WATER METERS OF THE PRESENT DAY;
WITH SPECIAL REFERENCE TO SMALL FLOWS
AND WASTE IN DRIBBLES.

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Although merely elementary knowledge, it is necessary to state at the outset that Water Meters are divided into the following classes:—

1. Low-Pressure Meters.
2. Inferential Meters.
3. Volume or Capacity Meters, without device for rendering them tight.
4. Meters of the Venturi class, which have a special function.
5. Waste-detection Meters, of the Deacon class.
6. Positive Meters, or Meters which provide a space to be filled and emptied of water, and which have some contrivance for rendering them tight at varying pressures and under diverse conditions of service.

Before treating each of these classes, it may be observed generally that they all have a useful purpose which they are capable of answering with more or less advantage, according to their individual merits. The mistake most commonly made, in the author's opinion, is that they are used indiscriminately, and frequently selected on account of first cost, without due consideration of the duty they have to perform.

The question next presenting itself is, what are the small flows to which this Paper has reference, and of what importance is the measurement of waste in dribbles? That all water supplied by

private companies, intent on earning dividends, should be paid for, goes without saying, provided the cost of measurement does not exceed that of allowing the pumped, impounded, filtered, and delivered water to run to waste.

Table 1 illustrates the large flows of water represented by leakages through comparatively small holes, when under a pressure of 100 feet head.

TABLE 1.

Diameter of Hole.	Gallons.		Number of persons that can be supplied at 15 gallons per head per day.
	Per hour.	Per 24 hours.	
Inch. $\frac{1}{4}$	381	9,144	610
$\frac{3}{16}$	214	5,136	342
$\frac{1}{8}$	95	2,280	152
$\frac{1}{16}$	24	576	38
$\frac{1}{32}$	6	144	10

The quantities in the above Table are estimated, and are confirmed by experiment at Liverpool.

But a wider and more important question arises when the needs of our increasing population and the necessity of larger supplies come forward for consideration. Ten gallons per head per day of the London water-supply admittedly represents waste. This quantity, based on a population of 5 millions, is 50 million gallons per day, or sufficient to supply 25 gallons per head per day to an increased population of 2 millions: or, in other words, is more than sufficient for the needs of the City of Berlin. To put the matter (if possible) still more plainly, if this waste is permitted to continue, £8,000,000 of capital, or one-fourth of the total approximate cost of the proposed Welsh scheme of water-supply (of 200,000,000 gallons per day) to London, will be spent in order to make up the deficiency caused by preventable waste.

Here is a great problem ; and the author believes the solution of it lies in the sale of water either by meter only (at very low prices it may be), or by meter with a fixed charge for a minimum supply at present rates in order to ensure health and cleanliness. He has devoted many years of his life to the production of an efficient instrument for the ordinary measurement of water, and especially for the purpose of registering dribbles ; with what amount of success he must leave to others to determine.

Returning to the different kinds of meters already classified.

1. *Low-Pressure Meters*.—These are more especially applicable to measuring small flows, such as dribbling supplies to flushing cisterns, but they can also be used for such services as supplies to private houses in which cisterns are used. The great objection to them is, as their name implies, that the whole of the pressure from the main is lost in passing through them ; and therefore they require to be placed at the highest elevation at or from which a supply is to be taken ; and this again involves—in the case of house supplies—the frequent entry of the meter-inspector and assistant to the top of the house, for the purpose of reading the index, and examining, repairing, or exchanging the meter.

The oldest and probably the best known meter of this type is the "Parkinson," Fig. 1, page 40, which was described in a Paper read before this Institution (Proceedings 1851, page 19). In general appearance and also in construction it much resembles a gas meter ; it has only one moving part, namely the drum, though it also requires at least one ball-valve for regulating the supply of water to it. The meter was again described in the Proceedings of 1882, page 41. It is very accurate down to the smallest dribble and will work a long time without requiring repairs. The quantity delivered by the smaller sizes however is rather limited, for a $\frac{5}{8}$ -inch meter is only rated to pass a maximum of 100 gallons per hour, a $\frac{3}{4}$ -inch 200 gallons, and a 1-inch 400 gallons per hour, or about one-third as much as meters of other kinds. In the larger sizes the supply is taken through two or more orifices of exactly the same diameter, but only that portion which passes through one of the apertures is

measured, and the total flow is computed by multiplication in the clockwork. It would seem that large errors (plus or minus) could

Fig. 1. "Parkinson."

easily accumulate by such an arrangement, through one or more of the openings becoming partly obstructed by impurities; indeed the author is informed that such is actually the case, when the water is not quite clean (see Mr. Ellington's Paper on Hydraulic Power Supply, Proceedings 1895, page 365).

Fig. 2. "Bascule."

The "Bascule," Fig. 2, is another meter of the low-pressure type. Like the "Parkinson," it has only one moving part, which is in the form of a double bucket, mounted on pivots, and so arranged that when one of the buckets is taking its supply from the main, the other is being emptied, and *vice versa*; each bucket when full overbalances the

other. In this meter also a ball-valve is required for limiting the supply. A meter of this kind was described by the late Sir William Siemens in the Proceedings of this Institution for 1854, page 6, and was called a "Bucket" meter; it was invented by Mr. Mead, of London.

2. *Inferential Meters.*—As the name implies, the water is not actually measured in this type of meter, but the quantity passed through it is “inferred” from the number of revolutions made by the fan or turbine, which is the only moving part. These meters are exceedingly convenient and useful, as they are comparatively small, light, and cheap; and they are fairly accurate when the water passes through at a good speed, as when used for filling water-carts, for filling large tanks (without ball-valves), or for similar purposes. When however the flow of water through them is frequently

Fig. 3. *Siemens' "Turbine."* Fig. 4. *Siemens' "Fan."*

slow, their registration is very unsatisfactory, as the fan or turbine then lags behind or stops entirely, while the water passes through freely. Probably the oldest and certainly the best known of this class was invented by the late Sir William Siemens in or about 1850. Two distinct kinds are made, namely the “Turbine,” Fig. 3, and the “Fan” meters, Fig. 4. In the

first, the water enters through the top of a vertically placed wheel with turbine-shaped buckets, and being discharged from these in a diagonal direction, the reaction of the water turns the wheel, which thereby actuates the clockwork of the dial. Retarding vanes on the wheel prevent it from running too quickly at the higher speeds. The footstep, also the top of the wheel-spindle, and the clockwork are lubricated with oil, which cannot readily escape; the clockwork arrangement is ingenious and effective. The “Fan” meter, like that of the

"Turbine" class, has an upright spindle, and is similarly furnished; but the wheel is driven by jets of water impinging on vanes secured to the spindle. In this country the turbine type is chiefly used, and abroad the fan type. The Siemens meters were fully described in the Paper which the inventor read before the members of this Institution in 1854 (Proceedings, page 6), and in Mr. J. J. Tylor's Paper (Proceedings 1882, page 43), and also in the Paper read by the late Mr. Henry Gill before the

Fig 5. "*Tylor Inferential.*"

Institution of Civil Engineers in 1891 (vol. cvii., page 203). In the latter Paper is described an arrangement for causing the jets of water to strike the vanes of the fan meter always at the same velocity, with the view of causing the meter to register the small flows as accurately as the large flows; but the author does not think this plan is a success, as the floating cylinder (or shutter) is liable to set fast, if for any length of time the meter is idle or is only registering a constant flow. Attempts have often been made to obtain the same accuracy at all speeds of the inferential meter, by combining a large and a small one; but the author has no personal knowledge of the

efficiency of this plan. The "Tylor Inferential," Fig. 5, is another well-known meter (Proceedings 1882, page 45); it is of the fan type, and the wheel is sometimes made of vulcanite, so that it practically floats in water, and the step has therefore no weight to carry, but acts only as a gentle guide.

A number of other types of inferential meters are made and used, especially abroad; they are far too numerous to mention, much more to describe. There is probably no great difference in their value. Vulcanite should count favourably in their construction; but they all fail to register small flows, yet in spite of this acknowledged defect they are habitually employed for measuring house services and other dribbling supplies with the result that the registered consumption, even in a water-closet town, is quoted at only 5 gallons per head per day, and less (see Mr. Gill's Paper, Proceedings, Institution of Civil Engineers, 1891, vol. cvii, page 239); whereas in reality this should be nearer 15 or even 25 gallons per head per day.

3. *Volume or Capacity Meters.*—These meters are almost exclusively made in the United States of America, and their use is chiefly confined to that country, though some are also used here. In construction they are broadly speaking all the same, as they consist of a casing of either gun-metal or vulcanite, in which works a vulcanite block, serving both as piston and valve. They seldom possess any provision for taking up wear, and the parts are therefore difficult and expensive to repair. Hence, though they profess to measure the volume passing through them, they cannot measure small flows, as they are not tight even when new, and their leaky condition is necessarily augmented by wear. Their merits appear to be simplicity, small size, lightness, and cheapness; and for large flows they are said to be very accurate. The "Hersey," Fig. 6, page 44, the "Crown," Fig. 7, the "Bee" or "Thomson," Fig. 8, the Kent "Uniform," Fig. 9, (Proceedings 1895, page 365) the "Nash," and some others belong to this class. Several of these meters, such as the "Bee" and others, are of the disc type, and are founded on the patent taken out in this country in 1830 by Edward and James Dakeyne, for an engine or pump; and later by Davis and Bishop. Only in the Kent "Uniform" has an attempt been made to compensate for wear, by means of a lever adjustable by a set-screw against the edge of the oval piston-block. The part of the lever however which bears

against the piston is tipped with glass, a material quite unsuited

Fig. 6. "*Hersey.*" Fig. 7. "*Crown.*"

for such work on account of its brittle nature; and further, the lever is not automatically adjusted to the wear. Most, if not all, the other meters of the "Volume" type can be repaired only by mechanical manipulations

requiring high skill, or sometimes by renewal of parts; though how new parts of standard dimensions can fit old and worn parts, where no adjustment is possible, it is difficult to understand. It appears from recent comments in the American press that the unreliability of these meters to record accurately the small flows to private houses &c. is being more and more recognised. When the water is not very clean, is rather hard, or for some time stagnant, the meter will set fast, while still allowing a large quantity to pass—of course unregistered. Judging from their general construction, and from reports of their workings, as well as from the author's own experiments, he fails to discover any advantage to be

Fig. 8. "*Bee.*" Fig. 9. *Kent "Uniform."*

obtained from the use of these meters over those of the Inferential type. Indeed he has come to the conclusion that they do not equal in accuracy a well made and well maintained Siemens meter.

