THE MAIN DRAINAGE

OF THE

HOUSES OF PARLIAMENT,

WESTMINSTER.

ON

THE SHONE HYDRO-PNEUMATIC SYSTEM.

BY

THE ENGINEER,

ISAAC SHONE, C.E., F.G.S.

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SHONE HYDRO-PNEUMATIC SYSTEM,

WITH DRAWINGS AND HYDRAULIC SEWERAGE TABLE (FOR OFFICE REFERENCE FOR ARCHITECTS AND ENGINEERS) EXPLANATORY OF SCIENTIFIC AND SANITARY DRAINAGE.

By ISAAC SHONE,

ASSOC. MEM. INST. C.E., F.G.S.

SEPTEMBER, 1887.

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PART I.

" Invention knocks hard and often before the doors of the mind open to receive it, and too frequently then the reception is but a surly one, and attention is deferred from visitor to visitor until one comes who will not be denied."

PREFACE.

I HAD intended long ere this to write and publish a book explanatory of the Shone Hydro-Pneumatic System of House and Town drainage; but, up to the present time, I have been too much occupied with other matters connected with the development of the system to be able to carry out completely my original intention.

The great interest, however, manifested by the public generally and by Medical Officers of Health, Engineers, Architects, and Surveyors especially, in the new drainage works of the Houses of Parliament, has induced me to issue this pamphlet as, and by way of a small instalment of what is to follow and which it is my intention on an early date to publish.

I feel that I cannot allow this opportunity to pass by without mentioning the fact that I owe a great debt of gratitude to His Grace the Duke of Devonshire, K.G., who—acting on the advice of Mr. G. A. Wallis, M. Inst. C.E., and Mr. Henry Currey, F.R.I.B.A. (Member of the Council, and a Past Vice-President of the R.I.B.A.), in conjunction with the Corporation of Eastbourne—gave me the *first* chance I ever had of demonstrating on a large scale—and in one of, if not the most beautiful, important, and attractive seaside health resorts (Eastbourne) in this country—the feasibilty and sanitary value of my system of town drainage.

Messrs. Wallis and Currey and the Corporation of Eastbourne approached the consideration of the principles and *modus operandi* of my system of drainage *without prejudice;* and I feel confident that the Select Committee of the House of Commons appointed to investigate the drainage and ventilation arrangements of the Houses of Parliament did likewise—otherwise, judging solely from past experience with other works, the extraordinary opposition which my system has encountered at the hands of a certain few engineers—not a thousand miles from Westminster, would, I am afraid, have influenced them in favour of adopting some plan on old rather than on new lines. The works on the new lines, however, were approved of by the Government, and when the present Session of Parliament assembled in January last, they were practically complete. On that occasion the First Commissioner of Her Majesty's Works and Public Buildings, the Right Hon. David Plunket, Q.C., M.P., invited the representatives of the Press to inspect the works; in due course a great number of notices appeared in the various journals and newspapers, descriptive of the New Works. I will give here extracts from two of them only, as samples of the expression of opinion on the part of the Press:—

The Lancet (January 29th, 1887) said:—

"The much-needed reconstruction of the main sewers of the Houses of Parliament has been carried out during the recess by Mr. Isaac Shone, the engineer in charge of the works, and on Tuesday last a select party, including representatives of some of the daily and weekly journals, were personally conducted by the engineer to view the alterations which have been made. Mr. Shone has issued an explanatory pamphlet, which, to a certain extent, is historical, and serves to show what an absolutely modern science is sanitation as carried out at present, and how crude were the attempts in this direction fifty years ago, even in the hands of men of genius with command of unlimited funds.

"We must congratulate the Members of both Houses upon the very important sanitary reform which has been effected by means of these works. There can be no doubt that the condition of the House will be immensely improved, and we think that much credit is due both to Sir Henry Roscoe's Committee and to Mr. Shone, who has so efficiently carried out the recommendations of that Committee. The machinery for keeping the Palace sewers empty will, of course, be constantly supervised by skilled persons, who, it is evident, must always be present night and day, both in and out of Session, in order that the proper supply of compressed air may be maintained, and the possible accident of sudden flood be grappled with. However, there is little likelihood of sewage accumulating in the Palace of Westminster in the future. Our Legislators have shown themselves alive to the importance of 'passing it on.' Let us hope they will next turn their attention to the recipients of it, and take unhappy Barking and poor Father Thames into their kindly consideration."

Iron (January 28th, 1887) said :—

"We have dealt thus lengthily with the subject of the new sewerage works at the Houses of Parliament because that subject fully merits it, and it does so on two main grounds. In the first place, the proper sanitation of the House of the National Assembly is of national importance. Of no less national importance, in the second place, is the system adopted for ensuring the sanitary condition of that House: for what can be effected by it in one place can be, and is being, effected by it in others, and that, too, at a minimum of cost as compared with that of the ordinary cumbrous sewerage system.'

The *Times* (January 26th, 1887) describes the system in operation at the Houses of Parliament as

"Beautifully simple and effective."

To those who act as if the Sanitary Engineers (of the old school) had brought drainage works in particular to such a degree of perfection that there was really no room for further improvement, I would commend a statement of Sir Robert Rawlinson's which appears in a letter of his addressed to the *Sanitary Engineer and Construction Record*, New York, in the issue dated August 6th, 1887, which is as follows:—

"Sanitary engineering is a new science, and as its main purpose is to make health, comfort, and a prolongation of life practicable, its study to a useful purpose must be important."

I have no hesitation in submitting the drainage works described in the following pages to sanitarians generally as being worthy of their best consideration, because they exemplify in a most practical way the principles and *modus operandi* of my Hydro-Pneumatic system of drainage—the sole and all-important object of which is to enable engineers, architects, and surveyors at all times, and under all sorts of natural adverse conditions, which are peculiar to flat as well as to undulated surfaces of ground, to institute self-cleansing drains and sewers, without which high-class sanitary drainage is impossible.

ISAAC SHONE.

4, Westminster Chambers,
London, S.W.

September, 1887.

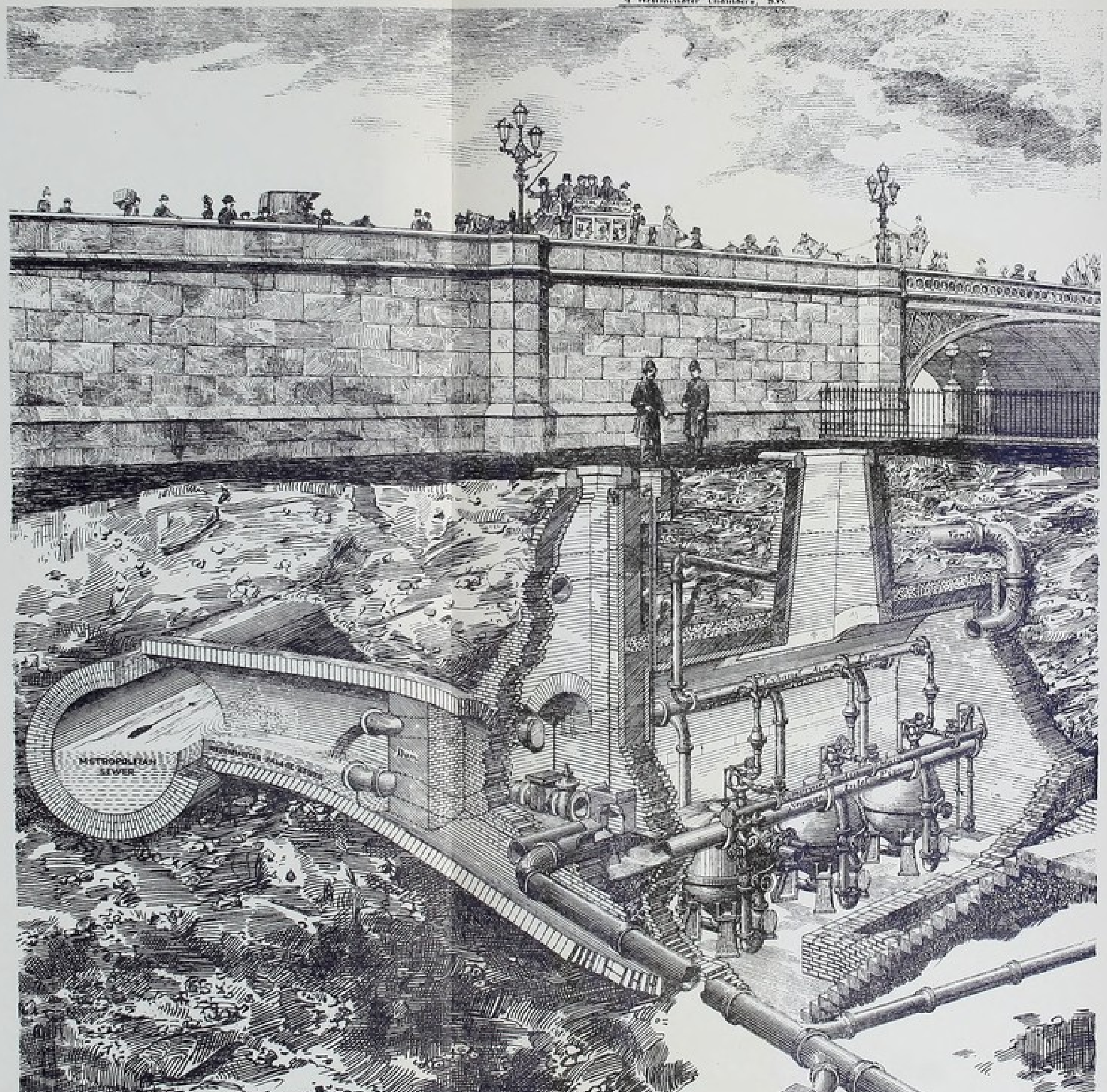
CONTENTS.

* Shone's improved *Hydraulic and Compressed Air Tables* have just been published by E. & F. N. Spon, price 10s. 6d., and will be found to contain useful information for Town Drainage, Mining, and Compressed Air-Power Engineers.

Houses of Parliament Westminster.

Drainage & Ventilation Works on the Shone Hydro-Pneumatic System

(Engineer) Isaac Shone C.E.
3 Westminster Chambers, S.W.



"Sectional perspective view of the Pneumatic Ejector Station, looking from the base of the Clock Tower in the direction of Westminster Bridge."

THE SHONE HYDRO-PNEUMATIC SEWERAGE SYSTEM.

(1). The bulk of this work formed the subject matter of a pamphlet which I wrote for the information of the members of the Imperial Legislature in January last, as will be seen by reference to pages 33 to 50 inclusive. But that pamphlet was in some respects incomplete, as it did not contain all the drawings and explanatory matter that were originally prepared for it. The reason for their omission being that I was afraid to make the pamphlet too bulky for the purpose for which it was intended. (See paragraph 18, page 41.)

(2). A number of members of various professional associations of engineers and architects, who have inspected the new works from time to time since January last, have intimated to me that if the additional drawings, with further explanatory matter referring to the work were published, together with the original matter and drawings, they would be of great service and interest to those professional men who are more or less directly interested in sanitary drainage works; and hence the reason why this pamphlet is now issued to the public.

(3). In judging of the relative merits of the works executed, the reader must carry in his mind a clear conception of the leading sanitary principles which govern all sanitary drainage works, and of what was required to be done in order to do away with the unsanitary conditions described in the pages of the pamphlet addressed to the members of the Imperial Legislature, and which forms the end part of this book —beginning at page 37.

To do this effectually, *i.e.* to abrogate the *unsanitary* conditions and to create *sanitary* conditions in lieu thereof, it was impossible to avoid the execution of some such works as were recommended by the Select Committee.

(4). The substitution of small pipe sewers for the large sewers which existed at the Palace at the date of the appointment of the Select Committee, could no doubt have been undertaken in conjunction with some other plan of pumping the sewage than that which has been adopted.

The conditions, however, obtaining at the Houses of Parliament, as now ascertained by actual experience, warrants me in stating that there is no plan in existence —with which English Engineers at all events are acquainted—that can compare for efficiency with the Pneumatic Ejector Plan adopted.

(5). The quantity of sewage proceeding from the Palace when Parliament is in session amounts to about forty-five or fifty gallons per minute, and not to about 150 gallons per minute as I had anticipated the maximum quantity would be.

The area of the Palace and courtyards to be drained was stated in evidence to be about eight acres, but I believe it is more like ten or twelve acres. For the purposes of calculation, however, I will assume it to be ten acres. An inch of rainfall falling uniformly in twenty-four hours on this area would yield about 160 gallons per minute.

The following table (No. 1) will show the maximum quantities of sewage and rainfall to be received and ejected, supposing that the rainfalls should at any time equal the rainfalls given in the table.

TABLE No. 1.

Amount of rainfall in 24 hours.	Total quantity of rainfall which would have to be dealt with per minute.	Total quantity of sewage which would have to be dealt with per minute.	Total rainfall and sewage per minute.
1 inch.	160 gallons.	50 gallons.	210 gallons.
2 inches.	320 ,,	50 ,,	370 ,,
3 ,,	480 ,,	50 ,,	530 ,,
4 ,,	640 ,,	50 ,,	690 ,,
5 ,,	800 ,,	50 ,,	850 ,,
6 ,,	960 ,,	50 ,,	1010 ,,
12 ,,	1920 ,,	50 ,,	2020 ,,

On the 17th August, 1887, extraordinarily heavy thunderstorms passed over London. The rainfall recorded for London and the suburbs, on the evening of that day, varied from 0·59 inches in Westminster, to 1·42 inches per hour in Camden Square. Notwithstanding this so-called "phenomenal and tropical downpour," the basement of the Houses of Parliament was kept free from flooding; and the subway—retained specially for the temporary storage of storm water—had passed into it about as much water only as could be received and ejected in two minutes!

(6). The drainage of the Houses of Parliament, as viewed by the light of the foregoing statement and Table (No. 1), demonstrates the folly of carrying sewage and rainfall in one and the same drain and sewer. Personally, I hold, and have held for years, strong views in favour of the *separate system*, which our veteran sanitarian, Mr. Edwin Chadwick, C.B., has for years advocated, and which was originally the conception of Mr. John Phillips, C.E. This latter gentleman, I am proud to say, acted as Resident Engineer in charge of the Houses of Parliament Works for me; and I desire to add publicly here my belief that his conscientious testimony as to what he saw of the successful working of my system at Eastbourne induced the Select Committee ultimately, after mature deliberation and investigation, to recommend its adoption at the Houses of Parliament.

(7). The remarks which Mr. Phillips makes in his excellent pamphlet on "Town Drainage," and which every sanitary engineer ought to possess, are worth reproducing here; and I have taken the liberty of doing so. He wrote, in 1872, as follows:—

(A). "The principle of drainage in towns which I advocate, and which was first proposed by me, is called the *separate system*.* This was in 1847, when I was chief surveyor of a large portion of the metropolitan sewers. While so engaged, I examined many miles of these sewers with the view to improving their form and construction; experimented on the air currents, in order to determine where and how to ventilate them; and gauged the sewage and rainfall currents, so as to arrive at the sizes of sewers necessary to drain different urban and suburban districts. After many years' labour and study in this employment, I perceived that it was a great mistake to discharge the sewage into the same channels that received the rainfall, as by so doing the ground we lived on, the air we breathed, and the water we drank were being continually polluted;

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* It is generally thought that Mr. Menzies is the originator of this system. But this is not the fact. I had matured and proposed it nearly eighteen years before he resuscitated it in 1865.

and it appeared to me that the only practical and effectual remedy for this state of things was to discharge the surface and sub-soil water by one set of channels into the water courses and rivers, and to remove the sewage by another set into the country, and there utilise it by irrigation upon, and purify it by filtration through the land.

