heroism succeeded in saving Grantham's life.

255. The Order of the Hospital of St. John of Jerusalem in England has decided to bestow upon Stevens a silver medal and on Grantham a bronze medal in recognition of their gallant conduct. The Prince of Wales, as Grand Prior of the Order, will make the presentations at Marlborough House on a date to be fixed by his Royal Highness.—*The Westminster Gazette*, September 25, 1907.

256. Death of a Sewer Flusher. Poplar Sewer Flusher's Fatal End. Strange Evidence.

At the Poplar Coroner's Court on Tuesday, Mr. Wynne E. Baxter, the East London Coroner, and a jury were engaged for a considerable time in investigating the death of Walter Smith, aged 37, a sewer flusher in the employ of the Poplar Borough Council, late of 29, Tibbatts Road, whose death was alleged to be due to poisoning by sewer gas, contracted in the course of his employment. Mr. W. M. Thompson watched the proceedings on behalf of the widow, who gave evidence, and stated that the deceased had always been a strong, robust man. On Thursday evening he returned home with his clothes wet from being down the sewer, and complaining of acute pains in the stomach. He was subsequently seized with severe vomiting and trembling, and died the next day. Witness said that deceased had not eaten any fish to her knowledge. He had frequently complained of the effects of the gas in the sewers, and had been medically attended. By Mr. Thompson: He used to smell very strongly of gas when he came home. At times the deceased had long hours.

Walter Elliston, a lodger, said the deceased had often complained to him that the sewer gas had affected him.

William Bray, mate of the deceased, said they had been working together for three days at the sewer in Leven Road, near the gas-works, to relieve a bad blockage. The smell was very bad all the time; they both had to be frequently pulled up on account of becoming giddy, and when they reached the top they were like "drunken men." On Thursday, the day the deceased was taken ill, the gas was very bad, and deceased complained several times. Witness had also been queer.

The Coroner: There is a suggestion that your hours are long?

Witness: We work overtime.

The Coroner: Do you get paid for that?

Witness: No, sir; we get time allowed.

By the Coroner: Deceased had had his meals with him, and he had not seen him eating any fish.

Mr. C. E. Green, Chairman of the Works Committee, gave evidence, and stated that printed regulations were supplied to all sewermen, and other evidence was given to prove that all the regulations had been complied with in this case.

Dr. Kirk Toland, who attended the deceased, expressed the opinion that the death was due to ptomaine poisoning, and not in any way connected with sewer gas. Deceased himself said that he had been eating some fish.

Dr. Percy John Clark, of Spital Square, divisional surgeon, who made the post-mortem examination by order of the Coroner, deposed that the death in his opinion was due to ptomaine poisoning, and not the result of sewer gas.

After considerable discussion the jury returned a verdict of "Death from ptomaine poisoning."—*East London Advertiser*, November 9, 1907.

257. A Malvern Hydro.

The fifth day of the trial of the action which Dr. Fergusson, proprietor of a hydropathic establishment, is bringing against the Malvern

Urban District Council, saw the close of the case for the plaintiff, and the opening of the defence. Dr. Fergusson seeks damages from the Council on account of losses sustained through an outbreak of typhoid fever at the hydro, which he alleges was due to pollution of his water supply by sewage from the Council's drains. Defendants deny this allegation, and plead contributory negligence on the part of the plaintiff.

Dr. Otto Carlo Prausnitz, bacteriological expert, was re-examined by Mr. McCall, K.C., for the plaintiff. He stated that he was not aware of any "explosive" outbreak of typhoid fever ever having been due to any cause than food and drink.

By leave of his lordship, Mr. Lush, K.C., for the defendants, then put certain questions to Dr. Fergusson in reference to the damages which the latter is claiming. Plaintiff mentioned the following sums as having been paid by him in respect of the several claims :—

£1,000 Mr. Openshaw, and £200 costs, plaintiff's own costs being £200.
£813, Carter.
£260, Mr. Wetton.
£110, Phyllis Read.
£1250 and costs, Mrs. Merton.
£200, and costs, Miss Hope.
£395, Mr. and Mrs. Ball.
£23, Olive Nash.

He also paid to the relatives of Lilian Davis, deceased, 10*l*., and to the mother of Emily Plumridge, deceased, 5*l*. There were further claims for the damage to his business, as to which evidence would be given by his auditor. The latter, it was stated, had not arrived from Worcester, being possibly delayed in the journey by the fog.—*Daily Telegraph*, January 22, 1908.

Pollution of Water by Sewage.

Judgment in this case was delivered to-day. The arguments were concluded on Friday last, and are reported in *The Times* of Friday and Saturday. It was an application by the defendants for judgment or a new trial in an action tried before Mr. Justice Lawrance and a special jury. The case is reported in *The Times* of January 14, 17, 18, 22, 23, 24, 28 and 29. The action was brought by Dr. Fergusson, the lessee and proprietor of a hydropathic establishment at Malvern, to recover losses which he had suffered owing to his visitors having contracted typhoid fever, as he alleged, by reason of the defendants having negligently allowed sewage to contaminate his private water supply. The defendants pleaded (1) that the loss was occasioned by reason of the defective construction of the plaintiff's water-pipe; (2) that the typhoid fever was caused by the drainage system of the plaintiff's establishment being defective. The learned

Judge at the trial left certain questions to the jury, which, with their answers, were as follows: (1) Had the plaintiff any proprietary interest in the water flowing from the Tudor well into his tanks?—No. (2) Had the plaintiff any license from the owners to use the water? —No. (3) Were the defendants guilty of negligence in permitting sewage to escape from their sewer?—Yes. (4) If yes, was the plaintiff guilty of contributory negligence?—No. (5) Was the escape of sewage from the sewer the cause of the outbreak and the illness, or was the outbreak due to the state of the drainage of the house, or due to both causes?—The escape of sewage was the only cause. (6) Could the outbreak of illness have been prevented if the plaintiff had acted with reasonable care?—No. (7) What were the damages?—7500*l.* The learned Judge directed judgment to be entered for the plaintiff for 7500*l.* and costs. The defendants now moved for judgment, or in the alternative for a new trial. The grounds of the motion were, *inter alia*, that upon the findings of the jury the defendants were entitled to have judgment entered for them; that there was no evidence of any duty by the defendants towards the plaintiff not to pollute the water in question, or to take care not to pollute it; that there was no evidence of negligence or breach of duty on the part of the defendants; and that the learned judge had mis-directed the jury.

Mr. Montague Lush, K.C., Mr. Montague Shearman, K.C., and Mr. H. A. McCardie appeared for the defendants; Mr. McCall, K.C., Mr. Macmorran, K.C., and Mr. Southall appeared for the plaintiff.

The Court allowed the appeal.

Sir Gorell Barnes, after going in great detail through the facts of the case, said that the conclusion he arrived at from the facts and the findings of the jury was that the plaintiff was without the defendants' knowledge taking water from the waste pipe or drain, which carried the water from their land to an old brick pit, some one, not the plaintiff, having at some time or other made a rough connexion with this waste pipe by means of a pipe leading to the plaintiff's dietetic tank at a point about half-way to the brick-pit. The plaintiff did not ascertain the source of this supply until 1902. The water was collected on the defendants' land, and sent down their own waste pipe and the pollution occurred on the defendants' land. The defendants did not know of the connexion, nor did they know of the escape of the sewage which caused the pollution. If the defendants had known of the connexion and that the plaintiff was using the water, a license to use the water might perhaps be reasonably inferred. The plaintiff was using water which belonged to the defendants without any right to do so. There was, in those circumstances, no evidence of any damage to the plaintiff except that which was brought about by his own act in thus taking the water. There was no breach of any duty on the part of the defendants towards him. Judgment must, therefore, be entered for the defendants, with costs there and below. It was, in the circumstances, unnecessary to go into the other points raised.

The Lords Justices delivered judgment arriving at the same conclusion.

Upon the application of Mr. McCall, assented to by Mr. Montague Lush, the costs when taxed were to be paid to the defendants' solicitors upon their undertaking to repay them if the plaintiff appealed to the House of Lords and the appeal was successful, the plaintiff undertaking to present a petition of appeal within six weeks.—*The Times*, May 5, 1908.

258. Alleged Sewer Gas Poisoning at Walsall. Conflict of Medical Evidence.

Yesterday, Mr. T. H. Stanley held an inquest at Walsall respecting the death of Horace Arthur Tivdale, aged six months, son of a whip-thong maker, of Longacre Street. Evidence was given by the parents that the cellar of the house which they occupied had for some time past been in a wet condition in consequence of water running into it from the street sewer, to which it was connected. Recently there had been water in the cellar to the depth of several feet, and, complaint having been made to the landlord, the drain was opened on Friday last and the water allowed to run off. Next day, however, a smell which had previously been observed recurred, and was at times so extremely bad as to be described as almost unbearable. On Sunday evening the child was placed in a cradle in the kitchen, from which room the cellar was approached, and he was subsequently noticed to be very unwell. Dr. Deakin was called in, but the child became worse during the night, and, after being apparently convulsed, death ensued.

Dr. Wilson, borough medical officer of health, who had made a post-mortem examination, said he found no symptom of sewer gas poisoning, and he attributed death to convulsions brought on by teething, accelerated by inflammation of the throat and congestion of the lungs, which he considered to be the result of a cold. In answer to the jury, he said the inflammation might have been caused by sewer gas, but he did not think it accelerated the child's death.—Dr. Deakin said when he was called in the child was in a state of collapse with symptoms such as would occur in a case of poisoning by sewer gas. He noticed a bad smell immediately he entered the house, and had the child removed to another room. He was present at the post-mortem examination, and was satisfied that death had resulted from sewer gas poisoning. As the child was not teething, convulsions could not have arisen from this cause. To make quite sure that his theory was correct he had taken a sample of the child's blood to Birmingham University, where it had been scientifically examined, with the result that his view was fully confirmed.—The Coroner said that in view of the conflict of medical evidence it was advisable to call a further medical witness. He accordingly adjourned the enquiry for this purpose.—*The Birmingham Daily Mail*, February 7, 1908.

Death from Sewer Gas Poisoning.

Yesterday an adjourned inquest was held at Walsall, before Mr. T. H. Stanley, respecting the death of Horace Arthur Tivdale, aged six months, son of a whip-thong maker, of Longacre Street. At the opening of the enquiry there was a conflict of medical evidence as to the cause of death, which Dr. Wilson (borough medical officer) attributed to convulsions due to teething, but Dr. Deakin, who had attended deceased, took the view that it was a case of poisoning by sewer gas.—Mr. G. A. Phillips, surgeon, now said he was of opinion death was due to asphyxia, probably produced by convulsions, which was consistent with the accompaniment of poisoned gas.—In reply to the Coroner, he added that if, as stated by Dr. Deakin, the blood when examined by the spectroscope was found to be contaminated with the product of sewer gas, it would point to the absorption of sewer gas and death caused thereby.—A verdict of "Death from sewer gas poisoning" was returned.—*The Birmingham Daily Post*, February 10, 1908.

259. Widow's Claim for Damages for Loss of her Husband.

The hearing of this case occupied several days. It was an action brought by Mrs. Margaret Sophy Brown, the widow of H. W. Brown, formerly farm bailiff at the Three Counties Asylum, near Arlesey, Bedfordshire, in which the plaintiff claimed damages from the defendant, Mr. Francis Noel Butler, as clerk to the committee of visitors of the Three Counties Asylum, for the loss of her husband owing to the alleged negligence of the defendant in supplying impure water for the consumption of the said H. W. Brown, and also in providing him with improper medical treatment under his contract of service. The defendant denied liability.

Mr. Rawlinson, K.C., and Mr. W. A. Casson were for the plaintiff; Mr. Lush, K C., Mr. Clavell Salter, K.C., and Mr. C. Stimson were for the defendant.

Mrs. Brown, the plaintiff, stated that her husband was appointed farm bailiff to the Three Counties Asylum in 1892 at a salary of 125*l.* per annum with a cottage within the asylum grounds. A supply of water was laid on to the cottage. The water was pumped from two wells into softening tanks, and carried thence to water towers, and from there supplied the inmates of the asylum and witness's house. On July 20, 1906, witness and her husband went to Yarmouth for a holiday and returned on July 25. On August 22 her husband first complained of being ill, and on August 24, Dr. Laurie, who was acting as *locum tenens* for one of the medical officers of the asylum, attended him and diagnosed his complaint as a touch of influenza, and said that he might be allowed to eat anything he liked. On September 4, Mr. Brown's temperature was so high that Dr. Laurie suggested calling in Dr. Hughes, a medical officer attached to the asylum, who came to the conclusion that the patient was suffering from typhoid fever. Dr. Laurie attended her husband for 12 days, and during that time the latter was allowed to come down stairs each day. He died of typhoid fever on October 1. The water at times was not fit even for cooking. Witness complained frequently to Thompson, the resident engineer, who said that the committee would not spend any more money on the water, as they had spent so much in softening it. Witness also complained to the steward of the asylum, Ekins, who said the same as Thompson. Ekins said some day there would be a serious outbreak of fever, as the wells were in a very bad state. Rather than drink water at witness's house, Ekins was in the habit of going to fetch soda-water from his own house. There were 1200 people living on the asylum estate. The sewage was conveyed by pipes to a sewage farm. After her husband's death the drains, which passed near the wells, were opened and were found to be in a terrible state. Ekins told her husband that it had been known for years that the drains were in a bad state. Her husband used to drink a glass of water at night and one in the morning.

Cross-examined by Mr. Salter: The wells supplied all the people living on the estate. When her husband returned from Yarmouth he said he never felt so well in his life. She did suggest that Dr. Laurie's negligent treatment of her husband during the first twelve days of his illness was the cause of his death a month later. She was not aware of the fact that the pipe which supplied her house also supplied a brewery company, an aerated water manufactory, and also the male dining-hall in the asylum.

Mr. T. A. Hodges, a jeweller at Hitchen, said that on October 2, Ekins told him that a fissure had been found in the well 7 ft. below the surface through which sewage matter had been oozing, and that he had seen water coming out of the tap at Brown's house absolutely filthy.

Mr. W. H. Scott said that he had been engineer at the asylum from 1895 to 1900. He examined the wells from time to time and found them in a filthy condition. He had them cleaned. There was water oozing through the brickwork which smelt like sewage. He thought it came from defective drains which took sewage from the building. He told the medical officer that water oozed through the brickwork, and mentioned sewage to him, but he pooh-poohed the idea.

Cross-examined: It was about six months after he went to the asylum that he told Dr. Swain that sewage was coming into the wells. He mentioned the matter in his monthly report to Dr. Swain, but the latter asked him to strike it out of his report, and he rewrote the report. Dr. Swain said that it was a matter for himself rather than for witness.

Mr. W. B. Graham, M.Inst.C.E., said that he examined the wells on January 27 last, and found that they had recently been lined with cement 3 in. thick from top to bottom. The wells ought to have been lined with impervious lining made of cast iron so that no water from outside could reach them, and all drains carrying sewage in the neighbourhood of the wells ought to have been made of cast iron instead of earthenware as was the case. The conditions were highly dangerous.

Dr. W. Bullock, lecturer in bacteriology at the London Hospital, said that the failure to detect typhus germs in water would not preclude the possibility of a person having caught typhoid fever therefrom. It was very difficult to detect the presence of typhus bacilli in water among other bacteria.

Mr. E. Bousfield, M.R.C.S., said that he had had twenty years' experience as bacteriologist to municipal authorities. The fact of no typhus bacilli being found in water did not show that the water was free from them. In the whole supply of water to London no attempt was made to find typhus bacilli, but only coli.

Other medical evidence having been called, as well as two witnesses who spoke to Brown's health on his return from Yarmouth, the plaintiff's case was concluded.

Mr. Lush having opened the case for the defendant,

Mr. W. H. Ekins, clerk and steward of the Three Counties Asylum, stated that he had been a great friend of the plaintiff's husband for thirty years. At the beginning of August 1906, Brown told witness that he had been suffering from diarrhœa. On one occasion witness fetched some soda-water from his own house to the plaintiff's, but not for the purpose of drinking it himself. Some one staying at Brown's house had been ordered to drink soda-water, and Brown said that he had forgotten to order it, whereupon witness fetched some of his own. The soda-water was made of the same water that everybody drank. The water was perfectly good. It was occasionally turbid when it was turned in again after having been stopped. In saying to the witness Hodges " He ought to have been alive now," he was referring to the improper nursing which Brown received the first fortnight after he was ill. He asked Dr. de Lisle to authorize the obtaining of a trained nurse for Brown until the committee sat, and told him that he would himself pay the expenses if the committee declined to.

Evidence was called to the effect that Brown suffered from diarrhœa during the early part of August.

Dr. Langworthy Laurie stated that he was in practice at Leicester and had previously had great experience of typhoid fever. In August 1906 he acted as *locum tenens* for Dr. Dixon at the asylum. He saw Brown on August 24, and made a provisional diagnosis of influenza. Typhoid fever and influenza were very much alike in their early stages. He told Mrs. Brown that her husband must be kept in bed on a diet of milk and soda-water. If Brown was given solid food it was entirely against his orders. On August 29, he had his suspicions that Brown's complaint was typhoid fever. What he saw the next day confirmed his impression, and he told Mrs. Brown and pointed out to her how much depended on good nursing. On September 3, spots appeared on the patient and confirmed witness's diagnosis. He did not attend him after September 4, for fear of any possible infection, on Dr. de Lisle's advice. Brown was suffering, in witness's opinion, from ambulatory typhoid with influenza.

Dr. E. W. Goodall, resident medical superintendent of the Eastern Fever Hospital, Homerton, S.E., and Dr. Hughes, junior assistant medical officer at the Three Counties Asylum, stated that in their opinion Dr. Laurie's treatment of Brown was the proper treatment under the circumstances.

Dr. J. F. Dixon, medical officer at the asylum, said that in his opinion Brown was treated in a proper manner by Dr. Laurie. In the summer of 1906, excepting cases of diarrhœa, there were no symptoms of typhoid fever among the inmates.

Cross-examined: Fifteen cases of diarrhœa were put in the infirmary, but none in the isolation hospital. There were four deaths; one patient died of enteritis and another of colitis. A common cause of both diseases was drinking water contaminated with sewage.

Dr. E. Swain said that he was medical superintendent of the asylum from 1876 to 1900. While Scott was there as engineer he never told witness that sewage was percolating into the well. Witness never returned any report of Scott's to him to be rewritten. Scott never complained of anything except the sand at the bottom of the well.

A. Thompson, resident engineer at the asylum, stated that he inspected the wells every Friday. The old adit had been blocked up with brickwork and a cement face. When the valves had been shut and were subsequently opened, the sudden rush of water stirred up the natural deposit of the iron pipes and the lime from the water-softening system. Mrs. Brown complained to him several times of the water not being fit to drink, and he examined the water and found it was turbid, and told her to let it stand.

Cross-examined: He did not report the plaintiff's complaints to the medical superintendent. There were percolations from the old adit into the well, but, not being a chemist, he did not know whether they were contaminated.

Dr. S. E. de Lisle, resident medical superintendent of the asylum, said that the first case of typhoid fever in 1906 was on September 10. The patient had been working on the sewage farm, and told witness subsequently that he was pulling up mangold-wurzels and had eaten a bit of one. There were sixteen cases, all in the male epileptic ward. There was only one case on the female side, and that was a nurse who had just returned from her holiday. Water from the same source had been drunk by the inmates and staff for twenty-four years. In 1903 a nurse had typhoid fever, and in 1902 a male attendant. Sir Thomas Stevenson's reports caused witness to have suspicions of the water, and he caused filters to be used.

Cross-examined: The first patient in the outbreak of 1906 told him he had eaten a turnip, and he had so stated in his report. He did not pin himself to the theory of the turnip, though it seemed to him feasible. When he wrote to Mr. Deacon to come and test the water he said in his letter that water was percolating through the brick sides of the well shaft, and probably through a chink in the shaft 130 ft. down, and that the well was reported to be contaminated by sewage. The latter statement referred to Sir T. Stevenson's report. There were cases of dysentery at the asylum in most years during the summer months.

A. Robinson, clerk of the works, gave evidence as to the satisfactory condition of the drains in January, 1907.

Sir Thomas Stevenson said that he had made an inquiry into the circumstances relating to Brown's death. He thought it probable that Brown contracted the disease twelve days before August 6. Yarmouth was seldom free from typhoid; it was continually being imported by sailors, who were very prone to ambulatory typhoid. Having regard to the facts of the present case, in his view the water supply was certainly not the cause of the outbreak. He could not account for the inmates escaping if the general water supply was contaminated. When he wrote in his report that his examination showed that the well water was contaminated with excrementary matter it was because the bacillus coli was present. Rats might have been the cause of the contamination. If the drains were leaking that also might account for it. The discovery of the typhus bacillus in water was very difficult. The amount of chlorine which he found indicated that such impurities as were present were not caused by sewage. In the water which percolated into the well there was less chlorine than there was in the well water.

Mr. G. F. Deacon, C.E., said that when he stated in his report in October, 1906, "I think there is no room for doubt that the outbreak was caused by the water," he was under the impression that there had been a general outbreak of typhoid fever. When he heard that the outbreak was only partial, he did not think the water was the cause.

Dr. Eustace Hill and Dr. P. Boobbyer, medical officers of health for Durham county and the city of Nottingham respectively, also gave evidence.

Owen Jones, sanitary inspector to the Biggleswade Urban District Council, said that on August 30, 1906, a case of typhoid fever was notified from Arlesey village, three from Shefford were notified in September, and another case from Arlesey in October.

In the course of the case the charge of negligence with regard to the medical treatment of Brown by Dr. Laurie was abandoned.

In the result the jury found a verdict for the plaintiff with 650*l.* damages, and intimated that in their view Dr. Laurie ought to be exonerated from all blame.

Judgment was entered accordingly, and an application for a stay of execution was refused.—*The Times*, March 17, 1908.

260. Willesden Sewage Tragedy. Inquest and Verdict. Brave Attempts at Rescue Praised.

Yesterday afternoon, at the Kilburn Coroner's Court, Mr. Reginald Kemp held an inquest touching the tragic circumstances of the death of George Berry, 48, of Barry Road, Willesden, who, as previously reported in "The Indicator," met with his death by being overcome and poisoned by sewage gas at the Willesden Sewage Farm, Stonebridge.

Mr. Stanley W. Ball, Clerk of the Council, expressed sympathy with the widow, and added that he hoped the sympathy would take a practical form. Berry had been employed by the Council for many years, and always discharged his duties in a very satisfactory manner. The members and officials of the Council greatly deplored the lamentable occurrence.

The widow gave formal evidence of identification and said deceased always enjoyed good health. He left home quite well on Monday morning, and she did not see him alive again.

Mr. O. Claude Robson, Engineer to the Council, explained the method of working, which was in use at the farm. There were fourteen tanks, of which seven were constantly at work. It was necessary occasionally to clean the tanks and for that purpose the water and sludge was drawn off by a sewer. There was a grating at the bottom of the pit, and on Monday morning that grating was found to be blocked with rags and other refuse, brought down by the heavy storms on Sunday. At the time of the accident deceased had gone to the grating by an iron step ladder and was presumably engaged in cleaning out the grating. *The instructions which witness had given were that the cover of the tank should be taken off some time before going down, but perhaps deceased had not done so.*

The Coroner: I suppose they get used to the work and do not take sufficient care.

Witness: It is the old adage, sir, "Familiarity breeds contempt." It was, added Mr. Robson, probably over-zeal on the deceased's part which led to the accident. He was an old and valued servant and was much esteemed by his fellow workmen and the officials of the farm.

Charles Painter, of Carlyle Avenue, a tankman on the farm, said he had worked ten years with deceased. Witness was working a hundred yards away from the deceased on Monday morning, but had left him at the tank a minute before. Witness suddenly missed deceased and on running to the spot found deceased lying at the bottom of the chamber. He at once went down, but was being overcome by the sewer gas when he was pulled out. Deceased was then unconscious. Witness could not say whether deceased went down at once after taking the cover off, but he knew that sometimes he had done so. Once or twice witness had been slightly affected by the gas when he had gone down too quickly. They would never have specific instructions about going down. Berry, being foreman, would know all about the engineer's instructions.

Questioned by the jury, witness said he did not know the work was so dangerous.

The Coroner: I should have thought that a man of your long experience would fully appreciate the danger.

George Brinkley, another employee at the farm, said he had been cautioned by the engineer against going down too soon. Lamps were provided to lower into the tanks to test the quality of the air.

Witness had always carried out these instructions and thought deceased would have done so.

Questioned by Mr. Ball, witness said deceased passed him just before the accident, and said he was going to look at the tank. Witness ran to the assistance of the deceased after Painter and Smith had become unconscious. He helped to pull them out with a rope passed under their bodies.

The Coroner: I should have thought a man's common sense would tell him what to do under the circumstances without precise instructions.

Edward Willis, formerly assistant engineer to Mr. Robson, stated that he had personally instructed the deceased and other men to allow the cover to remain off some time before entering the tanks, to lower a lamp, and, if there remained any doubt, not to descend without a rope tied round them. On several occasions witness had descended into the tanks with deceased, and showed him how all danger could be avoided. These instructions were particularly given to the deceased as foreman. There was no doubt that excess of zeal led to the accident. Everything had been provided for the safety of the men.

Painter, recalled, denied that he had ever had instructions as to lowering lamps. He had seen lamps on the farm, but had not thought they were used for that purpose.

Witness alleged that men had not been allowed time to allow the air to get pure before going down.

The Coroner: I do not believe that you are hustled to such an extent as that.

Frank Smith, another farm servant, said he had not often gone down the tanks, but agreed that they did not have time to allow the air to become quite pure. Witness proceeded to explain how he descended to the rescue of the deceased and the other man who were lying in the tank. He had just time to fasten the rope round the men when he fell down unconscious. Witness had only just come out of hospital, where he had been since the accident.

Alfred Booth, superintendent of the farm, said he gave Berry instructions on Monday morning to take the covers off the tanks and let them remain off for an hour. Berry must have been thoroughly acquainted with the danger of going down before the tank was ventilated. There was danger in taking a naked light down on account of petrol and marsh gas.

Hugh Patrick Lowe, employed on the farm, said the accident could have been avoided if the deceased had been provided with tools long enough to reach the grating without having to descend all the way to it.

The Coroner said there was no doubt that instructions had been given the deceased to leave the covers off the tanks some time before going down. This was a case of familiarity breeding contempt and the deceased did not realise the danger he was running. Everything had been done by the Council that could be done and the affair was a pure accident. He suggested, however, that the Council should post their warning notices at the farm.

The jury returned a verdict of "Accidental death" and expressed a hope that the Council would do all in their power to provide further safeguards against such accidents.

The Coroner then proceeded amidst signs of approval from the jurymen to warmly praise the brave conduct of the men, Humphrey. Lowe, Painter, Smith, and Brinkley, in trying to rescue the deceased, They had without a moment's hesitation gone at the risk of their lives to the deceased's assistance. He hoped that the District Council would recognise the bravery of these men.

Mr. Stanley Ball said the Council appreciated the men's bravery and, he thought, would recognise it. (Hear, hear).—*The Birmingham Daily Mail*, February 7, 1908.

261. Resourceful Constable. Rewarded for Saving Two Sewermen's Lives.

Sir A. de Rutzen, the Bow-street magistrate, yesterday presented Police-constable Wm. Gough, 56 NR, with a cheque for 10*l.* as a reward for his prompt and intelligent action in saving two men from asphyxiation by sewer gas. On May 23 the constable received information that two men who had been testing the drains in Bethune-road, Stoke Newington, were lying unconscious in a manhole. The aperture being small, it was impossible for anyone to descend and pull the men out. Constable Gough obtained a pair of reins from a passing van, and, making a noose in each end, succeeded by this means in pulling the men to the surface, being assisted by a number of the onlookers.

After the first man had been safely brought out the constable instructed some of the onlookers in the use of artificial respiration. He then returned to the manhole and hauled up the second man, who was then apparently lifeless. By practising artificial respiration for half an hour he brought both men back to consciousness. In the opinion of the doctor who had been summoned to the scene both men owed their lives to the constable's prompt action.—*The Daily Mail*, June 4, 1907.

262. SEWER SMELLS AT NOTTING HILL.

The Public Health Committee reported that the medical officer of health had called their attention to the receipt of complaints of offensive smells emanating from the ventilating openings with the new relief sewer of the London County Council serving the northern portion of the borough, which complaints have been confirmed by reports from the district sanitary inspectors. It will be remembered, the Committee said, that in September last similar complaints were before the Council, and that representations were made to the London County Council, as a result of which all the surface ventilators on the sewer in question were temporarily closed, but it would appear that during the recent spell of cold weather the said ventilators were re-opened. They had accordingly given directions for a communication to be addressed to the London County Council urging that the ventilators in Cornwall Road and Clarendon Road, the thoroughfares more particularly affected by the nuisance, shall be again closed.

After hearing a statement by the chairman of the committee, the Council approved of the action of the committee.—*The Indicator*, March 28, 1907.

263. SEWER VENTILATION. CONFERENCE AT GREENWICH.

A conference, convened by the Greenwich Borough Council, to consider the question of the ventilation of the London County Council sewers in that Borough, and the Boroughs of Woolwich, Deptford, and Lewisham, was held at the Town Hall, Greenwich, on Tuesday evening. The Mayor of Greenwich, Councillor C. Stone, presided. Woolwich was represented by Councillors A. Hall, J. Harper and H. S. Syer, the Medical Officer of Health and the Borough Engineer, and the representatives of Greenwich were Councillors Dr. J. G. Parker, J. M. Stone and E. Pascoe Williams, and the Medical Officer of Health and the Borough Engineer. Councillor J. M. Stone explained the danger which was threatened to the Boroughs represented by the fact that the sewage of the whole of South London was taken through there, and the following resolutions were approved :—

"That in the opinion of this conference the ventilation of the new London County Council sewers by means of surface ventilators will be open to grave objection and will constitute a danger and injury to the district, and this conference calls upon the London County Council to adopt some other and less objectionable method of ventilation."

"That owing to the mischiefs likely to arise if the new London

County Council sewers are ventilated by means of surface ventilators, the London County Council be requested to consider the prevention of foul emanations by adopting a system of raised ventilators or other appliances for disposing of the noxious effluvia or alternatively the destruction of the deleterious elements and purification of the gases by electrical or other means."

"That should it be found absolutely necessary to have a ventiator for the sewer while it passes under Blackheath, such ventilator consists of a coke furnace to be placed on a site on Blackheath enclosed in a mound and ornamented by shrubs, and enclosed by a 6 ft. unclimbable fence as far away as possible from any houses, and that the London County Council be requested to consider the question of ventilating the whole length of the sewer by means of coke furnaces."

"That in consideration of the fact that the effluvia from the existing sewer have proved to be an intolerable nuisance and been much complained of by those living in the neighbourhood of the surface ventilators, the London County Council be asked that any improved system which is adopted for the new sewers should also be applied to the existing sewer."—*Kentish Independent*, May 4, 1907.

264. Offensive Sewers in the West End.

Dr. T. Orme Dudfield, Medical Officer of Health for Kensington, in his annual report says that with the return of summer last year the usual shower of complaints began of noxious emanations from sewer ventilators and untrapped street gullies. Owing to the long continued prevalence of hot weather and absence of rain, the complaints were more numerous than in summers of ordinary climatic conditions, and they came from many parts of the borough. Complaints were received with regard to the sewers in Philbeach-gardens, where there are twenty-two untrapped (brick pit) gullies, six surface-sewer ventilators, and one 6-in. by 4-in. shaft ventilator. The nuisance is generally great in this thoroughfare, the sewer discharging at each horn of the crescent into the County Council's main line (Counter's Creek) sewer—a sewer which has often formed the subject of complaint. Serious complaints were again made with respect to the large circular ventilator immediately north of the railway bridge in Warwick-road, at the cab rank nearly opposite to the entrance to the Earl's Court Exhibition, and also with regard to a similar opening at the west end of Pembridge-square, on the County Council's main line ("Middle Level") sewer, and they were temporarily closed. But the most serious complaints came from residents in Clarendon-road and Cornwall-road, the nuisance having begun to manifest itself within a day or two after what is described as the "Relief" sewer came into operation. In last year's report mention was made of a letter received from the Chief Engineer of the County Council, dated July 9, in which it was stated that the said sewer, designed for the prevention of flooding of basements of houses in many streets, would be completed in about a fortnight—as it was. But no sooner had it been brought into operation than complaints of smells began to come in. Two may be cited: "Drains outside 120 Clarendon-road (Cornwall-road corner) are very offensive, and at times the odour is unbearable." "Continuous offensive and unhealthy smells arise from the ventilation holes of new sewer laid through Clarendon-road and Cornwall-road." The latter quotation is from a complaint to the Council signed by many ratepayers. The sewer referred to commences from the Middle Level Sewer at the junction of Basing-road with Cornwall-road, running thence along Cornwall-road, Clarendon-road, and Holland-park-avenue to Upper Addison-gardens, where it discharges into the Counter's Creek Sewer. It is circular in shape, 5 ft. in diameter, and in its course of about 2238 yards is ventilated by seventeen circular gratings 24 in. in diameter. Complaints of the bad smells were received from residents in the vicinity of several of these openings, especially in Clarendon-road and Cornwall-road. Complaints in regard to the Council's own sewers were reported to the Works Committee and the Public Health Committee before the vacation; and during the vacation to the Borough Engineer with a view to compliance with a Standing Order which reads as follows: "*Gullies*—Offensive street gullies to be efficiently trapped. . . ."—*The Builder*, September 21, 1907.

265. Greenwich. Emanations from Sewers.

The Highways Committee reported that they had duly considered the subject of the complaints of the nuisance caused by the offensive emanations arising from the main sewers, referred to them from the Council. The committee have recommended as follows: (*a*) That urgent representation be made to the London County Council to the effect that the emanations from the new sewers are causing the greatest discomfort and nuisance to the inhabitants, and that this council has been pressed to take legal action to obtain the abatement of the nuisance, and that, being advised that the ventilation by surface ventilators is not, under the circumstances, necessary, the Borough Council would be glad to know that the same will be forthwith closed and other means adopted which will avoid the nuisance, and that the London County Council be informed that the

Borough Council feel that the matter is of the utmost urgency and importance to the people of the borough, and that, unless some action is at once taken, the pressure upon this Council will be such as to compel them, reluctantly, to take the matter in hand themselves.

(*b*) That, while this Council feel that they are not in a position, and under no obligation, to specify any works or system of ventilation which would prove adequate for the efficient ventilation of the main sewers, this Council repeats its opinion that a large ventilating pipe carried from the Trafalgar-road sewer to the shaft at the electricity generating station at Hoskins-street, with an electrically driven fan, would materially improve the ventilation of the sewer at this point, and that this Council do urge the London County Council to provide such ventilating pipe.—*The Local Government Journal*, October 26, 1907.

266. East Westmorland Council.

The ordinary meeting was held at Kirkby Stephen, yesterday. when Mr. R. B. Thompson presided over a gathering of about twenty members.

NEWBIGGIN SEWERAGE.

Dr. Craven presented a report, dealing with the liability of traps made of bricks and jointed in cement, to get crushed by the steam roller, when placed by the side of the highway. If the water-seal was lost, as it was sure to be if the brickwork did not remain water-tight, the sewer would be ventilated at the street level. That happened a year ago, when diphtheria broke out in the village and ended fatally, and it would probably happen again. On several occasions, he had reported that the water supply of the village was most seriously defective, many of the inhabitants carrying water long distances. Not only did that lead to want of domestic and personal cleanliness, but it tended to make the drains and sewer detrimental to health. He enclosed copy of a letter received from Dr. T. H. Gibson, Kirkby Stephen, complaining of a foul smell from a gully by the roadside.—The Inspector attributed the smell to the nature of the matter emptied into the roadside grate.—Dr. Craven said it was a moot question whether there was a deposit of solid matter in the sewer, for want of a sufficient force of water, which might account for the diphtheria.—The Inspector stated that there was any amount of fall.—Dr. Craven emphasised the need of a free supply of water, and the Chairman said one was offered, but certain owners had refused it on account of the expense.—Mr. G. E. Thompson stated how the matter stood in regard to the water supply, and offered to again interview the parties principally concerned.—

The Inspector was instructed to make good some defective joints in the sewer, and the water question was deferred.—Mr. G. E. Thompson said it was repeatedly brought to his notice that there was still a stone drain under Mr. Beck's shop, connected with the main sewer, and the Inspector said he thought such was the case. The owner had agreed to have it disconnected.—It was decided that the drain be opened.—*Penrith Observer*, November 5, 1907.

267. Sewer Ventilation.

The committee reported that they had considered the question of sewer ventilation, and recommended that, as an experiment, one of Webb's patent lamps should be purchased and fixed at the top of Upper Yarborough-road.—Mr. Cochrane said the recommendation arose out of the complaints which had been made with reference to the sewer gas, and the danger which accrued to the public. It was hoped that the lamp would satisfactorily consume the gas, and so would rid the residents in the neighbourhood of any annoyance. It should be the endeavour of the Council to make East Cowes the healthiest and happiest town in the Island. The cost of providing the lamp would be 20*l.*—Mr. Groves pointed out that provision was not made in the estimate for the expenditure, and the balance had been cut very fine indeed.—The Chairman said he had intended to call attention to the same point.—Capt. Derham said he pointed out, when the rate was made, that the working balance would be very small. At the same time he would like to say that he had seen the lamps, and found that they answered well.—The Chairman said the Council could provide the lamp during the next half-year. He did not think there would be much danger if the matter was allowed to stand over until then, as it was not until the summer that the smell was particularly offensive.—Mr. Cochrane said that judging by the rate of progress which the Council usually made, they need not worry, as they would not have to pay the amount until 1909.—*Capt. Matthews suggested that it would be well if the Council delayed the matter until they were in a position to provide the lamps necessary to meet the requirements of the whole District, and purify all the sewers at once. A rate of* 1*d. in the* £ *would cover the cost. The matter should be seriously considered, because the high ventilators were as much a source of danger as were the surface ventilators.* The sooner the work was done the greater would be the relief as far as he, personally, was concerned. He was not prepared to say that the present ventilators injuriously affected the health of the people, but *he was satisfied that there was a very great nuisance, and his opinion in that direction would be substantiated by many residents who lived in the neighbourhood* *of the ventilator which the Council now proposed to light up.*—The letter from the firm who would supply the lamps was read by the Clerk. - From this communication it appeared that four lamps, at a price of 20*l.* each, and four costing 15*l.* each—a total of 140*l.*—would be required to meet the demands of the district.—*Capt. Matthews then moved that the matter should be referred back to the Committee for further consideration.—Capt. Derham said he could corroborate what Capt. Matthews had stated with regard to the annoyance to residents. He believed in having fresh air in his house, but owing to the stench from the ventilators he had had to keep his windows shut.*—Mr. Groves said the patent lamps would partly replace the gas lamps, so that the Council would save a little in that direction.—Eventually Capt. Matthews' motion was carried, it being understood that the Surveyor would endeavour to obtain from authorities who had used the lamps information as to whether they could be adopted with advantage.—*Isle of Wight Leader*, January 4, 1908.

268. Ventilating House Drains.

The deputations of the Works and Health Committees appointed to consider the question of the ventilation of house drains, reported that after going very carefully into the matter they had come to the conclusion that the better course is to put the inspection chamber and intercepting trap as near to the cesspool as is possible, and to ventilate the drain by carrying the ventilating pipe up the house from the highest available point of the drain, leaving the cesspool unventilated.—*Rochester Town Council, Chatham News*, July 11, 1908.

269. Sewer Gas at Belford.

The Surveyor had received several complaints regarding to sewer gas coming from the sewers in Belford. There were eight open gratings in the sewers and the stench from these was almost unbearable during the recent hot weather; in fact the smell was so foul that two of the gratings were covered with bags. The nuisance was serious, and could be remedied by having the present gratings removed and airtight covers put on in their places, and if this were done it would be necessary to have ventilating shafts erected in order to get rid of the sewer gas. This could be done at a moderate cost. If the present gratings were removed, trapped street gullies would require to be put in by the County Council to carry off the surface water. He suggested that the matter be referred to Belford Parish Council for their consideration.

The Clerk said he had received quite a number of complaints regarding this nuisance. The Surveyor had told him that day that he had brought it before the Council several times, but nothing had been done. Several people in Belford had recently been suffering from bad throats. He could not say it was attributable to the stench, but the fact remained that there was quite an epidemic. Mr. G. Atkinson Clark, their chairman, was expected back next week, and as he took an interest in these matters he thought they might leave it over till next meeting. He moved accordingly, and his motion was seconded.

Mr. Dixon thought there should not be any more delay, there had been quite enough already, and he moved as an amendment that the matter be referred to the Belford Parish Council to look into the matter. In his opinion that course would expedite matters.

Mr. Humphreys seconded, and on a vote the amendment was carried, the mover and seconder only supporting the motion.—*The Berwick Advertiser*, July 11, 1908.

270. Calne. Meeting of the Urban Sanitary Authority. Dangers of Ventilating Shafts.

The Medical Officer on the Dangers of Ventilation Shafts and Pig-Keeping near Dwelling Houses.—The Medical Officer said he begged to draw the Council's attention to a possible source of danger to the public health arising from the ventilation shafts connected with the sewers. The inner surface of those shafts being of iron corroded by the action of the atmosphere or sewer gas, and the rust falling in scales or powder blocked the bottoms of the shafts, rendering them useless. He had recently seen instances of such blocks, and he had specimens present for their inspection. He suggested that they have some of the shafts opened and a report made upon them, as it was a most important subject and one that required their careful attention. Within the last fortnight he had inspected the houses in Victoria Terrace, and he found five water closets not attached to the sewers but with cesspools, the emptying of which caused much annoyance to the neighbours. There were closets at three houses attached but with no water or flushing apparatus, and also six houses with four closets with no water or flushing apparatus, and at four of the houses they connected with the sewer but there was no water, and the flushing tanks were used as a receptacle for rubbish. On the north side of Victoria Terrace, pigs were kept too near dwelling houses. On the south side within 25 feet of the house, there was a pigstye with three fattening pigs, also some manure evaporating in the sun and filling the air with an unpleasant odour. In another stye there were four fattening pigs and six little ones, and in another six pigs. The smell from these pigs and manure was detrimental to the health of those living in the district and steps should be taken to abate the nuisance and to prevent its recurrence. The Council would remember that the question of pigs being kept too near dwelling houses was brought before them about a year ago, and they then had an instance of the detriment to health, and he did not want a repetition of it. They were sitting on a volcano, which might at any time burst out and injure the public health. Dr. Campbell then showed the members of the Council a portion of a ventilation shaft with the blocked part at the bottom. The Surveyor, in reply to a question, said there were about twenty-six of these shafts in the town. They ought to be so constructed that the lower part could be opened and flushed out occasionally. On the motion of Mr. F. C. Henly, it was resolved that the Surveyor open some of the shafts and report as to their condition. With reference to the closets at Victoria Terrace, Mr. Gale observed that members of the Council seemed afraid to move any motion because there was someone concerned. He moved that in all cases where it was found that the closets were within the regulation distance of the sewer that the owners of the property be called upon to connect. Mr. G. H. Hunt seconded. Mr. Gunning observed that there were plenty of similar cases in other parts of the town and they ought to treat all alike. The Mayor: This is a definite instance which we should deal with first. Mr. Hunt: If Mr. Gunning knows of any other cases he should bring them before us now and let us deal with them. The motion of Mr. Gale was agreed to. As to the keeping of pigs, the Medical Officer mentioned that in the case reported on the person had put the pigs as far as possible from his own house, but near to that of his neighbour, so that he had not treated his neighbour as himself. Mr. F. C. Henley remarked that he did not think it would be any hardship to working men in the town not to keep pigs near dwelling houses, for he was certain that during the last eighteen months many who had kept pigs must have lost money by it. The Medical Officer added that the health of the whole neighbourhood was endangered by the keeping of pigs near dwelling houses. The inspector was asked to inspect the pigstyes, and in the cases where pigs are kept too near dwelling houses, to serve notices calling upon the owners to abate the nuisance forthwith.—*The Wiltshire Times*, July 18, 1908.

271. Ventilation of the City Sewers. A Matter vitally affecting the Public Health.

A question of pressing importance in the city, and one to which Dr. Vann (the Medical Officer) has frequently drawn the attention of the City Council is the ventilating of the sewerage system. In this direction something has been done in the past, but a great deal yet remains to be done, and it is expected that the City Council will go fully into the matter at an early date, because, as Councillor Raine remarked, ventilation shafts are as necessary almost as an outlet for the sewage. The difficulty is as to the most suitable places to erect these unsightly shafts, as naturally the citizens would not like to have Durham streets disfigured by them.

Not only has the Medical Officer frequently commented upon this matter, but in 1902 the Surveyor (Mr. J. T. Pegge) presented a report on the same subject. According to this report the sewers enter the river at seventeen different points, and generally for some distance from the outlet were under water. This caused solid matters to settle in the pipes at these places, and in consequence periodical flushing and cleaning out has had to be resorted to. When the river is in flood the sewage is not observable, as the greater dilution and scour caused by the increased body of water flowing along the quick falling river bed carried away all traces of its presence, and the rapid current washing down enormous quantities of sand effectually cleanses the river.

The total length of old sewers of which the Surveyor in 1902 possessed any record was 15,513 yards, and these, at one ventilator per 100 yards, would eventually require 150 ventilating manholes and 75 tall ventilating shafts. As the greater part of the new intercepting sewers were at such a level as to be submerged when the river was in spate, the Surveyor was of opinion that it would be impossible to have open manhole covers, but in lieu thereof the brick ventilating pillars built in fences and boundary walls would effect the ventilation.

Including those already laid, the length would approximate to 8000 yards, so that these would require 80 ventilating manholes, and 40 tall shafts, giving a total on the two systems of 230 ventilating manholes and 115 tall shafts. This, however, was a somewhat excessive estimate, as fully half of the old sewers were in short lengths, and many of the manholes at the intersection of two sewers would in the above calculation be counted twice. He suggested that nineteen ventilating columns and seven shafts on buildings trees, should be provided.

The nineteen 24 ft. ventilation shafts, 6 inches in diameter, should, the Surveyor suggested, be erected in the following places: Near the station gates in Old Elvet, where the sewers linked; Hallgarth Street facing Mountjoy Terrace; Quarry Head Lane, near St. Oswald's Cemetery; Moatside Lane, near Mr. Rushworth's; Duck Pond, Sherburn Road, Back Lane, Silver Street, Moatside Lane, Wanless Terrace, Ellis Leazes, Edward Street, Sunderland Road, junction of

Framwellgate and Sidegate, junction of Castle Chare and Tentei Terrace, Crossgate and South Street, Atherton Street and Allergate, Flass Street, Waddington Street, and North Road.

The estimated cost of 48 manholes, vent columns, and shafts was £500.—*The Durham Chronicle*, September 4, 1908.

272. Deadly Sewer Gas. Three Men have a Narrow Escape from Death.*

Three men were overcome by poisonous gases in an underground sewer at Bristol, and had a narrow escape from death, being rescued in a state of collapse. The men were corporation employés, whose duties took them to inspect a section of a broad sewer running beneath the city streets at St. Phillips. Samuel Lever was the first to descend the manhole, from which the various channels radiated. He was followed by a companion named Jno. Gane. They had not gone far into the recesses of the sewer chamber when Lever called to Gane that the sewer gas was overpowering him. Gane hurried to his assistance, but he, too, had begun to feel the effect of the noxious vapours, and these almost prostrated him before he had taken many steps. The foreman named Jas. Smith had heard a shout, and noticed from the roadway that something was amiss. He pluckily made a dash into the sewer and brought out the others, but he had no sooner done so than he collapsed and had to be assisted by persons who had come on the scene. The three men were conveyed to the hospital. Smith soon regained consciousness, but artificial respiration had to be resorted to before Gane and Lever were brought round.—*The People*, April 11, 1909.

273. Sewermen's Medals. Descent into Foul Air to the Work of Rescue.

Two heroes were rewarded at Bristol yesterday, when William Jones and John Gane, sewermen employed by the Bristol Corporation, were awarded the gold and bronze medal respectively of the Humane Society.

In April last, whilst a man named Lever was working in a street sewer, he was overcome by a rush of gas.

Gane descended to the rescue, but he was overcome. Jones went down, and, in a partly conscious condition, managed to get a rope round Lever, who was raised into the fresh air. Then Jones fastened a rope round Gane before ascending to safety himself.—*The Morning Leader*, July 16, 1909.

* See page 101, *supra*.

274. London Sewer Gas.

An extraordinary manifestation of the great quantity of sewer gas generated in the main sewers of London occurred on Monday last outside St. Paul's Station, within a few yards of the Queen Victoria Street railway bridge. During a heavy rainstorm the water ran in a stream to the open grating of a sewer manhole, and was blown in fine spray by the force of the sewer gas, which was driven out at great pressure by the sudden influx of the storm waters into the sewers. The odour was too strong to permit of very close examination, but considering the size of the grating and the height of the spray, the pressure to which the sewer gas was being subjected would not have been less than 200 lb. per square inch, about five times greater than the inadequate average pressure of the water mains supplying London's fire hydrants.—*London Government Officer and Contractor*, July 23, 1906.

275. Sewage Gas Danger. Renewal of the Poisonous Odours in Dwelling-Houses.

There was a recurrence yesterday morning of the sewage gas poisoning in the tenement at the corner of Oxford Street and Main Street, Gorbals, Glasgow, where, about a week ago, some forty people were seriously affected.

About two o'clock Arthur Dalinsky, who resides at 10 Oxford Street, was awakened by his wife, who complained of being sick and of smelling a bad odour in the house. It was discovered also that one of the children had turned sick. Dr. D. A. Chalmers, casualty-surgeon, was called, and found on examination that the woman and her child were suffering from gas poisoning, and applied medical relief.

Later it was discovered that Mrs. Jacobs and Helen Davis or Fletcher, residing at the same address, were affected by sewage gas escaping from a ventilator into the house, and were also attended.

The master of works, the medical officer of health, and the sanitary inspector were advised of the occurrence. They are making investigations.—*Daily Record and Daily Mail*, February 26, 1909.

276. Sewer Gas. Alarming Poisoning Case on South-Side. Forty Persons Affected. Narrow Escapes.

A most alarming case of sewer-gas poisoning is reported from the South-Side of Glasgow this morning, in which no fewer than eighteen families were affected. But for the fortunate circumstance of one man discovering during the night that his children had taken ill, there is little doubt that all the people in the two tenements affected would have remained undisturbed while the poisonous fumes were polluting the houses. If such had been the case, the death-roll would have been little less than appalling.

The scene of the occurrence was the block of buildings at the corner of Oxford Street and Main Street, Gorbals. It is said that about two or three o'clock this morning, Arthur Dalinsky (30), who resides on the first landing of 10 Oxford Street, found that one of his family had been attacked with a sudden and unaccountable sickness. He attended the sufferer, but on visiting the other children he was astonished to find that they were all more or less in a bad condition. Becoming alarmed, the man immediately telephoned to the Southern Police Office, and Dr. D. A. Chalmers, Casualty Surgeon, Inspector Moffat, and Sergeant M'Donald hurried to the spot.

By this time many of the neighbours had been awakened, and the scene which ensued is without parallel in the recollection of the police officials. The scared residents were all more or less under the influence of the poisonous gas. Some had fainted, others were so weakened that they had to be carried out of their houses, while the rest managed to totter down stairs to fresh air and safety. A considerable number were vomiting freely, and others complained of bursting headaches.

The doctor and his assistants quickly aroused those who still had their doors closed, and soon practically every member of the eighteen families resident at Nos. 10 and 14 Oxford Street had been warned of their danger and conveyed to the street. Some of the people had been completely overcome by the stench which had invaded their apartments, and it was only through the combined use of stimulants and fresh air that they were restored to sensibility. The worst sufferers were those found in the houses where the windows had been closed during the night, and in some cases these persons were in a very bad condition. Everyone was hurried out of the poisoned atmosphere as quickly as possible, and there were those so thoroughly scared that dress etiquette was thrown to the winds, and a speedy departure made en deshabille. Mothers were seen running with their children in blankets, and for a time the greatest excitement prevailed.