4. *The Venturi*.—The possibility of constructing the “Venturi” meter is due to the practical absence of loss of head in the main, which is contracted and again expanded by means of properly formed cones. The difference between the pressure where the water is passing through the main pipe before arriving at the meter, and where it is passing through the neck of the tube, forms the index for gauging the flow. These facts were discovered over a century ago by the Italian philosopher Venturi; and the meter has been perfected by Mr. Clemens Herschel of America. It has no moving parts, except the registering gear, driven by clockwork; it is cheap, considering the large volume of water it deals with, and for ordinary rates of flow in water-mains it is said to be very accurate, and it is certainly most convenient and useful; but it must of course not be used below its rated capacity.

Fig. 10. “Deacon.”

5. *Waste-Detection Meters*.—

A simple and effective meter of this class, Fig. 10, has been invented by Mr. G. F. Deacon of Liverpool, and it is in extensive use. The water enters the upper and smaller end of a conoidal tube (though in some of the meters it passes upwards from below), in which is mounted on a rod a circular disc, so as to be able to move freely up and down. As the flow increases, the disc will fall, and will rise when it decreases; its motion is communicated to a pencil outside the meter by a thin metallic cord passing through a gland, and suitably counterweighted. The movements of the pencil are traced on a sheet of moving paper with divisions representing hours, generally 24. A diagram is thus traced, which indicates to the initiated the varying flow through the main; and

the exact rate in gallons per hour can be measured for any time of the day or night, and by these means waste is readily detected. The total quantity passed is often computed by a special attachment; and can be read off on dials, as in ordinary meters. Several meter manufacturers make attachments to their instruments for obtaining

Fig. 11. "Kennedy."

similar results; and this is effected by causing a uniformly moved strip of paper to become marked with a line for every 100 gallons passed. This is of course convenient for many purposes; but for general waste-detection and locating, especially in large mains, the "Deacon" apparatus seems the more convenient.

6. *Positive Meters.*—The aim of all positive meters is to measure accurately (positively) and record the water passing through them. Hence they have each one or more cylinders (with their pistons and valves), which are alternately filled and emptied; and of course they have suitable counters.

The "Kennedy" meter, Fig. 11, was brought out about 47 years ago, and it still retains its high reputation; it was described and illustrated in the Proceedings of this Institution for 1856, page 151, and 1882, page 42. It has a single, vertical, double-acting cylinder, with its piston packed with a rolling india-rubber ring, and a valve representing an ordinary plug-cock, but having a thin plug, which does not cover the inlet and outlet ports when at half stroke; hence little or no concussion is caused through

the reversal of the valve, as the water is never quite stopped in its change of movement into one or the other end of the single cylinder. The reversal of the valve is effected by a tumbling weight, which is raised by the piston-rod in both its up and down strokes, and which in falling forces down a double-ended lever on the end of spindle of the plug-valve; suitable spring buffers finally arrest its fall. As this method of reversing the valve does not produce uniform lengths of stroke at varying speeds of the meter, an ingenious counter is employed, which by means of suitable ratchets and pawls practically measures the lengths of each stroke, and adds them up, thereby producing a very accurate registration. These meters are of large capacity; hence their movements are slow, so that the wear and tear of the parts are small; and further, they discharge large quantities of water under small heads, or differences of pressure at inlet and outlet. The rolling piston-rings are now said to be very durable, but heavy shocks will sometimes cause them to slip from their proper position, and become damaged. The meter is very bulky and rather noisy. The valve when at mid-stroke leaves the inlet and outlet passages momentarily open to each other, so that for a very short time water can pass from inlet to outlet without entering the meter, and therefore without being measured. However, when the meter has been properly packed, adjusted, and oiled, the interval of time is so exceedingly small as not sensibly to affect the registration; and this part of the construction has for the last few years been much improved by the adoption of Mr. Muirhead's arrangement, whereby the valve is started from rest by the movement of the piston before the tumbling weight falls over; hence the work of reversing the valve is not entirely dependent on the falling weight, and the action of the valve is said to be now much more certain. According to the manufacturer's instructions, the meter requires to be cleaned, oiled, and generally to be seen to every month, and it is not recommended to place it underground; but the author is well aware that the latter recommendation is far from being followed by users. This he believes is the only single-cylinder positive meter in use at the present time. The number of parts and of the special tools required for its repair, as well as the numerous

directions for attending to the meter, indicate some of the disadvantages attendant upon the general use of it.

Nearly all the other types of positive meter have two measuring cylinders with their pistons and valves, and are of the "Duplex" class, in which the piston of one actuates the valve of the other.

Fig. 12. "*Frost.*"

Some have their cylinders horizontal, and others have them vertical. The "Frost" or "Manchester," Fig. 12, has one cylinder vertical and the other horizontal; and they all have flat gun-metal valves, working in straight lines on gun-metal faces. The two cylinders of this class are nearly always of the same capacity, but in the "Tylor Positive," Fig. 13, there is a small difference in their size, and in the "Frost" there is a considerable difference in their dimensions. Why there should be this large difference between the cylinder capacities the author is unable to say; and he is still less able to explain why the valve

supplying the small cylinder or cylinders should be so abnormally large, and why that supplying the large cylinder with water should be of such diminutive dimensions.

The best known "Duplex" meters are:—The "Frost," Fig. 12, (Proceedings 1857, page 175, and 1882, page 42); the "Tylor Positive," Fig. 13; the "Worthington" (American), Fig. 14; the "Fragier" (French), Fig. 15, made by Michel (Proceedings Institution of Civil Engineers, vol. lxxxvi, page 444); the "Schreiber" (French), Fig. 16; the Kent "Absolute," Fig. 17, page 50, bearing a strong resemblance to the "Fragier"; the "Goodwin," looking much like a "Worthington." The "Schmid" meter, Fig. 18, page 50, is also of the duplex type; but, unlike the general run of this sort, its pistons have their length of stroke controlled by a crank-shaft, cranks, and connecting-rods, and

the piston of one cylinder serves as valve for the other. As the pistons have no packing, the meter is even worse than the

Fig. 13. "Tylor Positive."

Fig. 14. "Worthington."

"Worthington" meter, as both pistons and valves must soon become leaky with wear, and when new are apt to set fast with small

Fig. 15. "Frager."

Fig. 16. "Schreiber."

impurities. The crank-shaft appears to require frequent lubrication from the outside. They are used abroad only; an attempt to manufacture them satisfactorily in this country utterly failed.

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The piston packing in this class is generally of leather, which the author has not found in his experience to be the best material.

Fig. 17. *Kent "Absolute."*

In the Kent "Absolute," Fig. 17, it is a combination of leather for wearing surface, and of corrugated india-rubber discs for expanding the leather as it wears. In the "Worthington," Fig. 14, page 49, the pistons are intended to float in the water, but the author very much doubts their ability to continue to do this, after long exposure to heavy external pressures. They are further without any packing, like the discs or links &c. of the volume meters; hence they must be liable to set fast

with dirty or hard water, and must become leaky with wear, and to repair them is an expensive process, as it involves renewal of four pistons.

Several of the duplex meters ("Frost," "Frager," and Kent "Absolute") have stuffing-boxes, which require attention from time to time; and the slide-valves of all—on account of their limited and rectilinear movements—soon become leaky by ordinary wear, and in even moderately hard water they often become fixed or grown to their seatings, if left at rest for a short time. All meters of this

class can be repaired only by skilled workmen, and must in all cases be removed to the workshop for the purpose. Several of them

Fig. 18. "*Schmid.*"

are crowded with small screws, pins, and springs, which often give trouble by breakage; and the dismounting and re-assembling are tedious work in most of them.

Next in importance to accuracy, durability, simplicity, and general efficiency, must be considered the quantity of water delivered under a given effective head. Judged from this standpoint the "Kennedy," Fig. 11, page 46, is far ahead of all others; while the "Parkinson Low-Pressure," Fig. 1, page 40, the "Siemens Inferential," Figs. 3 and 4, page 41, and the "Tylor Positive," Fig. 13, page 49, are much below the average in this respect.

The difficulty of estimating the amount of water expected to be used in any prospective supply, or that used in an existing service, is strikingly illustrated in the Paper by the late Sir William Siemens (Proceedings 1856, page 116). Thus of the amounts supplied to fifteen consumers, firstly as estimated, and secondly as found by meter measurements, the value was £685 of the first, and of the second £4,170; and the author is fully convinced that it is not easier now to guess even approximately the amount of a certain water supply than it was forty-three years ago. Still, many water-works engineers are in favour of selling water by contract rather than by meter.

Early in 1884 the author's attention was directed by one of the largest London Water Companies to the great want of a good water meter, which should be free from the defects of those already in use, and which should above all be simple, and should be able to register the smallest dribbles for long periods without liability to derangement. After considerable study and not a few experiments he brought out his first meter in 1888. It was of the three-cylinder horizontal type, having a single flat valve with a double movement, which caused it to remain always tight; and the three-cylinder arrangement produced a steady flow, as well as quiet working. These meters were before the public for about seven years, and most of those made are still doing good service; but they were composed of too many working parts for thorough efficiency.

Further study, a few experiments, and assistance from the manufacturers, Messrs. Beck and Co., of Great Suffolk Street,

Southwark, produced the present type, now called the "Imperial," shown one quarter full size in Plates 1 and 2. Here the single-acting three-cylinder arrangement is retained, as is also the double movement of the valve, now made with a hemispherical face; and there is the same absence of small screws and springs, while the dismounting and remounting are even simpler and easier than in the first type. It has however in its construction ten fewer moving parts; and therefore the force required to drive it, and the wear and tear, are much reduced.

The meter consists, as will be seen, of the following parts. The lower portion or body A, Plate 1, contains the three cylinders B, and the valve-seating C, with its three ports and passages D, communicating with the bottom of the cylinders; and there is a discharge port and passage E. Inlet and outlet connections F and G, and strainer H, Fig. 23, Plate 2, are also attached to the body portion. I is the cover, with the rib K for holding down the strainer; and it has a prolongation at the top for receiving the counter gear. The unequal spacing of the bolt-holes prevents the cover from being wrongly fixed to the body. Though the counter gear contains a few novelties—such as the entire absence of brackets, screws, springs, and small pins, and has a conveniently hinged glass cover—still essentially it does not differ much from the counters of other meters. L, Fig. 21, is the valve with its three arms, in the ends of which are cup-shaped bushes, for receiving the spherically shaped heads of the piston-rods M, Fig. 19; and to these are secured the pistons, composed of upper and lower piston-plates, nuts, and flexible piston packings. The water entering the meter, as shown by the arrows, passes up through the strainer into the upper portion of the casing, and presses equally downwards on all the three pistons, and also on the valve. According to the position of the valve, the lower end of each cylinder in succession is communicating with the outlet passage, and its piston is therefore forced down by the superior pressure above, and thus discharges the contents of the cylinder. At the same time one or both of the other cylinders is having its piston raised, whereby water is drawn in through the passages, and the lower part is filled. Thus

each lower end of the three cylinders B is in due course filled and emptied, one or two pistons always supplying the active force, so that there is no dead-point. The length of the stroke is regulated by the flanged projection N on the valve L, Fig. 19, coming into rolling contact with a similar flange O on the valve-seating C; a slight skew of the ports causes the pistons to endeavour to take a longer stroke than they should, and the roller-paths restrict this tendency. The teeth in the valve and the notches in the valve-seating prevent the valve from turning round on its own axis, Figs. 21 and 22, Plate 2. A pin in the upper part of the valve engages the crank of the crank-spindle P, Fig. 19, which communicates motion to the clockwork in the usual manner. The pins through the upper ends of the piston-rods prevent the pistons from falling out of the cylinders, should the meter happen to be turned upside down.