"In my preliminary report in 1849, on the drainage of the metropolis, I proposed this system for adoption."

(B). "Nothing is more harassing to the inhabitants of towns than to be continually annoyed by defective drainage and sewerage, and to be endeavouring periodically to abate fevers and epidemics occasioned thereby. It has been said that 'it is not now possible to revert to the separate system in towns, because the surface being already drained, and the sewage from the houses being already carried off by the single or combined system, the alterations would be attended with enormous difficulty and cost.' Nothing therefore remains but to continue to battle with the present system. When, however, it is determined to remedy it, no system of works would lead to that end so surely and so satisfactorily as that of the double or separate system of drains, which could easily be arranged and constructed, and the sewage utilised and purified by the process of irrigation and land filtration, as I have pointed out. And with reference to the present drains and sewers in towns, they could be made to conform to this system without much difficulty and expense. It should be borne in mind that, as regards the sewerage and the disposal of the sewage, a great evil is to be remedied, that palliatives act only locally and temporarily, and are wasteful of means; and that it is far better, and in the end much cheaper, to work in accordance with sound principles that will lead to permanency and success. Clear and defined plans with these objects in view could easily be laid down, and the works carried out as circumstances and funds permit."

I have long since perceived the soundness of Mr. Phillips' views. In 1879 I published the "Hydraulic Sewerage Tables" annexed to this pamphlet, my object being to try to show at a glance, if possible, what a sanitary engineer must do if he would remove sewage from houses and towns by hydraulic rule. I hope that by adding these tables to this pamphlet my original object, which is as strong as ever, may be the more widely acted upon.

(8). In connection with the consideration as to whether or not the provisions made by me for dealing with the sewage and rainfall are *reasonably adequate* or not I may state that Mr. Prim, the resident engineer at the Houses of Parliament, in a report addressed on the 6th June, 1885, to Dr. Percy, F.R.S., and which is embodied in the Report on the Sanitary Arrangements of the Houses of Parliament "ordered by the House of Commons to be printed 6th August, 1885," gives a number of details as to rainfalls varying from ·11 to ·74 of an inch in the twenty-four hours, the latter of which he designated an "exceptionally heavy rainfall." In all the cases cited to show that the big sewer of the Palace was occasionally flooded, there was not one recorded to prove a rainfall of one inch in the twenty-four hours. But he made the following statement:— "When it is considered that a rainfall of one-tenth of an inch over the whole area of the building and its courtyards (eight acres) amounts to 18,144 gallons, or eighty-one tons; and that during the twenty-four hours of the 15th of last April no less than 134,000 gallons of rain fell over that area; were it not that the Houses of Parliament sewer had such a large capacity, this immense quantity of storm-water within its own area or watershed, in addition to the sewage, would have proved exceedingly troublesome throughout the entire basement of the building." The 134,000 gallons spread over the twenty-four hours would be equal to ninety-three gallons per minute only, and of course this quantity quadrupled and added to the sewage of the

Palace would only be equal to what one of the Gas-Engine Air Compressors could dispose of through the Ejectors.

(9). Again, Sir Robert Rawlinson, in the evidence he gave before the Select Committee, in answer to question No. 1129, stated :—

"The power should be in duplicate, so that you should not be running to waste. For ordinary purposes, perhaps for nine months in the year, one set of apparatus would be sufficient; but you should have the other in reserve for emergencies. If you had pumps that would throw not less than 12,000 gallons per hour, that in duplicate would be 24,000 per hour, and that would give you a full maximum of 576,000 gallons per day; and according to the statement we have had made, that would be in excess of anything that you can anticipate having to provide for; but the cost of providing for that excess would be insignificant (and the cost of working the excess would be nothing); I would consequently provide for the excess; I would provide power in excess of anything I could anticipate, simply because the first cost additional for apparatus would not be a large item, and the extra working costs would be nothing as regards labour, and would be a very small sum as regards fuel."

According to Sir Robert Rawlinson's testimony, one pump that would deal with 12,000 gallons per hour should suffice, and this should be in duplicate, so that both together could deal with 24,000 gallons per hour as a maximum. This, he thought, would be a fair and reasonable provision to make. But, 24,000 gallons per hour is only equal to 400 gallons per minute; and pumps that could only deal with this quantity would have been completely overpowered on the 17th August, 1887: See (5).

(10). Supposing, however, that ordinary pumps had been specified to do the work of the Houses of Parliament in lieu of the Pneumatic Sewage Ejectors. The speed of ordinary pumps is about 100 feet per minute, and to get anything like good results from them they must be kept running at that speed. If such a pump were put down at the Houses of Parliament to pump the normal volume of sewage—viz., fifty gallons per minute—the size of a double-acting pump suitable for the work would be about four inches diameter. *But such a pump would not take all the unscreened sewage as it proceeds from the Palace as the Ejectors receive it*—to avoid even the temporary retention of sewage under "the Speaker's Green"—*which, in this case, is a point of the first sanitary importance.* But when the quantity of fifty gallons increases to 500 or 1,000 gallons per minute, which may happen in a few minutes, how many pumps would be required to deal with the larger volumes and how could they be set to work automatically as the ejectors are set to work?

A centrifugal pump* to deal automatically with *fifty gallons per minute of unscreened sewage* is equally out of the question—as anyone who is acquainted with the principle, action, and working of this pump will at once see.

(11). The Hydraulic Flushing Ejectors at the heads of the twelve-inch and nine-inch sewers contain respectively 750 and 600 gallons of water, and they each occupy two and a half minutes and one and three-quarter minutes respectively in discharging their contents. But the supplementary discharge of these comparatively large volumes of water, added to the

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* The mean useful effect of eleven experiments, conducted by the German Admiralty upon eleven separate centrifugal pumps, was only 24·26 per cent., with an average lift of 14 feet only; but with an average volume of about 1,800 gallons per minute (Busley—"Die Schiffsmaschine," vol. II., page 228); whereas by the Ejector System the useful effect would be at least double the above.

normal sewage flow of fifty gallons per minute, has no appreciable effect upon the Ejectors, although, as a matter of fact, the additional volumes which have thus to be dealt with at a moment's notice, so to speak, are in excess of the quantity that would proceed from one inch of rainfall upon the entire area of ten acres if spread over the twenty-four hours!

(12). There are, as will be seen further on in this pamphlet, four Gas-Engine Air Compressors of four nominal horse power each, ready to be set to work in a few minutes when occasions of heavy rainfall demand their being employed. One engine is continually kept at work, and although the engine is not doing more than about the one-tenth of what it is able to do—because it is able to deal with a volume ten times greater than the normal sewage flow obtaining at the Houses of Parliament—yet the cost, *in gas consumed*, does not exceed, on the average, *about* $3\frac{1}{2}$*d. per hour per engine.* I mean to say that one of these engines will provide compressed air sufficient for the ejectors to receive and eject about ten times more sewage than the maximum quantity that has been found to proceed from the Palace when Parliament is in Session.

(13). I mention this fact for the reason that some engineers talk about the extraordinary cost attending the use of compressed air in lieu of steam for pumping water or sewage, and they dilate at the same time upon the low efficiencies attending the use of compressed air as a motive power. If what has been stated about the Houses of Parliament in particular is correct—and I am sure the statements cannot be controverted—what is the use of talking about losses and waste of power when the whole cost of ejecting ten times the normal sewage flow at the Palace would barely exceed 4d. per hour, reckoning gas at 3s. 9d. per 1,000 cubic feet?

It is true that one of the four horse-power gas engines, because the maximum amount of work of which she is capable of doing is not forthcoming, is, so to speak, running nine-tenths of its power to waste; but can anyone devise a means by which the Houses of Parliament work could be done for the one-tenth of the cost which is now incurred, viz., ·35 of a penny per hour?

It is thus evident to *unprejudiced* minds that it is something worse than sheer nonsense to talk, as some engineers do, of low efficiencies with such *irregular* work as must always obtain in connection with sewage and rainfall pumping to inconstant heights.

(14). But the one great object aimed at in the work carried out at the Houses of Parliament was to see that neither sewage-proper, by itself, nor sewage in combination with rainfall, should be allowed to remain in the drains and sewers long enough to decompose and become a dangerous and permanent source of nuisance; and that object, I contend, has been accomplished *practically* perfectly.

(15). Since the completion of these works, Mr. Atkinson, the inventor of the Gas-Engine Air Compressors in use at the Houses of Parliament, has made some very valuable improvements to his gas-engine, by which the gas consumption, whilst the engine is at full work, and whilst it is running empty and doing no work, is reduced some 15 per cent. and 33 per cent. respectively; or, supposing the engine to be running half-time during the working day, the saving in gas consumed would be equal to 24 per cent. as compared with the Gas-Engine Air Compressors at the Houses of Parliament.

(16). The Engineers for the Birmingham Compressed

Air Motive Power Company, viz., Professor Henry Robinson, M. Inst. C.E., and Mr. John Sturgeon, C.E. and M.E., are now engaged in erecting works for compressing and supplying air power, in competition with steam and gas, and which will amount in the aggregate finally to about 15,000 horse power!

(17). With some of the Otto Gas-Engines, and the use of "Dowson Gas," wonderfully economical results have been attained already, as may be seen by a reference to an instructive Paper, entitled "Gas Power compared with Steam Power," by Mr. J. C. Dowson, which is to be found in the *Transactions* of the Institute of Civil Engineers: Vol. LXXXIX., page 329.

In places where coal and coal gas cannot be procured at anything like reasonable prices, gasoline, which is the lighter product obtained from the distillation of petroleum, may be used. I have seen one of Atkinson's 4 H.P. Cycle Gas Engines driven by gasoline-gas, produced by a small, compact, inexpensive, and perfectly automatic gas-making machine belonging to "The Automatic Gas Machine Company, Limited," 3, Victoria Street, Westminster, S.W. The price of gasoline in London, at the present time, is about 1s. 2d. per imperial gallon, and one gallon of the oil will yield 200 cubic feet of gas per hour; therefore, 1,000 cubic feet would cost 5s. 10d; and this would make the cost equal to about 1½d. per brake horse-power per hour.

The following table (No. 2), which the British Gas Engine and Engineering Company has endorsed, will be useful as showing the number of gallons which can be ejected to the heights stated, with the several nominal horse-power engines, given in the table, and that by the use of *ordinary* and not "Dowson Gas."

TABLE No. 2.

SIZE OF ENGINE.	Cubic feet of gas of average quality consum'd per day of 24 hours.	Cost at 3s. per 1,000 cubic feet per day of 24 hours.	Cubic feet of gas of average quality consumed per hour.	Cost at 3s. per 1,000 cubic feet per hour.	Air pressure in lbs per square inch.	Cubic feet of compressed air per minute.	Gallons of sewage per minute.	Feet lift of sewage.
1 H. P. nom	850	s. d. 2 6½	31·25	d. 1 625	5	25·3	164	11·5
					10	11·97	74	23
					15	7 11	44	34·5
					20	5 175	32	46
					25	3·87	24	57·5
					30	2·7	16	69·
2 H. P. nom	1,560	s. d. 4 8	65	d. 2·3	5	58·5	365	11·5
					10	26·6	166	23
					15	15·8	99	34·5
					20	11·5	72	46
					25	8·6	54	57 5
					30	6·0	37	69
4 H. P. nom.	2,640	s. d. 7 11	110	d. 4	5	130	813	11·5
					10	59	370	23
					15	35·2	220	34 5
					20	25·6	160	46
					25	19·2	120	57·5
					30	13·6	85	69
6 H. P. nom.	3,600	s. d. 10 10	150	d. 5·4	5	208·	1,300	11·5
					10	94·7	592	23
					15	56	350	34·5
					20	40·9	256	46
					25	30·7	192	57·5
					30	21·6	135	69

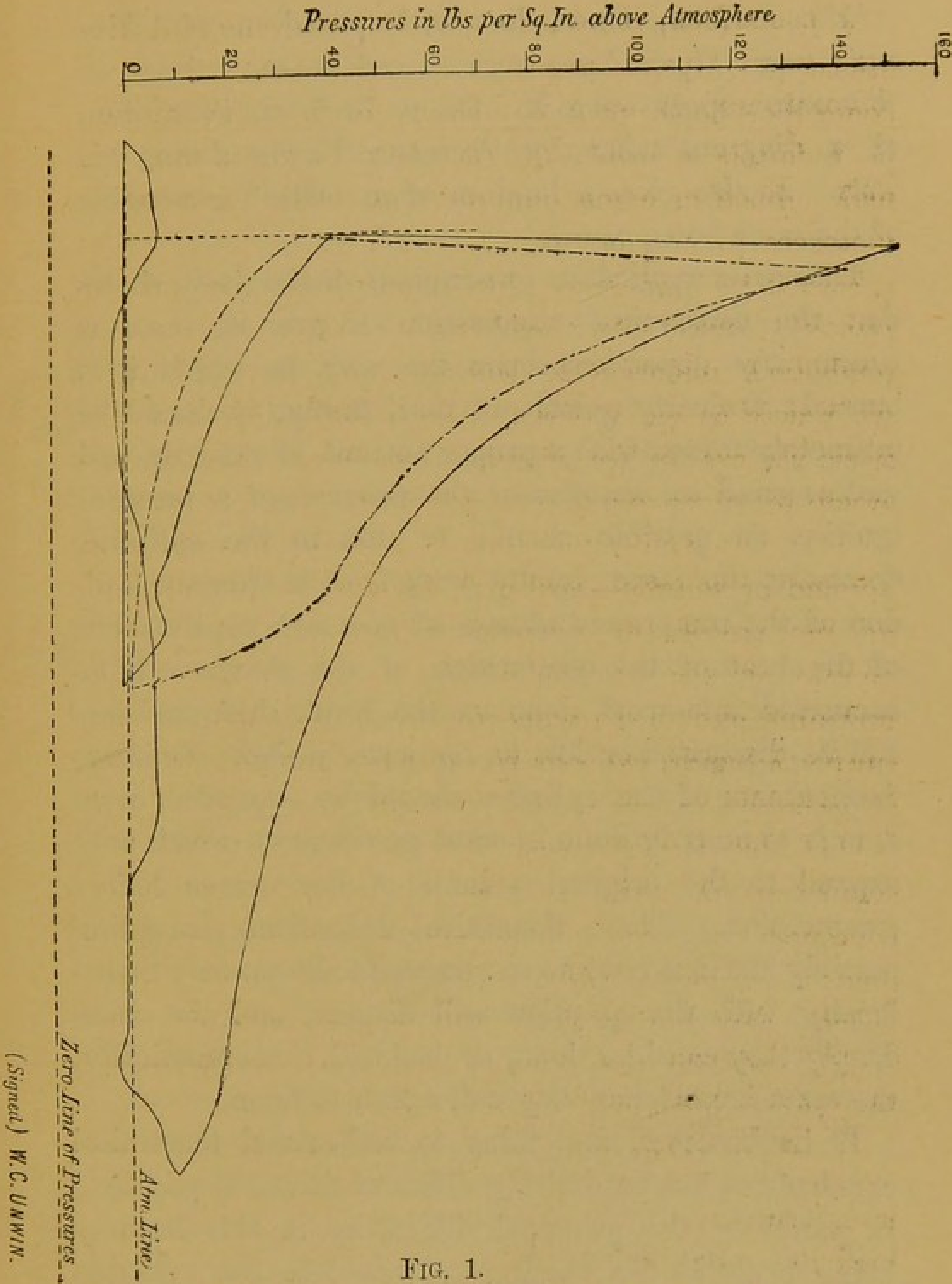


FIG. 1.

