# METER RATES

FOR

# WATER WORKS

BY

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# PREFACE

This book deals with the problem of distributing the burden of supporting a water-works system among those who use the water, in a just and equitable manner. It also deals with the technic of handling the statistics that must be used, of making the required computations and of estimating the revenue that will be produced by a given set of rates.

The preparation of this material for publication was the direct outgrowth of service by the author as Chairman of the Committee on Meter Rates of the New England Water Works Association. In that capacity he found that the members of his Committee were very capable water works men, representing, by their business connections, both public ownership and private ownership. One was connected with a public rate fixing body, and two were in practice having to do with the rate problem from various aspects.

The first work of the Committee was to find the views of its own members, and without attempting to formulate any principles as to the amount of rates, to get an agreement as to the form of rates that would best distribute the burden upon all takers with a minimum of injustice. After the Committee had decided upon such a form of rate, it was presented to the membership of the Association for general discussion. The Committee then had to defend its proposals and in some cases to modify them, until finally a form of rate was reached which was adopted by the Association.

Since that time the author and his partners in professional work have had to do with establishing water rates in a number of water-works systems.

The need of standardizing methods of handling statistics and of making calculations being great, a number of methods have been devised and used in these cases. Those that have been found most certain in application and useful in results are shown in these chapters.

In the development of the subject, the various reports of the Committee of the New England Water Works Association on Meter Rates, which were drawn by the author as Chairman of the Committee, are taken as a starting point. Additional explanatory and statistical matter is added, many kindred subjects are investigated and practical methods of application that have been tested by experience are added.

Diagrams are used to show the meter rates now in force in many American cities. These are drawn to permit ready comparison. Free use has been made of the Committee's reports and data and also of the writings of others, especially of those who were and are personal friends of the author, and who are also solid, substantial water works men who have contributed to the development of the meter business, and who have helped to establish the principles of fair rates.

If some of these quotations are old, it does not follow that the business is not developing. It rather indicates that some of the underlying principles do not change and that they were recognized by practical water works men long ago.

New York City,
September 14, 1917.

# TABLE OF CONTENTS

# METER RATES FOR WATER WORKS

## CHAPTER I

### REASONS FOR METERS

The one efficient, economical and practical method for lessening the waste of water in New York begins with a water meter on every service pipe.—John R. Freeman; Report on New York's Water Supply, 1900, p. 71.

There are two reasons for the use of water meters. The first is that selling water by measurement is the only logical and fair way of conducting the business. It is the only way that does not result in gross inequalities and discriminations against some of the takers, and in favor of others. The second reason is that metering water is the only practical method yet found for restricting excessive waste.

The first reason is the one that in the long run is controlling. It is unanswerable. In itself it is a sufficient reason for the adoption of the meter system.

As a practical matter under the conditions of the water works business as they have developed in the United States in the last thirty years, the need of stopping waste has been more important and has more often led to the installation of meters.

When a water-works system is first installed, all the plumbing fixtures in houses are new and they are in general reasonably tight; people will ordinarily draw only the amounts of water that they need, and waste is comparatively small in amount. As time goes on, rust, corrosion, the hardening of rubber valves, and other changes result in leakage from plumbing fixtures. Small leaks running constantly make little impression on people who do not realize their significance. Yet a leaky water closet may waste without attracting attention as much water as would supply twenty families.

As time goes on people become accustomed to the waste of water in their houses and indifferent to it; and it is the experience of American cities where the meter system has not been used that the consumption always increases more rapidly than the population. It may be a long time before the output becomes double the legitimate use; but after that point is reached the rate goes on with greater acceleration until three-quarters of all the water that is furnished is wasted.

The only limit to the increase is that a time comes when the new works required to supply the ever-increasing waste become so large and cost so much to build, that the burden cannot be further borne, and a better method is adopted.

The problem is a very old one. Frontinus, Water Commissioner of Rome, under the Emperors Nerva and Trajan, A.D. 97–100, wrote an account of the water works of Rome, which has been made available to American readers.

Frontinus found that each taker of water in Rome was supplied through a little instrument which served the purpose of a water meter. In the years that preceded his administration abuses had grown up; the sizes of some of the orifices in the meters had been increased; taps had been made for new takers and old taps had been surreptitiously kept in service by the water men or inspectors after the right to their use had terminated. Frontinus took up the matter of correcting these abuses, and he states: *

> Whatever had been unlawfully drawn by the water men, or had been wasted as the result of official negligence, has been recovered; this is practically equivalent to the finding of new sources of supply. And in fact the supply was almost doubled.

The experience of Rome, so concisely stated by her Water Commissioner, has been repeated over and over in American cities in the last decades.

* Translation by Clemens Herschel; "The Water Supply of Rome." Dana Estes & Company, Boston, 1899, p. 61.

The experience of Pittsburgh is not different from that of other American cities which have supplied water at fixed rates and without limiting in any way the amount of water used and wasted by consumers. Under these conditions the volume of water pumped always increases faster than the population, and is only limited by the fact that after a time the cost of securing and distributing the water becomes so great as to make rational measures imperative.

Natural gas was formerly sold in Pittsburgh at a fixture rate, the amount charged for heating a house depending upon its size. The practice has, however, been given up, and all gas is now sold by meter. The temptations to abuse the privilege of using water supplied at a fixture rate are quite as great as they are in the case of gas. In fact the opportunities are better, because gas cannot be discharged unburned into a house without making it uninhabitable, and if an excessive quantity of gas is burned, the house becomes too warm for comfort. There is thus a certain physical limit upon the amount of gas which can be used in a house. With water, however, this is not so. Faucets can be left open and leaks allowed to remain unrepaired, and the water allowed to flow to the sewers in absolutely unlimited quantities without benefiting anyone.

* * * * * * * * *

There is often a prejudice against the use of meters, which arises from the thought that people will be limited in the use of water, and cannot use as much as they desire without making excessive payments for it. There is also the feeling that if the consumption of water in the city should be reduced to one-half or one-fourth of the present consumption, each person would have to get along with one-half or one-fourth as much water as is now used. As a matter of fact, this idea does not present even remotely the truth. A majority of people are reasonably careful in the use of water and do not waste excessive amounts. * * * * It is the minority of people who, by carelessness or wilful waste, discharge water into the sewers in large quantities, and increase enormously the amount of water which must be provided, and consequently the cost of water to all the people.

At the present time the loss inflicted by the careless or wasteful people is borne by the whole city. If a meter is put on every service, the people who waste water will have to pay for it, and others will be relieved from the burden and the cost of water to them will be materially reduced. The cost to the people who are now wasting water will also be reduced, if they are willing to learn by experience, as nearly all of them will, that they cannot waste water without paying for it.—Report of Filtration Commission, Pittsburgh, 1899, pp. 74–75.

The introduction of meters has been an unqualified success in checking waste. When water is measured, and all the water that is used or wasted is paid for, the quarterly bills are effective reminders of the need of tight plumbing. People cease to be indifferent to continual flows of small quantities. Even the plumbers learn in time; and the standards of plumbing in cities where the meter system has been some time in use are higher than elsewhere.

The experience in checking waste by the general use of meters has been universally satisfactory and has fully justified all the expense and trouble of the introduction.

It is no longer necessary to argue with engineers in favor of water-waste restriction, and there is practical unanimity as to the means by which such restriction may and should be accomplished; but, unfortunately, the water works of too many American cities are managed, not by engineers, but by bodies of laymen, destitute of technical knowledge, and apt to follow the uneducated judgment of the people at large, when they are not following something less commendable. It is, therefore, in most cases, necessary for the engineer to obtain the consent of the people to be benefited in the manner he proposes, and it would seem that the only question left to discuss is how best to obtain that consent.—John C. Trautwine, Jr., Trans. Am. Soc. C.E., Vol. XLVI, 1901, p. 420.

There is no doubt that the most efficient means of preventing waste of water on the premises of the water takers is the universal use of water meters, for if every water taker is obliged to pay for all the water entering his premises, whether used or wasted, the quantity wasted is very sure to be reduced to a minimum.

The argument has been advanced that the use of meters tends to reduce the consumption of water for sanitary purposes below a point conducive to public health, but this argument has little foundation in fact. The great cause of waste of water is the continual small trickling streams which are of no practical benefit in cleansing drains.

By the adoption of a minimum rate which provides an ample allowance for all domestic purposes, the objection to the use of meters on sanitary grounds is obviated.—Dexter Brackett, Trans. Am. Soc. C.E., Vol. XXXIV, 1895, p. 197.

The relation between landlord and tenant in flat and apartment houses is one of the most bothersome to water takers when meters are installed. It does not directly concern the water department. The landlord is responsible for all water drawn and if tenants waste water unreasonably he suffers. Considerable friction is caused at times, and this friction makes the installation of meters more difficult. But after a while the landlords learn to keep the plumbing fixtures in order and free from the leakage which is the chief source of waste; and when this is done the tenants will seldom run up excessive bills. The inducement to economy is not as strong as it is in small houses each having its own meter, and the consumption may not be quite as low. Whatever it is, an average will be reached after a time, and the rents will be gradually readjusted as necessary to cover it. In the end the tenant will pay for the average amount of water drawn.

Metering each apartment separately (as is done with gas and electricity) is difficult, becuase of the plumbing arrangements, and because one hot water system commonly serves the whole establishment. It might possibly be done, but is not considered advantageous.

In the long run the strongest reason for using meters is that it furnishes a means of distributing more equitably the burden of supporting the service. G. Bechmann, for many years Chief of the Water Works of Paris, France, writes: *

> The meter permits combining absolute liberty of the taker to draw required water with a control on the part of the works that is constant and sure. The taker pays for nothing that he does not get and the works furnish nothing for which they are not paid. It is almost the realization of the ideal.

But the ideal is only reached slowly. The use of water meters has served to make water works conditions somewhat better than they were before, but a great deal remains to be done. This is because the meter rates that are in common use are not always or usually equitable. On the contrary, they have been frequently only a little less discriminatory than the fixture rates which preceded them. This has been due to a variety of causes. Sometimes it has been due to a lack of information as to what really are fair rates. In other cases, perhaps, the influence of certain classes of water takers has stood in the way of the adoption of rates that were fair to all.

* Distributions D'Eau, p. 439; Paris, 1888.

