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THOS. E. HARRISON, President,
in the Chair.

No. 1,431.—“On the Systems of Constant and Intermittent Water Supply, and the Prevention of Waste, with special reference to the restoration of Constant Service in Liverpool.” By GEORGE FREDERICK DEACON, M. Inst. C.E.¹

1. INTRODUCTORY.

It has always been the custom to regard modern systems of drainage and water supply as great sanitary benefits; and if the state of things which they have induced be considered simply in relation to that which, without them, would exist in a densely-peopled district, the estimate is correct. But in the search for personal comfort in matters of household arrangement, the system of mere external drainage and water supply, for ages thought sufficient, was changed to one in which arterial connections were introduced between the dwellings of hundreds of thousands of people.

The altered arrangement had its obvious benefits, but, like almost every change in the manner of applying any scientific principle, or in the details of an invention, it developed new defects, which were either not noticed, or, if regarded at all, were treated as comparatively unimportant. These defects, however, are by no means necessarily inherent in the altered system, but are a consequence of the utter thoughtlessness with which the details in connection with dwelling-houses have in many instances been carried out.

It is useless to inquire whether those who so readily caught at the idea of bringing drains and water pipes into more convenient places, ever contemplated the magnitude of the evil, which on the introduction of such new channels for the spread of epidemic disease,

¹ The discussion upon this Paper occupied portions of two evenings, but an abstract of the whole is given consecutively.

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would become possible. Certain it is, that if any had the knowledge of the results which might ensue they were powerless to insure throughout the country the exercise of those precautions which could alone render the system safe. The public drainage and water supply may generally have been executed under the best advice of the day; but, owing partly to the want of parliamentary powers, partly to the difficulty of supervising in detail the work of speculative builders, partly to the fact that the control of the engineer was no longer thought necessary when the doors of dwelling-houses were reached, and partly to an abuse of the feeling that every Englishman's house is his castle—the strange incongruity has arisen, of works intimately affecting personal health and comfort, devised in a manner so crude, and indicating so little thought and intelligent action, that, when contrasted with the comparative perfection of those arrangements which might at a trifling extra cost have been adopted, the anomaly appears almost unaccountable.

Unexceptionable house drainage, however seldom realised, is generally regarded as indispensable; but the necessity for preventing waste of water is far less obvious. The consumer recognises in such prevention no direct sanitary benefit, and so takes little pains that the water fittings shall be of the best possible construction, and the pipes of the required strength; and although on the part of those who supply the water great alarm is often manifested, the conditions required to prevent leakage, even when no substantial impediment to its prevention exists, are often entirely disregarded. It might be supposed that water companies would be so influenced by the risk of increased future expenditure, that they at least would resort to all practicable means for the prevention of waste; but, at the present time, many of those companies are allowing water to be laid on at high pressure for the supply of service pipes and fittings such as must inevitably, in the course of a few years, lead to great and continuous waste; and if this obtains under the control of bodies whose pecuniary interests are so intimately affected, it is easy to understand that the laxity in the case of many water committees of corporations and local boards is equally great.

When conditions such as these prevail, it is not strange that the state of pre-existing fittings and pipes is almost wholly neglected. There are but few towns, except those in which a water supply has only recently been introduced into the houses, which do not present the most incongruous combination of pipes and fittings of every kind in use since, or even before, the abandonment of those

hollow trunks of trees which formed some of the earliest water mains, and many miles of which have recently been dug up. Between such antiquated appliances, and the pipes of the great strength and fittings of the comparatively perfect mechanism now known to be necessary to resist the influence of frost, surface traffic, and increased internal pressure, the step is a wide one; even the very existence of many pipes is often unknown. It is not surprising therefore that under both roads and houses there are innumerable sources of continuous waste, which no ordinary inspection, however careful, can detect. Exhaustive reports have been prepared by engineers; Parliamentary Committees and the Board of Trade have inquired into the subject in the most thorough manner, and in a few towns complete success has attended the endeavours to prevent waste; but all this has done little to relieve the feeling of comparative helplessness which so generally prevails.

Under these circumstances the Author submits the following remarks on the subject generally, together with the results of his experience in the matter, gained in connection, not indeed with the metropolis, but with a town of the first importance, the water supply of which, having been changed from constant to intermittent service, has been regarded as a most unfortunate example of the evils resulting from waste of water.

2. SOURCES OF WASTE, AND EFFECT OF INTERMITTENT SERVICE ON THE SUPPLY.

The waste of water may be divided into two classes:—

1st. Continuous or hidden waste, being that which flows from pipes and cisterns below ground, and sometimes by hidden pipes from cisterns above ground.

2nd. Discontinuous or superficial waste, being that which arises from defective fittings above ground, or from taps and valves temporarily left open.

In addition to these sources of waste there is frequently a considerable loss of water in its application to useful purposes; but as any attempt to induce a spirit of parsimony in this respect is reprehensible, it would be an error to treat the loss thus occasioned as one for the prevention of which it is desirable to adopt active measures. The expression, "water used or consumed," will therefore, in this Paper, include such as is drawn off by hand, whether actually applied to useful purposes or not.

Out of every 100 gallons of water passing into a service main during twenty-four hours, it is not unusual for 35 gallons to be

lost by continuous or hidden waste, and 35 by discontinuous or superficial waste, while only 30 are drawn off for use.

This being the mode of disposition of the water under constant service, it is obvious that, if the duration of supply to the main in question were reduced to twelve hours a day, half the water hitherto wasted, or in this instance 35 gallons out of every 100, would be saved, less the waste from fittings connected with cisterns, which would continue until the storage was exhausted. But this would not be a correct measure of the gross reduction in the volume of water taken, as experience shows that the consumers would, while the water remained on, draw more freely than before, and would generally store as much of it as possible until the supply valve was again opened.

Thus the system of intermittent supply increases to some extent the use, or rather misuse, of water, reducing at the same time the most important element of waste nearly in direct proportion to the reduction in the hours of supply, and as it is the most obvious method by which the loss of water may be limited, the expedient has frequently been resorted to.

3. OBJECTIONS ON SANITARY GROUNDS TO INTERMITTENT SUPPLY AND WASTE OF WATER.

When water is cut off from a district, the mains and pipes discharge themselves chiefly through leaks at low levels. Air rushes in from defects at higher levels to fill the space lately occupied by the water, or, if an opening to a pipe happens to be beneath a liquid, that liquid is forced into the mains by atmospheric pressure.

In most towns defects of this nature are probably as numerous and important as in Liverpool, where open ends and large holes in water pipes have been found in direct communication with the sewers and drains, and in such relation to the system of mains and pipes that an indraft of sewer air must inevitably have taken place each day during intermittent service, with which air the water first drawn in the morning must have been charged.

In the poorer districts of many towns water is laid on to closets by pipes direct from the mains. Under intermittent supply the basin cannot, therefore, be flushed out except while the water is on. The more frequent stoppage of the drains follows of necessity, and the pan often remains charged in consequence. The supply pipes are in many instances commanded only by common cocks, which

are liable to be left open, and in such cases there must be an indraft from the closet pan each time the water is cut off from the district. These evils, which any person interested in the details of the distribution of water may ascertain, deserve the gravest consideration.

The system of compelling the poorest classes in overcrowded and unhealthy dwellings to store water for fifteen or twenty hours out of the twenty-four—as is frequently the case—in such inadequate vessels as they may be able to provide is also an evident sanitary evil, and is, in the Author's judgment, a most fertile element in the production of intemperance. The storage of water in cisterns for drinking and culinary purposes is most objectionable, much more so than is generally understood. Such cisterns are commonly found in close contiguity to, or even connected by a pipe with, the drainage system of the house. They are often uncovered, and so become the receptacles for decaying animal matter; frequently, too, they are exposed to the direct rays of the sun, and become polluted with organic growth; while, when containing water from some sources, they are often the cause of lead poisoning. The Author has in numerous instances found the overflow pipes from covered cisterns for storing drinking water actually connected with the soil pipes below the traps, so that the surface of the water was in direct contact with air from the house drains and sewers.

Under the intermittent system water for drinking is necessarily subject more or less to these conditions: under the constant system it may be drawn direct from the main, and the cistern may be retained for other purposes.

But, apart from all considerations of the intermittent service which it so often induces, the waste of water is harmful in itself; although some influential men advocate a supply of water so abundant that it may be wasted to an unlimited extent, on the plea that it flushes the sewers and teaches people to be cleanly. But these impressions are not borne out by the facts. Of all the water wasted a large portion does not find its way direct to the drains. Throughout the older parts of Liverpool, for example, even during a dry summer season, and although the basement of every house had been drained, the cellars and the soil around were in most cases completely saturated with water from the town supply. This was their state under intermittent service, and if constant service had been a possibility without a reduction of waste, its blessings would have been greatly alloyed by the augmentation of a condition which could not fail to

exercise a prejudicial influence on the comfort and health of the people.

In isolated instances, and for a short space of time, some individual drain may be benefited by the excess of water; but by the larger portion of the waste, viz., that which finds its way through the ground, and thence through the brickwork, injury is done to the structural condition of the sewers, and to their effective action.

The most enthusiastic advocate of superabundant supplies would scarcely suggest that a larger quantity than 100 gallons per head per day should be given; but assume that 100 gallons per head per day, in excess of the water used, flow continuously down a single house drain. Suppose there are ten inmates, a number far above the average for each house, there will be wasted in twenty-four hours 1,000 gallons, a quantity which could not have the smallest beneficial influence upon any drain. It would be a mere dribble, such as would pass from a pipe, under ordinary pressures, through a hole the size of a pin's head.

The main sewers and outfalls in the lower parts of towns, where the quantity of water is usually too great, receive the aggregated dribblets, and moreover, as in those parts the pressure in the mains is greatest, they receive the larger portion direct, and not after passing through the branch sewers above, to which they might in isolated cases be of some benefit.

Happily the cleanliness of branch sewers and drains is not dependent upon the waste of water. It is the result of experience that the sudden discharge of 2 gallons of water through a soil drain each time that drain is made use of is thoroughly effective in cleaning it, and this sudden flush is provided for by all properly drawn-up regulations as to water fittings. Further, at the heads of all branch sewers in towns flushing chambers for intermittent action may be constructed which will give a perfectly satisfactory result with an expenditure of water no greater than 1 quart per head per day.