NOTE.—"Cycle" diagram in full black line. Diagram No. 10, Trial 1.
Nominal horse-power, 4. Diameter of cylinder $7\frac{1}{2}$ inches. Revolutions, 148·6.
Mean effective pressure, 32·5 pounds per square inch, calculated for stroke of $10\frac{1}{8}$ inches, or 35·6 pounds per square inch on working stroke of $9\frac{1}{4}$ inches.
"Otto" diagram in dotted black line, from Dr. Slaby's report, pro Inst. C.E., 1885, Appendix to Jenkins' lecture.
Nominal horse-power, 4. Diameter of cylinder, $6\frac{3}{8}$ inches. Revolutions, 156·7.
Mean effective pressure, 52·9 pounds per square inch for stroke of $13\frac{1}{2}$ inches.
The diagrams are superposed by taking the volumes of compressing stroke equal.

(18). Professor Unwin has lately tested one of Atkinson's new "Cycle" gas-engines, and he has written an elaborate report upon it. On p. 13 is an illustration of a diagram taken by Professor Unwin during his tests. It also gives a diagram of an "Otto" gas-engine of the same horse-power.

Theory as applied to gas-engines distinctively shows that the economical combustion of gas in them is enormously dependent upon the way in which it is burned; it clearly points out that, firstly, it should be intimately mixed with a proper amount of pure air, and that as small an amount of the products of a previous ignition as possible should be left in the cylinder. Secondly, the more rapidly work is done after the ignition of the compressed charge of gas and air, the more of the heat of the combustion of the charge will be converted into work done on the crank shaft, and less will be dissipated or lost in the water jacket. Thirdly, the contents of the cylinder should be expanded more than is commonly done in most gas-engines, which only expand to the original volume of the charge before compression. These theoretical deductions (excepting possibly the first one) no one acquainted even only superficially with the question will dispute, and the more deeply they consider them, or deal with them practically, the more importance they will attach to them.

It is, however, one thing to understand theoretical conclusions, but an entirely different matter to put them in practice; the principal difficulties in this instance being to obtain the varying capacities in the cylinder, so as to drive out practically all the residuum, to draw in a charge, to compress it into a suitable capacity for ignition, to expand it to a greater volume than when drawn in at atmospheric pressure and temperature, and to drive out the consumed charge, in a mechanical manner. Atkinson's "Differential" engines, however, did perform these operations, and as a result these engines would develop a brake or effective horse-power for less gas than any other engine. The "Cycle" engine has been designed on the same theoretical principles, but with still greater relative expansion. It is constructed with one single-acting piston coupled to the crank shaft in such a manner that it makes two outward and two inward strokes for each revolution of the shaft, a short suction stroke, a rather shorter compressing stroke, a long expansion working stroke, and a rather longer exhaust stroke.

The cut of the indicator diagram will make this clear; for comparison, the diagram of an "Otto" gas-engine of a similar power is shown. The advantages of the Atkinson "Cycle" engine are at once obvious; it will be seen that its expansion line keeps above the Otto expansion line, giving a very considerable gain in power even up to the expansion to original volume, and in addition to this there is a clear gain of the power shown in the diagram by the continued expansion. The Otto engine commences to exhaust at 30lbs. to 40lbs. pressure. The "Cycle" engine continues to expand down to 14lbs. pressure.

Another great advantage of the "Cycle" engine is in the valve gear, which is extremely simple; there is no slide, ignition is always certain, and there is never any difficulty in starting. Also as the engine gives out power every revolution it is much more regular, and is not subject to such heavy intermittent shocks as compared with engines that only get an ignition at the most at every other revolution.

Owing to the arrangement of the working gear, the work is done in one-fourth of the time required in any other engine, consequently the loss to the water-jacket is less. This is clearly shown by the diagram. According to Professor Unwin's report, the "Cycle" engine loses only 19·37 per cent. of the total heat in the gas to the water, compared with the usual fifty per cent. and over lost by other engines. He also certifies that a four horse-power engine will give a brake horse-power for 22·11 cubic feet of gas (the lowest published tests of any other four horse-power engine is thirty-two cubic feet, which is forty-four per cent. more than the amount required by "Atkinson's" engine). When the engine is working at full power, the loss due to engine friction, back pressure, &c., is only one tenth, which is remarkably little, and is a conclusive proof of the durability of the engine.

(19). A number of architects, after seeing the Hydraulic Flushing Ejectors at the Houses of Parliament, were wishful to see a drawing of my Hydraulic House-Sewage Ejector—and for their information I have added the illustration (Fig. 2) on page 17.

This apparatus, like the Pneumatic Sewage Ejector, will take all unscreened sewage as it proceeds from the House, and it will automatically eject the same into the public sewer without the expenditure of any other power than that which the natural storage of the sewage resources of the household yields.

Illustration Fig. 3 is given by way of showing how the apparatus may be used for connecting the house drains with the main sewer. The house sewage ejector is intended to be used at houses which are already connected with public sewers more or less foul and dangerous, as it is at once both a sewage-gas trap, and a main-drain flusher and ventilator. It is equally a necessary adjunct to the small main-drains of new houses, whether the latter are joined to old or to new gravitating sewers.

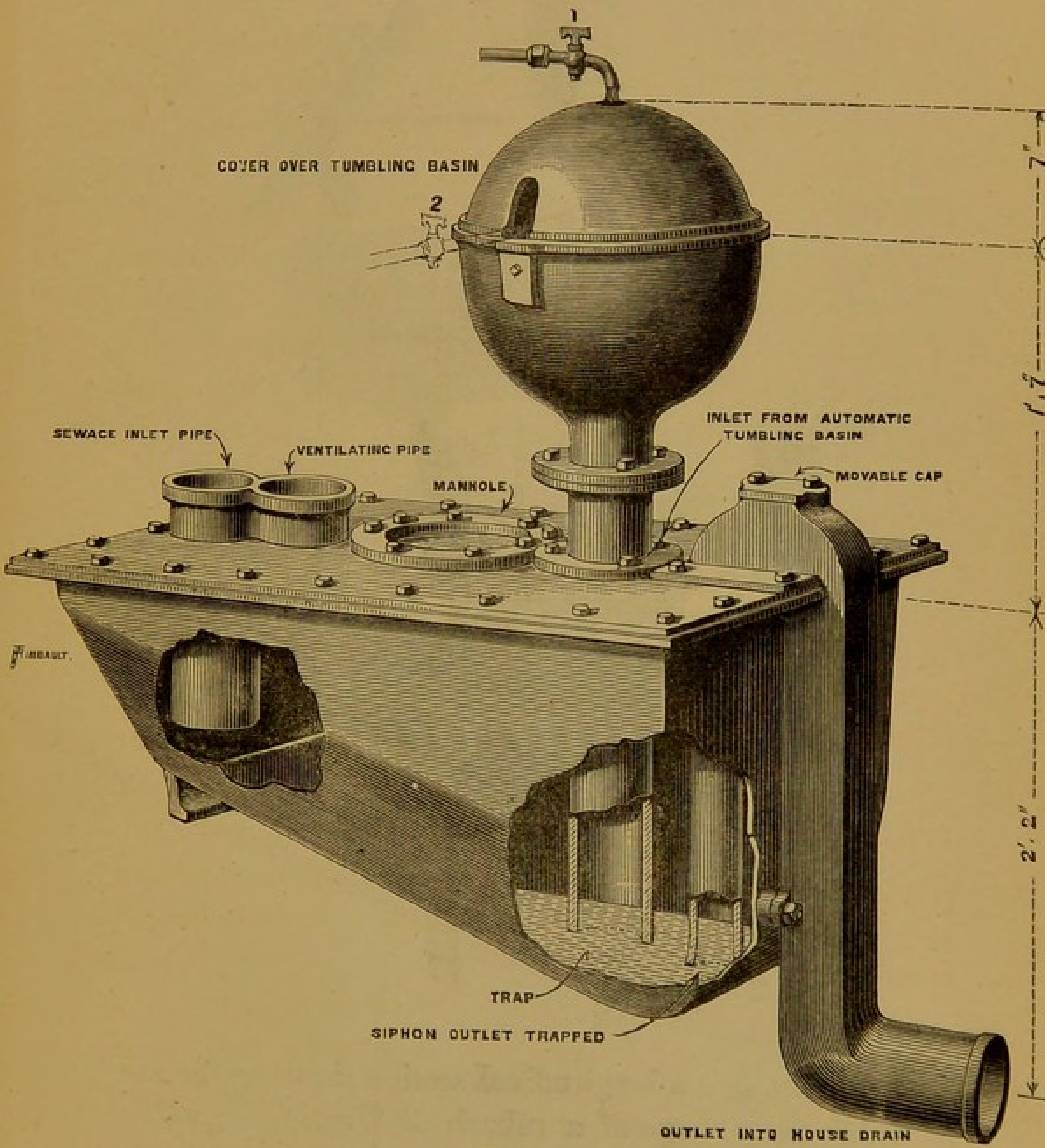


Fig. 2.

(20). Illustration Fig. 4 is suggestive of the way in which a large mansion or Institution may be drained by the aid of the Pneumatic Ejectors.

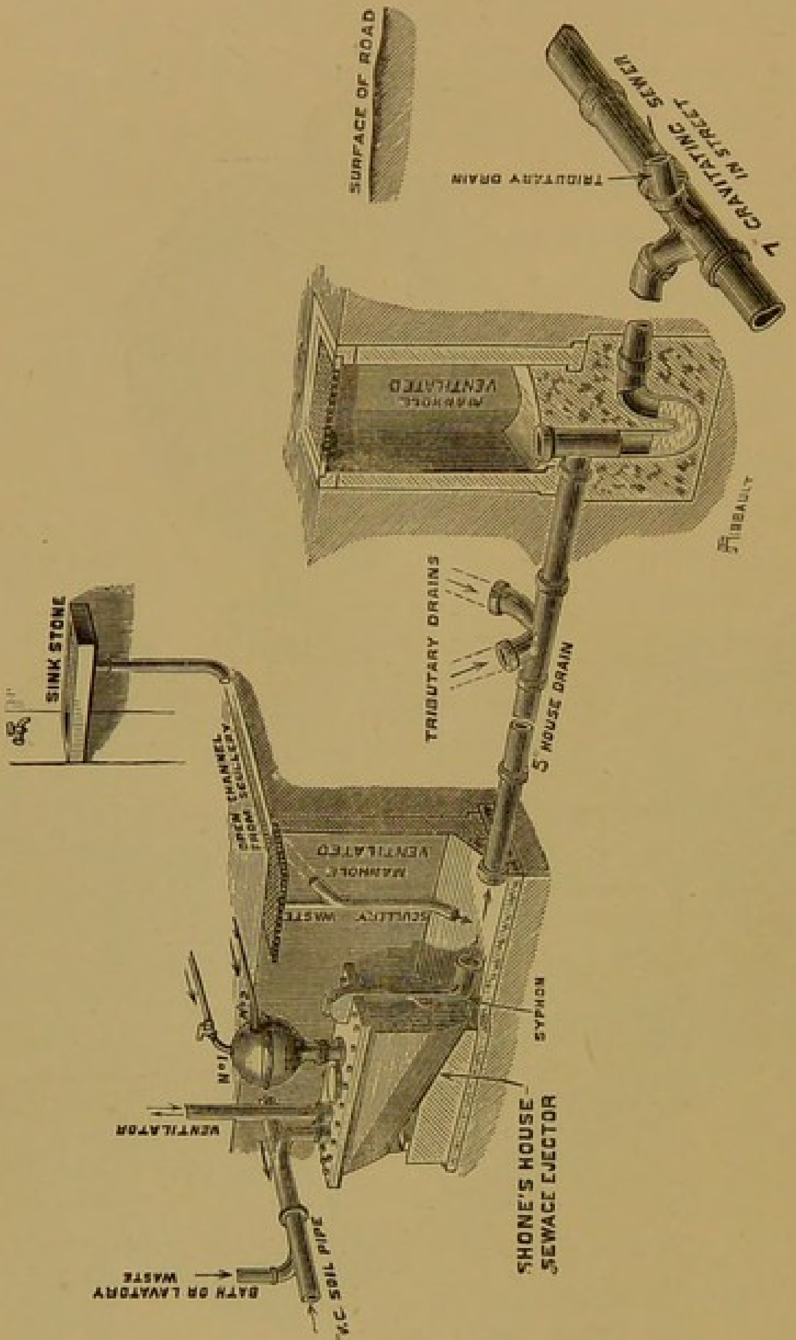


Fig. 3.

(21). Fig. 5 is a longitudinal section showing the way in which the sewage of a suburb of Warrington, called Latchford, is received and Ejected over a canal, into the old system of sewers which previously were sewers of deposit and non-self-cleansing, but which are now, by the aid of the Pneumatic Ejectors, made self-cleansing;

because the Pneumatic Ejector acts on these old sewers in the same way as if it were a Hydraulic Flushing Ejector at the head of them.