It is not our purpose to inquire into the reasons for these inequalities in present rates. What it is proposed to do is first to give a very brief statement of the widely varying kinds of meter rates in common use in the United States at the present time, and to do this in such a way as to suggest means by which the technique of making meter rates may be improved. Afterward it is proposed to consider the general conditions of the water-supply business in its bearings upon meter rates.

## CHAPTER II

## BEGINNINGS OF THE METER BUSINESS

Keeping accounts is at the foundation of an economical conduct of any business, and to keep accounts in the water-supply business, the water must be measured, that is, metered.—Clemens Herschel, Trans. Am. Soc. C.E., Vol. XXXIV, 1895, p. 212.

No attempt will be made to develop a full history of the introduction of meters in American water-works systems. The pages of technical journals and municipal reports have been filled with it for thirty years. But a brief glance at some of the early conditions is necessary to an understanding of present conditions.

If a cheap and reliable water meter had been available in the early days of American water works, it would, no doubt, have been generally used and the discussion of equitable meter rates would have come much earlier.

Probably a great degree of the irregularity in the manner of assessing water rates is due to the fact that in the infancy of the business there was no simple, cheap, and efficient way of measuring with approximate accuracy the quantity of water used by the individual consumer. At the outset we are confronted with a condition appertaining, perhaps, to no other line of business.—John C. Chase, Journal N.E.W.W. Assn., Vol. XVII, 1903, p. 174.

Without going too minutely into history, it appears that the water meter in a comparatively attractive form first made its appearance in the United States between 1870 and 1880. The advantages of the meter system were recognized at an early date, and in the decade beginning with 1880, rapid advance was made.

The commonest use of meters was to apply them to a selected number of services in each system. The services selected to be metered were usually the ones taking the most water in that system, or the ones where there was greatest uncertainty as to the amount of water drawn.

Many water works superintendents desired to use more meters, but were reluctant to do so because of their high first cost and the trouble and expense of taking care of them, and because they were not satisfied as to the accuracy of the measurement.

The art of meter construction was not so far advanced, and the art of testing, and keeping meters in repair in water works shops had not reached its present state of development.

It must also be taken into account that at that time the waters commonly supplied in American cities were not of nearly as good quality as those supplied at the present time. Many of them carried turbidity and sediment and floating matters in quantities which either wore out the moving parts of the meters or tended to cover them with slime and to choke them and in all cases reduced the accuracy of measurement.

An able manufacturer of meters, John Thomson, presented an admirable paper to the American Society of Civil Engineers, describing the types of meters in use at that time and the difficulties of making a meter of a satisfactory degree of accuracy and, at the same time, at a price low enough to make it attractive to American water works men. He urged a lowering of the standards of test.

For all practical purposes, in ordinary public service, a meter which would register to within 5 to 7 per cent of accuracy, between fair minimum and maximum rates of discharge, is, in the writer's judgment, as in that of many others, amply accurate to effect the desired purpose. And when our water works officials will have arrived at the same conclusion, meters may then be purchased at a discount from present net prices of from 20 to 25 per cent. Furthermore such a standard of accuracy would, in ordinary practice, result in decreased cost of maintenance and increased life of the meter, because of the practical conditions of service under which meters are frequently set.—Trans. Am. Soc. C.E., Vol. XXV, 1891, p. 58.

This suggestion was forcibly met at the time by Mr. Emil Kuichling of the Rochester water works, who stated:

While it may be conceded that the only rational way of charging and paying for water consumed by individuals or corporations is by meter measurement, yet the present cost of these measuring devices and their maintenance is generally regarded as being altogether too large to render their extensive introduction expedient in our large cities. Many water works officials would doubtless cheerfully recommend, and perhaps strongly urge the adoption of meters for all classes of consumers, if they could obtain reasonably accurate, sensitive and durable machines at somewhat lower prices than appear to prevail at the present time; and it is mainly in consequence of existing prices, which the public regards as too high, that all efforts to introduce a general meter system have, in the majority of cities, met with determined opposition. . . .

In lowering the limit of accuracy, however, the standard of sensitiveness must not be affected, but, on the contrary, should rather be increased than diminished. Leakage of fittings and waste by small streams or dribblings flowing constantly, usually give rise to greater consumption than the legitimate use. The writer has often measured the leakage from a defective faucet, ball-cock, and closet-valve, in households and places of business, and found that a discharge of from 150 to 400 gallons per day from a single fixture rarely excites notice on the part of the inmates, and that a request to repair such fixture is regarded as grievous oppression. A loss of several hundred gallons per day by continuous leakage, in a household where the legitimate use is actually much smaller than this amount, is a circumstance of frequent occurrence where an efficient system of house to house inspection is not enforced. . . .

The remedy usually prescribed in such a community is general metering; but here we are at once confronted with the fact that many of the meters in the market either fail to register such small streams, or else that the power required to overcome the friction of closely fitted parts is greater than is tolerable. . . . If it be assumed that a daily per capita consumption of 40 gallons is a reasonable quantity, then an average family of five persons should use 200 gallons per day, all of which would ordinarily be drawn at a rapid rate from the fixtures, and would therefore probably be recorded by almost any meter; but if only a single fixture in the dwelling were leaking at the rate of 200 gallons per day, how many meters would reveal the fact on their dials, especially after having been in service for a few years? . . .

In conclusion, therefore, it may be stated that a thoroughly serviceable meter should have great sensitiveness, but need not have a very high degree of accuracy. How these qualities can be combined with durability and economy is a question whose solution is left to the skill of inventors.—Emil Kuichling, Trans. Am. Soc. C.E., Vol. XXV, 1891, p. 66.

Under these conditions the use of meters was, for the most part, limited to the larger services, such as those supplying factories and railroads, and meter rates were established with particular reference to such large consumers. Meter rates established to cover the business of supplying a few large consumers do not necessarily give much aid in arriving at a fair schedule of rates to be applied to single houses.

In other respects, these early rates reflected different ideas from those that are now held in regard to many matters. Early rate schedules, partial and one-sided as they were, based on the experiences of the time and not upon any study of the whole situation, have persisted in American water works practice to an extraordinary extent. Sometimes these early rates were written into long term contracts that tended to preserve them. Sometimes only inertia and perhaps, still more often, perplexity as to what would be a fair schedule of rates to adopt in place of the old one may be the final determining influences that prevent breaking away from the old and unjust schedules.

Fig. 1 shows the percentage of services that were metered in each of a number of American water-works systems prior to 1900. It is compiled from information in the three editions of the American Water Works Manual, 1888, 1890 and 1897, by M. N. Baker, of the "Engineering News," and from a paper by George I. Bailey, in the "Engineering News,"* giving the statistics of metering in 1900, with admirable comments. The plotting may not be complete, in that there may have been other systems, especially small ones, that had meters to as great a relative extent as some of the systems that are shown.

Worcester, Atlanta, and Yonkers were the pioneer systems in using meters, but Fall River, Utica, Providence, Pawtucket, and Newton were not far behind.

In the last sixteen years the increase in the use of meters has been rapid and the number of completely metered systems at the present time is very much greater. At the present rate of increase the time is not far distant when water meters will be practically universal in the United States.

* Vol. 45, p. 279.

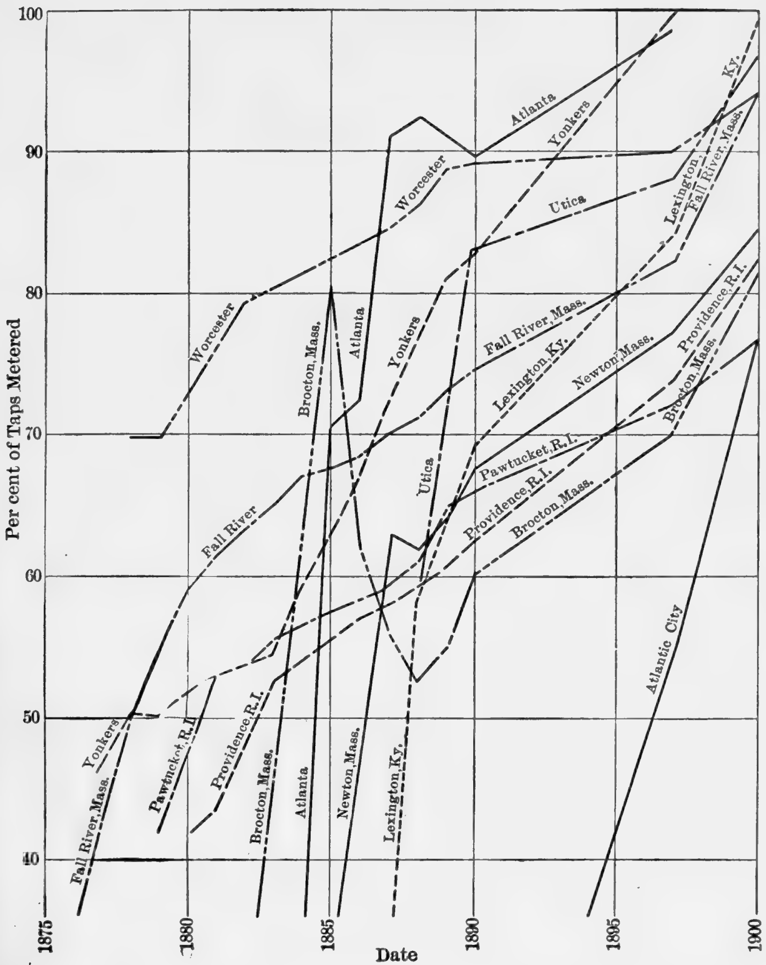


FIG. 1.—Showing the Per Cent of Services Metered at Various Dates in a Number of American Water-works Systems where Meters were First Generally Used.

## CHAPTER III

## FORMS OF METER RATES NOW IN USE

I do not believe that there is any other line of business that has such great and unreasonable variety in its schedules of charges as will be found in water works.—Allen Hazen, Jour. N.E.W.W. Assn., Vol. XXVI, 1912, p. 102.

**Units of Volume.** Water is sold at meter rates either by the 100 (or 1000) cubic feet or by the 1000 U. S. gallons. Both units are in common use. In the early days of metering, the use of cubic feet predominated, and it seemed at one time as if this unit might be universally adopted Recently, however, there has been a tendency to go back to the gallon. The gallon is more easily understood by the public than the cubic foot. It is also the ordinary basis of most water works statistics.

