

(*Paper No. 2617.*)

The Waste of Water in Public Supplies, and its Prevention."

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INTRODUCTION.

THE fact that a large portion of the whole quantity of water in most public supplies is wasted, or lost, without the knowledge of the Water Authorities or the consumers, is as incontrovertible as it appears to be difficult to conceive. An idea of the real condition of things may be gained by regarding the system of mains, pipes, and fittings, supplying any given community, as a rapidly-leaking reservoir, and by considering that the water which actually reaches the consumers is merely the overflow from that reservoir, or, in other words, the volume supplied to that reservoir in excess of the leakage.

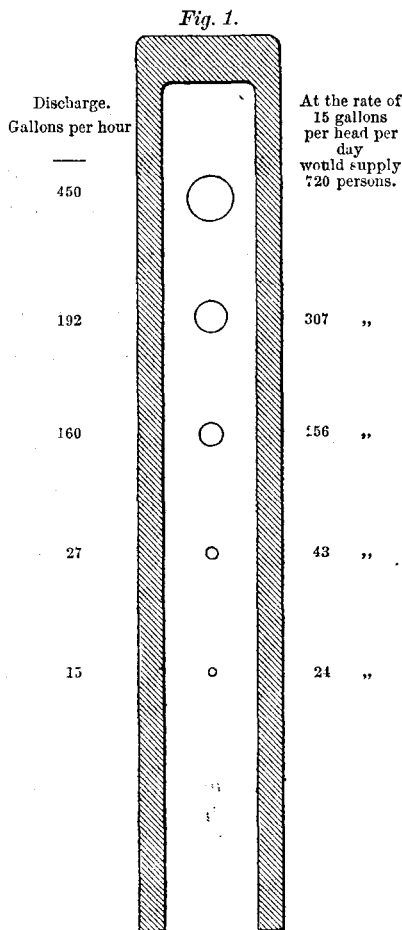
Even now, the majority of the water-undertakings of this country lose by leakage more than one-half the total quantity of water supplied from the source. The proportion is often higher, and rises in many cases to three-fourths, or more; while, in comparatively new countries, such as America, Australia, and New Zealand, the portion so lost is on the average still greater.

A growing, but still imperfect knowledge of these facts has brought about the more obvious remedies; and these, combined with the extension to more than six-and-a-half millions of persons of the method of waste-prevention introduced by Mr. G. F. Deacon, M. Inst. C.E., and described by him in the Proceedings,¹ has lately further improved the average, and, in particular instances, has caused the total rate of supply of water from the source to fall so low, by the reduction of leakage, without any restriction whatever of the quantity used, that a comparison between the present and past conditions at once confirms the accuracy of the statements made above.

¹ Minutes of Proceedings Inst. C.E., vol. xlii. p. 143 *et seq.*

How easy it is to double or treble the demand upon the source of supply by permitting leakage in the water-mains, ferrules, pipes, and fittings may be readily understood from a consideration of the great waste of water occasioned by leaks of apparently insignificant size.

To illustrate this important point, *Fig. 1* shows a lead pipe drilled with various sized holes, the burr on the inside not being removed. The actual number of gallons per hour which passed through each hole under a pressure of 45 lbs. per square inch is noted on the drawing, together with the corresponding number of persons which that quantity would supply at the exceptionally high rate of 15 gallons per head per day. Leaks of magnitude varying from the fine needle upwards are almost innumerable in distributing-pipes and fittings. They arise from cracks and holes in the barrels and joints of cast-iron pipes, defects in the ferrules connecting the mains with the service-pipes, splits or other holes in the service-pipes, and defects in the fittings by which the water is drawn off. When underground, they are generally incapable of being detected by ordinary means. Even in comparatively retentive soil, their individual magnitude is often too small to cause superficial dampness or to waste away the surrounding ground into sewers and drains; and