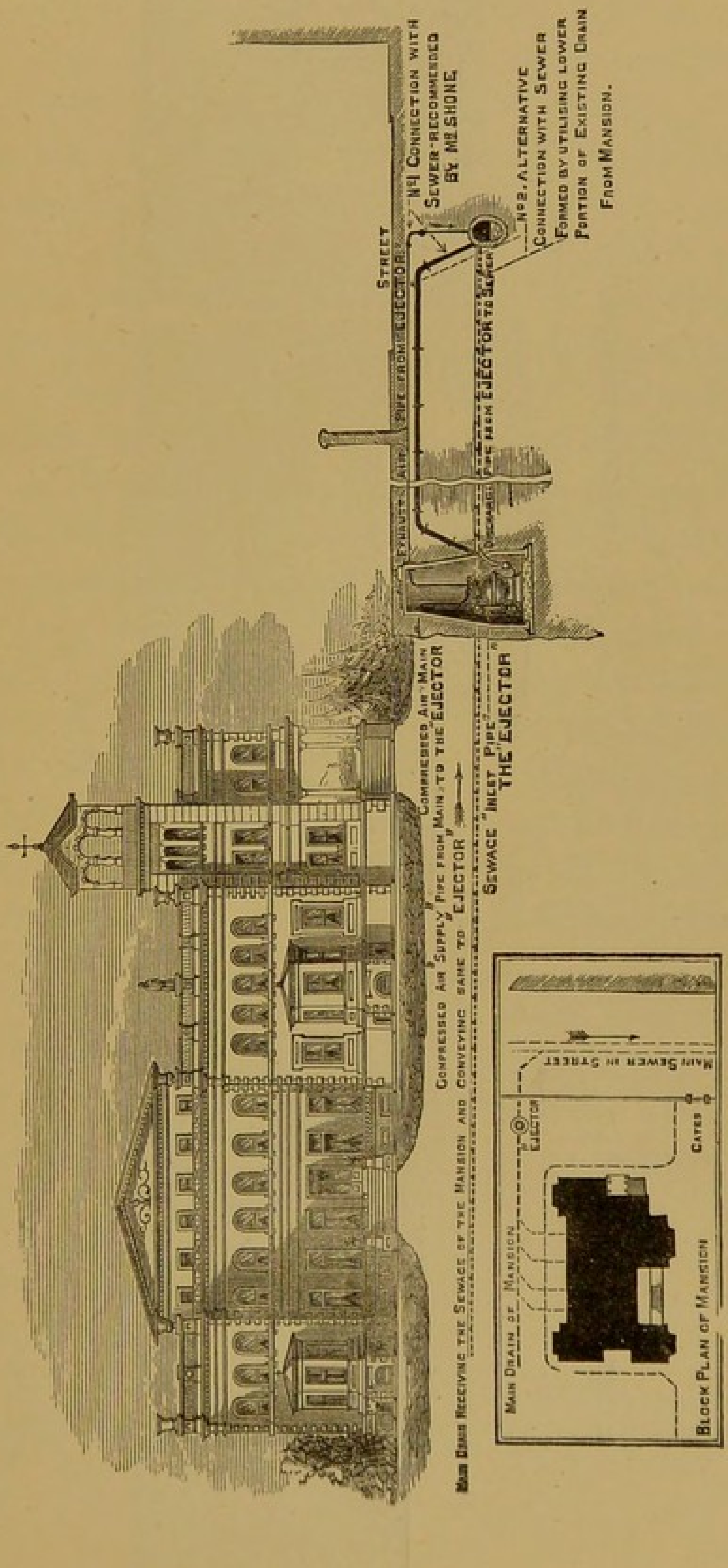
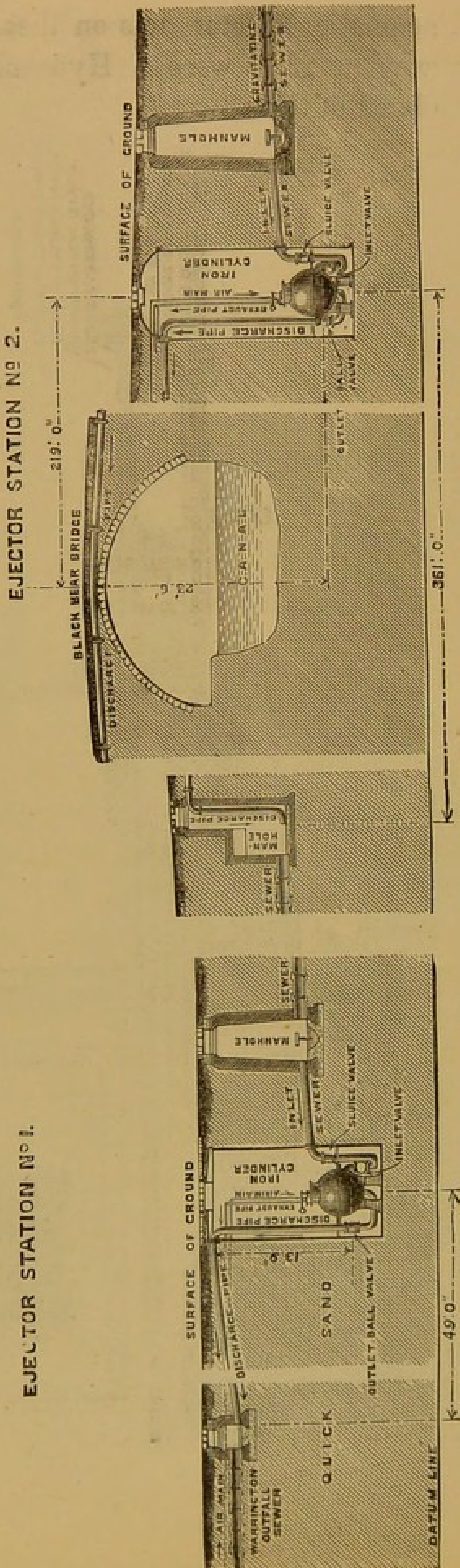


Fig. 4.



EJECTOR STATION No 2.
SURFACE OF GROUND
MANHOLE
GRAVITATING SEWER
INLET SEWER
SLUICE VALVE
INLET VALVE
IRON CYLINDER
AIR MAIN
EXHAUST PIPE
DISCHARGE PIPE
BALL VALVE
OUTLET
219' 0"
BLACK BEAR BRIDGE
DISCHARGE PIPE
CANAL
23' 6"
361' 0"
MAN-HOLE
SEWER
EJECTOR STATION No 1.
SURFACE OF GROUND
DISCHARGE PIPE
SAND
QUICK
OUTLET BALL VALVE
13' 9"
49' 0"
AIR MAIN
WARRINGTON OUTFALL SEWER
DATUM LINE

Fig. 5.

This illustration may, however, mislead some people, as it gives the Ejector system the appearance of receiving the sewage at one point, and lifting it in a series of steps or stages till it finally reaches the outfall. This mode of dealing with sewage, however, in a number of places, may not only be advantageous, but economical.

At the same time the sewage of Ejector Station No. 2 might be carried in an iron sewage pipe, like a water pipe, to and past Ejector Station No. 1, direct to the outfall, without passing into the Ejector at No. 1 Station at all. In that case the iron sewage-main would be common to both Ejectors. The size of the pipe carrying the sewage from No. 2 to No. 1 would be made suitable to the volume of sewage ejected from that station. But when the sewage main reached Station No. 1, its size would then be increased from that point forward, so as to make it large enough to carry the discharges from Nos. 1 and 2 Ejector Stations. The advantages of this plan of ejecting sewage under pressure, and preventing all possibility of sub-soil leakage from without, and the leakage of sewage from within, as well as the prevention of sewage gas emanations on the line of the outfall sewage main, must by this time be self-evident to every sanitary engineer.

(22). Plate 6, too, will help to show how power may be derived for operating my system from a water wheel, and distributed over large areas for receiving and expelling both sewage and the water supply of a town.

(23). Plate 7 will doubtless convey a good idea as to the way in which the apparatus used in connection with the Shone System is employed.

The Hydraulic Sewage Ejector is seen to be connected with the baths, w.c.'s, &c., of the house, and the

Hydraulic Flushing Ejector is shown as being at the head of the small, but properly graded, pipe sewer, leading the sewage of the houses, as well as the flushing water, to the Pneumatic Ejector Station, from whence it is ejected, under pressure or otherwise, to the outfall, which may be a river, the sea, or land for utilisation or treatment.

(24). Illustration Fig. 6 shows the application of the Pneumatic Ejectors at the Houses of Parliament, which with the explanations which appear in the latter portion of this pamphlet will be readily understood.

(25). The plates which were omitted from the pamphlet issued to the Members of the Imperial Parliament are the following, and are annexed hereto :—

Plate 4.

Fig. 1 shows in plan the Houses of Parliament and the line of its main sewers, &c.

Figs. 6 and 7 show in plan and section the 750 gallon Hydraulic Flushing Ejector, which is fixed at the head of the twelve-inch main sewer; and Figs. 8 and 9 show in plan and section the 600 gallon Hydraulic Flushing Ejector which is fixed at the head of the nine-inch central sewer.

Plate 5.

Fig. 2 is a longitudinal and cross section of the old main sewer with the new twelve-inch iron pipe laid on its invert, &c.

Fig. 12 shows the way in which the nine-inch and twelve-inch sewers are ventilated.

Fig. 13 shows the way in which the subway (the old

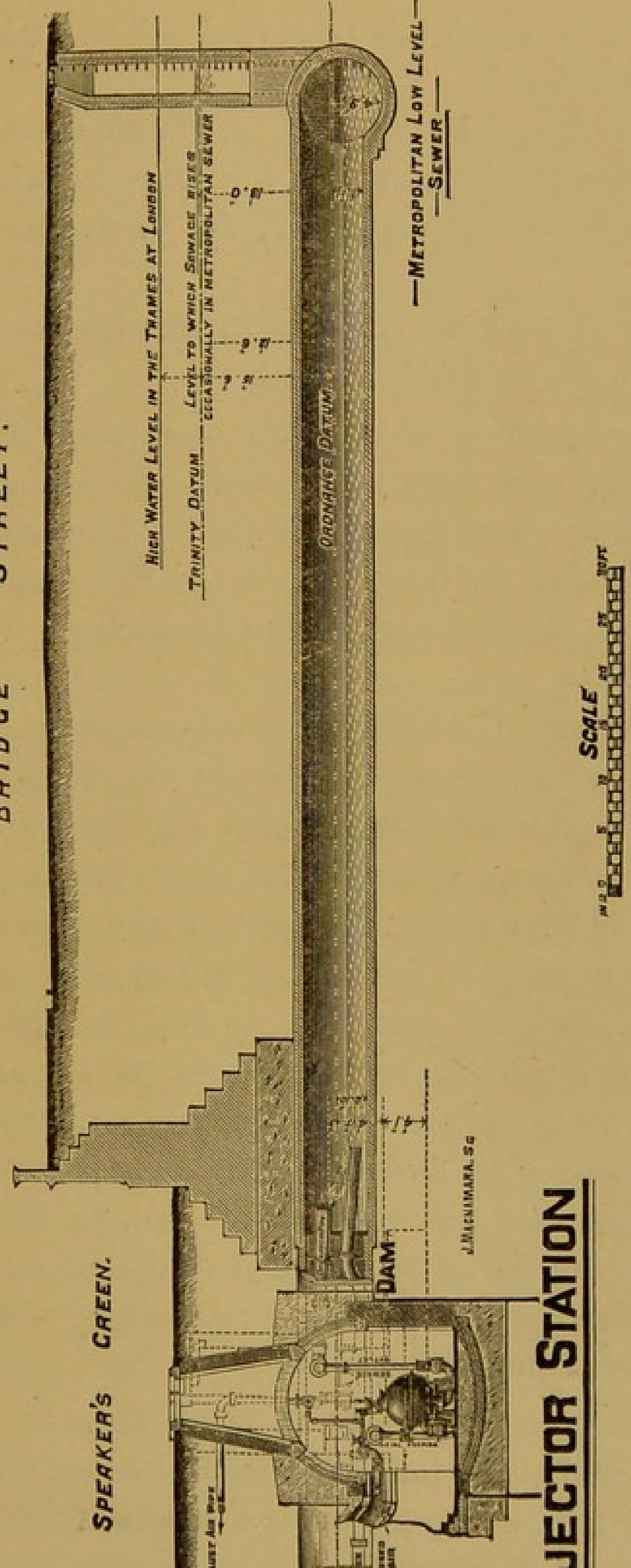

BRIDGE STREET.
SPEAKER'S GREEN.
HIGH WATER LEVEL IN THE THAMES AT LONDON
TRINITY DATUM
LEVEL TO WHICH SEWAGE RISES OCCASIONALLY IN METROPOLITAN SEWER
ORDNANCE DATUM
METROPOLITAN LOW LEVEL SEWER
DAM
EJECTOR STATION
EXHAUST AIR PIPE
COMPRESSED AIR
SCALE
J. MACNAMARA, SC.

FIG. 6.

main sewer), in which the new twelve-inch main sewer is laid, is ventilated.

Figs. 14, 15, and 16 are plan, longitudinal, and cross sections respectively, showing the way in which the connections have been made with the twelve-inch main sewer.

Figs. 17, 18, and 19 are details, showing the inspection caps on the twelve-inch main sewer.

(26). The question of cost has been raised by one or two engineers who thought the works might have been carried out for less money. Possibly they could, but doubtless neither the Government nor the nation would wish to adopt the cheapest design for such work at such a building!

The question of cost is of course important in the abstract. But if sewerage on the old lines costs less than sewerage on the new lines, which may be the case in numerous instances, although not so in the majority of cases; and if the main drains and sewers on the old lines are for the most part drains and sewers of deposit, and badly ventilated, and consequently foul and unsanitary; and the sewers on the new lines are self cleansing and efficiently ventilated, and consequently sanitary—*as the new main sewers of the Houses of Parliament now are;* then it is manifest that the question of cost, as it is sometimes raised by the advocates of a system of drains and sewers on the old lines, is most misleading and hurtful to the cause of sanitary science.

(27). There are at present no fewer than twenty-two different installations on the Shone System—and not the least important amongst these is the beautifully situated and quaint old town of Henley-on-Thames, which is so celebrated for its Regattas. At Henley, a comparison may be fairly drawn, as between the initial and annual cost of works actually carried out by me, and the *estimated* initial and annual cost of a counter-scheme, *on the old lines*—which had been submitted to the Corporation of Henley, and had been rejected, before I was commissioned to prepare my scheme, which was accepted.

The rejected scheme embraced the taking into the sewerage system, (1) sewage proper, (2) subsoil water, and (3) half an inch of rainfall in twenty-four hours. This was a pumping scheme, and the maximum quantity of sewage, subsoil water, and rainfall estimated to be pumped was 192·6 cubic feet, or 1,204 gallons per minute. The accepted scheme is on the "separate system," and when all the main sewers were completed they were practically free from subsoil water. The Corporation, *very wisely indeed*, have passed a bye-law strictly prohibiting the passage into the sewers of rainfall and other waters, which would not, if allowed to flow into the Thames, unreasonably pollute it. By thus adopting the *separate system*, the maximum quantity of sewage-proper, unavoidable leakage, and unavoidable rainfall, which will have to be dealt with, has been estimated to be 250 gallons per minute only, or just the $\frac{1}{5}$th of the quantity provided for in the rejected scheme.

The estimated cost of the rejected gravitation and pumping scheme on the old lines, as given by the engineer of that scheme, is stated below; as is the cost of equivalent works actually carried out on the Shone System.

INITIAL COST.

Estimated Initial Cost of the Rejected Gravitation and Pumping Scheme.	£ s. d.	£ s. d.	Initial Cost of the Accepted Scheme on the Shone System as executed.	£ s. d.	£ s. d.	Difference in favour of the Shone System. £ s. d.
Gravitation Sewers, Manholes, Junctions, Tank Sewer, Contingencies, &c... ..	..	9,805 2 7	Gravitation Sewers, Junctions, Manholes, Ventilators, Ejectors, Ejector Stations, C.I. Sewage and Air Mains, and Air Vessels, &c., complete	..	8,655 5 1	1,149 17 6
Buildings and Outfall Works	6,395 2 5		Buildings and Outfall Works	3,631 4 2		
Machinery	2,427 5 0	8,822 7 5	Machinery	2,490 15 6	6,121 19 8	2,700 7 9
		£18,627 10 0			£14,777 4 9	£3,850 5 3

ANNUAL COST OF WORKING.

Rejected Scheme.	£ s. d.	£ s. d.	Accepted Scheme.	£ s. d.	£ s. d.	Difference in favour of the Shone System. £ s.
Cost of Pumping ..	*240 0 0		Coal, Oil Waste, &c...	235 0 0		
Treatment of Sewage, 5,000 persons at 1s. 6d.	375 0 0		Engineer, Fireman, cost of attending to Outfall Works; and repairs and maintenance of Sewers and Ejector Stations ..	225 0 0	460 0 0	255 0 0
Repair and maintenance of Sewers	100 0 0	715 0 0				
		£715 0 0			£460 0 0	£255 0 0

* This item must have been under-estimated.

(28). According to the foregoing, the first and annual cost of the rejected scheme exceeded the first and annual cost of the accepted scheme, as now executed, by 20·7 and 35·6 per cent. respectively. But this is not all. The sewage had to be lifted 41 ft. only, as per the rejected scheme, whereas the lift, including friction, is 180 ft. in the executed scheme. Moreover, the site selected for the outfall in the executed scheme is about one mile further away from the town than the site which had been proposed for the outfall in the rejected scheme.

By placing the outfall where it is, in a wood, out of sight and out of mind—*and on my system, the outfall and pumping station can be placed anywhere, on poor, out-of-the-way, and unobjectionable situations*—all opposition disappeared; and the Corporation were able to purchase the land required for the outfall site, at a *reasonable price.*

It is to be hoped that this brief description of the works at Henley will satisfy engineers that it is a great mistake to take it for granted—as some people have done—that because I want, in order to set my *sanitary* system in operation, (1) stoneware gravitation sewers, (2) iron sewage delivery pipes, (3) iron compressed air delivery pipes, (4) pneumatic ejectors and ejector stations, and (5) air compressing plant, the first cost of establishing the system must, therefore, be greater than it is for a gravitation and pumping system on the old lines.