It would be advantageous if one or the other unit could be universally adopted. Either is suitable. At the present time use and preference for the two units is so evenly divided that the universal adoption of either does not seem to be possible at an early date.

In this discussion gallons will be uniformly used, and where rates are referred to which are expressed in cubic feet they will be converted into gallons for uniformity.

One cubic foot equals 7.48052 gallons. For most rate calculations the round figure 7.5 may be used for converting one to the other.

In Canada, the Imperial gallon, equal to 1.20 U. S. gallons, is used.

Where the metric system is employed, the cubic meter, equal to 264 U. S. gallons, is the basis of measurement.

**Time Interval.** With some kinds of meter rates the time interval is not stated, but many of them are expressed in amounts of water drawn within a certain time interval. The periods used are the day, the month, the quarter, the half year, and the year.

It is convenient to have the periods for which meter rates are given correspond to the periods for which collections are made, but this is not necessary and is by no means always the case in existing schedules.

In a great majority of water-works systems domestic water rates are collected quarterly. The amounts are not large enough to make the trouble of monthly collections necessary or desirable.

The work of meter reading, bookkeeping and collecting may be distributed uniformly throughout the year, with quarterly collections, by dividing the area that is supplied into districts, for each of which the quarter terminates on a different day, and by making these districts sufficiently numerous the work will be well distributed.

The meters of those takers who use large quantities of water are always read monthly and monthly collections are customary. Some water-works systems on the Pacific coast and elsewhere collect from all customers monthly.

In that which follows, the year and the day will be used. The year is more convenient as a basis where the figures relate to rates and annual payments and are used in making up an annual budget. The day has the advantage of giving a clearer conception of the amount of water that is drawn by a service. Where rates are defined in terms of other lengths of time, they will always be converted into one of these units in that which follows.

Meter rates in use at the present time are extremely varied in their methods of expression, as will be shown by a number of typical examples reproduced in Chapter IV. These examples, however, by no means exhaust the possibilities of variation, and the list could be indefinitely extended.

An adequate classification of all these various meter rates would be difficult. At the present time only a rough general classification will be attempted.

**Minimum Rate.** A minimum rate is an amount that is collected in any event even though the price of the quantity of water registered by the meter does not amount to it. Minimum rates are used by a great majority of water-works systems.

**Service Charge.** A service charge is a charge for the service, which is an addition to the amount that is charged for water. Service charges bear some relation to minimum rates and the two are never used at the same time; either one or the other is used. The service charge is being adopted in many rate schedules at the present time, but has not yet come into general use. (Example: Madison, p. 50.)

**Modified Service Charge.** Under this form there is a minimum charge for a certain quantity of water and the amount of the minimum is made up of what would otherwise be the service charge and the meter rate for that quantity of water that is furnished for the minimum charge. Except for very small water quantities, this form of rate produces a result more easily reached by a simple service charge. Two subdivisions of this form may be noted: one described on page 70 and called the Committee's Alternate Procedure; and another form, which is perhaps simpler, which has been recently adopted at Philadelphia, and is found on page 52. The Weston, Mass., rate (p. 54) is also to be classed under this head.

By the **uniform rate** is meant a rate that is charged for all quantities of water sold. The smallest consumer gets the same rate per 1000 gallons as the largest one, with the exception that there may be a minimum rate or a service charge. The meter rate schedule of Chelsea may be given as an example of uniform rate (p. 42).

The **sliding scale** is used to include all those schedules of rates under which varying rates are charged according to the quantities of water drawn. A great majority of all meter rate schedules now in use have a sliding scale. Sliding scale rates must be further classified, because there are various ways of producing the slide.

The **jump scale** was an early form of sliding scale and is still in use, although it has been largely replaced by one of the better forms. The quantities of water up to a certain limit are charged at a certain price; beyond that limit and inside another limit another and lower price is made, and beyond that there is another limit and another price, and so on. In some cases two prices only are used; in others three, four or more, up to a dozen or twenty, and in fact divisions may be so numerous that the scale practically becomes a table which gives the water rate for every quantity of water that a meter records.

The jump scale as ordinarily used with a limited number of divisions is open to the defect that anyone can get a lower bill at certain points by drawing an additional quantity of water, that quantity being sufficient to take him into the next lower classification. In other words, by drawing more water, the price per unit is reduced to a greater extent than the increase in the volume. (Example: Harrisburg, p. 46.)

**Modified Jump Scale.** Under this arrangement each step in the jump scale is subdivided into two parts, the second of which comprises all those quantities for which it would be possible to get a lower rate by drawing more water. For these quantities a lump sum collection is made, which sum is the minimum that could be obtained under the next step. For the first part of each step the rate remains as with the jump schedule.

This type of schedule has been officially used in only a small number of systems. (Examples: Syracuse, Winnipeg, pp. 54 and 56.) Practically it has found much wider application, because in works where the jump scale is used the practice has grown up of giving customers the advantage of any theoretical saving that might be made, on the supposition that they had actually increased their drafts to the point of bringing them into the next lower division.

**Common Sliding Scale.** Under this arrangement the water first drawn up to a certain limit is charged at a certain rate. Additional quantities are charged at a lower rate, but the higher charge on the first quantity remains as part of the bill in all cases. This is the best type of sliding scale in common uses. (Example: Atlanta, p. 36.)

Schedules under this form may be further subdivided as to the number of classes or rates that are provided. Schedules with only two rates have been used by the Wisconsin Railroad Commission and occasionally elsewhere. (Example: Madison, p. 50.)

Schedules with three rates give more flexibility, especially where the amount of slide is considerable. The three-rate schedule was adopted by a Committee on Water Rates of the New England Water Works Association and the points of slide were defined. The form of schedule recommended by this Committee will be found in Chapter V.

Scales with four or more points of slide have been commonly used and in some cases the number of rates has been very great. If the changes in the sliding scale are made very numerous, the irregularities can be practically smoothed out and the scale of rates become almost a table showing the amount to be collected for each quantity of water that is drawn.

It may be pointed out that with a schedule of this kind, the number of divisions can be made so great that it is immaterial whether the jump scale or the common sliding scale is used. Either scale can be arranged to produce substantially the same results, or, in other words, to produce the same charges for the same quantities of water. It is only necessary that the changes should be sufficiently great to make this possible.

**Logarithmic Rate Scale.** Mr. J. H. Harlow states (in conversation with the author) that he used a logarithmic scale of water rates in some small companies with which he was connected some twenty years ago.

The amount to be paid for water can be described by a logarithmic equation. If $Q$ is the number of thousands of gallons drawn per annum, $C$ is a constant and $x$ is an exponent. The amount of the bill ($B$) may be found as follows:

$$B = C(Q^x).$$

The amount of slide that it is desired to produce depends upon the value of the exponent. For the uniform water rate $x = 1$. For a sliding scale, giving manufacturers a lower rate than the smaller consumers, $x$ would be less than 1.

Mr. Harlow states that he practically used $x = 0.9$ to give an amount of slide that corresponded approximately on an average with the slide that was used in the systems with which he compared rates before adopting it. Studies based on representative rates now in force indicate that a value of $x$ of about 0.84 comes nearer to representing present average rates.*

From a purely theoretical standpoint such a rate is simple and distributes the slide over the whole length of the scale with the utmost uniformity. Theoretically this is very attractive. From a practical standpoint bills would have to be made out from a line drawn on large scale logarithmic paper, or by the use of a log-log slide rule. Such methods of computation could not be understood by more than a very few of the takers, and it would be difficult to convince takers of the justice of rates computed by methods which they could not understand.

The logarithmic scale has probably had more influence on the form of water rates now in use than would at first be supposed because it is possible to select rates under the common form of sliding scale that will produce results that do not differ widely from logarithmic rates; and a study of water rates of many American systems and discussion of them with those who have drawn them convinces the writer that the logarithmic scale idea has been entertained in many places, and without being named as such it has entered to a considerable extent into the preparation of the rates that have been used.

**As to the Frequency with which Different Kinds of Rates are Used.** An examination of about 100 meter rates in representative American cities where meters have been adopted to a substantial extent indicates the following distribution of kinds of rates. Statistics from other sources would undoubtedly show somewhat different distribution. Nevertheless the figures probably give a fair idea of the present American practice in regard to forms of meter rates.

In about 2 per cent of the cases, the uniform rate is used without a minimum or service charge. In a further 9 per cent there are no minimum or service charges, but the sliding scale is used, so that the smaller takers pay more per thousand gallons than the larger ones. In about 10 per cent of the cases a service charge is used with either a uniform rate or a sliding

* See Fig. 19, p. 65, for a graphic representation of a logarithmic rate in comparison with certain average values.

scale. In the remaining 79 per cent of the systems a minimum charge is used.

With reference to the amount of slide, the following figures are made up to show the ordinary and not necessarily the extreme amounts of slide. The amount of slide may be defined as the ratio between the rates per 1000 gallons for the smallest and largest quantities sold to a customer. This result is reached by excluding special rates made to extremely large takers, and which do not apply to quantities of less than 100 million gallons per annum. At the other end of the scale a few rates applying only to quantities of less than 100 gallons per day are excluded.

On this basis it is found that about 15 per cent of the systems have a uniform meter rate, and 85 per cent use the sliding scale. Of these 14 per cent use scales with a total amount of slide of less than 1.5 to 1; 14 per cent have scales with slides greater than the above, but not exceeding 2 to 1; 19 per cent have slides greater than the above, but less than 3 to 1; 16 per cent with slides less than 4 to 1; 20 per cent have slides less than 5 to 1; and 2 per cent have scales that slide more than 5 to 1. For all the systems, including the 15 per cent with uniform rates, the medium slide is as 1 to 2.35, and the average slide is as 1 to 2.67. If rates for extreme quantities were included, the average amount of slide would appear to be greater.

**Simplicity of Meter Rates.** A meter rate schedule to be successful and practical must be simple. The people who pay the bills made up under it must be able to understand the method of computation. It is important that the scale shall be equitable as far as it is possible to make it equitable and at the same time keep it simple. But there are so many considerations that legitimately might be taken into account in fixing an equitable scale of rates that if they were all to be taken into account it might result in a scale that would not be simple enough to be practical. Within limits simplicity is more important than equity.