RESULTS OF EXPERIMENTS ON THE FLOW OF WATER THROUGH CIRCULAR HOLES IN A HALF-INCH LEAD-PIPE, UNDER A PRESSURE OF 45 LBS. PER SQUARE INCH—GIVING AN IDEA OF THE NUMBER OF PERSONS THAT MIGHT BE SUPPLIED BY THE DISCHARGE THROUGH FLAWS OF VARIOUS SIZES.

in such cases they do not make themselves known by the falling in of the surface. Of larger-sized underground leaks discharging through self-made channels into sewers and drains, previously unknown examples are now frequently discovered by the waste-water-meter system. They have been detected of almost every size, even up to continuously-flowing quantities sufficient for the supply of 2,000 or 3,000 houses.

APPROXIMATE DETERMINATION OF TOTAL WASTE.

Before proceeding further with the details of the subject, it is clearly important to notice that supply and consumption are not equivalent or convertible terms.

The supply is the whole quantity of water drawn from a source. The consumption is the quantity of water which reaches the premises of the consumer and is drawn off for use, whether lavishly or otherwise. The waste, or loss, is the difference between these two, *i.e.*, the supply minus the consumption.

The water thus lost is a quantity entirely unknown to the consumer, and generally unknown also to the Water Authority, by whom much of it, often the whole, is, unfortunately, believed to be included in the consumption. There is no water-supply in which some unnecessary waste does not exist, and there are few supplies, if any, in which the saving of a substantial proportion of that waste would not bring pecuniary advantage to the Water Authority; whose object, therefore, should be to reduce the entirely harmful loss, and thus prevent the volume of water supplied from unduly exceeding the volume consumed. It is to be particularly noted that the "consumption" here referred to includes all lavish expenditure of water, all waste in the mode of use, all application or misapplication, the curtailment of which could possibly be regarded by the consumer as an interference with his privileges of free and unrestricted use of the supply. The "water wasted or lost," on the other hand, is a portion of the supply which cannot directly or indirectly benefit the consumer, and the saving of which must of necessity benefit everybody concerned.

The proportion between the supply and consumption may generally be ascertained, at least approximately, without much trouble or expense. In the majority of towns there is no consumption of importance between 3 and 4 A.M.; and if, for any manufacturing

purpose, such consumption does take place, its amount can be readily ascertained. Most of the cisterns fill up before that time, and the morning use of water has not begun. Gaugings of the supply from the service-reservoirs, made every quarter-hour from midnight to 5 A.M., will give a result which in many cases must astonish the Water Authorities. For the purpose of such gauging, the supply to the service-reservoir must, of course, be entirely cut off. If the reservoir is of large area and the outflow relatively small, so that the fall of water-level is very slow, it is desirable to observe the varying levels by means of the hook-gauge; otherwise an ordinary levelling-staff, or fixed vertical gauge-board, is sufficient.

The minimum outflow will be found some time between midnight and 5 A.M., and if, about that period, closer readings are taken, the rate of flow will be found to be very nearly constant for an hour or two. This minimum flow is approximately the rate of useless and possibly harmful leakage of the district supplied; and, if the volume during one hour of such minimum flow be multiplied by twenty-four, the result will be, approximately, the total daily waste of the district, and will, as already stated, be commonly found to be a large proportion of the whole quantity supplied. If Water Authorities would more frequently make this simple experiment, a better understanding of the importance of the subject would soon be arrived at. It is the first step towards producing that conviction as to the facts, without which no efficient reduction of the existing loss is likely to be undertaken. When this conviction has been reached, all doubt as to the expedience of taking remedial measures will be removed.

OUTLINE OF THE HISTORY OF WASTE PREVENTION.