(29). The various questions put to me personally by many of the gentlemen who have inspected the new Drainage Works at the Houses of Parliament, induce me to hope and believe (as I have already intimated in paragraph 2, p. 1), that the addition of the foregoing pages, together with the drawings, &c., connected therewith, to my original pamphlet, which is to be found in the succeeding pages, will tend to the further elucidation of the character and nature of my Hydro-pneumatic System of House and Town Drainage.

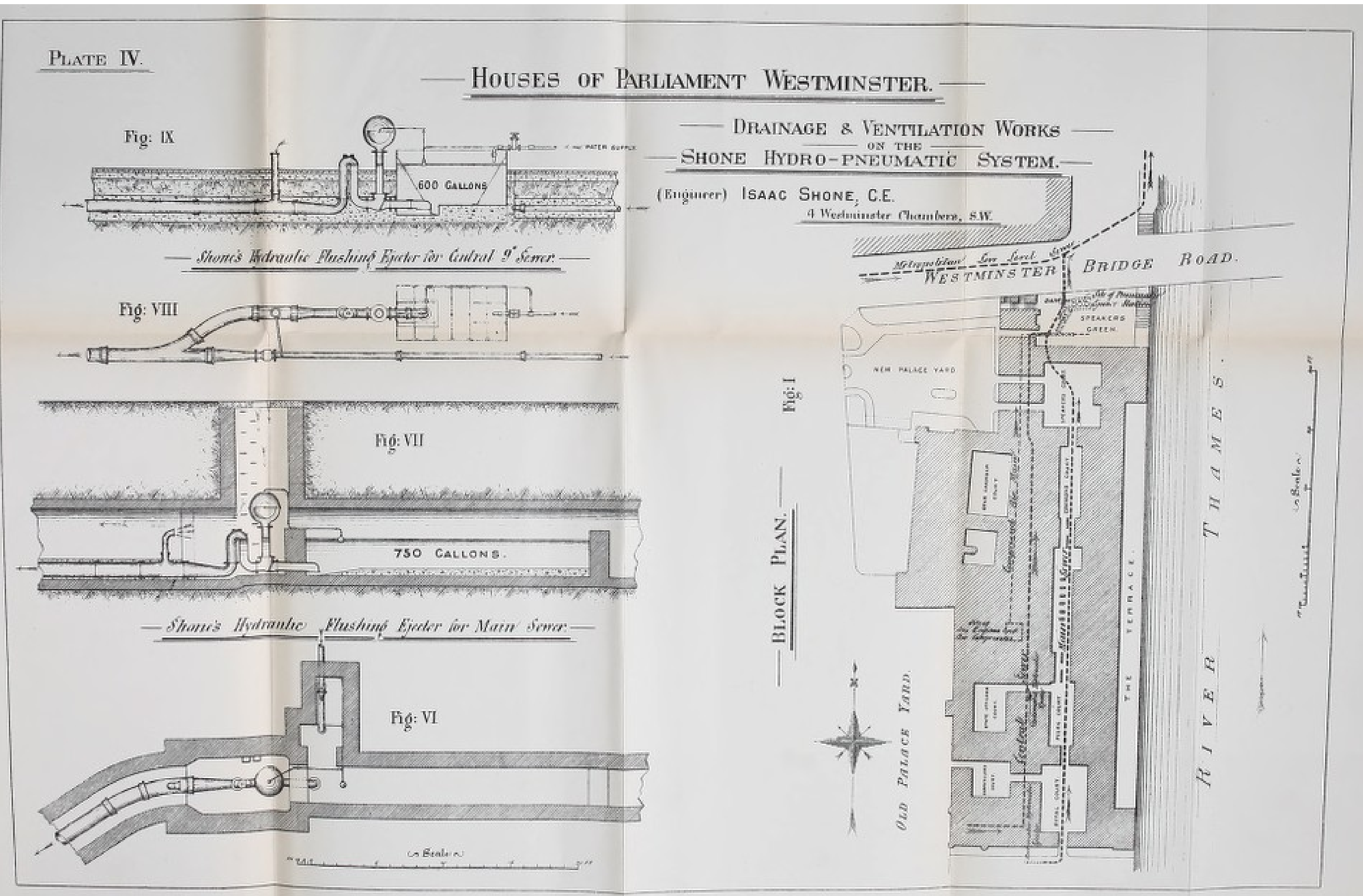


Plate IV.
Houses of Parliament Westminster.
Drainage & Ventilation Works
on the
Shone Hydro-pneumatic System.
(Engineer) Isaac Shone, C.E.
4 Westminster Chambers, S.W.
Fig: IX
600 Gallons
Water Supply
Shone's Hydraulic Flushing Ejector for Central 9" Sewer.
Fig: VIII
Fig: VII
750 Gallons.
Shone's Hydraulic Flushing Ejector for Main Sewer.
Fig: VI
Scale
Westminster Bridge Road.
New Palace Yard
Speakers Green
The Terrace.
River Thames.
Old Palace Yard.
Block Plan.
Fig: I
Scale

PLATE V.

HOUSES OF PARLIAMENT WESTMINSTER

DRAINAGE & VENTILATION WORKS ON THE SHONE HYDRO-PNEUMATIC SYSTEM

(Engineer) ISAAC SHONE, C.E.
4 Westminster Chambers, S.W.

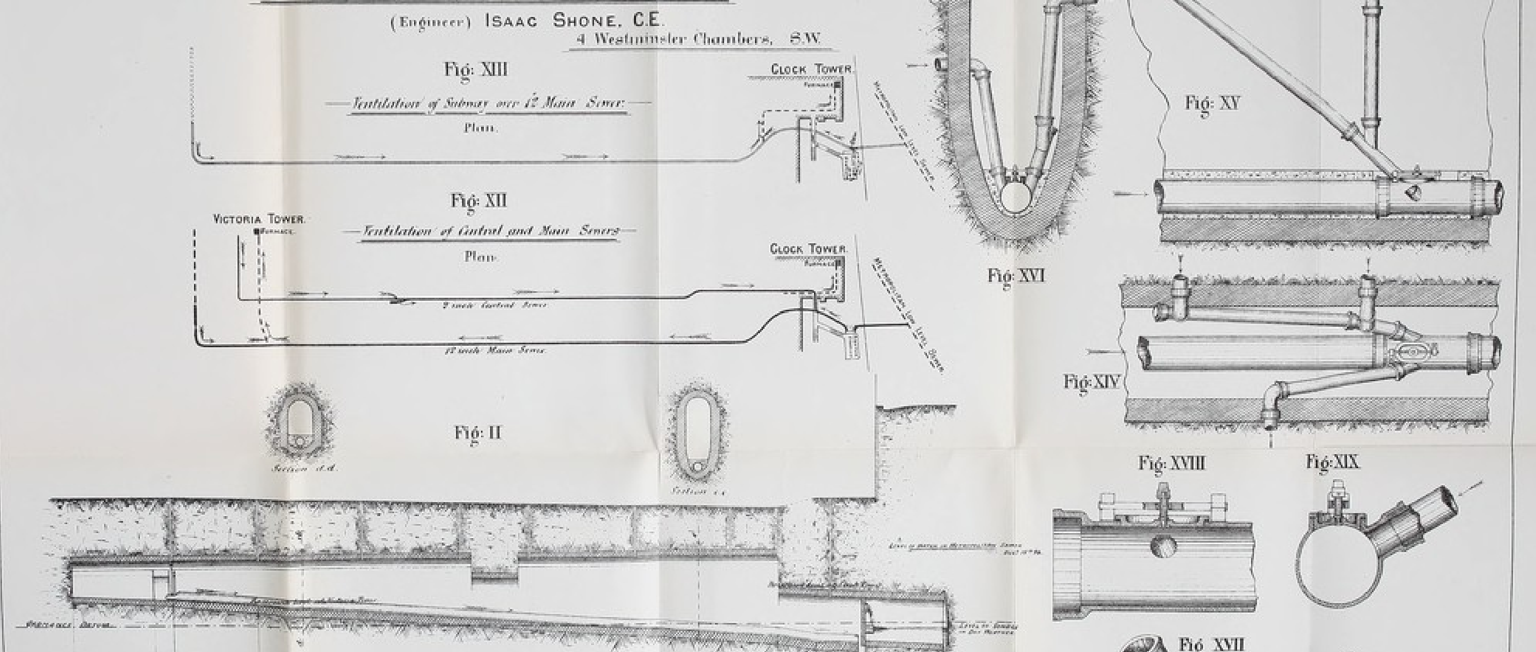
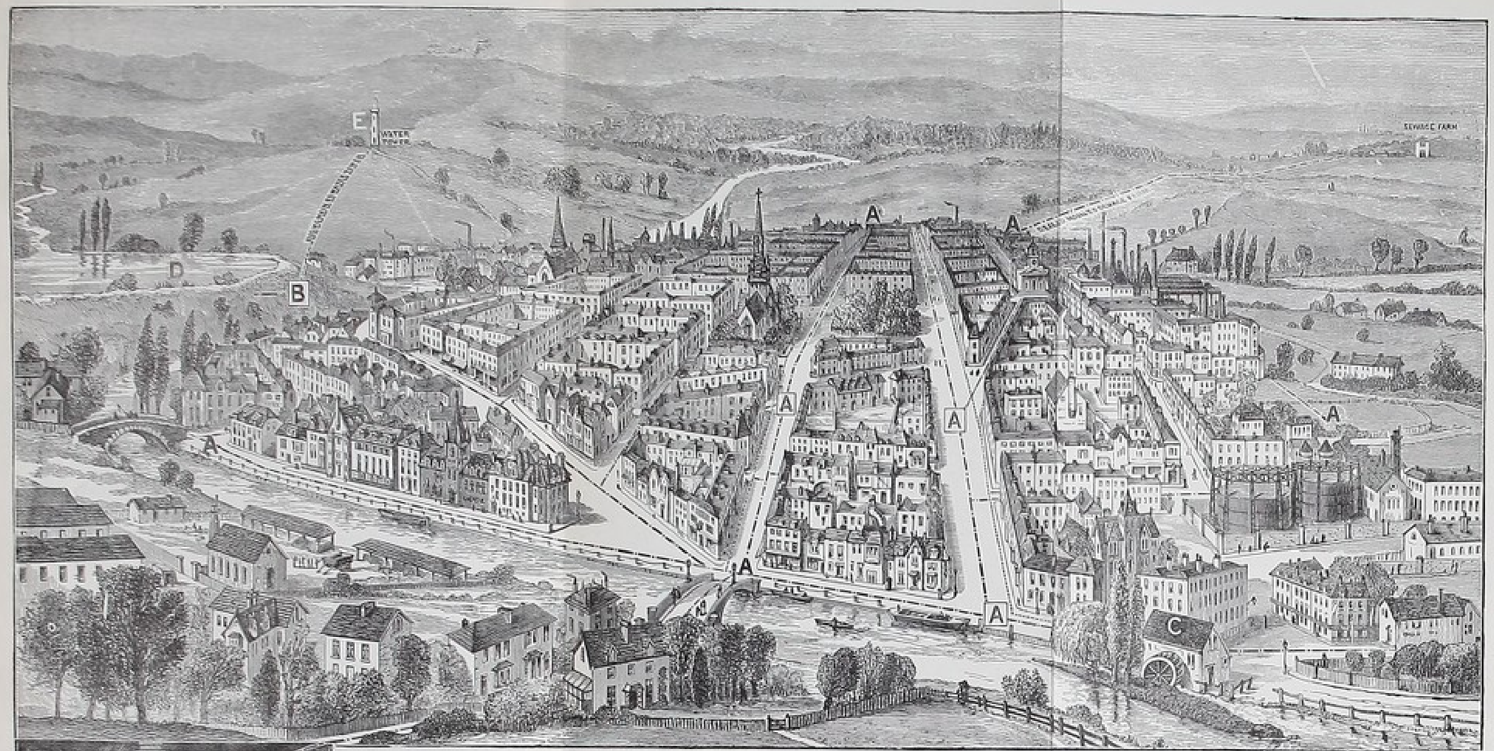
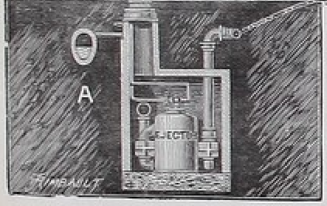


PLATE 6.





A. The points marked A in the print are underground chambers, in which one or more pneumatic Ejectors are placed, for ejecting Sewage. One of these Ejectors is shown in its relative position in the lower left-hand corner.

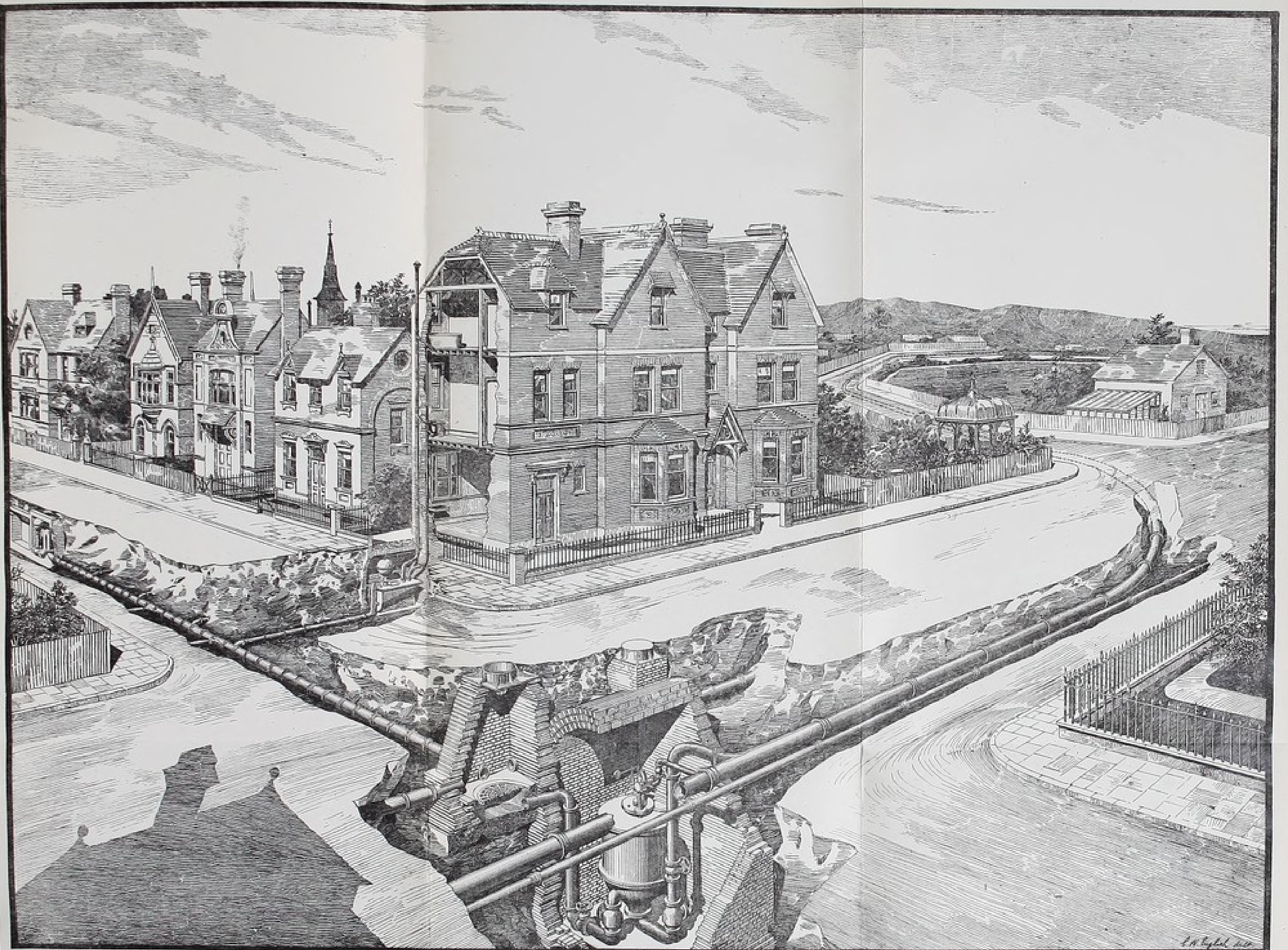
B. A similar Ejector for supplying the town with water, which lifts water from the Reservoir D to the Water-tower E.