The advocates for carelessness in the distribution of water may find numerous examples of the disastrous influence of too strong a feeling of security in abundant supplies. That such supplies are desirable cannot be doubted, but it is equally true that they should be conserved with the greatest care for the reduction of rates, the cheapening of manufactures, the systematic and intermittent purifying of sewers and streets, and last, but not least, to provide ever-flowing fountains among the dwellings of the poor.

4. PARLIAMENTARY POWERS GENERALLY FOUND NECESSARY TO PREVENT WASTE.

Now although intermittent supply is the easiest method of limiting the waste of water, it would probably have been seldom resorted to had not the authorities believed that they were powerless to contend by any other means with the growing waste. Nor has an examination of the methods adopted in those towns which have been most successful in preventing waste, often done more than suggest a remedy which has generally been regarded, by representatives of the ratepayers at least, as worse than the disease. To the reports made by Dr. Pole, M. Inst. C.E., to the Board of Trade and Home Office in 1870 and 1871 on the constant service system, the Author is indebted for much of the following information concerning the change from intermittent to constant supply in two of the towns in which that change has been successfully carried out.

In 1850 the Norwich Waterworks Company obtained an Act incorporating the Waterworks Clauses Act, 1847, which bound them to give a constant supply. When, in 1851, this condition was complied with, and the pressure of water increased to that due to the height of the new reservoirs, the old mains gave way to such an extent as ultimately to necessitate their entire renewal.

In this manner it is probable that the waste was almost wholly confined to the private pipes and fittings, but the means which the Company possessed to control that waste were limited by sections in the Waterworks Clauses Act, which gave power to enter premises between 9 A.M. and 4 P.M., to ascertain if there were any waste or misuse of water;¹ also power to impose a fine not exceeding £5 for any wilful act whereby the water might be wasted.²

Such precautions as these clauses rendered possible were taken by the Company; but in Norwich, as everywhere, they proved almost abortive; and about the year 1859, the expenditure of water being 40 gallons per head per day, the Company were compelled to revert to intermittent service.

In the same year, acting under the advice of Mr. Hawksley, Past-President Inst. C.E., the Company obtained an Act to enable them to prescribe the nature in detail of all fittings and pipes and the work in connection therewith, and to interdict the use of any existing fittings and pipes which in their judgment might tend to waste.³

¹ 10 Vic. cap. 17, sec. 55.

² 10 Vic. cap. 17, sec. 57.

³ 22 Vic. cap. 15, secs. 45, 46.

The consumers had now no option but to abide by such regulations as the Company chose to make with reference to the fittings and pipes, and in a few years the consumption of water was reduced from 40 gallons to about 15 gallons per head per day, while constant service was restored. It must, however, be borne in mind that these results were obtained, first, by the renewal of the public mains, and, secondly, by the exercise of the almost unlimited powers vested in the Company.

In Manchester, the Corporation, having adopted the Waterworks Clauses Act, and received for the first time in 1851 an abundant supply of water from new works, gave a constant service, and were enabled to continue it. As in the instance of Norwich, however, the repression of waste was attempted under the Waterworks Clauses Act, 1847, and failed. In 1858 the Corporation, therefore, obtained an Act empowering them to refuse to supply water to any apparatus not so constructed as to prevent waste.¹ But, inasmuch as no authority was named in the Act to settle the repeated disputes as to whether the fittings were so constructed as to prevent waste, this clause proved of little value; and in 1860 they again went to Parliament, and obtained clauses² which were in effect similar to those already referred to as having been granted about the same time to the Norwich Waterworks Company; while in 1867 some minor additions were made to the Act.

By means of the great powers over the consumer's fittings thus placed in their hands, the Corporation of Manchester have not only been enabled to maintain constant service, but to prevent waste to an extent sufficient to retard considerably the rate of annual increase of consumption.

These cases are examples of the difficulties to be encountered, and of the ineffectual efforts to prevent the waste of water, except in a comparatively slight degree, without almost absolute control over the consumer's fittings and pipes. The provisions in this respect of the Waterworks Clauses Act have not, it is believed, hitherto proved sufficient in any town to enable constant service to be given and maintained, except with a ruinous expenditure of water.

The powers, however, to control waste possessed by the Corporation of Liverpool are, with the following exceptions, limited to those given by this Act.

1. In 1847 it was enacted that the Corporation should not be compelled to supply any water-closet, or the apparatus or pipes

¹ 21 & 22 Vic. cap. 87, sec. 4.

² 23 Vic. cap. 93, secs. 3, 4, 5.

connected therewith, which had not been constructed in a manner approved of by the Council.¹

In an Act obtained in 1850, a clause was introduced inflicting penalties for wilful waste of water.²

By the Act of 1862, powers were obtained to cut off the water where anything in contravention of the provisions of the Waterworks Acts was done to lead to waste; and further, it was provided that any person wrongfully suffering any fitting to be so used or contrived as that the water was, or was likely to be, wasted, should forfeit a sum not exceeding £5, and should remove, replace, or alter, or permit to be removed, replaced, or altered, the objectionable fitting or pipe.³

Although at first sight they may appear satisfactory, these provisions have been so difficult to work, that, except when waste could actually be proved in each individual case, they have never been enforced.

The difficulty of satisfying a magistrate that a fitting is likely to cause waste is very great; while the necessity for taking into court all cases of waste, in which it is desirable to bring any person under the operations of the last-named provision of the Act of 1862, renders the clause almost abortive. On the other hand, the power to cut off the water supply can only be enforced to a limited extent by a corporation who are guardians of the sanitary condition of the town; and even where this step is resorted to, its effect is to punish the tenant instead of the landlord, who, in houses above £13 rental, is responsible for the work.

The only proper control over fittings or pipes, which the Liverpool Corporation possess, is in connection with water-closets. That control is to a limited extent given, as already stated, under the Act of 1847, and in 1866 it was further provided that every water-closet or urinal should have an apparatus to prevent waste, to be approved of by the Corporation.⁴

When compared with those provisions which had been found necessary to reduce the consumption to any considerable extent in some other towns, it is clear how very little real power over the consumer's pipes and fittings the Liverpool authorities possess.

5. PAST CONDITIONS OF SUPPLY AND DEMAND IN LIVERPOOL.

Before explaining the method lately adopted in Liverpool for the prevention of waste of water, and the results which have attended

¹ 10 & 11 Vic. cap. 261, sec. 111.

² 13 & 14 Vic. cap. 80, sec. 20.

³ 25 & 26 Vic. cap. 107, secs. 65, 66.

⁴ 29 & 30 Vic. cap. 126, secs. 37, 38.

those measures, the conditions of supply and demand during the last few years will be briefly stated.

In the year 1858, water was for the first time laid on constantly to nearly the whole district, an area of 60 square miles, which the Corporation were bound to supply. The quantity available, under the most unfavourable conditions, was apparently ample, and it might reasonably have been expected to meet the demands of the increasing population for many years to come; but within seven years the people were again subjected to the intolerable annoyance of intermittent service. In August 1865 it was found necessary to reduce the service throughout the borough to twelve hours, in September of the same year to seven, and ultimately to three hours a day; yet, notwithstanding this, the mean consumption for the year was 25·01 gallons per head per day, not including trade supplies.

Various steps were then taken to obtain further supplies; and before 1870 the whole available yield was increased by about one-fifth, by sinking new wells and boring in the New Red Sandstone near Liverpool, and by the purchase of water at Rivington, hitherto given as compensation. Notwithstanding this, however, the average number of hours' service was gradually and of necessity decreased, while the consumption per head did not diminish; and in 1873 it was for the first time found necessary to place the Out Townships, containing 109,749 persons, under intermittent service.

A new supply had been talked about, but many years must elapse before the necessary works could be carried out, while any year might bring with it a dearth of water. Powers for such a supply could only be obtained on condition that constant service would be given; and it had been ascertained by experiments that the average constant service would not be less than 33·5 gallons per head per day, exclusive of trade supplies by meter. Even if the Liverpool people had believed that they were justified in asking for it, with the examples of Norwich, Manchester, and many other towns before them, the fact that so large a proportion of their present supply during twenty-four hours was utterly and harmfully wasted would have constituted a powerful argument in the hands of opposing counsel. The further prevention of waste was therefore regarded as a necessity; while the restoration of constant service, which, it appeared to the Author, ought to be given with the existing supply, was looked upon as a possible concomitant.

In Table A, page 140, columns 4, 5, and 6, the number of hours' service per day, from the year 1860 to the present time, is given; and in column 7 will be found the corresponding rates of con-

sumption per head per day. On Plate 4 the same quantities are represented by diagrams.

Inasmuch as the great reduction which has taken place in the number of hours' service has been accompanied, in many instances, by an increase of the rate per head, it is not surprising that experiments to ascertain the amount taken during twenty-four hours' service should have indicated that, in 1873, 33·5 gallons per head per day, exclusive of trade supplies, were necessary for the constant service of Liverpool, showing that an increase of 5·2 gallons had taken place in nine years; and although it may not be right to charge the whole of that increment to waste, yet only a small portion of it can be due to extended legitimate use.

To these considerations should be added the fact, that during the same period the trade supplies measured by meter, and shown in column 10, have greatly increased.

The number of hours' supply per day must have been still smaller, had not the mean rainfall for several years past been above the general average, and this circumstance had no doubt engendered a feeling of false security, which an examination of the figures referred to will not justify.

To illustrate the effect which was being produced by the increasing consumption and the diminishing hours of supply, column 8, Table A, and one of the lines in Plate 4, show the average rate of consumption per head per hour in each year; and column 9 gives the corresponding percentage of increase of that rate on the year 1864, when the original constant service was for the last time given.

6. PAST MEASURES FOR THE PREVENTION OF WASTE IN LIVERPOOL (Plate 4).

Ordinary house-to-house inspections had been regularly made from the year 1863 to 1873. In cases of actual waste arising from defects, notices to repair were served upon the persons responsible for the water rates, and such other steps were taken as the legal powers rendered available. Columns 11 and 13, Table A, show that the number of house-to-house inspectors was yearly increased up to 1873, when the system was discarded, and, for reasons hereafter given, the regular visitations entirely ceased. In column 12, and on Plate 4, the proportion of inspectors at different times to each million persons is given.