About forty years ago, when the pressures at which water was supplied began to be increased, it was recognized by those who paid attention to the subject that the pipes and fittings of a waterworks system could not be left to take care of themselves without suffering ever-increasing deterioration, even if the visible and more inconvenient leakages were from time to time cured. Naturally, the first repairs were those of visible defects in the house-fittings. Owing, however, to the originally inefficient construction of such fittings, the result of their repair soon proved to be unsatisfactory; and, in certain places in which the need was

most pressing, the authority of Parliament was sought and obtained by the Water Authorities to interdict the use of existing domestic fittings, and to prescribe in detail the nature of all new fittings to be provided and fixed by the persons responsible for payment of the water rates.

At great cost to the owners and tenants, these powers were in a few cases enforced, and a considerable reduction of the supply, without any restriction of the consumption, was effected. By the decrease of velocity and friction thus brought about in the mains and pipes, the pressure was increased, and the mains and pipes thereupon leaked to such an extent that in some cases their entire renewal became necessary. The whole change was a much more serious one than had originally been contemplated. There can be no doubt, however, that, in those places in which it was thoroughly carried out, great advantages in point of economy and simplicity have since been reaped. Closely connected with such innovations, in this country at least, was the change in certain towns from intermittent to constant supply. While excessive waste continued, a constant supply could not be afforded; but, when excessive waste was prevented, constant supply became—as regards both the expenditure of water and of money—cheaper than intermittent supply. With these changes, became also apparent the necessity for a system of house-to-house inspection, by means of which the fittings could be brought under the observation of the Water Authority, and caused to be repaired or renewed.

The principal defects of this system of more or less complete renewal of the fittings and pipes, followed by house-to-house inspection for the maintenance of the fittings, were:—1. The great cost thrown upon the landlords or tenants by the renewal of pipes or fittings, which, though of indifferent quality, may not have been causing waste. 2. The great cost thrown upon the Water Authority by the renewal of pipes, which, though leaking in some places, may have been generally sound. 3. The frequent inquisitorial visits of the inspectors to private dwelling-houses, whether defects existed or not. 4. The impossibility of detecting certain hidden causes of waste, which are the most important of all. 5. The impossibility of checking the inspector's work, and of ascertaining how he spent his time.

The first successful attempt to remove the whole of these defects, and to substitute for a laborious, expensive, and comparatively inefficient method, a system of almost automatic inspection and

localization of leakage, was initiated in connection with the Liverpool water-supply by Mr. Deacon in 1873. The developments of this method, and the improvements since introduced into it, have been so remarkable as to call for a further statement concerning it.

THE DIFFERENTIATING, OR WASTE-WATER-METER IN ITS PRESENT IMPROVED FORM.

In the case of the waste-water-meter, as in that of every important invention, experience has suggested alterations, which, without changing the principle, have simplified the apparatus or increased its efficiency.

The principle of the meter is simple enough. It consists substantially of a hollow truncated cone, the smaller end of which a disk tends, in virtue of a weight or spring, to fill. When a flow of water takes place through the cone from the smaller towards the larger end, the disk, being guided axially, necessarily moves in the same direction, and ceases to move the instant it reaches such a position that the pressure upon it, due to the velocity of the water between it and the side of the cone, is exactly equal to the counter-pressure of the weight or spring. The volume per hour being ascertained by actual test for each position of the disk, a pencil indirectly attached to the disk is caused to show upon the revolving diagram of the meter (*Fig. 2*) the actual rate of flow in gallons per hour, at every instant. Thus the flow is differentiated, its mode as well as its volume is automatically recorded, and the great advantages of a knowledge of the mode of flow are secured.

In order that every waste-water-meter of the same class may give identical results, it is necessary that not only the cone and disk and pressure of the weight or spring should be identical, but that the distribution of velocity over the transverse sectional area of the stream approaching the cone and disk should be uniform, and uninfluenced by the direction or section of the pipe through which the water reaches the meter. The unsteadiness and singing of a gas-jet, which may be produced by the partial closing of a gas-tap perhaps fifty or a hundred diameters distant from the jet, is a familiar phenomenon. In precisely the same way, the existence of valves, bends, or enlargements in the approach-pipes to waste-

water-meters would, in the absence of proper precautions, cause important differences in their records.