Happily everyone recovered sufficiently to be able to remove to the houses of friends in the district, and to-day they are all practically in their usual health, except in several cases where headaches have followed the sickness of the early morning.

The tenement is one of three storeys, with three doors on each landing, and it is thought that the number of persons who suffered from the effects of the gas is about forty.

Dr. Chalmers describes the stench as simply putrid. It was overpoweringly strong and sickening, and the Doctor himself was beginning to feel its effects after he had finished his work. It is said that the neighbours have been aware of an unusual smell of sewer gas for some considerable time past, and some of them had taken the precaution to keep their windows open night and day.

The Corporation sanitary authorities have been communicated with, and a thorough investigation is being made to-day.

An idea of the poisonous properties of the gas which affected these people will be gleaned from the fact that two cats which were yesterday put in a cellar in the tenement in question, were found to have died shortly afterwards.

The following are the names of several of the persons who were poisoned :—

Janet Mitchell (19), 14 Oxford Street.
Mary Docherty or Watson (49).
Mary Dunn or Docherty (27).
Lean Wersieser (34).
Nathan Holdofsky (39).
Dorah Holdofsky (37).
Laurence Philip (16), 10 Oxford Street.
Annie M'Kay (18).
Arthur Dalinsky (30).
Abey Dalinsky (5).
Venie Dalinsky (6).
Alexander Dalinsky (1½).

Glasgow News, February 17, 1909.

277. Borough Council of Lewisham.

A meeting of the Council was held on Wednesday, the Mayor (Alderman H. Percival Stebbing) presiding.

The following—among other—reports and recommendations were submitted, and approved or adopted :—

The Works and Highways Committee report that they have received a letter from the London County Council on the subject of the ventilation of the new high-level sewer. The Main Drainage Committee (it was stated) had considered the Borough Council's proposal that a coke furnace, connected with a shaft, should be erected on the sewer in High-road, Lee, and did not see their way to entertain the proposals, but were prepared, if the Borough Council would provide suitable sites, to advise the County Council to erect ventilating columns on the sewer. When this new sewer was constructed provision was made for 43 surface ventilators along its length, but five only were open, the others having been closed down. The Borough Surveyor had stated that he can only suggest four suitable sites in the borough, for the erection of ventilating columns. The Committee did not think that these, with the five existing open ventilators, would provide adequate ventilation for the whole length of sewer, and they were not satisfied of the efficiency of this mode of ventilation. Further, it appeared to the Committee that the effect would be that nearly the whole length of this sewer would be ventilated into the borough. Continuous complaints are received as to offensive sewer emanations and the Committee recommend that the London County Council be requested forthwith to efficiently ventilate their sewer and prevent it being a source of nuisance in this borough.—*The South Eastern Herald*, July 30, 1909.

278. Gloucester City Council. Ventilation of Sewers.

On the report and recommendation of the City Surveyor, the Sanitary Committee resolved that in order to improve the ventilation of the sewers in the neighbourhood of Denmark-road, the City Surveyor be authorised to arrange for the erection of ventilating shafts in suitable positions.

Mr. Vallender said he was very glad that steps were to be taken in the direction indicated. As a representative of the East Ward, he had received a lot of complaints about the smells arising from the sewer gratings, especially in the lower portions of Oxford-road and Henry-road.

Mr. B. V. Bruton said the closing of those sewer gratings had been rather a pet subject of his, and during the time he had been on the Council he had advocated that something should be done to remedy the condition of affairs complained of. He thought that anyone had only to walk along thoroughfares like Alfred-street or Denmark-road to become a supporter of the course which he advocated. (Hear, hear.) He thought that the minute was worded in such a way as not to give full effect to the decision of the Committee. The Committee decided that the Surveyor should be authorised to obtain permission to erect ventilating shafts in certain positions in the area comprising Hinton-road, Malvern-road, and North-road, and then to close certain of the man-holes, in order that trials might be made as to the success of that system.

Mr. Bibby confirmed Mr. Bruton's statement. That district was chosen because it was really the termination or the blind end of the drainage system, and that it was, therefore, better suited for the purposes of the test than any other. At the expiration of about six months the Surveyor would make a report on the subject, and if the system were proved to have been efficient it could be extended to other parts of the city. (Hear, hear.)

The Mayor said he thought the minute, which was drafted so that its terms might be as wide as possible, covered the intention of the Committee.

The minute was confirmed.—*Gloucester Journal*, October 2, 1909.

279. Sewer Gas Tragedy.

A number of workmen were engaged in the construction of a new sewer at Monkseaton, near Whitley Bay, Northumberland, yesterday morning, and a few minutes after they had descended the shaft they were assailed by sewer gas. There was a frantic rush to the mouth of the shaft, but three men became unconscious before reaching it. With great difficulty and danger to the rescuers they were brought to the surface, and artificial respiration was applied. Two men recovered, but the third, whose name is Green, died. He is said to have belonged to Annan, Scotland, and to have left eight children.—*The Daily Telegraph*, August 10, 1909.

280. The Progressive Bad Smell Failure.

To the Editor of the Borough News.

Sir,

"The wherefore and the why" Progressives failed, when they had the chance, to remedy the bad smell nuisance is set out in the following official report (see minutes of Progressive Council) presented to the Progressive Council in November, 1904.

The Progressive public (de) cryer of Lewisham should pay still another visit to the libraries and make himself acquainted with the facts and reasons (and concern himself less with the fancies, a malignant growth) of his Progressive colleagues' past failures.

The "Borough News" has never failed in courtesy to opponents, and, in the interests of the ratepayers of the borough, I am assured that you will publish the appended official report in full,

Remaining ever faithful to efficiency and economy,

A. H. Trenchard.

BOROUGH OF LEWISHAM. COPY OF BOROUGH SURVEYOR'S REPORT ON SEWER VENTILATION, NOVEMBER, 1904.

3. The question of the ventilation of the sewers in the Borough has received the attention of the committees of the Council from time to time, owing to the complaints received from residents as to the smells emanating from surface road ventilators, and the committee have received the following report from the Borough Surveyor :—

" The whole question of the ventilation of sewers is surrounded by difficulties, and unfortunately engineers hold very different opinions as to the best means of dealing with the matter. In many places the surface gratings are closed and columns erected in order to ventilate the sewers, but this in my opinion, and I have made many tests in connection with the subject, simply means that the nuisance is removed from the road surface, and that the sewers are very inefficiently ventilated, unless some artificial means of forcing a draught up the columns is adopted. The air which does find its way out of the top of the columns is far more foul than that which is emanated from the surface gratings; this is caused by the more sluggish current which is always found in a deep sewer, and my opinion of columns is that you practically deepen your sewer by the height of your column, that is to say, if a sewer is 10 ft. deep and you erect a 30 ft. column, you are practically converting that sewer, for the purposes of ventilation, to a sewer 40 ft. deep, and I think that whatever different opinions engineers may hold on the subject of ventilation generally, they are agreed that a deep sewer is more difficult to ventilate than a shallow one. A very good example of this exists in this borough. The old sewer in Stanstead-road averaged about 10 ft. deep; it was in a very defective condition, the gradients were irregular, in places flat, and in other places steep, the bottom also being defective. This sewer was reconstructed in 1893 at an average depth of about 25 ft. It is one of the best laid sewers in the borough and is at an even gradient the whole way. During the time the old sewer was in existence we very seldom had complaints of smells from it; since the new sewer was constructed we are continually receiving complaints. Of course there are many ways of inducing an artificial current up the column ventilators, but they are all attended with serious drawbacks. The most common form of inducing a current is by means of heat, but it is a very expensive method and is attended by some danger. If a naked jet of gas is burnt in the column and any coal gas leaks into the sewer, which it frequently does, there is very great danger of an explosion. The other method of applying jets of gas are practically adaptations of the Davy lamp, by which the gas is burned inside a wire gauze, but this, unfortunately, seems to considerably reduce the efficiency of the heating power, and also further increases the cost. Another method of inducing a draught is by means of a cowl with an Archimedian screw, but this, in my opinion, is a complete failure and is worse than useless, because the time when sewers most require an artificial means of ventilation is on dull still days when there is no wind, and then of course, the cowls do not revolve, and the Archimedian screws practically block the columns and prevent the little ventilation which one might get without an induced current. I some time ago tried an experiment with a revolving fan fixed in a column, the fan being driven by a jet of water under pressure from the Water Company's main. I utilised the water afterwards by conveying it into a flushing tank, where it flushed the sewers. This was effectual to a certain extent, but it was too expensive to adopt generally. The complaints of smells from sewer ventilators have largely increased since the coming into operation of the London County Council's bye-laws as to drainage, which necessitate the use of interceptors to block off the house drainage from the sewer; under the old system each house was compelled to have a ventilating pipe from the highest point of the drain; each one of these pipes acted as a ventilator to the sewer, and the surface gratings in the road in most cases acted as fresh air inlets. This theory of mine is borne out by the fact that on the St. German's Estate, which has been laid out nearly entirely since interceptors have become compulsory, we have more complaints than from any other part of the borough. This may appear to be somewhat of a contradiction to my condemnation of column ventilators, but the one thing is very different from the other; column ventilators are as a rule erected about 100 yards apart, whereas house ventilators are of course erected to each house, and in the 100 yards there would probably be on the average about 22 separate house ventilators, and also with the old system we still had the open surface gratings in the roadway. I would suggest as a partial mitigation of the nuisance, that the sewer ventilators should be put much nearer together; at present when sewers are sanctioned we ask for manholes about 100 yards apart: and also that efforts should be made by combined action of the Borough Councils to obtain the repeal of the London County Council's bye-law with reference to interceptors. I am afraid this would cause a considerable amount of difficulty, as the majority of the medical officers in London are in favour of interceptors, and will advise their Councils against the repeal of this bye-law. I should like to point out that although the interceptor was not made compulsory until the passing of the London County Council's bye-laws in 1900, many of the Boards of

Works and Vestries in the Metropolis insisted on their use, whereas in Lewisham we not only did not insist on them but we advised builders not to use them, and I think that this action has been justified over and over again by the low death rate in the parish of Lewisham. My idea of an ideal sewer is a trough of the necessary depth to drain adjoining premises, finished off level with the road surface with a continuous open grating. If such a thing were constructed I firmly believe we should never have a single complaint."

The London County Council on October 30, 1900, made drainage bye-laws under the provisions of section 202 of the Metropolis Management Act, 1855, and No. 5 of such bye-laws provides as follows:

"Every person who shall erect a new building shall provide in every main drain or other drain of such building which may immediately communicate with any sewer, a suitable and efficient intercepting trap at a point as distant as may be practicable from such building, and as near as may be practicable to the point at which such drain may be connected with the sewer. He shall, except in cases where the means of access to be provided in compliance with the preceding bye-law shall give adequate means of access to such trap, provide a separate manhole, or other separate means of access to such trap for the purpose of cleansing it."

And this bye-law, so far as practicable, is made to apply to the reconstruction of drains as well as to drains of new buildings. The committee concur in the views expressed by the Borough Surveyor, and recommend that a précis of the Borough Surveyor's report be forwarded to the Metropolitan Borough Councils, and that they be asked whether they would be willing to co-operate with this Council in requesting the London County Council to take the necessary steps to repeal the bye-law made by them, requiring the fixing of intercepting traps.—*Lewisham Borough News*, October 15, 1907.

281. Lewisham Borough Council. Smells at Hither Green. The Lee Shaft.

The Works Committee reported that they had received a letter (May 14) from the Clerk of the London County Council on the subject of the ventilation of their main sewer stating that the Main Drainage Committee do not see their way to recommend the County Council to adopt the suggestion for the construction of a coke furnace with a shaft thereon at Malyons-road, but they will be prepared, if the Council would provide suitable sites, to advise the County Council to erect ventilating columns on sewer in lieu of existing surface ventilators. This Council suggested an alternative site for the furnace column at Lee High-road, but no reply had been received from the London County Council. The Committee having regard to the probability of warm weather, when the nuisance from the sewer is likely to be increased, have directed that the London County Council be asked to take into consideration the alternative site as soon as possible.

A MISTAKE AND A SMELL.

The Works Committee reported, that on May 20, a very serious nuisance from the Ravensbourne and Sydenham sewer in Rushey Green was reported, and representations thereon were at once made to the London County Council. The committee had received a letter in reply from the chief engineer, who states that enquiries made on the ground brought out the fact that during the night of the 19th ammonia liquor was allowed to escape into the sewer from the works of the South Suburban Gas Company, and that the company's engineer had since informed him that this occurred through the carelessness of one of the employees of that undertaking, who had been severely reprimanded.—*Lewisham Borough News*, June 19, 1909.

282. Rochdale's Sanitary System.

To the Editor of the Rochdale Observer.

Sir,—Before we can understand Rochdale's position in this matter of the disposal of night-soil, we must realise that the pail system originated here, and that though it has since spread to other towns to a certain extent, nowhere else has it superseded the old dry-earth or midden system to the same extent as in Rochdale. We may take it for granted that if the pail system had gained a strong footing there would not have been so much general conversion to water-carriage as has taken place during recent years in many of the neighbouring towns. The places which are being converted in Oldham, for example, are invariably midden closets. So far as I have been able to ascertain, the Oldham Corporation have yet to convert their first pail closet. In my opinion, the Rochdale system is the best possible one. I know that many people object to the sanitary vans passing in the public streets, but this could easily be avoided by collection in the night as was originally intended. To say that the present system is unhealthy is quite untrue. Nowhere will you be able to find a healthier or finer looking body of men than the sanitary carters and collectors.

As I have considerably over one hundred houses on the water-carriage system (some slop-water and others fresh-water), I hope that my experience may be of service. I find that the repairs to water closets form one of the principal items in my annual bill for repairs. For 138 water closets it totals over 40*l*. per annum. During the hot summer months I have numerous complaints of the abominable smell arising from the Corporation manholes in Elliott-street, George-street, James-street, John street, and Albion-street (all at Castleton). All these streets (with the exception of John-street) have been paved during the past six years, and new sewers have been laid. I fear that similar conditions will obtain all over Rochdale if the water-carriage system is generally adopted. In spite of drain ventilation and trapping, and all the precautions that can be taken, the gases generated by the soil in its passage through the drains and sewers of the town must to a considerable extent escape and poison the atmosphere. You may prove this any hot summer day by watching the air bubbles rising through the water of a trapped gully. I should like to ask the public of Rochdale: Is it better to take the nightsoil away and cremate it or have it generating poisonous gases in the sewers? At present Rochdale has an excellent sanitary system. The works in Entwisle-road have recently been fitted with new and costly plant for dealing with the refuse, and I notice that there is a considerable economy this year accruing from its operation.

To sum the matter up, it will, in my opinion, be a huge mistake if the Joint Committee's recommendations are carried into effect. I know, of course, that there is always a strong and almost overwhelming tendency towards movement in public affairs. I wish that all the changes and alterations were improvements and that all the movement was progress in the real sense of the word. A great scientific observer in sociological matters (Mr. Bagshot) has placed it on record that "the desire for change is inherent in the human breast," but that if men could be content to "lay in the sun a little," and not be so feverishly anxious to take action, probably nine-tenths of our mistakes would be averted, and real social progress would proceed more rapidly in the long run.

I have been much amused by your calculations as to the cost of the proposed conversion to the property owners, and also as to the amount of increased rent which would be necessary to pay interest on the capital involved. In your issue of June 12 you tell us that the Oldham Corporation have paid an average contribution towards the cost of conversion of 5*l*. per closet, but you don't tell us what proportion the property owner has contributed. To-day (Wednesday) you say that the cost of conversion will be about 3*l*. or 4*l*. per closet. Apparently, then, the Oldham property owners have been making a profit of 1*l*. or 2*l*. per closet on this job. Wicked property owners! I called in at my plumber's this morning to inquire about the cost of water closets. I have now his authority to say that the expense of the apparatus and the laying on of the fresh water would be at least 3*l.* 10*s.* in each case, and that the connection with the drain where this is convenient would be 1*l.* 10*s.* In 99 cases out of 100, however, a new drain would be required, and the average cost would work out at from 7*l.* to 10*l.* per closet with drainage complete. In your estimate of 1*d.* per week rent to pay interest on outlay you forget that there is a charge for fresh water of at least 6*s.* per closet per annum, and also that any increase put on the rent will be rated for, so that the landlord will get only two-thirds of the advance, the balance going in the increased rates. Kindly see how this works out: Average cost, say, 7*l.* per closet; interest at 5 per cent., 7*s.*; water rate, 6*s.*; and repairs to closet, 5*s.* a year; making a total of 18*s.* per annum. If 6*d.* per week per house is put on rents it will bring in 26*s.* gross per year, on which one would pay in rates 8*s.* 6*d.*, leaving a net receipt of 17*s.* 6*d.* towards an expenditure of 18*s.* a year on closets. Thus, an average increase of 6*d.* per week per house would be required.

Yours, etc.,

MICHAEL STOCKS.

The Rochdale Observer, June 19, 1909.

283. VENTILATION OF DRAINS AND SOIL PIPES.

BY SIR CHARLES A. CAMERON, C.B.

There can be no possible doubt whatever that the most important problem in sanitary science is how to secure freedom from contaminated air in our homes, and in the buildings in which people congregate or spend their time during working hours. Pure air, being as necessary for healthy life as good or unadulterated food, is, unfortunately, but too often overlooked by those interested in building operations, with the result that, owing to the omission of suitable safeguards, residences become unhealthy, and eventually the whole neighbourhood falls into disrepute, and is considered undesirable, and the dwellers who can afford it seek other localities where nature provides a purer atmosphere. But those too poor to move have to remain and struggle to retain health under the vitiated conditions obtaining.

Now, what has produced these lamentable conditions? The causes are not far to seek, yet they are generally ignored, and all because of the want of intelligent legislation needed to compel the adoption of proper methods of ventilation and sanitation in all and every habitation both now in existence and building. There are some by-laws on the subject of the latter adopted by Councils and Municipalities, but they are far from stringent enough, and are more often neglected than observed.

As regards the ventilation of dwelling-rooms, this most important matter is left to the discretion of the often careless or ignorant architect, who generally leaves it to his inexperienced assistant; or to the "jerry builder," and it is no exaggeration to say that where a system of ventilation *is* specified by the architect, it is but too often sacrificed to satisfy the selfish, or mistaken, economy of the owner or builder, who concludes that *this item can best be left out without being missed*! And yet, strange to say, the *cost of this item of such vital importance would seldom amount to more than* "1 *per cent.*" *on the cost of the structure*!

The result of this serious neglect is not at first recognised, but if we reflect we can easily realise that if it did not exist the health of our towns and cities would be much better than it is. There would be less typhoid, diphtheria, and other zymotic diseases; our hospitals would not be so full, or so expensive to maintain, and local rates would also be relieved, not to speak of the all-important saving of life, particularly amongst infants!

Foremost amongst the evils at present existing, is the "air-inlet" for ventilating soil-pipes, hitherto adopted in all classes of buildings. These are so constructed that the mica hangs open, even when uninjured, but it more often happens that it is destroyed by children and others; and the filthy gas, slowly generating in the soil pipe and trap, can, and does, find its way out into the surrounding atmosphere, at the level of the lower dwelling rooms. It is often detected plainly by the least delicate nostrils, and is always contaminating the air, being breathed by dwellers in the neighbourhood. It is astonishing that this evil should not have been corrected before this. At last, however, intelligent Sanitary Officers have become alive to its seriousness, and have sought for a substitute which, while admitting fresh air freely as induced by the updraught in the soil pipe, will close automatically against any leakage of foul air. Such a "fresh air inlet" has been designed by a firm of ventilating engineers, a sample of which I have before me, and it also possesses the merit (which in this case seems invaluable under the conditions of the positions in which such valves are usually placed, i.e. near ground level) of not being easily injured or disordered.

Major W. H. Horrocks, M.D., D.Sc., R.A.M.C., in a very able paper, read before the Royal Society on February 7th last, upon "Experiments made to determine the Conditions under which

'Specific' Bacteria derived from Sewage may be present in the Air of Ventilating Pipes, Drains, Inspection Chambers, and Sewers," mentions as one of his conclusions resulting from his investigations the following: "An air inlet, even when provided with a mica valve, may be a source of danger when it is placed at or about the ground level."

I go further, and say that those "inlets" generally in use are an absolute source of evil; and no doubt Major Horrocks had in view their imperfection and liability to damage in the conclusion he came to. For I would submit that to ensure proper ventilation of the soil pipe at all, *it is essential that the "air inlet" be placed as near as possible to the drain trap.* We know that sewer gas is heavier than air, and during the periods between the flushing of the pipes there is more or less of this gas forming in the lowest parts of both ventilating and air inlet pipes. If, therefore, the inlet valve is placed high above the drain trap the air would have to pass down through a column of gas heavier than itself before it could reach the junction with the soil (or ventilating) pipe, and this arrangement must in consequence be defective; whereas, when junctioned with the soil-pipe close to the trap, there would be no obstruction to the constant circulation of air throughout.

In view of the foregoing the only measures required, therefore, is legislation to condemn *in toto* the existing injurious "inlets," and compel the adoption of such as are not only proof against the leakage of injurious gases, and at the same time are so constructed as to remain safe from mischievous destruction in whatever position they may be placed.—*The Sanitary Record*, October 24, 1907.

Table A

Arc = D × 3·141592. Area = D² × 0·785398. (Pipe Flowing Full)

Arc = D × 2·0943952. Area = D² × 0·631852. (¾ Vertical Height)

Arc = D × 1·9107344. Area = D² × 0·556218. (⅔ Vertical Height)

Arc = D × 1·570796. Area = D² × 0·392699. (Pipe Flowing Half Full)

Arc = D × 1·2308584. Area = D² × 0·229180. (⅓ Vertical Height)

Arc = D × 1·0471976. Area = D² × 0·153546. (¼ Vertical Height)

Diameter of Pipe in Inches	Pipe Flowing Full				¾ Vertical Height				⅔ Vertical Height				Pipe Flowing Half Full				⅓ Vertical Height				¼ Vertical Height				Diameter of Pipe in Inches
	Areas	Wetted Periphery	Hydraulic Mean Depth	Kutter page 16. Coefficient *m*	Areas	Wetted Periphery	Hydraulic Mean Depth	Kutter page 16. Coefficient *m*	Areas	Wetted Periphery	Hydraulic Mean Depth	Kutter page 16. Coefficient *m*	Areas	Wetted Periphery	Hydraulic Mean Depth	Kutter page 16. Coefficient *m*	Areas	Wetted Periphery	Hydraulic Mean Depth	Kutter page 16. Coefficient *m*	Areas	Wetted Periphery	Hydraulic Mean Depth	Kutter page 16. Coefficient *m*	
	Sq. Feet	Feet			Sq. Feet	Feet			Sq. Feet	Feet			Sq. Feet	Feet			Sq. Ft.	Feet			Sq. Feet	Feet			
3	0·0491	0·7854	0·0625	15·22	0·0395	0·5236	0·0754	17·89	0·0348	0·4777	0·0728	17·43	0·0245	0·3927	0·0625	15·22	0·0143	0·3077	0·0465	11·64	0·0096	0,2618	0·0367	9·33	3
4	0·0873	1·0472	0·0833	19·61	0·0702	0·6981	0·1006	23·06	0·0618	0·6369	0·0970	22·36	0·0436	0·5236	0·0833	19·61	0·0255	0·4103	0·0621	15·13	0·0171	0·3490	0·0489	12·19	4
5	0·1364	1·3090	0·1042	23·76	0·1097	0·8726	0·1257	27·79	0·0965	0·7961	0·1213	26·98	0·0682	0·6545	0·1042	23·76	0·0398	0·5128	0·0776	18·43	0·0267	0·4363	0·0611	14·92	5
6	0·1963	1·5708	0·1250	27·66	0·1580	1·0472	0·1508	31·23	0·1391	0·9554	0·1456	31·33	0·0982	0·7854	0·1250	27·66	0·0573	0·6154	0·0931	21·58	0·0383	0·5236	0·0733	17·53	6
7	0·2672	1·8326	0·1458	31·36	0·2150	1·2217	0·1759	35·44	0·1893	1·1146	0·1698	35·43	0·1336	0·9163	0·1458	31·36	0·0780	0·7180	0·1086	24·51	0·0522	0·6108	0·0855	20·06	7
8	0·3491	2·0944	0·1667	34·91	0·2808	1·3962	0·2011	40·41	0·2472	1·2738	0·1941	39·32	0·1745	1·0472	0·1667	34·91	0·1019	0·8206	0·1241	27·42	0·0683	0·6981	0·0978	22·46	8
9	0·4418	2·3562	0·1875	38·29	0·3554	1·5708	0·2262	44·20	0·3129	1·4330	0·2183	43·03	0·2209	1·1781	0·1875	38·29	0·1289	0·9231	0·1396	30·22	0·0864	0·7854	0·1100	24·78	9
10	0·5454	2·6180	0·2083	41·53	0·4388	1·7453	0·2514	47·83	0·3863	1·5923	0·2426	46·58	0·2727	1·3090	0·2083	41·53	0·1591	1·0257	0·1551	32·92	0·1066	0·8727	0·1222	27·05	10
11	0·6600	2·8798	0·2292	44·64	0·5310	1·9198	0·2765	51·28	0·4674	1·7515	0·2669	49·98	0·3300	1·4399	0·2292	44·64	0·1926	1·1283	0·1707	35·54	0·1290	0·9599	0·1344	29·25	11
12	0·7854	3·1416	0·2500	47·63	0·6319	2·0944	0·3017	54·64	0·5562	1·9107	0·2911	53·25	0·3927	1·5708	0·2500	47·63	0·2292	1·2308	0·1862	38·09	0·1535	1·0472	0·1466	31·40	12
13	0·9218	3·4034	0·2708	50·53	0·7415	2·2689	0·3268	57·84	0·6528	2·0700	0·3154	56·41	0·4609	1·7017	0·2708	50·53	0·2690	1·3334	0·2017	40·57	0·1802	1·1345	0·1589	33·52	13
14	1·0690	3·6652	0·2916	53·32	0·8600	2·4434	0·3519	60·93	0·7571	2·2292	0·3396	59·52	0·5345	1·8326	0·2917	53·32	0·3119	1·4360	0·2172	42·98	0·2090	1·2217	0·1711	35·60	14
15	1·2272	3·9270	0·3125	56·02	0·9873	2·6180	0·3771	63·93	0·8691	2·3884	0·3639	62·38	0·6136	1·9635	0·3125	56·02	0·3581	1·5386	0·2327	45·33	0·2399	1·3090	0·1833	37·60	15
16	1·3963	4·1888	0·3333	58·65	1·1233	2·7925	0·4022	66·84	0·9888	2·5477	0·3881	65·22	0·6981	2·0944	0·3333	58·65	0·4074	1·6411	0·2482	47·62	0·2730	1·3963	0·1955	39·52	16
17	1·5762	4·4506	0·3541	61·20	1·2682	2·9670	0·4274	69·64	1·1163	2·7069	0·4124	67·98	0·7881	2·2253	0·3541	61·20	0·4599	1·7437	0·2638	49·85	0·3081	1·4835	0·2077	41·40	17
18	1·7671	4·7124	0·3750	63·68	1·4217	3·1416	0·4525	72·38	1·2515	2·8661	0·4367	70·67	0·8835	2·3562	0·3750	63·68	0·5156	1·8463	0·2793	52·02	0·3454	1·5708	0·2200	43·22	18
19	1·9690	4·9742	0·3958	66·09	1·5840	3·3161	0·4777	75·04	1·3944	3·0253	0·4610	73·29	0·9844	2·4871	0·3958	66·09	0·5745	1·9488	0·2948	54·13	0·3850	1·6580	0·2322	45·00	19
20	2·1817	5·2360	0·4167	68·46	1·7551	3·4906	0·5028	77·62	1·5450	3·1846	0·4852	75·82	1·0908	2·6180	0·4167	68·46	0·6366	2·0514	0·3103	56·08	0·4266	1·7453	0·2444	46·76	20
21	2·4053	5·4978	0·4375	70·78	1·9350	3·6652	0·5279	80·14	1·7034	3·3438	0·5094	78·29	1·2026	2·7489	0·4375	70·78	0·7019	2·1540	0·3258	57·98	0·4703	1·8325	0·2566	48·50	21
22	2·6398	5·7596	0·4583	73·01	2·1237	3·8397	0·5531	82·60	1·8695	3·5030	0·5337	80·72	1·3199	2·8798	0·4583	73·01	0·7703	2·2566	0·3413	59·83	0·5162	1·9168	0·2688	50·20	22
23	2·8852	6·0214	0·4792	75·20	2·3211	4·0142	0·5783	85·02	2·0433	3·6623	0·5580	83·09	1·4426	3·0107	0·4792	75·20	0·8419	2·3591	0·3569	61·64	0·5642	2·0071	0·2811	51·97	23
24	3·1416	6·2832	0·5000	77·34	2·5273	4·1888	0·6033	87·36	2·2248	3·8215	0·5822	85·40	1·5708	3·1416	0·5000	77·34	0·9167	2·4617	0·3724	63·41	0·6143	2·0944	0·2933	53·51	24
25	3·4089	6·5450	0·5208	79·45	2·7424	4·3633	0·6286	89·68	2·4141	3·9807	0·6065	87·65	1·7044	3·2725	0·5208	79·45	0·9947	2·5642	0·3879	65·14	0·6665	2·1816	0·3055	55·11	25
26	3·6870	6·8068	0·5417	81·50	2·9662	4·5378	0·6536	91·92	2·6111	4·1400	0·6308	89·88	1·8435	3·4034	0·5417	81·50	1·0759	2·6668	0·4034	66·84	0·7208	2·2689	0·3177	56·67	26
27	3·9761	7·0686	0·5625	83·52	3·1988	4·7124	0·6788	94·16	2·8159	4·2992	0·6550	92·04	1·9880	3·5343	0·5625	83·52	1·1602	2·7694	0·4189	68·52	0·7773	2·3562	0·3299	58·21	27
28	4·2761	7·3304	0·5833	85·49	3·4401	4·8869	0·7038	96·30	3·0283	4·4584	0·6793	94·20	2·1380	3·6652	0·5833	85·49	1·2478	2·8720	0·4344	70·19	0·8360	2·4434	0·3422	59·72	28
29	4·5870	7·5922	0·6042	87·45	3·6902	5·0614	0·7290	98·44	3·2485	4·6176	0·7035	96·28	2·2935	3·7961	0·6042	87·45	1·3385	2·9746	0·4499	71·85	0·8968	2·5307	0·3544	61·21	29
30	4·9088	7·8540	0·6250	89·34	3·9491	5·2360	0·7542	100·53	3·4764	4·7769	0·7278	98·34	2·4544	3·9270	0·6250	89·34	1·4324	3·0771	0·4655	73·50	0·9597	2·6180	0·3666	62·68	30
31	5·2415	8·1158	0·6458	91·24	4·2167	5·4105	0·7793	102·58	3·7120	4·9361	0·7520	100·34	2·6207	4·0579	0·6458	91·24	1·5295	3·1797	0·4810	75·14	1·0248	2·7052	0·3788	64·13	31
32	5·5852	8·3776	0·6667	93·08	4·4932	5·5850	0·8044	104·59	3·9553	5·0953	0·7763	102·34	2·7925	4·1888	0·6667	93·08	1·6297	3·2823	0·4965	76·77	1·0919	2·7925	0·3910	65·55	32
33	5·9396	8·6394	0·6875	94·90	4·7784	5·7596	0·8296	106·59	4·2064	5·2546	0·8005	104·28	2·9698	4·3197	0·6875	94·90	1·7332	3·3849	0·5120	78·39	1·1612	2·8798	0·4033	66·94	33
34	6·3050	8·9012	0·7083	96·69	5·0724	5·9341	0·8547	108·53	4·4652	5·4138	0·8248	106·22	3·1525	4·4506	0·7083	96·69	1·8398	3·4874	0·5275	80·00	1·2326	2·9670	0·4155	68·31	34
35	6·6814	9·1630	0·7292	98·45	5·3752	6·1086	0·8798	110·44	4·7317	5·5730	0·8491	108·17	3·3407	4·5815	0·7292	98·45	1·9496	3·5900	0·5430	81·60	1·3063	3·0543	0·4277	69·66	35
36	7·0686	9·4248	0·7500	100·18	5·6857	6·2832	0·9050	112·39	5·0060	5·7323	0·8734	109·97	3·5343	4·7124	0·7500	100·18	2·0626	3·6926	0·5586	83·19	1·3819	3·1416	0·4399	70·98	36

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APPENDIX VII.

ORIGINAL TABLES—HYDRAULIC, HYDRO-DYNAMIC, THERMO-DYNAMIC, AND MATHEMATICAL.

TABLE "A" IS A HYDRAULIC TABLE.

284. It shows, for pipes ranging from 3 to 36 in. in diameter, the following particulars: the areas in square feet, the wetted periphery, the hydraulic mean depth, and Herr Kütter's coefficients applicable to drain and sewer pipes. The Table shows these particulars under six phases, according as the pipe is full, $\frac{3}{4}$, $\frac{2}{3}$, $\frac{1}{2}$, $\frac{1}{3}$ and $\frac{1}{4}$ full of sewage.

The following are the formulæ from which the table was calculated:—

285. Formulæ Explanatory of Table A.

Column 1.		Diameter of pipe in inches.
Columns 2, 6, 10.		Area of flow in square feet (= A).
Let D	=	Diameter of pipe in *feet*.
" f	=	Coefficient of area.
Then A	=	$D^2 f$.
Columns 3, 7, 11.		Wetted periphery (= P).
Let a	=	Coefficient of arc.
" D	=	Diameter of pipe in feet.
Then P	=	D a.
Columns 4, 8, 12.		Hydraulic mean depth (= r).
Then r	=	$\frac{A}{P} = \frac{D f}{a}$.

Columns 5, 9, 13. Kütter's coefficient (Kütter's "Hydraulic Tables," translated by L. D. A. Jackson, p. 16).*

$$m = c\sqrt{r}.$$

$$\text{where } c = \sqrt{\frac{1}{0{\cdot}000057 + \frac{0{\cdot}0000133}{r}}}.$$

$$\therefore\ m = \sqrt{r} \times \sqrt{\frac{1}{0{\cdot}000057 + \frac{0{\cdot}0000133}{r}}}.$$

$$= \frac{r}{\sqrt{{\cdot}000057\,r + {\cdot}0000133}}.$$

* Published by E. & F. N. Spon, Ltd.

Table B

Diam. of Pipe in Inches	Fall per 1000 Feet	Gradient 1 in	Equivalent Pressure of Air per 1000 Feet of Pipe	Pipe Flowing Full			¾ Vertical Height			⅝ Vertical Height			Pipe Flowing Half-Full			⅜ Vertical Height			¼ Vertical Height			Diam. of Pipe in Inches
				Velocity of Flow of Sewage	Discharge of Sewage	Population Served at 10 Gallons per Head per Day	Velocity of Flow of Sewage	Discharge of Sewage	Population Served at 10 Gallons per Head per Day	Velocity of Flow of Sewage	Discharge of Sewage	Population Served at 10 Gallons per Head per Day	Velocity of Flow of Sewage	Discharge of Sewage	Population Served at 10 Gallons per Head per Day	Velocity of Flow of Sewage	Discharge of Sewage	Population Served at 10 Gallons per Head per Day	Velocity of Flow of Sewage	Discharge of Sewage	Population Served at 10 Gallons per Head per Day	
	a	b	c	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
			Lbs. per Sq. Inch	Ft. per Sec.	Galls. per Min.		Ft. per Sec.	Galls. per Min.		Ft. per Sec.	Galls. per Min.		Ft. per Sec.	Galls. per Min.		Ft. per Sec.	Galls. per Min.		Ft. per Sec.	Galls. per Min.		
3	30	33·3	13·02	2·637	48·5	3,880	3·099	44·6	3,568	3·019	39·3	3,144	2·637	24·3	1,944	2·017	10·9	872	1·621	5·8	464	3
4	20	50·0	8·68	2·773	90·5	7,240	3·261	85·7	6,856	3·162	73·2	5,856	2·773	45·3	3,624	2·123	20·3	1,624	1·724	11·0	880	4
5	12	83·3	5·208	2·603	132·9	10,632	3·044	125·0	10,000	2·956	106·8	8,544	2·603	66·5	5,320	2·019	30·1	2,408	1·634	16·3	1,304	5
6	10	100·0	4·340	2·766	203·3	16,264	3·223	190·7	15,256	3·133	163·2	13,056	2·766	101·7	8,136	2·158	46·3	3,704	1·754	25·2	2,016	6
7	8	125·0	3·472	2·805	305·6	24,448	3·259	262·3	20,984	3·169	224·6	17,968	2·805	140·3	11,224	2·200	64·2	5,136	1·793	35·0	2,800	7
8	6	166·7	2·604	2·704	353·4	28,272	3·130	329·0	26,320	3·046	281·9	22,552	2·704	176·7	14,136	2·130	81·2	6,496	1·744	44·6	3,568	8
9	5·5	181·8	2·387	2·839	470	37,600	3·278	436	34,880	3·191	374	29,920	2·839	235	18,800	2·246	108	8,640	1·844	60	4,800	9
10	4·0	250·0	1·736	2·626	536	42,880	3·025	497	39,760	2·946	426	34,080	2·626	268	21,440	2·085	124	9,920	1·717	69	5,520	10
11	4·0	250·0	1·736	2·823	698	55,840	3·243	645	51,600	3·161	553	44,240	2·823	349	27,920	2·250	162	12,960	1·857	90	7,200	11
12	3·0	333·3	1·302	2·609	767	61,360	2·993	708	56,640	2·917	607	48,560	2·609	384	30,720	2·085	179	14,320	1·725	99	7,920	12
13	2·5	400·0	1·085	2·527	872	69,760	2·892	803	64,240	2·820	689	55,120	2·527	436	34,880	2·025	204	16,320	1·679	113	9,040	13
14	2·5	400·0	1·085	2·666	1067	85,360	3·046	981	78,480	2·976	843	67,440	2·666	534	42,720	2·143	250	20,000	1·781	139	11,120	14
15	2·0	500·0	0·868	2·505	1151	92,080	2·859	1057	84,560	2·790	908	72,640	2·505	576	46,080	2·019	271	21,680	1·682	151	12,080	15
16	2·0	500·0	0·868	2·623	1371	109,680	2·989	1257	100,560	2·917	1080	86,400	2·623	686	54,880	2·119	323	25,840	1·768	181	14,480	16
17	2·0	500·0	0·868	2·737	1617	129,360	3·114	1480	118,400	3·040	1270	101,600	2·737	809	64,720	2·216	381	30,480	1·753	214	17,120	17
18	2·0	500·0	0·868	2·848	1884	150,720	3·237	1723	137,840	3·160	1481	118,480	2·848	942	75,360	2·311	446	35,680	1·935	250	20,000	18
19	1·5	666·7	0·651	2·560	1887	150,960	2·906	1723	137,840	2·839	1482	118,560	2·560	944	75,520	2·080	447	35,760	1·746	252	20,160	19
20	1·5	666·7	0·651	2·652	2166	173,280	3·006	1975	158,000	2·937	1699	135,920	2·652	1083	86,640	2·159	515	41,200	1·814	290	23,200	20
21	1·25	800·0	0·543	2·502	2253	180,240	2·833	2052	164,160	2·768	1765	141,200	2·502	1127	90,160	2·040	536	42,880	1·717	320	25,600	21
22	1·25	800·0	0·543	2·580	2550	204,000	2·920	2321	185,680	2·854	1998	159,840	2·580	1275	102,000	2·168	608	48,640	1·776	343	27,440	22
23	1·25	800·0	0·543	2·659	2872	229,760	3·006	2612	208,960	2·938	2248	179,840	2·659	1436	114,880	2·175	686	54,880	1·835	387	30,960	23
24	1·25	800·0	0·543	2·734	3216	257,280	3·089	2924	233,920	3·019	2515	201,200	2·734	1608	128,640	2·240	769	61,520	1·892	435	34,800	24
25	1·00	1000·0	0·434	2·512	3206	256,480	2·836	2912	232,960	2·772	2505	200,400	2·512	1603	128,240	2·061	767	61,360	1·743	435	34,800	25
26	1·00	1000·0	0·434	2·577	3557	284,560	2·907	3229	258,320	2·842	2778	222,240	2·577	1779	142,320	2·118	853	68,240	1·793	484	38,720	26
27	1·00	1000·0	0·434	2·641	3931	314,480	2·978	3566	285,280	2·911	3068	245,440	2·641	1966	157,280	2·173	944	75,520	1·841	536	42,880	27
28	1·00	1000·0	0·434	2·703	4327	346,160	3·045	3922	313,760	2·979	3378	270,240	2·703	2164	173,120	2·226	1040	83,200	1·889	591	47,280	28
29	0·85	1176·5	0·379	2·550	4379	350,320	2·870	3965	317,200	2·807	3414	273,120	2·550	2190	175,200	2·102	1053	84,240	1·785	599	47,920	29
30	0·85	1176·5	0·379	2·605	4787	382,960	2·931	4333	346,640	2·867	3732	298,560	2·605	2394	191,520	2·150	1153	92,240	1·828	657	52,560	30
31	0·80	1250·0	0·347	2·581	5065	405,200	2·901	4579	366,320	2·838	3944	315,520	2·581	2533	202,640	2·132	1221	97,680	1·814	696	55,680	31
32	0·80	1250·0	0·347	2·633	5505	440,400	2·958	4976	398,080	2·894	4286	342,880	2·633	2753	220,240	2·177	1329	106,320	1·854	758	60,640	32
33	0·70	1429·0	0·304	2·511	5584	446,720	2·819	5042	403,360	2·759	4345	347,600	2·511	2792	223,360	2·078	1340	107,020	1·771	770	61,600	33
34	0·70	1429·0	0·304	2·559	6040	483,200	2·871	5453	436,240	2·810	4698	375,840	2·559	3020	241,600	2·119	1460	116,800	1·807	834	66,720	34
35	0·70	1429·0	0·304	2·605	6516	521,280	2·922	5880	470,400	2·862	5070	405,600	2·605	3258	260,640	2·160	1576	126,080	1·843	901	72,080	35
36	0·70	1429·0	0·304	2·651	7016	561,280	2·973	6530	506,400	2·910	5453	436,240	2·651	3508	280,640	2·200	1699	135,920	1·879	972	77,760	36

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TABLE B.

286. This is also a Hydraulic Table. It shows (1) the diameter of pipe in inches; (2) the fall per 1000 ft. in length; (3) the corresponding gradient; (4) the equivalent pressure of air (in lb. per square inch) per 1000 ft., for pipes ranging, as in Table A, from 3 to 36 in. in diameter, when those pipes are charged full, $\frac{3}{4}$, $\frac{2}{3}$, $\frac{1}{2}$, $\frac{1}{3}$ and $\frac{1}{4}$ full.

With regard to each of these details, the Table gives (*a*) the velocity of flow of sewage in feet per second; (*b*) the quantity of sewage discharged in gallons per minute; and (*c*) the population servable at 10 gallons per head per diem. The following explanations and formulæ will show how the Table B has been prepared.

287. Formulæ Explanatory of Table B.

Column *a*		Inclination of pipe in feet per 1000 ft. length.
Column *b*		Gradient.
Column *c*		Air pressure required to propel sewage waters through 1000 ft. of pipe in lb. per square inch.
So that		
Column *c*	=	$a \times \frac{14 \cdot 7}{34} = a \times \cdot 434.$
Columns 1, 4, 7, 10, 13, 16		Velocity of flow of sewage in feet per second.
s	=	Sine of angle of inclination $= \frac{\text{fall of pipe in ft.}}{\text{length of pipe in ft.}}$
Let v	=	Velocity in feet per second.
m	=	Kütter's coefficient.
Then v	=	$m \sqrt{s}.$
Columns 2, 5, 8, 11, 14, 17		Discharge of sewage in gallons per minute ($= d$).
A	=	Area of flow in pipe in square feet.
v	=	Velocity of flow in feet per second.
Then d	=	$6 \cdot 24 \times 60 \times \text{A}v = 374 \cdot 4 \times \text{A}v.$

Columns 3, 6, 9, 12, 15, 18 — Population served by the given pipe. When the village, town or city to be drained of its liquid wastes by it, is to be drained on the "Separate System." This is equivalent to saying that the liquid discharges (both in the aggregate and per head of the population) are approximately equal to the water supply after use—which is a good definition of the word "sewage."

As will be seen, the unit volume of sewage to be dealt with in the sewers, for the calculation purposes of the Table, is taken as being equal to 10 gals. per head per diem. of the population; and it is assumed also, that the one-half of this volume will flow, in 400 minutes, into and through the main sewers to any desired outfall, which may be the land, river, or sea; or it may be to some central steam-lifting station, or to a Shone hydro-pneumatic ejector station, whence the sewage delivered by gravitation sewers or otherwise to such stations, would be pumped or forced to its final destination.

On the basis thus stated, each inhabitant would discharge 5 gal. of sewage into the sewers during 400 minutes, or $\frac{5}{400} = \frac{1}{80}$ gal. per minute.

Therefore to ascertain the number of inhabitants or population for which each drain or sewer pipe would be suitable, the volume of sewage *d*, given in the Table under the column headed "Discharge of Sewage," must be multiplied by 80:—e.g. the Table shows that a 12-in. pipe laid at a gradient of 1 in 333, when charged *full bore*, will cause 767 gallons of sewage or water to flow through it at a velocity of 2·609 ft. per second; consequently under such conditions the 12-in. pipe would suffice to discharge the sewage of a population of $(767 \times 80) = 61{,}360$, as given in the Table.

In small hamlets or villages, and even in small towns in the provinces in this country the average water supply does not exceed 10 gallons per head per day. That volume, therefore, has been taken as the primary basis for calculating the populations given in it. In fact, however, the average volume of sewage discharged per head per day varies in different villages and towns between 10, 15, 20, 25, 30 and 35 gallons per head per day—the latter being the average for London. To get at the number of inhabitants which the various drain and sewer pipes included in the Table, when the sewage discharges per head per day correspond to the discharges of 15, 20, 25, 30, or 35 gallons per head per day, the populations given in the Table have only to be divided by $1\frac{1}{2}$, 2, $2\frac{1}{2}$, 3, $3\frac{1}{2}$, respectively. For instance, in London a 12-in. sewer discharging sewage, when the volume flowing through it fills it, will suffice for a population only of $(61{,}360 \div 3 \cdot 5) = 17{,}531$, and not 61,360 as given in the Table.

But in order to provide space enough in the final gravitation outfall sewer for the sewage of the future population, say e.g., in 33 years, after the execution of the works required for the drainage of the sewage of the population existent at the date of the completion of the new works, the engineer would consider it his duty to put down a sewer in the first instance capable of discharging the maximum volume of sewage which would be due from the estimated population existing at the date of the completion of the new works, when it was *half* full, so as to make adequate provision for the natural growth thereafter of the population of the town or district to be drained.

On these assumptions, therefore, the 12-in. pipe running half bore would only be suitable, as the table shows, for a present population of 30,680; when, however, the volume of the sewage discharged by it exceeded by 33 per cent. the one-half of its total full carrying capacity, the volume flowing through it would then be $= 384 \times 1 \cdot 33 = 512$ gallons per minute. This therefore would represent the maximum volume of sewage that would be discharged by a population of $\left(\frac{512 \times 800}{10}\right) = 40{,}960$. And, as the Table shows that a 12-in. sewer laid at a gradient of 1 in 333, will carry, when it is charged two-thirds full of sewage, 607 gallons per minute, and this latter, on the foregoing basis, would represent the maximum flow of sewage due from a population of 48,560, i.e. when the average sewage output was only equal to 10 gallons per head per day; obviously, therefore, the 12-in. sewer would suffice to receive and discharge the sewage of 40,960, the population for which, in the judgment of the engineer, sewers should be provided, and, subject to the approval of the L.G.B., paid for in the usual way out of money to be borrowed for the purpose from the Public Works Loan Commissioners.

But if the average volume of sewage discharged by a population whose outfall sewer is 12 in. in diameter, and is laid at a gradient of 1 in 333, is equal to what it is, e.g., in London, i.e. 35 gallons per head per day, then the population for which it would be suitable, when charged half full of sewage, would be $\frac{384 \times 800}{35} = 8777$. When the pipe became two-thirds full, moreover, it would suffice for a population of $\frac{607 \times 800}{35} = 13{,}874$.

288. It will be noticed that to Table B a supplementary Table B_1 is appended. The explanation of this is as follows :

The full tables from which Table B has been compiled are 34 in number (i.e. for pipes ranging from 3 to 36 in. in diameter inclusive), and are all worked out with the same fulness of detail as Table B_1 is; that is to say they give for each of the pipes dealt with the results of laying such pipe at a considerable number of other gradients than those given in Table B. A glance at Table B_1 will show what is meant. It deals only with a 12-in. pipe, and is printed as an example of the fuller tables. But besides the special gradient for a self-cleansing velocity allocated to it in Table B, namely 1 in 333, it also shows the results in velocity, discharge and population which would correspond to any one of the various other gradients given in Table B_1. This amount of detail appears to me altogether needless for the purpose of this book, as the materials supplied by Table B are complete in themselves, and give the practical engineer exactly the information he requires, without the incubus of extraneous matter.

289. The time-unit of 400 minutes per diem as the time in which one-half of the whole day's sewage discharges flows into drains and sewers is based upon the practice of prevailing authorities with regard to the carrying capacities of water-supply pipes, and drains and sewers respectively. As to water pipes, it is considered desirable that they should be capable of conveying the water-supplies for domestic, manufacturing, and fire extinguishing purposes in six hours per day; while drains and sewers should be made large enough to carry the whole of the sewage and other waste fluids of towns and villages in seven to eight hours. The mean between these extremes is $\frac{420+480}{2} = 450$ minutes; but I regard it as safer to provide in all cases main outfall sewers large enough to take half of the liquid wastes of towns in 400 minutes.

There is another aspect from which Table B may be studied. It shows that according as any given pipe is charged full, or $\frac{3}{4}$ full, or $\frac{1}{2}$, $\frac{1}{3}$, or $\frac{1}{4}$, etc., full, there is a corresponding velocity of discharge, which is in each case accurately indicated in the Table.