From the above description it will be seen that the meter is positive in its action, that the lengths of stroke are definite, that the speed of water through it is practically uniform, as in a three-throw pump, so that there is no concussion or water-hammer; that there is no backlash between any of the working parts, and that the meter can therefore be run at any convenient speed without noise. It has few working parts, not a stuffing-box nor a spring among its details, and is self-lubricating. It contains no small parts, neither pins nor screws; the three studs and nuts (permanently securing the valve-seating), the cover-bolts, and the piston nuts are the only appliances of the sort used. As soon as the cover has been removed, the whole of the working parts can be taken out, examined, cleaned, new piston-cups fitted, and other ordinary repairs effected, if necessary, even without removal from its position in the pipe line. The only joint which has to be made is that between the body and the cover; and any leakage here is at once detected, as it is outwards. As to durability, the author has frequently been informed by users, who take out meters for repair every two years, that it has been a common occurrence to find they require only cleaning, painting, and re-testing, to be again fit for service; even the piston-cups often serve two terms, of two years each. The valve-faces never require

any attention, as they soon polish themselves bright like mirrors, and remain quite tight.

In order to test for himself the practical working of this meter, the author had one of $\frac{1}{4}$ -inch size affixed to the service pipe of his private house in February 1896, and tested it for accuracy at various times with satisfactory results. In May 1897 an American "Volume" meter of $\frac{1}{2}$ -inch size, being the smallest he could obtain, was fixed tandem with the "Imperial," which was first cleaned and furnished with new piston-cups, so as to put both on the same footing. Both meters were tested before fixing, at various speeds, and were found to be practically correct, though the "Volume" meter was disinclined to register flows below about two gallons per hour. The service is partly direct through draw-off taps on the ground floor and basement; and partly through a ball-valve in the main cistern, for supply to bath, lavatory, and hot-water cistern. From 21st May 1897 to 20th May 1899 the "Imperial" had registered 100,248 gallons, and the "Volume" meter 81,772 gallons, or more than 18 per cent. less than the "Imperial" for the two years. As the inhabitants of this house do not allow dribbling wastes by leaky or half-closed taps to continue, the author feels certain that for an average house the readings of the two meters would have shown much greater difference. Weekly readings showed the "Volume" meter to be from 10 to 50 per cent. slower than the "Imperial"; and in one night of twelve hours in April 1898, when a leaky fitting had been discovered, the "Volume" registered only 5 gallons, while the "Imperial" registered 29 gallons; on another occasion, also of twelve hours, the figures were 9 gallons and 29 gallons respectively. The meters were tested from time to time in the two years, and both were found to be correct, excepting the "Volume's" objections to small flows. When the meters were tested in May of last year, the "Imperial" was practically correct at all speeds, down to 2 gallons per hour, below which it was not tried; while the "Volume" would not register 4 gallons per hour, and at 5 gallons per hour it was 10 per cent. slow, while at 48 gallons per hour it was practically correct. The rate of working in this house, according to a large number of observations, varies from a

mere dribble up to 100 gallons per hour, which has been found sufficient for all purposes. These experiments, the author would submit, prove that the "Imperial" meter is in every way fitted for measuring supplies to private houses, in addition to its suitability for general use; and that a meter which will not measure the smallest dribble is misleading and costly for such service.

As comparative tests of different types of meters are but seldom recorded, the author thinks that the following results of tests of four meters, Table 2, coupled in line on the supply to a country water-works, will be of interest. The supply was varied from time to time by hand, and each meter was tested for accuracy before fixing, with the results given.

TABLE 2.—*Tests of Four Water Meters.*

Meters.	"Positive."	"Inferential."	"Volume."*	"Positive."†
Initial Errors.	- 3 per cent.	+ 7 per cent.	+ 2 per cent.	+1½ per cent.
1889				
4 February .	2,780	1,990	2,346	2,898
13 „ . .	2,800	3,260	2,454	2,958
18 „ . .	1,310	880	850	1,370
25 „ . .	1,960	1,410	1,344	2,040
4 March . .	2,000	1,310	578	2,090
11 „ . .	1,880	1,200	2,358	1,980
18 „ . .	2,060	1,325	1,405	2,150
25 „ . .	2,080	1,345	1,465	2,300
1 April . .	2,320	1,680	1,802	2,346
8 „ . .	2,250	1,850	2,040	2,364
Totals registered .	21,440	16,250	16,642	22,496

Here certainly there seemed little to choose between an "Inferential" and a "Volume" meter; both were practically 25 per cent. slow on the average of the ten weeks' test.

* This meter stopped several times. † The author's first type of meter.

In conclusion, the author trusts that he has neither claimed greater merits for the "Imperial" than are due to it, nor understated the advantages of other types; and hopes that he has not tired the members with descriptions and statements which may be familiar to many of them.

Discussion.

Mr. SCHÖNHEYDER said that in making a new meter of the type shown on Plates 1 and 2, as in making any new machine, difficulties were very often met with at the outset, and he had found a few difficulties, which, however, had been completely overcome, although it took some time to find out their nature. These had been overcome by changing the material from which certain parts were made, and not in any way by changing the construction. The first parts to give trouble were the piston-cups. They had been at first made of leather, but it was impossible to get leather of uniform thickness or substance. Some of the leathers when placed in water became hard, some soft, some swelled, and some shrank. He had made many experiments, the result of which were piston-cups such as were shown. These were quite soft, and acted singularly well. They were made of a kind of vulcanite, or hard rubber. He did not know what substance was mixed with it, as that was the secret of the makers. The next difficulty was with the crank-spindle P, Fig. 19, of the meter, which had been made of gun-metal. The bush in which it worked was also gun-metal. After a time several of the crank-spindles seized in their bearings, and either stopped the meters or the counters. He then had the bushes made of vulcanite, and now the gun-metal crank-spindles worked satisfactorily. He had a further difficulty where the valve-pin touched the crank-spindle. It was found that sometimes the spindle and sometimes the crank wore away, which was probably owing to air accumulating in the top of the meter, and the two metals working together perfectly dry. Sometimes the end of the crank was cut

completely away, and sometimes the pin, but by fixing vulcanite in the crank that difficulty was overcome. Further, in the counter-plate, where the pinion-spindle passed through the plate, there were at first two pieces of metal working together. These sometimes seized, but now the plates were always bushed with vulcanite, which had overcome that difficulty. He referred to the exhibits, which consisted of all the various portions of $\frac{1}{2}$ and $\frac{3}{4}$ -inch meters shown separately. The cylinders in the $\frac{1}{2}$ -inch meter, Fig. 24, Plate 3, were of gun-metal, but the cylinders of the other one were of vulcanite, which he found very useful in hard water, or when a meter had to stand still for any length of time. He showed two meters in action, one worked by water coming from a tank on the top of the building 90 feet above the platform, the other worked by a suction head of about 10 feet. The cover with its counter gear was taken away from the latter, to show the action of the valve and pistons. By turning on a tap the meters were made to move. In testing meters at the works a column of water, similar to that shown in the glass tube, was always used to see if the meters worked sufficiently free before they were sent out, and they generally worked with a 3-foot head. It also showed, when working very slowly, whether the meter was quite tight; if it continually dribbled, but did not move, it showed there was a leak in it. By turning the tap on a little harder a higher speed was obtained, and it would be seen that the stream of water was quite steady and the meter noiseless even at the higher speeds. There were two meters on the table which had been in use. The first had been kindly lent by the Southwark and Vauxhall Water Co. It was a $\frac{1}{2}$ -inch meter, Fig. 25, Plate 3, which had been in use two years and five months, and had registered 267,000 gallons. The company tested it before the seals were broken, at 450 and 20 gallons an hour, and it was found correct. After receiving it he had it tested down to 5 gallons an hour, and at that speed it showed a slight leakage of about half a gallon an hour. Members examining it would find there was practically nothing amiss with it, except that it was dirty, and probably the cups might require to be renewed after their $2\frac{1}{2}$ years service. Cleaning and re-testing were about the most it needed.

(Mr. Schönheyder.)

There was also shown a $\frac{1}{4}$ -inch meter, which had been in use at his house for two years, running tandem with a disc meter. It had been at work altogether nearly four years. The valve was quite perfect, as bright as gold, and tight. Nothing had been done to it. The cups were also in good condition after their two years' service. He had had it tested lately at various speeds from 200 gallons an hour to 2 gallons an hour, and it was practically correct, there being small errors of perhaps $\frac{1}{2}$ or 1 per cent. No lubricant was used on the valve except water.

Mr. J. E. H. DE KEY asked whether the discussion would be confined to the author's meter under discussion, or to the Paper as a whole.

The CHAIRMAN said that the discussion would deal with anything relating to water meters in general. As Mr. Hawksley was one of the greatest authorities on water engineering, perhaps he might wish to say something on the water meter.

Mr. CHARLES HAWKSLEY said he came rather as a learner than as an instructor in the matter of water meters. He had learnt a good deal about water meters during the last forty years, but he had not that intimate personal knowledge of their details which many of the members present possessed. It was generally known that each meter had its own defects; some of these had been described in the Paper as applying to a particular class of meter, such for instance as the inferential meter, which could not register very small quantities of water, although small quantities were matters of great importance to those who had water to sell. As would be the case in a large retail business, if the scales of the shopkeeper would not measure ounces, and he was obliged to give away everything, for instance, below a pound weight; the shopkeeper would not flourish, and so it was with those who supplied water; unless the meter would measure small quantities it was not very useful, especially in those many cases in which waste went on by dribblets. He thought the different defects of the meters referred to had been touched upon

so well in the Paper that it would be a waste of time to recapitulate them. He might state, however, with regard to the low-pressure meters, that the "Parkinson" meter, Fig. 1, page 40, had been found to give very good results during the many years in which it had been in existence. It had, of course, the great drawback that it would not transmit pressure. Then again there were defects which arose in many meters, good in the first instance, while they were new, but which ceased to register accurately because of the wear and tear of the various working parts, especially the valves. Further, most of the members would know that a meter would work very well with one kind of water, and yet when taken into another district or another town would be found to be a complete failure. Hard water perhaps would ruin it very rapidly by wearing the faces of the valves, whereas with soft water it would work admirably, or the reverse might be the case. Meters might be put out of order by rust in soft water districts, a difficulty which would be unknown in a hard water district. Having thus mentioned some of the general principles, on which depended the success or otherwise of any particular meter, he thought he might leave it to others who were better acquainted with the details of each meter to enlighten the members with regard to their various peculiarities.