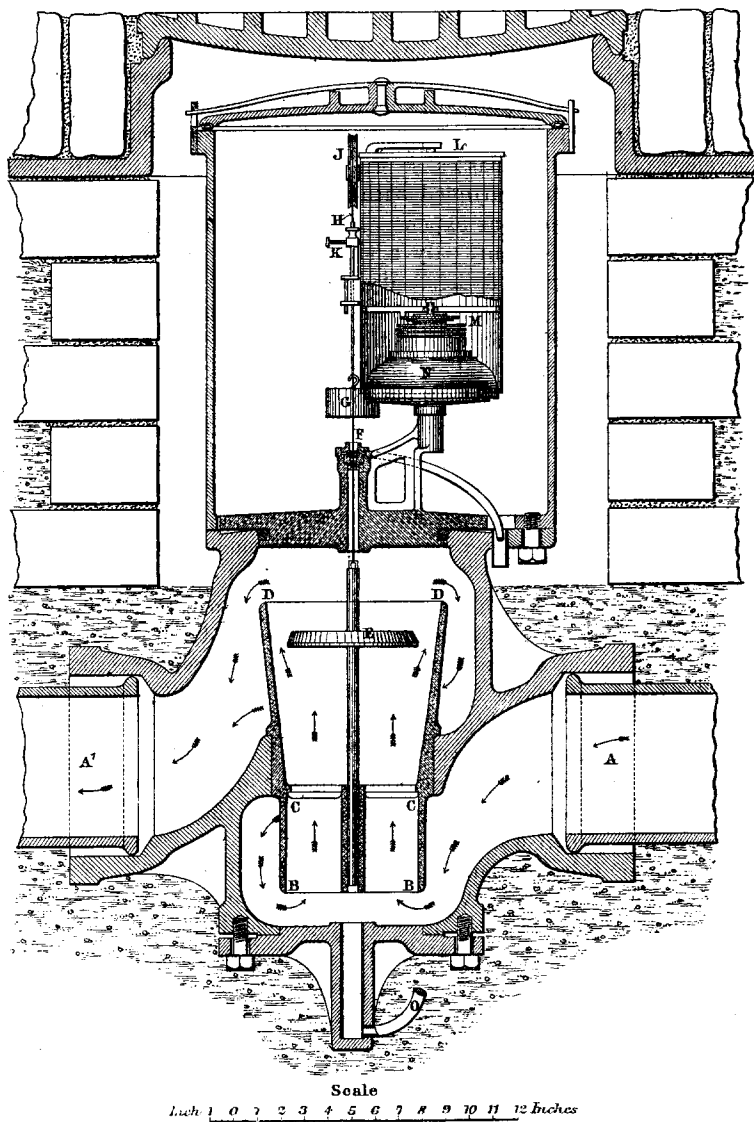
In the earlier meters this difficulty was to a sufficient extent met, as illustrated in Mr. Deacon's Paper read before the Institution,¹ by causing the water to flow through equalising grids of precisely similar figures; but every one experienced in the management of waterworks knows the objections to grids or strainers on the direct line of any water main. Such meters were therefore placed on by-passes, so that when they were not in use the supply might be continued without passing through the grid; but this arrangement was expensive in first cost and increased the difficulty of management. By a simple device, Mr. Deacon subsequently removed the necessity for by-passes—so arranging the parts of the meter as to equalise the flow without any obstruction or risk of arresting foreign matter. He caused the flow towards the disk to take place over a turned circular edge, at which previously produced eddies, or irregular distribution of the flow, gave place to the greater influence of the law of uniform flow over a sharp edge. Such circular edges could be precisely reproduced, and were perfectly effective for the purpose intended. Moreover, when an abnormal flow takes place, as in the case of a fire, the disk of the meter now moves into such a position as to give the full waterway. A pair of longitudinal diaphragms check the helical motion which sometimes occurs. Since these changes were introduced, waste-water-meters have been placed direct upon the mains without any restriction of the flow, the whole resistance to the passage of water through the meter being no greater than that of a few yards of the main upon which it is placed. But perhaps the greatest improvement effected has been the inversion of the meter and the concentration in the disk of the counter-balance weight, formerly hung at the end of the wire by which the recording pencil was worked.