To exemplify this, and at the same time to show the practical value of the Table, let us assume (what indeed is now apparently admitted on all hands) that the minimum velocity of discharge consistent with self-cleansing of drains and sewers is in this country $2\frac{1}{2}$ ft. per second. Let us now consult the Table, say, at a pipe 12 in. in diameter. We find that such a pipe, laid at a gradient of 1 in 333 will discharge when running full bore, its liquid contents at the rate of 2·609 ft. per second. This result, being more than 4 per cent. above the standard of $2\frac{1}{2}$ ft., is therefore a good self-cleansing velocity. Similarly in the case of any other pipe within the limits of the Table,

Table B₁

12-INCH PIPE

Fall per 1,000 Feet	Gradient 1 in	Equivalent Pressure of Air per 1,000 Feet of Pipe	Pipe Flowing Full: Velocity of Flow of Sewage	Pipe Flowing Full: Discharge of Sewage	Pipe Flowing Full: Population Served at 10 Gallons per Head per Diem	¾ Vertical Height: Velocity of Flow of Sewage	¾ Vertical Height: Discharge of Sewage	¾ Vertical Height: Population Served at 10 Gallons per Head per Diem
		Lbs. per Square Inch	Feet per Second	Gallons per Min.		Feet per Second	Gallons per Min.	
0·5	2,000·0	0·217	1·065	313	25,040	1·222	289	23,120
1·0	1,000·0	0·434	1·506	443	35,440	1·728	409	32,720
2·0	500·0	0·868	2·130	626	50,080	2·444	578	46,240
3·0	333·3	1·302	2·609	767	61,360	2·993	708	56,640
4·0	250·0	1·736	3·012	886	70,880	3·458	818	65,440
5·0	200·0	2·170	3·368	990	79,200	3·864	914	73,120
6·0	166·7	2·604	3·690	1,065	86,800	4·233	1,001	80,080
7·0	142·9	3·038	3·985	1,172	94,000	4·572	1,082	86,560
8·0	125·0	3·472	4·260	1,253	100,240	4·887	1,156	92,480
9·0	111·1	3·906	4·519	1,329	106,320	5·184	1,227	98,160
10·0	100·0	4·340	4·763	1,401	112,080	5·464	1,293	103,440
a	b	c	1	2	3	4	5	6

Fall per 1,000 Feet	⅔ Vertical Height: Velocity of Flow of Sewage	⅔ Vertical Height: Discharge of Sewage	⅔ Vertical Height: Population Served at 10 Gallons per Head per Diem	Pipe Flowing Half-Full: Velocity of Flow of Sewage	Pipe Flowing Half-Full: Discharge of Sewage	Pipe Flowing Half-Full: Population Served at 10 Gallons per Head per Diem
	Feet per Second	Gallons per Min.		Feet per Second	Gallons per Min.	
0·5	1·190	248	19,840	1·065	157	12,560
1·0	1·684	351	28,080	1·506	222	17,760
2·0	2·381	496	39,680	2·130	313	25,040
3·0	2·917	607	48,560	2·609	384	30,720
4·0	3·368	701	56,080	3·012	443	35,440
5·0	3·765	784	62,720	3·368	495	39,600
6·0	4·125	859	68,720	3·690	546	43,680
7·0	4·456	928	74,240	3·985	586	47,840
8·0	4·763	992	79,360	4·260	627	50,160
9·0	5·052	1,052	84,160	4·519	665	53,200
10·0	5·325	1,109	88,720	4·763	701	56,080
a	7	8	9	10	11	12

Fall per 1,000 Feet	⅓ Vertical Height: Velocity of Flow of Sewage	⅓ Vertical Height: Discharge of Sewage	⅓ Vertical Height: Population Served at 10 Gallons per Head per Diem	¼ Vertical Height: Velocity of Flow of Sewage	¼ Vertical Height: Discharge of Sewage	¼ Vertical Height: Population Served at 10 Gallons per Head per Diem
	Feet per Second	Gallons per Min.		Feet per Second	Gallons per Min.	
0·5	0·851	73	5,840	0·704	40	3,200
1·0	1·214	104	8,320	0·996	57	4,560
2·0	1·703	146	11,680	1·409	81	6,480
3·0	2·085	179	14,320	1·725	99	7,920
4·0	2·408	207	16,560	1·992	114	9,120
5·0	2·693	231	18,480	2·228	128	10,240
6·0	2·930	253	20,240	2·441	140	11,200
7·0	3·186	273	21,840	2·636	151	12,080
8·0	3·406	292	23,360	2·818	162	12,960
9·0	3·613	310	24,800	2·989	172	13,760
10·0	3·808	327	26,160	3·150	181	14,480
a	13	14	15	16	17	18

[*To face page* 315]

a gradient can be found which will give a self-cleansing velocity for that pipe when delivering full bore.

On the other hand, let us suppose that the same 12-in. pipe laid at the same gradient is running only ⅓ full; then the Table shows a velocity of only 2·085 ft. per second, which is over 16 per cent. below the standard of 2½ ft., and therefore is not a self-cleansing velocity.

In all cases, as will be observed, the velocity for a pipe half full is the same as that for a pipe fully charged.

290. From the foregoing explanations the following important inferences are inevitable:—

(*a*) Even when the engineer is able to lay his sewer pipes at the gradient suitable to their respective diameters, unless the volumes of liquid in any given street or district are sufficient to half fill them, he cannot obtain a self-cleansing velocity.

(*b*) And further in proportion as the supply of those liquids falls short of a half full charge, sewage-sludge deposits will form on the inverts of the sewers; and as the volumes of these deposits increase, so will the volume of sewage gas emitted from them increase also.

(*c*) When this is the case, the necessity of effective ventilation seems too palpable to require any laboured demonstration; and the imperfect devices hitherto adopted with that end in view, have all been notoriously unsuccessful.

291. But even the above facts do not exhaust, or nearly exhaust, the difficulties in the way of the sanitary engineer when planning a system of sewerage and drainage.

He is confronted by the following formidable problem. He may see his way to the execution and efficient working of a system perfectly well adapted to the demands of the supply, in his district, of the sewage proper. But this would not at all satisfy the requirements of the Local Government Board, who generally insist that the sewers shall be of such dimensions as will be sufficient to enable them to carry not only the sewage *wastes*, but also rain waters to the extent of making their discharging capacity six times more than would suffice for the sewage alone.

Therefore whatever arrangements or provisions are made for purification or other treatment of the effluent at the outfall, they must be made to apply to the whole of that sixfold quantity of liquid discharge. If, however, at any time that quantity should be exceeded by reason of more abundant rainfall, then the surplus must be discharged through storm overflows by conduits, to be provided on the lines of the main sewers, and conducted to the outfall, or elsewhere, to undergo a proper treatment (less stringent than the ordinary wastes are subjected to) before they are allowed to be finally discharged into the sea or into any stream or river suitable for their reception. This at least is the usual prescription, though in some cases the carriage and treatment of storm overflow waters may be more easily accomplished, and special treatment may be partially or wholly dispensed with.

The enforcement of these empirical conditions tends greatly to increase the initial and annual costs of the sewage and pumping, as well as the outfall treatment works; and, what is still more important, they tend to a serious extent to diminish the hygienic effects aimed at by their construction, as I shall proceed at once to demonstrate. Supposing, for example, that the empirical rules and regulations above referred to were enforced in a town or district whose population discharged on the average 25 gallons per head per day of sewage proper into the sewerage system; and that the outfall and other subsidiary sewers are to be circular in shape and to be large enough, when they are half filled with sewage and rainfall combined, to carry six times the estimated dry weather flow of sewage from a present estimated population, say, of 10,000; and that the size and gradient of the final outfall sewer in particular should be adjusted so as to cause the whole of the sewage of the present population to flow freely through it at the self-cleansing velocity of $2\frac{1}{2}$ ft. per second, or 150 ft. per minute, when the sewer was filled only to the one-half of its total carrying capacity. The total present dry weather volume of sewage proper that would proceed from the population of 10,000 per day would therefore be $= 10,000 \times 25 = 250,000$ gallons. Now by multiplying this by 6, we get 1,500,000 gallons per day. But the engineer responsible for the designing and carrying out of the work would be obliged to make provision in his sewers for the discharge of the sewage of 10,000 people immediately after the construction of his new works, and this provision should be made in such a way as that the total estimated dry-weather flow multiplied by 6 could pass through the outfall sewer, as already indicated, when it became half filled with sewage, as the engineer would then doubtless consider that he would be making ample provision for any additional volumes of sewage which would accrue from the population that would grow up in the town during the period when the money borrowed, as above mentioned, for the construction of the new drainage works would have been paid back, or reduced in the usual way. In which case, his outfall sewer would have to be large enough to discharge not $1\frac{1}{2}$ million gallons as a maximum, but 3,000,000 gallons of sewage per day, at a velocity of $2\frac{1}{2}$ ft. per second, or 150 ft. per minute.

Assuming, again, that the one half of the 3 million gallons of sewage and rainfall combined passed through the sewer to the outfall in 400 minutes, then the sewer would have to discharge $\frac{3,000,000 \div 2}{400}$ $= \frac{1,500,000}{400} = 3750$ gallons per minute. By dividing this latter volume by its velocity in feet per minute we can calculate the number of gallons contained in 1 foot of its length; and also what its diameter in inches should be:—Thus, if we call the total volume of liquids to be discharged by the pipe per minute G; the volume contained in 1 ft. of its length g; the velocity in feet per minute of the liquids V, the constant 0·034, the volume in decimals of a gallon contained in a pipe 1 in. in diameter 1 ft. long, we can determine in the manner following what the diameter of the pipe in inches should be. Thus $g = \frac{G}{V} = \frac{3750}{150} = 25$.

and $$d = \sqrt{\frac{g}{0·034}} = \sqrt{\frac{25}{0·034}} = 27 \text{ in.}$$

By reference to Table B we find that a 27-in. sewer-pipe, laid at a gradient of 1 in 1000, will discharge, when quarter full, the sewage of a population of 42,880 at a velocity of 1·841 ft. per second, provided the water supply and the sewage is equal on the average to 10 gallons per head per day. And the same pipe, laid at the same gradient, would carry the sewage discharges of a population of $\frac{42,880}{2·5} = 17,152$, where the water supply and sewage discharges were equal to 25 gallons per head per day. But, even then, the coefficient of velocity would be = 36 per cent. short of the velocity needed to make a sewer-pipe of 27 in. in diameter self-cleansing.

But according to Table No. III, which is on page 362, a 27 in. sewer pipe, to carry 3722 gallons per minute at a velocity of 150 ft. per minute, when full, must be laid at a gradient of 1 in 927; and the *maximum* dry weather flow of sewage that would proceed from a population of 10,000, discharging sewage into the sewers at the rate of 25 gallons per head per day, would not, according to my rule for estimating the maximum dry weather flow in gallons per minute of the sewage proper, exceed $\left(\frac{10,000 \times 25}{2 \times 400}\right) = 312$ gallons per minute. The velocity at which this volume would travel on the invert of a 27-in. pipe can be ascertained by reference to the figures in cols. 1 and 4 of Table No. VI on page 382. The figures in col. 1 are arrived at by dividing the total volume any sewer-pipe is capable of discharging when full by any smaller volume than its complement that may be flowing on its invert. Col. 1 in the case under consideration is, therefore, $= \frac{312}{3750} = 0 \cdot 08$; and the figures in col. 4 opposite to them, viz. 0·3867 multiplied by the velocity of 2·5 ft. per second, will give the velocity at which the smaller volume, i.e. the 312 gallons, will travel per minute. Thus, $0 \cdot 3867 \times 2 \cdot 5 = 0 \cdot 96675$ ft. per second, which is short by 1·53325 ft. per second of being a self-cleansing velocity. In other words, it is $\frac{2 \cdot 5 - 0 \cdot 96675 \times 100}{2 \cdot 5} = 61 \cdot 33$ per cent. less than it should be. Obviously such a sewer could not fail to be, as long as it existed under the conditions stated above, a sewer of deposit, and consequently an *insanitary sewer*.

After many years' experience and study of English house and town drainage and drainage ventilation, as well as sewage disposal and treatment problems, I venture most respectfully and seriously to suggest that the Local Government Board should henceforward, wherever practicable, reduce the volume of sewage and rainfall combined from, say, 150 gallons per head per day, to 50 gallons per head per day, as a maximum, and that they should also insist in all cases, where the combined system of town drainage was adopted, that the main gravitation outfall sewer should not be capable of discharging more than the whole of the sewage of the estimated existent population of the town or district planned to be drained, at the date of the completion of the new drainage works, at a velocity of 2½ ft. per second, when it was half full. I say, if these conditions were substituted for those now in force, all that would be reasonably necessary to do in the vast majority of towns and districts in this country, for dealing with the present and future sewage and rainfall discharges combined, would be done both on the score of efficiency, in a sanitary sense, and on the score of economy in so far as the initial and annual costs connected with the works as a whole, were concerned.

For example, upon this suggested basis the ultimate maximum volume of the sewage of a population of 10,000, estimated as above to be discharged into the sewers, viz. 3750 gallons per minute, for which sewers, outfall lands, tanks, treatment works, etc., etc., would have to be provided, in accordance with the present regime of the Local Government Board, would be reduced to $3750 \times \frac{50}{150} = 1250$ gallons per minute. The diameter of the outfall sewer that would then be suitable to pass that volume through it at a velocity of 150 ft. per minute when it was half full would have to be, approximately, 16 in.

This pipe, however, to give a self-cleansing velocity when full, The various considerations here advanced may also be usefully illustrated by the two drawings Nos. 42 and 43. Both of these are strictly "true to life," in other words, they represent actual situations in existence to-day.

New paragraph, to replace old one on page 319.

Errata.

n page 318 on the third line from the bottom *the word* "half" *should be deleted.*

n page 319 on the seventh line from the top *the letter* "a" *should be substituted for the word* "the."

he last paragraph of Section 291, which is on page 319, applies to a drawing which by inadvertence has been omitted, *and the words* "plan and" on the same page, third line from the bottom—*should have been omitted.*

The difficuities in the way of Sanitary Engineers acting as such, which are described on pages 318 and 319, can readily be overcome by adopting the Circular Omnibus-form of Sewer specially designed for use with the Shone Antiseptic Sewerage System of the 20th Century, which will be fully described and illustrated in Part II. of this book.

ONE—*Sewage Drainage Systems.*

would discharge 1307 gallons per minute, if laid at a gradient of 1 in 495; but even this smaller pipe, though laid at the steeper gradient, would fail to cause the dry weather flow of the sewage of the population of 10,000 to have a greater velocity than 1·6567 ft. per second, which would still be 0·8433 ft. per second below the self-cleansing velocity, and consequently would be = 34 per cent. short of what it should be. On the other hand, the 17-in. sewer pipe filled half bore would suffice to carry the sewage proper of a population of 42,700.

The treatment of the sewage at the outfall, of course, is a very important matter indeed; but I submit that in comparison with the health or ill-health question, as it affects the drains and sewers of the towns or districts in which the sewage, treated at the outfall, is produced, it is of minor, if not, comparatively speaking, of negligible importance.

Moreover, the question as to the initial cost involved in the purchasing and laying down of the larger insanitary sewer pipe, in lieu of the smaller and more sanitary one, is of real and urgent importance to the ratepayers who pay for the drainage works. Some idea may be formed of this practical and pressing monetary aspect of the business we are now discussing by our drawing a comparison between the initial cost, say, of buying and laying in the ground a cast-iron pipe of 27 in. in diameter, and buying and laying one down of 17 in. in diameter for, say, town water-supply distribution works. The larger pipe will cost nearly double the cost of the smaller 17-in. pipe sewer. This approximate extra proportion cost would apply also to the sewer pipes, if they were made in stoneware instead of iron; and so I seriously suggest that the Local Government Board should as speedily as possible amend their existing rules and regulations, by which they compel the sanitary authorities of this country to do something that results in wasting enormous sums of public money ostensibly for the purpose of improving the sanitary conditions of their homes, and villages, and towns, but really, as I have now demonstrated, with exactly the opposite effect.

It need hardly be added that all the difficulties described above will be intensified where the towns or districts concerned are situated on flat, low-lying or tide-locked lands.

The various considerations here advanced may also be usefully illustrated by the two diagrams which face this page, and both of which are strictly "true to life"; in other words, they represent actual situations in existence to-day.

292. Drawing No. 42 shows in plan and section a public egg-shaped main sewer, and transverse and longitudinal sections of same. It represents the sewerage system of a large coast town, the

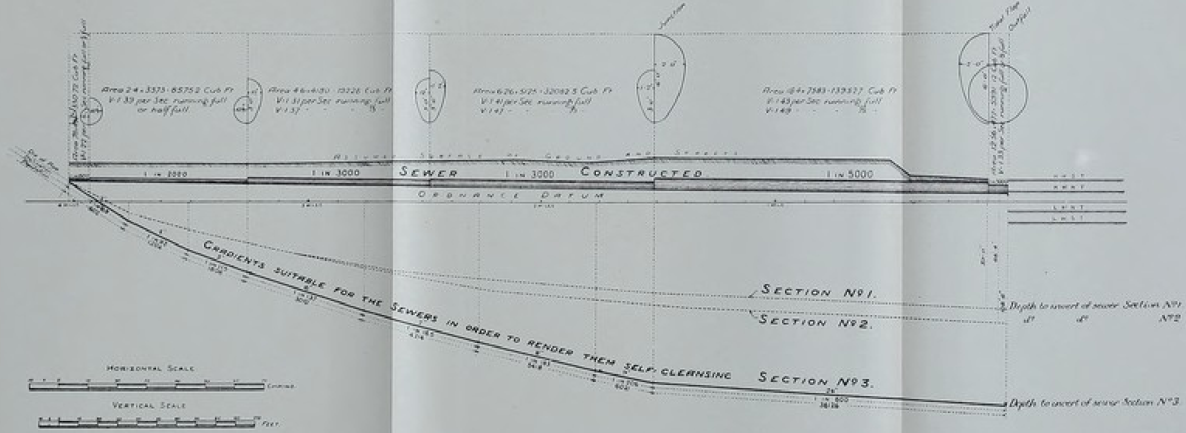
site of which is extremely flat and low lying. We will call th "Town A."

Above the longitudinal section are given the transverse dimensions, shapes, etc., of the sewers as designed and laid, and below the section are given also the dimensions and inclinations of circular sewer pipes calculated to be necessary to carry the sewage to the outfall at self-cleansing velocities. The drawing shows, further, the estimated population for whose sewage each sewer is ideally adapted, under hydraulic laws, for the effectual sanitary removal of their sewage to the outfall.

The sewerage system of Town A embraces, as the drawing shows, three sections, comprising three main sewers each about 4 miles long. Had these main sewers been laid at the self-cleansing gradients which are dictated by hydraulic and hygienic principles, it is clear that their bottom ends would have been respectively 59 ft., 66 ft. 4 in., and 106 ft. 6 in. vertically below the level of the inverts of the three sewers actually laid, at the outfall; and these figures appear on the drawing. But it is needless to add that sewers descending to such depths would be impracticable and on the score of expense alone would be prohibitive. Moreover, as it happened, the local authority shrank from incurring the cost of any kind of pumping either at the outfall or elsewhere; so that the engineer to whom the designing and working out of the system was entrusted had no other course open to him but to drain the town wholly as best he could by gravitation alone. And it must be frankly admitted that taking into consideration the untoward conditions with which he had to grapple, he executed the task as ably and as well as in my opinion it was possible for him to do with the knowledge he possessed at the time. With the object of preserving as far as practicable the inverts of his sewers from deposits, he designed flushing gates and penstocks to be introduced at suitable points in the main sewers. By a systematic and free use of a large number of these contrivances it was confidently anticipated that the sewers could be adequately flushed in sections without having to use drinking or other expensive water for the purpose.

It was soon found that the hopes entertained of the success of this method of treatment were doomed to disappointment. I pass over as a detail the unsavory, not to say filthy, manual labour involved in the process. But, as might have been foreseen, after the new works were started the flushing operations aggravated in quantity and in noisomeness the foul emanations from the sewers by unduly agitating the sewage liquids and crude sewage deposits, and driving noxious fumes up private house-drains, and through manhole-cover openings, gullies and vent-shafts into the air of the streets. I say the flushing process aggravated those evils; but in no

DRAWING No 42.



[Face p. 320.

case could it be expected that tide-locked sewers, of the dimensions and length, and laid at such flat gradients as those in Town A, could have failed to produce unwholesome and unpleasant effects. The result was that the residents petitioned the local authority, as well as the Local Government Board, to take steps to remove the nuisances in question.

293. The second district or place I propose to discuss, which will help me to illustrate the difficulties that beset sanitary engineers who are called upon and are expected to design sewers in accordance with the rules and regulations of the Local Government Board, which shall work efficiently by gravitation power alone, in districts whose natural surfaces are practically flat, I will call "Town B."

On account of this town being flat and absolutely undrainable, hygienically speaking, by gravitation power alone, my firm (Shone and Ault) prepared a scheme for draining it on the Shone Hydro-pneumatic System. What I shall state in the following pages about it may therefore be taken as being correct, because the matters referred to are within my own personal knowledge. The various reasons which led the Local Sanitary Authority to ask the Local Government Board to sanction a scheme for the drainage of the town B, by gravitation, need not be stated here. Suffice it to say that the engineer selected by the authority of the Town B to design and carry out the Gravitation scheme had no alternative but to lay his outfall sewer at the best gradient that was available to him. The provision, however, of the Local Government Board, by which he was compelled to provide his main outfall sewer large enough to permit of a volume of sewage and rainfall that would be equal in the aggregate to six times the dry weather flow of sewage, warranted him in pleading, as he did, at the Local Government Board Inquiry into the merits of the scheme, that a sewer 24 in. in diameter laid at a gradient of 1 in 1000 would permit of his sewer being to all intents and purposes a self-cleansing sewer, and the result was that the Local Government Board Inspector, who held the Inquiry, approved of his plans.

The following drawing, No. 43, to which I now desire to call your attention shows to scale two circular sewers, the one (marked P_1) 10-in. in diameter and the other (P_2) 24 in. Both circles are vertically bisected, and the left half of the circumference of the small circle is drawn with a full line, while its right half is a dotted line, and the converse is the case with the large circle. It will be seen by consulting Table B for those diameters, that if the larger pipe is laid at a gradient of 1 in 1000, and the smaller at a gradient of 1 in 250, both will, when charged full or half full, cause the sewage

case could it be expected that tide-locked sewers, of the dimensions and length, and laid at such flat gradients as those in Town A, could have failed to produce unwholesome and unpleasant effects. The result was that the residents petitioned the local authority, as well as the Local Government Board, to take steps to remove the nuisances in question.

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I estimated that when in Town B the sewerage works should have been completed, and when most of the drains of the houses should have been connected up to the main sewers, the maximum dry weather flow of sewage available to discharge into the outfall sewer would only suffice to charge even the smaller 10-in. pipe to the extent coloured black, which is equal to one-third of its diameter. That being the case, the velocity would only be 2·085 ft. per second, or 0·415 ft. less than the self-cleansing rate of 2½ ft. In other words, it would be 16·6 per cent. too slow. Thus the inhabitants would have to put up with a sewer of deposit until the possibly far distant time when the maximum dry weather volume of the sewage was sufficient to half fill it. Then, and not till then, could the 10-in. pipe perform its functions properly as a self-cleansing and sanitary sewer.

On the other hand, had the town possessed a sloping surface sufficient to permit the laying of a 10-in. sewer pipe at a gradient suitable for it, namely 1 in 250; and had the local authority instructed their engineer to drain the houses and other buildings of the town of their sewage waters only, or only with the addition of a limited quantity of rain falling on the roofs and yards; that, and no other would be the gradient at which such a sewer would be laid, for it would involve a minimum of trenching work, and would act efficiently from a sanitary point of view. But owing to the flatness of the ground of Town B and its comparatively water-logged condition, coupled with the Government regulations above alluded to, it was impossible to lay the 10-in. pipe at the gradient of 1 in 250. Consequently a pipe of 24 inches in diameter was decided upon, and was laid at a gradient of approximately 1 in 1000. By again referring to Table B, it will be seen that such a pipe will when full or half full of liquid discharge the same at the self-cleansing velocity of approximately 2½ ft.† per second. But to attain this result in practice, it would be necessary that the pipe should be supplied with no less a quantity than 1438 gallons of liquid per minute to be half full; a quantity which at the rate of 25 gallons per head per day would correspond to the population of 46,016.

When I add that the total population of Town B is at this day

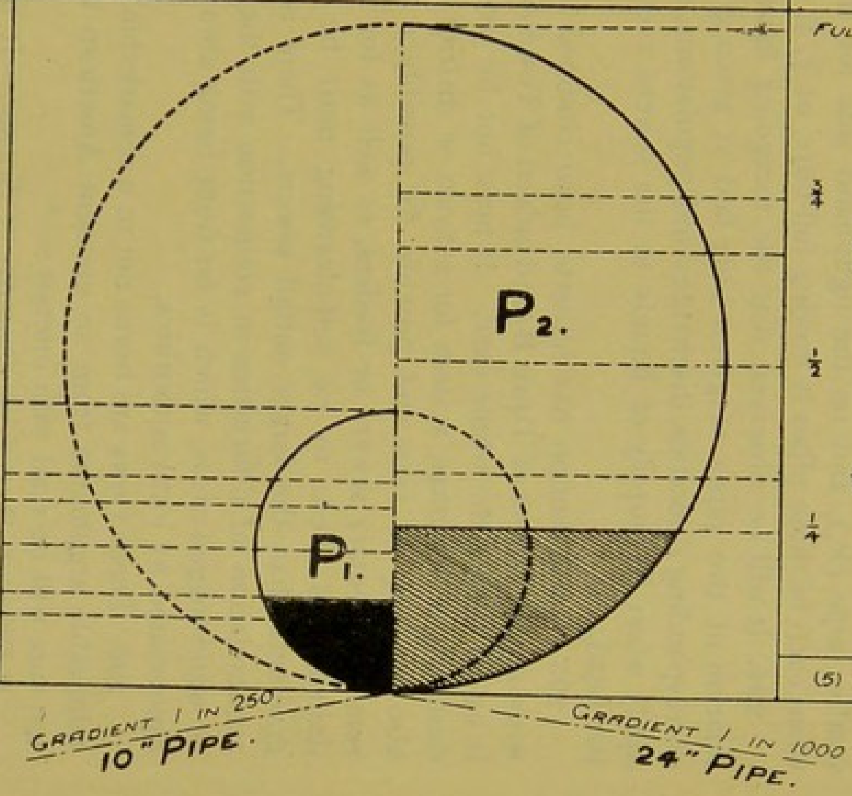
* More exactly, 2·445 and 2·626 feet per second respectively.

† More exactly, 2·445 feet per second.

10″ Sewer.

Population served when sewage discharge = 10 gallons per head per day.	Volume of flow. Gallons per minute.	Velocity of flow feet per second.	Depth of flow of sewage.
42 880	536	2 626	Full
39 760	497	3 025	¾
34.080	426	2·946	⅔
21 440	268	2 626	½
9.920	124	2 085	⅓
5 520	69	1·717	¼
Col.^n (1)	(2)	(3)	(4)

NOTE:—The Velocities & Volumes of Sewage given in the Diagram-Table, correspond to those given in Table B which appears on Page........



24″ Sewer.

Depth of flow of sewage	Velocity of flow feet per second	Volume of flow gallons per minute.	Population served. when sewage discharge = 10 gallons per head per day.
Full	2 445	2876	230 000
¾	2 763	2615	209 200
⅔	2 701	2 250	180 000.
½	2·445	1 438	1 ·5 040
⅕	2·004		55 04
¼	1·693	589	31 120
(5)	(6).	(7)	(8)

under 6000, the value of the probability will be realised of their attaining at any near date the desirable position of having a system of hygienic self-cleansing sewers. This, again, demonstrates that in the meantime the people must be content with sewers of deposit, and their consequent nuisances and dangers to health.

Referring once more to Drawing No. 43, the resultant velocities, volumes of flow, and corresponding populations (at the rate of 10 gallons per head per day) are marked on the left-hand side for the smaller pipe (P_1), and on the right-hand side for the larger (P_2); when each of these pipes is flowing full-bore, or $\frac{3}{4}$, $\frac{2}{3}$, $\frac{1}{2}$, $\frac{1}{3}$, or $\frac{1}{4}$ full.

294. It will be observed that the foregoing figures showing the relation of two pipes of given bore laid at given gradients to their corresponding velocities, discharges and populations, are those which apply when the supply of liquids to the sewers averages 10 gallons per head.

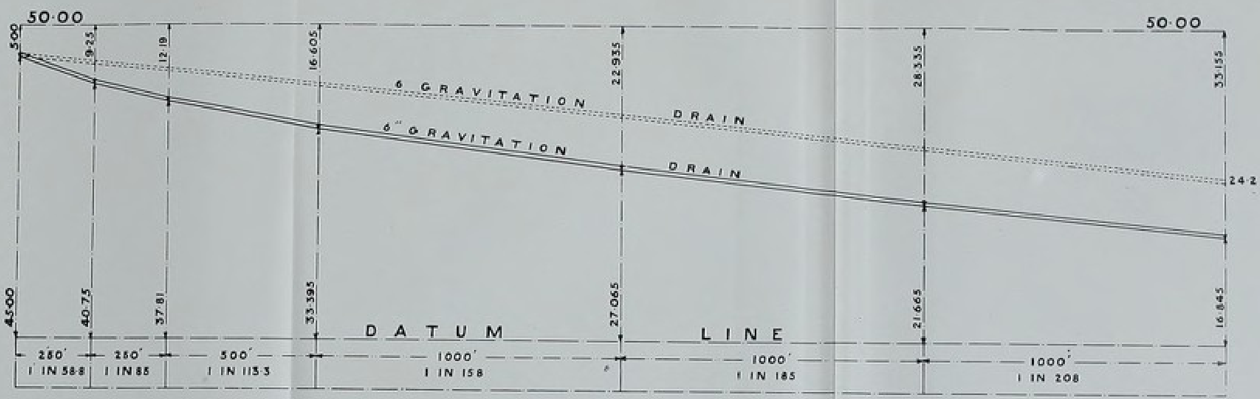
295. Our attention has hitherto been confined to an analysis of *main outfall sewers* of Town B (and indeed of Town A also); but this is by no means the whole case. It must not be overlooked that in designing a sewerage system for a town or district the engineer has also to keep in view and provide for possibly a great number of smaller tributary sewers or feeders, as well as for house and other drains. All these to be self-cleansing must be laid at steeper gradients than the larger outfall sewers. There is, in a word, an accumulation of difficulties in connection with the drainage of flat or water-logged areas, which is far from being always recognised or appreciated by local authorities.

296. These views are borne out in a remarkable manner by some admirable arguments from an eminent American authority which I am sure will be read with interest:—*

"*Effect of Decreasing Quantity of Sewage.*—It must be borne in mind that the flow decreases in volume in arithmetical ratio as we ascend the sewer, becoming zero at the summit. In illustration: If we assume a 6-in. sewer 4000 ft. long, with a grade of 0·48 per 100, to have a tributary population for each 100 ft. of its length of fifty persons, and each person to contribute 50 gallons per day of sewage, to be discharged in 16 hours, with the sewer running half full, the computed maximum velocity at its lowest level becomes, approximately, 144 ft. per minute. The volume of sewage, however, at distances of 250, 500, 1000, 2000 and 3000 ft. from its summit, is but $\frac{1}{16}$, $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$ and $\frac{3}{4}$ of that at the point where it is running half full, and, by computation, supposing the sewer laid at a uniform grade,

* "The Separate System of Sewerage," by C. Staley, President of the Case School of Applied Science, Cleveland, Ohio; and G. S. Pierson, C.E., pp. 75–76.

DRAWING No. 44



To face p. 325.]

the theoretical velocities at these points become, approximately, as follows :—

Distance.	Velocity.
250 ft.	73·4 ft. per minute.
500 ,,	89 ,, ,,
1000 ,,	105·11 ,, ,,
2000 ,,	124·42 ,, ,,
3000 ,,	135·88 ,, ,,
4000 ,,	144 ,, ,,

"Or, assuming the inclination to be increased as we approach the summit, so that the velocity shall be maintained at the uniform rate of 144 ft. per minute, the inclination at the several points, theoretically, becomes about as follows :—

Distance.	Inclination.
250 ft.	1 in 58·8 = 1·700 per 100
500 ,,	1 in 85 = 1·176 per 100
1000 ,,	1 in 113·3 = ·870 per 100
2000 ,,	1 in 158 = ·632 per 100
3000 ,,	1 in 185 = ·540 per 100
4000 ,,	1 in 208 = ·480 per 100

"These figures very plainly illustrate what is so often observed in practice, and explain the frequency of stoppages in the higher levels of a system of sewers. They also illustrate the great benefit to be derived from the use of automatic flushing tanks at dead ends, by which the sewer is intermittently filled to a fair working capacity, and its stranded contents swept on to the mains before they have accumulated to a degree interfering with the working of the sewer. Flushing tanks at dead ends so surely counteract the defects above stated that lateral sewers, to which they are applied, may be designed with uniform inclination throughout.

"The grade of streets frequently prevents the inclination of sewers being increased to the proper degree toward the summits, and in this case flush tanks are indispensable."

The above I think sufficiently explains itself, but I have thought it desirable to illustrate it by the diagram, Drawing No. 44, which is a longitudinal section showing the depths in feet, which the hypothetical 6-in. drain or sewer would attain if it were laid under a practically horizontal street, for a total length of 4000 ft. at the various gradients stated in the extract. It will be seen, for example, that if the ideally perfect self-cleansing drain or sewer were 5 ft. in depth below the street level at its upper end, it would be 33·155 ft. at its lower or bottom end, while, if it had been laid at the uniform gradient of 1 in 208—which is the gradient estimated to be suitable for it, to enable it to carry the total volume of sewage arriving at its bottom end at the estimated self-cleansing velocity of 144 ft. per minute—its total depth below the street surface level would then be only 24·2 ft., or nearly 9 ft. too shallow for the self-cleansing standard.

The above passage, thus explained, emphasises in a striking manner the formidable difficulties which beset the sanitary engineer in the effort to solve the problem of hygienic drainage.

Table C.

RELATIVE DISCHARGING CAPACITIES OF PIPES WITH EQUAL HEADS.

d	$\sqrt{d^5}$	2	3	4	5	6	7	8	9	10	11	12
1	1·000	..	..	..	..	..	..	..	..	..	..	..
2	5·657	1	2·7557	5·6569	9·8821	15·588	22·918	32·000	42·957	55·902	70·943	88·182
3	15·588	..	1	2·0528	3·5861	5·6569	8·3165	11·612	15·588	20·286	25·744	32·000
4	32·000	..	..	1	1·7469	2·7557	4·0513	5·6569	7·5938	9·8821	12·541	15·588
5	55·902	..	..	..	1	1·5774	2·3191	3·2382	4·3469	5·6569	7·1789	8·9234
6	88·182	..	..	..	..	1	1·4702	2·0528	2·7557	3·5861	4·5510	5·6569
7	129·642	..	..	..	..	..	1	1·3963	1·8744	2·4392	3·0955	3·8478
8	181·019	..	..	..	..	..	..	1	1·3424	1·7469	2·2170	2·7557
9	243·000	..	..	..	..	..	..	..	1	1·3013	1·6515	2·0528
10	316·228	..	..	..	..	..	..	..	..	1	1·2691	1·5774
11	401·312	..	..	..	..	..	..	..	..	..	1	1·2430
12	498·830	..	..	..	..	..	..	..	..	..	..	1
13	609·338	..	..	..	..	..	..	..	..	..	..	..
14	733·365	..	..	..	..	..	..	..	..	..	..	..
15	871·421	..	..	..	..	..	..	..	..	..	..	..
16	1,024·00	..	..	..	..	..	..	..	..	..	..	..
17	1,191·58	..	..	..	..	..	..	..	..	..	..	..
18	1,374·62	..	..	..	..	..	..	..	..	..	..	..
19	1,573·56	..	..	..	..	..	..	..	..	..	..	..
20	1,788·85	..	..	..	..	..	..	..	..	..	..	..
21	2,020·92	..	..	..	..	..	..	..	..	..	..	..
22	2,270·16	..	..	..	..	..	..	..	..	..	..	..
23	2,536·99	..	..	..	..	..	..	..	..	..	..	..
24	2,821·81	..	..	..	..	..	..	..	..	..	..	..
25	3,125·00	..	..	..	..	..	..	..	..	..	..	..
26	3,446·94	..	..	..	..	..	..	..	..	..	..	..
27	3,788·00	..	..	..	..	..	..	..	..	..	..	..
28	4,148·54	..	..	..	..	..	..	..	..	..	..	..
29	4,528·92	..	..	..	..	..	..	..	..	..	..	..
30	4,929·50	..	..	..	..	..	..	..	..	..	..	..
31	5,350·62	..	..	..	..	..	..	..	..	..	..	..
32	5,792·62	..	..	..	..	..	..	..	..	..	..	..
33	6,255·83	..	..	..	..	..	..	..	..	..	..	..
34	6,740·58	..	..	..	..	..	..	..	..	..	..	..
35	7,247·20	..	..	..	..	..	..	..	..	..	..	..
36	7,776·00	..	..	..	..	..	..	..	..	..	..	..

d	13	14	15	16	17	18	19	20	21	22	23	24
1	..	..	..	..	..	..	..	..	..	..	..	..
2	107·72	129·64	154·05	181·02	210·64	243·00	278·17	316·23	357·25	401·31	448·48	498·83
3	39·089	47·045	55·902	65·690	76·440	88·182	100·94	114·76	129·64	145·63	162·75	181·02
4	19·042	22·918	27·232	32·000	37·237	42·957	49·174	55·902	63·154	70·943	79·281	88·182
5	10·900	13·119	15·588	18·318	21·316	24·590	28·149	32·000	36·151	40·610	45·383	50·478
6	6·9100	8·3165	9·8821	11·612	13·513	15·588	17·845	20·286	22·918	25·744	28·770	32·000
7	4·7002	5·6569	6·7218	7·8987	9·1913	10·603	12·138	13·798	15·588	17·511	19·569	21·766
8	3·3662	4·0513	4·8140	5·6569	6·5826	7·5938	8·6928	9·8821	11·164	12·541	14·015	15·588
9	2·5076	3·0180	3·5861	4·2140	4·9037	5·6569	6·4756	7·3615	8·3165	9·3422	10·440	11·612
10	1·9269	2·3191	2·7557	3·2382	3·7681	4·3469	4·9760	5·6569	6·3907	7·1789	8·0227	8·9234
11	1·5184	1·8274	2·1714	2·5516	2·9692	3·4253	3·9211	4·4575	5·0358	5·6569	6·3218	7·0315
12	1·2215	1·4702	1·7469	2·0528	2·3887	2·7557	3·1545	3·5861	4·0513	4·5510	5·0859	5·6569
13	1	1·2035	1·4301	1·6805	1·9555	2·2559	2·5824	2·9357	3·3166	3·7256	4·1635	4·6309
14	..	1	1·1882	1·3963	1·6248	1·8744	2·1457	2·4392	2·7557	3·0955	3·4594	3·8478
15	..	..	1	1·1751	1·3674	1·5774	1·8057	2·0528	2·3191	2·6051	2·9113	3·2382
16	..	..	..	1	1·1636	1·3424	1·5367	1·7469	1·9736	2·2170	2·4775	2·7557
17	..	..	..	..	1	1·1536	1·3206	1·5013	1·6960	1·9052	2·1291	2·3681
18	..	..	..	..	..	1	1·1447	1·3013	1·4702	1·6515	1·8456	2·0528
19	..	..	..	..	..	..	1	1·1368	1·2843	1·4427	1·6123	1·7933
20	..	..	..	..	..	..	..	1	1·1297	1·2691	1·4182	1·5774
21	..	..	..	..	..	..	..	..	1	1·1233	1·2554	1·3963
22	..	..	..	..	..	..	..	..	..	1	1·1175	1·2430
23	..	..	..	..	..	..	..	..	..	..	1	1·1123
24	..	..	..	..	..	..	..	..	..	..	..	1
25	..	..	..	..	..	..	..	..	..	..	..	..
26	..	..	..	..	..	..	..	..	..	..	..	..
27	..	..	..	..	..	..	..	..	..	..	..	..
28	..	..	..	..	..	..	..	..	..	..	..	..
29	..	..	..	..	..	..	..	..	..	..	..	..
30	..	..	..	..	..	..	..	..	..	..	..	..
31	..	..	..	..	..	..	..	..	..	..	..	..
32	..	..	..	..	..	..	..	..	..	..	..	..
33	..	..	..	..	..	..	..	..	..	..	..	..
34	..	..	..	..	..	..	..	..	..	..	..	..
35	..	..	..	..	..	..	..	..	..	..	..	..
36	..	..	..	..	..	..	..	..	..	..	..	..

25	26	27	28	29	30	31	32	33	34	35	36	d	$\sqrt{d^5}$
..	..	..	..	..	..	..	..	..	..	..	..	1	1·000
552·43	609·34	669·63	733·36	800·61	871·42	945·87	1,024·00	1,105·9	1,191·6	1,281·1	1,374·6	2	5·657
200·47	221·12	243·00	266·13	290·53	316·23	343·24	371·60	401·31	432·41	464·91	498·83	3	15·588
97·656	107·72	118·37	129·64	141·53	154·05	167·21	181·02	195·49	210·64	226·47	243·00	4	32·000
55·902	61·661	67·762	74·211	81·016	88·182	95·715	103·62	111·91	120·58	129·64	139·10	5	55·902
35·438	39·089	42·957	47·045	51·359	55·902	60·677	65·690	70·943	76·440	82·185	88·182	6	88·182
24·105	26·588	29·219	32·000	34·934	38·024	41·272	44·682	48·255	51·994	55·902	59·981	7	129·642
17·263	19·042	20·926	22·918	25·019	27·232	29·558	32·000	34·559	37·237	40·035	42·957	8	181·019
12·860	14·185	15·588	17·072	18·638	20·286	22·019	23·838	25·744	27·739	29·824	32·000	9	243·000
9·8821	10·900	11·979	13·119	14·322	15·588	16·920	18·318	19·783	21·316	22·918	24·590	10	316·228
7·7870	8·5892	9·4390	10·337	11·285	12·283	13·333	14·434	15·588	16·796	18·059	19·376	11	401·312
6·2647	6·9100	7·5938	8·3165	9·0791	9·8821	10·726	11·612	12·541	13·513	14·528	15·588	12	498·830
5·1286	5·6569	6·2166	6·8083	7·4325	8·0899	8·7810	9·5064	10·267	11·062	11·894	12·761	13	609·338
4·2612	4·7002	5·1652	5·6569	6·1756	6·7218	7·2960	7·8987	8·5303	9·1913	9·8821	10·603	14	733·365
3·5861	3·9555	4·3469	4·7607	5·1972	5·6569	6·1401	6·6473	7·1789	7·7352	8·3165	8·9234	15	871·421
3·0518	3·3662	3·6992	4·0513	4·4228	4·8140	5·2252	5·6569	6·1092	6·5826	7·0773	7·5938	16	1,024·00
2·6226	2·8927	3·1790	3·4815	3·8008	4·1370	4·4904	4·8613	5·2500	5·6569	6·0820	6·5258	17	1,191·58
2·2734	2·5076	2·7557	3·0180	3·2947	3·5861	3·8924	4·2140	4·5510	4·9037	5·2722	5·6569	18	1,374·62
1·9859	2·1905	2·4073	2·6364	2·8781	3·1327	3·4003	3·6812	3·9756	4·2837	4·6056	4·9417	19	1,573·56
1·7469	1·9269	2·1176	2·3191	2·5317	2·7557	2·9911	3·2382	3·4971	3·7681	4·0513	4·3469	20	1,788·85
1·5463	1·7056	1·8744	2·0528	2·2410	2·4392	2·6476	2·8663	3·0955	3·3354	3·5861	3·8478	21	2,020·92
1·3766	1·5184	1·6686	1·8274	1·9950	2·1714	2·3569	2·5516	2·7557	2·9692	3·1924	3·4253	22	2,270·16
1·2318	1·3587	1·4931	1·6352	1·7852	1·9430	2·1090	2·2833	2·4658	2·6569	2·8566	3·0650	23	2,536·99
1·1074	1·2215	1·3424	1·4702	1·6050	1·7469	1·8962	2·0528	2·2170	2·3887	2·5683	2·7557	24	2,821·81
1	1·1030	1·2122	1·3275	1·4493	1·5774	1·7122	1·8536	2·0019	2·1570	2·3191	2·4883	25	3,125·00
..	1	1·0989	1·2035	1·3139	1·4301	1·5523	1·6805	1·8149	1·9555	2·1025	2·2559	26	3,446·94
..	..	1	1·0952	1·1956	1·3013	1·4125	1·5292	1·6515	1·7795	1·9132	2·0528	27	3,788·00
..	..	..	1	1·0917	1·1882	1·2898	1·3963	1·5080	1·6248	1·7469	1·8744	28	4,148·54
..	..	..	..	1	1·0884	1·1814	1·2790	1·3813	1·4883	1·6002	1·7170	29	4,528·92
..	..	..	..	..	1	1·0854	1·1751	1·2691	1·3674	1·4702	1·5774	30	4,929·50
..	..	..	..	..	..	1	1·0826	1·1692	1·2598	1·3545	1·4533	31	5,350·62
..	..	..	..	..	..	..	1	1·0800	1·1636	1·2511	1·3424	32	5,792·62
..	..	..	..	..	..	..	..	1	1·0775	1·1585	1·2430	33	6,255·83
..	..	..	..	..	..	..	..	..	1	1·0752	1·1536	34	6,740·58
..	..	..	..	..	..	..	..	..	..	1	1·0730	35	7,247·20
..	..	..	..	..	..	..	..	..	..	..	1	36	7,776·00

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TABLE C.

297. This table shows the relative capacities of pipes of different bores to discharge water, or air, or gas, on the basis that their capacities are in the proportion of the square root of the fifth power of their respective diameters. For instance if D represents the diameter of a large pipe, and *d* that of a small pipe, and *n* the number of small pipes that will have a discharging capacity equivalent to that of a single large pipe, then

$$n = \sqrt{\left(\frac{D}{d}\right)^5}$$

For a concrete example, suppose D to be 12 in. and *d* 3 in.; then

$$n = \sqrt{\left(\frac{12}{3}\right)^5} = 32.$$

Of course the above formula is ideal (like almost all formulæ of applied science); it assumes equality of length and gradient and of the degree of smoothness or roughness of the interior periphery. This consideration, however, does not at all detract from the value of the formula in the way of guidance provided reasonable allowances are made for any differences which may exist in any of the respects just stated.

Table D

COMPRESSED AIR TABLE

Pressure above Atmosphere: Lbs. per Sq. In.	Pressure above Atmosphere: Feet-head of Water	Relative Volume of Free Air after Compression: Isothermal Cubic Feet	Relative Volume of Free Air after Compression: Adiabatic Cubic Feet	Ratio of Compression, $\frac{P_2}{P_1}$	Average Load in Lbs. per Sq. In. against Compressing Piston: Isothermal	Average Load: Adiabatic	Average Load: Mean	Horse-power required per Cubic Foot of Free Air: Theoretical Indicated Horse-power in Air Compressor	Horse-power required: Theoretical Horse-power plus 25 per cent. Friction in Engine and Compressor	Number of Cubic Feet of Free Air required plus 20 per cent. Slip in Valves per Gallon of Water to be Lifted	Net Horse-power obtained per 1 Cubic Foot of Free Air in Water Lifted to Heights in Column B	Percentage of Useful Effect, 100 × Column M / Column K
A	B	C	D	E	F	G	H	I	K	L	M	N
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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TABLE D.

298. This is a Compressed Air Table, and shows the following particulars as to air pressures of from 1 to 100 lb. per sq. in. over atmospheric pressure, viz.:—

(*a*) Equivalent to head of water in feet.
(*b*) The relative volume of free air after compression both isothermal and adiabatic.
(*c*) The ratio of compression; i.e., the ratio of the absolute pressure of the atmosphere (say 14·7 lb.) to the absolute pressure due to compression.
(*d*) The average load against the air-compressing piston in lb. per sq. in.
(*e*) The horse power required per cub. ft. of free air.
(*f*) The number of cub. ft. of free air required per gallon of water to be lifted.
(*g*) The net horse power obtained per cub. ft. of free air.
(*h*) The percentage of useful effect.

299. The Formulæ on which this Table is based are the following:—

Column A.

Let p_1 = Absolute pressure of atmosphere (say 14·7 lb.).
p_2 = ,, ,, due to compression.
Then $A = p_2 - p_1 = p_2 - 14{\cdot}7$ represents the pressure in lb. per square inch above atmosphere.

Column B. Head of water in feet, corresponding to lb. per square inch in Column A.

$$B = (p_2 - 14{\cdot}7) \times 2{\cdot}307.$$

Column C. Volume of free air compressed isothermally $= \dfrac{p_1}{p_2}$.

Column D. Volume of free air compressed adiabatically $= \left(\dfrac{p_1}{p_2}\right)^{\cdot 7093}$

Column E. Ratio of compression $= \dfrac{p_1}{p_2}$.

Column F. Average load against compressing piston during isothermal compression $= p_1 \times \log_e \frac{p_2}{p_1}$.*

Column G. Average load against compressing piston during adiabatic compression.†

$$p_m = \frac{n}{n-1} \times \frac{p_2}{r} - \frac{1}{n-1} \times p_1 \quad . \quad . \quad (a)$$

Where $p_m =$ mean pressure.

$n = 1{\cdot}41.$

$r = \left(\frac{p_2}{p_1}\right)^{\cdot 7093}$ (i.e. ratio of adiabatic to original volume).

Excluding the atmospheric pressure, the formula becomes :—

$$p_m = \frac{n}{n-1} \times \frac{p_2}{r} - \frac{n}{n-1} \times p_1 \quad . \quad . \quad (\beta)$$

But $p_2 = p_1 \frac{p_2}{p_1}$, therefore $\frac{p_2}{r} = p_1 \times \frac{\frac{p_2}{p_1}}{\left(\frac{p_2}{p_1}\right)^{\cdot 7093}}$

$$= p_1 \left(\frac{p_2}{p_1}\right)^{\cdot 2907}$$

The formula can therefore be written

$$p_m = \frac{n}{n-1} \times p_1 \left\{ \left(\frac{p_2}{p_1}\right)^{\cdot 2907} - 1 \right\}$$

$$= 3{\cdot}439 \times 14{\cdot}7 \left\{ \left(\frac{p_2}{p_1}\right)^{\cdot 2907} - 1 \right\}$$

$$= 50{\cdot}5522 \left\{ \left(\frac{p_2}{p_1}\right)^{\cdot 2907} - 1 \right\} \quad . \quad . \quad (\gamma)‡$$

Column H. Mean of columns F and G (actual pressure in well cooled compressing cylinder) =

$$7{\cdot}35 \log_e \frac{p_2}{p_1} + 25{\cdot}2761 \left\{ \left(\frac{p_2}{p_1}\right)^{\cdot 2907} - 1 \right\}.$$

* Cotterill "Steam-Engine as Heat-Engine," p. 85

† Ibid., p. 339.

‡ The same results can be deduced from Pernolet's formulæ given by Röntgen (2nd edition, by Dubois), pages 203–205, 322–323.

Column I. Indicated horse-power in air-compressor to compress 1 cub. ft. of free air from 14·7 lb. pressure and 60° F.

$$= \frac{7279{\cdot}51\left\{\left(\frac{p_2}{p_1}\right)^{\cdot 2907} - 1\right\} + 2116{\cdot}8 \log_e \frac{p_2}{p_1}}{2 \times 33000}$$

$$= {\cdot}1102956\left\{\left(\frac{p_2}{p_1}\right)^{\cdot 2907} - 1\right\} + {\cdot}032073 \log_e \frac{p_2}{p_1}.$$

Column K. Indicated horse-power of steam engine, allowing 15 per cent. for friction in the engine and air-compressor

$$= {\cdot}12684 \times \left\{\left(\frac{p_2}{p_1}\right)^{\cdot 2907} - 1\right\} + {\cdot}036884 \log_e \frac{p_2}{p_1}.*$$

Column L. Number of cubic feet of free air required per gallon of water to be lifted, allowing 10 per cent. loss for slip in the air-compressor valves and in the ejector

$$= \frac{1{\cdot}1 \times \frac{p_2}{p_1}}{6{\cdot}24} = {\cdot}176282 \frac{p_2}{p_1}.$$

Column M. Net horse-power obtained per 1 cubic foot of free air in water lifted to the height of column B

$$= \frac{10 \times (p_2 - 14{\cdot}7) \times 2{\cdot}307}{33000 \times {\cdot}176282 \frac{p_2}{p_1}}$$

$$= {\cdot}0582966 \times \frac{p_2 - 14{\cdot}7}{p_2}.$$

Column N. Percentage of useful effect

$$= \frac{5{\cdot}82966\,(p_2 - 14{\cdot}7)}{p_2\left\{{\cdot}12684\left[\left(\frac{p_2}{p_1}\right)^{\cdot 2907} - 1\right] + {\cdot}036884 \log_e \frac{p_2}{p_1}\right\}}.$$

* The addition of 15 per cent. for friction, though sufficient for non-condensing compound engines of not less than 100 I.H.P., would not be sufficient for engines of smaller size; 25 per cent. at least would have to be added, and consequently the percentage of useful effect given in column N would be smaller.

Table E.