The work done by the house-to-house inspectors will be adverted to under another head; for the present it is sufficient to examine the table and diagrams to be satisfied that, though they had

no doubt produced useful results, there was nothing to indicate that, by increasing their number, much further saving would be produced. Indeed, the superficial and generally intermittent waste which they were able to discover and prevent was comparatively small. Experience also was adverse to the possibility of success in the endeavour to reduce the consumption materially even while maintaining intermittent service; and the idea of restoring constant service, with the existing parliamentary powers, was generally regarded as chimerical.

Under these circumstances, in 1873, a draft bill was prepared embodying clauses very similar to those which had enabled Norwich and Manchester to produce the results already explained. It was requisite, however, that the measure should pass the ordeal imposed by Parliament in the Municipal Borough Funds Act.

Without explaining the history of the proposed bill, it may be stated that the bulk of the ratepayers were apathetic regarding it; for when, in March 1874, the poll was taken, it appeared that, out of 151,853 votes which might have been given, only 44,259 were returned. Of these, 33,811 votes were recorded against the bill, which was therefore abandoned.

7. EXPERIMENTS IN DISTRICTS COMMANDED BY ORDINARY METERS.

In 1872 the Author had made a series of experiments, with a view to devise means for discovering the locality of a larger proportion of the waste than the house-to-house inspectors were enabled to trace. In carrying out those investigations, the mains supplying fourteen districts in the most densely populated part of the town, containing in the aggregate about 31,080 persons, were provided with ordinary piston meters.

Special house-to-house examinations were made, and the superficial and generally intermittent waste thus discovered was checked; but, although in some districts a marked diminution in the consumption was at the time produced, the results in others were not satisfactory. It appeared, indeed, that in order to detect actual waste in all those fittings which were liable to lead to waste, and thus to bring them, within reasonable time, under the power of the Corporation, it would be necessary, even in this comparatively small section of the town, to employ a large number of inspectors. Further, it was not at all clear that, even if all the fittings liable to lead to waste had been renewed, a very large proportion of the total waste would be prevented.

CONSTANT AND INTERMITTENT WATER SUPPLY.

TABLE A.

Year.	Total Population supplied.	Number receiving Constant Service.	Number of Hours' Service.			Average Rate of Consumption per Head in Gallons.				Number of Inspectors.	Proportion of Inspectors to a Million of Persons.	System of Inspection.
			Average, including the Constant Supply Districts.	Average to those on Inter- mittent Service.	Minimum.	For all Purposes excepting Manufactories supplied by Meter.			For Trade Purposes by Meter per Day.			
						Per Day.	Per Hour.	Percentage of Increase of Rate per Hour on 1860.				
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1860	491,449	491,449	24	{ All con- stant. }	24	27·39	1·141	..	1·43	{ No syste- matic in- spection. }	..	{ No systematic In- spection.
1861	500,000	500,000	24	"	24	27·47	1·144	·263	1·46	"	..	Ditto.
1862	508,750	508,750	24	"	24	27·6	1·15	·788	1·62	"	..	Ditto.
1863	517,590	517,590	24	"	24	28·27	1·178	3·243	1·75	2	3·86	{ Regular house-to- house inspections commenced.
1864	526,586	526,586	24	"	24	28·35	1·181	3·506	2·07	4·5	8·55	{ House-to-house in- spections.
1865	535,740	74,065	18·82	18	3	25·04	1·330	16·564	2·47	5	9·33	Ditto.
1866	545,055	71,801	11·99	10	5	21·48	1·791	56·968	2·37	5·5	10·09	Ditto.
1867	554,534	81,725	15·89	14½	12	25·37	1·597	39·965	2·87	7	12·62	Ditto.
1868	564,182	85,847	13·19	11½	7	23·25	1·763	54·513	2·65	8·5	15·06	Ditto.
1869	573,998	90,177	13·04	11	7	24·79	1·901	66·608	2·72	9·5	16·55	Ditto.
1870	583,987	94,725	12·27	10	7	24·87	2·027	77·651	3·07	10	17·12	Ditto.
1871	594,152	99,503	11·93	9½	7	25·98	2·177	90·798	3·37	13·5	22·72	Ditto.
1872	604,415	104,515	12·21	9¾	7	24·38	1·997	76·022	3·53	17	28·12	Ditto.
1873	614,962	136,058	12·22	9½	7	24·47	2·003	75·548	4·00	15·5	25·20	{ Last year of regular house-to-house in- spections.
1874	625,830	234,956	15·57	10½	10½	23·86	1·532	34·268	4·19	15·7	25·02¹	{ Waste-water meter system only. No ordinary house-to- house inspections.
1875	632,643	317,747	17·28	10½	10½	22·56	1·305	14·373	4·24			
First quarter Fortnight ending Mar. 30	634,161	373,278	18·44	10½	10½	22·33	1·211	6·135	4·24			

¹ This includes one chief inspector and one waste-water meter inspector who are not engaged in the work of ordinary inspection

In four of the districts, which fairly represent the whole, and contain in the aggregate 7,817 persons, it was found, before any special examinations had been made, that while the consumption during nine hours averaged 17·26 gallons, and during twenty-four hours 34·5 gallons per head per day, the rate of flow between 1 A.M. and 4 A.M. was as high as 29·8 gallons per head per twenty-four hours. Moreover, it was ascertained that the rate of this nocturnal flow was constant, while the flow during the day was an ever-varying quantity. This result had been anticipated. The steady flow during the night indicated the rate of waste, while the flow during the day was made up of the waste together with the unsteady flow, due to water being drawn for use. From these figures it may fairly be inferred that 4·7 gallons per head per day, or the difference between the nocturnal rate and the total supply, was approximately the legitimate consumption of water in those districts under constant service.

Assuming what in such districts is very nearly true, that the rate of continuous waste during the nine hours of intermittent service was the same as the nocturnal rate under constant service, the actual amount of that waste during the nine hours was found to be 11·1 gallons per head, while the water taken, being the difference between this and the 17·26 gallons, the total supply during the same time, was 6·16 gallons, or 1·46 gallon per head more than the legitimate use under constant service.

The house-to-house inspections, though persevered in for some time, produced but little effect, and it was obvious that some much less laborious method of detecting the particular fittings causing waste was necessary; while there was a strong impression that a large portion of the continuous waste must be ascribed to other causes than those which the inspectors detected.

The iron mains and lead service pipes in these four districts were old and shallow, and therefore, before charging the private lead service pipes below ground with the fault, nearly all the public iron pipes and the whole of the public lead service pipes were renewed.

Experiments were then conducted in the following manner:—

A district was divided into a number of blocks of houses, each block being placed in charge of a trustworthy man at the same hour, while the occupants were requested not to allow any water to be drawn until they received further notice. As an additional precaution, these men closed and fastened every tap, ball-cock, and other fitting, in order to prevent all use, and so far as possible all superficial waste. The meter resumed its steady rate of move-

ment, and the quantity found to be still passing averaged 7·9 gallons per head per day; while in one of the four districts in question it was as high as 14·5 gallons. Outside each house, under the footways, the service pipes had been provided with stopcocks, and while the fittings were still tied it was found that each individual waste could in nearly every instance be heard, when the street was quiet, by applying the turning key to the stopcocks and placing the ear upon it.

The application of this system of detecting waste has been long known, but it was found impracticable to carry it out successfully during the day, except as an experiment, because it was necessary in each case to tie up and watch the fittings, and because the noise of traffic rendered the sounding operations extremely difficult.

During the night these obstacles did not exist. So long as the Engineer or any of his chief assistants personally superintended the nocturnal work, the results were successful; and by counting the strokes per minute of the meter from time to time it was easy to ascertain the waste, which had been checked by closing those stopcocks through which water was discovered to be passing. The premises connected with such stopcocks being reported on the following morning, became the subjects of examination by the day inspector.

The advantages of the system were manifest, as the labour of discovering waste was reduced, the certainty of discovery increased, and the annoyance to conscientious householders by an ordinary house-to-house inspection removed.

By these means the consumption of water for the whole set of experimental districts, containing 31,080 persons, which under nine hours' service had been 19·5 gallons, and under constant service 33·5 gallons per head per day, was reduced under constant service to 13·3 gallons, and subsequently to about 12 gallons; while in one district of 2,134 persons it was brought down to 6·6 gallons, without altering a single fitting which had not been found to be actually wasting water.

A little consideration showed, however, that, in order to obtain such results over the whole district of supply, including a population of 630,000, in a sufficiently short time to ward off the expected dearth of water and to restore constant service, several districts must be inspected every night. The difficulty of efficient supervision would have been very great, and it would have been impossible to ascertain how far the closing of the stopcocks commanding wasteful property had been faithfully performed, as no

record was preserved of the change in the rate of movement of the piston meter, except that returned by the inspectors themselves. The cost, too, of reliable piston meters and of the necessary chambers was at least £112 for each district of about 2,500 persons, while the expense of maintenance was considerable.

8. THE WASTE-WATER METER.

It was under these circumstances that the Author devised an automatic check upon the motions, at once of the night inspectors and of the water, the cost of which is comparatively small. The instrument known as the Waste-water Meter (Plate 6, Fig. 11) records the time and rate of flow through the main, after the manner in which an indicator diagram records space and pressure. The diagram drawn by the instrument distinguishes water wasted from water used. It registers not only the change of velocity, induced by the closing of any stopcock during the night, but the time at which the men commenced work, and the time at which they ceased work. Such an instrument would, if applied to all service mains, give the means, first, of ascertaining at any time the most wasteful districts, and thus enable the superintendent to concentrate the energy of his men on the streets which most require attention, and subsequently of insuring the efficiency of the examinations during which the waste is limited to a few premises only. (See Reference Table B, next page.)