The meter in its present form is illustrated in *Fig. 2*.

The water entering at A passes around the outside, and beneath the horizontal circular edge B of the hollow cylinder CB. In this cylinder it flows upwards with a distribution dependent upon the law of constant flow over the sharp edge of the cylinder, so that irregularities in the distribution of the velocity produced at sections more distant from the cone are reduced to a minimum. The plane surface BBC is one of the longitudinal diaphragms

¹ Minutes of Proceedings Inst. C.E., vol. xlii. Fig. 11, Plate 6.

Fig. 2.



DEACON'S WASTE-WATER METER.

by which the tendency to helical motion or vortex motion is checked. From the cylinder the water passes up the cone CD and lifts the loaded and guided disk E into such a position that the pressure upon its under side, due to the velocity of the water past it, is precisely equal to the effective downward weight. The water finds its exit, as it entered, over a sharp edge D, and continues its course along the main at A'. The wire F is kept taut by the small counterbalance weight G (hanging from the band H over the pulley J) and carries the pencil or pen at K. L is the drum, caused to revolve once in twenty-four hours or in six hours, as may be required, by a friction clutch M driven by the eight-day clock N within it.

The diagram may be rapidly mounted by withdrawing the drum, wetting the gummed edges of the paper, and folding it round the drum with the zero-line at a mark made on the drum for the purpose. It can be as rapidly removed, by simply cutting with a knife down the noon line. Except in connection with the clock, and between the fine wire, which may be removed at the cost of a few pence, and the gland through which it passes, there are no frictional bearing-surfaces whatever; and, as all parts except the body are made of non-oxidisable metal, it is not surprising that the cost of maintenance is trifling—much less than it can be in any integrating meter. The meter is placed under the carriage-way direct upon the main, and access to it is easily obtained through a strong surface box.

MAINTENANCE OF REDUCED WASTE.

It has been sometimes urged, in disparagement of the waste-water-meter system, that a district having once been got into proper order, very soon gets wrong again. Of course it does so if left to itself. Leaks constantly break out, but rarely or never cure themselves, and the broad problem to be solved is, by what means can they be most cheaply and quickly detected, localized, and repaired?

In the following Table, the condition of one hundred waste-water-meter districts in a single town on the first application of the system is given, and the condition of the same districts at different periods afterwards. In connection with these figures the Author desires to draw particular attention to the following facts. Before the introduction of the meters, the house-to-house system

of inspection had been applied, with 3·9 inspectors to each 100,000 persons, and the result is shown by the first column of percentages of districts wasting different quantities of water. The waste-water-

When Waste-Water-Meters were first applied it was found that the number of these	—	Some Months later.	Seven Years later than the last Column.	Thirteen years later.
	Per cent.	Per cent.	Per cent.	Per cent.
Districts wasting less than 5 gallons per head per day was }	0	2	20	40
Districts wasting between 5 and 10 gallons per head per day was }	4	38	56	46
Districts wasting between 10 and 15 gallons per head per day was }	4	40	24	14
Districts wasting between 15 and 20 gallons per head per day was }	24	12	0	0
Districts wasting between 20 and 25 gallons per head per day was }	24	4	0	0
Districts wasting between 25 and 30 gallons per head per day was }	14	2	0	0
Districts wasting between 30 and 35 gallons per head per day was }	14	0	0	0
Districts wasting between 35 and 40 gallons per head per day was }	8	0	0	0
Districts wasting between 40 and 45 gallons per head per day was }	2	2	0	0
Districts wasting between 45 and 50 gallons per head per day was }	4	0	0	0
Districts wasting between 50 and 100 gallons per head per day was }	0	0	0	0
Districts wasting between 100 and 150 (actual 132) gallons per head per day was }	2	0	0	0
	100	100	100	100