In other words, minor inequalities in the distribution of the burden can be, and practically must be, permitted to exist in the interests of simplicity. On the other hand, a careful study of the problem will probably show that when all the equitable considerations that practically can be taken into account are considered and the rates growing out of these are ascertained, it will be possible to adopt a schedule in simple form that gives rates that coincide reasonably well with those that are desired.

To put it more specifically, a scale of rates can be adopted in the general three-rate form adopted by the New England Water Works Association, with service charges graded according to meter size, and rates in this form can be selected to produce any distribution of the burden that, as the result of other considerations, may be found to be desirable. The deviations between the desired rates and the rates represented by such a schedule most nearly approximating the desired rates will not be very large at any point and will be equally divided between those upward and downward.

**Ambiguity in Water Rates.** It takes a good degree of mastery of the English language to express all the ideas to be incorporated in a water rate schedule in terms of unmistakable clearness and at the same time to be concise. In some existing schedules clearness has been sacrificed to conciseness, with the result that the expression is ambiguous. Those who draw the rates in the first place know what they intend, and the local interpretation is correct. It is therefore seldom that local misunderstanding results. But there are some rates now in use so drawn that an outsider cannot tell with certainty how they are interpreted and what the bills for certain quantities should be. The commonest uncertainty is as to whether the rates should be classified under the jump scale or the sliding scale.

It is always safer in making a plotting of local rates to have someone from the Water Registrar's Department assist, to make sure that all the interpretations are in accord with local custom. Several times the author has found, after carefully plotting rates shown on a printed schedule, that the local interpretation was different from that which he had assumed it to be.

**Periodic Revision of Meter Rates.** The water-works business is a growing business and the conditions in it are constantly changing. In addition to the changes in relative prices of labor and supplies, there are the changes that grow out of constantly increasing business and of the additional investments that are needed to meet the added business.

The additional investments to meet growing business may be divided broadly into two classes:

First, the additions to the distribution system, which ordinarily go forward approximately in proportion to the increased business, so that the investment always bears a relation to the business done that changes only slowly and gradually, and

Second, investment in the supply works, which is ordinarily made in a series of steps of considerable size, because it is not ordinarily feasible to add small units to the supply works.

For instance, if the supply works have a capacity of 10 million gallons per day and the business grows so that this amount is no longer adequate, an addition must be built, and as a practical matter it would not ordinarily be possible to add reservoirs, pipes, pumps, filters and other facilities to take care of an additional two million gallons per day that would meet the requirements of the next few years. Instead, as a practical matter of economical development, the new works must anticipate the probable growth of at least ten or fifteen years, and sometimes of twenty to thirty years. The new works will almost always add 50 per cent and often 100 per cent or more to the whole investment in supply works. This is a matter of broad practical experience and rests on the underlying conditions of the business.

The effect of this condition upon water rates must be taken into account. If water rates were fixed each year to yield exactly operating expenses, depreciation and a fixed return upon the investment, there would normally be a reduction in the water rates so fixed every year during the period for which a given outfit of supply works was adequate, because as the years went by each year would show more business, and with fixed or practically fixed investment in supply works the same charges would be distributed over a greater volume of water, and the cost per 1000 gallons would decrease. This would continue until an addition was made to the supply works and at that time, with the new investment, a substantial addition would have to be made to the water rates.

As a practical business proposition, it is not feasible to let water rates fluctuate in this manner from year to year, and, by common consent, they are fixed at rates which are allowed to run through a term of years. Under these conditions the rates should be fixed with reference to the average conditions through a term of years and not alone with reference to the conditions of a particular year. Under such a system the surplus to be accumulated during the years just before constructing new supply works, and when the load factor of the old works is high, should theoretically be sufficient to meet the deficits in the years of and following the construction of new works when the load factor is low.

Unfortunately there is no system or regularity in the manner of fixing or revising water rates at the present time. The two conditions that principally lead to changes in water rates are these:

First, the need of an increase in water rates in connection with additions to the plant, which is necessary because old rates are too low to carry the plant financially through a period of enlargement and improvement.

Second, a reduction in water rates, which is most likely to be made toward the end of a period following one enlargement of the supply works and before the next one is required. At such a time the works are operated on a load factor that is higher than can be maintained as an average through a term of years, and this tends to produce a surplus of revenue.

Under the second of these conditions there is apt to be court action to compel a company to reduce its rates, or with a municipally owned plant there is opportunity for a new administration to make political capital out of a reduction in water rates. These reductions may be brought about even though the removal of the surplus handicaps or makes impossible the financing of additions to the works that are needed, or that will be soon needed.

Whenever a rate is revised either to produce more or less revenue, the opportunity is presented to also change the distribution of rates among the different classes of consumers, so as to make them more equitable.

That is to say, if there is to be an increase of rates, there should be an inquiry as to what takers are paying the least relatively at the present time, and the increase should be made so as to apply particularly to such takers, and, on the other hand, when a decrease is to be made, the inquiry should be made as to what takers are paying most relatively under present rates, with a view to giving greatest reduction to them.

Reconsideration of rates at fixed intervals of five or ten years, with changes when necessary, is a policy that merits serious consideration.

**As to the Average of Meter Rates Now in Use.*** The data collected by the Committee on Meter Rates upon this point are interesting although not much direct use will be made of them in that which follows. A large number of rates were examined and the results represent roughly at least the present ordinary American practice.

From these rates a calculation was made of the annual charge for a quantity of 10,000 gallons drawn at a uniform rate throughout the year, and for 30,000, 100,000, etc., up to 10,000,000 gallons per annum. In computing these amounts when a discount was allowed for prompt payment, it was assumed that this discount would be claimed by 0.9 of the takers, and 0.9 of such discount was, therefore, deducted from the computed amounts. In connection with these rates a statement was obtained from each plant showing whether the service and meter were paid for by the department or by the taker, or whether its cost was divided between them, and in all cases showing the approximate average amount paid by the plant on account of each new service and ⅝-inch meter. . . .

The divergence between the practice of different works in respect to bearing the cost of service pipes and meters must be taken into account in some way in order to compare properly the meter rates used in connection with them. The simplest way of doing this is to deduct 10 per cent of the average cost to the works of each service from the amount computed by

* Jour. N.E.W.W. Assn., Vol. XXVIII, 1914, p. 209.

the schedule for each quantity. This course is followed and the annual rates that follow are thus reduced by an amount equal to 10 per cent. of the work's contribution to the cost of each service. Obviously in applying any rates deducted from these figures to a particular case, it will be necessary to add one-tenth of the corresponding contribution to the works to the cost of services in that plant.

The Committee believes that meter rates, where most of the services are metered, may be more safely taken as an indication of good practice than rates in those cities where the meter system has been used only to a limited extent. In them, most of the revenue is derived from meter rates. There have usually been discussions of the equity of the meter rates as between different classes of takers, and it may be assumed that in most cases the rates have been reduced during a term of years to fairly satisfactory shape. On the other hand, where meters are used only to a limited extent, it frequently happens that schedules of rates are in force that are not well adapted to the service, and their inconsistencies have not been removed because of the limited use that has been made of them. With this in mind, fifty representative reports were selected for study. In each of these more than 50 per cent of the services were metered; most but not all of the selected works were in New England.

It would be unfair to speak of the results so obtained as the average meter rates for New England conditions, or of any conditions, because the rates in different works differ considerably in form and amount, and another selection of fifty cities equally representative would give somewhat different results. The results are nevertheless believed to be in a general way representative of present practice.

An interesting comparison may be made with a compilation of meter rates by George W. Biggs, Jr., chief engineer of the American Water Works & Guarantee Company. This compilation shows the amounts that would be paid for various annual quantities of water in 146 works, about half of them municipally owned works, the others being water companies. In Mr. Biggs's figures, no deduction is made on account of the contribution of the works toward the cost of the service and meter. Obviously an allowance must be made for this item to make the results comparable with those obtained from the fifty rates investigated by your Committee. In the absence of information as to what the average contribution has been, it is assumed that it has been $12.50 per service, this being about one-half of the normal total cost per service, and a deduction of 10 per cent of this, or $1.25 per annum, has been made from the figures compiled by Mr. Biggs. This correction is sufficiently close for practical purposes, and any error in it will not have an important influence on that which follows. As Mr. Biggs's quantites were not always the same as those for which the Committee's calculations have been made, interpolations have been made which are sufficiently accurate.

It appears that the average amount of slide in the scale for which data were collected by Mr. Biggs, representing works all over the United States, is somewhat greater than in the fifty scales examined by your Committee. For annual quantities from 30 to 300,000 gallons the average from 146 cities all over the country is distinctly higher than the average for the fifty works mainly in New England. On the other hand, with annual quantities above 1,000,000 gallons the order is reversed, and the average rates deduced from the 146 cities are lower.

On the whole the two series of results show surprisingly little divergence. On an average, the slide begins to take place at about the same point, and except for small differences above mentioned the amount of slide is nearly the same in both cases.

It is possible to find rates to be inserted in the schedule which the Committee now proposes which will produce charges for the different amounts of water drawn corresponding approximately with those indicated by the two sets of data. Upon trial it is found that a service charge of $3 per annum (plus 10 per cent of the cost of the service pipe and meter to the works), a domestic rate of 21 cents per 1000 gallons, an intermediate rate of 16 cents, and a manufacturing rate of 11 cents, produce amounts which fall between the two sets of data above mentioned for nearly all quantities, and correspond well with both of them.

These rates may thus be taken as representing in a general way, and with a fair degree of accuracy, the present average American practice in meter rates.