The apparatus has been described elsewhere, and was recently reported upon to the Liverpool Corporation by Mr. F. J. Bramwell, M. Inst. C.E. It is unnecessary, therefore, to do more than to refer to Plate 5, and to explain, that in the instruments now made the diagram is carried on a revolving drum 6 inches diameter, and is divided by horizontal lines into sixty-two spaces, each of which represents 100 gallons per hour; so that the maximum rate of flow capable of being registered is 6,200 gallons per hour. By vertical lines the diagram is divided into twenty-four equal spaces, each of which passes the pencil in one hour. In the actual sheets the horizontal lines are not quite equidistant.

9. APPLICATION OF THE WASTE-WATER METER SYSTEM.

Arrangement of Distributing Mains.—Although perhaps there are no features peculiar to Liverpool in the manner in which the distributing mains are laid, it is desirable to give examples of their arrangement before describing the details of the Waste-water Meter system.

REFERENCE TABLE B TO PLATE 5.

Figure.	Population of District.	Class of Property.	Gross Rate per Head per Day.					
			Before Introduction of Waste-water Meter System.			After Treatment under Waste-water Meter System.		
			Inter-mittent.	Constant.	Rate from 1 to 5 A.M. per 24 Hours.	Constant.	Rate from 1 to 5 A.M. per 24 Hours.	
2	2,062	Old and chiefly low-class cottage and court house property, about £8 to £13 rental, with a few shops.	19·64	30·01	24·15	8·82	4·65	
3	1,778	Principally cottage property, £13 to £22 rental, some court houses, and a few houses and shops up to £60 rental.	24·04	33·55	24·97	11·16	5·94	
4	1,858	Chiefly high - class dwelling - houses, £60 to £200 rental, with some smaller houses.	17·14	19·81	16·08	13·65	8·78	
5	2,337	About half the area cottage and court house property, £8 to £13 rental. The remainder half better - class dwelling - houses and shops up to about £50 rental.	18·14	28·94	18·99	11·89	5·13	
						Prior to Night Inspection.	A few Weeks after Night Inspection.	
6	3,190	Chiefly offices and shops.	..	34·18	28·93	13·1	7·75	
7	1,283	Almost exclusively offices.	..	35·59	31·61	17·81	8·79	
8	1,883	Old property, dwelling-houses large and small, numerous lodging-houses, shops, warehouses, manufactories.	..	35·85	24·21	23·52	11·09	
9	2,143	Chiefly low - class dwelling - houses, rental £6 to £16.	..	27·49	21·28	9·29	5·17	

The principal mains, shown by strong lines on Plate 6, Fig. 10, are charged at all times. From them most of the fire hydrants and larger manufactories are supplied. The subsidiary or service mains, distinguished by light lines, vary in diameter from 2 to 6 inches, and are commanded by valves near their junctions with the principal mains. Of these valves there are about three hundred in the borough, and under intermittent service they were opened and closed every day.

Division into Waste-water Districts.—The existing arrangement of services for distribution is as far as possible adopted. Where, however, a service is too large, it is divided, or a portion is added to an adjoining district, while in some instances, where the services are too small, two or three are combined to form one meter district. Each case is considered in relation to the estimated population, and the anticipated rate of consumption per head, bearing in mind the fact that if the flow at any time exceed 6,200 gallons an hour the diagram will be imperfect. In some cases, after the waste has been greatly diminished on a service, an adjoining district is connected with it, in order to reduce the total number of meters employed.

The largest waste-water meter district in Liverpool contains 4,271 persons, the average maximum rate of flow being about 3,500 gallons an hour, and the mean rate per head per day 13·5 gallons.

The smallest meter district contains 870 persons, the average maximum rate of flow being 4,000 gallons an hour, and the mean rate per head per day 51 gallons.

The total number of meter districts on the 10th April, 1875, was 120, and the population under control 306,912; so that the average population of the districts was 2,557.

Fixing the Meters.—A district having been selected, a sketch is prepared showing the place the meter is to occupy. In Plate 6, Fig. 10, is indicated the position of the meters and connecting pipes under three different conditions. A single length of pipe is removed from the outlet side of the service valve, and connecting pipes are laid to beneath the nearest point of the footway and convey the water through the meter. The cast-iron meter cover is placed in the footway next to the kerb.

Diagrams of Initial Consumption.—After a meter has been fixed, readings are taken to ascertain the consumption of water in the district under the ordinary intermittent supply. The district is next placed under constant service, and the consumption ascertained under that system, before any measures for the prevention of waste are commenced. In twenty-four hours a complete diagram is drawn. If the meter is left for seven days, seven complete

[1874-75. N.S.]

diagrams will be superimposed upon each other. In such cases the night consumptions are distinct ; but the day consumptions, owing to the greater fluctuation, are generally more or less confused. It is therefore usual at first, when particularly accurate information is required, to remove the diagrams every second or third day.

Fixing Stopcocks.—The next step is to attach stopcocks to the lead service pipes of all premises, or blocks of premises, which are not already capable of being controlled from the exterior. The details of the stopcock and its cover are most important ; and in Liverpool the existing plugcocks and defective covers have created much difficulty. All new stoptaps are on the screwdown principle, and the loose valve is so arranged that it cannot fall out when the stuffing-box is removed. The surface cover is fixed into the upper side of the flag with Portland cement. The hinged lid is round, and large enough for a man to pass his arm down. Though all new pipes are laid 2 feet 6 inches deep, the stopcocks are fixed just within arm's length, in order that a washer may be replaced without opening the ground.

Census returns.—The number of persons included in the area under test is now to be determined. In residential property a fair estimate can sometimes be made on the basis of the Government census, or by analogy from actual numbering by the water inspectors in another and similar class of property. Where, however, as frequently happens, a satisfactory estimate cannot be made, inspectors are sent to every building to inquire the number of occupants, and in these cases they also examine the fittings, and furnish a return in the following form (see next page).

RETURN OF POPULATION AND FITTINGS IN DISTRICT NO. 270, PARLIAMENT STREET AND CARYL STREET.

Name of Street.	No. of Premises.	No. of Persons.		Plug Cock.	Screw-down Cock.	Storage Cistern.	Water-closets.						Horses.	Miscellaneous.
		Day Occupants.	Day and Night Occupants.				Double valve Cistern.	Old Regulating Cistern.	Common Cock.	Pan Closet.	Single Valve.	Self-acting.		
Worthington Street	62	1	285	17	13	1	13	3	..	..	1	..	7	{ 1 donkey, 1 cart, 7 standpipes.
Crow	16	..	86	2	4	..	2	1	..	..	..	..	3	1 ditto.
Derryhouse	32	..	165	16	20	1	11	1	2	..	2	..	..	..
Parliament	4	6	3	2	1	1	..	..	..	..	1	..	..	..
Perry	63	3	237	6	4	..	2	..	1	..	..	..	4	{ 1 cart, 4 stand- pipes.
Glover	21	1	77	3	7	..	1	2	1	..	..	..	3	1 cart.
Pleasant Hill	22	9	105	5	8	2	1	1	..	..	1	..	..	7 carts.
Caryl	56	10	258	23	32	1	20	1	..	1	..	..	..	1 donkey.
Stanhope	19	6	67	12	9	6	2	1	..	..	1	..	..	..
	295*	36	1,283	86	98	12	52	10	4	1	6	..	17	{ 2 donkeys, 12 standpipes, 10 carts.

* Of this number eleven are empty.

Records of results.—The population having been obtained, the diagrams already taken, both for constant and intermittent service, are worked out, and the results entered in a suitable book, a portion of one page from which is here given:—

DISTRICT No. 260.—POSITION of METER, *Mill Street, corner of Warwick Street.*

	Population.
Day occupants	85
Day and night occupants . . .	1,977
	<hr/> 2,062

Date.	Total Consumption in twenty-four Hours.	Rate of Consumption in Gallons per Head per Day.		Remarks.
		Average for the twenty-four Hours.	Average from 1 to 5 A.M.	
1874.	Gallons.			
May 7 . .	36,800	17·85	..	Intermittent service.
„ 8 . .	39,850	19·32	..	Ditto ditto.
„ 9-10. .	39,000	18·91	..	Ditto ditto.
„ 11 . .	60,680	29·43	24·44	Constant service.
„ 12 . .	62,950	30·53	26·19	Ditto ditto.
„ 13 . .	63,370	30·73	25·02	{ Commenced fixing stop-cocks—constant service.
„ 15 . .	..	..	24·09	Constant service.
„ 19 . .	..	..	26·19	Ditto ditto.
„ 20 . .	..	..	20·94	Ditto ditto.
„ 25 . .	62,160	30·14	25·6	Ditto ditto.

Night Inspections.—The intermittent and constant service diagrams having been obtained, and the above forms filled up, the night inspections, which constitute important features of the system, are commenced. Each day the superintendent of the waste-water department examines the books, and ascertains the three or four districts in which the largest saving is likely to be made. He sends to the night-complaint office an instruction for those districts to be visited that night; and the waste-water meter in-

PARADISE STREET DISTRICT.

Street.	No.	Night Reports.	Time of closing Stopcock, A.M.	Name of Night Inspector.	Name of Day Inspector.	Date.	Report of Day Inspector.
Paradise St. . .	4	Great noise on S.C. . . .	Jan. 15, 1875. 12.20	Brady	Garner	Jan. 19	Found deft. pipe and valve at 80 Lord St. Noticed. Also ditto pipe burst at back of 2 Paradise St. under flags; shut S.C. Noticed.
Ditto betn. 10 & 20	10 & 20	Ditto ditto	12.30	"	"	"	Found a $\frac{3}{4}$ -in. pipe burst under parapet 5 ft. deep, and the water running into the sewer.
Ditto	12 & 14	Ditto ditto	12.35	"	"	"	
Lord St. . . .	50 & 52	Ditto ditto	1.5	"	"	20	
Ditto	36	Ditto ditto	1.10	"	"	21	Plumber has been repairing fittings in 2 cisterns and W.C.
Ditto	6	Ditto ditto	1.15	"	"	"	Deft. ball-cock in underground cistern. Noticed.
South John St. .	25	Great waste inside left S.C. shut.	1.40	"	"	"	B.C. deft. to store cistern. Noticed.
King St. . . .	23	Noise on S.C.	1.55	"	"	19	Plumber been repairing fittings to W.C.
King St. . . .	27	Great noise on S.C. . . .	2.0	"	"	20	Deft. B.C. to storage cistern: repaired.
						20	Found $1\frac{1}{2}$ -in. lead pipe burst under flags in Leicester Buildings; shut S.C. Noticed.