meter system was then put into operation with the same number of inspectors, and a remarkable change in a few months is indicated by the second column, where the majority of the districts are shown to be wasting the smaller quantities of water. Seven years later,

the proportion of inspectors was less, and the percentages of the wasteful districts was, as shown by the third column, still lower. Thirteen years later, the number of inspectors per 100,000 persons was only 3·1; and the fourth column shows that all the districts occupy one of the three lowest classes of waste, which only 8 per cent. of them occupied at first; while 40 per cent. occupy the lowest class of all, in which at the end of the house-to-house system there were none. Thus it is clear that as the districts improve with the repairs and renewals, the facility with which they are further improved increases. The staff, in short, which is competent to bring the waste within moderate limits, is far more than sufficient to keep it down, or even to bring it within still lower limits.

PARTICULAR EXAMPLES OF THE APPLICATION AND MAINTENANCE OF THE WASTE-WATER-METER SYSTEM.

Out of the six-and-a-half millions of persons to whom the system has been applied, the Author has received from the engineers or managers of a few waterworks the particulars of their districts, and these have been tabulated in the Appendix, together with an estimate of the financial benefits resulting from the saving of water effected.

DOMESTIC FITTINGS.

It has often been urged that good fittings and pipes are the true means of preventing waste; but a full and frank admission of this does not render less obvious the advantages of any method by which the hidden waste—occurring even in entirely new districts—may be readily detected.

In districts where no pipe or fitting is more than a few years old, where every fitting before being fixed had been taken to pieces by the proper officer of the Water Authority, tested under hydraulic pressure, and, if found satisfactory, stamped, and where the pipes have been laid under the strictest conditions,—continuous waste is always recorded by the differentiating meter, and may be readily localized by one of the methods described in Mr. Deacon's Paper already referred to.

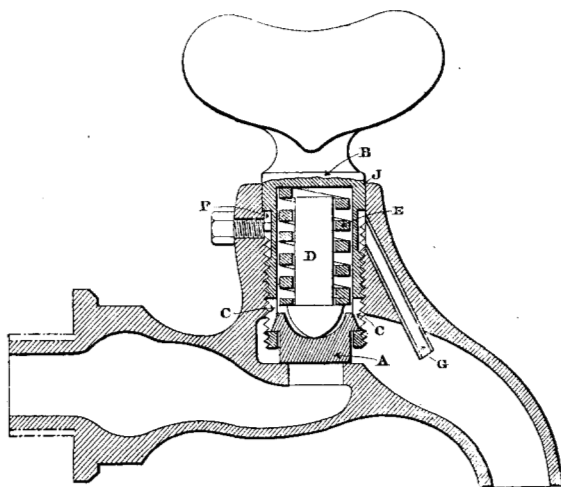
The low rate of constant supply in two or three places—in which statutory power to interdict the use of existing fittings and

pipes, and to prescribe the nature in detail of all new fittings, was obtained some forty years ago—has often been mentioned in support of the sufficiency of house-to-house inspection; the truth being that the condition was chiefly due to an almost complete re-construction of the works and fittings of distribution; and, however good that condition may be, it cannot be maintained without continuous detection and repair of flaws. The authorities of most of the places of which particulars are given in this Paper, possessed no such powers as these over the consumers' fittings and pipes. Undoubtedly it is desirable to possess them, but they need not be, and should not be, employed, except where persistent waste occurs from an existing fitting or pipe.