Three sets of rates are shown in the following table:

| Annual Gallons. | Quantity, Cubic Feet. | 50 Selected Works with most of the Services Metered, Less 10 Per Cent of Cost of Services. | | 146 Works Compiled by Mr. Biggs less $1.25 per Service per Annum. | | Rate of $3 + 0.21 Domestic + 0.16 Inter. + 0.11 Mfg. | |
|---|---|---|---|---|---|---|---|
| | | Amount of Bill. | Cents per 1000 Gallons. | Amount of Bill. | Cents per 1000 Gallons. | Amount of Bill. | Cents per 1000 Gallons. |
| 10,000 | 1,330 | 5.22 | 52.2 | ....... | ..... | 5.10 | 51.0 |
| 30,000 | 4,000 | 7.05 | 23.5 | 10.50 | 35.0 | 9.30 | 31.0 |
| 100,000 | 13,300 | 22.80 | 22.8 | 27.00 | 27.0 | 24.00 | 24.0 |
| 300,000 | 40,000 | 63.90 | 21.3 | 69.00 | 23.0 | 66.00 | 22.0 |
| 1,000,000 | 133,000 | 180.00 | 18.0 | 180.00 | 18.0 | 178.00 | 17.8 |
| 3,000,000 | 400,000 | 471.00 | 15.7 | 435.00 | 14.5 | 498.00 | 16.6 |
| 10,000,000 | 1,330,000 | 1370.00 | 13.7 | 1200.00 | 12.0 | 1268.00 | 12.7 |

A word of caution may well be added at this point. There is often a temptation to conclude that a particular set of rates is too high or too low because it is above or below the general average, or above or below rates in some other system selected for comparison. This temptation must be resisted. A fair judgment of water rates cannot be reached in this way. With some other commodity such a comparison might be made. The water resources of the country are very great, but they are also most varied. It costs far more to collect, treat, pump, carry, store and distribute water in some cases than in others. A two to one ratio in actual water costs when compared on the same basis is not uncommon between neighboring systems, and in extreme cases much wider ratios are found. In discussing what water rates are fair, every tub must stand on its own bottom. But the methods of distribution of the total charge that is otherwise found to be fair among the different classes of takers may well be standardized.

## CHAPTER IV

## GRAPHICAL COMPARISON OF METER RATES

When the flat rate system fails, as it usually does in the long run, it is usually succeeded by the meter system of charging.—Halford Erickson, Proc. Am. W.W. Assn., 1913, p. 53.

The diversity of meter rates is such that a direct comparison between schedules of rates in force in any two works cannot ordinarily be made. To make a comparison it is necessary to compute the annual bills for a number of assumed quantities of water under each of the schedules and then to compare these amounts with each other. Even then the comparisons may differ at each of the points selected. To make the comparison of value it is necessary to use a considerable number of such points. At some points one schedule may be higher, and at another point it may be lower, and in any case the ratios will be variable. The business is too complicated to be compared adequately in that way.

To aid in understanding such figures, the results may be plotted; that is to say, the annual bills for each annual quantity of water may be made into a diagram. More conveniently, the annual bills may be divided by the annual quantities and the average annual payments per 1000 gallons for each quantity ascertained and plotted.

If such a series of results are plotted on a natural scale, owing to the extremely wide range in quantities from the smallest consumers to the largest, the results for the relatively small takers must be shown upon too small a scale to be of practical use. If the scale is enlarged to show the bills of the smaller takers properly, the diagram becomes so large that it is impracticable to show the rates charged to the largest consumers. A series of diagrams may be resorted to, but is is more convenient to make use of logarithmic paper.

By selecting convenient logarithmic scales, practically the whole range of rates in the water works business can be represented on one small sheet of paper. Such a blank sheet for plotting rates was prepared by a committee of the New England Water Works Association. Its size is 11 by $8\frac{1}{2}$ inches and the scales and ranges were selected to conveniently and adequately represent the ordinary range of the water-works business. These sheets have been printed for separate distribution, and are available in quantities for meter rate studies. The figures used in this volume to show meter rates are based on this sheet, reduced in size and with fewer lines so as to avoid crowding.

On this sheet the vertical scale shows the average rates per 1000 gallons. The principal horizontal scale shows the quantities in thousands of gallons per annum, but there is an auxiliary scale which shows the quantities in gallons per day. This is useful in giving a clear idea of the quantities.

The diagram is divided into three parts by two vertical lines heavier than the others. The position of these two lines were chosen more or less arbitrarily by the committee to classify the consumers according to the quantities of water drawn by each. These three divisions are called for convenience Domestic, Intermediate and Manufacturing.

Domestic consumers are all those using less than 820 gallons per day, or 10,000 cubic feet per quarter; manufacturing consumers are those taking over 8200 gallons per day, or 100,000 cubic feet per quarter. The intermediate consumers are those that fall between. The names have no significance beyond defining the quantities of water which they represent.

By always using the same sheet, the position of the line upon it comes to have a definite meaning to one who is making a number of such plottings, and comparison between different rate schedules may be rapidly and accurately made. The sheets being printed on moderately thin paper, it is possible to make blue prints from them and also to trace a line from one sheet to another, so that a tracing may be made showing the plotting of a number of different meter rates in direct comparison with each other on a single sheet. More simply, two sheets may be superimposed upon each other, when the comparison of the two rates represented will be at once apparent.

The primary line plotted and the one to which most importance is attached is the average price per 1000 gallons. This is the most useful basis of comparison.

Another less generally useful but often helpful basis is to compare the annual bills. These may be plotted on the same paper, three lines being normally used, the first one running from the beginning of the scale up to services having bills of $50 per annum, the second line showing bills running from $50 to $500 per annum, and the third line showing bills running from $500 to $5000 per annum. From these diagrams the quantities of water that can be purchased for various sums of money per annum can be at once ascertained.

On this form of diagram the simplest plotting is, of course, the uniform rate. An unlimited uniform rate would be represented by a horizontal straight line going entirely across the diagram. If a minimum is used, the horizontal line will stop at the point corresponding to the greatest quantity of water that can be drawn under it and a diagonal line will go from that point upward to the left, giving rates for smaller quantities that are proportional to the reciprocals of those quantities. The rate sheet of Chelsea, Mass., Fig. 6, page 43, is mentioned as a plotting of this kind.

With the sliding scale the line is higher at the left for the small quantities and gradually falls toward the right for the larger quantities. If the amount of slide is comparatively small, the drop is not very great, as for instance at Winnipeg and at Oak Park, Figs. 11 and 16. The drop may come all at one point or be distributed at a number of points, according to the number of steps in the slide.

The jump scale gives a line with steps as at Harrisburg, Pa., and Oak Park, Ill., Figs. 7 and 16. The modified jump schedule porduces less abrupt changes, as shown by examples at Syracuse, N. Y., and Winnipeg, Can., Figs. 10 and 11.

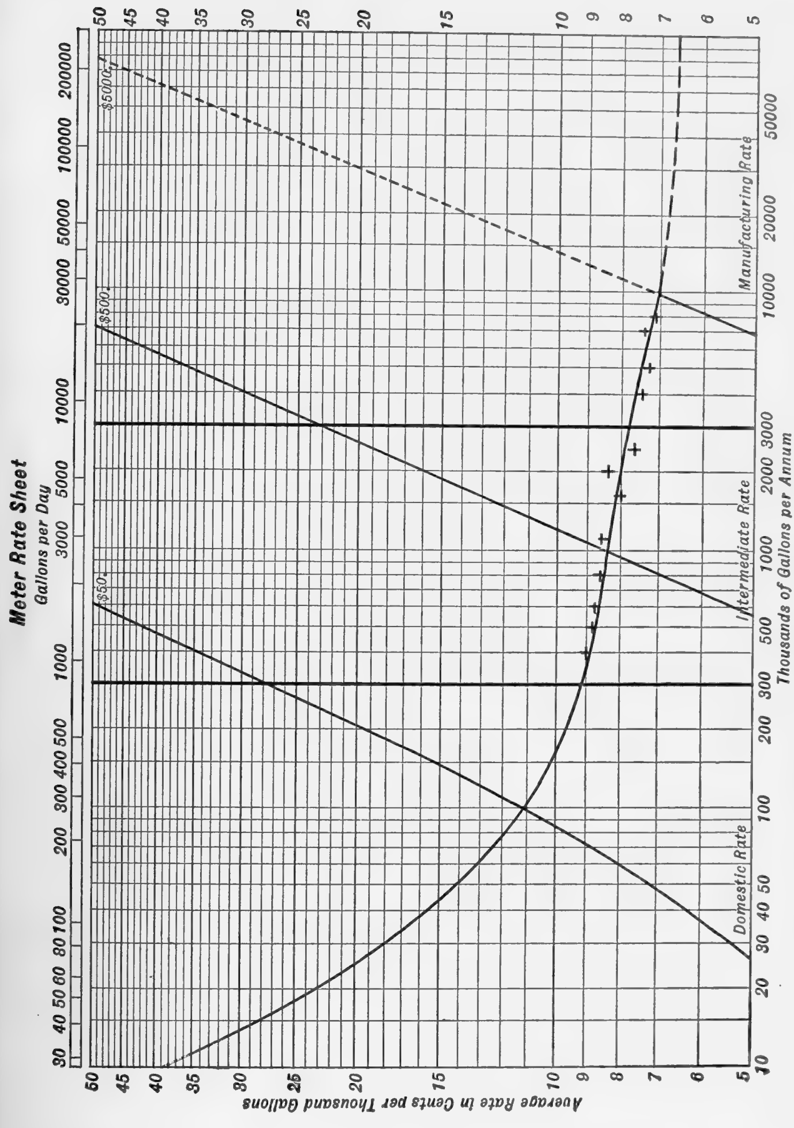


FIG. 2.—Showing Meter Rates in Madison, Wis., and the Method of Plotting.

The sliding scale in the ordinary form gives a more gradual drop in the lines at the points of change, as at Atlanta, Ga., Belmont, Mass., Hartford, Conn., etc., Figs. 3, 4 and 8.

The effect of the service charge is to give a broad, sweeping curve at the left of the sheet for the lower rates, as at Madison, Wis., Fig. 2. This resembles somewhat in its general form that produced by a minimum rate, but the change is gradual and is represented by a curved line instead of by the two straight lines with an angle which results from the use of a minimum.

In order to plot a rate schedule, a list of quantities in thousands of gallons per annum, ranging from the smallest to the largest, is taken, and the annual payment for each is computed. In doing this, if cubic feet are used and if other periods than the year serve as a basis for the rate schedule, the corresponding quantities in the units of the schedule are found before applying the rates.

Sometimes a discount for cash payment is allowed, and where this is done, for the purpose of plotting it may be assumed that nine-tenths of the discount is to be deducted on the supposition that on an average nine-tenths of the consumers will avail themselves of it.

The annual bills for the several quantities of water divided by the respective quantities show the average prices per 1000 gallons paid by a consumer drawing those quantities of water in the course of a year, and these average prices are then plotted against the corresponding quantities.

When there is a service charge depending upon the size of the meter, the rate for any given quantity will depend somewhat upon the size of meter through which that quantity is drawn, and to obtain results that are of value for comparison it is necessary to make assumptions as to the sizes of meters that will be used in connection with the different quantities.