C. An Air-Compressing Station from which all the Ejectors are actuated. In this case a water-wheel is most advantageous, but the compressed air can be conducted from a distance without sensible loss. A steam engine, gas engine, or any other prime mover will drive an Air Compressor cheaper and better at the central station than a number of small pumps at different points could do the same work.

D. Water Reservoir for supplying the lower parts of the town.

E. Water-tower with tank for supplying the higher parts of the town.

H. Sewage farm situated in such a place that the purified water cannot flow to the wells that supply water to the town.



THE SHONE HYDRO-PNEUMATIC DRAINAGE & SEWERAGE SYSTEM.

PART II.

PREFACE.

As every Member of the House of Lords and every Member of the House of Commons is necessarily interested in the sanitary condition of the Houses of Parliament, and as efficient drainage, and ventilating arrangements connected therewith, contribute more than anything else towards the attainment of satisfactory sanitary conditions, the Author hopes that this pamphlet, descriptive of the old and new *main* drainage works (a copy of which he has the honour of presenting to each Member of both Houses), will satisfy them that the Select Committee of the House of Commons, appointed on the 23rd March, 1886, "to inquire into the Ventilation of the House," were fully justified in condemning the old, and in recommending new and improved main drainage works to be carried out.

After the report of the Select Committee had been referred to the Commissioners of Her Majesty's Works and Public Buildings, the then First Commissioner, Lord Elgin, requested the Author to report upon and to supply estimates in detail for executing the works recommended by the Committee. Subsequently, he was honoured with instructions from His Lordship to prepare the necessary drawings, specifications, &c., for submission to Contractors to tender upon; and he was at the same time appointed the Engineer to carry out the works, with as little delay as possible. The confidence thus reposed in him by Lord Elgin has been continued by the present Chief Commissioner, the Right Hon. D. R. Plunket.

The works being now complete, the Author respectfully asks each Member of both Houses to do him the honour to inspect them, more especially as he confidently submits them to their notice as being practically—what they really ought to be, at the Imperial Houses of Parliament—as "reasonably perfect" a sample of sewage-drainage works, on the lines of the English water-carriage system, as it is necessary, on sanitary grounds, to attain to.

Apropos of the importance of this statement, the Author takes the liberty of quoting here an extract from Professor Huxley's address to the Society of Arts on the 25th October, 1881. He then said:—"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. If it is perfect, then it is very perfect; and, in fact, it is the only possible system in great cities in the present day. It has, however, this terrible peculiarity, that if it is imperfect, it becomes the most admirable 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?"

ISAAC SHONE.

4, Westminster Chambers,
London, S.W.

January, 1887.

CONTENTS.

THE MAIN DRAINAGE

OF THE

HOUSES OF PARLIAMENT,

WESTMINSTER.

---

(1). In 1839 Sir Charles Barry laid down, under the middle of the Houses of Parliament, from north to south, a large nearly flat-bottomed brick sewer, which discharged into a similarly constructed sewer in Abingdon Street, near the Victoria Tower. The main sewer in 1839

(2). This sewer, owing to its bad form, excessive size, little fall, and absence of any means for flushing it, accumulated a large amount of sewage deposit, the gaseous emanations from which continually polluted the air of the Palace.

(3). In 1846 the smells from the Palace sewer were so bad that Sir Charles Barry consulted Mr. John Phillips, C.E., who was then the Chief Surveyor to the Westminster Commissioners of Sewers, with a view to its improvement. Mr. Phillips, after examining the sewer, recommended that a narrow, deeply curved invert, with a reversed fall, should be substituted for the old invert, and that it should be continued northward, across the Speaker's Green, into the outlet of a sewer in Bridge Street, which latter he found to be about five feet lower than the sewer in Abingdon Street.

The original 1839 sewer amended about 1848.

(4). Sir Charles Barry not only adopted and carried out these recommendations, but the increased depth enabled him to construct two main branch drains from near the lower end of the new portion of the sewer, for draining the east and west sides of the Palace at a much lower level than they were originally.

(5). By the better gradient thus obtained, and by the narrow and deeply curved invert put in, the sewer as altered, supplemented with ample flushing power, became self-cleansing, and it continued in this improved condition for a quarter of a century, until twelve or thirteen years ago.

At that time, about 1873, the Metropolitan low level sewer—seven feet nine inches in diameter—was put down through Westminster, and the Palace sewer was connected with it; its bottom at the junction being about twenty-one inches above the bottom of the Metropolitan low level sewer.

The outlet end of the Palace sewer converted into a sewage-creek.

(6). Ever since this work was done there has been daily, in dry weather, from three feet six inches to four feet in depth of sewage flowing on the bottom of the Metropolitan low level sewer, and this created a constant head of sewage against the Palace sewer outlet, converting it into a creek, for a length of about two hundred feet—containing from one foot nine inches to two feet three inches in depth of nearly stagnant sewage, which was always present upon the bottom of the Palace sewer.

The Palace sewer and Metropolitan low level sewer inundated in rainy weather.

(7). But besides this: in wet weather the Metropolitan sewer was not only always filled with sewage water, but sometimes this water has risen to ten feet above the crown of the Metropolitan sewer, or thirteen feet above Ordnance datum. During wet weather, therefore, the Palace sewer, and its main branch drains, have been filled with sewage and rain water, which could not be discharged until the flood-water contained in the Metropolitan low level sewer had subsided, by being cleared out by the pumps at Abbey Mills, Bow, and by running it off through the sluices at Blackfriars and elsewhere into the Thames.

(8). Hence, for twelve or thirteen years past, the Palace sewer, as well as its main branch drains, have been periodically converted into a series of sewage reservoirs; and from these the sewage water, as it accumulated and filled them, pressed out the foul gases contained within them, up the various contributing drains into the Palace. This discharge of sewage-gas into the Palace has been going on more particularly at night time, during the Sessions of Parliament, when the gas has been burning throughout the Palace, and when the waste hot water and steam from the warming and ventilating appliances of the Palace were discharged into the drains and sewers, and fermented the sewage lying therein.

Owing to the Palace sewers being filled with sewage and rainfall, the sewage-gas contained therein was driven out, thus polluting the air of the Palace.

(9). The unpleasant effects, caused partly by the Metropolitan low level sewer, and partly by the sewer and drains under the Palace, as already described, became at last so intolerable that Parliament had no alternative but to refer the subject to a Committee of the House of Commons.

Committee of the House of Commons appointed to investigate the subject.

(10). But until the first Session of Parliament in 1886 no remedy was found for the evils complained of, which then had become so pronounced as to cause the House of Commons to suspend its sitting on one occasion.

(11). In the early part of 1886 a Committee was appointed, Sir Henry E. Roscoe, F.R.S., being the Chairman. It is evident from the reports of the Committee that the members set about their work in a thoroughly exhaustive and business-like way.

(12). Two of the members—viz., the Hon. Alan de Tatton Egerton and Mr. L. H. Isaacs—fortunately had a thorough practical knowledge of the subject upon which the Committee was asked to report. They deemed it desirable personally to examine the interior of the main sewer under the Palace, from the Victoria Tower to the point of discharge at the Speaker's Green; and, having regard to the then state of the main sewer (which is exemplified by Fig. 22, Plate 1), this was a disagreeable, not to say courageous, work to undertake.

The main sewer inspected by the Hon. Alan de Tatton Egerton, M.P., and Mr. L. H. Isaacs, M.P.

(13). From what they observed, they came to the conclusion that the smells so much complained of, and so frequently experienced within the Palace, were mainly due to the faulty sewers and drains under the Palace, and more especially to the connection of the main sewer with the Metropolitan low level sewer running through Westminster.

It appears from Mr. Isaac's evidence before the Committee that at the termination of his subterranean survey he presented himself as a witness, and deposed to the state of things which he found to exist beneath the Palace. Subsequently, he repeated his examination of the main sewer, and deposed a second time to what he had seen.

(14). Mr. John Phillips, who had had a large practical experience as a Sanitary Engineer, and who had advised Sir Charles Barry as to the improvements which were effected in the drainage of the Palace about 1848, as already mentioned, was also asked to give evidence before the Committee.

(15). With that object Mr. Phillips made examinations of the sewer, and of some of the branch drains, under the Palace, and endorsed the views of Mr. Isaacs in regard to the faulty character of the same. He subsequently, from his special knowledge of the circumstances connected with the drainage arrangements both inside and outside the Palace, submitted to the Committee a thoroughly practical and scientific plan for again improving the main sewerage arrangements of the Palace, and rendering them perfectly independent of the Metropolitan low level sewer as a means of discharge by gravitation.

Mr. Phillips suggests a plan for improving the drainage arrangements of the Palace.

(16). This plan of Mr. Phillips' was supported by Major Hector Tulloch, R.E., Local Government Board Inspector, who had previously reported to the President of the Local Government Board upon the defects of the drainage of the Houses of Parliament.

Major Hector Tulloch, R.E., supported Mr. Phillips' plan, which the Committee finally recommended to Parliament for adoption

(17). The Committee, after due consideration of the subject in all its bearings, recommended to Parliament that the plan, as proposed by Mr. Phillips, on the Shone Hydro-Pneumatic System, should be adopted; and their recommendations have been substantially carried into effect.

(18). It would swell this pamphlet to the proportions of a good-sized book were the new and improved works adequately described by drawings and otherwise in detail; but such a book, interspersed as it necessarily would have to be with more or less technical matter, would be inappropriate under the circumstances; and therefore, the Author's aim in the following pages will be to give, as plainly but as briefly as possible, a general outline only of the salient features of the new works.

The description, &c., of the new works purposely condensed.

(19). The statements already made as to the main sewer constructed in 1839, of the improvements effected in it by Sir Charles Barry in 1848—at Mr. Phillips' suggestion—and the subsequent alteration which was made in it when it was joined to the Metropolitan low level sewer, about 1873, will be better understood by reference to the drawings which accompany this pamphlet.

Reference to the drawings accompanying this pamphlet.

(20). The drawing facing page 1 is a sectional perspective view of the Pneumatic Ejector Station, looking from the base of the Clock Tower in the direction of Westminster Bridge. This drawing, with the working model of the Ejector, which is fixed in the Ejector Chamber, will assist Members the more readily and clearly to comprehend the automaticity as well as the simplicity of the Shone System.

Fig. 23, Plate 1, is a cross section of the 1839 sewer, showing, by black colour, the invert waterway necessary to pass through it the maximum quantity of sewage obtaining at the Palace when Parliament is in Session. Fig. 20 is a longitudinal section of the same sewer, amended and otherwise.

(21). It will be seen that the original sewer had a gradient of 1 in 923 only, but by the alteration suggested by Mr. Phillips in 1846 it was increased in 1848 to 1 in 215.

(22). Fig. 21 is a sketch plan, showing the Bridge Street sewer outlet into the Thames, as Mr. Phillips recollects it to have been in 1846, and it also shows how the Palace sewer was subsequently connected with the Bridge Street sewer outlet.

(23). The other figures on Plate 1 are all self-explanatory, excepting Figs. 22 and 24. Fig. 22 indicates the erratic way in which the branch drains were connected with the Palace sewer in 1839 and 1848. Fig. 24 will be referred to more particularly hereafter, when the nature and value of the new works are explained.

(24). There were about 122 subsidiary drain connections made with the main sewer originally, and these were formed at various levels on either side of the sewer as shown by Fig. 22.

Description of new works.

(25). The new works, briefly described, consist (1) in improving the gradients of the main sewer and its principal tributaries; (2) in reducing the sizes of the sewers—the main sewer, for example, from ten feet six inches high by three feet wide, as per Fig. 22 on Plate 1—to one of twelve inches in diameter, as illustrated by Fig. 24; this latter figure also shows the waterway on the invert of the new main sewer, with its improved gradient, when that sewer is charged with the maximum quantity of sewage which obtains during the Parliamentary Sessions.

The chief tributary is reduced from twenty-four inches high by fifteen inches wide, and laid at an average gradient of 1 in 372, to a pipe sewer of nine inches in diameter, laid at a gradient of 1 in 309; (3) in providing superior flushing appliances (Shone's Automatic Hydraulic Flushing Ejectors) for the sewers, at a considerably reduced expenditure of water; (4) in providing an improved method of ventilating the main sewers; (5) in forming proper connections between the drains and the main sewers, and giving extraordinary facilities for inspection at the junctions; (6) in severing absolutely the large tunnel-like connection between the Palace sewer and the Metropolitan low level sewer by means of a "Dam," constructed as per Fig. 4, Plate 2, within the former sewer; in dispensing with the big cumbrous penstock and flap valve arrangements connected therewith, and substituting therefor a small twelve-inch iron sewer with sluice and reflux valve; (7) in providing, in case of need, improved automatic arrangements for permitting the Palace sewage and rainfall to flow into the Metropolitan low level sewer by gravitation, on the principle heretofore adopted, independently altogether of the Ejector system, but without the possibility of the foul gases from the Metropolitan low level sewer getting into the Palace sewer; (8) in preventing the hot water and steam from the boilers, &c., from passing into the drains and sewers, and providing a separate and independent outlet for same into the Thames; (9) in providing means whereby the sewage and rainfall proceeding from the Houses of Parliament shall flow uninterruptedly therefrom both in dry and wet weather, irrespective of the height at which the Metropolitan low level sewer is discharging sewage, or sewage and rainfall in combination.

Shone's Pneumatic Sewage Ejectors.

(26). This latter all-important desideratum is effected by means of Shone's Pneumatic Sewage Ejectors, which are fixed in a chamber under the Speaker's Green, near the Clock Tower. These Ejectors are placed below the level of the Houses of Parliament main sewer, so that the sewage and rainfall flows to and into them by gravitation. There are three Ejectors, one of 500 and two of 350 gallons capacity. They can be worked separately or unitedly, just as the flow of sewage or rainfall is small or large.

(27). These Ejectors do not, as is the case with pumps, permit sewage-sludge or road detritus to accumulate in the pit, sump, or well pumped from; for they themselves become, as it were, the equivalent of so many pits, sumps, or wells, into which the sewage and rainfall flows by gravitation. All foreign matter heavier than water settles on the bottom. The longest time, however, during which this temporary settlement of heavy matter takes place, does not exceed fifteen minutes at most, even with the large Ejector, and this comparatively long interval of rest to the Ejector only happens when the minimum flow obtains—viz., at the time when Parliament is not in Session.