Although modern water-fittings leave much to be desired, they are generally excellent as compared with those of the past, but the desire for cheapness in first cost is still the cause of much waste and subsequent expense. Testing and stamping by the Water Authorities, when properly performed, is the only way known to the Author of maintaining a sufficiently high standard. The interests of different trades make it practically impossible in large communities to confine the plumbers to the use of fittings of a single type, and, indeed, with one exception, no single type of domestic water-fitting can be said to be manifestly better than another. That exception is certainly a notable one. 'By the invention of Lord Kelvin there is one practicably imperishable water-tap, on a new but now well-proved principle, without fibrous or organic washer of any kind. These taps are extensively used, though they cannot be produced at the lowest prices; but, where introduced, they entirely remove the constant nuisance and cost of leaking washers.

The principle of this fitting is so new that it deserves a detailed explanation. The tap is illustrated in *Fig. 3*. The washer A is of metal, and closes, as in other taps, upon a metallic seat. Metallic washers have frequently been tried in the past, but have always failed through the metallic surfaces becoming scored by the gritty particles which are occasionally found in all water; so that, when the washer is screwed down to the seat, either these particles prevent perfect contact and permit leakage, or else the water passes along the little furrows occasioned by their scouring action. In Lord Kelvin's tap, the washer is so arranged that, when it comes in contact with the seat, the handle is not suddenly arrested. The turning is permitted to continue somewhat beyond the point at which the flow ceases, so that at every operation of

closing and opening the metallic washer is rubbed upon the seat. This is accomplished as follows:—The washer A is held in the can B by two gudgeons projecting from it, which are confined by the slots CC. The arrangement provides that whenever the can is turned the washer must turn also, and it further provides that the can may move parallel to its axis without moving the washer in the same direction. Pressing centrally upon the washer, is the hemispherical head of a rivet-shaped piece of metal, D, and upon the shoulder of the rivet-head the spring E presses. The can B being screwed into the body of the tap, it is clear that, upon

Fig. 3.Scale $\frac{3}{4}$ full size.

closing the tap, turning may continue after the washer has reached its seat, so that burnishing of the surfaces takes place on every occasion of opening and closing.

Another remarkable improvement, also due to Lord Kelvin, is the abandonment of the usual stuffing-box for preventing the upward passage of water when the tap is open. At F there is an annular groove cut in the outside screwed portion of the can, and from a point in the body of the tap opposite to that groove there is a tube, G, leading into the outlet or "bib" of the tap. The water, in passing out, induces a current down the tube G, and so carries away any leakage rising between the screwed surfaces as

high as the annular groove F. The result is that no water issues between the can and the body at J, and thus the necessity for a stuffing-box is entirely dispensed with.

There are some other peculiarities of construction which cannot easily be described. The improvements have now all stood the test of time, and the combination has resulted in a perfect piece of mechanism for domestic water-supply purposes.



APPEN

PARTICULAR EXAMPLES OF THE APPLICATION AND

Town.	Immediately before the Application of the System.			After the Application of the System.			Cost of Introduction of the System (Capital).	Annual Working Expenses.	Population.
	Year.	Service.	Average Daily Supply per Head.	Year.	Service.	Average Daily Supply per Head.			
Bath ¹ . .	1885	Constant	Gallons. 47·70 ²	1890	Constant	Gallons. 21·00 ²	£. 2,575	£. 348	59,000
Birkenhead	1882	Constant	25·32 ²	1890	..	17·10 ²	3,059	473	92,947
Carlisle ³ .	1877	..	42·56 ²	1890	..	18·80 ²	998	100	41,175
Gloucester	1883	Constant	32·00 ⁵	1891 ⁶	..	{15 to 16 ³ }	2,000	169	37,000
Lambeth ⁷ .	1880	Constant	33·00 ²	1890	Constant	18·34 ²	6,000	2,390	341,856
Leamington	..	..	24·00 ⁵	..	Constant	16·00 ⁵	370	112	22,797
Liverpool .	1873	{ Inter-mittent }	24·25 ²	1873—	Constant	33·50 ²	..	..	..
				1876	..	20·25 ²	..	..	..
				1890	Constant	16·00 ²	30,589	3,668	755,689
Portsmouth	..	..	35·00 ²	..	Constant	19·47 ²	..	..	111,300
Southwark & Vauxhall . .	1880	{ Inter-mittent }	29·00	1890	Constant	18·00	16,800	1,963	842,000 ⁸
Widnes .	1886	Constant	11·29	1890	Constant	8·09	350	70	21,000
Yokohama.	..	..	..	1891	Constant	15·4 ⁹	..	..	87,500