There is no fixed rule governing this. In the plottings here presented it is assumed that meters will be used corresponding approximately with the ordinary average practice of the systems for which returns to the New England Water Works Association, Committee on Meter Rates, in 1916, were received, and which will be referred to in more detail later.

In carrying out this idea, in the following tabulation two quantities have been selected within the normal range of quantities covered by each size of meter $\frac{3}{4}$ inch and over, those quantities being selected so as to fall about at the quarters of the range of each meter size and always being round figures to facilitate plotting. In the case of the $\frac{5}{8}$-inch size of meter more points are taken, as the normal range in output for this size of meter is larger.

As an example of this method of plotting, Madison, Wis., is taken. The Madison rates follow on p. 50. Computations leading up to the plotting of the average rates is given in the table on p. 32.

This form of calculation will serve as a type, but meter rates are so varied that no one standard form of table can be always used. It is not difficult, however, to make the calculations and to tabulate the results for any rate, and in many cases short-cuts can be found that will shorten the procedure.

If the slide in the rates is but little and comes about slowly the points selected for calculation and plotting may be farther apart; while, on the other hand, if there are sudden and considerable changes, additional points in the neighborhood of those changes will be needed.

The Madison rate only goes as far as the 4-inch meter, and as a 4-inch meter is not large enough to handle the largest quantities of water shown on the meter rate sheet, the line cannot be extended to the end. However, it is apparent that the service charges for larger meters will be relatively small, and as the quantities increase the average rate would approximate more and more closely the 5 cents per 100 cubic feet, which is the lowest rate for large quantities in Madison, or 6.67 cents per 1000 gallons, and the line is drawn arbitrarily to this point at the edge of the sheet from the last point that is plotted. Madison being mainly a residential town, it may be that there are no services requiring meters larger than 4 inches, and as far as Madison is concerned the sheet seems to extend further than the business requires.

CALCULATION FOR PLOTTING METER RATES AT MADISON, WIS.

| Thousands of Gallons per Annum. | Hundreds of Cubic Feet per Six Months. | Size Meter. | Six Months' Service Charge. | Water at 6 Cents. | Water at 5 Cents. | Total Six Months' Bill. | Total Annual Bill. | Average Rate per 1000 Gallons. |
|---|---|---|---|---|---|---|---|---|
| 10 | 7 | $\frac{5}{8}$ | 1.50 | 0.40 | ..... | 1.90 | 3.80 | 38.0 |
| 15 | 10 | $\frac{5}{8}$ | 1.50 | 0.60 | ..... | 2.10 | 4.20 | 28.0 |
| 20 | 13 | $\frac{5}{8}$ | 1.50 | 0.80 | ..... | 2.30 | 4.60 | 23.0 |
| 30 | 20 | $\frac{5}{8}$ | 1.50 | 1.20 | ..... | 2.70 | 5.40 | 18.0 |
| 50 | 33 | $\frac{5}{8}$ | 1.50 | 2.00 | ..... | 3.50 | 7.00 | 14.0 |
| 70 | 47 | $\frac{5}{8}$ | 1.50 | 2.80 | ..... | 4.30 | 8.60 | 12.3 |
| 100 | 67 | $\frac{5}{8}$ | 1.50 | 4.00 | ..... | 5.50 | 11.00 | 11.0 |
| 150 | 100 | $\frac{5}{8}$ | 1.50 | 6.00 | ..... | 7.50 | 15.00 | 10.0 |
| 200 | 133 | $\frac{5}{8}$ | 1.50 | 8.00 | ..... | 9.50 | 19.00 | 9.5 |
| 300 | 200 | $\frac{5}{8}$ | 1.50 | 12.00 | ..... | 13.50 | 27.00 | 9.0 |
| 350 | 233 | $\frac{3}{4}$ | 1.75 | 14.00 | ..... | 15.75 | 31.50 | 9.0 |
| 500 | 333 | $\frac{3}{4}$ | 1.75 | 20.00 | ..... | 21.75 | 43.50 | 8.7 |
| 600 | 400 | 1 | 2.00 | 24.00 | ..... | 26.00 | 52.00 | 8.7 |
| 800 | 533 | 1 | 2.00 | 32.00 | ..... | 34.00 | 68.00 | 8.5 |
| 1100 | 733 | $1\frac{1}{2}$ | 2.75 | 44.00 | ..... | 46.75 | 93.50 | 8.5 |
| 1600 | 1067 | $1\frac{1}{2}$ | 2.75 | 45.00 | 15.83 | 63.58 | 127.16 | 8.0 |
| 2000 | 1333 | 2 | 3.75 | 45.00 | 34.17 | 82.92 | 165.84 | 8.3 |
| 2500 | 1667 | 2 | 3.75 | 45.00 | 45.83 | 94.58 | 189.16 | 7.6 |
| 3500 | 2333 | 3 | 6.00 | 45.00 | 79.17 | 130.17 | 260.34 | 7.5 |
| 5000 | 3333 | 3 | 6.00 | 45.00 | 129.17 | 180.17 | 360.34 | 7.2 |
| 7000 | 4667 | 4 | 10.00 | 45.00 | 195.83 | 250.83 | 501.66 | 7.2 |
| 8000 | 5333 | 4 | 10.00 | 45.00 | 229.17 | 284.17 | 568.34 | 7.1 |

On Fig. 2 these figures are plotted. The average annual bills are shown by other lines. In reproducing the meter rate sheet on a smaller scale many of the lines on the original are omitted.

Similar diagrams for the other meter rates that are given as examples are shown in connection with those rates at the end of this chapter.

**Another Method of Handling Service Charges.** First compute the rate for all quantities as if there were no service charges and plot it as a thin line on the diagram, calling it the base rate line. Then find or estimate and add at the various points the average addition that is made by service charges. In doing this it is assumed that all domestic services (less than 820 gallons daily) are served by $\frac{5}{8}$ meters. The service charge for a $\frac{5}{8}$-inch meter will be used in computing rates for all these quantities. It is also assumed that larger meters will be used for larger quantities of sizes suited reasonably to the drafts of the several takers.

If the service charge for a $\frac{5}{8}$-meter is \$5.00 per annum, the additions to be made to the base rate will be as follows:

| | |
|---|---|
| 10,000 gallons per annum at | 50 cents per 1600 gallons |
| 20,000 | 25 |
| 50,000 | 10 |
| 100,000 | 5 |
| 300,000 | 1.67 |

These (and additional intermediate values) are then added to the base rate and plotted, the line so drawn stopping at the 300,000 gallons per annum heavy line, which is the limit of the domestic rate classification.

For all larger quantities the service charges will increase with the meter sizes approximately in proportion to the quantities of water drawn (assuming always that the meter is reasonably adapted in size to its work) and the general average payment for service charges for all intermediate and manufacturing rates is ascertained. If full statistics are available proceed as follows:

Find, first, the total annual quantity of water sold through all meters $\frac{3}{4}$ inch in size and over.

Find next the total service charges at the proposed rates for those meters.

From these two figures is found by division the average amount per 1000 gallons that the service charges increase the average cost to the taker.

In making this calculation, it is suggested that charges for larger meters on services installed solely or mainly for fire service be omitted.

If full records are not available, then an estimate may be made based on an estimated average or normal sales from meters of various sizes.

The normal 100 per cent load factor use of a meter is taken as that quantity which would pass running uninterruptedly so that the head lost in passing is about 5 pounds for the smaller meters of standard types and either somewhat more or somewhat less for the larger ones, depending upon the type of meter. These figures are much less than the manufacturers' ratings of the meters, which are based on a loss of head of 25 pounds and are too high for practical every-day use.

The 100 per cent load quantities for meters of various sizes on this basis are as follows:

| Size of Meter, Inches. | Ratio of Capacity. | Millions of Cubic Feet per Year. | Gallons per | | | Velocity in Pipe of Exact Diameter, Feet per Sec. |
|---|---|---|---|---|---|---|
| | | | Minute. | Day, in Thousands. | Year, in Millions. | |
| 5/8 | 1 | 0.50 | 7.11 | 10.24 | 3.74 | 7.439 |
| 3/4 | 1.7 | 0.85 | 12.09 | 17.41 | 6.36 | 8.783 |
| 1 | 3 | 1.50 | 21.33 | 30.72 | 11.22 | 8.717 |
| 1½ | 6 | 3 | 42.67 | 61.44 | 22.44 | 7.748 |
| 2 | 10 | 5 | 71.1 | 102.4 | 37.40 | 7.264 |
| 3 | 20 | 10 | 142.2 | 204.8 | 74.81 | 6.458 |
| 4 | 30 | 15 | 213.3 | 307.2 | 112.21 | 5.449 |
| 6 | 60 | 30 | 426.7 | 614.4 | 224.42 | 4.843 |
| 8 | 100 | 50 | 711 | 1024 | 374.03 | 4.540 |

It is next assumed that under normal conditions of use some average load factor, say 6 per cent, will be reached on all large meters except those which are larger than otherwise required because of fire service considerations and such meters are now, excluded from consideration because rates charged for them as service charges obviously depend upon fire requirements and not on the ordinary delivery of water. In other words, the calculation of meter rates for the purpose of plotting and comparison is not intended to include payment for meters that are unusually large from the standpoint of delivering water and that are required for another purpose.

For each size of meter this quantity of water corresponding to a 6 per cent (or some other per cent) load factor is placed beside the service charge and the amount of service charge for that size and quantity in cents per 1000 gallons is ascertained by division. The average of these amounts for meters larger than ⅝-inch (giving more weight to those sizes which produce or probably will produce the greater parts of the revenue in that system) is taken as the average addition to the base price for water sold through large meters. This amount in cents per 1000 gallons is then added to the base rates for all quantities taken by intermediate and manufacturing users.

The line drawn to represent this rate will normally be not far from the line previously drawn for the quantity of 300,000 gallons per annum with ⅝-inch meters and the two lines should be connected at or near that point.

The line showing combined base and average service charges may be made heavier than the base line. The heavy line, representing the approximate average rates paid by takers, should be used in comparing rates.