TABLE OF PRESSURES, TEMPERATURES, VOLUMES, RATIO OF VOLUMES, MEAN PRESSURES, ETC., OF COMPRESSED AIR AND PERMANENT GASES. (By Isaac Shone, C.E., based on Thurston.)

Absolute Pressures in Lbs. per Sq. In.	Temperature (Fah. deg.) above :—		Temperature (Cent. deg.) above :—		Volumes of Compressed Air or Gas		Pressures above Atmosphere in Lbs. per Sq. In. = Col. A − 14·7	Ratio of Volumes at Normal Temperature and Pressure to Volumes at Pressures in Column A and H		Ratio of Volumes at Pressures in Columns A and H to Normal Temperature and Pressure		Mean or Average Loads against Compressing Piston in Lbs. per Sq. In. above Atmosphere	
	Absolute Zero	Fah. Zero	Absolute Zero	Cent. Zero	Adiabatic	Isothermal		Adiabatic	Isothermal	Adiabatic	Isothermal	Adiabatic	Isothermal
A	B	C	D	E	F	G	H	I	K	L	M	N	O
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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TABLE E.

300. This is the set of Tables referred to in my letter on p. 28.

It gives the various mechanical effects of applying air compressed at increasing pressures above the normal pressure of the atmosphere from 1 lb. to 100 lb. per sq. in.

Col. A gives the absolute pressures.

Cols. B and C give on the Fahrenheit scale the temperatures above absolute zero and Fahrenheit zero; and cols. D and E give the same temperatures on the Centigrade scale.

Cols. F and G give the resultant volumes of the compressed air, adiabatic and isothermal respectively.

Col. H gives the successive pressures above the atmospheric pressure, simply subtracting 14·7 from the figures in col. A.

Cols. I and K give the ratios of the volumes at the normal temperature and pressure, to the volumes at the successive pressures given in cols. A and H.

Cols. L and M are the reciprocals of cols. I and K, and give the ratios of the pressures given in cols. A and H to those at the normal temperature and pressure.

Lastly, cols. N and O give the resultant mean loads against the compressing piston in lb. per sq. in. above the atmospheric pressure.

The formulæ from which the figures in the Table have been calculated may be expressed as follows:—

Let t = absolute temperature due to the degree of tension, the normal pressure and temperature being taken as 14·7 lb. per square inch, and 60° F., or 15·56° C. respectively.

T = normal absolute temperature = 60° + 461·2 F., or 15·56 + 274 C.

p = absolute pressure in lbs. per square inch (col. A).

P = normal absolute pressure = 14·7 lb. per square inch.

R = ratio of compression.

H = hyperbolic logarithm of R.

m = adiabatic mean load against compressing piston due to compression.

M = isothermal mean load against compressing piston due to compression.

v = adiabatic volume due to the degree of tension.
v_1 = isothermal " " "
V = normal volume = 100.

Then $t = \left(\frac{p}{P}\right)^{\cdot 29} \times T$: (cols. B and D).

$$v = \frac{P \times V}{p} \times \frac{t}{T}: \text{(col. F)}.$$

$$v_1 = \frac{P \times V}{p}: \text{(col. G)}.$$

$$\frac{V}{v} = \frac{100}{v}: \text{(col. I)}.$$

$$\frac{V}{v_1} = \frac{100}{v_1}: \text{(col. K)}.$$

$$\frac{v}{V} = \frac{v}{100}: \text{(col. L)}.$$

$$\frac{v_1}{V} = \frac{v_1}{100}: \text{(col. M)}.$$

$$m = 3\cdot439\ P\left[\left(\frac{p}{P}\right)^{0\cdot2907} - 1\right]: \text{(col. N)} = 50\cdot553$$
$$\left[\left(\frac{p}{P}\right)^{0\cdot2907} - 1\right].$$

$$M = p \times \frac{1 + H}{R} - P, \text{ where } R = \frac{p}{P}: \text{(col. O)} = P \times H.$$

Explanation and Use of Table.

Col. A gives the absolute or total pressures above a vacuum for which the various temperatures, volumes, etc., on the same lines, are calculated.

Cols. B and D give the theoretical absolute temperatures, the one expressed in Fahrenheit and the other in Centigrade degrees, above a zero ascertained from observations upon permanent gases made by scientists. They served to show the temperature which would be obtained by expanding or compressing air and other gases from the normal point, supposing that no heat was absorbed or radiated in the operation.

Cols. C and E are similar to B and D, except that they give the actual readings on thermometers, graduated to the respective scales, which would be observed if the gas were tested under the conditions named in the previous paragraph. For example: Taking a volume of air at atmospheric pressure and a temperature of 60° Fah. (15·56° Cent.), and compressing it to 26 lb. per square inch above the atmosphere (col. H), or 40·7 lb. per square inch absolute pressure (col. A) without parting with or adding to any of its heat externally, the temperature of the volume of air would be increased by the act to 700·27° Fah. (389·04° Cent.) above the theoretical zero, or to 239·07° Fah. (115·04° Cent.) if measured on the scale of a thermometer.

Col. F gives the resultant volumes of a gas when 100 volumes at the normal temperature and pressure are expanded or compressed to various pressures from a vacuum to 100 lb. per square inch above the atmosphere (col. H) adiabatically, i.e. without parting with or adding to the *quantity* of heat contained in the 100 volumes operated upon. Thus 100 normal volumes of air compressed to 11 lb. per square inch above the atmosphere (col. H) would be reduced to 67·258 volumes adiabatically.

Col. G gives the number to which 100 normal volumes of a gas would be enlarged or reduced when expanded or compressed to the various pressures isothermally, i.e. keeping the temperature of the gas at a constant point by extracting the heat from the gas as rapidly as it is developed. Thus 100 normal volumes of air compressed to 11 lb. per square inch above the atmosphere (col. H) would be reduced to 57·198 isothermally.

Col. H gives the pressures that would be read off an ordinary pressure gauge, or the pressures above, or below the normal atmospheric, being 14·7 lb. per square inch less than the corresponding figures in col. A.

Cols. I and K are useful for ascertaining the quantity of *free* or atmospheric air which should be taken in by compressors to yield a given quantity of compressed air at any given pressure. Example: Let it be required to know what quantity of free air should be taken into a compressor in order to produce 500 cubic feet of compressed air at a pressure on the gauge of 26 lb. per square inch. (*a*) Opposite to 26 lb. in col. H, will be found the ratio 2·0607 in col. I; and 500 × 2·0607 = 1030·35 cubic feet of free air needed if compressed adiabatically. (*b*) Opposite to 26 lb. in col. H, will be found the ratio 2·7687 in col. K; and 500 × 2·7687 = 1384·35 cubic feet of free air needed if compressed isothermally. As compressed air conveyed along pipes, and stored up in receivers, parts with its excess of heat, by radiation, until it finally reaches the same temperature as the outside air, the ratios given in col. K should always be used in estimating the size of the compressors for producing a required quantity of compressed air.

Cols. L and M are the reverse of the last-named, as they are useful for estimating the quantity of *compressed* air obtainable from a given volume of free air compressed to any given pressure. Example: What quantity of compressed air will 1030·35 cubic feet of free air produce, when (*a*) compressed to 26 lb. per square inch above atmosphere, adiabatically; and what quantity will 1384·35 cubic feet free air produce when (*b*) compressed to the same degree isothermally? (*a*) Look in col. H for 26 lb., and opposite in col. L will be found the adiabatic ratio 0·485; and 1030·35 × 0·485 = 500 cubic feet, the quantity required. (*b*) Opposite 26 lb. in col. H is found the isothermal ratio in col. M = 0·361; and 1384·35 × 0·361 = 500 cubic feet, the quantity required.

Cols. N and O give the mean loads on compressing pistons when producing air at the several degrees of compression, and will be found useful in estimating the power to be exerted in the steam cylinder, turbine or other motor in order to compress any required quantity of air to any pressure up to 100 lbs. above atmosphere. The mean loads due to compression in actual practice are never so much as those given in col. N, nor so little as those named in col. O, for the reason, on the one hand, that the metal of the compressors rapidly conveys away much of the active heat developed by compression, and thereby tends to keep down the pressure within the cylinder towards the isothermal point, and this tendency is assisted as much as possible in various designs of compressors by means of water jackets outside, water injections into the cylinders, and in other ways. On the other hand, whatever means are adopted to carry off the heat developed by compression, they are not so perfect as to convey that heat away as quickly as it is produced; the pressure within the most perfect compressor is, as a consequence, never so low as that due to isothermal compression. The mean loads against a compressing piston will, therefore, in practice always range between those given in cols. N and O according to the degree of perfection obtained in the working of each compressor. It is obviously impossible to give a hard and fast rule for obtaining the practical mean load on a compressing piston, but for safe and approximate estimates it may be taken as being an average of the loads given in cols. N and O opposite to any desired pressure.

301. *TABLE F.*

Showing the Velocities at which Bodies (including Water) Fall freely in Air to the Earth.

Observations.—In strictness, these velocities are those of bodies (solid or liquid) falling *in vacuo*. But for all practical purposes of the sanitary engineer the resistance of the air may be disregarded.

The force which it is now universally admitted the Earth exerts on all bodies, and which is called gravity, is a uniform force, acts in a vertical direction, and produces the same acceleration in all bodies. The letter g denotes the acceleration due to gravity. The value of g increases slightly as we pass from the equator towards the poles. But in the latitude of London g equals very nearly 32·19 feet per second, and in practice it may be taken as 32·2 feet per second.

Again, the value of g is not the same at different points above the earth's surface, as it varies inversely as the square of the distance of the body acted upon from the centre of the earth. But, seeing that any heights to which we can ascend are very small compared with the radius of the earth, the change thus caused in the force of gravity will be very small.

Thus on the whole we may practically, in the vicinity of any given place, regard the value of g as constant; for instance, in the neighbourhood of London $g = 32{\cdot}2$ approximately.*

Formulæ.—Let $g = 32{\cdot}2$ feet per second, as just explained. Let H' = the height in feet (or h'' the corresponding height in inches) from which the given body falls; T the time in seconds occupied by the given body in falling vertically in free air from the given height H' or h'' to the earth; and V the resultant velocity in feet per second acquired by the body at the end of its fall; then

$$(1)\quad V = \sqrt{2gH'}\text{; or } \sqrt{64{\cdot}4 \times H'}\text{; or } 8{\cdot}025\sqrt{H'}$$

$$(2)\quad V = \frac{2H'}{T}$$

$$(3)\quad V = gT$$

$$\text{Also } (4)\quad H' = \frac{gT^2}{2}\text{; and } (5)\quad T = \frac{\sqrt{2H'}}{g}.$$

---

* If the value of gravity is required for any other latitude or height above sea-level, it may be found from the value of g at London and at sea-level (i.e. $g = 32{\cdot}19$) by the formula: $\gamma = 32{\cdot}19\,(1 + {\cdot}005133 \sin\lambda)\left(1 - \frac{2H}{R}\right)$; where λ = the latitude; H = height above sea-level; R = radius of the earth in feet, viz. 20,923,000 at equator, 20,853,000 at poles, and 20,888,000 mean radius.

TABLE F.

V (Vel. in Feet per Second)	T (Time in Seconds)	H′ (Height in Feet)	*h*″ (Height in Inches)	V (Vel. in Feet per Second)	T (Time in Seconds)	H′ (Height in Feet)	*h*″ (Height in Inches)
Col. 1	Col. 2	Col. 3	Col. 4	Col. 1	Col. 2	Col. 3	Col. 4
0·1	0·0031	0·00015	0·0018	4·1	0·1274	0·2613	3·1356
0·2	0·0062	0·00031	0·00372	4·2	0·1305	0·2742	3·2904
0·3	0·0093	0·0014	0·0168	4·3	0·1336	0·2874	3·4488
0·4	0·0124	0·0025	0·0300	4·4	0·1367	0·3009	3·6108
0·5	0·0155	0·0039	0·0468	4·5	0·1398	0·3147	3·7764
0·6	0·0186	0·0055	0·0660	4·6	0·1429	0·3288	3·9456
0·7	0·0217	0·0076	0·0912	4·7	0·1460	0·3432	4·1184
0·8	0·0248	0·0099	0·1188	4·8	0·1491	0·3579	4·2948
0·9	0·0279	0·0125	0·1500	4·9	0·1522	0·3730	4·4760
1·0	0·0311	0·0155	0·1860	5·0	0·1554	0·3888	4·6656
1·1	0·0342	0·0188	0·2256	5·1	0·1585	0·4045	4·8540
1·2	0·0373	0·0224	0·2688	5·2	0·1616	0·4204	5·0448
1·3	0·0404	0·0262	0·3144	5·3	0·1647	0·4367	5·2404
1·4	0·0435	0·0304	0·3648	5·4	0·1678	0·4533	5·4896
1·5	0·0466	0·0349	0·4188	5·5	0·1709	0·4702	5·6424
1·6	0·0497	0·0398	0·4776	5·6	0·1740	0·4874	5·8488
1·7	0·0528	0·0449	0·5388	5·7	0·1771	0·5048	6·0576
1·8	0·0559	0·0503	0·6036	5·8	0·1802	0·5228	6·2736
1·9	0·0590	0·0560	0·6720	5·9	0·1833	0·5409	6·4908
2·0	0·0622	0·0623	0·7476	6·0	0·1865	0·5599	6·7188
2·1	0·0653	0·0686	0·8232	6·1	0·1896	0·5788	6·9456
2·2	0·0684	0·0753	0·9036	6·2	0·1927	0·5978	7·1736
2·3	0·0715	0·0823	0·9876	6·3	0·1958	0·6172	7·4064
2·4	0·0746	0·0896	1·0752	6·4	0·1989	0·6369	7·6428
2·5	0·0777	0·0972	1·1664	6·5	0·2020	0·6569	7·8828
2·6	0·0808	0·1051	1·2612	6·6	0·2051	0·6773	8·1276
2·7	0·0839	0·1133	1·3596	6·7	0·2082	0·6979	8·3748
2·8	0·0870	0·1218	1·4616	6·8	0·2113	0·7189	8·6268
2·9	0·0901	0·1306	1·5672	6·9	0·2144	0·7401	8·8812
3·0	0·0932	0·1398	1·6776	7·0	0·2176	0·7623	9·1476
3·1	0·0963	0·1495	1·7940	7·1	0·2207	0·7842	9·4104
3·2	0·0994	0·1591	1·9092	7·2	0·2238	0·8064	9·6768
3·3	0·1025	0·1692	2·0304	7·3	0·2269	0·8288	9·9456
3·4	0·1056	0·1795	2·1540	7·4	0·2300	0·8517	10·2204
3·5	0·1087	0·1902	2·2824	7·5	0·2331	0·8748	10·4976
3·6	0·1118	0·2012	2·4144	7·6	0·2362	0·8982	10·7784
3·7	0·1149	0·2125	2·5500	7·7	0·2393	0·9220	11·0640
3·8	0·1180	0·2242	2·6904	7·8	0·2424	0·9460	11·3520
3·9	0·1211	0·2361	2·8332	7·9	0·2455	0·9703	11·6436
4·0	0·1243	0·2488	2·9856	8·0	0·2487	0·9958	11·9496

TABLE F.—*continued.*

V (Vel. in Feet per Second)	T (Time in Seconds)	H′ (Height in Feet)	h'' (Height in Inches)	V (Vel. in Feet per Second)	T (Time in Seconds)	H′ (Height in Feet)	h'' (Height in Inches)
Col. 1	Col. 2	Col. 3	Col. 4	Col. 1	Col. 2	Col. 3	Col. 4
8·1	0·2518	1·0207	12·2484	13	0·4041	2·6270	31·5240
8·2	0·2549	1·0461	12·5532	14	0·4352	3·0493	36·5916
8·3	0·2580	1·0717	12·8604	15	0·4663	3·5007	42·0084
8·4	0·2611	1·0976	13·1712	16	0·4974	3·9832	47·1984
8·5	0·2642	1·1239	13·4868	17	0·5285	4·4969	53·9628
8·6	0·2673	1·1503	13·8036	18	0·5596	5·0417	60·5004
8·7	0·2704	1·1772	14·1264	19	0·5907	5·6176	67·4112
8·8	0·2735	1·2043	14·4516	20	0·6217	6·2228	74·6736
8·9	0·2766	1·2318	14·7816	21	0·6528	6·8609	82·3308
9·0	0·2798	1·2588	15·1056	22	0·6839	7·5313	90·3756
9·1	0·2828	1·2876	15·4512	23	0·7150	8·2307	98·7684
9·2	0·2859	1·3160	15·7920	24	0·7461	8·9757	107·7084
9·3	0·2890	1·3447	16·1364	25	0·7772	9·7250	116·7000
9·4	0·2921	1·3737	16·4844	26	0·8083	10·5189	126·2268
9·5	0·2952	1·4030	16·8360	27	0·8394	11·3479	136·1748
9·6	0·2983	1·4326	17·1912	28	0·8705	12·1010	144·1212
9·7	0·3014	1·4626	17·5512	29	0·9016	13·0874	157·0488
9·8	0·3045	1·4928	17·9136	30	0·9327	14·0068	168·0816
9·9	0·3076	1·5232	18·2784	31	0·9638	14·9554	179·4648
10	0·3108	1·5542	18·6504	32	0·9949	15·9352	191·2224
11	0·3419	1·8810	22·5720	33	1·0260	16·9480	203·3760
12	0·3730	2·2400	26·8800				

Note.—In an Appendix on p. 228 of Mr. Adams's valuable work on "Sewers and Drains for Populous Districts" (Van Nostrand Company), a Table is inserted showing the values of *g*, from Francis' Hydraulic Experiments for the Latitudes and Heights above the Sea, of which the following is a copy :—

TABLE F_1.

Height above the Sea in Feet	Latitudes						
	30°	35°	40°	45°	50°	55°	60°
0	32·1239	32·1383	32·1537	32·1695	32·1854	32·2008	32·2152
100	32·1236	32·1380	32·1534	32·1692	32·1851	32·2005	32·2149
200	32·1233	32·1377	32·1531	32·1689	32·1848	32·2002	32·2146
300	32·1129	32·1374	32·1528	32·1686	32·1845	32·1998	32·2143
400	32·1226	32·1371	32·1524	32·1683	32·1842	32·1995	32·2140
500	32·1228	32·1368	32·1521	32·1680	32·1839	32·1992	32·2137
600	32·1220	32·1364	32·1518	32·1677	32·1835	32·1989	32·2134
700	32·1217	32·1361	32·1515	32·1674	32·1832	32·1986	32·2131
800	32·1214	32·1358	32·1512	32·1671	32·1829	32·1983	32·2128
900	32·1211	32·1355	32·1509	32·1668	32·1826	32·1980	32·2125
1000	32·1208	32·1352	32·1506	32·1665	32·1823	32·1977	32·2121
1100	32·1205	32·1349	32·1503	32·1662	32·1820	32·1974	32·2118

302. *TABLE G.*—AREAS OF CIRCLES, IN SQUARE FEET; THE

Diameter	AREAS IN			
Inches	0″	⅛″	¼″	⅜″
0		0·000085	0·00035	0·00076
1	0·00544	·00690	·00852	·01031
2	·02179	·02463	·02761	·03076
3	·04908	·05326	·05761	·06213
4	·08724	·09281	·09851	·10440
5	·13638	·14326	·15033	·15757
6	·19635	·20462	·21305	·22166
7	·26722	·27688	·28669	·29666
8	·33799	·36006	·37122	·38256
9	·44178	·45414	·46667	·47937
10	·54537	·55914	·57303	·58709
11	·6598	·67504	·69029	·70572

Diameter	AREAS IN					
Feet	0″	1″	2″	3″	4″	5″
1	0·7854	0·922	1·07	1·23	1·40	1·58
2	3·1416	3·41	3·69	3·98	4·28	4·59
3	7·07	7·47	7·88	8·29	8·73	9·17
4	12·57	13·09	13·64	14·19	14·75	15·32
5	19·64	20·29	20·97	21·65	22·34	23·04
6	28·27	29·06	29·87	30·68	31·50	32·34
7	38·48	39·41	40·34	41·28	41·24	43·20
8	50·27	51·32	52·38	53·46	54·54	55·64
9	63·62	64·80	66·00	67·20	68·42	69·64
10	78·54	79·85	81·18	82·52	83·86	85·22
11	95·03	96·48	97·93	99·40	100·88	102·37
12	113·09	114·67	116·26	117·86	119·47	121·09
13	132·73	134·44	136·16	137·89	139·63	141·38
14	153·94	155·78	157·63	159·49	161·36	163·24
15	176·72	178·68	180·66	182·65	184·66	186·67
16	201·06	203·16	205·27	207·39	209·53	211·67
17	226·98	229·21	231·45	233·71	235·97	238·24
18	254·47	256·83	259·20	261·59	263·98	266·39
19	283·53	286·02	288·52	291·04	293·56	296·10
20	314·16	316·78	319·42	322·06	324·72	327·38

DIAMETER BEING IN PARTS OF AN INCH, INCHES AND FEET.

Square Feet ½"	Square Feet ⅝"	Square Feet ¾"	Square Feet ⅞"	Diameter Inches
0·00136	0·0028	0·00306	0·00417	0
·01227	·01439	·01669	·01917	1
·03408	·03758	·04125	·04508	2
·06681	·07167	·07666	·08187	3
·11045	·11667	·12306	·12962	4
·16499	·17257	·18033	·18825	5
·23044	·23939	·24851	·25777	6
·30673	·31711	·32759	·33824	7
·39406	·40574	·41759	·42957	8
·49224	·50528	·51849	·53187	9
·60132	·61572	·63027	·64504	10
·72131	·73708	·75302	·76912	11

Square Feet 6"	Square Feet 7"	Square Feet 8"	Square Feet 9"	Square Feet 10"	Square Feet 11"	Diameter Feet
1·77	1·97	2·18	2·41	2·64	2·89	1
4·91	5·24	5·59	5·94	6·30	6·68	2
9·62	10·08	10·56	11·04	11·54	12·05	3
15·90	16·50	17·10	17·72	18·35	18·99	4
23·76	24·48	25·22	25·97	26·73	27·49	5
33·18	34·04	34·91	35·78	36·67	37·57	6
44·18	45·17	46·16	47·17	48·19	49·22	9
56·75	57·86	58·99	60·13	61·28	62·44	8
70·88	72·13	73·39	74·66	75·94	77·24	9
86·59	87·97	89·36	90·76	92·17	93·60	10
103·87	105·38	106·90	108·43	109·98	111·53	11
122·72	124·36	126·01	127·68	129·35	131·04	12
143·14	144·91	146·69	148·49	150·29	152·11	13
165·13	167·03	168·95	170·87	172·81	174·76	14
188·69	190·73	192·77	194·83	196·89	198·97	15
213·83	215·99	218·17	220·35	222·55	224·76	16
240·53	242·82	245·13	247·45	249·78	252·12	17
268·80	271·23	273·67	276·12	278·58	281·05	18
298·65	301·21	303·77	306·35	308·94	311·54	19
330·06	332·75	335·45	338·16	340·88	343·61	20

303. *TABLE H.*—Powers of Numbers (n); or the Relative Powers of Circular Pipes of Diameters (d) (in Inches or Feet) to Discharge Air or other Gas, or Water.

n or d	$n^{2·5}$ or $\sqrt{d^5}$ (For air or gas)	$n^{2·6}$ or $\sqrt{d^{5·2}}$ (For water)	n or d	$n^{2·5}$ or $\sqrt{d^5}$ (For air or gas)	$n^{2·6}$ or $\sqrt{d^{5·2}}$ (For water)
1	1·0	1·0	51	18,575	27,521
2	5·7	6·1	52	19,499	28,947
3	15·6	17·4	53	20,450	30,417
4	32·0	36·8	54	21,428	31,932
5	55·9	65·7	55	22,434	33,492
6	88·2	105·5	56	23,468	35,099
7	129·6	157·5	57	24,529	36,751
8	181·0	222·9	58	25,619	38,451
9	243·0	302·7	59	26,738	40,199
10	316·2	398·1	60	27,885	41,995
11	401·3	510·1	61	29,062	43,839
12	498·8	639·5	62	30,268	45,732
13	609·3	787·5	63	31,503	47,674
14	733·4	954·8	64	32,768	49,667
15	871·4	1,142·5	65	34,063	51,710
16	1,024·0	1,351·2	66	35,388	53,804
17	1,191·6	1,581·9	67	36,744	55,949
18	1,374·6	1,835·3	68	38,130	58,146
19	1,573·6	2,112·3	69	39,548	60,396
20	1,789	2,414	70	40,996	62,698
21	2,021	2,740	71	42,476	65,054
22	2,270	3,092	72	43,988	67,463
23	2,537	3,471	73	45,531	69,926
24	2,822	3,877	74	47,106	72,444
25	3,125	4,312	75	48,714	75,017
26	3,447	4,744	76	50,354	77,645
27	3,788	5,267	77	52,027	80,330
28	4,149	5,789	78	53,732	83,070
29	4,529	6,342	79	55,471	85,868
30	4,930	6,927	80	57,243	88,722
31	5,351	7,543	81	59,049	91,635
32	5,793	8,192	82	60,888	94,605
33	6,256	8,874	83	62,762	97,634
34	6,741	9,591	84	64,669	100,722
35	7,247	10,341	85	66,611	103,870
36	7,776	11,127	86	68,588	107,077
37	8,327	11,949	87	70,599	110,344
38	8,901	12,807	88	72,645	113,672
39	9,499	13,701	89	74,727	117,061
40	10,119	14,634	90	76,843	120,512
41	10.764	15,604	91	78,996	124,025
42	11,432	16,613	92	81,184	127,599
43	12,125	17,661	93	83,408	131,237
44	12,842	18.749	94	85,668	134,937
45	13,584	19,877	95	87,965	138,702
46	14,351	21,046	96	90,298	142,530
47	15,144	22,256	97	92,668	146,422
48	15,963	23,508	98	95,075	150,379
49	16,807	24,803	99	97,519	154,401
50	17,678	26,141	100	100,000	158,489

APPENDIX VIII.

304. THE NEW HYDRAULIC TABLES.*

In recent years a number of tables relating to the flow of water in pipes have been published, purporting to set forth the convenient manner, the relative diameters, velocities, quantities and gradients in proper relation to each other, in accordance with formulæ more or less intricate. Most, if not all, of these formulæ have their theory based upon the flow of *water* in pipes, conduits or canals, and the author has felt that, when estimating the sizes and gradients of pipes to convey sewage, engineers are very liable to err in not making due allowance for the increased friction inseparable from a foul liquid like sewage, frequently charged with grit, and silt, besides pieces of vegetable matter, rags, hair and the thousand and one particles of refuse matter that find their way into sewers along with the water supply which has been utilized by the people. Undoubtedly, these matters must render the resistance to the flow of sewage in pipes greater than that due to the flow of potable water, not only because the periphery of the sewer pipe is more or less fouled by slime and greasy matter, but also because the regularity of form and slope of the invert is broken by deposits of heavier matters such as grit, sand, etc.

Further, the fact that sewers are, for the sake of economy, built of stoneware pipes with joints every 2 ft. or at most 3 ft., or of brick-work or concrete, the roughness of the internal surfaces of the sewers is more pronounced than in the case of iron pipes used for water supply. This consideration of roughness, due to construction, has been taken into account by various authorities who have published hydraulic formulæ, but they do not seem to have considered that, with foul and heterogeneous sewage to pass through sewers, the roughness of the conduits or pipes must exaggerate the resistance to flow by providing projections for floating or suspended matters

* These Tables were prepared for me for this Book by my late partner Mr. Ault, assisted by his son and Mr. Hanssen and Mr. Walrond.

to lodge against, which in turn prevent their fellows from being carried along freely and without interruption.

For these reasons, I have for some years used a formula which allows for a somewhat higher resistance to the flow in a pipe than most other formulæ, and allows for a relatively higher resistance in the larger sized sewers than in the smaller ones. It cannot claim any very high degree of accuracy for general practice any more than other formulæ for sewerage work, but claims to be a fairly correct expression for the flow of sewage in pipes and conduits under actual working conditions.

According to this formula

$$V = 107 \cdot 5\, R^{0 \cdot 6} \sqrt{S} = M \sqrt{S} \quad \ldots \quad (1)$$

$$M = 107 \cdot 5\, R^{0 \cdot 6} \quad \ldots \quad (2)$$

$$G = 21 \cdot 5143\, d^{2 \cdot 6} \sqrt{S} = 2 \cdot 042\, V d^2 \quad \ldots \quad (3)$$

$$d = \sqrt[5 \cdot 2]{\frac{G^2 l}{462 \cdot 87\, H}} = \sqrt[5 \cdot 2]{\frac{G}{462 \cdot 87\, S}} = \sqrt[5 \cdot 2]{\frac{G \frac{1}{S}}{462 \cdot 87}} \quad (4)$$

$$H = \frac{G^2 l}{462 \cdot 87\, d^{5 \cdot 2}} \quad \ldots \quad (5)$$

$$\frac{1}{S} = \frac{111\, d^{1 \cdot 2}}{V^2} \quad \ldots \quad (6)$$

The advantage of such a formula is that it is homogeneous and suitable for calculating tables which correspond closely with actual practice. The velocity and rate of discharge agree very nearly with other formulæ for all ordinary sizes of stoneware and brick sewers, but it is somewhat low for new cast-iron pipes above 10 in.

This, however, appears to me to be an error on the safe side, as almost all cast-iron sewage pipes gradually get coated with deposit, that reduces the velocity of flow and rate of discharge.

The velocities found by this formula correspond to the following values of n in Kutter's formula :—

For a 6-in. pipe $n = 0 \cdot 011$ approximately
" 10-in. " $n = 0 \cdot 012$ "
" 21-in. " $n = 0 \cdot 013$ "
" 100-in. " $n = 0 \cdot 014$ "

305. Tables I. and II.

These give the areas (A) in square feet, and the hydraulic mean depths (R) in feet for circular sewers flowing full bore, from 3 in. to 100 in. in diameter (Table I.), and for oval sewers (old form) from 4 in. to 6 ft. horizontal diameters (Table II.), flowing full bore, two-thirds full and one-third full.

The tables are useful to engineers for working out the velocities of flow of water or sewage in pipes or conduits according to various formulæ propounded by different authorities.

The hydraulic mean depth (R) of a circular sewer flowing full or half full is one-fourth of the diameter in feet or one-fortyeighth of the diameter in inches.

The hydraulic mean depth (R) of an oval sewer r (old form) flowing full is $0{\cdot}5793429\,\rho$ or $0{\cdot}28967145\,D$; ρ being the radius, and D being the diameter of the upper transverse arc of the sewer.

The form of oval sewer referred to as the "old form" is that originally proposed by the late Mr. John Phillips, C.E., and its fundamental dimensions are as follows:—

Horizontal diameter	=	D	=	2ρ
Vertical diameter or height	=	$1\frac{1}{2}D$	=	3ρ
Radius of invert	=	$\frac{1}{4}D$	=	$\frac{1}{2}\rho$
Radius of sides	=	$1\frac{1}{2}D$	=	3ρ

The area in square feet of any oval sewer of this form is

When flowing full	=	$1{\cdot}148525\,D$	=	$4{\cdot}5941\,\rho$
When flowing two-thirds full	=	$0{\cdot}7558\,D$	=	$3{\cdot}0233\,\rho$
When flowing one-third full	=	$0{\cdot}2841\,D$	=	$1{\cdot}1364\,\rho$

306. Tables III. and IV.

Table III. gives the gradients $\left(\frac{1}{S}\right)$ and discharges in gallons per minute (G) for circular sewers from 3 to 100 in. diameter, when flowing full at velocities varying from 2·0 to 3·5 ft. per second (columns 1 to 15); and Table IV. gives the gradients $\left(\frac{1}{S}\right)$ and discharges in gallons per minute (G) for oval sewers from 4 in. to 6 ft. horizontal diameters when flowing full, two-thirds full and one-third full, for various velocities from 2·0 to 3·5 ft. per second (columns 1 to 15).

It should be noted that as the hydraulic mean depth (R) of circular sewers is the same when running full or half-full, the gradients for the same velocity will be equal in each case, but the discharge will, of course, be one-half those given in Table III. when the sewer is only running one-half full.

In columns 16 and 17 of both tables are given the velocities, in feet per second (V_s) and discharges in gallons per minute (G_s) for sewers when laid at a gradient of $\frac{1}{10000}$.

As it frequently happens that the Sanitary Engineer requires to ascertain the conditions of flow in a sewer when laid at any given gradient, these columns have been added in order to simplify the operations in arriving at an estimate of those conditions, and they give, when used with Table V., by a single multiplication, the velocity of flow in feet per second, or the discharge of liquid in gallons per minute for such sewers laid at any gradient.

As S in this case $= \frac{1}{10000}$, the $\sqrt{S} = \frac{1}{100}$, and $V = \frac{M}{100}$, and therefore the value of V_s, as given in columns 15 for the various sewers, is for any other gradient directly proportional to $100\sqrt{S}$.

The numerical value of $100\sqrt{S}$ is given for a large number of gradients in Table V., and the gradients $\left(\frac{1}{S}\right)$ required to give a certain velocity in any pipe, or, conversely, the velocity due to any gradient, can thus readily be found.

If we call the velocity for a gradient of 1 in 10000 V_s and the velocity due to any other gradient = V, then the following two relations hold good for all cases :—

$$\frac{V}{V_s} = 100\sqrt{S} \qquad . \quad . \quad . \quad . \quad . \quad (7)$$

$$V = 100\sqrt{S} \times V_s \qquad . \quad . \quad . \quad . \quad (8)$$

Example 1.—Let it be desired to lay an 18-in. pipe to such a gradient that sewage will flow through it, with a velocity of 3 ft. per second. We find from Table II. that $V_s = 0{\cdot}5968$ ft. per second for a gradient of $\frac{1}{10000}$; then

$$100\sqrt{S} = \frac{3{\cdot}0}{0{\cdot}5968} = 5{\cdot}0268.$$

By referring to Table V., we find the nearest tabular number to $5{\cdot}0268$ of $100\sqrt{S}$ is opposite a gradient of $\frac{1}{390}$, and this is therefore the gradient required when V = 3 ft. and *d* = 18 in.

Example 2.—What is the velocity of flow in an 18-in. pipe laid at a gradient of 1 in 500?

For an 18-in. pipe at a gradient of $\frac{1}{10000}$ (see Table III.), $V_s = 0·5968$; and from Table V., for a gradient of $\frac{1}{500}$ $100\sqrt{S} = 4·472$; and

$$V_s \times 100\sqrt{S} = 0·5968 \times 4·472 = 2·67 \text{ ft. per second.}$$

Example 3.—It is desired to lay a 2-ft. × 3-ft. oval sewer at such a gradient $\left(\frac{1}{S}\right)$ as will give 3 ft. per second velocity to the sewage when running full bore.

From Table IV., $V_s = 0·77473$ for a gradient of $\frac{1}{10000}$; then

$$100\sqrt{S} \text{ (for } V = 3) = \frac{3}{0·77473} = 3·872;$$

and from Table V., $3·872$ = a gradient of $\frac{1}{666}$.

Example 4.—Required the velocity V of sewage flowing full bore in an oval sewer 1 ft. 6 in. × 2 ft. 3 in. when laid at a gradient of $\frac{1}{600}$.

From Table IV., V_s of a 1 ft. 6 in. × 2 ft. 3 in. sewer at a gradient of 1 in 10,000 = 0·65193; and from Table V., $100\sqrt{S}$ for a gradient of $\frac{1}{600} = 4·083$.

$$V = V_s \times 100\sqrt{S} = 0·65193 \times 4·083 = 2·6618 \text{ ft. per second.}$$

Column 16 gives the discharge G_s in gallons per minute for the formula (3) page 344, which for a gradient of 1 in 10,000 becomes

$$G_s = 21·5143 \times d \times \frac{1}{100} \quad . \quad . \quad . \quad (9)$$

Here again the discharge is directly proportional to $100\sqrt{S}$, and the discharge for any gradient can therefore be found in the same way as the velocity of flow, namely :—

$$\frac{G}{G_s} = 100\sqrt{S} \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

$$G = 100\sqrt{S}\, G_s \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

where G is the discharge in gallons per minute due to any other gradient.

Example 5.—We require the quantity of sewage due to a velocity of 3 ft. per second in an 18-in. pipe when flowing full bore, and we found, in Example 1, that to obtain this velocity the value of $100\sqrt{S} = 5\cdot0268$. The discharge at a gradient of 1 in 10,000 according to the Table is 395 gallons per minute; and the discharge G for a gradient of 1 in 396 is therefore

$$G_s \times 100\sqrt{S} = 395 \times 5\cdot0268 = 1986 \text{ gallons per minute.}$$

Example 6.—The gradient required for discharging any given quantity of sewage, say 1200 gallons per minute through an 18-in. pipe, is found as before by finding

$$100\sqrt{S} = \frac{G}{G_s} = \frac{1200}{395} = 3\cdot038,$$

and the gradient in Table V. corresponding to this value of $100\sqrt{S}$ is between 1080 and 1090, say, 1 in 1085, at which gradient the 18-in. pipe will discharge 1200 gallons of sewage per minute when flowing full bore.

Example 7.—Required the discharge of an oval sewer 2 ft. × 3 ft. running full when laid at a gradient of $\frac{1}{1000}$.

From Table V., the value of $100\sqrt{S}$ for this gradient = $3\cdot162$ and the gallons per minute due to a gradient of $\frac{1}{10000}$ = (from Table IV.) 1333, then

$$G = G_s \times 100\sqrt{S} = 1333 \times 3\cdot162 = 4215 \text{ gallons per minute,}$$

the discharge required.

Example 8.—Required the discharge of an oval sewer 2 ft. × 3 ft. 9 in. running two-thirds full, when laid at a gradient of $\frac{1}{1500}$.

From Table V., the value of $100\sqrt{S} = 2\cdot582$ for a gradient of $\frac{1}{1500}$.

From Table IV., the discharge (G_s) for a 2 ft. 6 in. + 3 ft. 9 in. oval sewer, when running two-thirds full and having a gradient of $\frac{1}{10000}$ = 1650 gallons per minute

$\therefore$ $1650 \times 2\cdot582 = 4260$ gallons per minute, the discharge required.

Example 9.—At what gradient should a 2 ft. 10 in. × 4 ft. 3 in. oval sewer be laid to discharge 2500 gallons per minute when running one-third full?

From Table IV., such a sized sewer when running one-third full and having a gradient of $\frac{1}{10000}$ will discharge 666 gallons per minute

$$\therefore \frac{2500}{666} = 3\cdot752 = 100\sqrt{S},$$

and, from Table V., the gradient corresponding is $\frac{1}{710}$, the gradient required.

Example 10.—What will be the velocity of flow of sewage under the conditions given in the last example?

From Table IV., the 2 ft. 10 in. × 4 ft. 3 in. sewer, running one-third full will have a velocity of 0·77974 ft. per second when laid at a gradient of $\frac{1}{10000}$. The velocity required = $V = 100\sqrt{S} \times V_s$ (formula 8) and as shown by Example 9, $100\sqrt{S} = 3\cdot752$

$\therefore$ $3\cdot752 \times 0\cdot77974 = 2\cdot92$ ft. per second, the velocity required.

307. Table V.

Actual Value of $100\sqrt{S}$ *for various Gradients.*

The use of this Table has already been explained in describing the two preceding ones. In introducing this new value in connection with hydraulic calculations, the author would mention that he has found this value far more convenient in use than $\sqrt{S}$ alone, as the small decimal fractions are apt to confuse those that are not constantly engaged with hydraulic calculations. Take, for instance, a gradient of $\frac{1}{1000}$, then $\sqrt{S} = 0\cdot001$, and $S = 0\cdot03162$. There is of course no difficulty in multiplying or dividing with this latter figure for those who are constantly using decimals, but nevertheless the value of $100\sqrt{S} = 3\cdot162$ appears far less liable to cause mistakes.

308. Tables VI. and VII.

Proportional Parts of Circular and Oval Sewers.

The Tables III., IV. and V. answer all questions relating to sewers flowing full bore or relating in the case of oval sewers to flows of one-third and two-thirds full as well as full bore; but these are conditions which rarely obtain in gravitating sewers as frequently it is found desirable to ascertain conditions of flow when the sewers are partly occupied only with sewage.

Tables VI. and VII. have been prepared to render easy the ascertaining of the various properties of circular and oval sewers for any depth of sewage flow.

Column 1 gives the proportion between the vertical depth of sewage flowing upon the invert of a sewer and the diameter of that sewer. The circle and the oval are divided by parallel horizontal lines into 100 parts of equal height, each proportional part thus representing a vertical height expressed in hundredths of the diameter of the circle or major axis of the oval.

Example 11.—In an 18-in. sewer the proportional depth = of 0·40 will thus correspond to an actual depth of (18 in. × 0·40 =) 7·2 in. of sewage flowing on the sewer invert.

Example 12.—In an oval sewer 2 ft. 4 in. × 3 ft. 6 in. when the proportional depth of flow = 0·54 the actual depth of flow will be (3·5 × 0·54 =) 1·89 ft.

Column 2 multipliers for areas (a_m) have been calculated by the aid of a table giving the "areas of the segment of a circle." They give the area of any segment of the proportional height given in column 1, when multiplied by the full area of the sewers.

$$a = a_m \times A \quad . \quad . \quad . \quad . \quad (12)$$

Example 13.—What is the sectional area of the current of sewage in a 27-in. pipe, when the depth of sewage is 19·17 in.?

A depth of 19·17 in. in a 27-in. pipe, gives a proportional depth of sewage $\frac{19 \cdot 17}{27} = 0 \cdot 71$. The value in column 2 opposite 0·71 is 0·7593. The total area A of a 27-in. sewer is 3·976 sq. ft. (Table I., column 2), and the sectional area of the flow is therefore:—

$$a = 0 \cdot 7593 \times 3 \cdot 976 = 3 \cdot 0191 \text{ sq. ft.}$$

Example 14.—What volume of foul air will be expelled from an oval sewer 4 ft. × 6 ft., and a quarter of a mile (= 1320 ft.) in length, when a heavy thunderstorm increases the depth of sewage from 1 ft. 6 in. to 3 ft.?

Total area (A) of a 4 ft. 6 in. × 6 ft. sewer (Table II., column 2) = 18·3764 sq. ft. Proportional area (a_m) for 1 ft. 6 in. depth = $\frac{1 \cdot 5}{6} = 0 \cdot 25$. From the Table VII., column 2, a_m proportional area for depth 0·25 = 0·1623.

Proportional depth for 3 ft. = $\frac{3}{6} = 0 \cdot 5$.

The proportional area for 0·5 = 0·4433.

Total volume of foul air expelled = 1320 ft. × 18·3764 sq. ft. × (0·4433 − 0·1623) = 1320 × 18·3764 × 0·2810 = 6825 cub. ft.

Example 15.—The sectional area of a current of sewage traversing a 21-in. pipe is 1·5 sq. ft.; what is the depth of the sewage?

The sectional area of a 21-in. sewer (Table I., column 2) = 2·4053 sq. ft. Therefore $a_m = \frac{1 \cdot 5}{2 \cdot 4053} = 0 \cdot 6236$.

The proportional depth of sewage Table VII., column 1, corresponding to this value of a_m is between 0·59 and 0·60, and by interpolation we find it = 0·598. The actual depth will be 21 in. × 0·598 = 12·56 in.

u is the versed sine or depth of liquid and the wetted perimeter is the arc of the liquid. The depth of flow u given in Table VI., column 1, relate to segments of a circle whose diameter equals 1. Similarly, in Table VII., the depths of flow u given in column 1 relate to segments of an oval whose major axis or height equals 1.

Column 3. Proportional hydraulic mean depth.

The hydraulic mean depth can be obtained from the table by knowing the diameter of a sewer and the depth of the sewage flowing in the same.

When D = diameter of a circular sewer in ft., then the hydraulic mean depth r of any segment is

$$r = \frac{D}{4} \times r_m = R\, r_m \qquad . \quad . \quad . \quad (13)$$

The hydraulic mean depth R of an oval sewer flowing full bore is 0·5793431 = 0·28967 D = 0·1931 the major axis or vertical height which we will call D_1 of the sewer in feet and the hydraulic mean depth of any segment of an oval sewer

$$r = D_1 \times 0.14984 \times r_m = R\, r_m \qquad . \quad . \quad (14)$$

Example 16.—If in a 4 ft. 6 in. sewer the depth of sewage is $23\frac{3}{4}$ in. what is the hydraulic mean depth of the section of flow?

Proportional depth of sewage $\frac{23 \cdot 75}{54} = 0 \cdot 44$

r_m corresponding to 0·44 = 0·9179.

$$r = \frac{4 \cdot 5}{4} \times 0 \cdot 9179 = 1 \cdot 0326.$$

Example 17.—An oval sewer 3 ft. 4 in. × 5 ft. has a depth of sewage flow of 2 ft.; what is the hydraulic mean depth of the flow?

$$\frac{2\cdot 0}{5\cdot 0} = 0\cdot 4 \text{ proportional depth of flow.}$$

From Table VII., the proportional hydraulic mean depth (r_m) for a flow in an oval sewer 0·4 of the height = 0·8061.

$$\therefore \quad r = D_1 \times 0\cdot 1913 \times r_m$$
$$= 5\cdot 0 \times 0\cdot 1931 \times 0\cdot 8661$$
$$= 0\cdot 7783 = \text{the hydraulic mean depth required.}$$

Column 4. Multipliers for velocity.

The velocity of flow is calculated from formula 1, page 344.

If we call the velocity in any segment of a sewer v having a hydraulic mean depth r, then

$v = 107\cdot 5\ r^{0\cdot 6} \times \sqrt{s}$, and if the tabular number $= v_m$, then:

$$v_m = \frac{v}{V} = \frac{107\cdot 5\ r^{0.6}\sqrt{s}}{107\cdot 5\ R^{0.6}\sqrt{S}} \qquad . \quad . \quad (15)$$

When R = 1 then

$$v_m = r_m^{0\cdot 6} \text{ and } v = V\,v_m \qquad . \quad . \quad . \quad (16)$$

that is, the velocity in any segment of the sewer is equal to the velocity in the sewer when flowing full bore, multiplied by the tabular number v_m given in column 4, and the figures given in column 4 are simply the 0·6 power of the proportional hydraulic mean depths (r_m) given in column 3.

Example 18.—The velocity in a 15-in. sewer flowing full is 2·5 ft. per second; what will the velocity be when the depth of the sewage is 11¼ in.?

$$\text{Proportional depth of sewage} = \frac{11\cdot 25}{15} = 0\cdot 75.$$

Column 4. v_m for depth 0·75 = 1·1194.

Actual velocity v, when depth of sewage is 11¼ in.; $v = 2\cdot 5 \times 1\cdot 1194 = 2\cdot 799$ ft. per second.

Example 19.—The velocity in a 2 ft. 8 in. × 4 ft. oval sewer flowing two-thirds full is 3 ft. per second. What will be the velocity when flowing one-third the vertical height or ($4\cdot 0 \times \frac{1}{10} =$) 0·4 ft. depth of sewage?

From Table VII., column 4, the proportional velocity (v_m) for 0.1 depth of flow = 0·4786 and for two-thirds depth of flow = 1·053. The velocity for the $\frac{1}{10}$ depth of flow will be $3 \times \frac{0 \cdot 4786}{1 \cdot 053} = 1 \cdot 36$ ft. per second.

The sanitary engineer has often to meet the question what the gradient of a sewer should be, in order to render it self cleansing, with the minimum dry weather flow of sewage. Such a question can easily be answered by means of these tables, for when V_s = velocity flowing full bore at a gradient of 1 in 10,000 and V = self-cleansing velocity say, 2·5 ft. per second, and v_m the proportional velocity given in this column, then:

$$100\sqrt{S} = \frac{V}{V_s v_m} \quad . \quad . \quad . \quad . \quad (17)$$

Example 20.—At what gradient should an 18 in. sewer be laid, in order that the sewage should flow with a velocity of 2·5 ft. per second, when the proportional depth of the sewage is 0·20?

The velocity due to a gradient of $\frac{1}{10000}$ full bore flow, from Table III. = V_s = 0·5968.

The proportional velocity (v_m) for a depth of flow 0·20, from Table VI. = 0·6457.

$$\therefore\ 100\sqrt{S} = \frac{2 \cdot 5}{0 \cdot 5968 \times 0.6457} = 6 \cdot 488 \quad \text{(formula 17)}$$

and the gradient equivalent thereto (from Table V.) = $\frac{1}{238}$, the gradient required.

Example 21.—The velocity of flow, when this sewer is flowing full bore, at a gradient of 1 in 238 is as already stated

$$V = 100\sqrt{S}\,V_s \text{ (formula 8).}$$

V = 0·5968 ft. per second × 6·488 = 3·872 ft. per second. The maximum velocity of flow takes place when the proportional depth of sewage = 0·81, and at the gradient $\frac{1}{238}$ this would be

$$\begin{aligned} v &= V_s v_m \times 100\sqrt{s} \quad . \quad . \quad . \quad (18) \\ &= 0 \cdot 5968 \times 1 \cdot 1252 \times 6 \cdot 488 \\ &= 4 \cdot 357 \text{ ft. per second.} \end{aligned}$$

Column 5. Multipliers for discharge. The figures in this column are based on those in columns 2 and 4. The corresponding figures of the two columns being simply multiplied together, giving the discharge due to any sectional part of a sewer, when the discharge from the sewer, flowing full bore, is taken as unity.

If g_m = the proper proportional discharge, a_m the proportional area due to any given depth, r_m the proportional mean depth, as already explained, then

$$g_m = a_m r_m^{0 \cdot 6}.$$

The actual discharge from any segment of a sewer = g, and

$$\left.\begin{aligned} g &= 100 \sqrt{S} G_s g_m \\ &= G g_m \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (20)$$

The figures are used in the same way as those in column 4, namely :—

$$100 \, S = \frac{g}{G_s g_m} = \frac{v}{V_s v_m}.$$

Example 22.—If a 15-in. pipe laid at a gradient of $\frac{1}{458}$ discharges 1149 gallons per minute when flowing full bore, how much sewage will it discharge when the depth of flow is $11\frac{1}{4}$ in.?

$$\text{Proportional depth of sewage} \frac{11 \cdot 25}{15} = 0 \cdot 75$$

g_m for 0.75 = 0·9005. (Column 5, Table IV.)

Actual discharge 1149 × 0·9005 = 1034·7 gallons per minute.

Example 23.—A 72-in. sewer is put down at a gradient of 1 in 2089, so as to have a velocity of 3 ft. per second, when flowing full or half full. The sewer will convey 31,758 gallons of sewage per minute, when flowing full, the quantity of storm water is estimated at 15,000 gallons per minute, the dry weather flow is 1500 gallons. Find the depth of flow and the velocity for this latter quantity.

Proportional discharge (g_m) of sewage = $\frac{1500}{31758}$ = 0·0472.

Corresponding proportional depth col. 1 = 0.143 (by interpolation).

Corresponding proportional velocity col. 4 = 0·5375 (by interpolation).

Actual depth of flow :—

$$72 \text{ in.} \times 0 \cdot 143 = 10 \cdot 3 \text{ in.}$$

Velocity with 1500 gallons of sewage per minute :—

$$= 3 \text{ ft.} \times 0 \cdot 5375 = 1 \cdot 613 \text{ ft. per second.}$$

Example 24.—It is required that an oval sewer, 2 ft. 6 in. × 3 ft. 9 in., shall discharge 3000 gallons of sewage per minute at a velocity of 2·5 ft. per second.

(*a*) What will be the depth of flow?
(*b*) What should be the gradient?
(*c*) What will be the maximum discharge of such a sewer laid at the gradient (*b*)?
(*d*) What will be the velocity at the maximum discharge?

(*a*) The depth of flow in any sewer, for a given velocity, is in relation to the sectional area of the flow or in the relation of a_m given in columns 2 of Tables VI. and VII. The proportional area a_m is found by dividing the given flow (in the case before us 3000 gallons per minute) by the full bore flow due to the given velocity.