¹ Approximate rate of intermittent supply with partial house-to-house inspection in 1884, 31 gallons per head per day.

² For all purposes including trades not supplied by meter.

³ Before the introduction of the system, house-to-house inspection was employed and the rate of supply was 42·56 gallons per head per day.

⁴ Of these, about 38,200 receive the public water-supply.

⁵ For all purposes, including trades supplied by meter.

⁶ In June, 1884, after 8 months' application of the system, the pressure on pipes and fittings increased from 40 lbs. to 60 lbs. per square inch, and the supply was reduced to 19 gallons per head per day.

⁷ The system has been hitherto applied to 341,856 persons, out of a total population of 659,899.

DIX.

MAINTENANCE OF THE WASTE-WATER-METER SYSTEM.

Remarks.	Authority.	Annual Saving of Water.	Net Annual Saving to the Town, assuming Water worth 6d. per 1,000 Gallons, and Charging Interest and Depreciation at 8 Per Cent.
		Gallons.	£.
Waterclosets and baths general . .	Charles Gilbey . .	215,350,000	4,730
{ Waterclosets and baths general. Supply previously brought down from 35 to 25·32 gallons per head per day, by house-to-house inspection, and could not be reduced lower . . }	W. A. Richardson .	278,863,760	6,253
Waterclosets and baths general . .	{ J. Hepworth, M. Inst. C.E. . . }	364,240,800	8,926
Waterclosets and baths general . .	{ R. Read, Assoc. M. Inst. C.E. . . }	140,442,000	3,162
{ Waterclosets throughout, baths in about one-half the houses . . }	{ S. H. Louttit, Assoc. Inst. C.E. . . }	1,858,437,285	43,591
Waterclosets and baths general . .	{ W. De Normanville, Assoc. M. Inst. C.E. . . }	66,567,240	1,522
{ House-to-house inspection in operation in 1873, prior to application of the system . . }	{ G. F. Deacon, M. Inst. C.E., J. Parry, M. Inst. C.E. . }	1,751,498,000	37,672
{ House-to-house inspection in operation prior to application of the system . . }	{ H. R. Smith, Assoc. M. Inst. C.E. . }	630,898,485	
	{ J. W. Restler, M. Inst. C.E. . . }	3,372,600,000	81,008
{ Five per cent. of the premises have waterclosets and baths . . }	.. ..	24,528,000	515
No waterclosets. Bathing very general	{ Major-General H. S. Palmer, R.E., Assoc. Inst. C.E. }		

⁸ The system has been hitherto applied to 648,600 persons, out of a population of 842,000.

⁹ Waste less than 1 gallon per head per day, arising principally from taps out of repair, burst lead pipes, and fractures of service-pipes due to earthquakes. System in operation since the completion of the works in 1887.

NOTE.—It is impossible to assign to the water saved a uniform value per 1,000 gallons; but in this country a new supply can rarely be obtained for less than 6d., and commonly costs 7d. to 9d. per 1,000 gallons.

A fair idea of the financial benefits resulting from the reduction of waste in the foregoing cases may therefore be arrived at by putting the value of the water at 6d. per 1,000 gallons, and by deducting the annual expenses, including interest and depreciation upon capital expenditure, incurred in introducing the system.