EXAMPLE OF CALCULATION

| Size of Meter. | Average Sales, Thousands of Gallons per Annum at 6 Per Cent Load Factor. | Assumed Annual Service Charge for Meters of this Size in a Certain System. | Service Charge Amounts to How Many Cents per 1000 Gallons for this Quantity. |
|---|---|---|---|
| ¾ | 380 | 7.00 | 1.84 |
| 1 | 675 | 10.00 | 1.49 |
| 1½ | 1350 | 18.00 | 1.33 |
| 2 | 2250 | 25.00 | 1.11 |
| 3 | 4500 | 50.00 | 1.11 |
| 4 | 6750 | 75.00 | 1.11 |
| Average | ................ | ................. | 1.33 |

The average addition to be made to base rates for plotting all intermediate and manufacturing takers is thus 1.33 cents.

If every taker could be induced to use a meter graded accurately to the rate of his consumption, the rate per thousand gallons could be made so much greater and the graded service charge for large meters dispensed with. But with the actual tendency of takers to desire and demand meters larger than are really necessary, the graded service charge furnishes the most practical and the most equitable means of distributing the load.

**Typical Examples of Meter Rates.** The following schedules have been selected as examples of the commonest type of meter rates in use in the United States at the present time. They do not by any means represent extreme or unusual form. On the other hand, they are not selected as typical except as to form.

### Atlanta, Georgia

(Taker Pays for Service and Meter)

The minimum monthly rate to any consumer is 80 cents for 800 cubic feet (or 6000 gallons) or less.

A discount of 25 per cent will be allowed on bills paid by the 10th of the month following the month of consumption.

One rate will be charged for each store, dwelling or other premises supplied, of not less than 80 cents per month for each separate tenement.

In case one or more house or premises is allowed on one meter, but one rate may be charged while the houses are being built, but as soon as any part of house or houses is occupied all the rates allowed shall be collected.

**Wholesale Rates.** Wholesale rates will be allowed consumers who regularly use 10,000 cubic feet or over per month, and they will be supplied at the following unit prices:

1st 10,000 cubic feet, 10 cents gross per 100 cubic feet, $10.00, net $7.50.
2d 10,000 cubic feet, 9½ cents gross per 100 cubic feet, $9.50, net $7.12.
3d 10,000 cubic feet, 9 cents gross per 100 cubic feet, $9.00, net $6.75.
4th 10,000 cubic feet, 8½ cents gross per 100 cubic feet, $8.50, net $6.37.
5th 10,000 cubic feet, 8 cents gross per 100 cubic feet, $8.00, net $6.00.
6th 10,000 cubic feet, 7½ cents gross per 100 cubic feet, $7.50, net $5.62.
7th 10,000 cubic feet, 7 cents gross per 100 cubic feet, $7.00, net $5.25.
Excess at 7 cents gross, or 5.25 cents net, per 100 cubic feet.

(Plotted in Fig. 3.)

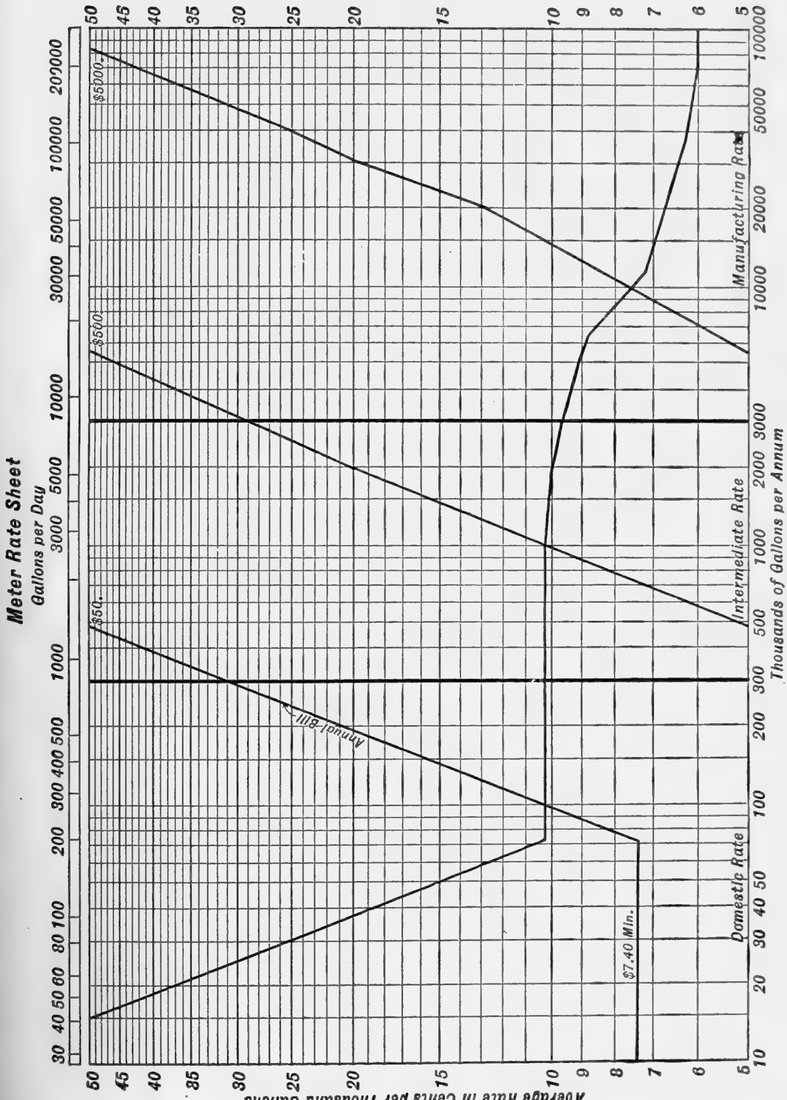


FIG. 3.—Showing Meter Rates in Atlanta.

## Belmont, Mass.

(Water Works Pay for Service and Meter)

A minimum charge of $3.00 for each six months, due January 1, and July 1, is made in advance for 1300 cubic feet of water.

Charges for any excess of the 1300 cubic feet are made at the following rates:

| | |
|---|---|
| 1,300 to 6,000 cubic feet | 23 cents per 100 |
| 6,000 to 34,000 | 19 |
| 34,000 to 100,000 | 15 |
| 100,000 to 150,000 | 13 |
| 150,000 to 200,000 | 11½ |
| 200,000 to 300,000 | 9½ |
| 300,000 to 400,000 | 7½ |
| 400,000 to 500,000 | 6 |
| 500,000 and over | 5 |

### Rent of Meters

| | |
|---|---|
| ⅝-inch meter | $1.00 for six months |
| ¾ | 1.50 |
| 1 | 2.00 |
| 1½ | 3.50 |
| 2 | 5.00 |

(Plotted in Fig. 4.)

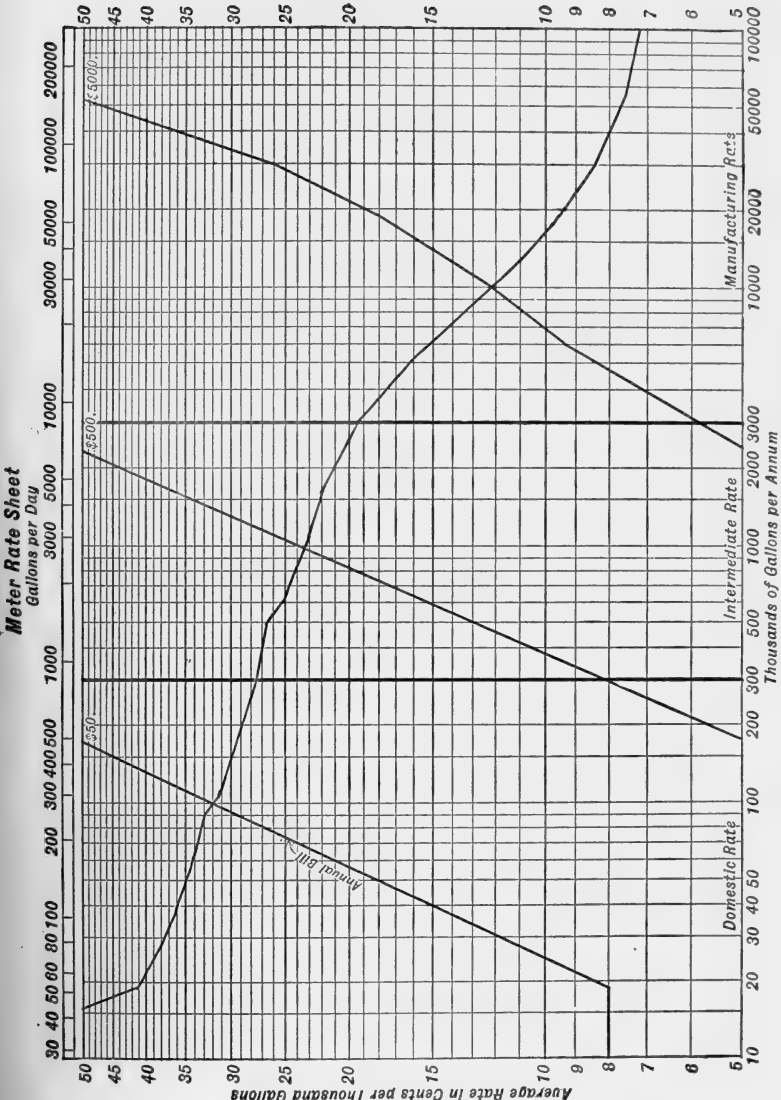


FIG. 4.—Showing Meter Rates in Belmont, Mass.

### Birmingham, Alabama

(Water Works Pay for Meter Only)

For 105,000 gallons per month or less, 20 cents per 1000 gallons.
For any quantity from 105,000 to 120,000 gallons per month, $21.00.
For any quantity from 120,000 to 128,572 gallons per month, 17½ cents per 1000 gallons.
For any quantity from 128,572 to 150,000 gallons per month, $22.50.

When the quantity used is more than 150,000 gallons per month:

| | |
|---|---|
| For the first 150,000 gallons.................... | 15 cents per 1000 gallons |
| For the next 150,000 gallons, or any part thereof | 14 |
| 150,000 | 13 |
| 150,000 | 12 |
| 150,000 | 11 |
| 150,000 | 10 |
| 150,000 | 9 |

For all that quantity exceeding 1,050,000 gallons per month, 8 cents per 1000 gallons.