From Table IV. the full bore flow of an oval sewer, 2 ft. 6 in. by 3 ft. 9 in., when V = 2·5, is 6714 gallons per minute and

$$a_m = \frac{3000}{6714} = 0 \cdot 4468.$$

The depth of flow corresponding to this proportional area is, say, 0·50 (column 1, Table VII.). The actual flow will be:—

$$3 \cdot 75 \times 0 \cdot 50 = 1 \cdot 875 \text{ ft. Answer to } (a).$$

(*b*) To obtain the required gradient we must first find the velocity of a full bore flow, when at 0·50 depth the velocity is 2·5 ft. per second. This is found by dividing the given velocity (2·5) by the proportional velocity given in column 4 of Table VII., or

$$\frac{2 \cdot 5}{0 \cdot 9576} = 2 \cdot 61 = \text{the velocity for full bore.}$$

From Table IV., the velocity for a gradient $\frac{1}{10000}$ (full bore flow) for the 2 ft. 6 in. by 3 ft. 9 in. sewer = V_s = 0·88576, and by formula (7)

$$\frac{V}{V_s} = 100\sqrt{S}.$$

$$= \frac{2 \cdot 61}{0 \cdot 88576} = 2 \cdot 947,$$

and from Table V., the gradient corresponding this value of

$$100\sqrt{S} = \frac{1}{1150}. \text{ The answer to } (b).$$

(*c*) The maximum discharge of an oval sewer is when the sewage flows 0·96 of its height, and the proportional discharge is 1·0541 (column 5, Table VII.). The proportional discharge for a depth of 0·50 is 0·4246.

$$\therefore \quad 3000 \times \frac{1 \cdot 0541}{0 \cdot 4246} = 7450 \text{ gallons per minute. Answer to } (c).$$

(*d*) The proportional velocity (column 4, Table VII.), for a depth of 0·96 is 1·0717, and for a depth of 0·50 is 0·9576.

$$\therefore \quad 2 \cdot 5 \times \frac{1 \cdot 0717}{0 \cdot 9576} = 2 \cdot 8 \text{ ft. per second. Answer to } (d).$$

Column 6. Multipliers for gradients.

The numbers in this column give, by a single multiplication, the increase in gradient required for any sewer in order to give a standard or any required velocity to any segmental flow, say to provide for the minimum dry weather flow of sewage.

The sine of the inclination (S) is inversely proportional, and the gradient is proportional to the 1·2 power of the hydraulic mean depth ($R^{1 \cdot 2}$ or $r^{1 \cdot 2}$), and for any given velocity of segmental flow

$$\frac{1}{s} = \frac{1}{S} s_m \quad . \quad . \quad . \quad . \quad (22)$$

Example 25. A 72-in. sewer laid at a gradient of 1 in 2089 will have sewage flowing through it with a velocity of 3 ft. per second, when full or half full. At what gradient should it be laid in order that a flow of sewage, 9 in. deep on its invert, may have this velocity?

Proportional depth of sewage $\frac{9}{72} = 0 \cdot 125$.

Corresponding multiplier for gradient (s_m) by interpolation between 0·2599 and 0·2375 = 0·2487. Gradient required 2089 × 0·2487 = 520.

The sewer should therefore be laid at a gradient of 1 in 520, in order that the dry weather sewage may flow along it with a self-cleansing velocity.

Example 26. An 18-in. pipe laid at a gradient of 1 in 570 will have a velocity of $2\frac{1}{2}$ feet per second, when flowing full or half full. What gradient should it be laid at in order that it may have the same velocity with a flow of sewage $4\frac{1}{2}$ in. deep?

Proportional depth of sewage $\frac{4 \cdot 5}{18} = 0 \cdot 25$.
Multiplier for gradient $(g_m) = 0 \cdot 5271$.
Gradient required, 1 in $570 \times 0 \cdot 5271 = 1$ in 300.

Example 27. Referring to the question (*b*) given in Example 24, this may be found also from column 6 of Table VII.

The gradient required for the full bore flow $\left(\frac{1}{S}\right)$ for an oval sewer 2 ft. 6 in. by 3 ft. 9 in., with a velocity of $2 \cdot 5$ ft. per second, is $\frac{1}{1255}$ (Table IV.). The gradient required to give the same velocity to a flow of $0 \cdot 50$ is $1255 \times 0 \cdot 9170$ (column 6, Table VII.) $= \frac{11}{1150}$, as found by the more circuitous method in Example 24.

309. A close study of this Table is most useful and interesting for a sanitary engineer, as it shows the effect of turning a small quantity of sewage into a large sewer laid at a flat gradient.

It shows conclusively that the velocity of flow depends only to a very slight extent upon the size of the sewer, but principally upon the quantity of sewage and the gradient, so that large sewers are not useful in proportion to their cost for conveying small quantities of sewage, as this work can be done better and cheaper by a small sewer properly adjusted to the quantity of sewage it has to carry, and laid at a proper gradient.

Taking for instance a flow of 92 gallons per minute, then the following gradients are required, for conveying the sewage in sewers, varying from 6 in. to 30 in. diameter, at a velocity of $2\frac{1}{2}$ ft. per second :—

Diameter of Pipe	Multiplier for Discharge	Multiplier for Gradient	Gradient for Full or Half-full Discharge	Gradient for 92 Gallons per Minute
in.				
6	$\frac{92}{184} = 0 \cdot 50$	1·0	1 in 152	1 in 152
9	$\frac{92}{414} = 0 \cdot 222$	0·67	1 ,, 248	1 ,, 167
12	$\frac{92}{735} = 0 \cdot 125$	0·496	1 ,, 350	1 ,, 173
18	$\frac{92}{1654} = 0 \cdot 0556$	0·316	1 ,, 570	1 ,, 180
24	$\frac{92}{2941} = 0 \cdot 0312$	0·223	1 ,, 805	1 ,, 180
30	$\frac{92}{4602} = 0 \cdot 0199$	0·185	1 ,, 1052	1 ,, 196

A 30-in. sewer should be laid at very nearly the same gradient as a 6-in. pipe in order to convey a quantity of 92 gallons per minute, at a self-cleansing velocity.

Similarly the following table gives the gradients at which oval sewers of various sizes should be laid in order to discharge 92 gallons per minute at a velocity of $2\frac{1}{2}$ ft. per second :—

Size of Sewer	Multiplier for Discharge G_m	Multiplier for Gradient $\frac{1}{S_m}$	Gradient for Full Bore Discharge	Gradient for 92 Gallons per Minute
ft. in. ft. in.				
1 0 × 1 6	$\frac{92}{1074} = 0{\cdot}0856$	0·4514	1 in 418	1 in 188
1 6 × 2 3	$\frac{92}{2417} = 0{\cdot}0381$	0·3146	1 ,, 680	1 ,, 214
2 0 × 3 0	$\frac{92}{4297} = 0{\cdot}0214$	0·229	1 ,, 960	1 ,, 220
2 6 × 3 9	$\frac{92}{6714} = 0{\cdot}0137$	0·1835	1 ,, 1255	1 ,, 230
3 0 × 4 6	$\frac{92}{9668} = 0{\cdot}0095$	0·1601	1 ,, 1562	1 ,, 250

These figures show that where there are great differences of flow between wet and dry weather that the oval sewer has a slight advantage as regards the smaller variation of velocity at the extremes of flow than a circular sewer. Yet the difference of gradient necessary to give $2\frac{1}{2}$ ft. velocity to the flow of 92 gallons per minute in an oval sewer 3 ft. × 4 ft. 6 in. as compared with that necessary for a 6 in. circular sewer is not great, being $\frac{1}{250}$ in the larger as compared with $\frac{1}{152}$ in the smaller sewer.

The actual depth of flow of the 92 gallons per minute would be 3 in. in the 6-in. pipe as compared with an actual depth of flow of $3\frac{3}{4}$ in. in the 30 in. circular sewer and $3\frac{1}{4}$ in. in the 3 ft. × 4 ft. 6 in. oval sewer.

The idea that a large sewer is more advantageous than a small one, still lingers in many minds, and large sewers laid at flat gradients are put down in places where there is not sufficient sewage to fill them sufficiently to render them self-cleansing.

This aspect of the discharging power of pipes is a most important one, because whilst it is generally admitted that sewers constructed and laid under streets in England will suffice when they are laid at gradients sufficient to cause the sewage proper to flow through them at a velocity of $2\frac{1}{2}$ ft. per second, in India, however (as Mr. Ault's practical experience there taught him), it is necessary to cause the sewage to flow at velocities of from $3\frac{1}{4}$ to $3\frac{1}{2}$ ft. per second. Hence the provision made for such in the following Table VIII.

310. Table VIII.

Proportional Parts of an Oval Sewer, the Height or Major Axis being Unity.

This Table may be regarded as supplementary to Table VII., as the proportional parts which it gives apply to Oval Sewers, of which the Major Axis is assumed to be Unity.

The Table is virtually self-explanatory, the data for it being (*mutatis mutandis*) identical with those of Table VII. It occupies pages 385–387.

TABLE I.—Circular Sewers.

Area and Hydraulic Mean Depth (Running Full).

Diameter Inches	Area Sq. Ft.	Hydraulic Mean Depth Ft.	Diameter Inches	Area Sq. Ft.	Hydraulic Mean Depth Feet	Diameter Inches	Area Sq. Ft.	Hydraulic Mean Depth Feet
1	2	3	1	2	3	1	2	3
d	A	R	*d*	A	R	*d*	A	R
3	0·0491	0·0625	35	6·6813	0·7292	67	24·4837	1·3958
4	0·0873	0·0833	36	7·0686	0·7500	68	25·2200	1·4167
5	0·1364	0·1042	37	7·4667	0·7708	69	25·9672	1·4375
6	0·1963	0·1250	38	7·8758	0·7917	70	26·7254	1·4583
7	0·2673	0·1458	39	8·2958	0·8125	71	27·4944	1·4792
8	0·3491	0·1667	40	8·7267	0·8333	72	28·2743	1·5000
9	0·4418	0·1875	41	9·1684	0·8542	73	29·0652	1·5208
10	0·5454	0·2083	42	9·6211	0·8750	74	29·8670	1·5417
11	0·6600	0·2292	43	10·0847	0·8958	75	30·6796	1·5625
12	0·7854	0·2500	44	10·5592	0·9167	76	31·5032	1·5833
13	0·9218	0·2708	45	11·0447	0·9375	77	32·3377	1·6042
14	1·0690	0·2917	46	11·5410	0·9583	78	33·1831	1·6250
15	1·2272	0·3125	47	12·0482	0·9792	79	34·0394	1·6458
16	1·3963	0·3333	48	12·5664	1·0000	80	34·9066	1·6667
17	1·5763	0·3542	49	13·0954	1·0208	81	35·7847	1·6875
18	1·7672	0·3750	50	13·6354	1·0417	82	36·6737	1·7083
19	1·9690	0·3958	51	14·1863	1·0625	83	37·5737	1·7292
20	2·1817	0·4167	52	14·7480	1·0833	84	38·4845	1·7500
21	2·4053	0·4375	53	15·3207	1·1042	85	39·4063	1·7708
22	2·6398	0·4583	54	15·9043	1·1250	86	40·3389	1·7917
23	2·8858	0·4792	55	16·4988	1·1458	87	41·2825	1·8125
24	3·1416	0·5000	56	17·1042	1·1667	88	42·2370	1·8333
25	3·4089	0·5208	57	17·7206	1·1875	89	43·2024	1·8542
26	3·6870	0·5417	58	18·3478	1·2083	90	44·1787	1·8750
27	3·9761	0·5625	59	18·9859	1·2292	91	45·1659	1·8958
28	4·2761	0·5833	60	19·6350	1·2500	92	46·1640	1·9168
29	4·5869	0·6042	61	20·2049	1·2708	93	47·1730	1·9375
30	4·9087	0·6250	62	20·9658	1·2917	94	48·1929	1·9583
31	5·2414	0·6458	63	21·6475	1·3125	95	49·2237	1·9792
32	5·5851	0·6667	64	22·3402	1·3333	96	50·2655	2·0000
33	5·9396	0·6875	65	23·0438	1·3542			
34	6·3050	0·7083	66	23·7583	1·3750			

TABLE II.—Oval Sewers (Old Form).

Area and Hydraulic Mean Depth when Flowing Full, and Two-Thirds and One-Third Vertical Height.

Size of Sewer	Flowing Full		Flowing Two-Thirds Full		Flowing One-Third Full	
	Area Sq. Ft.	Hydraulic Mean Depth Feet	Area. Sq. Ft.	Hydraulic Mean Depth Feet	Area. Sq. Ft.	Hydraulic Mean Depth Feet
1	2	3	4	5	6	7
D D	A	R	*a*	*r*	*a*	*r*
Ft. in. Ft. in.						
0 4 × 0 6	0·1276	0·0966	0·0840	0·1052	0·0316	0·0689
0 $4\frac{2}{3}$ × 0 7	0·1737	0·1126	0·1143	0·1228	0·0430	0·0805
0 6 × 0 9	0·2871	0·1448	0·1890	0·1579	0·0710	0·1033
0 8 × 1 0	0·5105	0·1931	0·3359	0·2105	0·1263	0·1378
0 10 × 1 3	0·7926	0·2414	0·5249	0·2631	0·1973	0·1722
1 0 × 1 6	1·1485	0·2897	0·7558	0·3157	0·2841	0·2067
1 2 × 1 9	1·5633	0·3379	1·0288	0·3683	0·3867	0·2411
1 4 × 2 0	2·0418	0·3862	1·3437	0·4209	0·5051	0·2756
1 6 × 2 3	2·5842	0·4345	1·7007	0·4735	0 6392	0·3100
1 8 × 2 6	3·1903	0·4828	2·0996	0·5261	0·7892	0·3445
1 10 × 2 9	3·8603	0·5310	2·5404	0·5787	0·9549	0·3789
2 0 × 3 0	4·5941	0·5793	3·0233	0·6314	1·1364	0·4133
2 2 × 3 3	5·3917	0·6276	3·5483	0·6840	1·3337	0·4478
2 4 × 3 6	6·2531	0·6759	4·1151	0·7366	1·5467	0·4822
2 6 × 3 9	7·1783	0·7241	4·7239	0·7892	1·7756	0·5166
2 8 × 4 0	8·1673	0·7724	5·3748	0·8418	2·0202	0·5511
2 10 × 4 3	9·2201	0·8207	6·0676	0·8944	2·2807	0·5855
3 0 × 4 6	10·3367	0·8690	6·8024	0·9471	2·5569	0·6199
3 2 × 4 9	11·5172	0·9172	7·5792	0·9997	2·8489	0·6544
3 4 × 5 0	12·7614	0·9655	8·3980	1·0523	3·1566	0·6888
3 6 × 5 3	14·0694	1·0138	9·2588	1·1049	3·4802	0·7232
3 8 × 5 6	15·4413	1·0621	10·1617	1·1575	3·8196	0·7577
3 10 × 5 9	16·8769	1·1103	11·1064	1·2101	4·1747	0·7921
4 0 × 6 0	18·3764	1·1586	12·0932	1·2628	4·5456	0·8266
4 2 × 6 3	19·9397	1·2069	13·1220	1·3154	4·9323	0·8611
4 4 × 6 6	21·5667	1·2552	14·1927	1·3680	5·3348	0·8955
4 6 × 6 9	23·2576	1·3034	15·3054	1·4206	5·7530	0·9299
4 8 × 7 0	25·0123	1·3517	16·4602	1·4732	6·1871	0·9644
4 10 × 7 3	26·8308	1·4000	17·6569	1·5258	6·6369	0·9988
5 0 × 7 6	28·7131	1·4483	18·8956	1·5785	7·1025	1·0332
5 2 × 7 9	30·6592	1·4965	20·1763	1·6311	7·5939	1·0677
5 4 × 8 0	32·6692	1·5448	21·4990	1·6837	8·0811	1·1021
5 6 × 8 3	34·7429	1·5931	22·8637	1·7363	8·5940	1·1365
5 8 × 8 6	36·8804	1·6414	24·2704	1·7889	9·1228	1·1710
5 10 × 8 9	39·0817	1·6896	25·7190	1·8415	9·6673	1·2054
6 0 × 9 0	41·3469	1·7379	27·2097	1·8942	10·2276	1·2399

TABLE III.*—GIVING GRADIENTS $\left(\frac{1}{S}\right)$ AND DISCHARGES (G) IN GALLONS

ALSO VELOCITIES (V_s), AND DISCHARGES (G_s), WITH A

Diameter of Sewer in Inches	Velocity in Feet per							
	2·0		2·25		2·5		2·75	
	Gradient, 1 in	Discharge Gals. per Min.	Gradient, 1 in	Discharge Gals. per Min.	Gradient, 1 in	Discharge Gals per Min.	Gradient, 1 in	Discharge Gals. per Min.
1	2	3	4	5	6	7	8	9
$= d$	$= \frac{1}{S}$	$= G$	$= \frac{1}{S}$	$= G$	$= \frac{1}{S}$	$= G$	$= \frac{1}{S}$	$= G$
3	104	37	82	41	66	46	55	51
4	147	65	116	73	94	82	77	90
5	191	102	151	115	122	128	101	140
6	238	147	188	165	152	184	126	202
7	287	200	227	225	183	250	151	275
8	337	261	266	294	215	327	178	359
9	387	331	306	372	248	414	205	455
10	440	408	348	459	281	511	232	561
11	493	494	390	556	316	618	261	679
12	547	588	433	661	350	735	290	808
13	602	690	476	776	386	863	319	948
14	659	800	520	900	422	1,000	348	1,100
15	716	919	565	1,033	458	1,149	378	1,263
16	773	1,046	611	1,175	495	1,307	409	1,437
17	831	1,180	657	1,327	532	1,475	440	1,622
18	890	1,323	704	1,488	570	1,654	471	1,818
19	950	1,474	751	1,658	608	1,843	502	2,026
20	1,010	1,634	798	1,837	647	2,042	534	2,245
21	1,071	1,801	846	2,025	686	2,251	567	2,475
22	1,133	1,977	895	2,022	725	2,471	599	2,716
23	1,195	2,160	944	2,429	765	2,701	632	2,969
24	1,257	2,353	994	2,645	805	2,941	665	3,232
25	1,321	2,552	1,044	2,870	845	3,190	699	3,507
26	1,384	2,761	1,094	3,104	886	3,451	732	3,793
27	1,449	2,977	1,144	3,347	927	3,722	766	4,091
28	1,513	3,202	1,196	3,600	968	4,003	800	4,399
29	1,578	3,435	1,248	3,861	1,010	4,294	835	4,719
30	1,643	3,675	1,300	4,132	1,052	4,595	869	5,050
31	1,710	3,925	1,352	4,412	1,094	4,906	904	5,393
32	1,776	4,183	1,404	4,701	1,137	5,227	939	5,746
33	1,843	4,447	1,456	5,000	1,180	5,558	975	6,111
34	1,910	4,721	1,509	5,308	1,222	5,900	1,010	6,487

* Supra, p. 317.

per Minute for Circular Sewers, at Various Velocities (V), Gradient of $\frac{1}{10000}$, the Sewers Running Full Bore.

Second = V						When Gradient $= \frac{1}{10000}$		Diameter of Sewer in Inches
3·0		3·25		3·5				
Gradient, 1 in	Discharge Gals. per Min.	Gradient, 1 in	Discharge Gals. per Min.	Gradient, 1 in	Discharge Gals. per Min.	Velocity Feet per Second	Discharge Gal. per Min.	
10	11	12	13	14	15	16	17	18
$= \frac{1}{S}$	= G	$= \frac{1}{S}$	= G	$= \frac{1}{S}$	= G	$= V_s$	$= G_s$	= *d*
46	55	39	60	34	64	0·2037	3·74	3
65	98	55	106	48	114	0·2421	7·91	4
85	153	72	166	63	179	0·2767	14·13	5
106	221	90	239	78	257	0·3087	22·7	6
127	300	109	325	94	350	0·3386	33·88	7
150	392	127	424	110	457	0·3669	47·95	8
172	496	147	537	127	579	0·3937	65·13	9
195	613	167	663	144	714	0·4194	85·65	10
219	741	187	802	161	864	0·4441	110	11
243	882	207	955	179	1,028	0·4679	138	12
268	1,035	228	1,121	197	1,207	0·4909	169	13
293	1,201	249	1,300	215	1,400	0·5133	205	14
318	1,378	271	1,492	234	1,607	0·535	246	15
344	1,568	293	1,698	252	1,828	0·5561	291	16
370	1,770	315	1,917	271	2,064	0·5767	340	17
396	1,985	337	2,149	291	2,314	0·5968	395	18
422	2,212	360	2,394	310	2,578	0·6165	454	19
449	2,450	383	2,653	330	2,857	0·6357	519	20
476	2,702	406	2,925	350	3,150	0·6546	590	21
503	2,965	429	3,210	370	3,457	0·6731	665	22
531	3,241	453	3,508	390	3,778	0·6913	747	23
559	3,529	476	3,820	411	4,114	0·7092	834	24
587	3,828	500	4,145	431	4,464	0·7268	928	25
615	4,141	524	4,483	452	4,828	0·7441	1,027	26
644	4,466	549	4,835	473	5,206	0·7612	1,133	27
673	4,803	573	5,199	494	5,599	0·778	1,246	28
701	5,152	598	5,577	515	6,006	0·7945	1,365	29
730	5,514	622	5,969	537	6,428	0·8108	1,490	30
760	5,888	647	6,373	558	6,863	0·827	1,623	31
789	6,274	673	6,791	580	7,313	0·8429	1,763	32
819	6,672	698	7,222	602	7,778	0·8586	1,909	33
849	7,082	723	7,666	624	8,256	0·8741	2,063	34

TABLE III.—CIRCULAR DRAINS

Diameter of Sewer in Inches	Velocity in Feet per							
	2·0		2·2		2·5		2·75	
	Gradient, 1 in	Discharge Gals. per Min.	Gradient, 1 in	Discharge Gals. per Min.	Gradient, 1 in	Discharge Gals. per Min.	Gradient, 1 in	Discharge Gals. per Min.
1	2	3	4	5	6	7	8	9
$= d$	$= \frac{1}{S}$	$= G$	$= \frac{1}{S}$	$= G$	$= \frac{1}{S}$	$= G$	$= \frac{1}{S}$	$= G$
35	1.978	5,003	1,563	5,624	1,266	6,253	1,046	6,874
36	2,046	5,293	1,616	5,950	1,309	6,616	1,082	7,273
37	2,114	5,591	1,670	6,285	1,353	6,989	1,118	7,682
38	2,183	5,897	1,725	6,630	1,397	7,372	1,154	8,103
39	2,252	6,212	1,779	6,983	1,441	7,765	1,191	8,535
40	2,321	6,535	1,834	7,346	1,486	8,168	1,228	8,978
41	2,391	6,865	1,889	7,718	1,530	8,582	1,265	9,433
42	2,461	7,204	1,945	8,099	1,575	9,005	1,302	9,899
43	2,532	7,551	2,000	8,489	1,620	9,439	1,339	10,376
44	2,603	7,907	2,056	8,889	1,666	9,883	1,377	10,864
45	2,674	8,270	2,113	9,297	1,711	10,338	1,414	11,363
46	2,745	8,642	2,169	9,715	1,757	10,802	1,452	11,874
47	2,817	9,022	2,226	10,142	1,803	11,277	1,490	12,396
48	2,889	9,410	2,283	10,579	1,849	11,762	1,528	12,929
49	2,961	9,806	2,340	11,024	1,895	12,257	1,566	13,474
50	3,034	10,210	2,397	11,478	1,942	12,763	1,605	14,029
51	3,107	10,623	2,455	11,942	1,988	13,278	1,643	14,596
52	3,180	11,043	2,513	12,415	2,035	13,804	1,682	15,174
53	3,254	11,472	2,571	12,897	2,083	14,340	1,721	15,763
54	3,328	11,909	2,629	13,388	2,130	14,887	1,760	16,363
55	3,402	12,354	2,688	13,889	2,177	15,443	1,799	16,975
56	3,476	12,808	2,747	14,398	2,225	16,010	1,839	17,598
57	3,551	13,269	2,806	14,917	2,273	16,587	1,878	18,232
58	3,626	13,739	2,865	15,445	2,320	17,175	1,918	18,877
59	3,701	14,217	2,924	15,982	2,368	17,771	1,957	19,534
60	3,776	14,703	2,984	16,529	2,417	18,378	1,997	20,202
61	3,852	15,197	3,043	17,084	2,465	18,996	2,037	20,881
62	3,928	15,699	3,103	17,649	2,514	19,624	2,077	21,571
63	4,004	16,210	3,163	18,223	2,562	20,262	2,118	22,272
64	4,080	16,728	3,224	18,806	2,611	20,910	2,158	22,985
65	4,157	17,255	3,284	19,398	2,661	21,569	2,199	23,709
66	4,234	17,790	3,345	20,000	2,710	22,238	2,239	24,444
67	4,311	18,333	3,406	20,610	2,759	22,917	2,280	25,190
68	4,388	18,885	3,467	21,230	2,808	23,606	2,321	25,948
69	4,466	19,444	3,528	21,859	2,858	24,305	2,362	26,717

AND SEWERS—*continued.*

Second = V						When Gradient $= \frac{1}{10000}$		Diameter of Sewer in Inches
3·0		3·25		3·5				
Gradient, 1 in	Discharge Gals. per Min.	Gradient, 1 in	Discharge Gals. per Min.	Gradient, 1 in	Discharge Gals. per Min.	Velocity Feet per Second	Discharge Gals. per Min.	
10	11	12	13	14	15	16	17	18
$=\frac{1}{S}$	$= G$	$=\frac{1}{S}$	$= G$	$=\frac{1}{S}$	$= G$	$= V_1$	$= G_1$	$= d$
879	7,504	749	8,124	646	8,749	0·8894	2,225	35
909	7,939	775	8,595	668	9,256	0·9046	2,394	36
940	8,387	801	9,079	690	9,777	0·9196	2,571	37
970	8,846	827	9,576	713	10,313	0·9344	2,755	38
1,000	9,318	853	10,087	735	10,863	0·9491	2,948	39
1,032	9,802	879	10,611	758	11,427	0·9636	3,148	40
1,063	10,298	906	11,148	781	12,006	0·978	3,357	41
1,094	10,806	932	11,699	804	12,599	0·9922	3,574	42
1,125	11,327	959	12,262	827	13,206	1·0063	3,800	43
1,157	11,860	986	12,839	850	13,827	1·0203	4,034	44
1,188	12,405	1,013	13,429	873	14,462	1·0342	4,276	45
1,220	12,963	1,040	14,033	896	15,112	1·0479	4,528	46
1,252	13,533	1,067	14,650	920	15,777	1·0615	4,788	47
1,284	14,115	1,094	15,280	943	16,455	1·075	5,058	48
1,316	14,710	1,121	15,923	967	17,148	1·0884	5,336	49
1,348	15,316	1,149	16,580	991	17,855	1·1017	5,624	50
1,381	15,934	1,177	17,249	1,015	18,576	1·1148	5,921	51
1,413	16,565	1,204	17,932	1,039	19,312	1·1279	6,228	52
1,446	17,209	1,232	18,629	1,063	20,062	1·1409	6,544	53
1,479	17,864	1,260	19,338	1,087	20,826	1·1537	6,870	54
1,512	18,532	1,288	20,061	1,111	21,604	1·1665	7,206	55
1,545	19,211	1,316	20,797	1,135	22,397	1·1792	7,551	56
1,578	19,904	1,345	21,547	1,159	23,204	1·1918	7,907	57
1,611	20,609	1,373	22,309	1,184	24,026	1·2043	8,273	58
1,645	21,325	1,401	23,085	1,208	24,861	1·2167	8,649	59
1,678	22,054	1,430	23,875	1,233	25,711	1·229	9,035	60
1,712	22,796	1,459	24,677	1,258	26,575	1·2413	9,432	61
1,746	23,549	1,487	25,493	1,283	27,454	1·2534	9,839	62
1,779	24,315	1,516	26,322	1,307	28,347	1·2655	10,257	63
1,813	25,093	1,545	27,164	1,332	29,254	1·2775	10,685	64
1,847	25,883	1,574	28,019	1,357	30,175	1·2895	11,125	65
1,882	26,685	1,603	28,888	1,382	31,110	1·3013	11,576	66
1,916	27,500	1,632	29,770	1,408	32,060	1·3131	12,037	67
1,950	28,327	1,662	30,666	1,433	33,024	1·3249	12,510	68
1,985	29,166	1,691	31,574	1,458	34,003	1·3365	12,994	69

TABLE III.—CIRCULAR DRAINS

Diameter of Sewer in Inches	Velocity in Feet per 2·0 Gradient, 1 in	2·0 Discharge Gals. per Min.	2·25 Gradient, 1 in	2·25 Discharge Gals. per Min.	2·5 Gradient, 1 in	2·5 Discharge Gals. per Min.	2·75 Gradient, 1 in	2·75 Discharge Gals. per Min.
1	2	3	4	5	6	7	8	9
$= d$	$= \frac{1}{S}$	$= G$	$= \frac{1}{S}$	$= G$	$= \frac{1}{S}$	$= G$	$= \frac{1}{S}$	$= G$
70	4,543	20,012	3,590	22,497	2,908	25,015	2,403	27,497
71	4,621	20,588	3,652	23,145	2,958	25,735	2,444	28,288
72	4,700	21,172	3,713	23,801	3,008	26,465	2,486	29,090
73	4,778	21,764	3,775	24,467	3,058	27,205	2,527	29,904
74	4,857	22,364	3,837	25,142	3,109	27,956	2,569	30,729
75	4,936	22,973	3,900	25,826	3,159	28,716	2,611	31,565
76	5,015	23,590	3,962	26,519	3,209	29,487	2,652	32,412
77	5,094	24,215	4,025	27,222	3,260	30,268	2,694	33,271
78	5,173	24,848	4,088	27,933	3,311	31,059	2,736	34,141
79	5,253	25,489	4,151	28,654	3,362	31,861	2,778	35,022
80	5,333	26,138	4,214	29,384	3,413	32,673	2,821	35,914
81	5,413	26,796	4,277	30,123	3,464	33,495	2,863	36,817
82	5,493	27,461	4,340	30,872	3,516	34,327	2,906	37,732
83	5,574	28,135	4,404	31,629	3,567	35,169	2,948	38,658
84	5,655	28,817	4,468	32,396	3,619	36,022	2,991	39,595
85	5,736	29,508	4,532	33,172	3,671	36,885	3,034	40,543
86	5,817	30,206	4,596	33,957	3,723	37,757	3,077	41,503
87	5,898	30,912	4,660	34,751	3,774	38,640	3,120	42,474
88	5,979	31,627	4,724	35,555	3,827	39,534	3,163	43,456
89	6,061	32,350	4,789	36,367	3,879	40,438	3,206	44,449
90	6,143	33,081	4,854	37,189	3,931	41,351	3,249	45,454
91	6,225	33,820	4,918	38,020	3,984	42,275	3,292	46,469
92	6,307	34,567	4,983	38,860	4,036	43,210	3,336	47,496
93	6,389	35,323	5,048	39,710	4,089	44,154	3,379	48,534
94	6,472	36,087	5,113	40,568	4,142	45,109	3,423	49,584
95	6,554	36,859	5,179	41,436	4,195	46,073	3,467	50,644
96	6,637	37,639	5,244	42,313	4,248	47,049	3,511	51,716
97	6,720	38,427	5,310	43,199	4,301	48,034	3,555	52,799
98	6,804	39,223	5,376	44,095	4,354	49,029	3,599	53,893
99	6,887	40,028	5,442	44,999	4,408	50,035	3,643	54,999
100	6,971	40,841	5,508	45,913	4,461	51,051	3,687	56,115

AND SEWERS—*continued.*

Second = V						When Gradient $= \frac{1}{10000}$		Diameter of Sewer in Inches
3·0		3·25		3·5				
Gradient, 1 in	Discharge Gals. per Min.	Gradient, 1 in	Discharge Gals. per Min.	Gradient, 1 in	Discharge Gals. per Min.	Velocity Feet per Second	Discharge Gals. per Min.	
10	11	12	13	14	15	16	17	18
$=\frac{1}{S}$	= G	$=\frac{1}{S}$	= G	$=\frac{1}{S}$	= G	$= V_1$	$= G_1$	= *d*
2,019	30,018	1,721	32,496	1,484	34,996	1·3481	13,489	70
2,054	30,882	1,750	33,431	1,509	36,003	1·3596	13,996	71
2,089	31,758	1,780	34,379	1,535	37,024	1·3711	14,514	72
2,124	32,646	1,809	35,341	1,560	38,060	1·3825	15,044	73
2,159	33,547	1,839	36,316	1,586	39,110	1·3938	15,586	74
2,194	34,459	1,869	37,304	1,612	40,174	1·4051	16,139	75
2,229	35,384	1,899	38,305	1,637	41,252	1·4163	16,705	76
2,264	36.322	1,929	39,320	1,663	42,345	1·4274	17,282	77
2,299	37,271	1,959	40,348	1,689	43,452	1·4385	17,872	78
2,335	38,233	1,989	41,389	1,715	44,573	1·4496	18,474	79
2,370	39,207	2,020	42,444	1,741	45,709	1·4606	19,088	80
2,406	40,193	2,050	43,511	1,768	46,859	1·4715	19,715	81
2,442	41,192	2,080	44,592	1,794	48,023	1·4824	20,354	82
2,477	42,203	2,111	45,687	1,820	49,201	1·4932	21,005	83
2,513	43,226	2,141	46,794	1,846	50,394	1·5039	21,670	84
2,549	44,261	2,171	47,915	1,873	51,601	1·5146	22,347	85
2,585	45,309	2,203	49,049	1,899	52,822	1·5253	23,037	86
2,621	46,369	2,233	50,196	1,926	54,058	1·5359	23,740	87
2,657	47,441	2,264	51,357	1,952	55,308	1·5465	24,456	88
2,694	48,526	2,295	52,531	1,979	56,572	1·557	25,185	89
2,730	49,622	2,326	53,718	2,006	57,850	1·5675	25,927	90
2,767	50,730	2,357	54,918	2,033	59,143	1·5779	26,683	91
2,803	51,851	2,388	56,132	2,059	60,450	1·5883	27,452	92
2,839	52,895	2,420	57,359	2,086	61,771	1·5986	28,235	93
2,876	54,130	2,451	58,599	2,113	63,106	1·6089	29,031	94
2,913	55,288	2,482	59,852	2,140	64,456	1·6192	29,841	95
2,950	56,458	2,514	61,119	2,167	65,820	1·6294	30,664	96
2,987	57,640	2,545	62,399	2,194	67,199	1·6396	31,502	97
3,024	58,835	2,577	63,692	2,222	68,592	1·6497	32,353	98
3,061	60,043	2,608	64,999	2,249	69,999	1·6598	33,218	99
3,098	61,261	2,640	66,318	2,276	71,420	1·6698	34,098	100

TABLE IV.—Giving Gradients $\left(\frac{1}{S}\right)$ and Discharges (G) in Velocities of Flow (V), also Velocities (V_s) and Sewers Flowing Full,

Size of Sewer	Depth of Flow	Velocities in 2·0 Gradient, 1 in	2·0 Discharge Gals. per Min.	2·25 Gradient, 1 in	2·25 Discharge Gals. per Min.	2·50 Gradient, 1 in	2·50 Discharge Gals. per Min.	2·75 Gradient, 1 in	2·75 Discharge Gals. per Min.
1	2	3	4	5	6	7	8	9	10
D D1		$\frac{1}{S}$	G	$\frac{1}{S}$	G	$\frac{1}{S}$	G	$\frac{1}{S}$	G
ft. in. ft. in.									
0 4 × 0 6	Full	175	95	138	107	112	119	92	134
	⅔rds do.	194	63	153	71	124	79	102	86
	⅓rd do.	116	24	92	27	74	30	62	32
0 4⅔ × 0 7	Full	209	130	166	146	135	162	111	179
	⅔rds do.	233	86	184	96	149	107	123	118
	⅓rd do.	140	32	111	36	90	40	74	44
0 6 × 0 9	Full	284	215	225	242	182	269	150	295
	⅔rds do.	315	141	249	159	202	177	167	194
	⅓rd do.	189	53	150	60	121	66	100	73
0 8 × 0 12	Full	402	382	387	430	257	477	212	525
	⅔rds do.	445	251	352	283	285	314	235	346
	⅓rd do.	267	94	211	106	171	118	141	130
0 10 × 0 15	Full	525	597	415	671	336	746	278	821
	⅔rds do.	582	393	460	442	372	491	308	540
	⅓rd do.	350	148	276	166	224	185	185	203
0 12 × 0 18	Full	653	859	516	967	418	1,074	345	1,182
	⅔rds do.	724	566	572	636	464	707	382	778
	⅓rd do.	435	213	344	239	278	266	230	292
1 2 × 1 9	Full	786	1,170	621	1,316	503	1,462	416	1,608
	⅔rds do.	871	770	689	866	558	962	461	1,058
	⅓rd do.	523	290	414	326	335	362	277	398
1 4 × 2 0	Full	923	1,528	729	1,719	590	1,910	488	2,101
	⅔rds do.	1,023	1,005	808	1,131	655	1,257	541	1,382
	⅓rd do.	614	378	485	425	393	472	325	520
1 6 × 2 3	Full	1,063	1,934	840	2,175	680	2,417	562	2,659
	⅔rds do.	1,178	1,273	931	1,432	754	1,591	623	1,750
	⅓rd do.	708	478	559	538	453	598	374	658

Gallons per Minute for Oval Sewers (Old Form) at Various Discharges (G_s) with a Gradient of $\frac{1}{10000}$, the also ⅔rds and ⅓rd Full.

Feet per Second: 3·0 — Gradient, 1 in	3·0 — Discharge Gals. per Min.	3·25 — Gradient, 1 in	3·25 — Discharge Gals. per Min.	3·5 — Gradient, 1 in	3·5 — Discharge Gals. per Min.	When the Gradient is $\frac{1}{10000}$: Velocity = V_s	Discharge = G_s
11	12	13	14	15	16	17	18
$\frac{1}{S}$	G	$\frac{1}{S}$	G	$\frac{1}{S}$	G		
78	143	66	155	57	167	0·26441	12·63
86	94	73	102	63	110	0·27842	8·75
52	35	44	38	39	41	0·21592	2·55
93	195	80	211	69	227	0·29003	18·86
104	128	88	139	76	150	0·30540	13·07
62	48	53	52	46	56	0·23685	3·81
126	322	108	349	93	376	0·33724	36·25
140	212	119	230	103	247	0·35510	25·12
84	80	72	86	62	93	0·27539	7·32
178	573	152	621	131	668	0·40077	76·59
198	377	169	408	145	4[illegible]0	0·42201	53·08
119	142	101	154	87	165	0·32728	15·47
233	895	199	970	171	1,044	0·45819	136·82
259	589	220	638	190	687	0·48246	94·81
155	221	132	240	114	258	0·37416	27·64
290	1,289	247	1,396	213	1,504	0·51115	219·80
322	848	274	919	236	990	0·53824	152·31
193	319	165	345	142	372	0·41742	44·40
349	1,755	298	1,901	257	2,047	0·56069	328·17
387	1,155	330	1,251	285	1,347	0·59039	227·40
233	434	198	470	171	506	0·45787	66·29
410	2,292	349	2,483	301	2,674	0·60746	464·38
455	1,508	387	1,634	334	1,760	0·63964	321·80
273	567	233	614	201	661	0·49606	93·80
472	2,900	402	3,142	347	3,384	0·65194	631·00
524	1,909	446	2,068	385	2,227	0·68648	437·00
315	717	268	777	231	837	0·53239	127·00

TABLE IV.—

Size of Sewer		Depth of Flow	Velocities in 2·0		2·25		2·50		2·75	
			Gradient, 1 in.	Discharge Gals. per Min.	Gradient, 1 in.	Discharge Gals. per Min.	Gradient, 1 in	Discharge Gals. per Min.	Gradient, 1 in	Discharge Gals. per Min.
1		2	3	4	5	6	7	8	9	10
D	D_1		$\frac{1}{S}$	G	$\frac{1}{S}$	G	$\frac{1}{S}$	G	$\frac{1}{S}$	G
ft. in.	ft. in.									
1 8 ×	2 6	Full	1,206	2,387	953	2,686	772	2,984	638	3,282
		⅔rds do.	1,337	1,571	1,056	1,767	856	1,964	707	2,160
		⅓rd do.	803	590	635	664	514	738	425	812
1 10 ×	2 9	Full	1,352	2,888	1,068	3,250	865	3,611	715	3,975
		⅔rds do.	1,499	1,900	1,184	2,139	959	2,376	793	2,612
		⅓rd do.	900	714	711	804	576	893	476	982
2 0 ×	3 0	Full	1,501	3,438	1,186	3,867	960	4,297	794	4,727
		⅔rds do.	1,664	2,262	1,315	2,545	1,065	2,828	880	3,111
		⅓rd do.	999	850	790	957	640	1,063	529	1,169
2 2 ×	3 3	Full	1,652	4,034	1,305	4,539	1,057	5,043	874	5,547
		⅔rds do.	1,832	2,655	1,447	2,987	1,172	3,319	969	3,651
		⅓rd do.	1,100	998	869	1,123	704	1,247	582	1,372
2 4 ×	3 6	Full	1,805	4,679	1,426	5,264	1,153	5,849	954	6,434
		⅔rds do.	2,001	3,079	1,581	3,464	1,281	3,849	1,058	4,234
		⅓rd do.	1,202	1,157	950	1,302	769	1,447	636	1,591
2 6 ×	3 9	Full	1,961	5,371	1,550	6,043	1,255	6,714	1,037	7,385
		⅔rds do.	2,175	3,535	1,718	3,977	1,392	4,418	1,150	4,860
		⅓rd do.	1,306	1,329	1,032	1,495	836	1,661	691	1,827
2 8 ×	4 0	Full	2,119	6,111	1.775	6,875	1,356	7,639	1,121	8,403
		⅔rds do.	2,350	4,022	1,857	4,524	1,504	5,026	1,243	5,530
		⅓rd do.	1,412	1,512	1,115	1,701	903	1,890	747	2,078
2 10 ×	4 3	Full	2,279	6,899	1,801	7,761	1,459	8,624	1,206	9,486
		⅔rds do.	2,527	4,540	1,997	5,108	1,617	5,675	1,337	6,243
		⅓rd do.	1,518	1,707	1,199	1,920	972	2,133	803	2,346
3 0 ×	4 6	Full	2,441	7,735	1,929	8,701	1,562	9,668	1,291	10,635
		⅔rds do.	2,707	5,090	2,139	5,726	1,732	6,363	1,432	6,999
		⅓rd do.	1,626	1,913	1,285	2,152	1,041	2,391	860	2,631
3 2 ×	4 9	Full	2,605	8,618	2,058	9,695	1,667	10,772	1,378	11,850
		⅔rds do.	2,888	5,671	2,282	6,380	1,848	7,089	1,528	7,798
		⅓rd do.	1,735	2,132	1,371	2,398	1,110	2,664	918	2,931

continued.

Feet per Second						When the Gradient is $\frac{1}{10000}$	
3·0		3·25		3·5			
Gradient, 1 in	Dis-charge Gals. per Min.	Gradient, 1 in	Dis-charge Gals. per Min.	Gradient, 1 in	Dis-charge Gals. per Min.	Velocity = V_s	Discharge = G_s
11	12	13	14	15	16	17	18
$\frac{1}{S}$	G	$\frac{1}{S}$	G	$\frac{1}{S}$	G		
536	3,581	457	3,879	394	4,178	0·69448	830·00
594	2,357	506	2,553	437	2,749	0·73128	575·00
357	886	304	960	262	1,033	0·56713	168·00
601	4,333	512	4,694	441	5,055	0·73535	1,063
666	2,851	568	3,089	489	3,327	0·77432	736
400	1,072	341	1,161	294	1,250	0·60051	215
667	5,156	568	5,586	490	6,016	0·77476	1,333
739	3,393	630	3,676	543	3,959	0·81591	923
443	1,275	378	1,382	326	1,488	0·63269	269
734	6,052	625	6,556	539	7,060	0·81288	1,641
814	3,982	694	4,314	598	4,646	0·85595	1,137
489	1,497	416	1,622	359	1,746	0·66382	331
802	7,018	683	7,603	589	8,188	0·84984	1,990
889	4,619	758	5,004	653	5,389	0·89487	1,379
534	1,736	455	1,881	392	2,025	0·69400	402
872	8,057	743	8,728	640	9,400	0·88576	2,380
967	5,302	824	5,744	710	6,186	0·93269	1,650
581	1,993	495	2,159	427	2,325	0·72333	481
942	9,167	803	9,931	692	10,695	0·92073	2,815
1,044	6,033	890	6,535	767	7,038	1·96591	1,951
627	2,267	535	2,456	461	2,645	0·75189	569
1,013	10,349	863	11,211	744	12,073	0·95484	3,296
1,123	6,810	957	7,378	825	7,945	1·00543	2,284
675	2,560	575	2,773	496	2,986	0·77974	666
1,085	11,602	924	12,569	797	13,536	0·98815	3,824
1,203	7,635	1,025	8,271	884	8,908	1·04051	2,650
723	2,870	616	3,109	531	3,348	0·80695	772
1,158	12,927	986	14,004	850	15,081	1·02074	4,401
1,284	8,507	1,094	9,216	943	9,925	1·07482	3,050
771	3,198	657	3,464	566	3,730	0·83355	889

Table IV.—

Size of Sewer	Depth of Flow	Velocities in 2·0 Gradient, 1 in	2·0 Discharge Gals. per Min.	2·25 Gradient, 1 in	2·25 Discharge Gals. per Min.	2·50 Gradient, 1 in	2·50 Discharge Gals. per Min.	2·75 Gradient, 1 in	2·75 Discharge Gals. per Min.
1	2	3	4	5	6	7	8	9	10
D D₁		$\frac{1}{S}$	G	$\frac{1}{S}$	G	$\frac{1}{S}$	G	$\frac{1}{S}$	G
ft. in. ft. in.									
3 4 × 5 0	Full	2,770	9,549	2,189	10,742	1,773	11,936	1,465	13,130
	⅔rds do.	3,071	6,284	2,427	7,069	1,966	7,855	1,624	8,641
	⅓rd do.	1,845	2,362	1,458	2,657	1,181	2,952	976	3,248
3 6 × 5 3	Full	2,937	10,528	2,320	11,844	1,880	13,160	1,553	14,476
	⅔rds do.	3,257	6,928	2,573	7,794	2,084	8,660	1,722	9,526
	⅓rd do.	1,956	2,604	1,546	2,930	1,252	3,255	1,035	3,581
3 8 × 5 6	Full	3,106	11,554	2,454	12,998	1,988	14,443	1,643	15,887
	⅔rds do.	3,444	7,604	2,721	8,554	2,204	9,505	1,821	10,455
	⅓rd do.	2,068	2,858	1,634	3,216	1,324	3,572	1,094	3,930
3 10 × 5 9	Full	3,276	12,628	2,588	14,207	2,096	15,786	1,733	17,364
	⅔rds do.	3,632	8,311	2,870	9,349	2,325	10,388	1,921	11,427
	⅓rd do.	2,182	3,124	1,724	3,514	1,396	3,905	1,154	4,295
4 0 × 6 0	Full	3,448	13,750	2,724	15,469	2,206	17,188	1,823	18,907
	⅔rds do.	3,823	9,049	3,020	10,180	2,446	11,311	2,022	12,442
	⅓rd do.	2,296	3,401	1,814	3,826	1,470	4,252	1,214	4,677
4 2 × 6 3	Full	3,621	14,920	2,861	16,785	2,317	18,650	1,915	20,515
	⅔rds do.	4,014	9,819	3,172	11,046	2,569	12,273	2,123	13,501
	⅓rd do.	2,411	3,691	1,905	4,152	1,543	4,613	1,275	5,075
4 4 × 6 6	Full	3,795	16,138	2,999	18,155	2,429	20,172	2,007	22,189
	⅔rds do.	4,208	10,620	3,325	11,948	2,693	13,275	2,226	14,602
	⅓rd do.	2,528	3,992	1,997	4,491	1,618	4,989	1,337	5,489
4 6 × 6 9	Full	3,971	17,403	3,138	19,579	2,541	21,754	2,100	23,929
	⅔rds do.	4,403	11,453	3,479	12,885	2,818	14,316	2,329	15,747
	⅓rd do.	2,645	4,305	2,090	4,843	1,693	5,380	1,399	5,919
4 8 × 7 0	Full	4,148	18,716	3,277	21,055	2,655	23,395	2,194	25,734
	⅔rds do.	4,599	12,317	3,634	13,856	2,944	15,396	2,433	16,935
	⅓rd do.	2,763	4,629	2,183	5,208	1,768	5,787	1,461	6,365
4 10 × 7 3	Full	4,326	20,077	3,418	22,586	2,769	25,096	2,288	27,705
	⅔rds do.	4,797	13,212	3,790	14,864	3,070	16,515	2,537	18,167
	⅓rd do.	2,881	4,966	2,277	5,587	1,844	6,208	1,524	6,828

continued.