Professor W. CAWTHORNE UNWIN, Honorary Member, said he did not know that he was an authority on meters, but he should like to compliment Mr. Schönheyder on the very great ingenuity of the design of his meter, and still more on the patience with which he had investigated the causes of errors and eliminated them. He had read the Paper with very great interest, and there was only one passage in it about which he wished to make a remark or two. The author had mentioned the "Venturi" meter, page 45, although that was a meter which hardly belonged to the class which he was chiefly dealing with, and in mentioning the "Venturi" meter he thought the author was not quite accurate. In the first place the author rather implied that the principle of the meter was discovered by Venturi. Venturi made experiments on converging and diverging orifices, but he did

(Professor W. Cawthorne Unwin.)

not think he even noticed that a certain difference of head in the meter was proportional to the square of the flow. In the "Venturi" meter a certain difference of head was measured, which was proportional to the square of the discharge. That result can be deduced from the most general principle in hydraulics, the theorem of Bernoulli. The idea of using a pipe of this kind for measuring water was entirely original with Mr. Herschel. But there was another point which was of some practical importance. The author said with regard to the "Venturi" meter that it must never be used below its rated capacity. He believed he meant something perfectly right, but the expression conveyed a false notion that the meter only measured one rate of flow. Every meter would cease registering at some discharge or other—it might be a very low one, or one less low—but there was a point at which every meter would cease to register. In the "Venturi" meter, of course, registration did not go on to very low discharges, or rather registration went on all right, but it became too small to be useful. In other respects it had a range of registration like any other meter, indeed more—there was practically no limit to its registering large flows. It had been stated that as ordinarily constructed the "Venturi" meter ceased to register when the velocity in the main on which it was placed fell below about one-half foot per second. He had been informed that Mr. Kent had constructed a "Venturi" meter for a velocity, in the main in which the meter was fixed, as low as 0.1 foot per second. The "Venturi" meter was really very interesting. He had an opportunity of making some measurements with a "Venturi" meter on a water main 48 inches in diameter, and the meter had been constructed for mains up to 60 inches in diameter. It formed an extraordinarily accurate gauging instrument where flow in water mains had to be dealt with. There was another point he might mention. Mr. Schönheyder seemed to have found great advantage in substituting some form of vulcanite for metal, where the surfaces were in rubbing contact under water. That the author had found vulcanite answer so well reminded him of the extraordinary durability of lignum vitæ bearings when lubricated in that way. Lignum vitæ was used for the support of the propeller-shafts of steamships and for footsteps of turbines, and

its durability when lubricated by water was extraordinary. In such cases the wear of metal bearings was very rapid.

Mr. PHILIP BRIGHT said he had only two or three remarks to make on the very interesting and fair Paper which Mr. Schönheyder

Fig. 28. "*Tylor Rotary Meter*, 1901."
Section on AA.

Sectional Plan on BB

had read. He was sorry the author did not let him know that he was going to illustrate the "Tylor" meter, because the one he showed, Fig. 5, page 42, had not been made for about eleven years, in fact the fan illustrated had not been made for sixteen years. The "Tylor" meter as now made was shown in Fig. 28. He could quite

(Mr. Philip Bright.)

bear out the remarks which Professor Unwin had made about the advantages of *lignum vitæ* (page 60). His firm had long used it in their large meters (8 inches to 12 inches), and found it most durable and entirely satisfactory. As to inferential meters, it was altogether a question of the size of meter which was employed. If small enough, they could be made to register very small flows indeed. Meters were made and were at work which would register 2 or $2\frac{1}{2}$ gallons an hour perfectly accurately. Their capacity at full flows was not very great, it was true—about 120 or 140 gallons an hour—but as most of the water which was taken into houses for domestic purposes came through ball-valves into cisterns, he did not think this was a matter of great importance. He had lately measured some ball-valves stamped by the New River Co., and had found that the $\frac{1}{2}$ -inch ball-valve had only got $\frac{1}{8}$ -inch way, and the $\frac{3}{4}$ -inch only 3-16ths-inch way. Turning to the author's Paper, he found it stated in Table 1, page 38, that $\frac{1}{8}$ -inch hole passed at 100 feet head 95 gallons per hour, or sufficient for a population of 152 people at 15 gallons per head per day; while a 3-16ths-inch hole passed 214 gallons per hour, or sufficient for a population of 342 people at the same rate of supply. Therefore an inferential meter costing only twenty to thirty shillings was quite capable of supplying the largest house with water, if the supply were a constant one—which he was glad to say was the case almost everywhere at the present day—and the house were fitted with a cistern, as all houses should be. The author had made some tests of a $\frac{1}{4}$ -inch positive and a $\frac{1}{2}$ -inch volume meter, page 54, but did not say what the respective costs of those two meters were. He, the speaker, found from the author's figures that the positive meter—assuming the charge for water to be 1s. per 1,000 gallons—produced a revenue of about 3d. per week more than the volume meter. He thought that the question of the original cost and the expenses of maintenance should also be given, so that it might be determined whether the 3d. a week was really revenue, or whether it was balanced by interest on capital and repairs. With regard to Professor Unwin's remark (page 60) about the friction of metal working-parts in metal bearings, he thought many people had found out that metal and vulcanite gave

better results. He believed Lord Kelvin's famous tap was originally made with a gun-metal valve and seating, but that the metal valve had now been superseded by a vulcanite one, the seating still being of gun-metal. As to water meters in general, they were not used for domestic supplies in England to any great extent, though they were in many other countries, and he thought the question of leakage in mains had a great deal to do with it. He saw it stated recently on official authority that the main waste in New York was 36,000,000 gallons a day; and it must be very large in London. If the author and other inventors could contrive a water meter which would register accurately, and charge to consumers all the waste which existed in water companies' mains, he believed that that meter would be universally adopted.

Mr. W. B. BRYAN said he had not expected to be called upon so early, and should have preferred to wait until he had heard what other inventors had to say in connection with their meters. He had suffered a great deal from inventors of meters, and other water-works engineers had probably done so also. He was responsible for looking after a revenue of £150,000 a year through water meters, and naturally such a large revenue required a great deal of care and study of the different types of meters. He thought there was room for several types of meters in all large waterworks. For instance, a positive meter could not be used for large supplies like those of railway companies and large manufacturers. Some of his company's supplies went as high as 300,000 gallons a day, and in such cases it was necessary, of course, to use inferential meters, and in these instances they registered with very considerable accuracy. For domestic and other small supplies an inferential meter perhaps was not quite as good as a positive meter, but the inferential meter had its advantages, as also had the positive meter. The positive meter sometimes stopped, and then the company would receive a sharp letter from the occupier of the house to know why his supply had been arbitrarily cut off by the water company. On the other hand, if an inferential meter stopped registering altogether, it did not stop the supply. That was an advantage to the consumer, but a little

(Mr. W. B. Bryan.)

disadvantage, perhaps, to the water company. The author had stated (page 39) that the sale of water by meter universally would have the great advantage of reducing waste. No doubt it would. On the other hand the cost of the meter and the meter rent in some districts would be very prohibitive. When he mentioned that his company alone supplied water to over 80,000 houses at a rental of less than 3*d.* per week, and perhaps 20,000 houses for 2*d.* a week, it would be seen that there was not much margin to pay for and keep in repair a very fine positive meter like the author's. And when he also stated that his company had 210,000 houses to supply, that the cost of a positive meter for each of those houses would be considerably over a million of money, and the annual cost of keeping them in repair would also be large, the members would see what a great business it would become. There was no doubt, on the other hand, that it would save capital by obviating the necessity for going further afield for water as early as would otherwise be the case, as the districts increased. With regard to the supply of water by meter to houses abroad, it should be remembered that in a city like Berlin the number of inhabitants per house was about 60, and in Vienna 69, consequently an inferential meter might be put in and register fairly for 69 or 70 people, but this would not be the case in London, as the average number of people to a house was only 6 or 7, or in the provinces only 5. It would therefore be seen that there was considerable room for inferential meters for large manufactory supplies, and for positive meters for smaller supplies. With regard to positive meters, he believed the "Kennedy" meter, Fig. 11, page 46, had many advantages over every other type of meter. Of course it had the disadvantage of bulk, especially in London. The author's meter was a distinct departure from every other type of positive meter. He thought very highly of it, and had to congratulate Mr. Schönheyder on the ingenuity that he had displayed in making such a meter. He might say a word or two about the "Deacon" meter, Fig. 10, page 45. This was used, as was well known, for detecting and helping to localise waste in the streets. His company's district, requiring sometimes 50 million gallons a day, was entirely governed by "Deacon" meters, which were most wonderful pieces of machinery for aiding

water-works engineers in detecting waste and localising it. As regarded the "Venturi" meter, that had great advantages in enabling one to gauge the flow pretty accurately through very large mains. His company had one on a 48-inch main, and the water had been checked by cubing a large reservoir through which the water had passed, and its registration was found to be very accurate. The great disadvantage the "Venturi" had for commercial purposes was that if the clock stopped, the registration stopped, and that would not suit waterworks companies.

The CHAIRMAN said he understood that Mr. Kennedy, the inventor of the "Kennedy" meter, was present, and the members would be glad to hear him on the subject.

Mr. THOMAS KENNEDY said his remarks were written and were in the hands of the Secretary. He was afraid they were rather long and abstruse, but they would probably be printed with the discussion. [*See page 79.*]

Mr. ISAAC SMITH said that, as no reference had been made in the Paper to his meter, he had been invited to show the model exhibited on the table and illustrated in the accompanying Fig. 29, page 66. The subject of water meters had occupied his attention for many years. His father, the late Sydney Smith, made a water meter fifty years ago on the principle of the gas meter. It worked very well, but having other inventions on hand the subject was dropped. He himself had brought out a meter in 1893, based upon the principle of a continuous spiral passage from the centre to the periphery of the drum, and having three ports of discharge. Owing to the difficulty in balancing the motor, excessive wear resulted. Last year he invented the device in which a series of spiral channels were incorporated in the drum, in place of one continuous spiral as in 1893. These spiral passages had a gradual taper from the inlet to the outlet ports, and were constructed so as to give perfect equilibrium to the drum. As will be seen from Fig. 29, they were cast within the motor. They may however be made of an alloy that admits

(Mr. Isaac Smith.)

of their being pressed out by a die. The sleeve of the drum had an upper and lower bearing, which rode upon the port box. There were four port holes. The walls of the entrance of the channels

Fig. 29. "Smith's Rotary Meter, 1899."

were so enlarged that only one port-hole was able to supply one channel at the same time. By this arrangement congestion of fluid at the entrance of the channels was effectively prevented. The port box being terminable, all sudden or violent pressure was resisted by this contrivance, and the irritation produced by shock was spent before the water emptied itself into the case of the meter. The following details showed the proportions of the drum and the method of describing the curves :—

No. of spiral channels in the drum . . .	= 3
No. of outlets " " " . . .	= 3
No. of inlets in port box . . .	= 4
Outside diameter of port box . . .	= Inside diameter of inlet pipe.
Area of the three spiral channels at inlet.	= Half area of inlet pipe.
Area of the three spiral channels at outlet	= Quarter area of inlet pipe.
Length of spiral channels . . .	= $1\frac{1}{4}$ th revolutions.
Depth of spiral channels . . .	= $2\frac{1}{2}$ times the width at inlet.
Width of inlet and outlet ports . . .	= $\frac{1}{8}$ diameter of inlet pipe.