PARADISE STREET DISTRICT—continued.

Street.	No.	Night Reports.	Time of closing Stopcock. A.M.	Name of Night Inspector.	Name of Day Inspector.	Date.	Report of Day Inspector.
Atherton St. . .	49	Great noise on S.C. . . .	Jan. 15, 1875. 2.30	Brady	Garner	Jan. 19	Corn mill, using water all night, supplied by meter.
Ditto . . .	45	Ditto ditto	2.40	"	"	"	Def't. B.C. in storage cistern. Bad. Left in hands of plumber.
Ditto . . .	7 Cl.	Great waste in closet at top end of court.	2.50	"	"	"	Def't. valve at water-closet cistern. Noticed.
Thomas St. . .	34	Noise on S.C.	3.0	"	"	"	Def't. cock in W.C. noticed.
Ditto . . .	36	Ditto	3.5	"	"	"	Ditto ditto.
Cable St. . . .	61	{ Stopcock on right of . . .	3.15	"	"	"	Def't. B.C. in storage cistern. Bad. Noticed.
		{ Noise on S.C.	..	"	"	"	Ditto ditto.
Ditto . . .	59	Ditto	3.30	"	Wynne	" 15	3 pipes burst inside. Noticed tenant.
Ditto . . .	53	Ditto open or shut . .	3.35	"	"	15	Supplied by meter.
Ditto . . .	33	Ditto ditto	3.40	"	"	" 16	Caused by the meters at Melville Chambers.
Ditto . . .	35	Ditto ditto	3.50	"	"	" 16	Ditto ditto.
Ditto betn. 41 & 43			4.0	"	"	" 15	S.C. def't. Bad. Reported complaint office.
Ditto oppt.	48	Opposite side	4.5	"	"	" 15	This is 45, supplied by meter.

spector, having obtained the information, places upon the meters commanding each a new diagram paper, which he removes on the following morning.

At about 11 P.M. the inspectors proceed in pairs to their respective districts, where their operations are conducted in the following manner:—

Each man takes one side of a street, raises the stopcock covers, and subjects the stopcocks, one by one, to a test, to ascertain if water is passing into the premises. If, on applying the turning key to the stopcock plug and the ear to the turning key, no sound is heard, the stopcock is turned until nearly closed; and if water be passing it will then, by reason of its increased velocity, make a sufficient sound to be heard.

In this manner the flow due to a quick dropping can be easily detected. If noise is heard with the tap open, the tap is at once completely closed, and tested again, when, if the sound is continued, there is evidence of waste on the street side of the stopcock.

It sometimes happens that a number of adjacent stopcocks sound both shut and open. In such cases the inspectors re-examine them, and are generally enabled to ascertain to which stopcock the leak is nearest. Having discovered this, they sound the flags of the footway, and the sets of the carriage way, and in most instances succeed in determining the exact position of the fault.

In other cases several consecutive stopcocks give sound shut or open, until one is reached which sounds when open only, and is most probably the cause of the whole group of sounds. It is closed, and the last stopcocks being re-examined are, if the sounds have ceased, cancelled from the notes.

The exact time of closing each stopcock at which the flow of water is detected is booked by the men, who are provided by the Corporation with watches for the purpose.

When the whole district has been traversed the inspectors retrace their steps, and open the closed stopcocks, after which they return to the office, which they generally reach before 6 A.M., and where they at once write, in copying ink, a report of their night's work. In Columns 1 to 5 of the preceding form are given the reports of one night's work by one inspector.

At 9 o'clock on the same morning a press copy of a night report is ready for each day inspector, who, accompanied by a labourer to open the ground and trace underground leakages, proceeds to ascertain the cause of the noises reported by the night inspectors, and makes his report in the last three columns of the above form.

Where the leakages arise from defective private pipes or fittings,

notices to repair or renew are issued, unless a new washer or an adjusted wire will do all that is required. In such cases the inspector performs the work free of charge. Defective public pipes are reported, and repaired by the Corporation pipe-layers.

Figs. 6, 7, 8, and 9, Plate 5, which will be again adverted to, are reduced examples of twenty-four-hour diagrams, showing the result of night inspections. The diagram from each district, subjected to an examination on the previous night, is brought to the office daily, and by its aid, in conjunction with the night reports, the superintendent determines the time, within a few minutes, when the inspectors commenced their work and left the district in each case, the localities of all, and the amounts of the more important leaks which have been checked, the initial rate of waste, and the final amount to which the closing of a limited number of stoptaps has reduced that waste.

The diagrams are preserved for reference, in the event of failure to discover the cause of waste at any of the reported points.

Tests for condition of Mains.—The diagram obtained after a night inspection in any district shows the lowest consumption reached by the closing of those stopcocks past which a flow of water has been detected. If a margin remains which cannot be accounted for by such trifling leakages as may have escaped the notice of the inspectors, or by leakages reported on the street side of the stopcocks, a special experiment either by day or night is made by the chief inspector to determine the condition of the public pipes. All the stopcocks having been closed, the diagram is examined. If a steady line is being drawn, it is a proof of steady waste. If, on the other hand, the horizontal line is broken here and there by a vertical line, similar to that produced by opening a tap, there is conclusive evidence either that all the stopcocks have not been closed, or that some house services are not provided with stoptaps. In old districts, however great the care on the part of the men, some omissions are in the first instance almost sure to be made; but, with the help of the meter, every service is ultimately controlled.

When the existence of the so-called "public waste" has thus been determined, it can generally be localised by a careful night inspection in which all the stopcocks are closed and sounded. If this is not entirely successful, the sewers are entered, and the position noted of any undue flow down a drain or weeping through the brickwork.

The ground is never opened until the locality of the fault is determined, and mistakes are of very rare occurrence.

Examples of District Diagrams.—Figs. 2, 3, 4, and 5, Plate 5, are examples of diagrams taken from four different districts, under both intermittent and constant service, before the prevention of waste under the Waste-water Meter system, and under constant service at a recent date. Figs. 6, 7, 8, and 9 are examples of diagrams taken during night inspections; showing the effect of closing those stopcocks which were found to be passing water. The dotted line in each case indicates the line which would have been drawn had no inspection been made, while the lower lines show the recent condition of the district. Each diagram is fully explained in Table B.

The experiments in the fourteen experimental districts commanded by piston meters were commenced in January 1873, but it was not until October in the same year that the first Waste-water Meters were fixed. In its earlier stages the system progressed but slowly. During the last twelve months, however, it has gained in speed; and, except for the purpose of obtaining the census in some districts, the house-to-house inspections have been entirely abandoned, and no premises have been entered except those in which the night inspections had previously discovered the existence of waste, or to which the attention of the officials had been specially drawn. For some time past twelve meters, controlling about 25,300 persons, have been fixed each month; and it is found that with one chief inspector, twelve ordinary inspectors, six labourers, one Waste-water Meter inspector whose exertions are confined to the meter districts, and two inspectors to attend to special reports in other districts, it is easy to restore constant service to 5,000 persons per week, to sustain it in the old meter districts, and to maintain the average consumption over the whole area supplied at a constantly diminishing rate.

The recent progress of the system may be shown by comparing the circumstances of 1873, of 1874, and of 1875.

In March 1874 about 170,996 persons, and in March 1875, 373,500 persons in the borough were receiving constant supply.

During 1873 the maximum number of hours' service to the intermittent districts in the borough was $10\frac{1}{2}$; the minimum, $7\frac{1}{2}$; and the average, 10. Since then the average has been maintained at $10\frac{1}{2}$ hours throughout the year.

In 1873 the Out Township supply to 91,835 persons was reduced for an average of fourteen weeks to 12 hours per day. Since then constant service has been maintained in the Out Townships.

At the beginning of 1874 the total population supplied was about 621,000. At the beginning of 1875 it had increased to about 632,000.

During 1873 the water taken for all purposes, excepting manufacturers' supplies measured by meter, was 5,437 million gallons, or 24·42 gallons per head per day. During 1874 the corresponding quantity was 5,478 million gallons, or 23·8 gallons per head per day.

In March 1874 the rate of supply was about 24·21 gallons per head per day.

In March 1875 it was about 22·26 gallons per head per day.

Actual Saving of Water.—It is to be regretted that comparatively few persons apprehend the importance of the work in progress, with anything like the eagerness which would be evinced if the reduction in the rate of waste, instead of being chiefly manifested by the restoration of constant service, were shown in the actual figures of water saved, as would be the case if Liverpool had in 1872 been receiving constant supply.

Fortunately the meters give the means of determining the actual saving in water, on the assumption that the town was receiving constant service from the beginning.

In nearly every waste-water district, the quantity of water taken, under the constant system, has been determined before discharging the initial rate of consumption.

The number of persons to whose service the Waste-water Meter system has been applied in Liverpool, to the 10th of April, 1875, is 234,000, but many of the districts have as yet received little attention at the hands of the night inspectors. Taking that moiety of the districts to which attention has been chiefly given, the supply to 117,425 persons, which under constant service averaged 32·12 gallons, has been reduced to 15·97 gallons per head per day. If the whole population under treatment be considered, the rate per head per day to 234,000 persons, is found to have diminished from 28·89 to 16·47, which is equivalent to a total saving of 1,060,792,200 gallons per annum.

It is known, by experiments in a few isolated cases, that the waste in these districts may be still further reduced; but the Author systematically avoids occupying the inspectors' time in those portions of the town to which constant service has been restored, except so far as it is necessary to do so, in order to keep down the total consumption, as district by district the change is made.

In comparing the rate of consumption per head per day in Liver-

pool, with that of other towns, the following considerations must not be lost sight of:—

Unlike most towns in which constant service has been given and maintained at a low rate of consumption, the inmates of four-fifths of the houses are provided with water-closets.