Feet per Second						When the Gradient is $\frac{1}{10000}$	
3·0		3·25		3·5			
Gradient, 1 in	Dis-charge Gals. per Min.	Gradient, 1 in	Dis-charge Gals. per Min.	Gradient, 1 in	Dis-charge Gals. per Min.	Velocity = V_s	Discharge = G_s
11	12	13	14	15	16	17	18
$\frac{1}{S}$	G	$\frac{1}{S}$	G	$\frac{1}{S}$	G		
1,231	14,323	1,049	15,517	904	16,711	1·05261	5,029
1,365	9,426	1,163	10,212	1,003	10,997	1·10841	3,485
820	3,543	699	3,838	602	4,133	0·85961	1,016
1,305	15,792	1,112	17,107	959	18,423	1·08391	5,710
1,447	10,392	1,233	11,258	1,063	12,124	1·14134	3,957
869	3,906	741	4,232	639	4,557	0·88514	1,153
1,380	17,331	1,176	18,776	1,014	20,220	1·11458	6,444
1,530	11,405	1,304	12,356	1,124	13,306	1·17364	4,465
919	4,287	783	4,644	675	5,001	0·9102	1,302
1,456	18,943	1,240	20,522	1,070	22,100	1·1447	7,233
1,614	12,466	1,375	13,505	1,186	14,544	1·20537	5,012
970	4,686	826	5,076	712	5,466	0·93479	1,461
1,532	20,626	1,306	22,344	1,126	24,063	1·17432	8,079
1,699	13,573	1,448	14,705	1,248	15,836	1·23654	5,599
1,020	5,102	870	5,527	750	5,952	0·95898	1,632
1,609	22,380	1,371	24,245	1,182	26,110	1·20344	8,984
1,784	14,728	1,520	15,955	1,311	17,183	1·2672	6,226
1,072	5,536	913	5,997	787	6,458	0·98275	1,815
1,687	24,206	1,437	26,224	1,239	28,241	1·2321	9,949
1,870	15,930	1,594	17,257	1,374	18,585	1·29738	6,894
1,123	5,988	957	6,487	825	6,985	1·00616	2,010
1,765	26,104	1,504	28,280	1,297	30,455	1·26032	10,974
1,957	17,179	1,667	18,610	1,438	20,042	1·32709	7,605
1,175	6,457	1,002	6,995	864	7,533	1·0292	2,217
1,844	28,074	1,571	30,413	1,354	32,753	1·28812	12,063
2,044	18,475	1,742	20,015	1,502	21,554	1·35637	8,359
1,228	6,944	1,046	7,523	902	8,102	1·0519	2,437
1,923	30,115	1,638	32,624	1,413	35,134	1·31553	13,215
2,132	19,818	1,817	21,470	1,566	23,121	1·38523	9,157
1,281	7,449	1,091	8,070	941	8,691	1·07429	2,669

TABLE IV.—

Size of Sewer	Depth of Flow	Velocities in 2·0		2·25		2·50		2·75	
		Gra-dient, 1 in	Dis-charge Gals. per Min.	Gra-dient, 1 in	Dis-charge Gals. per Min.	Gra-dient, 1 in	Dis-charge Gals. per Min.	Gra-dient, 1 in	Dis-charge Gals. per Min.
1	2	3	4	5	6	7	8	9	10
D D$_1$		$\frac{1}{S}$	G	$\frac{1}{S}$	G	$\frac{1}{S}$	G	$\frac{1}{S}$	G
ft. in. ft. in.									
5 0 × 7 6	Full	4,506	21,485	3,560	24,171	2,884	26,856	2,383	29,542
	⅔rds do.	4,966	14,139	3,948	15,906	3,198	17,674	2,643	19,441
	⅓rd do.	3,001	5,314	2,371	5,979	1,921	6,643	1,587	7,307
5 2 × 7 9	Full	4,687	22,941	3,703	25,809	3,000	28,677	2,479	31,544
	⅔rds do.	5,197	15,097	4,106	16,984	3,326	18,872	2,749	20,759
	⅓rd do.	3,122	5,675	2,466	6,384	1,998	7,093	1,651	7,803
5 4 × 8 0	Full	4,869	24,445	3,847	27,501	3,116	30,556	2,575	33,612
	⅔rds do.	5,399	16,087	4,266	18,098	3,455	20,109	2,855	22,120
	⅓rd do.	3,243	6,047	2,562	6,802	2,075	7,558	1,715	8,314
5 6 × 8 3	Full	5,052	25,997	3,992	29,246	3,233	32,496	2,672	35,746
	⅔rds do.	5,602	17,108	4,426	19,247	3,585	21,385	2,963	23,524
	⅓rd do.	3,365	6,430	2,659	7,234	2,153	8,038	1,780	8,842
5 8 × 8 6	Full	5,236	27,596	4,137	31,046	3,351	34,495	2,770	37,945
	⅔rds do.	5,806	18,161	4,587	20,431	3,716	22,701	3,071	24,971
	⅓rd do.	3,488	6,826	2,756	7,679	2,232	8,533	1,845	9,386
5 10 × 8 9	Full	5,422	29,244	4,284	32,899	3,470	36,554	2,868	40,210
	⅔rds do.	6,011	19,245	4,750	21,650	3,847	24,056	3,180	26,462
	⅓rd do.	3,611	7,233	2,853	8,138	2,311	9,042	1,910	9,946
6 0 × 9 0	Full	5,608	30,938	4,431	34,806	3,589	38,673	2,966	42,540
	⅔rds do.	6,218	20,360	4,913	22,905	3,980	25,450	3,289	27,995
	⅓rd do.	3,735	7,653	2,951	8,609	2,390	9,566	1,976	10,523

continued.

Feet per Second						When the Gradient is $\frac{1}{10000}$	
3·0		3·25		3·5			
Gradient, 1 in	Discharge Gals. per Min.	Gradient, 1 in	Discharge Gals. per Min.	Gradient, 1 in	Discharge Gals. per Min.	Velocity = V_s	Discharge = G_s
11	12	13	14	15	16	17	18
$\frac{1}{S}$	G	$\frac{1}{S}$	G	$\frac{1}{S}$	G		
2,003	32,228	1,706	34,913	1,471	37,599	1·34256	14,433
2,221	21,209	1,892	22,976	1,631	24,743	1·41369	10,001
1,334	7,972	1,137	8,636	980	9,300	1·09636	2,915
2,083	34,412	1,775	37,280	1,530	40,147	1·36924	15,717
2,310	26,646	1,968	24,533	1,697	26,420	1·44178	10,891
1,387	8,512	1,182	9,221	1,019	9,931	1·11815	3,175
2,164	36,668	1,844	39,723	1,590	42,779	1·39557	17,070
2,399	24,131	2,044	26,141	1,763	28,152	1·46951	11,829
1,441	9,070	1,228	9,826	1,059	10,582	1·13965	3,448
2,245	38,995	1,913	42,245	1,650	45,495	1·42157	18,492
2,490	25,662	2,121	27,801	1,829	29,939	1·49689	12,814
1,495	9,646	1,274	10,449	1,099	11,253	1·16089	3,735
2,327	41,394	1,983	44,844	1,710	48,294	1·44727	19,984
2,580	27,241	2,199	29,511	1,896	31,781	1·52395	13,848
1,550	10,239	1,321	11,092	1,139	11,946	1·18187	4,037
2,410	43,865	2,053	47,521	1,770	51,176	1·47266	21,549
2,672	28,867	2,277	31,273	1,963	33,678	1·55069	14,932
1,605	10,850	1,367	11,754	1,179	12,659	1·2026	4,353
2,493	46,408	2,124	50,275	1,831	54,142	1·49776	23,186
2,764	30,540	2,355	33,085	2,030	35,630	1·57712	16,030
1,660	11,479	1,414	12,436	1,220	13,392	1·2231	4,683

TABLE V.

Actual Values of $100\sqrt{S}$ for Various Gradients.

Gradient, 1 in $\frac{1}{S}$	$100\sqrt{S}$	Gradient, 1 in $\frac{1}{S}$	$100\sqrt{S}$	Gradient, 1 in $\frac{1}{S}$	$100\sqrt{S}$	Gradient, 1 in $\frac{1}{S}$	$100\sqrt{S}$	Gradient, 1 in $\frac{1}{S}$	$100\sqrt{S}$	Gradient, 1 in $\frac{1}{S}$	$100\sqrt{S}$
1	100·000	47	14·587	93	10·370	139	8·482	185	7·352	231	6·580
2	70·711	48	14·434	94	10·314	140	8·452	186	7·332	232	6·565
3	57·735	49	14·286	95	10·260	141	8·422	187	7·313	233	6·551
4	50·000	50	14·142	96	10·206	142	8·392	188	7·293	234	6·537
5	44·721	51	14·003	97	10·153	143	8·362	189	7·274	235	6·523
6	40·825	52	13·868	98	10·102	144	8·333	190	7·255	236	6·509
7	37·796	53	13·736	99	10·050	145	8·305	191	7·236	237	6·496
8	35·355	54	13·608	100	10·000	146	8·276	192	7·217	238	6·482
9	33·333	55	13·484	101	9·950	147	8·248	193	7·198	239	6·469
10	31·623	56	13·363	102	9·902	148	8·220	194	7·180	240	6·455
11	30·151	57	13·245	103	9·853	149	8·192	195	7·161	241	6·442
12	28·868	58	13·131	104	9·806	150	8·165	196	7·143	242	6·428
13	27·735	59	13·019	105	9·759	151	8·138	197	7·125	243	6·415
14	26·726	60	12·910	106	9·713	152	8·111	198	7·107	244	6·402
15	25·820	61	12·804	107	9·667	153	8·085	199	7·089	245	6·389
16	25·000	62	12·700	108	9·623	154	8·058	200	7·071	246	6·376
17	24·254	63	12·599	109	9·578	155	8·032	201	7·054	247	6·363
18	23·570	64	12·500	110	9·535	156	8·006	202	7·036	248	6·350
19	22·942	65	12·403	111	9·492	157	7·981	203	7·019	249	6·337
20	22·361	66	12·309	112	9·449	158	7·956	204	7·001	250	6·325
21	21·822	67	12·217	113	9·407	159	7·931	205	6·984	251	6·312
22	21·320	68	12·127	114	9·366	160	7·906	206	6·967	252	6·299
23	20·851	69	12·039	115	9·325	161	7·881	207	6·951	253	6·287
24	20·412	70	11·952	116	9·285	162	7·857	208	6·934	254	6·275
25	20·000	71	11·868	117	9·245	163	7·833	209	6·917	255	6·262
26	19·612	72	11·785	118	9·206	164	7·809	210	6·901	256	6·250
27	19·245	73	11·704	119	9·167	165	7·785	211	6·884	257	6·238
28	18·898	74	11·625	120	9·129	166	7·762	212	6·868	258	6·226
29	18·570	75	11·547	121	9·091	167	7·738	213	6·852	259	6·214
30	18·257	76	11·471	122	9·054	168	7·715	214	6·836	260	6·202
31	17·961	77	11·396	123	9·017	169	7·692	215	6·820	261	6·190
32	17·678	78	11·323	124	8·980	170	7·670	216	6·804	262	6·178
33	17·408	79	11·251	125	8·944	171	7·647	217	6·789	263	6·166
34	17·150	80	11·180	126	8·909	172	7·625	218	6·773	264	6·155
35	16·903	81	11·111	127	8·874	173	7·603	219	6·757	265	6·143
36	16·667	82	11·043	128	8·839	174	7·581	220	6·742	266	6·131
37	16·440	83	10·976	129	8·805	175	7·559	221	6·727	267	6·120
38	16·222	84	10·911	130	8·771	176	7·538	222	6·712	268	6·109
39	16·013	85	10·847	131	8·737	177	7·517	223	6·697	269	6·097
40	15·812	86	10·783	132	8·704	178	7·495	224	6·682	270	6·086
41	15·617	87	10·721	133	8·671	179	7·474	225	6·667	271	6·075
42	15·430	88	10·660	134	8·639	180	7·454	226	6·652	272	6·063
43	15·250	89	10·600	135	8·607	181	7·433	227	6·637	273	6·052
44	15·076	90	10·541	136	8·575	182	7·413	228	6·623	274	6·041
45	14·908	91	10·483	137	8·544	183	7·392	229	6·608	275	6·030
46	14·744	92	10·426	138	8·513	184	7·372	230	6·594	276	6·019

TABLE V.—*continued.*

Gradient, 1 in $\frac{1}{S}$	100 √S	Gradient, 1 in $\frac{1}{S}$	100 √S	Gradient, 1 in $\frac{1}{S}$	100 √S	Gradient, 1 in $\frac{1}{S}$	100 √S	Gradient, 1 in $\frac{1}{S}$	100 √S	Gradient, 1 in $\frac{1}{S}$	100 √S
277	6·008	326	5·539	375	5·164	424	4·856	473	4·598	610	4·049
278	5·998	327	5·530	376	5·157	425	4·851	474	4·593	615	4·032
279	5·987	328	5·522	377	5·150	426	4·845	475	4·588	620	4·016
280	5·976	329	5·513	378	5·143	427	4·839	476	4·584	625	4·000
281	5·966	330	5·505	379	5·137	428	4·834	477	4·579	630	3·984
282	5·955	331	5·497	380	5·130	429	4·828	478	4·574	635	3·968
283	5·944	332	5·488	381	5·123	430	4·822	479	4·569	640	3·953
284	5·934	333	5·480	382	5·116	431	4·817	480	4·564	645	3·938
285	5·924	334	5·472	383	5·110	432	4·811	481	4·560	650	3·922
286	5·913	335	5·464	384	5·103	433	4·806	482	4·555	655	3·907
287	5·903	336	5·456	385	5·097	434	4·800	483	4·550	660	3·893
288	5·893	337	5·447	386	5·090	435	4·795	484	4·546	665	3·878
289	5·882	338	5·439	387	5·083	436	4·789	485	4·541	670	3·863
290	5·872	339	5·431	388	5·077	437	4·784	486	4·536	675	3·849
291	5·862	340	5·423	389	5·070	438	4·778	487	4·531	680	3·835
292	5·852	341	5·415	390	5·064	439	4·773	488	4·527	685	3·821
293	5·842	342	5·407	391	5·057	440	4·767	489	4·522	690	3·807
294	5·832	343	5·400	392	5·051	441	4·762	490	4·518	695	3·793
295	5·822	344	5·392	393	5·044	442	4·757	491	4·513	700	3·780
296	5·812	345	5·384	394	5·038	443	4·751	492	4·508	705	3·766
297	5·803	346	5·376	395	5·032	444	4·746	493	4·504	710	3·753
298	5·793	347	5·368	396	5·025	445	4·741	494	4·499	715	3·740
299	5·783	348	5·361	397	5·019	446	4·735	495	4·494	720	3·727
300	5·774	349	5·353	398	5·013	447	4·730	496	4·490	725	3·714
301	5·764	350	5·345	399	5·006	448	4·725	497	4·486	730	3·701
302	5·754	351	5·338	400	5·000	449	4·719	498	4·481	735	3·689
303	5·745	352	5·330	401	4·994	450	4·714	499	4·477	740	3·676
304	5·735	353	5·323	402	4·988	451	4·709	500	4·472	745	3·664
305	5·726	354	5·315	403	4·981	452	4·704	505	4·450	750	3·652
306	5·717	355	5·307	404	4·975	453	4·698	510	4·428	755	3·639
307	5·707	356	5·300	405	4·969	454	4·693	515	4·407	760	3·627
308	5·698	357	5·293	406	4·963	455	4·688	520	4·385	765	3·616
309	5·689	358	5·285	407	4·957	456	4·683	525	4·364	770	3·604
310	5·680	359	5·278	408	4·951	457	4·678	530	4·344	775	3·592
311	5·671	360	5·271	409	4·945	458	4·673	535	4·323	780	3·581
312	5·661	361	5·263	410	4·939	459	4·668	540	4·303	785	3·569
313	5·652	362	5·256	411	4·933	460	4·663	545	4·284	790	3·558
314	5·643	363	5·249	412	4·927	461	4·658	550	4·264	795	3·547
315	5·634	364	5·241	413	4·921	462	4·652	555	4·245	800	3·536
316	5·625	365	5·234	414	4·915	463	4·647	560	4·226	805	3·525
317	5·617	366	5·227	415	4·909	464	4·642	565	4·207	810	3·514
318	5·608	367	5·220	416	4·903	465	4·637	570	4·189	815	3·503
319	5·599	368	5·213	417	4·897	466	4·632	575	4·170	820	3·492
320	5·590	369	5·206	418	4·891	467	4·627	580	4·152	825	3·482
321	5·581	370	5·199	419	4·885	468	4·623	585	4·135	830	3·471
322	5·573	371	5·192	420	4·880	469	4·618	590	4·117	835	3·460
323	5·564	372	5·185	421	4·874	470	4·613	595	4·100	840	3·450
324	5·556	373	5·178	422	4·868	471	4·608	600	4·083	845	3·440
325	5·547	374	5·171	423	4·862	472	4·603	605	4·066	850	3·430

TABLE V.—*continued.*

Gradient, 1 in $\frac{1}{S}$	100 $\sqrt{S}$	Gradient, 1 in $\frac{1}{S}$	100 $\sqrt{S}$	Gradient, 1 in $\frac{1}{S}$	100 $\sqrt{S}$	Gradient, 1 in $\frac{1}{S}$	100 $\sqrt{S}$	Gradient, 1 in $\frac{1}{S}$	100 $\sqrt{S}$	Gradient, 1 in $\frac{1}{S}$	100 $\sqrt{S}$
855	3·420	1200	2·887	1690	2·433	2180	2·142	2670	1·935	3320	1·736
860	3·410	1210	2·875	1700	2·425	2190	2·137	2680	1·932	3340	1·730
865	3·400	1220	2·863	1710	2·418	2200	2·132	2690	1·928	3360	1·725
870	3·390	1230	2·851	1720	2·411	2210	2·127	2700	1·925	3380	1·720
875	3·381	1240	2·840	1730	2·404	2220	2·122	2710	1·921	3400	1·715
880	3·371	1250	2·828	1740	2·397	2230	2·118	2720	1·917	3420	1·710
885	3·362	1260	2·817	1750	2·391	2240	2·113	2730	1·914	3440	1·705
890	3·352	1270	2·806	1760	2·384	2250	2·108	2740	1·910	3460	1·700
895	3·343	1280	2·795	1770	2·377	2260	2·104	2750	1·907	3480	1·695
900	3·333	1290	2·784	1780	2·370	2270	2·099	2760	1·904	3500	1·690
905	3·324	1300	2·774	1790	2·364	2280	2·094	2770	1·900	3520	1·686
910	3·315	1310	2·763	1800	2·357	2290	2·090	2780	1·897	3540	1·681
915	3·306	1320	2·752	1810	2·351	2300	2·085	2790	1·893	3560	1·676
920	3·297	1330	2·742	1820	2·344	2310	2·081	2800	1·890	3580	1·671
925	3·288	1340	2·732	1830	2·338	2320	2·076	2810	1·887	3600	1·667
930	3·279	1350	2·722	1840	2·331	2330	2·072	2820	1·883	3620	1·662
935	3·270	1360	2·712	1850	2 325	2340	2·067	2830	1·880	3640	1·658
940	3·262	1370	2·702	1860	2·319	2350	2·063	2840	1·877	3660	1·653
945	3·253	1380	2 692	1870	2·313	2360	2·059	2850	1·873	3680	1·649
950	3·244	1390	2·682	1880	2·306	2370	2·054	2860	1·870	3700	1·644
955	3·236	1400	2·673	1890	2·300	2380	2·050	2870	1·867	3720	1·640
960	3·228	1410	2·663	1900	2 294	2390	2·046	2880	1·863	3740	1·635
965	3·219	1420	2·654	1910	2·288	2400	2·041	2890	1·860	3760	1·631
970	3·211	1430	2·644	1920	2·282	2410	2·037	2900	1·857	3780	1·627
975	3·203	1440	2·635	1930	2·276	2420	2·033	2910	1·854	3800	1·622
980	3·194	1450	2·626	1940	2·270	2430	2·029	2920	1·851	3820	1·618
985	3·186	1460	2·617	1950	2·265	2440	2·024	2930	1·847	3840	1·614
990	3·178	1470	2·608	1960	2·259	2450	2·020	2940	1·844	3860	1·610
995	3·170	1480	2·599	1970	2·253	2460	2·016	2950	1·841	3880	1·605
1000	3·162	1490	2·591	1980	2·247	2470	2·012	2960	1·838	3900	1·601
1010	3·147	1500	2·582	1990	2·242	2480	2·008	2970	1·835	3920	1·597
1020	3·131	1510	2·573	2000	2·236	2490	2·004	2980	1·832	3940	1·593
1030	3·116	1520	2·565	2010	2·231	2500	2·000	2990	1·829	3960	1·589
1040	3·101	1530	2·557	2020	2·225	2510	1·996	3000	1·826	4980	1·585
1050	3·086	1540	2·548	2030	2·220	2520	1·992	3020	1·820	4000	1·581
1060	3·072	1550	2·540	2040	2·214	2530	1·988	3040	1·814	4020	1·577
1070	3·057	1560	2·532	2050	2·209	2540	1·984	3060	1·808	4040	1·573
1080	3·043	1570	2·524	2060	2·203	2550	1·980	3080	1·802	4060	1·569
1090	3·029	1580	2·516	2070	2·198	2560	1·976	3100	1·796	4080	1·566
1100	3·015	1590	2·508	2080	2·193	2570	1·973	3120	1·790	4100	1·562
1110	3·002	1600	2·500	2090	2·187	2580	1·969	3140	1·785	4120	1·558
1120	2·988	1610	2·492	2100	2·182	2590	1·965	3160	1·779	4140	1·554
1130	2·975	1620	2·485	2110	2·177	2600	1·961	3180	1·773	4160	1·550
1140	2·962	1630	2·477	2120	2·172	2610	1·957	3200	1·768	4180	1·547
1150	2·949	1640	2·469	2130	2·167	2620	1·954	3220	1·762	4200	1·543
1160	2·936	1650	2·462	2140	2·162	2630	1·950	3240	1·757	4220	1·539
1170	2·924	1660	2·454	2150	2·157	2640	1·946	3260	1·751	4240	1·536
1180	2·911	1670	2·447	2160	2·152	2650	1·943	3280	1·746	4260	1·532
1190	2·899	1680	2·440	2170	2·147	2660	1·939	3300	1·741	4280	1·529

TABLE V.—*continued.*

Gradient, 1 in	$100\sqrt{S}$	Gradient, 1 in	$100\sqrt{S}$	Gradient, 1 in	$100\sqrt{S}$	Gradient, 1 in	$100\sqrt{S}$	Gradient, 1 in	$100\sqrt{S}$	Gradient, 1 in	$100\sqrt{S}$
$\frac{1}{S}$		$\frac{1}{S}$		$\frac{1}{S}$		$\frac{1}{S}$		$\frac{1}{S}$		$\frac{1}{S}$	
4300	1·525	5280	1·376	6260	1·264	7240	1·175	8220	1·103	9200	1·043
4320	1·522	5300	1·374	6280	1·262	7260	1·174	8240	1·102	9220	1·041
4340	1·518	5320	1·371	6300	1·260	7280	1·172	8260	1·100	9240	1·040
4360	1·515	5340	1·368	6320	1·258	7300	1·170	8280	1·099	9260	1·039
4380	1·511	5360	1·366	6340	1·256	7320	1·169	8300	1·098	9280	1·038
4400	1·508	5380	1·363	6360	1·254	7340	1·167	8320	1·096	9300	1·037
4420	1·504	5400	1·361	6380	1·252	7360	1·166	8340	1·095	9320	1·036
4440	1·501	5420	1·358	6400	1·250	7380	1·164	8360	1·094	9340	1·035
4460	1·497	5440	1·356	6420	1·248	7400	1·163	8380	1·092	9360	1·034
4480	1·494	5460	1·353	6440	1·246	7420	1·161	8400	1·091	9380	1·033
4500	1·491	5480	1·351	6460	1·244	7440	1·159	8420	1·090	9400	1·031
4520	1·487	5500	1·348	6480	1·242	7460	1·158	8440	1·089	9420	1·030
4540	1·484	5520	1·346	6500	1·240	7480	1·156	8460	1·087	9440	1·029
4560	1·481	5540	1·344	6520	1·238	7500	1·155	8480	1·086	9460	1·028
4580	1·478	5560	1·341	6540	1·237	7520	1·153	8500	1·085	9480	1·027
4600	1·474	5580	1·339	6560	1·235	7540	1·152	8520	1·083	9500	1·026
4620	1·471	5600	1·336	6580	1·233	7560	1·150	8540	1·082	9520	1·025
4640	1·468	5620	1·334	6600	1·231	7580	1·149	8560	1·081	9540	1·024
4660	1·465	5640	1·332	6620	1·229	7600	1·147	8580	1·080	9560	1·023
4680	1·462	5660	1·329	6640	1·227	7620	1·146	8600	1·078	9580	1·022
4700	1·459	5680	1·327	6660	1·225	7640	1·144	8620	1·077	9600	1·021
4720	1·456	5700	1·325	6680	1·224	7660	1·143	8640	1·076	9620	1·020
4740	1·453	5720	1·322	6700	1·222	7680	1·141	8660	1·075	9640	1·019
4760	1·449	5740	1·320	6720	1·220	7700	1·140	8680	1·073	9660	1·017
4780	1·446	5760	1·318	6740	1·218	7720	1·138	8700	1·072	9680	1·016
4800	1·443	5780	1·315	6760	1·216	7740	1·137	8720	1·071	9700	1·015
4820	1·440	5800	1·313	6780	1·215	7760	1·135	8740	1·070	9720	1·014
4840	1·437	5820	1·311	6800	1·213	7780	1·134	8760	1·068	9740	1·013
4860	1·434	5840	1·309	6820	1·211	7800	1·132	8780	1·067	9760	1·012
4880	1·432	5860	1·306	6840	1·209	7820	1·131	8800	1·066	9780	1·011
4900	1·429	5880	1·304	6860	1·207	7840	1·129	8820	1·065	9800	1·010
4920	1·426	5900	1·302	6880	1·206	7860	1·128	8840	1·064	9820	1·009
4940	1·423	5920	1·300	6900	1·204	7880	1·127	8860	1·062	9840	1·008
4960	1·420	5940	1·298	6920	1·202	7900	1·125	8880	1·061	9860	1·007
4980	1·417	5960	1·295	6940	1·200	7920	1·124	8900	1·060	9880	1·006
5000	1·414	5980	1·293	6960	1·199	7940	1·122	8920	1·059	9900	1·005
5020	1·411	6000	1·291	6980	1·197	7960	1·121	8940	1·058	9920	1·004
5040	1·409	6020	1·289	7000	1·195	7980	1·119	8960	1·056	9940	1·003
5060	1·406	6040	1·287	7020	1·194	8000	1·118	8980	1·055	9960	1·002
5080	1·403	6060	1·285	7040	1·192	8020	1·117	9000	1·054	9980	1·001
5100	1·400	6080	1·283	7060	1·190	8040	1·115	9020	1·053	10000	1·000
5120	1·398	6100	1·280	7080	1·189	8060	1·114	9040	1·052		
5140	1·395	6120	1·278	7100	1·187	8080	1·113	9060	1·051		
5160	1·392	6140	1·276	7120	1·185	8100	1·111	9080	1·049		
5180	1·389	6160	1·274	7140	1·184	8120	1·110	9100	1·048		
5200	1·387	6180	1·272	7160	1·182	8140	1·108	9120	1·047		
5220	1·384	6200	1·270	7180	1·180	8160	1·107	9140	1·046		
5240	1·381	6220	1·268	7200	1·179	8180	1·106	9160	1·045		
5260	1·379	6240	1·266	7220	1·177	8200	1·104	9180	1·044		

TABLE VI.—CIRCULAR SEWERS.

Proportional Depth of Sewage	Multipliers for Area	Multipliers for Hydraulic Mean Depth	Multipliers for Velocity (New Formula)	Multipliers for Discharge (New Formula)	Multipliers for Gradient (New Formula)
1	**2**	**3**	**4**	**5**	**6**
$= u$	$= a_m$	$= r_m$	$= v_m$	$= g_s$	$= \frac{1}{S_m}$
1·00	1·00000	1·0000	1·0000	1·0800	1·0000
·99	·99831	1·0663	1·0393	1·0376	1·0801
·98	·99523	1·0941	1·0554	1·0504	1·1139
·97	·99126	1·1148	1·0674	1·0581	1·1393
·96	·98658	1·1316	1·0770	1·0626	1·1600
·95	·98131	1·1458	1·0851	1·0648	1·1774
·94	·97550	1·1579	1·0920	1·0652	1·1924
·93	·96923	1·1684	1·0979	1·0641	1·2053
·92	·96252	1·1775	1·1030	1·0617	1·2166
·91	·95542	1·1853	1·1074	1·0580	1·2264
·90	·94796	1·1921	1·1112	1·0534	1·2348
·89	·94015	1·1980	1·1145	1·0478	1·2420
·88	·93203	1·2029	1·1172	1·0413	1·2482
·87	·92361	1·2071	1·1195	1·0340	1·2534
·86	·91491	1·2104	1·1214	1·0260	1·2575
·85	·90594	1·2131	1·1229	1·0173	1·2609
·84	·89673	1·2150	1·1240	1·0079	1·2633
·83	·88727	1·2164	1·1247	·9979	1·2650
·82	·87760	1·2171	1·1251	·9874	1·2659
·81	·86771	1·2172	1·1252	·9763	1·2660
·80	·85762	1·2168	1·1249	·9648	1·2655
·79	·84734	1·2158	1·1244	·9527	1·2642
·78	·83688	1·2143	1·1235	·9403	1·2624
·77	·82625	1·2123	1·1224	·9274	1·2598
·76	·81545	1·2097	1·1210	·9141	1·2567
·75	·80450	1·2067	1·1194	9005	1·2530
·74	·79340	1·2033	1·1174	·8866	1·2487
·73	·78216	1·1994	1·1152	·8723	1·2438
·72	·77079	1·1950	1·1128	·8577	1·2383
·71	·75930	1·1902	1·1101	·8429	1·2323
·70	·74769	1·1849	1·1072	·8278	1·2258
·69	·73596	1·1793	1·1040	·8125	1·2188
·68	·72413	1·1732	1·1006	·7970	1·2113

TABLE VI.—CIRCULAR SEWERS—*continued.*

Proportional Depth of Sewage	Multipliers for Area	Multipliers for Hydraulic Mean Depth	Multipliers for Velocity (New Formula)	Multipliers for Discharge (New Formula)	Multipliers for Gradient (New Formula)
1	2	3	4	5	6
$= u$	$= a_m$	$= r_m$	$= v_m$	$= g_m$	$= \frac{1}{S_m}$
·67	·71221	1·1667	1·0969	·7813	1·2033
·66	·70019	1·1599	1·0931	·7653	1·1948
·65	·68808	1·1526	1·0889	·7493	1·1858
·64	·67590	1·1449	1·0846	·7331	1·1764
·63	·66364	1·1369	1·0800	·7168	1·1665
·62	·65131	1·1285	1·0752	·7003	1·1561
·61	·63892	1·1197	1·0702	·6838	1·1453
·60	·62647	1·1106	1·0650	·6672	1·1341
·59	·61397	1·1011	1·0595	·6505	1·1225
·58	·60142	1·0912	1·0538	·6338	1·1104
·57	·58884	1·0810	1·0478	·6170	1·0980
·56	·57621	1·0704	1·0417	·6002	1·0851
·55	·56356	1·0595	1·0353	·5835	1·0719
·54	·55088	1·0483	1·0287	·5667	1·0582
·53	·53817	1·0367	1·0219	·5500	1·0442
·52	·52546	1·0248	1·0148	·5332	1·0298
·51	·51273	1·0126	1·0075	·5166	1·0151
·50	·50000	1·0000	1·0000	·5000	1·0000
·49	·48727	·9871	·9922	·4835	·9845
·48	·47454	·9738	·9843	·4671	·9688
·47	·46183	·9604	·9760	·4508	·9526
·46	·44913	·9465	·9676	·4346	·9362
·45	·43645	·9323	·9588	·4185	·9194
·44	·42379	·9179	·9499	·4026	·9023
·43	·41117	·9031	·9407	·3868	·8849
·42	·39858	·8880	·9312	·3712	·8671
·41	·38603	·8726	·9215	·3557	·8491
·40	·37353	·8569	·9115	·3405	·8308
·39	·36108	·8409	·9013	·3254	·8123
·38	·34869	·8246	·8907	·3106	·7934
·37	·33636	·8080	·8799	·2960	·7743
·36	·32410	·7911	·8689	·2816	·7549
·35	·31192	·7740	·8575	·2675	·7353

TABLE VI.—CIRCULAR SEWERS—*continued.*

Proportional Depth of Sewage	Multipliers for Area	Multipliers for Hydraulic Mean Depth	Multipliers for Velocity (New Formula)	Multipliers for Discharge (New Formula)	Multipliers for Gradient (New Formula)
1	2	3	4	5	6
$= n$	$= a_m$	$= r_m$	$= v_m$	$= g_m$	$= \frac{1}{S_m}$
·34	·29981	·7565	·8458	·2536	·7154
·33	·28780	·7388	·8339	·2400	·6953
·32	·27587	·7207	·8216	·2267	·6750
·31	·26404	·7024	·8090	·2136	·6545
·30	·25232	·6838	·7961	·2009	·6337
·29	·24070	·6649	·7828	·1884	·6128
·28	·22921	·6457	·7692	·1763	·5916
·27	·21784	·6263	·7552	·1645	·5703
·26	·20660	·6065	·7408	·1531	·5488
·25	·19550	·5865	·7260	·1420	·5271
·24	·18455	·5662	·7109	·1312	·5053
·23	·17375	·5457	·6953	·1208	·4834
·22	·16312	·5248	·6792	·1108	·4613
·21	·15266	·5037	·6627	·1012	·4392
·20	·14238	·4824	·6457	·0919	·4169
·19	·13229	·4607	·6282	·0831	·3946
·18	·12240	·4388	·6101	·0747	·3722
·17	·11273	·4167	·5914	·0667	·3497
·16	·10328	·3942	·5721	·0591	·3272
·15	·09406	·3715	·5521	·0519	·3048
·14	·08509	·3485	·5313	·0452	·2823
·13	·07639	·3253	·5098	·0389	·2599
·12	·06797	·3018	·4874	·0331	·2375
·11	·05985	·2781	·4640	·0278	·2153
·10	·05204	·2541	·4395	·0229	·1932
·09	·04458	·2298	·4138	·0185	·1713
·08	·03748	·2053	·3867	·0145	·1496
·07	·03077	·1805	·3580	·0110	·1282
·06	·02450	·1555	·3274	·0080	·1072
·05	·01869	·1302	·2943	·0055	·0866
·04	·01342	·1047	·2582	·0035	·0666
·03	·00874	·0789	·2179	·0019	·0475
·02	·00477	·0528	·1713	·0008	·0293
·01	·00169	·0265	·1133	·0002	·0128

TABLE VII.—Proportional Parts of Oval Sewers (Old Form.)

Proportional Depth of Sewage	Multipliers for Area *	Multipliers for Hydraulic Mean Depth	Multipliers for Velocity (New Formula) Constant Gradient	Multipliers for Discharge (New Formula) Constant Gradient	Multipliers for Gradient (New Formula)
1	2	3	4	5	6
$= n$	$= a_m$	$= r_m$	$= v_m$	$= g_m$	$= \frac{1}{S_m}$
1·00	1·0000	1·0000	1·0000	1·0000	1·0000
·98	·9942	1·0893	1·0527	1·0466	1·1081
·96	·9836	1·1224	1·0717	1·0541	1·1486
·94	·9699	1·1454	1·0849	1·0522	1·1769
·92	·9539	1·1604	1·0934	1·0429	1·1954
·90	·9361	1·1702	1·0989	1·0286	1·2076
·88	·9167	1·1761	1·1022	1·0104	1·2149
·86	·8960	1·1786	1·1036	·9888	1·2180
·84	·8742	1·1781	1·1033	·9645	1·2174
·82	·8514	1·1751	1·1017	·9379	1·2136
·80	·8278	1·1697	1·0986	·9094	1·2070
·78	·8035	1·1624	1·0945	·8794	1·1979
·76	·7786	1·1532	1·0893	·8482	1·1865
·74	·7533	1·1421	1·0830	·8158	1·1729
·72	·7277	1·1295	1·0758	·7828	1·1573
·70	·7017	1·1158	1·0680	·7494	1·1405
·68	·6757	1·1009	1·0594	·7158	1·1223
⅔rds	·65809	1·03985	1·053	·6929	1·1088
·66	·6495	1·0851	1·0502	·6821	1·1030
·64	·6233	1·0686	1·0406	·6486	1·0829
·62	·5972	1·0514	1·0305	·6154	1·0620
·60	·5712	1·0335	1·0200	·5826	1·0403
·58	·5453	1·0145	1·0087	·5500	1·0174
·56	·5195	·9948	·9969	·5179	·9938
·54	·4939	·9742	·9844	·4862	·9691
·52	·4685	·9526	·9713	·4551	·9434
·50	·4433	·9304	·9576	·4246	·9170
·48	·4184	·9070	·9431	·3946	·8895
·46	·3938	·8830	·9281	·3655	·8613
·44	·3695	·8582	·9123	·3371	·8324
·42	·3456	·8326	·8959	·3096	·8026
·40	·3221	·8061	·8787	·2830	·7721
·38	·2991	·7790	·8608	·2574	·7410
·36	·2765	·7513	·8423	·2329	·7095

* This column gives proportional discharge when velocity is constant.

TABLE VII.—*continued.*

Proportional Depth of Sewage	Multipliers for Area *	Multipliers for Hydraulic Mean Depth	Multipliers for Velocity (New Formula) Constant Gradient	Multipliers for Discharge (New Formula) Constant Gradient	Multipliers for Gradient (New Formula)
1	2	3	4	5	6
$=u$	$=a_m$	$=r_m$	$=v_m$	$=g_m$	$=\frac{1}{S_m}$
·34	·2544	·7229	·8231	·2094	·6775
⅓rd	·24735	·71346	·8166	·202	·6669
·33	·2436	·7082	·8130	·1980	·6610
·32	·2329	·6935	·8028	·1870	·6445
·31	·2223	·6786	·7924	·1762	·6280
·30	·2119	·6634	·7817	·1656	·6111
·29	·2016	·6479	·7707	·1554	·5940
·28	·1915	·6324	·7596	·1455	·5770
·27	·1816	·6165	·7481	·1359	·5597
·26	·1718	·6002	·7362	·1265	·5419
·25	·1623	·5839	·7241	·1175	·5243
·24	·1529	·5672	·7116	·1088	·5064
·23	·1436	·5503	·6988	·1004	·4883
·22	·1346	·5330	·6856	·0923	·4700
·21	·1258	·5154	·6719	·0845	·4514
·20	·1171	·4977	·6579	·0771	·4329
·19	·1087	·4794	·6433	·0699	·4138
·18	·1005	·4606	·6281	·0631	·3944
·17	·0925	·4415	·6123	·0566	·3749
·16	·0847	·4220	·5959	·0505	·3551
·15	·0772	·4019	·5787	·0447	·3349
·14	·0669	·3815	·5609	·0392	·3146
·13	·0629	·3603	·5420	·0341	·2938
·12	·0561	·3385	·5221	·0293	·2726
·11	·0495	·3160	·5010	·0248	·2510
·10	·0432	·2928	·4786	·0207	·2290
·09	·0372	·2687	·4545	·0169	·2066
·08	·0315	·2434	·4283	·0135	·1835
·07	·0261	·2173	·4002	·0104	·1601
·06	·0209	·1897	·3688	·0077	·1360
·05	·0160	·1606	·3338	·0054	·1114
·04	·0116	·1301	·2942	·0034	·0865
·03	·0076	·0986	·2491	·0019	·0620
·02	·0041	·0664	·1965	·0008	·0386
·01	·0015	·0331	·1294	·0002	·0167

* This column gives proportional discharge when velocity is constant.

TABLE VIII.—PROPORTIONAL PARTS OF AN OVAL SEWER, THE HEIGHT OR MAJOR AXIS BEING UNITY.

Height of Segment or Flow	Proportional Area	Proportional Hydraulic Mean Depth	Proportional Velocity when $\frac{1}{S}$ is constant	Proportional Discharge when $\frac{1}{S}$ is constant	Proportional Gradient when v is constant
$= u$	$= a_m$	$= r_m$	$= v_m$	$= g_m$	$= \frac{1}{S_m}$
1	2	3	4	5	6
1·00	1·0000	1·0000	1·0000	1·0000	1·0000
0·99	0·9979	1·0638	1·0378	1·0356	1·077
0·98	0·994	1·0897	1·0529	1·0466	1·1086
0·97	0·9891	1·1086	1·0638	1·0522	1·1317
0·96	0·9833	1·1235	1·0724	1·0544	1·15
0·95	0·9767	1·1356	1·0793	1·0541	1·1649
0·94	0·9695	1·1456	1·085	1·0519	1·1772
0·93	0·9618	1·1538	1·0896	1·048	1·1873
0·92	0·9535	1·1606	1·0935	1·0427	1·1957
0·91	0·9448	1·1661	1·0966	1·0361	1·2025
0·90	0·9357	1·1705	1·0991	1·0284	1·2079
0·89	0·9262	1·1738	1·1009	1·0197	1·2121
0·88	0·9163	1·1763	1·1023	1·01	1·2151
0·87	0·9061	1·1778	1·1032	0·9996	1·217
0·86	0·8956	1·1786	1·1036	0·9884	1·218
0·85	0·8848	1·1787	1·1037	0·9766	1·2181
0·84	0·8738	1·178	1·1033	0·9641	1·2173
0·83	0·8625	1·1767	1·1026	0·951	1·2157
0·82	0·8511	1·1748	1·1015	0·9374	1·2132
0·81	0·8393	1·1724	1·1001	0·9234	1·2103
0·80	0·8275	1·1694	1·0984	0·9089	1·2065
0·79	0·8154	1·1658	1·0964	0·894	1·2022
0·78	0·8032	1·1618	1·0942	0·8788	1·1972
0·77	0·7909	1·1574	1·0916	0·8633	1·1917
0·76	0·7784	1·1525	1·0889	0·8476	1·1856
0·75	0·7658	1·1471	1·0858	0·8315	1·1791
0·74	0·7531	1·1414	1·0826	0·8153	1·172
0·73	0·7403	1·1353	1·0791	0·7989	1·1645
0·72	0·7274	1·1289	1·0755	0·7824	1·1567
0·71	0·7145	1·1222	1·0716	0·7657	1·1484
0·70	0·7015	1·1152	1·0676	0·749	1·1397

TABLE VIII.—*continued.*

Height of Segment or Flow	Proportional Area	Proportional Hydraulic Mean Depth	Proportional Velocity when $\frac{1}{S}$ is constant	Proportional Discharge when $\frac{1}{S}$ is constant	Proportional Gradient when v is constant
$= u$	$= a_m$	$= r_m$	$= g_m$	$= g_m$	$= \frac{1}{S_m}$
1	2	3	4	5	6
0·69	0·6885	1·1079	1·0634	0·7322	1·1308
0·68	0·6755	1·1003	1·059	0·7154	1·1215
0·67	0·6624	1·0925	1·0545	0·6986	1·112
⅔rds	0·6581	1·0899	1·0533	0·6930	1·1088
0·66	0·6494	1·0845	1·0499	0·6818	1·1023
0·65	0·6363	1·0763	1·0451	0·665	1·0922
0·64	0·6233	1·0679	1·0402	0·6483	1·082
0·63	0·6102	1·0592	1·0351	0·6317	1·0715
0·62	0·5972	1·0504	1·03	0·6151	1·0608
0·61	0·5842	1·0415	1·0247	0·5986	1·05
0·60	0·5712	1·0323	1·0193	0·5822	1·0389
0·59	0·5583	1·0229	1·0137	0·5659	1·0275
0·58	0·5453	1·0133	1·008	0·5497	1·016
0·57	0·5324	1·0035	1·0021	0·5336	1·0042
0·56	0·5196	0·9935	0·9961	0·5176	0·9922
0·55	0·5068	0·9833	0·99	0·5017	0·98
0·54	0·494	0·973	0·9837	0·486	0·9677
0·53	0·4813	0·9624	0·9773	0·4703	0·955
0·52	0·4686	0·9516	0·9707	0·4549	0·9422
0·51	0·456	0·9406	0·964	0·4396	0·9292
0·50	0·4435	0·9297	0·9572	0·4245	0·9162
0·49	0·431	0·9181	0·95	0·4094	0·9025
0·48	0·4186	0·9065	0·9428	0·3946	0·8889
0·47	0·4063	0·8947	0·9354	0·38	0·875
0·46	0·394	0·8828	0·9279	0·3656	0·861
0·45	0·3818	0·8706	0·9202	0·3514	0·8468
0·44	0·3697	0·8582	0·9124	0·3373	0·8324
0·43	0·3578	0·8457	0·9043	0·3235	0·8178
0·42	0·3459	0·8329	0·8961	0·3099	0·803
0·41	0·3341	·8199	0·8877	0·2965	0·788
0·40	0·3224	0·8068	0·8791	0·2834	0·7728
0·39	0·3108	0·7933	0·8703	0·2704	0·7574
0·38	0·2993	0·7797	0·8613	0·2578	0·7419
0·37	0·288	0·766	0·8522	0·2454	0·7262
0·36	0·2767	0·7519	0·8428	0·2332	0·7103
0·35	0·2656	0·7377	0·8332	0·2213	0·6942

TABLE VIII.—*continued.*

Height of Segment or Flow	Proportional Area	Proportional Hydraulic Mean Depth	Proportional Velocity when $\frac{1}{S}$ is constant	Proportional Discharge when $\frac{1}{S}$ is constant	Proportional Gradient when v is constant
$= u$	$= a_m$	$= r_m$	$= v_m$	$= g_m$	$= \frac{1}{S_m}$
1	2	3	4	5	6
0·34	0·2546	0·7233	0·8234	0·2096	0·6779
⅓rd	0·2474	0·7135	0·8166	0·202	0·6669
0·33	0·2438	0·7086	0·8133	0·1983	0·6615
0·32	0·2331	0·6937	0·803	0·1872	0·6448
0·31	0·2225	0·6787	0·7925	0·1764	0·628
0·30	0·2121	0·6633	0·7817	0·1658	0·611
0·29	0·2019	0·6478	0·7706	0·1556	0·5939
0·28	0·1918	0·632	0·7593	0·1456	0·5765
0·27	0·1818	0·6159	0·7477	0·136	0·559
0·26	0·1721	0·5997	0·7358	0·1266	0·5414
0·25	0·1625	0·5831	0·7235	0·1176	0·5234
0·24	0·1531	0·5664	0·711	0·1088	0·5055
0·23	0·1439	0·5493	0·6981	0·1004	0·4873
0·22	0·1348	0·5319	0·6847	0·0923	0·4688
0·21	0·126	0·5142	0·671	0·0845	0·4502
0·20	0·1174	0·4963	0·6568	0·0771	0·4314
0·19	0·1089	0·478	0·6422	0·07	0·4124
0·18	0·1007	0·4594	0·627	0·0632	0·3932
0·17	0·0927	0·4403	0·6113	0·0567	0·3737
0·16	0·0849	0·4209	0·595	0·0505	0·354
0·15	0·0774	0·401	0·5779	0·0447	0·334
0·14	0·0701	0·3807	0·5602	0·0393	0·3138
0·13	0·0628	0·3598	0·5415	0·034	0·2933
0·12	0·0562	0·3383	0·5219	0·0293	0·2723
0·11	0·0497	0·3161	0·5011	0·0249	0·2511
0·10	0·0434	0·2931	0·4788	0·0208	0·2293
0·09	0·0373	0·269	0·4549	0·017	0·2069
0·08	0·0316	0·2441	0·4291	0·0136	0·1841
0·07	0·0261	0·2177	0·4006	0·0105	0·1605
0·06	0·0209	0·1894	0·3685	0·0077	0·1358
0·05	0·0161	0·1603	0·3334	0·0054	0·1112
0·04	0·0116	0·1303	0·2944	0·0034	0·0866
0·03	0·0076	0·0992	0·2499	0·0019	0·0625
0·02	0·0042	0·0671	0·1977	0·0008	0·0391
0·01	0·0015	0·034	0·1316	0·0002	0·0173
0·00	0·0	0·0	0·0	0·0	0·0

APPENDIX IX.

In the issue of "The Builder" for the 28th April 1888, there appeared an illustrated Article written by the late Mr. John Phillips, C.E., headed "The Ventilation of Sewers," which elicited interesting and instructive letters of criticism upon it, copies of all of which, including the article itself, are reproduced below in the order in which they appeared in "The Builder" on the dates stated.

311. THE VENTILATION OF SEWERS.

By John Phillips, C.E.

The complete sanitary ventilation of sewers has never yet been properly accomplished. To discharge the sewer-air, charged with noxious gases constantly emanating from the sewage, up into the streets amidst the houses, and so to pollute the air which the people continually breathe, is neither sane nor sanitary. Yet this method of ventilation is that which has hitherto been, and is still pursued. This baneful system is stoutly defended by the statement that sewer-air is so largely diluted with fresh air, which descends into the sewers, as to be not only comparatively pure when it is discharged into the streets, but is so insignificant in volume there, compared with the large body of the atmosphere by which it is again diluted, as to be perfectly harmless when breathed. This lame argument has prevented, and still prevents, the application of proper improvements for ventilating the sewers. The truth, however, is that the sewer-air discharged into the streets is never so uniformly mixed with the atmosphere there, before it is breathed, as is supposed; for when it is breathed by those who reside in the houses, or pass along the streets at or near where it pours through the gratings, and where its full strength and flavour are almost undiluted, it is absolutely injurious to health; and no doubt the inhalation of disease germs from this source has caused very many deaths. It is to remedy this insanitary system that the simple and efficient method of ventilation presently to be described has been devised.

All the sewers in towns are now formed in connection with each other, and have manhole-shafts at their junctions, at intervals between the junctions, and at their upper ends; with open gratings bedded upon the shafts level with the streets. Owing to the sewer-air being always many degrees higher in temperature, and consequently lighter in weight, than that of the atmosphere—which high temperature and lightness are caused by the hot liquids which are discharged down the drains from kitchens, sculleries, washhouses, baths, lavatories, and factories—it freely flows or gravitates upwards: (1) from the lower to the higher ends of separate sewers; (2) from one sewer into another; (3) from the sewers in the lowest parts of a town to those in the highest parts; and (4) to the upper parts of all shafts, drains, and pipes connected with the sewers. From all these connections (when the upper parts are unsealed by flaps or water-traps) the sewer-air, highly charged as it is with noxious gases, escapes into the streets and houses with a celerity proportional to the excess of its temperature above that of the atmosphere.

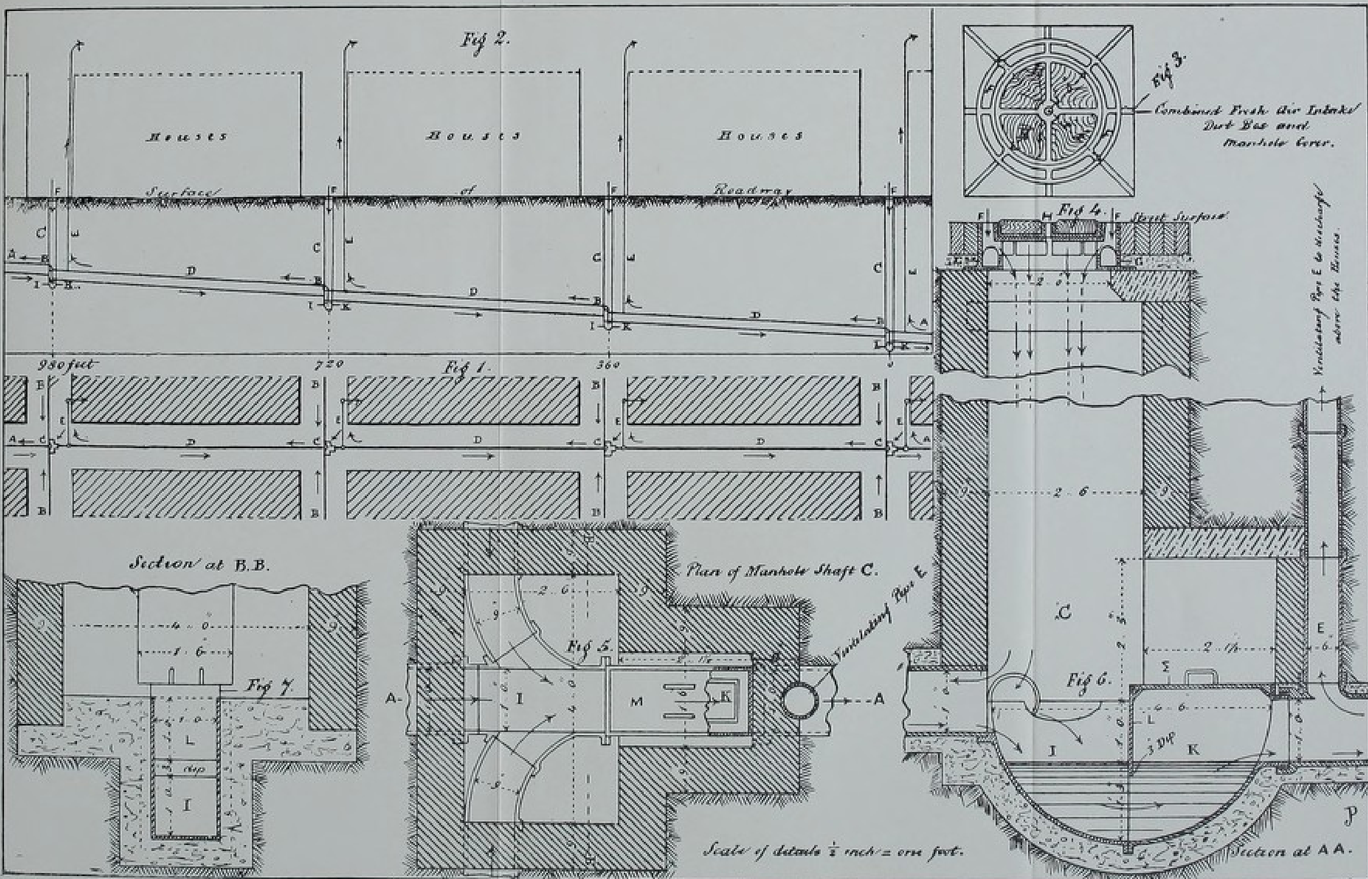
The gases exhaled from the sewage are carbonic acid, ammonia (which is a compound of nitrogen and hydrogen), and sulphuretted hydrogen. The proportional weight of the former gas to common air is as 3 to 2, and of the two latter gases as 3 to 5, and 7 to 100, respectively. The former, therefore, is very inert, while the two latter are very volatile. The warm sewage also exhales aqueous vapour in large quantities. The proportional weight of this vapour to common air is nearly as 5 to 8. Owing, therefore, to the extreme lightness of the ammonia, the hydrogen and the aqueous vapour, these, the moment they are produced, fly upwards to the highest points in the sewers, and also in the drains and pipes connected with them. If, therefore, these points be open or untrapped, the gases and vapours escape therefrom into the atmosphere wherever the openings happen to be, whether in the houses, the streets, or above the houses. It will now be readily perceived that the gases and vapour are for ever striving, of their own accord, to fly upwards above the houses, and they would go there if we would let them do so. Why, therefore, do we not let them go there? Why do we persist in discharging them into the streets, and so poison the air we breathe?