Example for 1½-inch Meter.

Area of 1½-inch pipe = 1.767 square inches.

Area of three spiral channels at inlet = $\frac{1.767}{2}$. . . = 0.883 square inch.

Area of each spiral channel at inlet = $\frac{0.883}{3}$. . . = 0.294 square inch.

Let x = width at inlet, then $x \times \frac{5x}{2} = 0.294$ square inch.

$$5x^2 = 0.588; x^2 = 0.1172$$

$$\text{therefore } x = \sqrt{0.1172} = 0.342$$

Depth = 0.342×2.5 . . . = 0.855 inch, approximately $\frac{7}{8}$ inch.

Spiral channels at inlet . . . = 0.342 inch wide, 0.855 inch deep.

Spiral channels at outlet . . . = 0.171 " " 0.855 " "

Thickness of channel walls . . . = $\frac{3}{32}$ inch = 0.0937 inch.

This meter possessed the advantage that there was no thrust either upwards or downwards, thus giving to the spindle free action in working the worm and recording wheel work without the slightest tendency to jam. It had proved upon the whole satisfactory when tested with normal and abnormal flows. When put to severe tests in different ways under pressure of 1 lb. to 80 lbs. and a dead head of 18 inches, it had responded with encouraging results. He had seen the drum in a small meter rotate quickly with a head of 12 inches, and the motor when fixed in the instrument could be blown down by a breath of air. He was not going to say it was a perfect meter, but what it needed was greater perfection in the quality of the clock-work.

Small flows and waste in dribbles had been made a special point by the author in dealing with his subject, and while, from a dividend point of view, and especially under the control of a private company, this was a matter of financial consideration, yet from a ratepayer's point, or on sanitary grounds, this economy might not turn out to be a paying one for the community, as it would tend to increase the risk of zymotic diseases. It would be a mistake to withhold the water-carts from the streets on account of cost; and when scarcity existed, the remedy ought to be sought in obtaining new supplies or an increase of pumping capacity. In the case of corporations being the proprietors of the water supply, their first care should not be

(Mr. Isaac Smith.)

directed towards lowering the rates by profits, but to keeping down the death rate by a liberal flushing of drains and a frequent use of the hydrant, especially in narrow streets and thickly-populated workmen's districts. No mention was made in the Paper with regard to different qualities of water met with in various localities. While some were comparatively free from the formation of silt, and afforded favourable conditions for the working of water meters, others held a good deal of matter in solution and rendered in a short time their accurate measurement a failure.

Mr. EDWARD B. ELLINGTON, Member of Council, said it was somewhat curious that the low-pressure "Parkinson" meter, Fig. 1, page 40, which could not register pressure, was the one that was largely used for the high-pressure hydraulic-power supply in London. The exhaust was registered, as it was only the pressure and not the water that was used, and the "Parkinson" meter had been admirably adapted for that purpose. The great difficulty with that meter was that it registered with perfect accuracy when the water was pure, but as the water registered passed through the machines it became contaminated with grease and bits of packing and so on, and a great deal of difficulty arose with it in consequence of the filling up of the drums, the meter thereby becoming inaccurate. There was another difficulty about the "Parkinson" meter in general use, namely, that it was a large meter, and in some cases a portion of the flow only was registered, when it became really an inferential meter. The accuracy of that meter for the larger sizes depended upon the same quantity of water passing through one, two, or three by-passages, of which only one was actually measured in the drum. To that extent therefore it was an inferential meter. With regard to the power supply, there was often, too, a difficulty in registering with the "Parkinson," because the water had to be passed first into an open tank and then from the tank to the meter. This was often inconvenient, and closed meters had to be used. The meters of the closed type, which had hitherto been used, had been principally of the Kent "Uniform" type. That meter had proved very satisfactory. As the author had stated (page 43), it would not register very small

flows, except for a short time after being put to work, and it was therefore necessary frequently to change the working parts. Kent's was the first meter applied for the registering of high-pressure water. Fig. 9, page 44, showed the application of that meter to the registration of high pressures. Most satisfactory results had been obtained, but there was still a considerable quantity of water passing through the various meters in dribbles. The only difficulty that arose with regard to the most perfect meters that could be used, such as the author's, was their relative cost, as had been pointed out by Mr. Bryan (page 64). The question of the cost of the meters in reference to dribbles was a very important one. The size of the author's meter was considerable in relation to its flow, as compared with, say, the "Kent." He thought the author was to be congratulated on the results he had obtained, and he hoped to have a further opportunity of testing his meter in connection with the hydraulic-power supply.

Mr. GEORGE COCHRANE said that many different types of meter were used to register water in the hydraulic system with which he was connected; but in Manchester he believed they used entirely the high-pressure meter of the Kent "Uniform" type, and he understood the registration there was very good indeed; as much as 98 per cent was registered in twelve months, and even over a period of four years the registration had been as high as 98 per cent. of the actual consumption. That was very good, and such a percentage could not be claimed in London. He thought it pointed to what could be done with meters under general conditions. There was also the advantage of not using a meter which stopped the flow in case of any breakdown. A positive meter had always that danger, particularly in hydraulic supplies. The stoppage of flow in such places as wharves, warehouses, and to steamship companies, was very serious indeed; and it was much better on the whole that some of the water should be lost, rather than that a serious responsibility should be incurred by any stoppage of the supply. With a registration of 98 per cent. he thought everyone concerned should be satisfied.

Mr. T. A. WHEATLEY said that, being a member of the firm manufacturing the meter invented by Mr. Schönheyder, he felt he was precluded from criticising the various makes described in the Paper; indeed he had no desire to do so as he thought the Institution was as much interested in the general question of the sale of water by meter (with special reference to the use of those of a positive type), as they were in the relative merits of appliances contrived for this purpose. It was stated many years ago that anyone producing a really reliable positive meter would find an enormous demand for it; it could hardly be said, however, that the combined output of meters of this class justified the prophecy. It might be urged that no one had as yet produced a positive meter which was an unqualified success; at any rate, a number of inventors and manufacturers had done their best to deserve it. He himself thought there were important reasons why positive meters were not more generally used than they were at present, and it was to several of these he asked permission to draw attention. One of them was the question of price. He was aware no substantial reduction in the selling price of positive meters had been made, the cost of which was appreciable; and regretted that, considering the capital and ingenuity which had been expended in the effort to cheapen them (in order to increase the demand), he did not see much prospect of improvement in this respect, especially in view of the onerous duty they had to perform, and the limitations which surrounded them. But what meter makers asked them to consider (in conjunction with first cost) was the earning capacity of the instruments and the comparatively small cost of upkeep. They claimed that by the use of positive meters, notwithstanding the initial cost, dividends could be earned and waste checked more effectually and cheaply than by any other means at present available. The next obstacle appeared to be the commercial immorality of the manufacturer, for, although any statements he might make as to any other of his productions were generally accepted as being approximately correct, this was not the case when they had reference to a water meter. He ventured to suggest that this reputation might not be wholly due to their faults and failures, but to some extent to a lack of appreciation of the

conditions under which it was reasonable to expect a meter to work satisfactorily. In order that a locomotive should do its work effectively and economically it was necessary to reduce mountains, raise valleys, metal roads, and lay rails ; in fact, everything in this case was done to adapt the conditions of work to the machine. But this was not so in the case of a meter ; it was too often stuffed into the ground without reference to its suitability for the duty required of it, and without any effort to bring the conditions of service within the range of the meter used. Care was of course taken to read the registration from time to time, but beyond that a meter was left to take its chance. If therefore in the course of a few decades it showed signs of wear or leakage it was not surprising ; the best recommendation he could offer under such circumstances was that the owner should send it back to the maker and demand a new one to replace it. A water meter had no governor to protect it from being overdriven on the one hand, and it was not a pressure-producing instrument on the other. It made a useful air vessel, though it was not designed to serve in that capacity ; it was not even an eel-butt or a mud-sumpt. He therefore appealed to the members to interest themselves more in the question of favourable working conditions for meters, as he felt it would pay them to do so. In one respect he admitted that meter makers were to blame, as they continued to designate the size of meters by that of the pipe to which they were attached, without reference to height, diameter, or even capacity in gallons per hour. In deciding on the size of the meter to be used, he suggested that not only the average quantity of water to be passed in the twenty-four hours should be accepted as a guide, but the maximum flow during any part of the day. He submitted, finally, that the most important reason why water meters (and especially those capable of measuring dribbles) were not in more general use was because public authorities, while alive to the necessity of a plentiful and pure water supply, failed to realise that preventable waste represented so enormous a percentage of the water supplied to consumers ; they did not recognise the fact, which would probably dawn on them sooner or later, that the solution of the problem of meeting the needs of our rapidly increasing population

(Mr. T. A. Wheatley.)

lay as much in conserving what we already possessed as in enormous expenditure for increasing it.

MR. WILLIAM MORRIS, engineer of the Kent Water Works, said he had taken great interest in meters for a long time, and thought Mr. Schönheyder's meter was one of the best. Mr. Schönheyder had frequently discussed the subject with him. Until he knew the results, after some years' working with those he had in use, he could hardly say whether it would be worth while to pay a larger price for them than for Siemens' inferential meters, Figs. 3 and 4, page 41, which generally worked very well. In the case of his company, domestic supplies were not given by measure; but there were a great many meters attached to private houses where, in addition to domestic supplies, water was taken for watering the gardens, and where it was important to impose some sort of check on the quantity of water used for this purpose, because it was taken from the mains at the hottest time of the year, and when the demand for all purposes was at its maximum. Unless some check was placed upon the water used for gardens, it was frequently allowed to run day and night on the grass plots. His company had established a system of requiring the water to be taken through a meter when required for the garden, charging, in addition to the ordinary rate for domestic purposes, something for the rent of the meter. Supposing, for instance, the water-rate of a house to be £4, his company asked £5 a year, or rather £1 5s. per quarter, for which the consumer would be entitled to use, say, 20,000 gallons. Consequently they were not so much concerned with the absolute accuracy of the meter in registering dribbles, the meter being fixed to act as a check upon undue consumption. In the great majority of cases it was found that the residential supplies did not exceed the quantity covered by their minimum rate, which was sufficient to give all the water that was required for gardens if it was used in moderation. But where consumers had very large gardens, or used water lavishly, the charge for water went far beyond the minimum rate. In such cases Siemens' meter seemed to be a very satisfactory one. In 1884 he went over to Berlin on behalf of the London water

companies to investigate the way in which that city was supplied by meter. It was at the time when a proposal was made that Londoners should have the option of taking their water by meter. He found in Berlin that the Siemens' meters were very satisfactory, because there were no cisterns whatever in the city, all the supplies being absolutely direct from the main, and when water was used, it was drawn at a considerable speed. In Berlin nearly all the houses were built in flats, and held from 70 to 100 and more inhabitants. Under that system he found that the landlord paid for the water supply for the whole of the premises, and therefore it did not matter to the individual consumer what he consumed, as he had to pay a fixed charge. The landlord in every case was bound under the police regulations to have a representative on the premises, and that representative could read the meter and see that there was no excessive consumption. At the time of his visit, under that system, about 12 gallons a head per day were being used in Berlin, but he believed more was being used now. When they tried to supply each separate family through a meter they had to put in a smaller meter, through which people could not get enough water to fill their pails in the proper time or flush their closets. Therefore an inch meter was the smallest they used. Under those circumstances the result was very satisfactory indeed. He believed there was a loss of only about 8 per cent. in the difference between the water assumed to be pumped by the engines and the water sold through the meters to the inhabitants of the city.