The term "domestic consumption" has been somewhat improperly applied and has a much wider signification than in most other towns, as it includes all supplies for sanitary purposes, and a large proportion for business purposes. In other towns it is usual to confine the term to the use of water in private dwellings only; and this difference would be equivalent, in most cases, to several gallons per head per day.

The system described has been tried in every class of property; and in some districts containing the best houses the saving of water has been quite as great as in any others. It is certain, moreover, that the most wasteful districts have not yet been reached, and there is every prospect of a rich harvest during the present year.

10. RELATIVE ADVANTAGES OF THE WASTE-WATER METER SYSTEM AND OF THE ORDINARY HOUSE-TO-HOUSE INSPECTIONS.

The policy of the present practice differs chiefly from that of the old system in four particulars:—

1. By never employing inspectors in any but those districts in which the meter diagrams show that the best results are likely to be attained. As the following facts illustrate, this alone is a great desideratum.

Out of a hundred waste-water meter districts, several cases have been chosen in order to show how widely the consumption and degree of waste differ in districts of the same age and class, before any special work has been attempted in connection with them. The dark figures are cases of large consumption, and the light figures of small consumption in similar districts. (See page 156.)

In the examples given there was nothing whatever to lead to the belief that any of the districts in dark figures would constitute more fruitful ground for the labours of the inspector than those in light figures. Under the ordinary system both would have been examined alike, and the energies of the inspectors in a great measure wasted.

2. By never employing inspectors to examine any premises in

which it has not been previously ascertained that waste is taking place.

Number of District.	Population.	Consumption per Head per Day.		Remarks.
		Average.	Night Rate of Waste.	
270 and 271 .	1,319	Gallons. 40·6	Gallons. 30·4	} Adjoining districts resembling each other in every respect.
258 and 264 .	2,778	11·8	7·3	
254	2,082	40·7	33·8	} Ditto.
266	1,661	14·67	9·1	
259	2,765	16·0	9·13	} Similar class of property, but the district which gave the higher rate of consumption would have been supposed to be less wasteful than the other, owing to many of the fittings being of a better class.
14	838	41·0	34·1	
18	4,012	15·8	12·5	} Districts in the same locality and property similar.
8	827	45·0	35·5	
7	2,570	55·0	45·6	} Ditto.
15	2,377	13·6	8·5	
237	2,261	54·8	44·5	}
262	3,430	11·5	7·37	

Although, as already stated, a great desideratum would be gained by adopting house-to-house inspection, but confining it to those districts only from which the meter diagrams show that the best results would be obtained, the advantage is greatly increased by abandoning regular inspections even in those districts, and by adopting means, such as have already been described, to ascertain in which premises waste is actually taking place.

With far better methods for detecting waste at their disposal than the house-to-house visitors have even possessed, the night inspectors of Liverpool do not, as a rule, find on an average more than about one leak at every tenth house.

The annoyance to the inmates, therefore, and the loss of time is in nine-tenths of the cases avoided, while the fact that in or under each house visited by the day inspector who follows up the night reports, a leak certainly existed on the previous night, is an incentive to the discovery of the source of waste which under the ordinary system cannot possibly exist.

3. By the detection of the more important, because the more continuous, sources of waste which are rarely discovered by house-to-house visitations.

It has been shown, at page 141, that in some of the experimental

districts a large portion of the waste was of a kind the source of which could not be detected by ordinary house-to-house inspections.

For the purpose of ascertaining the respective advantages as measured by the quantity of waste discovered by house-to-house visitors and by night inspectors, a number of districts in various parts of the town have been taken at random. The ordinary day inspections were made after the meters were fixed, and particular care was taken to insure their completeness, not only by examining the fittings and pipes thoroughly, but by testing the fittings by sounding. They show generally that the effect on the consumption thus produced, after subsequent examinations to ascertain that the defects discovered had been repaired, was to reduce the demand from a night rate of 20·6 gallons to 17·3 gallons per head per twenty-four hours.

Immediately the results of the day inspections had been ascertained, night inspections had been made, and it was found from the diagrams that a further diminution in the consumption of 7 gallons per head per day was thus produced.

In other words, where the most careful day inspection reduced the consumption from 20·6 gallons to 17·3 gallons, a night examination, if substituted for it, would have reduced the consumption from 20·6 gallons to 10·3 gallons.

The same advantages are also shown in a striking manner by comparing the proportion of waste detected by the inspectors in the past with that discovered by the night inspections.

In 1863, when the proportion of inspectors to a million persons was 3·86, the proportion of the leaks discovered from defective fittings and pipes to the number of premises visited was 14·1 per cent.

In 1870, after the system had been in operation for seven years, and when the proportion of inspectors to a million persons was 17·12, the proportion of the leaks to the premises visited was only 10 per cent.

In 1872, when the proportion of inspectors to a million persons was 28·12, the proportion of the leaks to the premises visited was only 9 per cent.¹

The special house-to-house visitations subsequently carried out

¹ The inference from this falling off of the number of defects reported in proportion to the number of inspections was, that the waste had been considerably diminished, and no doubt this was true of the particular class of waste which such inspections detected; but it has already been shown by the figures on Table A that though the number of hours' service was gradually reduced, the rate per head per day was actually increased.

under the more favourable circumstances in the districts referred to above, which are fair examples of the whole, when the proportion of inspectors to a million persons was 25·2, indicate that the proportion of the leaks to the premises visited was 12 per cent.; the diagrams at the same time showing that the repair of these leaks produced a reduction of 3·36 gallons per head per day in the night rate.

But in those very districts in which so high a proportion of waste had been checked, night examinations under the meter system, made immediately afterwards, detected an additional proportion of leaks to premises of 8 per cent., and an actual additional waste of 11·15 gallons per head per day.

An analysis of the returns of the day inspectors, made upon the reports from the nocturnal examinations, shows that the additional and much larger waste thus detected, though continuous, was attributable to causes which the house-to-house inspectors must necessarily have failed to detect.

A large proportion of the leaks thus discovered are due to defective pipes underground, and of these a few samples are exhibited, with notes as to the circumstances under which they were discovered, and the quantity of water which each will pass at 50 lbs. pressure.

4. By never renewing old mains except when the meter diagrams have shown that they are actually causing waste to an extent which justifies the expenditure.

In many waterworks the distributing mains are of all ages, and being, in a greater or less degree, constant sources of unseen waste, it is usual to spend a sum of money annually for the renewal of those which are believed to be the oldest, or which may have happened to show their deficiencies by leaks appearing above the surface of the ground. Only those who have tried it by absolute measurement can form any idea of the fallacy which commonly obtains in reference to this matter. In Liverpool it has been found that the number and importance of the defects in mains, which continue for years without giving any superficial indication of their existence, is very great. Experienced managers of waterworks have expressed the opinion, which was until recently shared in by the Author, that a main could not break across without revealing the fact in a short time. But the present system has brought to light many instances of broken mains in which the sharp edges of the fracture have been worn off in the course of years by water under a head of 100 or 150 feet. The other chief causes of waste from the mains are wooden plugs in old

ferrule-holes, either driven out by the water or leaking, wooden plugs partially decayed, which were formerly used instead of iron caps on the ends of mains, and blown lead joints. On the other hand, most of the oldest mains, although they are fractured by the slightest disturbance, and are liable at any time to lead to great loss, are perfectly tight, and might remain so for years.

It is, therefore, an obvious economy to have a better means of ascertaining their condition, and thus to gain maximum and immediate results, by the prevention of waste, from money the interest on great part of which was formerly lost for years.

11. COST OF APPLYING THE WASTE-WATER METER SYSTEM.

Where stopcocks on the service mains do not already exist, either inside or outside the houses, it is obviously desirable that they should be fixed, if only to avoid the great inconvenience arising from having to cut off the water from a large district each time a repair to any pipe or fitting becomes necessary. In Liverpool the work of fixing stopcocks had been commenced before the meter system was introduced; but, inasmuch as stopcocks outside the houses are necessary for the complete development of the system, the cost of providing them will be considered here.

In Liverpool, as in most other towns, a certain number of stoptaps, but probably only about one-fourth of the number required, already existed.

The cost of providing and fixing each new stopcock, including the surface cover, reflagging, renewing defective flags, and searching for the service pipe, is about 12s.

The average number of persons to each meter is 2,557.

The cost per thousand persons in a town in which stopcocks are already laid would average for the meter and fixing £14 7s. If, however, as in the case of Liverpool, the greater proportion of the stopcocks have to be charged to the system, the cost, including the meter, would be about £39 7s. per thousand persons.

The necessary plant having been provided, the operations for the prevention of waste immediately show a great reduction of expenditure.

The staff of inspectors has been somewhat reduced (see Table A) since the system was commenced, but there are no means of comparing accurately the water saved in each case, though it is obvious from a general comparison of the results under the two systems that a small fraction of the old staff would, under the district

system, have performed more work, while no increase in the numbers of the original house-to-house inspectors could have effected the saving since obtained. A clerk's time for about four hours a day is occupied in computing the diagrams and recording the results, but the number of turncocks has been diminished by three, so that on the whole the staff has been reduced.

12. TREATMENT UNDER THE WASTE-WATER METER SYSTEM AFTER THE RESTORATION OF CONSTANT SERVICE.

It has been already stated in effect that during the last twelve months all pipes and fittings, with the exception of those actually leaking in the meter districts, or reported by the public, have been left to themselves. Notwithstanding the greater proportion of waste which those pipes and fittings therefore occasion, and notwithstanding the fact that in the waste-water districts it was necessary to save 12 or 13 gallons per head per day on the initial constant supply before the consumption could be reduced to the same amount as the initial intermittent supply, it has been shown that a reduction in the total supply per head per day has been effected, and it has been further stated that the rate is gradually diminishing.

From these facts it is reasonable to conclude that when constant service has been everywhere restored, and the water saved, whatever it may be, is no longer absorbed in making up the difference between intermittent and constant service, but effects an immediate reduction in the total supply, the staff required to maintain or even to diminish the comparatively low consumption will be considerably less than at present.

From experience gained in the districts already under control, there is reason to believe that, in order to keep a proper record of the condition of the whole of the town, it will then only be necessary to take on the average one meter diagram for three or four days per month from each district. The total number of districts, including in the aggregate 632,000 persons, will be about 250, and the number of diagrams per day, including those from districts under examination, will probably not exceed 20.