The sewer-air which flows into the bottom of manhole-shafts from lower or outfall sewers has a natural tendency, owing to its lightness and elasticity on the one hand, and to the superior density or pressure of the atmosphere in and over the shafts on the other, to leap across the bottom of the shafts into and up the sewer or sewers entering there, rather than diverge and pass up the shafts into the streets. Engineers have been advised by "authority" to prevent the sewer-air from flowing up the sewers from lower to higher levels, and from one sewer into another, by placing self-acting flaps on the outlets of the sewers in the manhole-shafts. By this " suggestion " the sewer-air would be diverted up the shafts into the streets, provided the flaps closed tight against their seats ; but *then* no sewage could possibly pass out of the sewers. As, however, sewage is produced and passes into the sewers more or less continuously, the flaps, if closed, would be forced open from their seat by its pressure acting behind them, and then the open spaces, under and at the sides of the flaps, would permit the sewer-air to flow across the shafts into and up the sewers, discharging there, just the same as if no flaps were there at all. Hence, these flaps, for such a purpose, are useless, and a failure and waste of money wherever they have been used.

Again, it has often been attempted to ventilate sewers in towns by connecting them with tall chimney-shafts placed above ground, with coal or coke furnaces always burning at the bottom causing powerful draughts up them. It was supposed that the strong draughts thus produced in the shafts would draw the noxious sewer-air from all the sewers, as well as from all the house drains, into the shafts, and so thoroughly ventilate the sewers and the drains. This expedient, if successful, would have been a most excellent and commendable sanitary improvement in connection with the drainage of towns. But it was always found that, owing to the innumerable air-inlets to the sewers and the drains producing cross and opposing air-currents the ventilating effect of any shaft was only local—that is to say, the draught in the shaft had no power to draw to it the air-current in any sewer beyond the one with which it was directly connected.

It has resulted from these and other efforts and suggestions, that if the sewers of towns are to be thoroughly ventilated, each sewer must be treated separately, and where necessary divided into separate sections, for its perfect ventilation. This being so, the question arises : Can each sewer, or separate sections of it, be effectually ventilated by a simple, costless, and self-acting process ? The writer has no hesitation in saying that a power is always present in the sewers of towns which would, if practically utilised, thoroughly ventilate them, and so keep them free from sewage-gas accumulation, by the simple, costless, and self acting process which he will now proceed to describe. (Drawing 45.)

312. Fig. 1 is a plan, and Fig. 2 a longitudinal section of part of a street or road, showing a main sewer (A A) running beneath it ; and branch sewers (B) entering the main sewer (A A) from lateral streets ; manhole shafts (C) at the junctions of the branch sewers (B) with the main sewer (A A), dividing the main sewer (A A) into separate sewer sections (D) ; and ventilating pipes (E) going from the upper ends of the separate sewer sections (D) above the houses. Fig. 3 is a plan,



Diagrams in Illustration of Mr. John Phillips's Article on The Ventilation of Sewers.

[Face p. 390.

and Fig. 4 a section, of a combined fresh-air intake grating F, dirt-box G, and movable manhole-cover H, placed upon the manhole-shaft (C) level with the street. This combined arrangement is made of cast iron: the manhole-cover at the top being filled in with hard-wood. Fig. 5 is a plan, and Figs. 6 and 7 sections, of a cast-iron sewage-receiver (I), and discharger (K), placed at the bottom of the manhole-shaft (C). The receiver (I), and the discharger (K), are divided in the centre by a dip-partition (L), and upon the discharger (K) a movable air-tight cover (M) is placed.

Referring now to the plans and sections, it will be seen (1) that from the outlet of each upward sewer section D, the sewage falls into the receiver I, and proceeds from the discharger K into the head of the next downward sewer section D, without its flow or gravitation being obstructed; (2) that by means of the movable air-tight cover M, the discharger K, and the upper part of each separate sewer section D, are readily accessible for examining or cleansing them; (3) that by means of the dip-partition L, between the receiver I and the discharger K, any sewer, or the sewers generally in a town, may be divided for ventilation into any number of separate sections, as at D; (4) that by means of the air-intake gratings F, upon the manhole-shafts C, copious streams of fresh air continually flow from the streets down through the gratings into the shafts, and thence into and up the separate sewer sections D, until they are stopped by the dip-partitions L; and (5) that by means of the ventilating-pipes E, going from the upper ends of the separate sewer sections D to the housetops, the air currents in the sewers, with the vapour and sewage gas engendered therein, flow up the ventilating pipes E, and discharge over the houses into the atmosphere above the zone in which the people live.

It will be seen that the dip-partition L performs three most important functions: first, it permits the drainage to flow freely away under it; secondly, it prevents the sewer-air from passing up into the streets, and also into adjoining sewers; and, thirdly, it turns the sewer-air upwards into the ventilating pipe E, which discharges it above the houses. It will also be seen that the separate sewer sections D assume the form of inverted air-syphons—the manhole-shafts C being the short legs, and the ventilating pipes E the long legs of such syphons.

It is absolutely necessary, for the health of the houses as well as the streets, that proper syphon-traps should be placed on all house-drains near their discharging ends, and on all gully-drains near their receiving ends (where they are easy to be got at), in order that the foul air in the sewers shall not ventilate from the house-drains into the houses, and from the gully-drains into the streets. From the house-side of the syphon-traps on the house-drains air-shafts now lead up to the surface of the areas or yards for fresh air to flow down them into and up the drains which discharge into them; and from the upper ends of these drains, at the back of the houses, ventilating-pipes now lead up to and discharge over the house-tops. It will be observed that the system now proposed for ventilating the sewers closely approximates to that which is now in vogue for ventilating the house-drains, and as the latter is so eminently successful the former would be so too were the several arrangements and appliances now proposed for effecting it provided in connection with the sewers.

The power for ventilating the sewers, or the separate sections of them, is derived from the hot liquids before mentioned. These, by constantly entering the sewers from the house and other drains, and continually warming and expanding the air therein, thereby make its temperature higher, and its weight lighter and more elastic, than the external air. Atmospheric air and gases, from 32° and upwards of Fahrenheit's thermometer, expand $\frac{1}{490}$ of their volume for each degree that their temperature is raised. Hence it follows that 1000 cubic inches of air at 32° expand $(\frac{1000}{490}) = 2 \cdot 0408$ cubic inches for each additional degree of temperature. When, therefore, any ventilating pipe E, Fig. 2, is carried, say, 50 ft. above any sewer D, discharging into the manhole-shaft C, and the temperature of the air in the sewer D is, say, 10°, above that of the external air, the height to which the column of air in the pipe E expands above the column of exterior air is $= \frac{10}{490} \times 50 = 0 \cdot 020408 \times 50 = 1 \cdot 0204$ feet. It is this difference in height between the two columns of air that produces motion, or spontaneous ventilation, along any sewer D, and up the ventilating-pipe E.

About 100 years ago Joseph Michel Montgolfier, of Videlon-les-Annonais, near Lyons, in France, who invented the air-balloon and the hydraulic ram, proposed the most simple and accurate method of determining the velocity of the warmer and lighter column of air in any sewer D, and the ventilating pipe E, as pressed upwards by the colder and heavier column of air in and over any manhole shaft C. This consists in ascertaining (1) the difference in height of the two columns of air when they are of equal weight, and (2) the velocity of efflux up any sewer D, and up any ventilating pipe E, which is equal to the velocity a body acquires in falling through this difference in height. It is well-known that the space described by a body descending from rest near the earth's surface in the latitude of London is 16·1 feet in one second, and the velocity the body acquires at the end of that time is equal to twice the space it has described in that time, namely, 32·2 feet. From this relation of space to time the velocity per second a body acquires in descending through a given height is found by the formula $v = \sqrt{2gs}$, in which v is the velocity, g the acceleration due to gravity = 32·2 feet, and s the space described.

Now, in the case of any ventilating pipe E, 50 feet high, the space described (which is the difference in height of the two columns of air of equal weight) was found to be equal to 1·0204 feet. Then the velocity of efflux up any sewer D, and up any ventilating pipe E leading therefrom, is $= \sqrt{64 \cdot 4 \times 1 \cdot 0204} = 8 \cdot 106$ feet per second. As, however, this is the initial velocity, it must be reduced, say, one-tenth for retardation to the flow from contaminations, obstructions, friction, and bends. Hence the reduced velocity of efflux will be equal to $8 \cdot 106 - 0 \cdot 8106 = 7 \cdot 2954$ feet per second. The discharge in cubic feet per second is found by multiplying this velocity by the transverse area of the ventilating pipe E in feet. Thus, if the ventilating pipe E be 6 inches in diameter (its height being 50 feet and the temperature of the air therein 10° above that of the external air) the air discharge therefrom will be $= 7 \cdot 2954 \times 0 \cdot 19635 = 1 \cdot 4344$ cubic feet per second, or 85·947 cubic feet per minute. If the ventilating pipe E be 75 feet and 100 feet high respectively, the air discharge from it would be 2·1486 and 2·8648 cubic feet per second, or 128·9205 and 171·894 cubic feet per minute, respectively.

There is no doubt that the simple, efficient, and practical system of ventilating the sewers in towns as now proposed will, sooner or later, be generally adopted. At present a few house-owners here and there object to the ventilating pipes being carried up the flank or other walls of their houses to the roofs. When, however, it is generally understood that the drainage from the houses originates the necessity for the sewers to receive this drainage it is only fair and reasonable that facilities should be readily afforded by the house-owners for carrying the ventilating pipes from the sewers to the house-tops, in order that the houses and the streets should be unpolluted with sewage vapour and gases, and kept as sweet and healthy as possible. Wherever permission for this ventilating pipe is stubbornly withheld, then the law should make it compulsory, because the appliance is for the public benefit.

313.

CORRESPONDENCE IN "THE BUILDER" BETWEEN THE LATE MR. JOHN PHILLIPS AND MR. SANTO CRIMP, ON THE VENTILATION OF SEWERS, IN THE YEAR 1888, BEGINNING ON APRIL 28TH AND ENDING ON JUNE 2ND OF THAT YEAR.

The Builder, May 5th, 1888.

"THE VENTILATION OF SEWERS."

SIR,—Mr. John Phillips commenced his article quite accurately when he stated that "the complete sanitary ventilation of sewers has never yet been properly accomplished."

The desired object will most certainly not be attained by the adoption of Mr. Phillips's "suggestion."

The isolation of sewers by means of the water-trap is not new; I applied that method eight years ago, and have more recently isolated several miles of sewers in this district in the same manner.

The first experiment tried in Wimbledon was on a sewer passing up a hill with a steep gradient; the trap was placed at the junction of the sewer with the main outfall, and it was provided with a so-called air-inlet, brought to the surface and provided with an iron grating; at the end of the sewer a 6-inch pipe was carried above the roof of an adjacent building. So far, Mr. Phillips's plan was anticipated.

I thought at that time that the air would pass into the sewer at the "air-inlet" and out at the top of the hill. A week had not elapsed before I found I was wrong; the direction of the air in the sewer was prevailing down the hill and out at the "inlet." I commenced observations and found the same thing was occurring in other sewers; when further traps were inserted, therefore, means were provided to admit of the gases coming down to escape at levels sufficiently high to prevent inconvenience.

I was satisfied that continuous experiments were necessary, and I commenced a series, the observations being made with regard to the direction of flow of the sewer air, its temperature with that of the sewage, and the external air. These have been carried on for some months, and will be continued for a sufficiently long period to enable me to throw some light upon the subject, when the results will be made public.

In the meantime, I will merely say that Mr. Phillips's conclusions as to effect of temperature are entirely erroneous, so far as the Wimbledon sewers are concerned, and these do not differ from other sewers in any essential particulars, so far as I am aware.

W. Santo Crimp.

Wimbledon: April 30, 1888.

314. Sir,—In the article on the above subject which appeared in your last issue, Mr. John Phillips, C.E., states that the "complete sanitary ventilation of sewers has never yet been properly accomplished."

I would wish to state a few facts as to what has come under my attention in connection with this important subject, not with any idea of controverting Mr. Phillips's theory, but from a sense of fairness to the originator of a system of sewer ventilation tried with success in Tottenham.

In the early part of last year some of the ventilating manholes in the district gave considerable trouble, and complaints of the emission of noxious gases were numerous.

As a remedy, several upcast shafts were erected, but these in most cases proved ineffectual. Indeed, I have frequently noticed that the shaft acted as the inlet and the grating in the road as the outlet.

Eventually the system of sewer ventilation and deodorising of sewer gas, invented by Mr. R. Harris Reeves, was brought under the notice of the Local Board, and it was decided to obtain the assistance of that gentleman. After making careful observations into the requirements of the district, Mr. Reeves fitted his apparatus to the most offensive ventilators, with the result that, although the sewer air continued to be freely given off, it was quite innocuous, and complaints at once ceased, thus proving that by the introduction of this system the sanitary ventilation of sewers had been accomplished.

This question is so closely allied to the problem of the treatment of sewage that I might proceed to say without irrelevancy that Mr. Reeves does not stop at the ventilation of sewers and deodorising of sewer gas—he goes a step further and prevents sewer gas being made; also chemically treats the sewage whilst in the sewers ready for precipitation and manipulation at the outfall.

I recently had an opportunity of visiting Frome, where this system is in operation. In that town there is no smell either at the ventilators or at the sewage works.

The latter was locally known as the "Stinkeries," but now that term is in no way applicable.

C. J. Easton,
Chief Inspector, Sanitary Dept.,
Tottenham Local Board of Health.

May 2, 1888.

The Builder, May 12th, 1888.

315. "The Ventilation of Sewers."

Sir,—Mr. Santo Crimp is a clever sewer engineer. For this reason, I not only held him in great respect, but thought he would, when he had had longer experience, discover and introduce valuable sanitary improvements. But clever people sometimes make bold, impetuous, and wrong assertions; and sometimes, by doing so, they show the *expert* where and how they have come to wrong conclusions. I am sorry to see that these are prominent in Mr. Santo Crimp's letter. If I were to investigate the matters he has referred to at Wimbledon, I should soon find where and how he has blundered. When he was very young I investigated hundreds of similar cases in the Westminster sewers, and often found the causes which produced the effects most difficult to discover. It would appear, however, that Mr. Santo Crimp came intuitively to his conclusions without investigating the causes. If he did investigate and find them, what were they? As to his statement that he applied a "water-trap" in a sewer eight years ago, and more recently "isolated several miles of sewers" in the same manner, and "so far anticipated my plan," I may inform him that that plan had often been carried out by others, as well as by myself, before he was born. The result of my nearly fifty years' practical experience as a sewerage engineer is the "suggestion" as to ventilating sewers in my article which Mr. Santo Crimp will not be able to "write down." A *résumé* of that article may be given in the following form:—

What Mr. Santo Crimp, or any engineer, has to do in order to *effectually* ventilate the sewers under his care is as follows: First, put syphon traps on all the gully-drains near their receiving ends, and on all the house-drains near their discharging ends, so as to effectually prevent the air-currents in the sewers from passing up the former into the streets, and up the latter into the houses; secondly, put manhole shafts, with gratings and movable covers thereon level with the streets, at all the junctions of the sewers, and at intermediate places where the junctions are very wide apart; thirdly, put specially-constructed syphon-traps, with accessible movable air-tight covers on their outlet divisions, in the bottom of the manhole shafts, so as to divide the sewers, for the purpose of ventilating them, into separate sections, and to prevent the air-currents in the separate sections from passing out of their upper ends into the manhole shafts, and thence up the adjoining sections; and fourthly, put ventilating pipes, with air-tight joints, from near the upper ends of the separate sections to the housetops.

Now, if Mr. Santo Crimp, or any engineer, will properly carry out what I have described, he will find that currents of fresh air will be always flowing from the streets down the manhole shafts into and up the lower ends of the separate sewer sections there; and that the ventilating pipes, going from the upper ends of the separate sewer sections to the housetops, will be always discharging into the atmosphere there, the ventilation being produced by the temperature of the internal air being slightly in excess of that of the external air.

Mr. Santo Crimp says, in the last paragraph of his letter, "that my conclusions as to the *effect of the temperature* are entirely erroneous, so far as the Wimbledon sewers are concerned." One might infer from this that no hot or tepid waste-water is ever discharged from the houses into the sewers in Wimbledon, and that therefore the temperature of the air therein is never raised from that source. It would also seem that he does not believe what all scientists teach, namely, that heat is the cause of the expansion, lightness, elasticity, and movement of air, vapour, and gases, and consequently of all spontaneous ventilation.

JOHN PHILLIPS.

Putney, S.W., May 5, 1888.

The Builder, May 19th, 1888.

316. "THE VENTILATION OF SEWERS."

SIR,—In your last issue I am asked by Mr. Phillips to state what are the causes affecting sewer ventilation.

Mr. Phillips assumes one cause only—temperature; another factor is the sewage itself, whilst by far the most powerful agent is the wind.

As Mr. Phillips neglects the most important factor, to say nothing of the second, his assumptions are necessarily fallacious; it is a question of fact, and one that can be proved by any one who will provide himself with a few anemometers, and then make experiments for a few months.

W. SANTO CRIMP.

Wimbledon.

316. Sir,—Mr. Phillips appears quite certain that the custom of permitting sewer-air to escape through gratings terminating at the street level is neither sane nor sanitary, and paints a very highly-coloured picture of what takes place. No doubt, says he, that by the inhalation of disease-germs from this source, very many deaths have been caused. Can Mr. Phillips give one single case where death has been caused by the inhalation of disease-germs when passing over these terrible gratings?

Mr. Phillips is wrong when he asserts that the advocates of the street-level gratings hold that, by the admission of fresh air through these grates into the sewer, the air becomes comparatively pure. What they do hold is, that by the admission of fresh cool air into the sewer, much less foul air is generated, and that which does escape is so small in volume, compared with the atmospheric air into which it is discharged, that no harm can take place.

Mr. Phillips will admit, I am sure, that, by the application of the refrigerator, decomposition is delayed; and, if so, he must admit that decomposition in the sewer is delayed by the warm moist air being lowered in temperature by the admission of fresh cool air through the street level grates. It would be interesting to know how Mr. Phillips would apply his system of mid-feather trapping as shown in his diagram to a sewer with, say, a gradient of 1 in 600. The 3 inches required at each trap would scarcely be available, and as many sewers have even less fall than this, his system cannot by any means be considered a panacea.

Notwithstanding what is said to the contrary, iron flaps have proved to be of much value in breaking up a system of sewers into sections for the purposes of ventilation. It is not necessary to hermetically seal one end of each section of the sewers, but it is sufficient for all practical purposes to check the flow of air at each man-hole, and in suitable intermediate positions to erect upcast shafts.

All that is required is that the sewers be so designed and constructed as to be self-cleansing, that they be ventilated and cooled by the introduction of a sufficient number of shafts terminating at the street level surmounted by gratings, and intermediate upcast-shafts attached to high buildings, and that they be well and regularly flushed.

J. W. Brown.

West Hartlepool: May 14.

The Builder, May 26th, 1888.

317. "THE VENTILATION OF SEWERS."

SIR,—Evidently Mr. Santo Crimp did not investigate the causes of the downward and counter air-currents in his sewers at Wimbledon. Because his anemometers showed the air-currents to be downward he concludes that "the way the wind blows" and "the sewage itself," —he means the *flowing* sewage—are the causes which produce air-currents in sewers. I am surprised that he should advance this theory. That heat induces air-motion, and, consequently, ventilation, he entirely ignores. He does not seem to know that air, gas, or vapour, when heated, is expanded and rarefied, and thereby ascends and produces ventilation. It is heat which causes the wind to blow, and the air, gas, and vapour in sewers, and the air and smoke in chimneys to expand, rarefy, and flow upwards. He will find that as the breath exhales from his mouth it ascends. Why? From the cause I have stated. According to his theory—that the air-flow in sewers is caused by "the way the wind blows" and "the flowing sewage,"—heat has nothing to with the ventilation of sewers. By his theory he also ignores the fact that the gases and vapour which emanate from the warm sewage, and which are considerably lighter than common air, rise upwards to the highest points in the sewers, and also in the gully and house-drains connected therewith. From the latter the gases and vapour escape into the streets and houses if there be no water-traps there, and even through these if the pressure of the gases and vapour exceed that of the atmosphere and the small resistance offered by the water in the traps. He also forgets, or seems not to know, that *direct air-communication* between the sewers themselves, and between the sewers and the houses and streets by untrapped drains, and sometimes when these are trapped, causes downward and counter air-currents in the sewers. He also seems not to be acquainted with the fact that very often heated houses, aided by the kitchen and other fires burning therein, act as powerful suckers of air from the untrapped, and sometimes even from the trapped, drains connected with the sewers, just the same as tall cylinder glasses round gas-flames suck air into them from the rooms, and so intensify the draught and the light from the burners. That Mr. Santo Crimp did not investigate these and other causes to account for the downward and counter air-currents in his Wimbledon sewers before he jumped to the conclusion that the ventilation is caused by "the blowing of the wind" and the "flowing of the sewage" is not only surprising, but he proves himself thereby to be lamentably ignorant of the subject of which he poses himself to be a guide and professor. By trusting to his anemometers, and neglecting to stop off all possible air-connection between the sewers themselves, and between the sewers and the houses and streets by the house aud gully drains, his experiments, and his deductions therefrom, will be worthless and lost labour.

Mr. J. W. Brown says that I am wrong when I assert "that the advocates of the street-level gratings hold that by the admission of fresh air through these gratings into the sewer the air becomes comparatively pure." Does he not know what the leader whom he and others follow says at p. 15 of his "Suggestions"? He says that, "with the abundant means for ventilation suggested,"—viz., by the street-level gratings—"the air within the sewers (by dilution) will be *comparatively pure*." Thus it is not I, but the compiler of the "Suggestions," who has perpetrated this assertion. He goes on to say that, as "the air in the street" will be "changed and renewed many times during the day . . . the air in the sewers will be several millions of times less in comparative volume than the air in the street. The dilution of any sewer-gas will, therefore, be in some such proportion." In my article I said that this statement was a "lame argument," which it certainly is, and not only that, but mischievous and inexcusable. There is no doubt that this statement has prevented, and still prevents, the application of proper improvements for ventilating the sewers in towns. By always discharging sewer-air into the streets, the atmosphere there is always more or less poisoned. It is nonsense, therefore, to say that the atmosphere thus polluted, and breathed by the people, is not injurious to health. It is as dangerous to health as it would be to constantly pour poisonous drugs into water which the people drink and use for culinary purposes. To be always breathing air polluted with sewage gases, or drinking water containing a deleterious drug, is, in either case, slow poisoning, which produces disease, shortens life, and raises the death-rate.

The baneful system of constantly discharging noxious sewer-air into the streets is contrary to reason and common-sense, and to sanitary science. Yet this is the pet system which Mr. Brown and engineers of his school apparently advocate from the want of a knowledge of the correct principles upon which sewers should be ventilated. At this time of day this system is disgraceful, and should not be tolerated. It came into use first in the City of London, and then throughout the metropolis, during the second quarter of the present century, when overflow-drains from cesspools behind and under houses were being largely laid into the natural watercourses, ditches, and street sewers, and has been in vogue, without any improvement, ever since. I have done my best, from my long experience, to show how this evil system of ventilation may be easily and effectually remedied. The letters of Mr. Santo Crimp and Mr. Brown are specimens of how any one who is not of their school, and who presumes to improve unsanitary sewer ventilation and sanitary science, is met. Mr. Brown writes glibly about designing and constructing self-cleansing sewers. Does he know how to produce self-cleansing sewers? I feel sure he does not. If he follows the practice of some engineers of his school, who arrange the gradients of sewers from a given velocity of 150 feet per minute when the sewers are assumed to be running half full, then most of his sewers, like theirs, will be sewers of deposit, as no doubt they are, if the truth were known, owing to the sewers, in dry weather, never running one quarter full, and the velocity then being much less than the required self-cleansing velocity. Mr. Brown is surely not aware that (1) the egg-shape sewer, (2) the trapped catch-pit gully, (3) the 150-feet rate of velocity per minute at which sewage must flow to prevent the sedimentary matters from depositing, and (4) the separate system, i.e., that rain or surface water should be kept as much as possible out of the sewage carriers—all which are now used or adopted all the world over—were first introduced or enunciated by myself, for benefiting sanitary science, between thirty-nine and forty-four years ago.

JOHN PHILLIPS.

Putney, May 21, 1888.

P.S.—Mr. Brown asks me to "give one single case where death has been caused by the inhalation of disease-germs when passing over these terrible street-gratings." I do not now remember any actual case, but it is well known that deaths have resulted from this cause. The following letter, which Mr. Charles Slagg has kindly sent me, confirms my statement; and many such could be adduced if I had time to make researches:—

27 Hereford-road, Leominster:
21st May, 1888.

DEAR SIR,

In the *Builder* of the 19th inst. a correspondent asks you whether you can give "one single case," etc. No doubt you could give him one or more, but in case you should not remember one, of actual death resulting from foul sewer air, let me remind you of the death of a physician—I think, Astley Cooper Key, nephew of Sir Astley Cooper, who met a friend in Regent Street, and stopped to speak to him over an untrapped gully, and it was not until he felt ill that he looked down, and became aware of where he was standing. He went straight home, and soon after died, and he told the people round him how it happened.

I do not remember seeing the case mentioned anywhere since, but it was in the *Times* newspaper at the time.

I have known many cases of illness from the same thing, but could not, perhaps, state by name any other actual death.

Yours truly,
CHARLES SLAGG.

John Phillips, Esq., C.E.

318. Sir,—The discussion of this subject is both interesting and important. In it I beg to side with Mr. John Phillips, and to endorse the second paragraph in his letter; only I would not insist on the inlet being at the lower end of the sewer. More than nine years ago I put a ventilating disconnecting-trap in the centre of a street, with a fresh air inlet over it, and from the head of the street a 4½-inch iron blow-off pipe was carried up to above the top of the chimney cans and surmounted by one of my induced-current fixed ventilators, and I have heard no complaint since.

I think some experiments were made by passing smoke into the trap at the grating, and watching how long it took to come out at the outlet exhaust ventilator; but I forgot the time, although the impression on my mind is that the experiments were quite satisfactory.

In an unsatisfactory case some time ago, the blow-off pipe was only carried up the wall to about three-fourths of its height, and no exhaust ventilator used, and the effect was unsatisfactory. But in this latter case the work was not done properly.

In this connexion I would ask both Mr. Phillips and Mr. Santo Crimp to look at Fig. 10, sheet 2, of the specification of my patent, No. 1502, of March 22nd, 1883, and say if anything more is needed than what is shown in the said sketch. In this case the air and the water are both supposed to flow in the same direction, the foul air being discharged overhead, above the houses. I have called this the high-level system of sewer ventilation, which removes the objections made by Mr. Crimp.

As to using disinfectants and machinery for ventilating or deodorising the sewers or the gases in them, I think such, generally speaking, are unnecessary. We want the sewers well built, and with smooth bottoms, and all house-drains locked off them, and the said sewers so ventilated that no offensive gases or air from them will be blown off under the noses or mouths of the passers-by.

W. P. Buchan.

Glasgow, May 12.

The Builder, June 2nd, 1888.

319. "The Ventilation of Sewers."

Sir,—The assumption of Mr. Phillips that I am ignorant of the effects of temperature on gaseous and other bodies does not advance the argument in the least, since the assumption is groundless. I am well aware of the fact that the sun's heat is the primary cause of the wind blowing, but because the wind moves a ship along Mr. Phillips would argue that it is not the wind, but temperature, which moves the ship. In passing over a town the wind is broken up and deflected in all directions, in some cases passing down into the sewers, in others inducing currents out of them; but my experiments show that it is nearly always sufficiently powerful to overcome the effects of temperature in causing movements of sewer air.

We must not lose sight of the fact that Mr. Phillips bases his argument on the law relating to falling bodies, expressed by the fundamental formula $v = \sqrt{2gs}$, which he misapplies by neglecting all other factors, thus getting an entirely erroneous result. In order to bring this matter to an issue, I assert, Sir, that Mr. Phillips cannot produce one single instance where a velocity of 7·2954 feet per second, or even per minute, can be recorded in the 6-inch ventilating-pipe of a sewer, arranged in the manner suggested by him, the experiment to be made by an independent person, on a perfectly calm but cloudy day, when the results will not be vitiated by either wind or sun, and then to be published in your journal, together with the results obtained when a moderate breeze is blowing. I am perfectly willing to abide by the result, whatever it may be.

Mr. W. P. Buchan has kindly sent me a copy of his specification, No. 1502, and, as anticipated by him, my objection to Mr. Phillips's method of ventilation is effectively met by the arrangement shown in Fig. 10; the nuisance which would inevitably be experienced at the manhole at the street level being thus remedied.

W. SANTO CRIMP.

Wimbledon.

320. SIR,—Mr. Brown has no "pet" system of sewer ventilation, but he endeavours to put into practice that system which, to him, appears from practical experience to be in accordance with the requirements of sanitary science and common sense, viz. street-level gratings combined with high relief-pipes. The street-level gratings for the admission and circulation of the atmospheric air, and the high relief pipes to carry away the overheated sewer air.

Too much thought, it would seem, is being given to the sentimental objection to sewer air being permitted to escape into the streets, and much too little to the vastly more important question of preventing the accumulation in the sewers of putrid matter. By sewer air I mean the air and vapour from fresh sewage, and not the gases generated by the decomposition of the filth permitted by many to remain with perfect indifference.

An engineer's first object should be to see that the sewers are properly constructed, and, if this be done, it will not be necessary to trouble much about the consequences to individuals who may chance to stand over the ventilating grates.

It is not sufficient to say that "it is well known that deaths have resulted from inhalations of disease germs when passing over street-gratings"; an assertion without proof is of little value. I might reply by saying "it is *not* well known," and, when doing so, believe myself to be within the bounds of truth.

It is perfectly true that, in many instances, nausea has been caused by the smell of sewage; it is equally true that nausea has been caused by the smell of manure-works, tallow-works, tanneries, etc., but surely Mr. Phillips would not think of attempting to close these works because the processes carried on within them are objectionable to the sense of smell. Does he believe that everything which is objectionable to the smell is injurious to health? Is it the smell from the street-gratings Mr. Phillips so strongly objects to, or is it the old exploded idea that all sewer air contains much larger quantities of disease germs than the atmosphere, and that, in consequence, it must be avoided if life is to be preserved?

Mr. Phillips has not yet stated how he would apply his system of trapping a sewer with a gradient of 1 in 600.

I am quite sure that Mr. Slagg fully believes what he asserts in his letter to Mr. Phillips, and if the gentleman referred to had been the only person who has been taken ill in the street, and died shortly after reaching home, there would be fair ground for the theory; the assertion must, however, be taken with a grain of salt, as many thousands have been taken ill in the street and have died soon after arriving home, although miles from the site of a sewer grating. It must also be borne in mind that most diseases require some little time to develop themselves.

J. W. Brown.

West Hartlepool: May 29, 1888.

321. The foregoing correspondence that took place in the "Builder" in 1888 (April 28 to June 2) between the two eminent and practical sanitary engineers of the last century, viz. Mr. John Phillips, C.E., on the one hand, and Mr. Santo Crimp, C.E., on the other hand, "re the ventilation of Drains and Sewers," will, I venture to think, be of special interest to British Municipal Engineers and Surveyors at the present time. One has only to read (1) the evidence which Mr. Phillips gave in 1847 before the Metropolitan Sanitary Commission, and (2) Mr. Latham's second edition of his book on "Sanitary Engineering," or rather what he there describes as being some of Mr. Phillips' handiwork, to be satisfied that I am more than warranted in designating Mr. Phillips the prince of sanitary engineers of his time. Moreover, the late Sir Robert Rawlinson told me in effect, on several different occasions—and I thought it greatly redounded to his (Sir Robert's) honour—that all he knew of sanitary engineering he had learned from Mr. John Phillips. I am more than glad that I have this opportunity of bringing to the notice of the reader the name of a gentleman who, in my humble opinion, and in the opinion, I venture to say, of thousands of other admirers of his genius and sterling character, has had the scantiest of scanty justice, either at the hands of engineers, who appreciated and copied from, or the public who benefited by his works. The rate-paying London public especially derived large and direct pecuniary benefits from his work by substituting for the old style of insanitary sewers which he found in London his own superior egg-shaped sewers therefor. This he did shortly after he took office as the first Sewerage Surveyor of Westminster; and really it is not too much to say that, substantially, and to all intents and purposes, the methods and the various apparatus utilized, up to the present time, in connexion with modern sanitary town drainage engineering works, are mere copies or adaptations of the types of devices which Mr. Phillips designed or invented. In fact the only thing he failed to do was to solve the drain and sewer ventilation problems. But, to his praise be it said, he did not fail to do this from any feeling of indifference or for want of trying, as is evidenced by an article of his which appeared in an issue of the "Builder" for April 29, 1888, in which he stated—and "quite accurately," as Mr. Santo Crimp, M.Inst.C.E., wrote in the following issue of the "Builder," in reply to Mr. Phillips' article—that "*The complete sanitary ventilation of sewers had never yet been properly accomplished.*"

Having given the reader a fair insight into the questions which were at issue between Mr. Phillips and Mr. Santo Crimp as to what constituted good and bad practices in Municipal drain and sewer ventilation engineering, I will now try to give the reader a good idea also as to what specially constitutes good plumbing practices under the existing regime by quoting the following:—

322. EXTRACTS FROM THE WORK OF MR. GERARD I. G. JENSEN, C.E., ENTITLED "CAST-IRON HOUSE DRAINAGE, WITH ESPECIAL REFERENCE TO THE DRAINAGE OF TOWN HOUSES" (THE SANITARY PUBLISHING COMPANY, LTD., 5 FETTER LANE, E.C., 1908).

(*With the kind permission of the Author and the Publishers.*)

(p. 7)

A further advantage possessed by cast iron over stone-ware drains is their suitability for being delivered complete and ready for fixing in any situation and at any distance from the place of manufacture. All

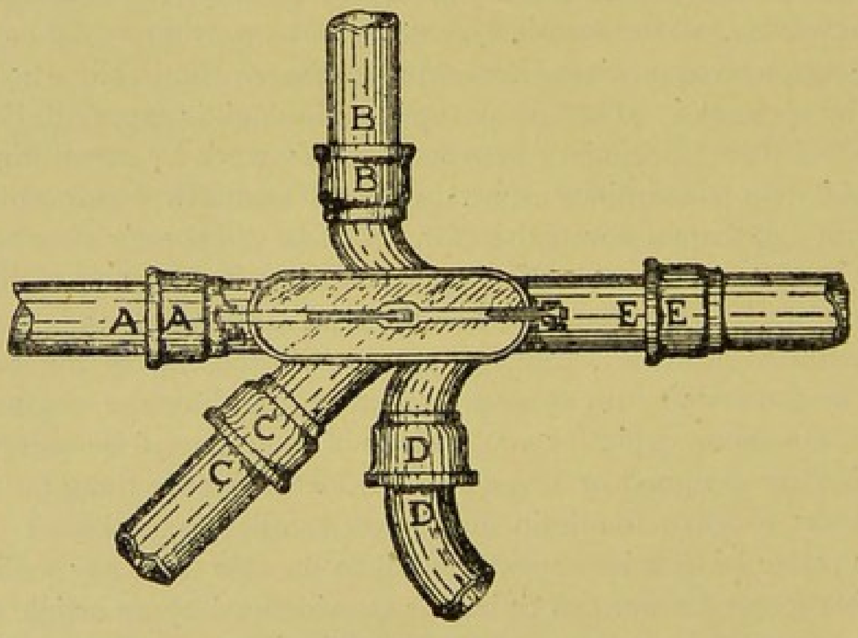


FIG. 3.

that is necessary for the purpose is to supply the manufacturer with accurate drawings, to scale, of the plans and sections of the buildings to be drained; the positions of the various drains, closets, sinks, soil and ventilation pipes and other adjuncts to the drainage system being accurately marked thereon.

The manufacturer will then be able to fit the various parts together in his workshops. The whole drainage system is put together by him and completed in all but jointing, and then carefully marked (as in Fig. 3) so that each part can be rearranged on arriving at its destination. As an alternative each pipe may be marked by a distinctive letter or number which is shown on the plan at the point at which the pipe is to be laid.

(p. 37)

Grease Traps.—Under the head of surface or gully traps must be included grease traps, which although not desirable appliances, nor strictly necessary ones, are nevertheless frequently used. Two types of the more efficient varieties of grease traps, made of iron and suitable for utilization in connection with cast-iron drains are shown in Figs. 52 and 53. The principle of the traps shown in Fig. 52 which is common to nearly all grease-traps is to admit and remove the waste water to and from the bottom of the apparatus. The grease is

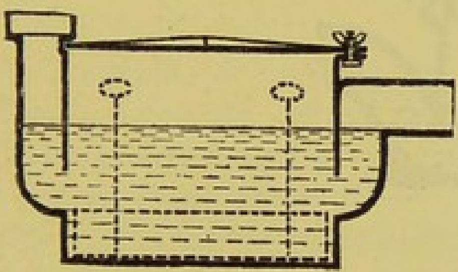


FIG. 52.

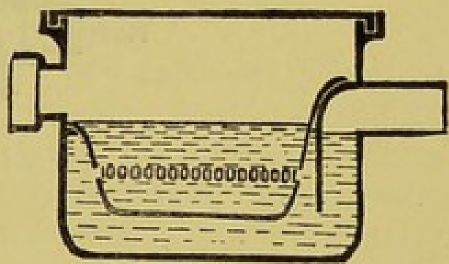


FIG. 53.

thus retained as it naturally seeks the surface of the water contained by the trap. It is subsequently removed by hand, either by being scooped out or by lifting out the tray with which some of the traps are provided. In the traps shown in Fig. 53, the grease is discharged into a tray which is perforated half-way down. The waste water flows out through the holes, whilst the grease and detritus are retained in the tray.

(p. 37)

Fig. 54 illustrates a grease trap which is provided with a water-jacket for cooling the grease immediately after it enters the trap. As will be seen from the illustration, the apparatus consists of two chambers. The inner one forms the grease-trap proper, whilst the outer retains the cooling water which is admitted at A and overflows at B. The trap has its advantages, but is not looked upon favourably by water companies, nor is the artificial cooling of grease strictly necessary.

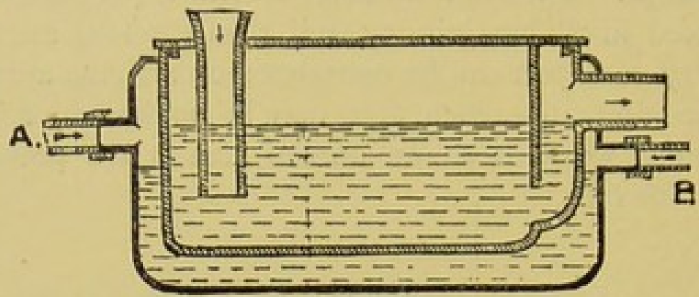


FIG. 54.

Flushing Rim Gullies.—In cases in which it is desired to pass grease into the drains, it is necessary to cool and solidify it before it is brought into contact with the drains, as it will otherwise tend to adhere to the sides of the piping and, by accumulating, eventually choke the drains. The trap illustrated in Fig. 55, which is known as a "flushing-rim gully," is designed with this object. Into it the

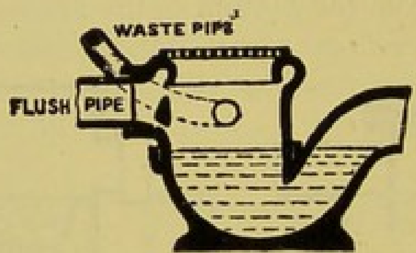


FIG. 55.

grease is discharged through the waste-pipe as shown, and is retained in the trap for a sufficiently long time to allow of its solidification on the surface of the water contained. From time to time it is then broken up and flushed out of the trap and through the drains by the discharge of an automatic flushing tank or bath whose discharge-pipe is connected to the flushing rim arm.

(p. 50)

Rust Chambers.—These are a species of access pipes which are, or should be, provided at bends in iron ventilation pipes. It is a common experience that the latter, even though properly protected on the interior surfaces, are liable to rust. Hence, as the pipes do not as a rule receive a proper flush of water in their interior, the scales of rust as they peel off, fall down the pipes to the nearest bend, there to accumulate and in time block the pipes. Rust chambers should therefore be fixed at all points on which an accumulation of rust is liable to take place; the object of the appliances being to provide a recess or pocket into which the rust may fall, and to a certain extent accumulate, without restricting the sectional area

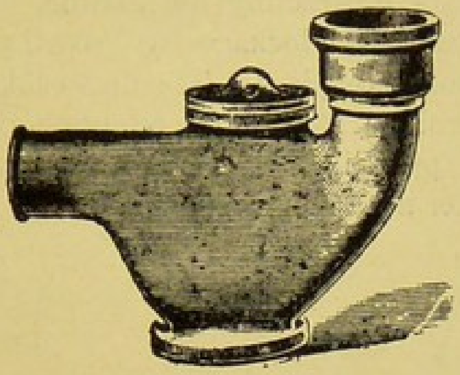


FIG. 82.

and efficiency of the ventilation pipe. Each pocket must, of course, be provided with an access cover (capable of being closed hermetically) through which the accumulations can at intervals be removed.

(pp. 94-95)

Examples of properly disconnected waste pipes are shown in Figs. 116 and 117. From these it will be noticed that the pipes may discharge either over or else under the grating, the point of discharge being, however, above the level of the standing water in both cases. Either system has its advantages and drawbacks. If the pipe is

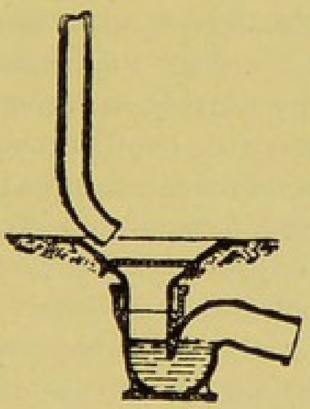


FIG. 116.

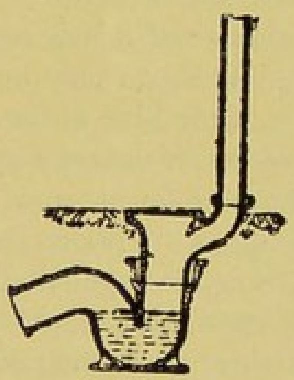


FIG. 117.

arranged to discharge over the grating, there is a risk that the latter may become obstructed by leaves, etc., or by the matted hair, soap, and grease discharged by the pipe, in which case waste water would overflow on the surrounding ground surfaces, and possibly soak into the foundations of the house. The waste pipe would, however, still be ventilated, as its outlet would remain free. Should, on the other hand, the pipe discharge *under* the grating, any matter discharged by the pipe would pass direct into the gully, and thence to the drain, without the chance of obstructing the grating. The latter would, however, still be liable to blockage by leaves, etc., in which case ventilation could not take place. The drawbacks of either system can, however, be avoided by a little attention on the part of the householder. The provision of a channel in connexion with the surface trap is neither necessary nor desirable.

(p. 104)

Bends, angles, and offsets should be, if at all possible, avoided in ventilation pipes. If they must be made, they should be as obtuse as practicable, in order to impede the air current as little as possible. Angles and bends increase friction and impede the circulation of air. Under other conditions, as with steam at high pressure, it is recognized that a bend in the pipe means a higher velocity for the steam passing it; an increase which can be brought about when the necessary pressure is available. With the very small margin of force existing in an ordinary ventilation pipe, however, only a decrease of velocity can result. As a matter of fact, it has been found by experiment that a right angle will diminish the air current by as much as one-half, so that a ventilation pipe with two such bends will only have one-quarter of the ventilating power of a straight pipe of similar length and diameter. If a sharp bend is unavoidable, then to maintain the air-current unimpaired it will be necessary to reduce the friction due to the bend. This can only be attained by suitably enlarging the sectional area of the pipe at the point at which the bend occurs, because it is obvious that if the velocity is decreased the bulk must be increased if a certain amount of air is to be passed through in a given time. With this object the writer has designed "Jensen's Bend," shown in Fig. 124, which is supplied by the manufacturers of suitable proportions for each individual case, having regard to the radius and degree of curve. As the relative discharging capacity of pipes varies as the square root of the fifth power of the diameter, or as $d^{2 \cdot 5}$, the enlargement of the pipe at the bend is made in that ratio. In the case of a sharp right-angle bend the reduction of the air-current is practically one-half, and the diameters of the bends in relation to the diameters of the pipes are therefore made in accordance with the following table in the case of bends of that description:—

TABLE VIII.

TABLE OF DIAMETERS OF JENSEN BENDS FOR VENTILATION PIPES.

Diameter of Ventilation Pipe	Diameter of Bend (roughly).	—
Inches	Inches	
2	$2\frac{3}{4}$	
$2\frac{1}{2}$	$3\frac{1}{4}$	
3	4	
$3\frac{1}{2}$	$4\frac{1}{2}$	
4	$5\frac{1}{4}$	
$4\frac{1}{2}$	6	
5	$6\frac{1}{2}$	
6	$7\frac{3}{4}$	

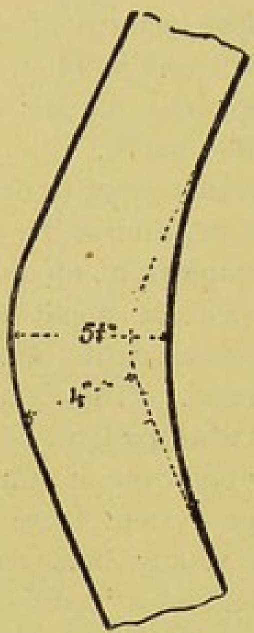


FIG. 124.

Up-cast shafts from drains, be they special ventilation pipes or soil-pipes should be continued full bore, or more correctly, of full capacity, to some convenient point above the ridge of the roof of the house and arranged to discharge all air passing through them, well out of the way of all windows, chimneys and other openings into the building upon which the pipes are fixed, and those adjoining. The outlets should at the same time be placed in as exposed a position as possible, in order that the wind may blow freely across them from all quarters and thus assist ventilation and disperse all vitiated air issuing from them. The openings of the pipes should be simply protected by copper wire guards. These will prevent birds from building their nests on the mouths of the pipes, and will not obstruct the air currents. Cowls, designed for the purpose of assisting the air-currents, are unnecessary; they are frequently also apt to get out of order, to shelter birds' nests, and to generally prove inefficient or detrimental. This liability to prove undesirable is not only present when the cowls are inefficient, but equally probable when, for the time being, the cowls are fulfilling the purposes for which they were designed.

It has, for instance, been found that the resistance offered by cowls placed upon soil-pipes (those designed to create "up-currents" no less than those arranged to prevent "blow-downs") to back-currents created by the discharges of closets has been so great as to permit of the syphonage of the closet traps. Under such conditions cowls are dangers to health. The free ingress of air to the soil-pipes at the right moment is of much greater importance than the extraction of a large quantity of air or the prevention of an occasional "back-draught," and in this connexion also it is necessary to prevent any impediment to the air which might be brought about by the use of unsuitable bends.

Air inlet pipes to drains should be placed at or near the surface of the ground, and in the positions in which they will be least liable to prove unpleasant should a "back-draught" take place. If possible, their openings should be quite unobstructed and simply protected by copper-wire guards, but, if necessary, mica-flap non-return valves may be utilized. These, however, require frequent inspection if their proper working is to be assured and are at best unreliable. It must further be borne in mind that in a properly designed and constructed drainage system there is at no time any dangerous gas. Hence, should at any time the air current in the drain be momentarily reversed and a "back-draught" through the air inlet pipe caused, the air issuing at that point can at the worst only be a little offensive and in no way dangerous.

The ventilation of soil and waste pipes claims attention, as numberless cases are to be seen daily, in which these pipes—even though recently constructed—are inefficiently or improperly ventilated and, in some instances, even quite unventilated.

With regard to soil-pipes (from closets, slop-hoppers, and urinals), little need, however, be said; their ventilation being extremely simple. The inlets are supplied by the drains, to which these pipes should be connected without the intervention of a trap, whilst the outlets are provided by continuing the piping full bore to some convenient position above the roof, in a manner similar to that advocated for out-let ventilation shafts. The portion of the piping above the junction of the highest water-closet on the stack is, in fact, and should be treated entirely as, an outlet ventilation pipe.

As regards waste pipes, by which is understood the discharge pipes of sinks, baths, and lavatories, it is no uncommon experience to find them constructed in the manner shown in Fig. 125. That is, the fittings are arranged to discharge into hopper heads, fixed on the stack pipes outside the house. It is obvious that this arrangement is highly insanitary, for the stack pipes and hoppers are soon coated with offensive deposits, emanations from which are liberated near windows and thence drawn into the house. Not infrequently, as shown in Fig. 126, the waste pipes are fixed without attempt at ventilation. Under these circumstances two evils arise. In the first place, when there is water in the traps under the fittings, the water

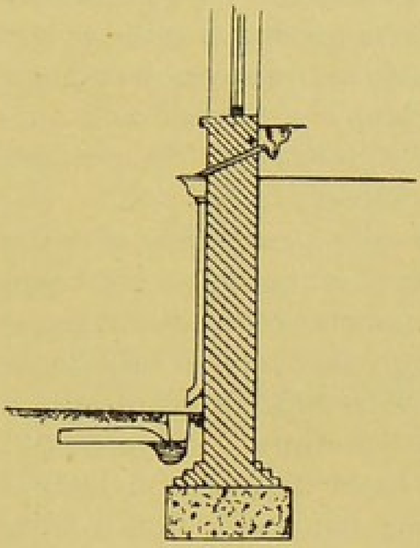


FIG. 125.

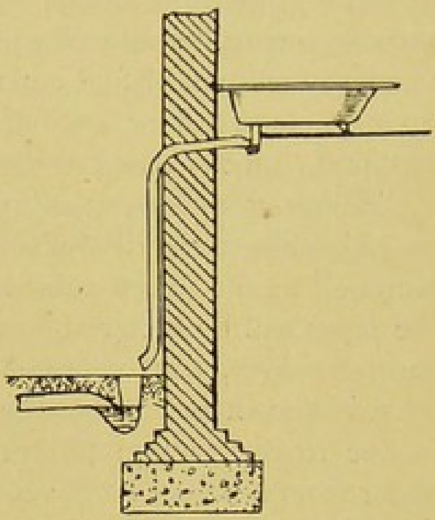


FIG. 126.

will at all times be exposed to the noxious gases generated in the waste pipes. These gases it will absorb and in time pass through

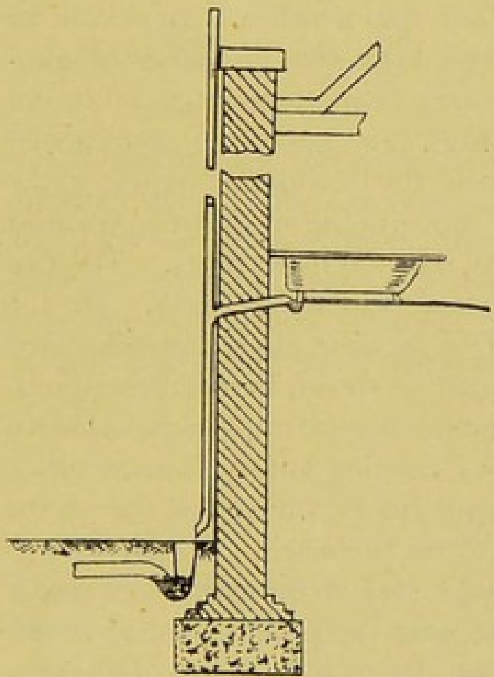


FIG. 127.