The CHAIRMAN intimated that the Institution would be very pleased to receive any written remarks on the Paper that any gentlemen connected with London or country water works might be pleased to send in. The Secretary had already received five or six letters on the subject, with remarks which would be added to the Discussion in the Proceedings. [*See pages 77-86.*]

Mr. J. MACFARLANE GRAY said he would not like the meeting to close without adding his voice in commendation of the great ingenuity displayed by Mr. Schönheyder in his meter. He had read

(Mr. J. Macfarlane Gray.)

the Paper with great care and studied the drawings and tried to think out, while reading it, the geometry of the motions of the parts. He commended all young engineers to do the same. He considered the meter to be a poem in engineering, and congratulated Mr. Schönheyder on his work.

The CHAIRMAN said that before closing the meeting he should like to say a few words. Many of the members were there to grind their own axes, and he also had an axe to grind. The members were well aware that the Government were establishing a Physical Laboratory. That was, they agreed to grant £12,000 to start the laboratory and to spend £4,000 a year in the management of it. In addition to a lot of experimental work which would be carried on, it was desired that a large amount of testing should be done, and he believed that if the physical laboratory would take up the question of testing meters some good might be done. In making some recent experiments, he wanted to get some perfectly reliable meters, and on enquiring if they could be tested, he found that there was nobody in the country who could test them. All he could do was to get two meters from the same manufacturer and try them together. He did not think that was a satisfactory way of having the meters tested, and desired to ask Mr. Schönheyder and the members whether they thought it would be worth while for the Physical Laboratory to spend part of the government money in putting up an establishment, where government testing could be done at a small charge for each meter. He felt sure the members would accord a hearty vote of thanks to Mr. Schönheyder.

Mr. SCHÖNHEYDER, in reply, thanked the members for the very kind way in which they had received his Paper, and also for the high praise which most of them had given him for the production of his meter. He had to apologise for his error in describing the "Venturi" meter, and he was obliged to Professor Unwin for the correction (page 59). In speaking about the meter not being used below its capacity, that, of course, applied to all meters. His idea was that, if a "Venturi" meter were placed between two companies' mains so as to

ascertain what water went from one company to another, at certain times of the day the flow would be so small that the meter would not register correctly. He thought Professor Unwin gave the minimum measurable speed of water in the "Venturi" meter to be one-half foot per second. This speed would deliver a very large quantity of water through a large main. With regard to Professor Unwin's remarks about *lignum vitæ* (page 60), he had used it, and thought at one time of using it very largely. He had fitted *lignum vitæ* in the bushes of the arms, and some of them had worked exceedingly well, though it had often dried and split. In preparing the various illustrations for the Paper, he had not intended to represent meters in their very smallest details as they were now made. If Mr. Bright would kindly lend the more recent drawing to the Institution he had no doubt it would be inserted with his remarks (*See* Fig. 28, page 61). Mr. Bright also spoke of using small inferential meters in registering supplies to houses. If a small meter was used a small delivery was obtained. The meter could not be used for both purposes, for measuring the dribbling supply to the house and for measuring large supplies. In his own house, the volume meter was fairly good down to about two gallons an hour, and in spite of that the difference in registration between this and his own make was enormous. In the night, when the flows were very small, the volume meter would hardly register, but his own meter kept on registering. As the result of two years' working there was a difference of about 18 per cent. If a large supply was wanted for gardens it must be had, and the small meter could not be used for such purposes. With regard to cost, the volume meter of which he spoke was very low, but it would now hardly register five gallons an hour, and how to repair it he did not know. It cost only £2, but that was very dear if 18 per cent. was lost by using it. The small quarter-inch meter which ran tandem for two years was only listed at £3 7s. 6d. It had had one new set of cups in that time, and as it stood now it was ready to work again, registering correctly down to two gallons an hour, and probably much less. Many water superintendents contended that if a meter registered down to five gallons an hour that was quite enough for all purposes. But if such

(Mr. Schönheyder.)

a meter was tried tandem with a correct meter that would measure small flows, the error would be seen at once. In his Paper he had pointed out that inferential meters were suitable for all large supplies, and he held with that still. As to the high cost of measuring water by positive meters, he might state that a good many "Imperial" meters were at work where only 4*d.* was charged per 1,000 gallons, and it was found advantageous to use them. With regard to the difficulty of measuring the water to small houses, or small flows, there was no reason why one meter should not be put to two or three houses. In one town where the whole supply was measured, a meter was put to four cottages, and this arrangement was found to work capitally. Mr. Morris had spoken about the great advantage arising from using the "Siemens" meter (page 72), but he was sure Mr. Morris was quite unaware of the amount of water lost, especially if he used the meter for house supplies. If he would be kind enough to put a correct positive meter tandem with one of his inferential meters, he thought interesting information would be gathered. He approved of the system of giving people a certain minimum quantity for a fixed yearly payment, but in comparing the Berlin supply with that of London, it must be remembered that in Berlin there were about sixty people to each house, in which case it was a very easy matter to measure the water by an inferential meter. He thanked Mr. Macfarlane Gray for his kind remarks (page 73); and entirely agreed with the Chairman's suggestion that it would be valuable to have a proper testing place for meters. [*See also page 86.*]

The CHAIRMAN added that he had asked the question about the Laboratory because he was the representative of the Institution of Mechanical Engineers on the Council of the National Physical Laboratory, and he therefore welcomed any suggestions upon the subject.

Communications.

Mr. JOSEPH BERNAYS wrote that he greatly appreciated the ingenuity displayed in the author's invention, and, having himself worked for some time in the same direction, had pleasure in

Fig. 30. "*Bernays' Positive Meter, 1895.*"

submitting particulars of his own positive meter, patented in 1895. This meter, Fig. 30, consisted essentially of two pairs of short cylinders cast together round a central space, with their centre lines at right angles to each other. These cylinders were fitted with pistons connected together rigidly in pairs by short rods which crossed one another and were jointed in their middle by a plain link. As the pistons reciprocated, the link turned completely over,

(Mr. Joseph Bernays.)

determining thereby the movements and strokes of the pistons. At the same time the centre of the link described a circle around the crossing point of the two connecting rods, which movement was utilised for working a circular slide-valve for distributing the liquid to the four cylinders. All parts dropped into their places without any internal screws or fastenings. Fig. 30 represented an encased meter of this construction, but if preferred the cylinders could be fitted with end covers, and the outer casing dispensed with.

Mr. HARRY FRANCOIS, engineer and manager of the Devonport Water Works, wrote congratulating the author on the Paper, and on the fair manner in which he had stated the case of meters of various makers. He quite agreed with the statements in the Paper, and would lay stress on the author's remarks on page 37 that the mistake most commonly made was that meters were indiscriminately used without due consideration of the duty they had to perform; and he did not hesitate to say that there was not a meter in the market suitable for every supply which a water-works engineer was called upon to give by measurement.

He had had some experience of the author's meter, and had found it to work very satisfactorily. It was the best meter he knew of for measuring the supply to urinals with flushing tanks, which were supplied by what might be termed "dribbles." He had one of the author's first meters, a $\frac{1}{2}$ -inch meter No. 106, supplied to him in June 1888. This meter had been constantly working since that time; it had had no repairs executed to it, having only been removed a few times, cleaned, and again refixed. It had been removed during the past week, cleaned, and tested, the result being that for a measured quantity into a tank of 1,000 gallons the meter registered 1,000 gallons. The "Imperial" meter had but one fault, that was, that the first cost was great compared with other meters.

Mr. FRED HUNTER, engineer and manager of the Sevenoaks Water Works, wrote that, so far as his experience of thirty-five years went, he must pin his faith to the "Kennedy" meter, Fig. 11,

page 46, for all purposes, but, like any other machine, it must be attended to. He regarded the Siemens' meter as next in efficiency.

Mr. THOMAS KENNEDY wrote that he thought the author had evidently given the subject much study, and had dealt with the various types in a very unbiassed manner. When intermittent supply was the rule, the measuring of small flows was unimportant. With constant supply, the author clearly showed its importance. In some cities, such as Paris and Brussels, where domestic supply was metered, no meter of the smaller sizes might be fixed which would not work with a flow of two litres per hour.

On page 48, the author, in describing the "Frost" meter, Fig. 12, said he was "unable to explain why the valve supplying the small cylinder should be so abnormally large, and why that supplying the large cylinder with water should be of such diminutive dimensions." This was a necessity in all meters of this class. The main piston had no work to do until it reached nearly the end of its stroke; then it had merely to move a small pilot valve. This valve directed, alternately, the water into the ends of the small cylinder, the piston of which moved the large cylinder valve. If the main piston was allowed at high velocities to strike the cylinder ends, fatal concussion would ensue. The piston of the small cylinder had work to do in moving the main cylinder valve, and pressure must be induced to enable it to do so. This was obtained by enlarging its passages, and by diminishing those of the large cylinder. The latter was the measuring cylinder, and the contracting of its passage was the cause of the small delivery of meters of this class. The $\frac{1}{2}$ -inch "Frost" meter delivered 43 gallons as against 100 gallons for the "Kennedy" $\frac{1}{2}$ -inch. If, as in a hydraulic pump, the main piston had work to do, there would be ample pressure to move the small cylinder piston, and restriction of the main passages would be unnecessary. As a meter, the principle was limited to small sizes. In fact a maker must decide to what extent he must contract his main cylinder-passage to get the reverse without injury. A few years ago the city of Boston, U.S.A., appointed a Commission to test water meters. All the meters presented were American types, except the "Frost."

(Mr. Thomas Kennedy.)