Each day, two or three districts of maximum waste will be provided with new diagrams, subjected to night examinations, and when brought below the average consumption, replaced on the ordinary list, and only provided with new diagrams when the district of which each forms a part is visited in its monthly turn.

13. TESTING AND STAMPING FITTINGS, AND INSPECTING NEW WORK.

A very important section of the work in connection with the prevention of waste is that relating to the class and quality of the pipes and fittings fixed in new premises, and substituted for those which have been prohibited. However good the fittings may be, it is certain that, unless some supervision is exercised over them by the authorities, large numbers will become, and continue to be, defective. If, however, they are satisfactory to begin with, only trifling repairs, easily effected, will in the large majority of cases be necessary.

It has already been stated that the power of the Liverpool Corporation to prescribe the details of water fittings is very limited, and, by way of insuring the execution of their requirements in cases of new fittings, they have adopted, with some modifications in detail, the system of testing and stamping fittings, and of advertising the names of those plumbers who agree to conform to their regulations, which has been successfully applied by the Manchester Corporation; with this difference, however, that the latter body have parliamentary powers to license the plumbers approved of.

The credit of originating the system in connection with the Manchester Waterworks is, it is believed, due to Mr. T. H. G. Berrey, Assoc. Inst. C.E.

In March 1873 the Liverpool Corporation invited each plumber to sign an agreement, undertaking that all work performed by him should be in conformity with the rules and regulations of the Water Committee.

The Corporation, on their part, place the names and addresses of such plumbers on the waste-water notices, and recommend them in preference to others. Nearly all the plumbers whose names appeared in the Liverpool Directory signed the agreement, and in comparatively few cases have the rules been infringed.

The published regulations, drawn up in 1873, have recently undergone some slight alterations, which experience has shown to be desirable. In their modified form they appear in the Appendix.

In the testing office a superintendent with one assistant and two boys are employed, whose duty is to examine each fitting superficially, and to ascertain that it apparently works satisfactorily. If a tap or ball-cock, to place it in jaws, provided with the means of supplying water at a pressure of 300 lbs. per square inch. If a regulating cistern or service-box, to ascertain by actual trial with water that the valves work truly, and that the delivery

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valve passes the 2-gallon flush in less than fifteen seconds. To weigh, gauge, or examine every part of each fitting, including valves, valve-seats, washers, valve-rods, and, in the case of alternating-valve regulating cisterns, to see that the valves have the prescribed lift, and that the lever has the prescribed play between the respective lifts. And to stamp those fittings only which are in all respects in conformity with the samples kept for exhibition.

The samples kept for exhibition are alluded to in Regulation 5.

Any person who desires to introduce a new description of fitting, or even a change in the form of an existing sample, is required to send it, not to the testing office, but to the Engineer. If after undergoing examination, and being subjected to such tests as are thought necessary, it is considered no less satisfactory in principle, quality, and workmanship than the general standard hitherto adopted, it is placed among the sample fittings, and may thenceforth, unless, of course, protected by patent, be copied by any other maker. No licence is given to the superintendent of the testing department to allow deviations in any respect from the adopted standard in each case.

At first sight, this great stringency may appear unnecessary. On the introduction of the system into Liverpool, some latitude was, however, given to the testing officer, and the consequence was that each maker endeavoured to undersell his neighbour by trifling reductions in the material and in the quality of workmanship. Thus step by step the standard was reduced, until at last it became necessary to insist that no change whatever should be made, unless one of the altered fittings was accepted as a standard sample.

The present system allows fair competition, and encourages the ingenuity of manufacturers.

The small fees charged for stamping are named in Regulation 4, and they render the department entirely self-supporting.

Clause 33 of the Regulations requires all authorised plumbers to fill up, and leave at the engineer's office, printed forms as notices that new or altered pipes or fittings are ready for inspection, and such notices are required to be given before pipes or fittings are covered.

Notwithstanding the satisfactory working of this system, by which it is made the interest of the plumber to do his work well, it must be allowed that in connection with old fittings difficulties frequently arise, for the removal of which an Act of Parliament should be obtained.

CONCLUDING REMARKS.

The Author has endeavoured to show the results of his experience in connection with a system for preventing waste, which has hitherto produced practical results in Liverpool only.

It has been necessary in many instances to refer to special districts, in order to explain particular points, and such districts have been selected as represent the results fairly, so that the remarks upon them are applicable generally to all similar districts.

In low-class districts of the metropolis the waste of water is probably even greater on the average than in Liverpool; but if constant service were restored to any single district, that very fact would in a great measure create its own cure. Many of the outlets for water, which under a few hours' supply are left continuously open, would, under constant supply, become such intolerable nuisances that the flow must inevitably be checked; and if the owners of property became aware that all cases of continuous waste would certainly be discovered by the night inspectors, and watched by the authorities until the cause was removed, in the manner which they might prescribe, the district would soon show a lower consumption than under intermittent supply.

In a system the success of which depends so much upon the careful and politic manner in which the details are attended to, it is obviously necessary that the control of such details should be delegated only to those whose energy and general qualifications render them peculiarly fitted to lay aside the ordinary practice in such matters, and to enter vigorously upon the new processes.

The Author cannot conclude without recording his belief that the success which is attending the introduction of the system into Liverpool is in a great measure due to the exertions of Mr. Joseph Parry, Assoc. Inst. C.E., in whose charge the superintendence of the waste-water department has been placed.

The communication is accompanied by a series of drawings, from which Plates 4, 5, and 6 have been compiled.

APPENDIX.

LIVERPOOL CORPORATION WATERWORKS.

REGULATIONS UNDER WHICH WATER WILL BE SUPPLIED BY THE LIVERPOOL CORPORATION.

1. *Application for and conditions of Supply.*—Persons requiring a supply of water must fill up, sign, and deliver a form of application, to be obtained at the Borough and Water Engineer's office, and pay to the Treasurer a sum equal to one-quarter's water rent, also a deposit (the amount of which will be stated when the application is presented), on account of any piping or fittings which may have to be furnished or laid for the applicants by the Water Committee.

2. Such persons must, at their own cost, provide, lay down, and maintain all service pipes and fittings which may be required within their premises, and 1 foot of pipe beyond the boundary thereof; and in the case of all premises situated outside of the borough, or of supplies for other than domestic purposes within the borough, they must also pay the cost of providing, laying, and maintaining the piping and fittings necessary to form a connection with the main, which work will be done on their behalf by the servants of the Corporation.

3. *Plumbers.*—The Corporation will publish on their water rent papers, on the waste-water notices, and in such other manner as they may from time to time consider necessary, the names and addresses of such plumbers as they may approve of, who undertake to execute work in accordance with the following regulations; and such plumbers will become responsible to the Corporation for the proper execution of all work done by them, and before they are placed on the list will sign an agreement accordingly. If they fail to comply with the requirements of the Corporation, their names will be struck off the list.

4. *Testing and Stamping.*—All fittings used in connection with a supply of water must be tested and stamped by the duly authorised officer before being fixed, and the following fees will be charged:—

Bib and stoptaps	2d. each.
Ball-taps	3d. „
Closet cisterns	3d. „
Closet cisterns with ball-tap	6d. „

5. *Sample Fittings.*—A set of standard fittings such as have been hitherto approved is exhibited in the stamping office; but the Engineer will give due consideration to the claims of any other fitting which may be presented for approval, and which, if considered satisfactory by the Committee, will be stamped, the sample purchased and placed among, and become one of the standard fittings. Before any fitting is withdrawn from among the approved samples, six months' notice will be given to the Master Plumbers' Association.

6. *Pipes.*—Every service pipe hereafter laid or fixed below ground shall be of lead; and every joint on every lead pipe, whether below the ground or not, shall be of the kind called a plumbing or wiped joint.

7. The depth of pipes below the surface of the ground must be at least

2 feet 6 inches, and they must be brought out through the boundary of the premises 2 feet 6 inches below the surface of the street or roadway.

8. Lead service pipes, for supplying water for domestic purposes, must be of the diameter stated below:—

For 1 house, not exceeding £20 per annum rateable value, $\frac{3}{8}$ inch diameter.

For 1 house, above £20, but not exceeding £70, or for 6 houses, not exceeding £13 each rateable value, $\frac{1}{2}$ inch diameter.

For 1 house above £70, or 14 houses not exceeding £13 each rateable value, $\frac{3}{4}$ inch diameter.

9. No house or block of offices in the same building belonging to the same person, shall have connection with the pipes or other fittings of any other premises, except where two or more houses of a rateable value exceeding £13 per annum each are supplied from one cistern, in which case a leading pipe from the cistern must be laid in the back passage, and separate branches taken therefrom into each house; and in all cases of blocks of houses, whether under or exceeding £13, supplied from one cistern, a by-pass pipe, with stopcocks, must be placed in such a manner as to lead the water direct from the mains to the houses during periods of constant service.

10. Lead pipes shall be of not less than the following weights per lineal yard:—

Pipes in the upper district and in the lower district¹ if supplied from a cistern—

$\frac{3}{8}$ inch diameter		4½ lbs. per yard.
$\frac{1}{2}$ " "		5 " "
$\frac{3}{4}$ " "		8 " "
1 " "		11 " "
1¼ " "		13 " "

Pipes in the lower district¹ under pressure from the main—

$\frac{3}{8}$ inch diameter		4½ lbs. per yard.
$\frac{1}{2}$ " "		7 " "
$\frac{3}{4}$ " "		11 " "
1 " "		15 " "
1¼ " "		18 " "

Any lead pipe of which the end is open so that it cannot remain charged with water, may, however, be of the weight given in the following scale:—

$\frac{1}{2}$ inch internal diameter		3 lbs. per yard.
$\frac{3}{4}$ " "		5 " "
1 " "		7 " "
1¼ " "		9 " "

11. Pipes of any other metal than lead shall only be fixed after samples thereof have been submitted to and approved by the Water Committee.