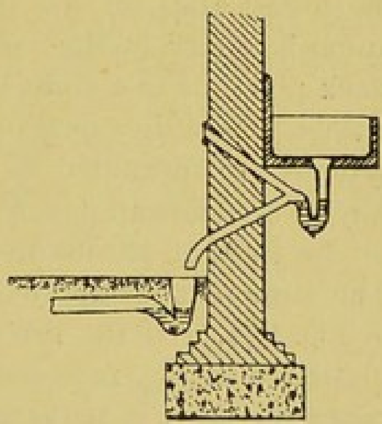


FIG. 128.

into the house. An even more serious drawback is that the water in the traps is liable to be drawn out by "momentum," by which is meant that the water of the traps is carried out by the momentum or impetus due to its own mass and velocity. In such cases the waste pipes will be ventilated into the house directly. The remedy for these evils is to ventilate the pipes above the eaves of the roof, as indicated in Fig. 127. This, of course, is only necessary in the case of waste pipes from fittings fixed upon the upper floors, as these pipes provide a considerable area of fouling surface, and a correspondingly increased amount of foul emanations. Short waste pipes from fittings upon the lowest floor are sufficiently well ventilated by the provision of "puff" pipes carried to the exterior, as shown in Fig. 128.

Reverting to long waste pipes and to soil pipes, there is of course no objection to the discharge of a number of fittings into a stack pipe common to all. Such an arrangement, in fact, has its advantages, as the pipes will be better and more frequently flushed. If such be the case, however, trap ventilation becomes essential to guard against what is known as "syphonage" and "back-pressure." "Syphonage" is due to the suction produced by the rapid descent of a body of water from a higher level which, in passing the branch from a fitting fixed upon a lower level, tends to suck out, or syphon out, the contents of the latter's traps, unless air is admitted independently in front of the trap. "Back-pressure" is the reverse of syphonage, and is due to the air which is forced down in front of a descending column of water. If no ready exit be provided for this air, the tendency is for it to be forced through the seal of any trap which it may pass in its descent. Either evil will be prevented by the provision of anti-syphonage pipes. These are subsidiary ventilation pipes taken off the lowest traps of the tiers (see Figs. 129 and 130) and carried upwards, either to the same height as the ventilation pipes of the stack pipes, or to a point a few feet above the level of the uppermost fittings, where they may be branched into the main pipes. The two systems are illustrated in Figs. 129 and 130 respectively. On the way up branches are taken off the anti-syphonage pipes and connected to the traps of all intermediate fittings, as shown in the illustrations. The same remarks apply to a horizontal tier of traps such as shown in Fig. 131. Of the two methods of treating anti-syphonage pipes, illustrated in Fig. 129 on the one hand and Figs. 130 and 131 on the other, the latter is perhaps the one to be preferred. By adopting it the intake of air for the anti-syphonage pipe is brought much nearer to the fittings than would be the case were the pipe treated as shown in Fig. 129. The air would for some distance be drawn through a comparatively large pipe, resistance by friction being thereby reduced. At the same time some benefit will be derived by the inrush of air into the stack pipe which follows the discharge of a fitting. The system is also the cheaper one, owing to the materials and labour saved.

To avoid the formation of "dead ends" in waste pipes, trap ventilation is also necessary in the case of single appliances when the branch waste—measured from the fitting to its junction with the vertical pipe—is of appreciable length. An anti-syphonage pipe as applied to such a fitting is shown in Fig. 132. The portion of piping which lies between the two junctions on the stack pipe may be left

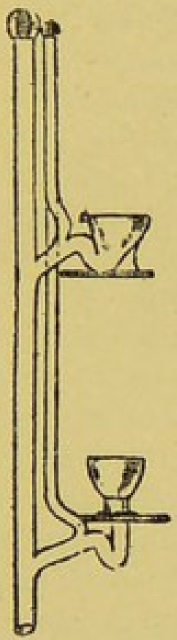


FIG. 129.

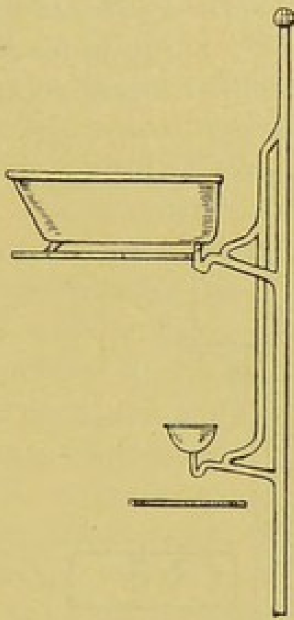


FIG. 130.

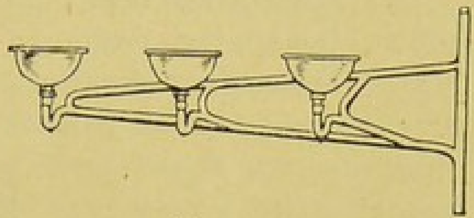


FIG. 131.

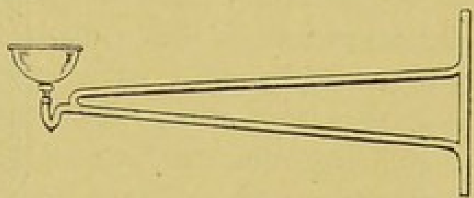


FIG. 132.

out if desired, but the saving is usually very small and hardly worth considering. There are cases, however, in which the ventilation of the branch waste will be greatly facilitated by the omission. In that case the anti-syphonage pipe must be of equal diameter to the waste pipe, and its bends made with as easy a sweep as possible and enlarged in accordance with the dimensions given in Table VIII.

(p. 131)

Whenever possible flushing-tanks should be fixed at some elevation—say, about six feet—above the inverts of the drains into which they discharge, in order that the water discharged may have attained a thorough scouring force by the time it reaches the drain. The greater the elevation, the greater, of course, the force imparted to the flush by its fall through the vertical flush-pipe. This flush-pipe by the way, as well as the outlet from the tank and the connexion of the pipe to the drain (which should be by means of a surface trap), should not be less than 3 inches in diameter for a 4-inch drain, 3½ inches for a 5-inch drain, and 4 inches for a 6-inch drain.

The capacity of the tanks must necessarily depend upon the diameters, lengths, and gradients of the drains upon which they are fixed. Broadly speaking, it may, however, be said that the following volumes of water will be found to give very good results:—

For a 4-inch drain . .	30 to 40 gallons.
For a 5-inch drain . .	40 to 60 gallons.
For a 6-inch drain . .	60 to 100 gallons.

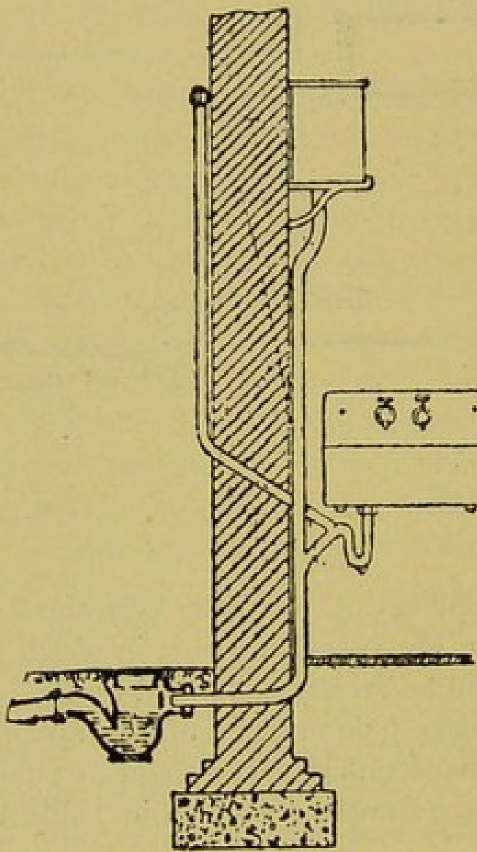


FIG. 141.

For a 9-inch drain at least 200 gallons of water will be required for each flush if it be desired to thoroughly clean its interior. Such a drain will, however, never be necessary for a town house.

Flushing tanks on branch drains will be sufficiently large if arranged to discharge from 25 to 30 gallons of water at each flush, which should take place at least once daily.

A discharge twice or three times weekly will usually suffice for tanks fixed on main drains, but the frequency of the discharges must of course be regulated according to whether or not the drains are laid to self-cleansing gradients, and with due regard to their dimensions. In all cases the discharge should, as far as possible, be arranged to take place in the evening, after the main flow in the drains has ceased. It is at this time that the greatest benefit is derived from flushing, as all solids which would otherwise remain to stagnate in the drains overnight will then be removed.

Invaluable though the benefits to be derived from the proper use of flushing-tanks are, water companies have raised objections to their use on account of waste. This has even been carried so far as to entirely prohibit the use of flushing-tanks unless the water is paid for by meter, a course which must necessarily be complied with until such time as the control of the water supply shall pass into more liberal hands. The alternatives which have been adopted in some cases—viz. to make use of waste and rain-water for the purpose of flushing—are reprehensible, since the former involves the retention of fouled water, and the latter is variable and uncertain. There is, however, no objection to the connexion of a bath-waste of suitable diameter to a flushing-rim gully, as in that case the water will be in constant movement, and there will be neither time nor room for the accumulation of deposits when connected to a flushing-rim gully receiving greasy waste-water; the bath-waste will, moreover, frequently be found a very efficient and inexpensive substitute for a flushing-tank if the bath is regularly made use of, or frequently filled and emptied for flushing purposes.

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323. Apropos of the views expressed by Messrs. J. Phillips and Santo Crimp on the one hand, and Mr. Jensen on the other hand, I mention here the fact that at the Congress of the Sanitary Institute held at Birmingham in September 1898, Professor A. Bostock Hill, M.D., D.P.H. Camb., read a Paper on "The Construction and Ventilation of House Drains," and at the same Congress Joseph Priestley, B.A., M.D., D.P.H., read a Paper entitled "Combined Drainage: its Pros and Cons," and at the discussion on these Papers Mr. Alderman Ernest Day, F.R.I.B.A., M.S.I., Architect, of Worcester, said:—

"He thought they were all agreed upon one point in connexion with private drains, that for combined drains or sewers there should be one water-trap and one air-trap. Having regard to sewers, it was utterly impossible to lay down any absolute scheme of ventilation unless they knew the local difficulties. Then so much depended upon gradients, atmospheric conditions, and other causes; but he thought they would all be agreed that under the existing arrangements one necessity existed, viz. that some outlet of sewer gas should be provided. The way in which this should be obtained was, perhaps, a matter of opinion. Personally, he rather favoured exhaust shafts, and on the top of such shafts should be a ventilator or destructor. He suggested that the Government should offer prizes for the best systems of sewerage, under ordinary or difficult conditions, which must be tabulated under various schemes, as A, B, C, D, and so forth, and offer large premiums, of say £100,000 or £50,000, which would make it worth the attention of clever and scientific men. He contended that such a proposal would be money well spent, for then the Local Government Board could say to a Local Authority, after an enquiry, which system they thought would be most suitable for the particular locality. Such advice and direction would be economic, and obviously beneficial to the community at large."

CONCLUSION

324. But for four things which I must mention before concluding this book (and which will occupy all the space and time at my disposal now) I should proceed at once, in the friendliest and most ingenuous way I know how, to criticize the foregoing able expositions of what I will venture to call the English builders' and plumbers' nineteenth and twentieth century methods—i.e. up to December 1913—for removing the sewage of houses and other buildings via soil and other waste-pipes and drains into public sewers. My criticism will, however, be inserted in the second part of this book, which will be published almost immediately.

325. The first of the four things that prevents me from doing so now is my great anxiety, at the present moment, that I should if possible succeed in placing this book in the hands of the President of the Local Government Board *before* he decides to act upon the recommendations of and the expert evidence given before the Departmental Committee appointed by him in 1908 "To Inquire and Report with Regard to the Use of Intercepting Traps in House Drains."

326. The second thing I desire to make known is the sad fact which many friends at home and abroad will doubtless learn for the first time by reading this announcement, viz. that in June 1912 my dear partner and friend, Mr. Edwin Ault, quite unexpectedly ceased to live! The following notice of his sudden death appeared in the issue of the "Wrexham Advertiser" for June 29, 1912:—

Death of Mr. Edwin Ault.

"We regret to announce the death, from heat-stroke, at Lahore, on Monday last, of Mr. Edwin Ault, the junior partner in the well-known engineering firm of Shone and Ault, of Victoria-street, London, and of Wrexham.

"The connexion of Mr. Ault with that firm, as pupil and assistant, and finally as the partner of Mr. Isaac Shone, the inventor of the world-wide known "Shone" Automatic Pneumatic Sectional Drainage System, had covered over half a century; and although in its earliest and most uphill years of development it was met with virulent and persistent criticism and hostility, it has emerged with complete victory to be recognized in every quarter of the civilized world—in the British Isles, in the continent of Europe, in India (Karachi and Bombay) and Burmah (Rangoon), over many parts of the United States of America, and in Egypt and elsewhere in Africa. Mr. Ault gave his high talents, his business capacity, and his unswerving fidelity and zeal throughout the prolonged period mentioned to the service of his chief and then partner, and not only aided him ungrudgingly by studying and mastering the scientific and technical features of the Shone system, but also had the courage and enterprise to spend several years of his life in visiting distant lands, unhealthy, and in some cases repulsive to the European, to supervise the construction of sanitary works of the greatest importance to the health of the communities on whose behalf they were designed and carried out. With this heroic devotion and energy he exhibited at all times a readiness to serve his firm's legitimate interests, combined with a self-denial and a modesty of demeanour that won the love of all who came into contact with him whether in the way of business or in the social amenities of private friendship.

" Mr. Ault resided in Wrexham for a great number of years prior to leaving for London, and was known and respected by a very large circle of friends who will all deeply mourn his decease. When in Wrexham, Mr. Ault was a prominent member of the Philharmonic Society, taking a keen interest in that choir's success when they won the prize in the chief choral competition at Carnarvon.

" When the Denbighshire Society in London was formed, Mr. Ault was one of its original members, and occupied the position of treasurer until leaving this country for Java last year. The deceased gentleman was a member of the National Liberal Club, and resided at Bromley, Kent. At a Committee meeting of the Denbighshire Society in London, held at the Welsh Club on Wednesday evening, the Chairman, Mr. W. A. Bayley, referred to the loss the society had sustained in the death of Mr. Ault, and proposed a vote of condolence with the family in their great and unexpected bereavement. The resolution was agreed to in silence, all the members standing. Those present also expressed their deep sympathy with Mr. Isaac Shone in his loss."

327. The above sufficed for his home friends and acquaintances in Denbighshire and elsewhere in Wales, but, of course, such a

notice would not be seen by many of his friends in England and abroad, and especially by those resident in India, Burmah, and elsewhere. For these reasons I have thought it my duty to add the following to the "Wrexham Advertiser's" kind and appreciative notice of his demise.

The sad event took place at Lahore on the evening of Sunday, June 23, 1912. The cause of his death was heat-stroke. It is consoling to know that the end was peaceful and free from pain, and occurred among near relatives whom he dearly loved and by whom he was dearly beloved. He had been engaged for some time in the Island of Java in the planning and preparation of an important scheme of drainage and sewerage disposal works. Finding himself at length relieved from that occupation he decided to return home, but intended to pay a visit on the way to his daughter and her husband, Mrs. and Mr. Walter G. Longdin, C.E.,* at Lahore, where they resided. It was not, alas! his destiny to proceed further.

The following pathetic letter from his daughter to her mother, Mrs. Ault, his bereaved wife, will give the sad details: —

NEVON'S HOTEL,
LAHORE.
27th June, 1912

"MY DEAREST MOTHER,

"This is a very heartbreaking letter to write and to receive, but I know you will want to know all the details.

"Father arrived from Calcutta on Tuesday, the 18th, and I didn't get down from Dalhousie till Wednesday morning. When he arrived Father complained of fever and blamed the new carriages on the railway, which apparently have only a single roof instead of a double one like the old ones. Walter advised him to go to bed at once, and

* Mr. Longdin was then, and is still, the Municipal Engineer of Lahore. Before he was appointed to his present post, he was assistant engineer in charge of the Western Division of Rangoon, Burmah, where he acquired considerable experience and proficiency in municipal and other engineering work of importance, and where, as I have been credibly informed, he gained the esteem and appreciation of those officials and others with whom he came in contact, including all the heads and chiefs of the various Municipal and Governmental Departments. He is one of the sons of the late Mr. Thomas Longdin, C.E., who was the Borough Surveyor and Engineer of Warrington for very many years, and if any municipal engineer in England ever deserved a substantial pension from his employers it was Mr. Longdin; the references made to him on pages 31, 32, and 33 of this book will at least tend to show what I mean.

on Wednesday we sent for the doctor, as his temperature was still 102°. The doctor could find nothing wrong with him excepting the fever, as he said he had no headache and no pain anywhere. The doctor gave him some medicine, and we did our best, to get the fever down. On Friday morning the doctor suggested that we should take Father to a nursing home, as they had every appliance there. He said that if we could only get the fever down Father would be all right—perhaps would only have to be in the home 2 or 3 days. We immediately moved him and he seemed quite comfortable. On Saturday afternoon Father grew very much worse and became unconscious. The doctor came at once, and after some time he rallied and became partly conscious. He never spoke coherently of himself again, but he answered indistinctly when he was spoken to, and he knew Walter and me. We stayed with him all night, and on Sunday morning the doctor was more hopeful. However, he gradually got worse, and he died at 6.30 on Sunday evening. His death was peaceful—there were no very bad struggles, and, thank God, he had somebody with him at the end who loved him.

"He had every comfort and attention that was possible. The doctor came continually, and Miss Tippetts, who keeps the home, couldn't have given him more attention. Walter was with him from Saturday afternoon till the end and scarcely left his bedside, and except for part of Sunday while I rested, I was there all the time too.

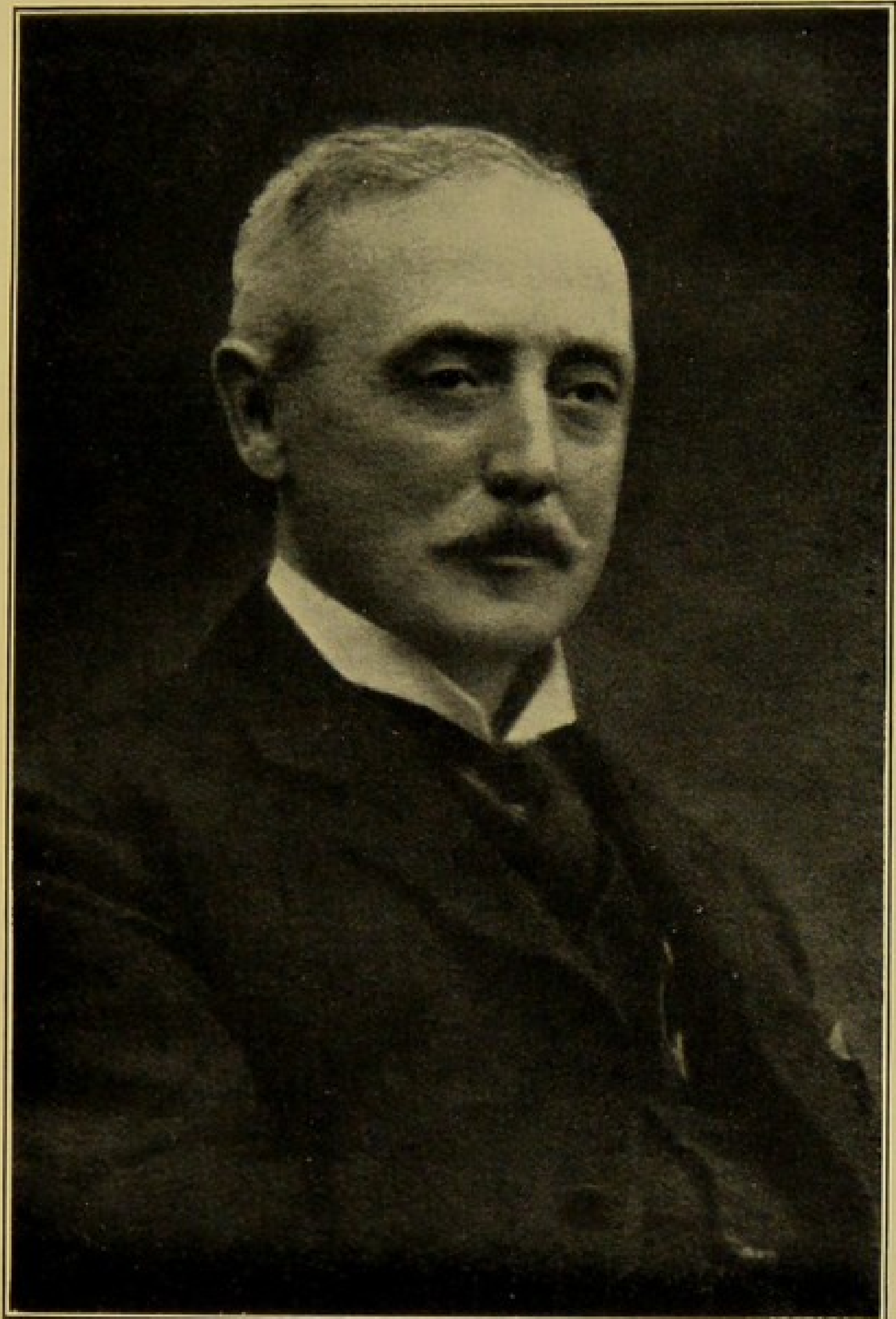
"With very much love to you,
"Yours,
"Ada Longdin."

328. The full particulars of Mr. Ault's connexion with me and my firm from his apprenticeship to the date of his death will be found in this book on pages 6 and 7.

Thanks to his son-in-law, Mr. Burmeister, who has retired from the business he carried on in Rangoon, and who now resides at Bremen in Germany, I am enabled to reproduce opposite a photo that was taken of him at Bremen last year, when he was en route to Java.

329. The third thing I wish to insert before concluding is that:—

In 1876 I wrote a pamphlet entitled "Wrexham Municipality up to 1876," in which is fully explained certain town improvements I had been considering for some time previously; and in 1875, when I was a member of the Wrexham Town Council, I had the privilege of explaining in the Council Chamber the nature and character of those improvements. A report of my speech on that occasion and



Yours faithfully
[illegible]

[*To face p.* 422

with its cost, including the value of labour which is lost. To be on the safe side, it may be taken that, for every life saved by sanitary works, twenty-five persons would escape sickness, and that £1 per case would represent but a moderate value of the result, including loss of time, physic, medical and other attendance. Thirdly, the value of the labour saved to the country by the prevention of premature death; for every adult female 5*s.* per week, and for every adult male 10*s.* per week, or a mean of 7*s.* 6*d.* per week, may be taken as the value of the labour over and above the cost of maintenance; so that if a town which has carried out sanitary works compares its savings under the foregoing heads with its expenditure, it will be found, in the course of a few years, that in all cases in which the sanitary works have been properly carried out, the money value of the lives saved and the sickness averted will exceed the full estimated cost of the works executed.

"Take Croydon as an example, the sewerage works of which were executed after plans prepared by that eminent sanitary engineer, Mr. Baldwin Latham, and to whose excellent work on sanitary engineering I am indebted for the information I now give you. At Croydon, to the end of 1867, no less than £195,000 had been expended in purchasing lands, construction of waterworks, sewers, sewerage irrigation works, public baths and general improvements. The average mortality of Croydon for seven years previous to the construction of sanitary works was 23·66 per thousand, and for thirteen years since it has been 18·64 per thousand, showing a saving of 5·02 per thousand per annum. The mean population for the thirteen years subsequent to 1855 was 37,375. Taking the mean saving of life at 5·02 per thousand, and multiply it by the mean population in thousands and again by the number of years, we get 2439 lives saved. Of this number six-tenths, or 1463, would be adults or persons above the age of twenty, but probably one-tenth of these would be infirm from age. After making this deduction, we have still 1317 persons in the full vigour of life who have been saved. By using the figures before quoted, in connexion with the lives saved, we shall get the money value of the benefits conferred by the works. Thus:—

	£	*s.*	*d.*
2439 Funerals, etc., saved, at £5 each	12,195	0	0
2439 by 25—60,975 cases of sickness preventive at £1	60,975	0	0
1317 value of labour at £19 10*s.* for 6½ years ..	166,929	15	0
	£240,099	15	0

"In this case, while £195,000 had been expended in all the public works, they had effected a saving equal to £240,000; so that in the short space of thirteen years a sum exceeding by 25 per cent. the total expenditure for works executed, and the purchase of free-hold property, has resulted from the prosecution of sanitary measures. Although it has been attempted to put a money value on life, we individuals feel that life is priceless, and that we may look to the 2439 persons saved from the jaws of death in this single town as the living testimony of the great value of sanitary works. To allow to perish by sanitary neglect is just the same as to take so many persons out of their homes and forcibly put them to death, and yet if this were done, the whole nation would revolt at the crime. Yet in how many instances do our local authorities look on, while poor and innocent victims are condemned to breathe a poisoned atmosphere, or drink poisoned water, which is a great crime in the eyes of humanity? I have taken the trouble to ascertain what is the state of things in Wrexham, and I am indebted to our Medical Officer of Health (Dr. Llewelyn Williams) for my information as to the population and death-rate for 1875. In January it was 39·2; February, 16·8; March, 49·0; April, 26·6; May, 23·8; June, 25·3; July, 28·1; August, 16·8; September, 25·3; October, 16·8; average 26·7 per thousand. By adopting the calculation referred to with respect to Croydon, to Wrexham, I arrive at the following results, and I base my calculations upon the population given in the last census, viz. 8537. Now, I see no reason why our death-rate should not be reduced from 27 to 18 per thousand, as it has been done in Croydon, in which case it is clear we should save lives at the rate of 9 per thousand, and if so how would the account stand? The population of 8537, multiplied by 9, will give 76·833 as the number saved per annum, and six-tenths would be adults, of whom one-tenth would be infirm from old age, etc.; this proportion deducted, we still have 41·5 per annum in the full vigour of life saved. The money calculation will, therefore, work out as follows:—

	£	s.	d.
Funerals 76·8 at £5	384	0	0
Cases of sickness 76·8 × 25 = 1920 at £1	1920	0	0
41·5 lives in health and strength at £19 10*s*. ..	809	10	0
Annual saving	£3113	10	0

"Messrs. Gilbert and Sharpe's contract for executing sewerage works, including outfall, was £6496 9*s*. 2*d*., and, notwithstanding this, you have a high death-rate, which is mainly owing to this fact—that we, as a sanitary authority, neglect to perform our duty. The works executed have done much to keep down the death-rate, but they can be made to do more; and it will certainly behove us, now that we have the proper complement of officers, to watch our own town—

to take heed of these reports from time to time, and to insist upon the performance of sufficient sanitary measures, in spite of breeches' pocket, or any other opposition which may be raised against us, wherever the want of sanitary measures may be made manifest to us by our officers. I have every confidence in my cause as an advocate for reform in the management of the affairs which belong to our local parliament; I have every confidence that the roads which are delineated upon the plans before you will sooner or later be made. The want of them will soon be felt more and more the longer you postpone their execution. Look around you; everywhere efforts are being made to improve the sanitary condition of the country. In some places their desideratum is accomplished by making new streets; in others whole houses are pulled down, and sewerage works are carried on simultaneously. In Birmingham they are about to spend half-a-million of money in making new streets for the benefit of the poor residents adjacent to those streets. In Liverpool and Glasgow, fabulous sums of money have been spent with the greatest possible advantage to the communities affected. Parliament has at last become alive to the importance of sanitary matters, and this year the Municipal Loans Act has been passed, which will enable us to borrow money at 3½ per cent. This we can now do, and have thirty years to pay back the principal—terms and conditions which I need hardly say will be a great boon to both large and small towns. If you will kindly support and pass my resolution to-day, I shall at a future meeting propose that the Provincial Insurance Company be respectfully asked if they will take up the money we borrowed from them at 5 per cent.; if they decline, then that they be requested to make some abatement in the rate of interest on the balance still owing to them. I shall also take stock of our indebtedness on the cemetery and other loans, with a view to show to the Council what would be its position pecuniarily supposing the roads proposed to be made were carried out, after borrowing all our money outside the Provincial contract—from the Public Works Loan Commissioners."

Mr. J. M. Jones, in seconding the motion, said that a more important question had never been brought before the Council, nor one which would be more likely to confer a greater blessing, not only on account of the relief to be given to the traffic, but from a sanitary point of view. He thought it would be well to get possession of the land on either side of the new streets, and as an immense area of valuable land would be developed for building purposes, the Council might sell it in plots, and by that means might get the roads free of cost, and perhaps be largely in pocket as well.

Mr. Sherratt having spoken of the "nonsensical improbabilities" that Mr. Shone had brought forward for the edification of the Council, Mr. J. Oswell Bury made what he termed his last speech at that Council. He gave every credit to Mr. Shone for the immense amount of trouble he had gone to—(hear, hear)—and he considered that he had proved his case. The opening of these roads would result in a better circulation of air through the town, and would, with the purification of the brook, conduce to lessen the death-rate, which had got up to an alarming pitch. (Hear, hear.) The death-rate, when presented to them every month, might not seem very high, but when they compared the returns for six or twelve months with other large towns the result was really sufficient to stir the Council up, and induce them to try to bring about an improved state of things.

Mr. Shone, in reply, read a letter from the Medical Officer, in which Mr. Williams said: "I wish very much indeed that you or some other member of the Council would take up the town brook question, for as my reports have been passed by, and as I am a servant of the Corporation, it would ill become me to press the matter further than I have done. But as I have often said, should enteric fever break out in your neighbourhood, I greatly fear it would spread very rapidly, and the consequences would be, of course, very serious, especially among the poor."

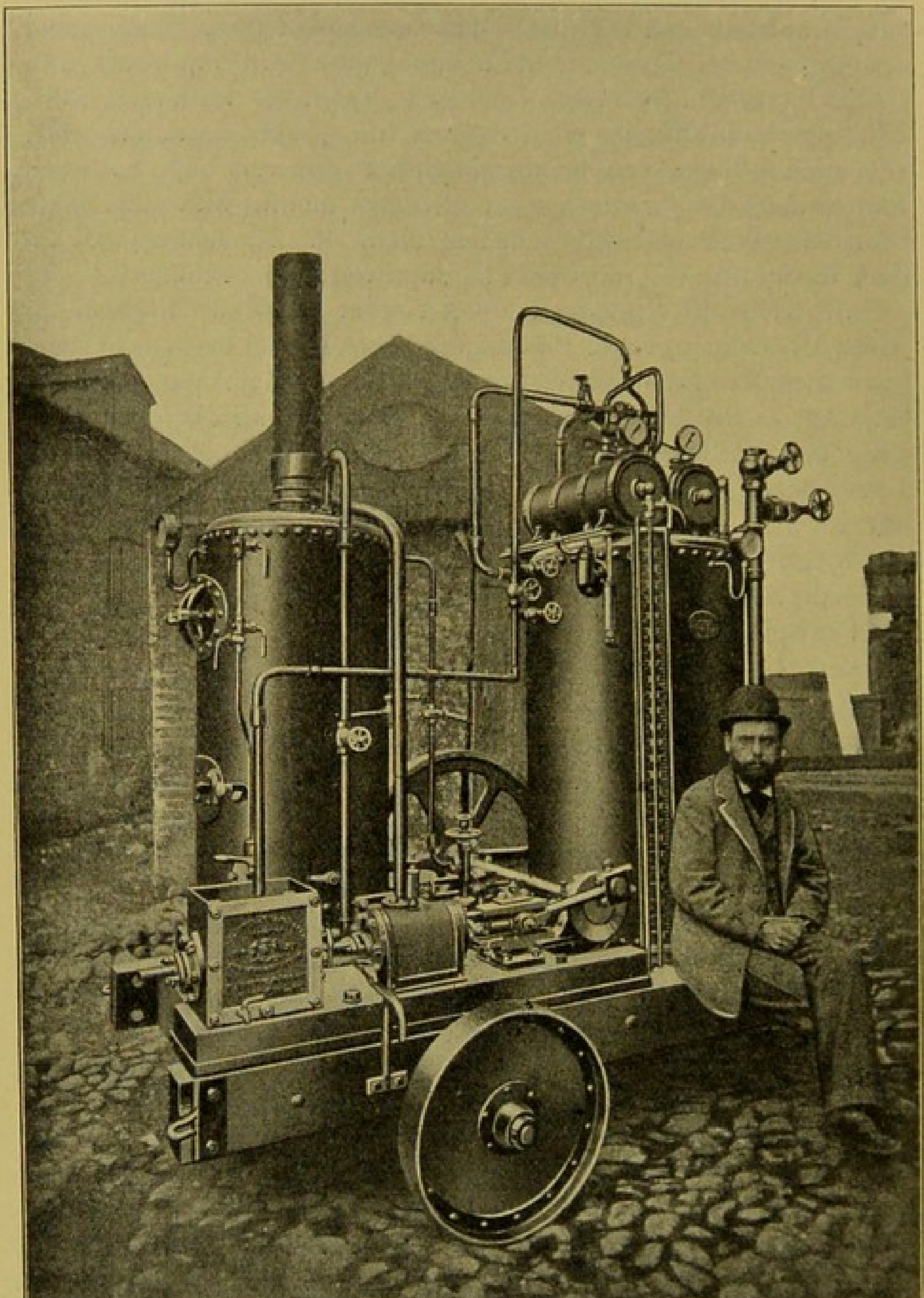
The motion was carried unanimously.

Major M. J. Wheatley, R.E.,* who is the owner of the Gwersyllt Hall property, and who takes a great deal of interest, to my certain knowledge, in our town and district—he it was, in fact, who reported officially to the War Department with reference to the site to be chosen for the North Wales military centre—and for whom I have had the honour of acting as agent for many years, on seeing the report in the "Wrexham Advertiser," wrote me immediately on the subject, and the following is the substance of his communication:— "I heartily sympathize with you in the efforts you are putting forth in Wrexham. If I were a despot I should insist upon the death-rates being reduced to 19 per thousand at the least, etc." Would that all sanitary authorities insisted upon being despots! They have the power by law to become such, if they will!

330. The fourth and last thing I desire to mention here has reference both to the scientific and the practical experimental works I deemed it necessary to resort to, in order to convince engineers generally that compressed-air power (against which at the commencement of my career as a Sanitary Engineering Reformer, mechanical engineers in particular were greatly prejudiced) when used in connexion with any given volume of town drainage work on the Shone

* Now (1913) Colonel M. J. Wheatley, C.B., R.E.

DRAWING NO. 46



The above illustration shows one of John Sturgeon's High-Speed Air-compressors which was used in connexion with the Shone Sewage Ejecting Plant erected and worked on Colonel Jones' Sewage Farm at Hafod-y-Wern, Wrexham, as described on pages 20 and 21 and by Drawing No. 3 on page 22.

Hydro-Pneumatic System would prove to be more economical and efficient mechanically and hygienically, than if ordinary pumping apparatus were applied to the like given volume of town drainage work. If the reader will peruse pages 28 to 34 of this book he will readily understand the nature of the difficulties that beset me at the outset; and if he will also peruse the last paragraph of Section 17, on page 29, he will see special reference is made to an automatic double-acting water ejector, which was, as explained on page 29, the joint handiwork of my partner, Mr. Ault, and Mr. Samuel Williams. The latter gentleman, I am pleased to say, has been for many years, and is at present the manager of the great Steel Works Co., of Brymbo.

The Drawing No. 46 on page 428 shows the machinery made purposely for me for experimenting with, in order to determine, approximately at least, the probable efficiencies that could be obtained by ejecting liquids on the Shone Ejector System.

331. To describe in technical detail the various parts and functions of the machinery illustrated would occupy more book space and time than I can afford to devote for such purposes at present; I therefore reserve further reference to the above and other experimental works for my next book entitled "Antiseptic House and Town Sewage Drainage Systems of the Twentieth Century." This second volume will contain full drawings and expositions of my New Non-septic Sewage Drainage and Drainage Ventilation Systems, and will be published immediately after the issue of this volume.

ADDENDUM

COMMUNICATIONS ADDRESSED TO THE AUTHOR RELATING TO THE SHONE HYDRO-PNEUMATIC SECTIONAL SEWAGE-DRAINAGE SYSTEM.

332. "I have said before, and I repeat it, that in my opinion your ejector system is, in economy and effect (sanitary and monetary), the only system that I can imagine as overcoming the difficulties, dangers, and cost of insufficient fall or outfall. We must come to the separate and ejector system to make the matter cheap and perfect. The simplicity of your effective system is its greatest merit, and that simplicity ensures a certainty and continuity of action."—J. J. Mechi, Esq.

333. "I could never believe in the practical application of Captain Liernur's Pneumatic System to the conditions of English life, but I am sure that if your countrymen will afford you one-half the opportunity he has enjoyed in Holland, you will succeed in revolutionizing the art of sewerage to the satisfaction of all nations."—Lieut-Col. Jones, V.C., M.Inst. C.E., Superintendent of the Government Sewage Farm at Aldershot.

Woodville, Edinburgh :
June 28, 1879.

334. Dear Sir,

"I recently witnessed experiments on a practical scale, with your "ejector" at Wrexham. They were perfectly satisfactory, and proved the correctness of all that you had said to me, and I have now the pleasure of stating my opinion regarding what I look upon as a most valuable 'Sanitary Improvement.'

"Experience has shown that the importance of a speedy and complete removal of sewage from dwellings cannot be over-estimated in a sanitary point of view.

"The beneficial effect of good sewerage and drainage upon the health and death rate of a community is very marked, but these benefits can only be secured by means of pipes laid with such a fall as shall make them self-cleansing, and it is obvious that in low-lying or flat districts it is difficult to obtain a proper fall, or at least that there is a temptation to be content with a flatter gradient than is desirable from hygienic considerations. In these districts even when the expense of pumping has been faced, motives of economy have often caused the gradients to be made very flat, and consequently there are long lengths of large-sized sewers coated with slime, and containing sometimes a great, and sometimes a small volume of sewage, moving along so slowly that it has time to deposit the heavier matters, or to decompose, and give off a large quantity of noxious cases, which pollute the common air, even if they do not find direct entrance into dwellings.

"When pumping is declined, and the sewage is run into the sea at low water, huge tank sewers are necessary to collect and store the sewage for some hours, until the tide has sufficiently receded to permit the discharge of their contents.

"Your 'Pneumatic' system offers important benefits to the inhabitants of such districts, amongst others the following:—

"(1) The generation of power at a central station upon a large scale, and therefore economically.

"(2) The distribution of this power by means of compressed air through small pipes to local 'ejectors.'

"(3) The perfect silent, simple, automatic action of these 'ejectors,' which draw upon the source of power only when they have work to do, and in proportion to the amount of work to be accomplished.

"Your scheme for subdividing the pumping power, hitherto concentrated at single stations near outfalls, and applying it at numerous points in the vicinity of the dwellings to be drained, renders it possible to have the sanitary advantage of good sewerage by means of small pipes laid on sufficiently steep gradients, while at the same time the total power required to lift the sewage is diminished rather than increased, inasmuch as the sewage from dwellings on the different levels of the district is raised, or forced directly to the outfall, without being permitted to gravitate to the low level to which it must fall if run by gravitation to a single distant pumping station. Other benefits conferred by your system are, that each 'ejector' or local pump, forms a complete barrier against the passage of gases from the main sewer beyond it to the house drains, and that it is possible to protect the air against the pollution caused by the ventilation of main sewers which is unavoidable by our present arrangements, but which, on your system may be obviated by the use of 'sealed sewers' of strong material. A certain amount of pollution by gases escaping from the ventilators of house drains, and small sewers tributary to the 'ejectors,' is still unavoidable (though the short lengths, small size, and proper grades of these ventilated tributary pipes will diminish the amount of pollution, and prevent danger), but it is of great importance to lessen so materially the demands upon the atmosphere of towns. It further permits of the use of the water-carriage system of sewerage, a system that, whether it be theoretically the best or not, is the only one that will be accepted by a community able to afford the cost, and it is so far superior to the 'Liernur' pneumatic system, in that it demands no alteration of present habits or arrangements, and might, indeed, be applied without the knowledge of the people served by it.

"Though you do not, like Captain Liernur, aim at the ultimate disposal of sewage, yet your system greatly facilitates that disposal on sewage farms, by raising it to various heights, and aiding distribution.

"At watering places, when sewage is run into the sea, you afford the means of forcing it out at high water, through a small pipe so that it is carried away by the ebbing tide, instead of being washed back upon the beach by the flowing tide, as is usually the case.

"As regards removal of sewage, a town on flat ground sewered in the manner proposed by you, would, except in the single particular of expense, be upon a par, or even better off than one situated on an eminence, and where consequently the best arrangements by gravitation were possible.

"One feature of your system which should commend it to the consideration of ratepayers is, that it lends itself extremely well to partial adoption, either as a supplement to gravitation or for trial on an experimental scale. In the latter case, power might be got from a factory engine near or distant, and should the trial give satisfaction, and the system be extended, the portion laid down for experiment would, pro tanto, be available at once.

"I may conclude by saying that I know of no recent sanitary invention more deserving of careful consideration at the hands of local authorities troubled by 'the sewage question.'

Yours faithfully,

JAMES A. RUSSELL, M.A., M.B., B.Sc.,
F.S.I. of Great Britain.

"ISAAC SHONE, Esq."

CHICAGO, *February* 16, 1894.

335. THE SHONE HYDRO-PNEUMATIC
SEWERAGE AND WATER SUPPLY CO.

URBAN H. BROUGHTON, Esq., Engineer,
Isabella Building, CHICAGO.

Dear Sir,

In response to your inquiry as to the operation of the "Shone System of Sewerage" as applied to the World's Fair Grounds in Jackson Park, I have the honour to say:—

I selected this apparatus from my previous experience with it, knowing that in the level low ground, with the sub-soil water so near the surface I could obtain grades for the sewers at a reasonable cost which would make them self-cleansing. The conditions which obtained at the World's Fair were exceptional, as it was impossible to foresee the amount of use, which determined the service required, at any particular locality, and while a total capacity of 6000 gallons per minute was provided, the amount which was considered a reasonable quantity, viz., 3000 gallons per minute, was exceeded on but few occasions, the largest measured quantity being about 3200 gallons per minute, delivered at the cleansing works from the ejectors. While this was a fact, regarding the aggregate, there were two or three locations in which the ejectors were very much over-worked, and the feature of an ample central power plant furnishing compressed air showed for us an economy in first cost not to be obtained with numerous local pumping stations, as the power distributed itself as required, giving us sufficient drainage at the points overworked, without dead machinery at those points not worked up to the average capacity.

I believe that no work was ever subjected to so severe a test as the existing conditions at Jackson Park compelled. It was in fact a plant sufficient for a large town, consisting of fifty-two ejectors, set in pairs at twenty-six stations all thrown into operation at once, with no previous opportunity to get into working order, and the whole apparatus started and operated for the occasion without hitch, and at no time during the Fair was any portion shut off from service through failure in the ejectors or compressed air pipes, such accidents as occurred being generally stoppages in the sewers themselves through the throwing in of garments or material which would have stopped any system of sewerage.

One of the governing conditions of the World's Fair work throughout in all departments was the rapidity with which it was necessary to complete the work, and in the case of the ejector system the laying of the air pipe, 5 miles in length, from the power plant to the ejectors was forced, in common with all other work. It was, however, laid very successfully of cast-iron pipe with lead joints, proved up in sections before acceptance from the contractors. The entire piping proved tight at the working pressure of 50 lb., giving us no trouble whatever; in the haste sufficient care, however, was not taken to keep the pipes free from sand, some of which adhered to the inside of the pipes and caused us some trouble by blowing through occasionally into the automatic valves of the ejectors. This, however, was the only occasion in my experience with the Shone ejectors, which experience extends over some six years, in which time I have used them in many locations, when anything of the kind has occurred, and this indicates that more care is necessary in laying air pipe than water pipe. In my report to the Director of Works now submitted, I have said that "I consider it the most satisfactory apparatus which we could have used."

In view of the extremely hard usage to which the system was exposed during the World's Fair at the hands of visitors unaccustomed to the conveniences of city life, it is my opinion that under no circumstances of ordinary town or city use is there any system of raising sewage requiring less care to maintain it in successful operation than this.

I am,
Very truly yours,
(Signed) WILLIAM S. MACHARG,
Engineer.

Translated from the Hungarian Original.

336. THE BURGOMASTER OF THE ROYAL FREE TOWN OF ARAD. No. 326/1898 Bgm.

MESSRS. HUGHES AND LANCASTER,
LONDON, WESTMINSTER,
47 VICTORIA STREET.

At your request I give you the following:—

The Royal Free Town of Arad is situated in the south-east of the great Hungarian Plain on the right bank of the Maros river.

The ground on which the town is built is very flat and the town area is protected against inundation by means of a circular embankment; in the spring and early summer when the ice begins to break up in the river, and the snow melts in the Transylvanian Alps, inundations frequently occur, and at such times the water rises about 6 metres above the level of the water in the river in summer and autumn, and about 3 to 4 metres above the street level.

The subsoil water rises to within 3 to 4 metres of the surface. The effective sewering of the town therefore presents unusual difficulties, partly owing to its flatness, and its being situated at a lower level than the river, partly owing to the surrounding circular embankments, and partly to the annual rise of water outside the town.

Ordinary effective drainage by gravitation for such a town is obviously quite out of question, and pumping from a single pumping station would also be undesirable owing to the difficulty of constructing deep sewers in the loose, porous, and water-logged subsoil of the town, at anything like permissible cost.

All these difficulties have been, however, successfully overcome by draining the town of Arad on the well-known Shone Hydro-Pneumatic system of sewerage, which makes it possible to obtain throughout the entire area of the inner town self-cleansing sanitary sewers, laid at steep gradients and at shallow depths, thus making the drainage of the town rapid and free.

The total area of the town of Arad is 1165 hectars with a total population of about 50,000 inhabitants. The greater part of the suburbs consist of small cottages with large courtyards, fruit and vine-growers' gardens which are not at present in need of drainage.

The town proper, the so-called Belvaros (inner town) occupies a central position close to the right bank of the river and running parallel to it, situated on alluvial ground and having an area of 158 hectars (390 acres) with a resident population of 16,000 and a floating population of 6700.

The boilers, air compressors, sewers, outfall mains and air mains are so arranged that the drainage system can be extended at any time and the present machinery arrangements will be able to deal with the sewage of 30,000 to 40,000 inhabitants.

For sewering purposes, the inner town is divided into five sections each of which is provided with two Shone pneumatic ejectors. By thus dividing the area to be drained into sections and laying down within each section small self-cleansing sewers of short lengths (175 mm.) all converging with good fall (1 in 200 and 1 in 150) to the ejector stations, it is possible to create those hydraulic conditions which are essential to the rapid transport of sewage by gravitation drainage to its point of outlet, the pneumatic ejector station.

As fast as the sewage flows by gravitation to each of the stations so fast does it drop into one or other of the pneumatic ejectors placed in each station. The difference of level between the top of the ejector and the invert of the gravitation sewers is just sufficient to keep these latter in a self-cleansing condition and quite free from sewage accumulations.

The valves on the inlet and outlet sewage pipes of the ejectors—and this, it need hardly be said, is a feature of great practical value—permit everything in the nature of sewage, solid and liquid, which will reach them through the gravitation sewers, to pass freely into and out of the ejectors. The employment of ejectors therefore dispenses with the necessity, which exists in connexion with ordinary sewage pumping installations, for screening the sewage.

The ejector is its own sump well and pump barrel and it is automatic in its action. It never permits any accumulation of sewage, solid or liquid, at the stations, so that it thus dispenses with all manual labour for the removal of the offensive solids in the sewage out of the sumps, cesspools or the pumping stations, which is so objectionable a feature in ordinary pumping stations.

Each ejector derives its ejecting power from compressed air produced at the air compressing station in Szel-utcza (Szel street).

The compressed air can be conveyed to any part of the town through small iron pipes, and any number of ejector stations can be provided with motive power in the same way as coal-gas is conveyed from the gas works to the various houses and buildings where it is used as an illuminant or for heating purposes, etc.

The loss of pressure in transmitting the compressed air from the air compressing station to the several ejector stations through a pipe system of 3544 metres length with a pressure of 1·70 kilo. per square cm. is very trifling.

The air supplied to the ejector varies in pressure from 1·69 kilo. to 1·05 kilo. per cm^2. It is in all cases sufficient to drive the sewage out of the ejectors and through the cast iron outfall sewers which are 4,159 metres long, raising it into a tank at the outfall works a height of 3·7 metres.

The air compressing station is built close to the river embankment in Szel-utcza, and consists of engine house, boiler house, coal house and brickwork chimney, engine driver and fireman's cottages, all works being carried out in a very careful and substantial manner.

The machinery consists of:—

Two complete sets of steam engines and air compressors, each able to work up to 47 indicated horse-power.

Cylindrical internally fired steam boilers of "dry back" marine type, and all necessary feed and circulating pumps, air receiver, etc., completely fitted up with all connections.

The length of gravitating sewer is 18,731 metres of 175 mm. diameter stoneware pipes with the necessary street manholes, automatic flush tanks, ventilating shafts, and junctions for house connections, etc.

After a trial period of six months the works were formally taken over by the town on the 20th of October, 1897.

The work of connecting the houses with the sewers was started in August 1896, and the number of house connections completed up to end of December 1897 was 780.

The reports of the Special Drainage Committee and of the Government Chief Engineer appointed to report on and take over the works state :—

1. That the works have been exceedingly well carried out and have been faultless in their operations since they started to work.

2. That the works provide for the discharge of considerably more sewage than they were originally intended to deal with, and can therefore be extended at once without any extra air compressing machinery.

3. That the town has been provided with an excellent system of drainage, and the extension of the system can be made at any time.

JULIUS SALACZ, m.p.
Royal Counsellor, Burgomaster.

ARAD : *January* 20, 1898.

337. *Translated from the Hungarian Original.*

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MESSRS. HUGHES AND LANCASTER,
LONDON.

In answer to your enquiry I am pleased to inform you that the sewerage works which you carried out for this Municipality from 1894 to 1897, have proved in every way most successful. The whole scheme, together with the machinery and materials which you supplied, have proved thoroughly good in design and in quality, and well in excess of what was specified in your contract.

The advantages which we have derived from our sewerage works on your well-known Shone Hydro-Pneumatic principle—the only one that could deal successfully and economically with the difficult problem of draining our town, which is frequently 3 or 4 metres below the Maros-river level, are such that the Town Council has resolved to extend the System to outlying districts. And as both the air compressing machinery and the sewage mains provided by you were designed upon liberal lines, we are now enabled to carry out these extensions without having to increase either our motive power plant or the rising main to the outfall works.

The health conditions of Arad have improved very materially since the completion of these important works, and I am very pleased to have an opportunity to add my testimony to the value of your excellent system of sewerage, as well as to the thorough and efficient manner in which your firm executed the works.

COLOMAN INSTITORIS, m.p.
Burgomaster.

ARAD : *September* 17, 1902.

[L. S.]

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LONDON: PRINTED BY WILLIAM CLOWES AND SONS, LIMITED,
GREAT WINDMILL STREET, W., AND DUKE STREET, STAMFORD STREET, S.E.