The first test was a full-bore test for a fortnight. As the supply-pipe was short, and the pressure considerable, the test was a severe one. The "Frost" went through that and the subsequent tests successfully. Nearly all the American meters broke down during the first test. Most of the meters were of the duplex type. The report gave photographs of the wrecks.

The method of reversing the piston in the "Imperial" and in the "Kennedy" meters required no diminution in the size of passages. They could be enlarged to any extent. In the former, the three pistons acted directly and continuously on the valve. In the latter the piston raised the hammer, and the valve was reversed by its fall, quite independently of the water pressure. He noted that, on page 53 the author said of his own meter:—"not a stuffing-box nor a spring among its details, and is self-lubricating." At the end of the excellent description of the "Kennedy" meter (page 47) he stated that the oiling and general seeing-to indicated some of the disadvantages attendant on its general use. This raised the question whether the working parts of a meter should be immersed in the water passing through it; or whether these parts should be protected by stuffing-boxes, and access given for oiling and seeing to these parts. A meter was an enlargement of the pipe, consequently it contained water comparatively still, which allowed it to deposit grit. In fact the water was well represented by the water scoured from a dead end, and was anything but a lubricant. The works (where these were in the water) could not be examined, nor the tightness of pistons, valves, &c., ascertained from time to time; the only indication of error was that the registration differed from the average. Then, as a rule, the meter was removed and sent to the makers, who found an extensive repair usually necessary.

Where a meter could be examined while at work, defects could be seen and rectified without removal, the works could be kept clean and oiled, and wear reduced to a minimum. This required periodic attention, the "disadvantage" could only mean the cost of this. The "Kennedy" meter was, as a rule, "seen to" by the water-works officials, consequently there were few cases where data were

obtainable. To this the water works of Irvine Corporation was an exception. The district was about 10 miles long and 4 miles wide, embracing five local authorities. The meters were owned and repaired by the consumers; and for the last fifteen years Kennedy's Meter Co. had contracted with the consumers for their maintenance. A man was sent there every three months, who examined, oiled, and saw to every meter. Non-registration was unknown. There were ninety-three meters, their capital value being £1,134. The cost of maintenance from year to year was fairly uniform; for last year it was:—

	£	s.	d.	s.	d.
Materials used	7	5	0	or 12	9 per cent.
Man's wages	16	3	0	or 28	6 „
Railway fares, country wages, &c.	7	13	0	or 13	6 „
	<hr/>				
	54 9 per cent.				

that is, rather less than $2\frac{3}{4}$ per cent. of the capital value. The chief drawback to economical attention was the great distance between one meter and another all over the district.

As to durability of piston rollers. At a large factory in Glasgow there was fixed a group of six meters of 6 inches. In January 1896 these were fitted with a vulcanite piston, a roller, and Muirhead gear. The small-flow test has since showed that all the rollers were watertight. The quantity of water measured by each in the interim, in millions of gallons, was, in round numbers 338, 340, 357, 239, 224, 228.

Mr. WALTER G. KENT wrote that he fully endorsed the author's contention that the indiscriminate use of one type of meter for the numerous purposes for which meters were employed could only be fraught with dissatisfaction to the water-works engineer. These many purposes entailed a great variety of conditions of pressure, quality of water, and rate of flow. For all of these there was no one meter yet made which would give equally satisfactory results, but for each combination of the above conditions there was a reliable instrument available. First cost should be the last, and efficiency the first consideration of water engineers who aimed at economy in

(Mr. Walter G. Kent.)

metering. In taking, for example, one class of work out of the many purposes above referred to, there was a curious difference in the practice of different countries, although each of them was broadly working on the lines above advocated. The class of work he referred to was that of constant supplies delivered through small pipes from $\frac{1}{2}$ to 1 inch diameter.

In England a large percentage of such supplies was delivered at a dribble of but two to ten gallons per hour, partly arising from the small number of people per supply—the average was about seven—and partly from the supply being usually delivered into cisterns through ball-cocks. Consequently, in England, a positive reciprocating packed piston meter was more generally employed, this being the only type of instrument that would, in the small sizes, reliably measure small flows.

On the Continent small flows were practically eliminated from consideration, as, in the large cities, which were chiefly metered, there were from seventy to eighty inhabitants per supply pipe. Therefore the minimum draft was never a small one, and it resulted that the inferential meter was adequate for the purpose.

In America also there was a comparative absence of small flows, but from a different cause. The number of people per supply was much the same as in England, but the consumption per head was several times as great. Twenty to forty gallons per head per day was as much as was taken in the large majority of English towns, but in some of the principal cities of America the consumption had touched the extraordinary figure of 200 gallons per head per day. The result of this was that positive rotary piston meters gave satisfactory results.

Turning for a moment to larger supplies, reference was made to the use of the "Uniform" rotary piston meter for the purposes of hydraulic supply. It might be of interest to engineers to know that all supplies—of which there were over 400—of the Manchester hydraulic-power system were metered by this instrument. The registration for the years ending on the 31st March for the past three years gave the following results:—

YEARS.				Percentage of the total quantity of water pumped, which had been registered by the meters, and paid for by the consumers.
1896-97	.	.	97·8	
1897-98	.	.	99·14	
1898-99	.	.	98·89	

Prior to 1896 the meters were largely of another type, and the percentage of registration was very much less. Here again was demonstrated the economy and efficiency of using the right instrument for the work to be done. A saving in first cost was no set-off against large annual loss.

There was a slight error in the first few lines of page 44 of the Paper, an old meter of the "Uniform" type, Fig. 9, having evidently been examined by the author. The lever, or tongue, was not now tipped with glass, but with a material equally hard though not brittle, and the lever was automatically adjusted to compensate for the wear.

Mr. L. S. M. MARSH, engineer to the Sheffield Corporation Water Works, wrote that the subject was one of very great interest to the water-works engineer, as, an absolutely satisfactory high-pressure water meter was in his opinion still to be invented, the necessary conditions being numerous and difficult of attainment. He did not think a metered domestic supply either feasible or desirable in English towns, and the problem of the prevention of waste could be more satisfactorily controlled by means of inspection, as had been proved in Sheffield and other towns where the domestic consumption, although entirely unrestricted, was only a little over 12 gallons per head per day of the population actually supplied.

The writer had not yet been able to discover a positive meter which, taking all considerations into account, could be said to be decidedly more satisfactory than one of the best inferential type. He noticed that the author insisted on a very high standard of efficiency by which the smallest dribble should be measured. He could only hope that such might be maintained by the author's invention.

Professor HENRY J. SPOONER wrote he much regretted that the discussion was not limited to the author's meter, or, failing that, adjourned, to be concluded at the next meeting, for he had noticed that most of the speakers either confined themselves to remarks on meters in general, or referred to a particular one in which they were interested. In the author's meter, the writer considered, they had one of remarkable simplicity, one that was noticeable for the absence of some of those features which had marred the success of many of the most promising ones. Most of the well-known positive meters would work satisfactorily so long as the water was clean and free from lime crystals or other matter in suspension, or was not soft. Mr. Charles Hawksley, in his interesting remarks (page 59), pointed out that some meters, that worked very well with a hard water, were quite unsuited for use with soft water, as the rust which formed in the pipes accumulated in the meters. In this connection the writer would like to call attention to the fact that not only did the oxygen which existed in large quantities in soft water rapidly decompose the iron of the pipes and meters, but it formed carbuncles or nodules,* which retarded the flow, not so much by the reduction of the sectional area of the pipes and passages as by the alteration of the character of the surface. The effect of the presence of solid matter in meters was clearly shown by the "Imperial" meter, Fig. 25, Plate 3, which the author exhibited at the meeting, one that he assured us had been in constant use at the Nunhead meter-testing establishment of the Southwark and Vauxhall Water Works for two years and five months. The relatively small amount of deposit on this meter surprised the writer very much, as in 1890 he had a "Lacoste" meter, Fig. 26,† tested at Nunhead, by kind permission of the engineer, and after running a few days it stopped, due to the space between the diaphragm and covers being rapidly filled with muddy matter. The writer could not believe that the two meters could have been connected to the same supply. He might add that the measurement tests of the "Lacoste" meter were highly satisfactory, and he had no doubt that it could be made

* Proceedings, 1899, page 479.

† Proceedings, 1890, page 433.

to give good results, if used to measure pure water only, and if it was periodically cleaned and oiled. The writer was not aware of this meter being used anywhere in this country. The author had very carefully defined the conditions under which the various types of meters were serviceable, but the writer feared that too often the most potent factor which influenced the selection of a meter was cost; hence it was that on the continent meters of the inferential type were so largely used. These meters, if made with every care and refinement, were capable of giving, within the limits defined by the author, most excellent results, but, when roughly and cheaply made, were exceedingly unsatisfactory, as the following reference to a test will tend to prove. In 1890 the writer was very much interested in water meters, and a friend of his procured for him from abroad an inferential meter of the turbine type, largely used for domestic purposes, and a "Frager" meter, Fig. 27, positive type, much used in France. These two meters were put to rough tests, but Mr. Godfrey Evans, the engineer of the Nottingham Corporation Water Works, having heard about them, and being on the look-out for a good meter, undertook to test them at his new testing station, and the following extract from Mr. Evans's report might be of interest to the members. Mr. Evans said:—"The turbine meter is not capable of registering small flows with accuracy. The turbine is of inferior design and finish, and is liable to a large amount of slip; the construction is such as to be quickly put out of order by corrosion or the adhesion of lime crystals. Generally speaking, the meter is rather roughly made up and finished, and already shows signs of wear, the oil being exhausted or escaped from the oil chamber, and the spindle having started to grind. . . . The 'Frager' double-cylinder meter appears to be capable of registering accurately any flow up to its full capacity, and there is little or no slip of water. The whole of the working parts are well made of gun-metal and are not liable to get out of order. Generally speaking, the meter is of good construction and finish, and appears to be capable of sustaining a large amount of use before showing signs of wear." In this class of meter it was of the greatest importance that the stroke should be absolute. As accurate

(Professor Henry J. Spooner.)

measurements could only be made by positive meters whose strokes were unvarying, the slightest variation, particularly in those with large pistons and short strokes, makes an appreciable difference in their efficiency. The writer noticed that the author claimed that the stroke of his meter was definite, but he would like to ask him whether he had determined the limit of speed at which it could be run, and beyond which the stroke would be affected by the momentum of the piston and its attachments. For obvious reasons the presence of any lubricant in a meter was objectionable where pure or drinking water was being passed; so, bearing in mind the splendid wearing qualities of lignum vitæ when lubricated with water, to which Professor Unwin had called attention (page 60), it seemed to the writer that it would be possible, by some slight alteration in the details, for the author to make his meter almost independent of a lubricant. Bearing in mind the trouble of periodically cleaning out the ports and passages, it might be worth while considering whether the body A, Plate 1, could not be advantageously fitted with a removable cover at the bottom. This of course would add slightly to the cost, which would be against it for most purposes, but it would, on the other hand, somewhat simplify the casting. In conclusion, he very heartily congratulated the author on his production of a meter which had evidently been thought out with great care, and one that, so far, had given such eminently satisfactory results. The fewness of its working parts, its simplicity, the working parts being easily get-at-able, and the fact that it could be worked by such a small head of water, were factors, the value of which could not be overrated, and he trusted that he would be able to emulate the public spirit of other inventors, and either lend or present a working model of it to the South Kensington Museum, where the nucleus of a very fine collection of working water-meters is on view.