¹ The lower district comprises all that area the surfaces of the streets within which are less than about 80 feet above the level of the old dock sill. The division passes through the following streets:—Speke Road, Aigburth Road, the Dingle, Beaufort Street, Thornton Street, Parliament Street, Great George's Street, Berry Street, Renshaw Street, Lime Street, Islington, Christian Street, Richmond Row, Comus Street, Rose Place, Bevington Bush, Blackstock Street, Vauxhall Road, Commercial Road, Stanley Road, Balliol Road, Westminster Road to Well Lane, across to the lower entrance of Litherland Park, and all to the north thereof. The division line is in the centre of the streets and roads named.

12. No pipe shall be laid through, in, or into any sough, drain, ash-pit, manure-hole, or other place from which, in the event of decay or injury to such pipe, the water might be liable to become fouled or to escape without observation, or without occasioning the necessity for immediate repair.

In any case in which any such sough, drain, ash-pit, manure-hole, or other place as aforesaid, shall be in the unavoidable course of the pipe, such pipe shall be passed through an exterior cast-iron pipe, or box of sufficient length and strength to afford due protection to the water pipe, and to bring any leakage or waste within the means of easy detection.

13. No pipe shall be brought above the level of the ground outside any building, except for the supply of an outside tap in a yard, in which case the pipe shall be properly protected from frost by brickwork or otherwise, and encased in felt, or other non-conducting material, to the satisfaction of the Engineer.

14. *Outside Stopcocks.*—Every separate service pipe must be provided with a stopcock and box, which will be fixed outside the private premises by, and in cases of domestic supplies within the borough at the expense of the Corporation.

15. *Tap from Mains.*—A tap shall be placed in each house, on the leading pipe from the main, in order that water may be drawn for drinking and culinary purposes without passing through the cistern.

16. *Storage Cisterns.*—Storage cisterns must be provided for all domestic supplies. Where there is a bath or hot-water apparatus, the cistern must hold not less than 50 gallons for each house. In other cases, not less than 25 gallons for each house.¹

17. Cisterns for the storage of water (not including water-closet and urinal regulating cisterns) shall, if of wood, be lined with lead of not less than 5 lbs. to the square foot. The iron, wood, or slate work shall be strong and well put together, and each cistern shall be provided with a ball-tap which must be securely fixed to the side thereof, and it must be in such a position as not to become submerged when the cistern is full, and the level of the water at such time shall be 3 inches below the overflow.

18. Domestic boilers, water-closets or urinals must in all cases be supplied from cisterns. All cisterns for the supply of water-closets or urinals shall either be on the alternating-valve principle, and so constructed as to be capable of delivering 2 gallons at each flush, which must be discharged within fifteen seconds, or otherwise so arranged as to produce the same result in an equally efficacious manner; but no valve except the ball-cock shall at any time have a greater pressure upon it than that due to the head of water in the cistern.

19. Overflow pipes of cisterns or other receptacles for storing water shall be not less than $\frac{3}{4}$ inch internal diameter, and wherever the level of the cisterns will admit of it, they shall be brought to conspicuous points above the ground on the outside of the building containing the cisterns, in such a manner as to act as warning pipes, but in no case shall they discharge over the ash-pit. Where a cistern is too low to admit of this, the overflow pipe shall be fixed in such a position as shall be determined, in writing, by the Engineer.

20. No pipe for the conveyance of, or in connection with, water supplied by the Corporation, shall communicate with any cistern or any receptacle used, or intended to be used, for rain water.

21. No cistern for a domestic supply of water shall be built or placed under the surface of the ground.

¹ After the introduction of the intermittent service, the Corporation obtained powers to require the use of storage cisterns for all new supplies, and until the constant service is firmly established it is not thought desirable to change the rule.—G. F. D.

22. Every cistern shall be in an accessible position and made capable of easy inspection.

23. Where a cistern is fixed in an exposed position it must be bricked around, or otherwise encased and covered, so as to prevent, as far as practicable, the action of frost upon the water.

24. *Water-closets.*—The pans or basins of all water-closets, not of the trough kind, must be of a semicircular shape, or of such other form as can be most efficiently flushed; the down pipe from the cistern to the basin of the closet must be of not less than 1½ inch in diameter, excepting in connection with pan closets where the head of water exceeds 8 feet, when the down pipe may be of 1 inch diameter. In the case of pan closets, the metal pan shall be capable of bearing a weight of 7 lbs.

25. *Trough Closets.*—The detail arrangements of all trough closets shall be submitted to, and approved of by the Engineer before such closets are fixed.

26. *Baths.*—Every bath must be provided with a well-fitted and perfectly water-tight ground outlet plug, with chain complete, or such outlet tap as shall be entirely independent of the inlet.

27. *Taps.*—None but screw-down taps, incapable of being suddenly closed, shall be fixed on pipes supplied direct from the main.¹

28. *Standpipes.*—Any standpipe fixed for the use of the occupants of more than one house must be fitted with a self-closing apparatus incapable of being suddenly shut.

29. *Water Meters.*—The Corporation will provide and fix all water meters, for the supply of water for trade purposes, and will also lay the service pipe from the boundary of the premises to the inlet of the meter, and fix the stopcock thereon, at the expense of the occupier of the premises.

30. *Steam Boilers.*—No steam boiler, or any description of closed boiler will be allowed to be supplied direct from a service pipe; but the supply will be given through meter, and a self-acting check valve must in every case be fixed on the pipe so as to prevent a return of the water.

31. *Fire Hydrants.*—Hydrants for fire or other purposes inside premises can only be permitted by the special sanction of the Water Committee, for which application must be made in every case.

32. *Inspection of Work.*—Before a connection for the supply of water can be made, or before any additional fittings can be connected to an existing service pipe, the work must be inspected and approved by the proper officer of the Corporation.

33. *Notice from Plumbers.*—Printed forms will, upon application, be furnished to plumbers who have signed an agreement to conform to the regulations, which they will be required to fill up and deliver at the Engineer's office, as notices of fittings being ready for inspection, and also of any alterations made in existing service pipes or fittings, and such notices must be given before pipes or other fittings are covered.

INSTRUCTIONS TO PLUMBERS AS TO REPAIRS OF DEFECTIVE FITTINGS.

All existing fittings which are so far defective that they cannot be effectually repaired to the satisfaction of the Engineer, must be replaced by stamped fittings, in all respects in conformity with the preceding regulations.

The attention of plumbers is directed to the following special cases.

¹ These regulations are given as recently settled; and, with the exception that the author would prefer to have all taps on the screw-down principle, he thinks them entirely satisfactory.—G. F. D.

Any single-valve regulating cistern, if found to be causing a waste of water after having, on a former occasion, been repaired on account of waste, shall, if the two periods of waste have occurred within twelve months, be replaced by a stamped cistern.

Common cocks (whether bib-cocks, stop-cocks, lever-handled or weighted cocks) to water-closets when requiring renewal, or left open through carelessness, must be replaced by stamped cisterns.

Whenever a leakage arises in, or repairs have to be effected to a ball-cock, in a cistern of which the overflow is connected with a drain or flush-pipe, the existing overflow must be cut off and brought to the outside, in accordance with Regulation 19.

Such underground cisterns as may cause unseen waste shall, if found to lead to waste in any case, be abolished.

GEORGE F. DEACON,
Borough and Water Engineer.

MUNICIPAL OFFICE, DALL STREET.

[Mr. DEACON

Fig: 1.

——— Mean Supply per Head per Day, } Excluding
 - - - - - Mean Supply per Head per Hour x 10 } Manufactories
 supplied by Meter.

- - - - - Average Number of Hours Supply,
 Including those in constant Service.
 Proportion of Inspectors to 1,000,000 Persons,
 Including Chief and Waste Meter Inspectors.

NOTE TO PLATE 5. See also pp. 144 and 153.

In Figs. 2, 3, 4, and 5, the upper dark lines are diagrams of Intermittent Service, and the middle faint lines corresponding diagrams of Constant Service, made before any prevention of waste had taken place; while the lower dark lines are diagrams of Constant Service, taken recently from the same districts, after the adoption of the Waste-water Meter system.

In Figs. 6, 7, 8, and 9, the faint lines are diagrams of Constant Service, broken between 11 P.M. and 5 A.M., by night inspections, such as those described at page 148; while the dark-lined diagrams show the reduction of waste subsequently produced by remedying the defects discovered by those night inspections.

Fig: 10.

PLAN SHEWING GENERAL ARRANGEMENT OF MAINS IN LIVERPOOL.

- Principal Mains.
- Distributing or Service Mains.
- Waste Water Meters.
- Double Fire Hydrants on Principal Mains.
- Single Fire Hydrants on Distributing Mains.
- Fire Plugs.
- Valves.

NOTE: In the Suburban Districts there is no marked distinction between Principal and Distributing Mains, and the Meters control all the Mains.

GEO. F. DEACON, DELT

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Fig: 11.

NOTE:

At each particular velocity of water the Disc (D) is pressed down and the weight (M) raised until a point is reached at which the pressure on the upper surface of the Disc due to that velocity exactly balances the excess of the weight (M) above that of the Disc and Tube suspended in the Water.

- A. Branch from Service Main.
- B. Branch to Service Main.
- C. Gauge Tube.
- D. Disc equal in diameter to top of Gauge Tube.
- E. Disc Seat.
- F. Tubular Stem of Disc guided by.
- G. Brass Tube.
- H. Lignum Vitae Plug connecting Stem of Disc with.
- I. Wire passing through.
- J. Brass Bush to.
- K. Pencil and Guide Wheels.
- L. Cord connecting Pencil with.
- M. Counterbalance Weight.
- N. Grid for equalizing flow of Water.
- O. Clock wound up when in use once in seven days.
- P. Drum revolving once in 24 hours, carrying ruled paper on which is recorded the height of the Pencil at each instant & the corresponding rate in Gallons per hour.
- Q. Channel & Pipe to carry away small quantity of Water oozing between the Wire and the Bush (J).
- R. Clock and Drum Chamber.
- S. Indiarubber Packing.
- T. Hinged Cover.
- U. Cover Flush with Footway.
- W. Joint of Portland Cement made after fixing Meter.

WASTE WATER METER.

THOS KELL, LITH 40 KING ST COVENT GARDEN