(28). But, owing to the wash-out shape of the delivery-pipe proceeding from the bottom of the Ejector, the action of ejection results in the heavier matter being expelled first out of the Ejectors, which are thus rendered self-cleansing.

(29). Moreover, they are self-ventilating; and so completely do they hermetically seal the sewage and air within them that they might be made to work in a drawing-room, without tainting in the slightest degree the atmosphere.

(30). The Ejectors are always receiving fresh compressed atmospheric air when the sewage is being expelled out of them, and the surplus of this air—*i.e.*, the volume of air which exerts a pressure superior to that of the atmosphere—and which is innocuous—after each charge of sewage has been ejected, escapes through the exhaust ports of the automatic gear into a pipe which conveys it to the ventilating shaft in the Clock Tower, whence it escapes into the atmosphere.

(31). The fresh air, at atmospheric pressure, which remains in the Ejector after each action of ejection, flows out of the Ejector as rapidly as it is displaced by the fresh charge of inflowing sewage, and that air, which is also innocuous, takes exactly the same route to and out of the Clock Tower shaft as the exhaust compressed air does.

The Hon. Alan de Tatton Egerton.

(32). The Ejectors are also self-acting; they will work only when they have work to do, as fast or as slow as the work accumulates—a function which the Hon. Alan de Tatton Egerton drew particular attention to, at the inquiry before the Select Committee of the House of Commons, of which he was a member.

(33). The Ejectors at the Houses of Parliament are emptied in about half a minute; but they take in dry weather, when Parliament is not in Session, from ten to fifteen minutes to fill. Whether, however, they fill in half a minute or in half an hour, they will be invariably emptied in about half a minute. Moreover, they form the most perfect sewage-gas trap, as between the Houses of Parliament sewer and the Metropolitan sewer, which it is possible to invent.

Gas-engine air-compressors.

(34). The compressed air required by the Ejectors to expel the sewage and rainfall is supplied by air-compressors, driven by Atkinson's admirable Patent Differential Gas Engines. There are four of these (of four horse power each) situated in the basement of the Palace, about 650 feet from the Ejector Station.

(35). But were the Gas-Engine Air-Compressors at Charing Cross, and the three Pneumatic Ejectors a mile, more or less, apart, instead of being in a cluster in one chamber, as they are at the Houses of Parliament, their automatic action and effectiveness would neither be improved nor impaired by the change!

(36). The four Gas-Engine Air-Compressors at the Houses of Parliament occupy a room which is twenty feet long, sixteen feet wide, and nine feet high. They, like the Ejectors, occupy little space, and may be fixed under the streets in cases where land is expensive or otherwise difficult to obtain.

(37). Plate 2 contains a plan and section of the Pneumatic Ejector Station, as well as a plan and section of the Air-Compressing Station, &c.

Lifts of Ejectors.

(38). The minimum lift for the Palace Ejectors is twelve feet, and the maximum lift will probably never exceed twenty feet.

Kaiser's Patent Counters.

(39). The minimum and maximum quantities of sewage, and sewage and rainfall together, it is now difficult to estimate; but as one of Kaiser's Patent Counters, which is shown on Plate 3, is attached to each Ejector, a practically accurate record can be kept of the quantities that will be received and ejected from time to time.

Ejectors act as sewage and water-meters.

(40). By the aid of these excellent Counters, therefore, the Ejectors actually become sewage-meters, giving accurately the quantity of sewage in dry weather, and of sewage and rainfall combined during periods of wet weather.

(41). From observations already made since the Ejectors have been at work, it is clear that one Gas-Engine Air-Compressor and one Ejector will deal with more than the whole of the largest quantity of sewage flowing from the Houses of Parliament at any one minute of time, even though that sewage should be supplemented by an amount of water equal to one inch and more of rain falling upon the entire area of the Palace and grounds in twenty-four hours.

Automatic Electrical Water Gauge.

(42). When one Engine and one Ejector are insufficient, during periods of extraordinarily excessive rainfall, there is a float within the sewage manhole, adjacent to the Ejector Chamber, which will rise and fall with the sewage and rainfall, and which will actuate one of Mr. Julius Sax's Automatic Electrical Tidal Water Gauges (shown on Plate 3).

(43). This apparatus is fixed within the Ejector Chamber, and a duplicate of it is also fixed in the Gas Engine Room, both being very effectively operated simultaneously by the float.

These instruments have faces resembling ordinary clocks, and the hands on them denote the exact level, in inches, of the water in the sewage manhole, from which the Ejectors are supplied.

(44). The moment one engine is overcome the electrical apparatus rings a bell within the Ejector Chamber, and in the Gas-Engine Room, at one and the same instant, and then the Attendant will set a second Gas-Engine to work; but if the sewage continues to rise in the sewage manhole, notwithstanding the setting to work of a second engine, the electrical apparatus will continue to indicate such increased height, and the Attendant will then put a third, and, if necessary, the fourth Gas-Engine to work.

(45). Each Engine can be set to work and stopped in about a minute.

Height of sewage in Metropolitan low level sewer.

(46). Besides having the means of ascertaining the quantity dealt with from day to day, and of seeing how the sewage and rainfall flows to the Ejector Station, there is also fixed, in the Ejector Chamber, a semi-mercurial and water-pressure gauge—designed specially for the purpose—by which the exact height of the sewage in the Metropolitan low level sewer can at all times be determined.

(47). This gauge is shown on Plate 3, Fig. 5.

(48). This pamphlet would be incomplete without some further special reference to the relative values of the old and the new main sewers as *sewage carriers*.

Velocity of flow of sewage in the 1839 sewer.

(49). The velocity of the flow of the sewage shown on the invert of the sewer of 1839, as per Fig. 23, Plate 1, would be about 1·11 feet per second, and this volume of sewage would only occupy about the $\frac{1}{32}$nd part of the entire sectional area of the sewer.

(50). Whereas, by the alteration made in the inclination of the sewer in 1848, at the suggestion of Mr. Phillips, the velocity of the same volume of sewage, carried in the new twelve-inch iron pipe, laid on the invert of the improved 1848 sewer, as per Fig. 24, Plate 1, would be 2·8 feet per second, and the waterway area of the latter sewer would be equal to the $\frac{1}{5 \cdot 4}$th part of the whole.

Velocity of flow in 12″ sewer $\frac{1}{5 \cdot 4}$th full.

(51). The former (49) is, to all intents and purposes, a non-self-cleansing velocity, whilst the latter (50), even though the pipe be only submerged to the extent indicated by Fig. 24, Plate 1, would be adequate to render it permanently self-cleansing.

(52). This alteration, consequently, had more than the hydraulic effect of doubling the *efficiency* of the sewer as a *sanitary sewage carrier*.

Efficiency of the new 12″ main sewer.

(53). This way of estimating the efficiency of a sewer, however, is misleading to the uninitiated. If by mechanical alteration the efficiency of a steam engine, for example, is doubled, it means that the owner of the engine is spared one-half of the original annual fuel cost—which, if the improved engine be a powerful one, may represent the interest on a comparatively large sum of money.

(54). But the number of preventable fatal accidents consequent upon improvements effected in the working of the extravagant engine are neither increased nor diminished by the fifty per cent. reduction in fuel consumption.

(55). On the other hand, an unnecessarily large and costly sewer may fail, as the sewer in question failed, during its normal and abnormal working condition, to perform its functions as a sanitary sewage carrier; and, if so, who can estimate the number of cases of preventable sickness and death resulting directly and otherwise from the existence of such a sewer?

(56). The Legislative enactments now in force, having for their object the reduction of fatal accidents in mines and on railways to a minimum, have undoubtedly had a most salutary effect; and yet, in point of numbers, the deaths which occur annually, and which are directly traceable to railway and mining accidents, are infinitesimally small as compared with the number of deaths which take place annually, and which are due directly or indirectly to foul drains and sewers. But, because the deaths from the former sources are generally sudden and violent, their character rouses public attention; whereas the deaths from the latter source are, to a large extent invisible, and on that account, and upon no other, public attention is not incited against them.

(57). Notwithstanding the enormously reduced size of the Palace main sewer, in all human probability the new twelve-inch main sewer will never be found more than half filled, at the outlet, during the greatest rainfall storms; neither will the Gas-Engine Air-Compressors or the Ejectors ever be required to dispose of anything approaching the maximum quantities which they are unitedly capable of dealing with.

(58). Besides improving, hydraulically, the capacity of the main sewer to receive and discharge the minimum as well as the maximum quantity of sewage and rainfall, by substituting a twelve-inch sewer for the old one, it will be seen from the drawings that the upper portion of the latter is converted into a convenient subway—

which is well ventilated—along which workmen can pass to and fro, in comfort, for the purpose of inspecting the condition of the new main sewer and its numerous connections.

(59). In case of a complete break down, too, of the Gas-Engine Air-Compressors and Ejectors during periods of heavy rains, this subway would act the part of a reservoir, as it has done heretofore.

(60). But this is a contingency which the Author thinks can never happen—except, of course, through carelessness—so long as the Houses of Parliament remain free from the influence of severe earthquake shocks.

(61). The ventilation of the new twelve-inch main sewer is effected by admitting fresh air into the subway which puts the basement of the Houses of Parliament into direct communication with the Ejector Chamber, and allowing it to proceed, firstly, along that subway into the Ejector Chamber; secondly, through the Ejector Chamber into an air-duct at the top of the eastern end thereof; and, thirdly, along this air-duct into the sewage manhole.

Ventilation of the new 12" main sewer.

(62). The air is made to pass out of the sewage manhole partly into the main twelve-inch sewer and partly through the rectangular air-opening, which communicates with the subway above the main sewer.

(63). That portion of the air which passes into the twelve-inch sewer proceeds direct to the furnace at the base of the Victoria Tower; but, before diverging from the line of the main sewer, it is joined by the air current which travels from the head of the sewer. Both currents, therefore, go together—from the point of divergence in the new twelve-inch main sewer—into and out of the Victoria Tower, along with the volumes of vitiated atmosphere proceeding from the Palace.

(64). That portion of the air which passes through the rectangular opening in the sewage manhole into the old sewer subway travels along that subway for a short distance only, when it makes a detour to the right, along with the air that is admitted at the head of the old sewer subway (to ventilate it), and proceeds along an air-duct direct to the furnace at the base of the Clock Tower.

(65). The air that ventilates the smaller nine-inch sewer is drawn from the upper end of that sewer to the Clock Tower furnace.

Cost of gas per hour and day for ejecting the Palace sewage and rainfall.

(66). The consumption of cannel-coal gas when one engine is running and compressing air to about 10 lbs. per square inch continuously for twenty-four hours, is about 2,000 cubic feet, which costs—reckoning gas at the price paid for it, viz., 3s. 9d. per thousand—7s. 6d. per day; which is just $3\frac{3}{4}$d. per hour for the four horse-power engine, or less than 1d. per horse-power per hour.

(67). The Atkinson Gas-Engine Air-Compressor is extremely simple, effective, and strong; and it affords extraordinary facilities for keeping the air-pressure constant. It has no slide valve—which occasionally gives trouble and expense in other Gas Engines; and an explosion takes place in its cylinder at every revolution. The speed of the piston at the instant of explosion is comparatively great, so that a proportionately increased quantity of heat is thereby converted into useful work—more than is obtained from other Gas Engines—because, the comparatively slow motion of the pistons of the latter, at the moment of ignition, allows the heat, to a large extent, to be transmitted to the cooling water surrounding the cylinders.

(68). The air-compressing cylinder of the Atkinson Engine can be worked as single-acting or double-acting by means of a very ingenious "easing-gear" arrangement—which, by simply turning a handle, admits compressed air under the inlet valves, and thus renders them inactive; and that without any loss of compressed air. The same "easing-gear" adjusts the air-pressure in the air-receivers also.

Attendance on engines and ejectors merely nominal.

(69). These engines require no other attention than that needed for lubricating, and occasionally to clean them; and as for the Ejectors—one of these has already been left to itself for a whole week, working night and day without anybody either lubricating or attending to it in any way.

(70). One of the Gas-Engine Air-Compressors and one of the Ejectors of the Palace, working continuously for twenty-four hours, day and night, could deal with the sewage of more than 20,000 people, reckoning the sewage discharges at twenty gallons per head per day—the lift to be twenty feet; and the total gas consumption, assuming the quality and price of the gas to be the same, would be no more nor less elsewhere than it is at the Houses of Parliament—viz., 7s. 6d. per day of twenty-four hours.

Contractors' names and addresses.

(71). The works were divided into three Contracts, the General Contract (No. 1) being let to Messrs. John Mowlem & Co., of Westminster; and the Special Contracts—(No. 2) embracing the supplying and fixing of the Pneumatic and Hydraulic Ejectors, to Messrs. Hughes & Lancaster, Chester; and (No. 3) for the supply and erection of the Gas-Engine Air-Compressors, to the British Gas-Engine and Engineering Company, Queen Victoria Street, London.

Cost of new works.

(72). The Author is pleased to be able to add that the work, as a whole, has been well and substantially executed without accident, and without there being any practical increase in the cost, which, in round figures, is a little over £11,000—the amount approximately estimated by the Engineer, in the first instance, for the guidance of the Treasury and of the Commissioners of Her Majesty's Works and Public Buildings.

(73). In conclusion, it may be said that modern sanitary science had its origin in this country some fifty years ago; and, as this is the Jubilee Year of Her Majesty's beneficent reign—during which so much, comparatively, has been done for the sanitary well-being of millions of Her Majesty's subjects—the present time would appear to be peculiarly appropriate for demonstrating to the Legislators of the greatest Empire in the world, through the medium of their own Houses of Parliament, the superiority of the new over the old system of draining houses and towns of their sewage-proper, separately from the rainfall, or otherwise.

(74). Finally, the object of the Engineer, in presenting a copy of this Pamphlet to each Member of both Houses of Parliament, is of a two-fold character—the one is to satisfy them that the money voted by Parliament, at the recommendation of Sir Henry Roscoe's Committee, for the purpose of executing the new drainage works, has been well spent; and the other is to try, through the instrumentality of the works themselves, to help forward the great and important cause of sanitary science.