Mr. SCHÖNHEYDER wrote that, referring to the cogent observations of Mr. Charles Hawksley (page 59), he recognised at the outset of his investigations and experiments that rust deposit, lime crystals in suspension, and similar evils were inevitable (in a greater or less

degree) in all water services, and that in course of time these impurities must unfavourably affect the working of a meter. He concluded therefore that any appliance capable of withstanding these onerous conditions must be so constructed that it could be taken apart, cleansed, and re-instated on the spot by unskilled labour, and it was to the production of a meter capable of being so dealt with that in a great measure his attention was directed. By having the dirt box inside the casing the operation of cleansing was facilitated, as both could be dealt with simultaneously, and the meter kept practically up to the standard of a new one. Owing to the overlapping motion of the valve and the speed with which the water passed through the ports, the valve and seating were not appreciably affected by the presence of sand, grit, or lime; and even in cases where meters had been found full of deposit the faces had been bright as mirrors and perfectly tight. When the difficulties mentioned above were unusually pronounced, the author recommended vulcanite cylinders in lieu of gun-metal ones.

Mr. Philip Bright observed (page 62) that if inferential meters were used "small enough" they could be made to register "very small flows indeed"—a statement carrying its own limitation; and while he added that their capacity at full flow was only about 120 or 140 gallons an hour he did not mention the pressure which would be necessary to force this quantity of water through them,—a vital consideration, which would have shown that it was impracticable to reduce the capacity of a meter to its smallest limits to secure accuracy. The impossibility of using small inferential meters in Berlin for domestic supplies was alluded to by Mr. Morris (page 73). Referring to inferential meters Mr. Bright added that "meters were made and were at work which would register 2 or $2\frac{1}{2}$ gallons an hour perfectly accurately." The author quite accepted this statement, but could only assume it had reference to tests made with a new meter, which should be easily attainable, and not to results taken in actual and prolonged work.

Inferential meters of the "best class obtainable" after a number of years' trial in a town, where all house supplies were measured,

(Mr. Schönheyder.)

proved so unsatisfactory that not only had they been superseded by "Imperial" meters, but it had been found an economy to discard those in actual use and to replace them by the positive type.

In further reply to Mr. W. B. Bryan (page 64), the author was glad to note his opinion that the metering of house supplies "would save capital by obviating the necessity for going further afield for water as early as would otherwise be the case"; but he regretted to learn that in the opinion of so competent an authority "the cost of meters and meter-rent in some districts would be very prohibitive." This was not the conclusion to which the author's figures had led him, whether the question was considered from the position of a waterworks shareholder, consumer, or ratepayer.

The meter mentioned by Mr. Isaac Smith (page 65) was apparently a new edition of the Siemens inferential meter; in the absence of actual working results it was impossible to say whether it would prove better or worse than those now in use.

Mr. Edward B. Ellington had compared the size and delivery of the "Imperial" meter with that of a "Kent" (page 69), to the disadvantage of the former. There was evidently some confusion on this point as the two were not capable of comparison; Messrs. Kent's "Absolute" meter, and not their "Uniform" meter, should have been selected for this purpose.

The information supplied to Mr. George Cochrane (page 69) of a registration of 98 per cent. of pumped water on the Manchester hydraulic system did not apparently coincide with his own experience, as he said, "such a percentage could not be claimed in London," and it was not in accordance with the statement of Mr. Ellington who, speaking of the same meter (page 68), said, "it would not register very small flows except for a very short time after being put to work."

The author thought that the meter described by Mr. Joseph Bernays (page 77) was most ingenious in construction, but he regretted to say he had not had an opportunity of investigating the results obtained in actual work, and therefore was unable to form an opinion as to its merits.

Mr. Harry Francis in his communication (page 78) pointed out a fault in the "Imperial" meter "that the first cost was great compared with other meters." If a comparison were made between the cost price of positive meters, these would be found to be practically the same, but they were of course more costly than those of the volume or inferential types. The author was not aware until he saw Mr. Francis's communication that he had been using his meter so long or with what results, and learnt with satisfaction that he had found it efficient for measuring dribbling supplies.

Mr. Fred Hunter's loyalty to his old friends the "Kennedy" and "Siemens" meters was much to be admired (page 78). As, however, they were not in the same category, the author did not understand how one of them could be classed as above or below the other in efficiency.

The remarks of Mr. Thomas Kennedy (page 79) on the "Frost" meter and the reasons for the great difference in the size of its two cylinders, the author regretted he was unable to follow. He had seen many of these meters at work, and had listened to the "thumping" at each reversal of the main piston; he had also been witness to several breakdowns due to this cause. It would therefore appear that if the theory of construction were correct, it was not supported in practice. Experience with the "Imperial" meter did not bear out Mr. Kennedy's contention that the water in a meter was not a good lubricant, or that the working parts being immersed in water could not be periodically examined, and consequently were allowed to run until expensive repairs were necessary. On the contrary, the greatest advantages accrued from all the parts of the meter being easily exposed as well as from the absence of stuffing-boxes and the like. The small cost of upkeep of the "Kennedy" meters of the Irvine Corporation was certainly very satisfactory (page 81).

The author was pleased to find himself in accord with the main contentions of Mr. Walter G. Kent (page 81), but he differed from him as to inferential meters on the Continent and volume meters in America proving adequate for the duty assigned to them. Positive meters were demanded in some of the most important continental

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cities, and the American technical journals bore witness to the fact that engineers were increasingly dissatisfied with volume meters, because they failed to register small flows.

The "Uniform" meters in use on the Manchester hydraulic system, quoted as giving an efficiency of 98 per cent. (page 83), though now packed at the edge of the piston-blocks with a self-adjusting lever made from durable material, were certainly not packed on the flat sides of the piston-blocks; how therefore they could register so large a percentage of the flow through them was incomprehensible.

The author thought that Mr. Marsh was probably right in his opinion (page 83) that an "absolutely satisfactory" meter had still to be invented; perfection was by no means easily obtained, but the author suggested that if Mr. Marsh would place one of the positive meters described in the Paper tandem with one of the "best type" inferential on a dribbling supply, he would probably make the discovery which up to the present time had eluded him. It was a matter of common knowledge that not one dribbling supply in ten, charged on the reading of an inferential meter, was paid for to the extent of two-thirds the value of the water consumed.

Professor Spooner having investigated the subject of water meters on somewhat different lines to the author, his comments (page 84) on the Paper were of exceptional value. The main point raised in his communication (page 86) was whether the inventor "had determined the limit of speed at which it could be run and beyond which the stroke would be affected by the momentum of the piston and its attachments." The author had made frequent and exhaustive trials to discover if such a limit as that could be found, and the appended tests from an independent source would probably be conclusive evidence that the danger indicated did not exist.

The $\frac{3}{4}$ -inch meter has $3\frac{3}{4}$ -inch cylinders, the pistons have a stroke of $1\frac{1}{8}$ inches and are very light, and at 100 revolutions per minute the meter delivers about 1,350 gallons per hour, but in practice it is very seldom run at this speed.

In regard to the meter lent by the Southwark and Vauxhall Co. (page 84), and attested by them as to length of service, registration, and high and medium tests, the author did not know on what

particular service it had been placed; and of course there was a great difference in the purity of water in different districts, according to the greater or less demand on the mains. It was however by no means an unfair specimen of the general condition of meters after two or three years' use. An examination of the "Imperial" meter will show that all the ports and passages are accessible by removing the valve-seating; no further provision therefore is necessary for cleaning purposes.

TABLE 3.—*Tests of $\frac{3}{4}$ -inch, "Imperial" Meter No. 3683, after having been seven months in use, when it worked slowly with 5 ft. 7 ins. head, and was found correct.*

Outlet.	Litres per hour.	Gallons per hour.	Per cent. error.	
			Slow.	Fast.
$\frac{3}{4}$ inch	6,666	1,468	—	—
$\frac{3}{4}$ inch cock	5,000	1,100	—	0·5
$\frac{1}{2}$ inch	3,428	754	—	0·2
10 m/m	2,927	644	—	0·2
8 m/m	2,308	508	—	0·5
7 m/m	2,069	455	—	0·3
6 m/m	1,666	367	—	0·5
5 m/m	1,200	264	—	0·7.
4 m/m	857	189	—	1·3
3 m/m	400	88	—	—
2 m/m	200	44	—	—
1 m/m	80	18	—	—
0·7 m/m	54	12	—	2·0
0·5 m/m	30	6·6	—	—

Having been asked to state what determined the direction of movement of the meter, the author wished to say that this was governed by the position of the ports in the valve and seating in relation to that of the cylinders. Thus, looking at Fig. 22, Plate 2, the port D_1 on the right-hand side of the seating communicates with

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the cylinder B_1 in the front; therefore when the valve is leaning over, say to the right as in Fig. 19, Plate 1, the bottom of the said cylinder B_1 will communicate with the discharge, and its piston must therefore descend, while one or both of the two other pistons will rise, and as this action is repeated in succession for each cylinder, the direction of movement is determined. It must be understood that Fig. 19 is not a correct section on a straight line, looking in plan, as each cylinder is at a right angle with its port. The form of the passages necessitated by this relative position is shown by the right-hand section, Fig. 20.

An excellent Paper, dealing fully with the subject of American water meters was read and discussed before the American Society of Civil Engineers by Mr. John W. Hill, of Wyoming, on 1st February 1899, when the assertion as to the inability of the volume meter to register small flows and the widespread desire for a better meter in the United States were fully borne out by the speakers.

WATER METERS. *Plate 1.*

"Imperial"
 $\frac{1}{2}$ -inch Positive Meter. (Schönheyder.)

Fig. 19.
 Section.

Cast-iron
 Gunmetal

Fig. 20.

Plan.
 Valve
 and
 Seating
 removed

Section
 through
 Cylinders.

WATER METERS.

Plate 2.

"Imperial"

$\frac{1}{2}$ -inch Positive Meter. (Schönheyder.)

Fig. 21.
Valve.

Cast-iron
Gunmetal

Fig. 22.
Vulcanite
Seating.

Fig. 23.
Case.

"Imperial" $\frac{1}{2}$ -inch Positive Meter. (Schönheyder).

Fig. 24. Unused.

Fig. 25.

After 2 years 5 months use.

Fig. 26. "Lacoste Domestic."

Fig. 27. "Frager."