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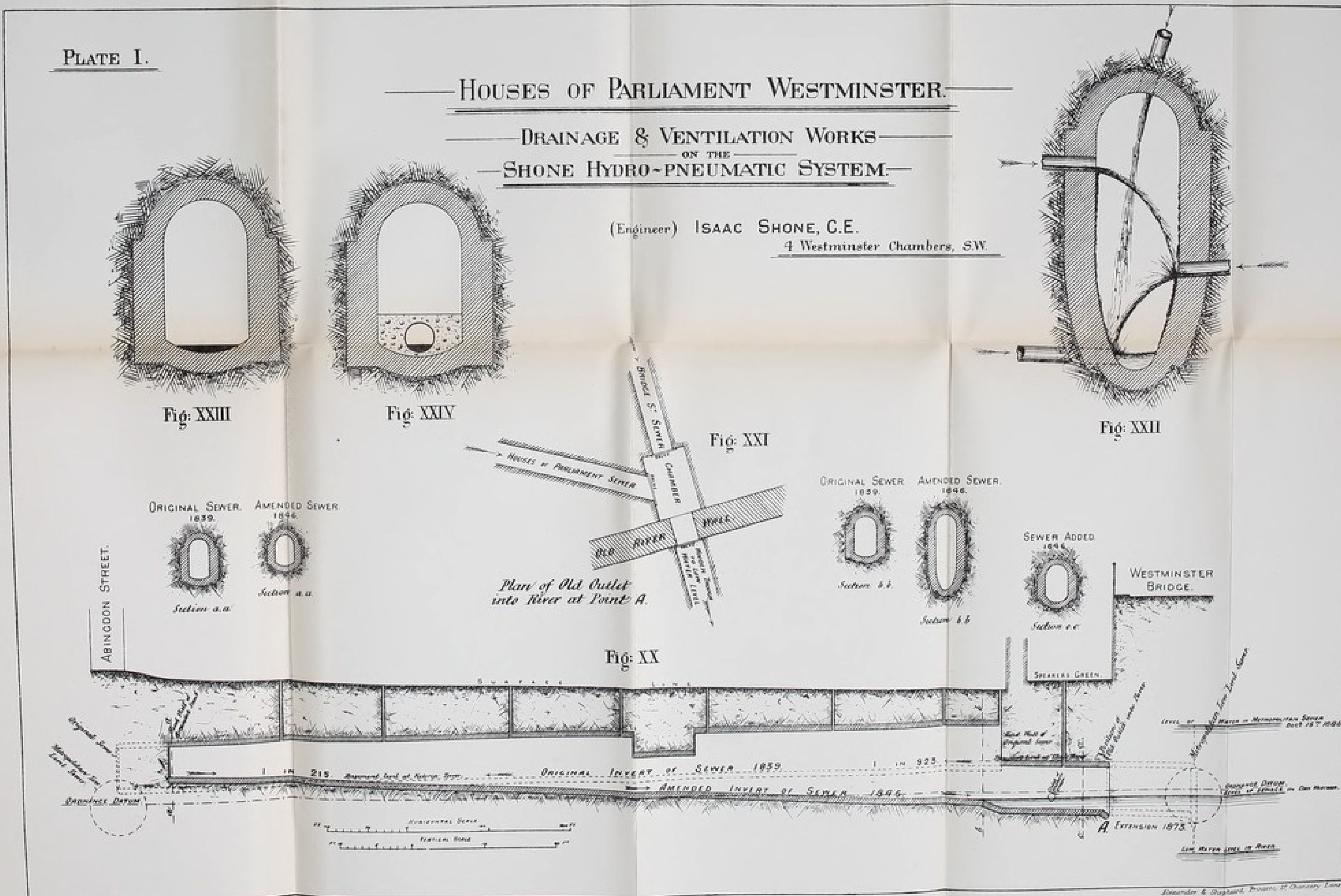


Plate I.
Houses of Parliament Westminster.
Drainage & Ventilation Works
on the
Shone Hydro-pneumatic System.
(Engineer) Isaac Shone, C.E.
4 Westminster Chambers, S.W.
Fig: XXIII
Fig: XXIV
Fig: XXII
Fig: XXI
Houses of Parliament Sewer
Bridge St. Sewer
Chamber
Old River Wall
Plan of Old Outlet into River at Point A.
Original Sewer. 1839.
Amended Sewer. 1846.
Section a.a
Section b.b
Sewer Added. 1846.
Section c.c
Abingdon Street.
Westminster Bridge.
Fig: XX
Speakers Green.
Ordnance Datum
1 in 215
Original Invert of Sewer 1839.
1 in 923
Amended Invert of Sewer 1846.
A Extension 1873.
Low Water Level in River.
Horizontal Scale
Vertical Scale
Alexander & Shepheard, Printers, 27 Chancery Lane

Plate II.

Houses of Parliament Westminster.

Drainage & Ventilation Works
on the
Shone Hydro-pneumatic System

(Engineer) Isaac Shone, C.E.
4 Westminster Chambers, S.W.

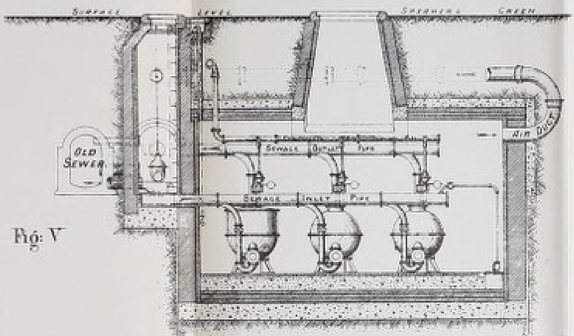


Fig: V

— Sectional Elevation. —

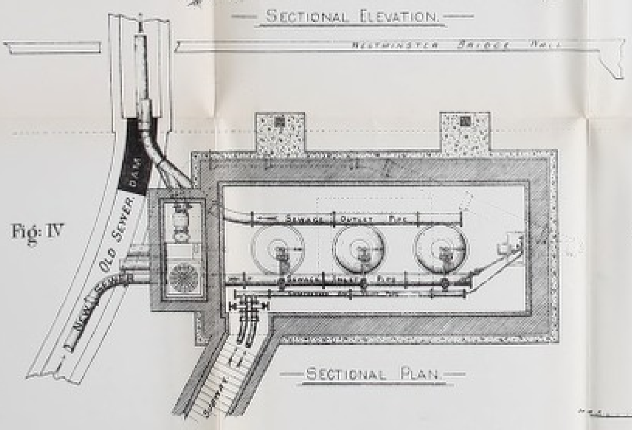
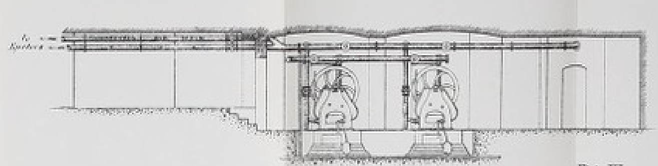


Fig: IV

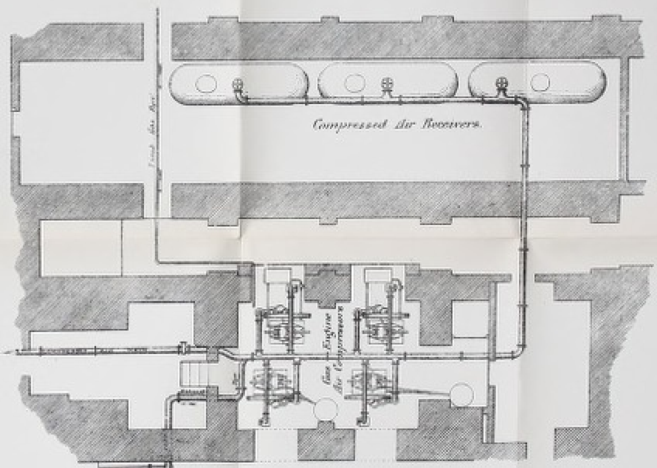
— Sectional Plan. —

— *Hydro-pneumatic Sewage Ejector Station* —
— *Shone's System.* —



— Sectional Elevation. —

Fig: XI



— Sectional Plan. —

Fig: X

— *Atkinson's Patent* —
— *Differential* —
Gas-Engine Air-Compressors. —

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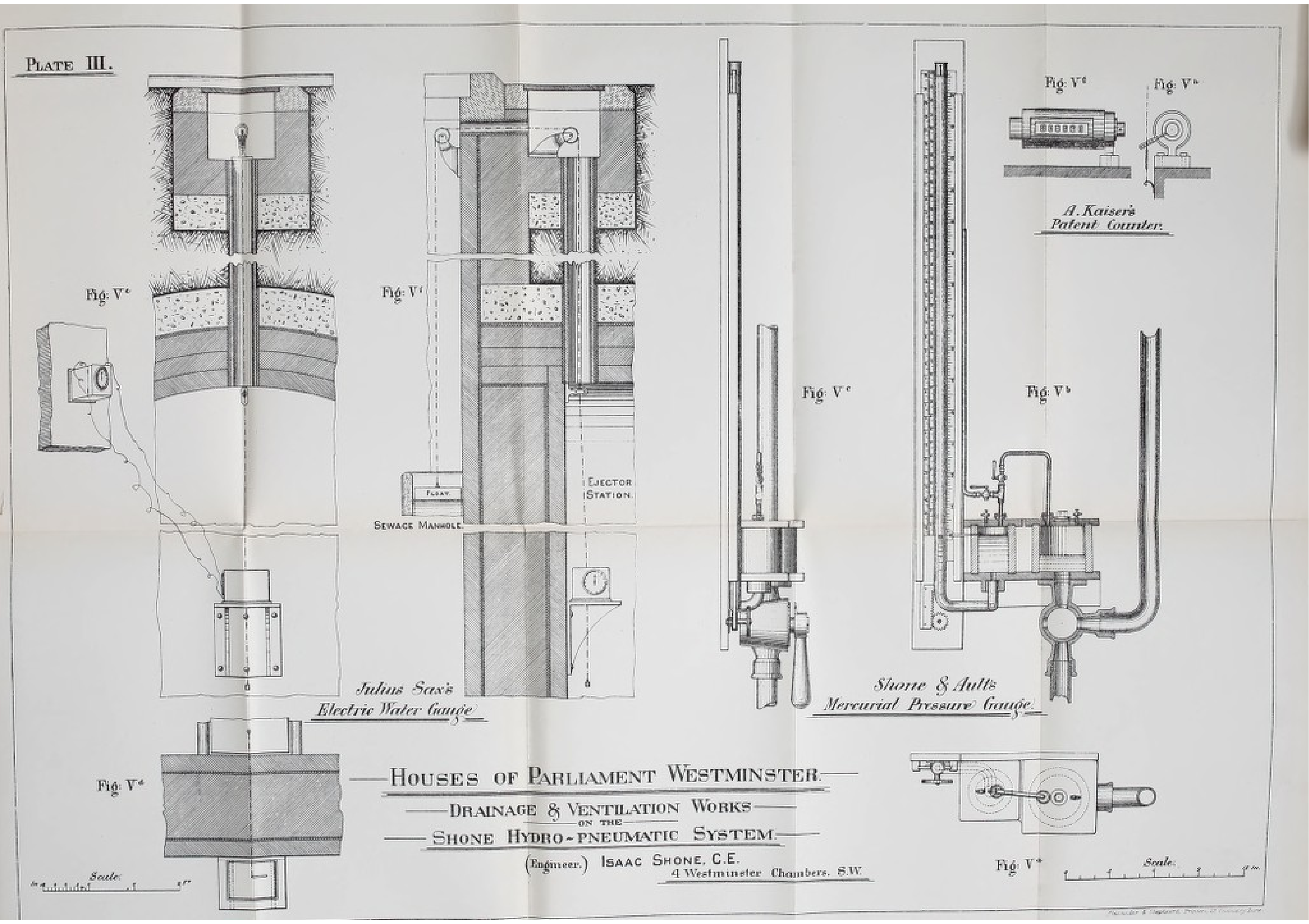

Plate III.
Fig: Vᶜ
Fig: Vᵈ
Fig: Vᵉ
Fig: Vᵇ
Fig: Vᵍ
Fig: Vʰ
Fig: Vᵃ
A. Kaiser's
Patent Counter.
Float.
Sewage Manhole.
Ejector
Station.
Julius Sax's
Electric Water Gauge.
Shone & Ault's
Mercurial Pressure Gauge.
Houses of Parliament Westminster.
Drainage & Ventilation Works
on the
Shone Hydro-pneumatic System.
(Engineer.) Isaac Shone, C.E.
4 Westminster Chambers, S.W.
Scale:
Scale:

TABLE (FOR PRACTICAL REFERENCE),

Showing the Velocities and Quantities discharged by Sewer Pipes, running full, with various heads, and the Populations for which the same would be suitable, allowing $2\frac{1}{2}$ and 4 cubic feet (or 15 and 25 gallons) per head, per diem, respectively.

By ISAAC SHONE, C.E., F.G.S.

WREXHAM, June, 1879.

SIZE OF PIPE. Heads in feet (a)	Pressure in lbs. per square inch (b)	Ratio, 1 in (c)	Fall in feet per chain of length (d)	4 INCH. (1)(2)(3)(4)	5 INCH.	6 INCH.	7 INCH.	8 INCH.	9 INCH.	10 INCH.	12 INCH.	15 INCH.	18 INCH.
132	57·29	40	1·65	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					
105·6	45·83	50	1·32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					
88	38·192	60	1·11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					
75·4	32·72	70	·943	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
66	28·644	80	·825	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
58·7	25·476	90	·733	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
52·8	22·915	100	·66	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
35·2	15·277	150	·44	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
26·4	11·458	200	·33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21·1	9·157	250	·264	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17·6	7·638	300	·22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15·1	6·553	350	·1886	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13·2	5·729	400	·165	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	5·208	440	·15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	4·774	480	·1375	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10·56	4·583	500	·132	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	4·34	528	·125	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	3·906	586·7	·1125	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8·8	3·819	600	·11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	3·472	660	·1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7·54	3·272	700	·0943	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7·0	3·038	754	·0875		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6·6	2·864	800	·0825		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6·0	2·604	880	·075		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5·87	2·548	900	·0734			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5·5	2·387	960	·0687			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5·28	2·292	1000	·066			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5·0	2·170	1056	·0625			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	1·736	1320	·05				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	1·302	1760	·0375						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	·868	2640	·025									[illegible]	[illegible]
1	·434	5280	·0125									[illegible]	[illegible]

Each pipe-size group has the columns: Velocity in feet per second (1); Volume in cubic feet per minute (2); Number of Population for which the pipe would be suitable at the various velocities, &c., allowing $2\frac{1}{2}$ cubic feet per head per diem (3); 4 cubic feet per head per diem (4).

☞ The Figures underlined indicate the velocities at which pipes, of the respective diameters given above, should discharge, when rainfall is admitted into them, in order to render them self-cleansing and free from road detritus, thus showing that sewer pipes, to convey sewage and rainfall together, should be laid at steeper gradients than when sewage is conveyed alone.—(Vide "Sanitary Engineering" by J. Bailey Denton, C.E., p. 150, and "Sanitary Drainage of Houses and Towns" by Geo. E. Waring, Jun., C.E., p. 165.)

NOTE.—The formulæ (deduced from "Box on Hydraulics") from which the above velocities and quantities are calculated, are:—for velocity, (1), $v = \left(\frac{(1 \cdot d)^2 \times H}{L}\right)^{\frac{1}{2}} \div 371 \cdot 98a$; and for quantity, (2), $C = \left(\frac{(1 \cdot d)^5 \times H}{L}\right)^{\frac{1}{2}} \div 6 \cdot 23$;

in which a = sectional area of pipe, in square feet; d = diameter of pipe, in inches; v = velocity, in feet per second; C = discharge, in cubic feet per minute; H = head, in feet; and L = length, in yards.

EXAMPLES TO ILLUSTRATE USE OF TABLES.

[illegible]

☞ N.B.—Medical Officers of Health and Sanitary Engineers and Surveyors are agreed that all sewers or drains should be so adjusted as to gradients and sizes that they should become when in use self-cleansing. Dr. Carpenter, of Croydon, in his work entitled "Preventive Medicine and Public Health," states—"See that the sewer of deposit is altered in its character and that it be made self-cleansing. Strike at the root of the evil, instead of merely transferring the mischief to some other place. . . . . Slow movement allows of chemical change with the evolution of gaseous matter. Self-cleansing sewers will not allow this process to take place; if therefore there is a smell from a sewer there is something wrong in its construction, and the engineer who manages or constructed it has been to blame."

The formulæ (4) and (7) with these Tables will, it is hoped, arrest the attention of those interested in the important question of Public Health. The Compiler believes that by showing the population for which the various-sized pipes are suitable, and by underlining those figures which show the working capacities of the pipes through which the self-cleansing velocities can be obtained, he will aid the Local Government Board and its Officers in accomplishing the great object of instituting Self-Cleansing Sewers, as recommended in Mr. (now Sir Robert) Rawlinson's "Suggestions."

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