The minimum rate is 75 cents for each dwelling, except that such minimum shall in no instance exceed three-fourths of the flat rate charge for a like service. Where a meter is placed upon a service pipe supplying water to more than one dwelling, the owner paying the water bill for the entire premises, the minimum charge shall apply to eight rooms or less and proportionate thereto based upon the total number of rooms where there are more than eight rooms so supplied by one service pipe, except that such minimum quarterly charge shall in no instance exceed three-fourths of the flat rate charge for a like service for the same period.

No meter rent shall be charged for a ⅝-inch meter or for any meter measuring water to a dwelling. Where a larger than ⅝-inch meter is placed upon a service, except in case of a dwelling, no minimum charge for water service shall be made, but meter rent shall be charged as follows:

| | Per Month. |
|---|---|
| For a ¾-inch meter, at the rate of | $0.25 |
| 1 | .40 |
| 1½ | .60 |
| 2 | 1.00 |
| 3 | 1.65 |
| 4 | 2.00 |

(These rates are condensed slightly from the originals.)
(Plotted in Fig. 5.)

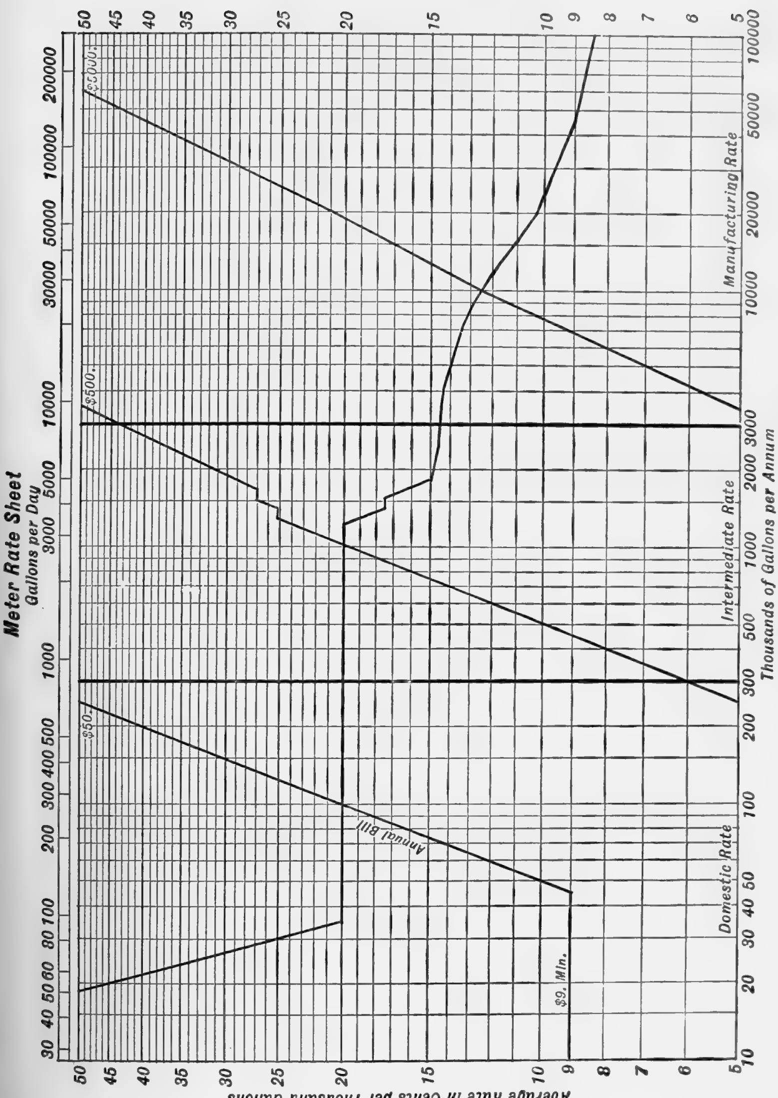


FIG. 5.—Showing Meter Rates in Birmingham, Ala.

## Chelsea, Mass.

(Water Works Pay for Service and Meter)

Each 100 cubic feet, $0.11 (equivalent to 14.7 cents per 1000 gallons).

The water charge, however, will not be less than $1.50 each quarter. For this minimum quarterly charge there may be used during the quarter 1364 cubic feet of water, equivalent to 10,200 gallons, an average of 112 gallons per day.

(Plotted in Fig. 6.)

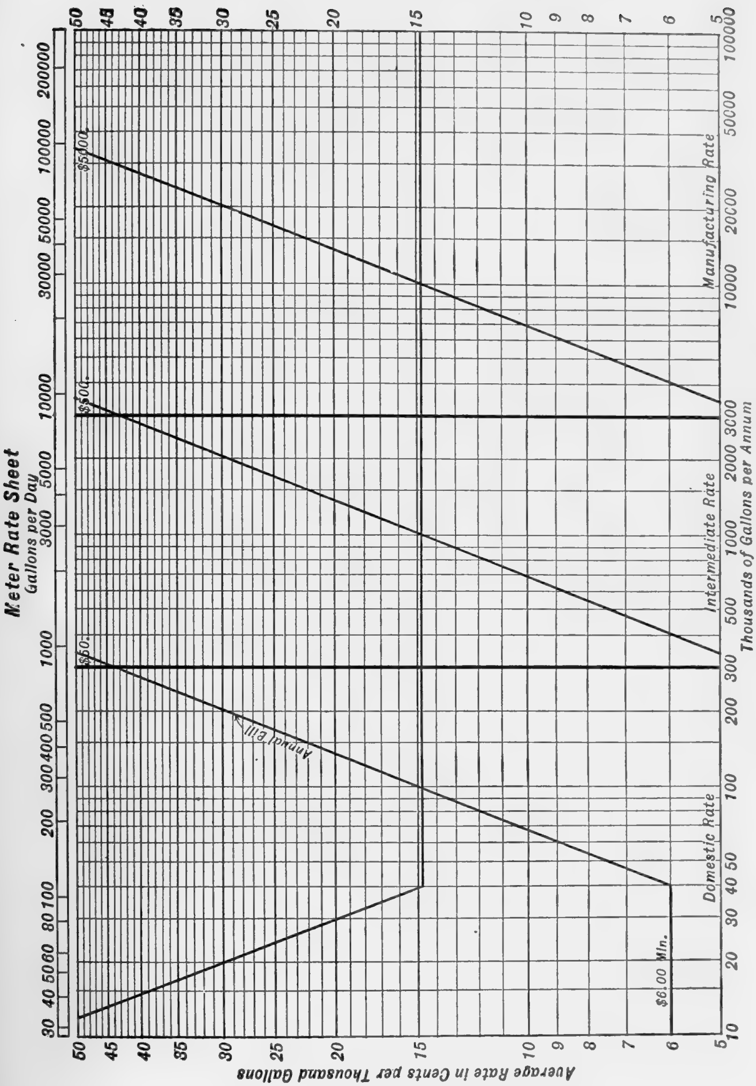


FIG. 6.—Showing Meter Rate in Chelsea, Mass.

## Hackensack Water Company

(Water Works Pay for Meter Only)

Established by the New Jersey Board of Public Utilities Commissioners to go into effect January 1, 1918

Rates for domestic, commercial and manufacturing purposes consist of two parts of elements: first, a fixed charge, and second, a proportional charge. The fixed charge is based upon the size of the meter required to furnish the service for the given property and is as follows:

| | Per quarter. |
|---|---|
| ½ or ⅝-inch | $1.00 |
| ¾ | 1.75 |
| 1 | 3.50 |
| 1½ | 9.00 |
| 2 | 12.00 |
| 3 | 29.00 |
| 4 | 42.00 |
| 6 | 79.00 |
| 8 | 127.00 |
| 10 | 144.00 |

The fixed charge shall be uniform throughout the entire territory served by the company.

In addition to the fixed charge, all water supplied shall be charged for in accordance with the sliding schedule of rates which will vary in the different districts as follows:

*New Milford District*

| | Per M cu. ft. |
|---|---|
| For the first 40,000 cubic feet in the year | $0.88 |
| For the excess over 40,000 and up to and inclusive of 400,000 cubic feet in the year | 0.80 |
| For the excess over 400,000 cubic feet and up to and inclusive of 4,000,000 cubic feet in the year | 0.73 |
| For the excess over 4,000,000 cubic feet in the year | 0.65 |

*New Durham Low Level District (outside of Hoboken) and Weehawken High Service District*

| | Per M cu. ft. |
|---|---|
| For the first 40,000 cubic feet in the year | $1.15 |
| For the excess over 40,000 cubic feet and up to and inclusive of 400,000 cubic feet in the year | 0.90 |
| For the excess over 400,000 cubic feet and up to and inclusive of 4,000,000 cubic feet in the year | 0.80 |
| For the excess over 4,000,000 cubic feet in the year | 0.65 |

*Englewood High Service District*

| | Per M cu. ft. |
|---|---|
| For the first 40,000 cubic feet in the year | $1.50 |
| For the excess over 40,000 cubic feet in the year and up to and inclusive of 400,000 cubic feet in the year | 1.10 |
| For the excess over 400,000 cubic feet in the year | 0.92 |

(Plotted in Fig. 15.)

(Plotted in Fig. 15, p. 61.)

This schedule is in the form of the N.E.W.W. Association. It has a fourth or special rate for any large consumers which was desirable in the case from the standpoint of existing business and contracts. It also embodies the principle of higher charge for high service water in the way that is described in Chapter XIX.

## Harrisburg, Penna.

(Taker Pays for Service and Meter)

**Domestic Purposes.** For domestic purposes, 100 cubic feet, 8 cents; provided that no dwelling house in which the metered water is used shall pay less than $4 per annum.

All metered water used and the charges not provided in the foregoing rates, to be charged, per 100 cubic feet, 8 cents.

**Manufacturing Purposes.** All persons, firms or corporations except railroad companies, using the following quantities of metered water for manufacturing and wholesale purposes, shall pay as follows, at a daily average per month:

| | Cents per 1000 Gallons. |
|---|---|
| Daily average less than 10,000 gallons | 8 |
| Daily average 10,000 to 15,000 gallons | 7 |
| 15,000 to 25,000 | 6½ |
| 25,000 to 35,000 | 6 |
| 35,000 to 50,000 | 5 |
| 50,000 to 75,000 | 4¾ |
| 75,000 to 100,000 | 4½ |
| 100,000 to 125,000 | 4¼ |
| 125,000 to 150,000 | 4 |
| 150,000 to 175,000 | 3¾ |
| 175,000 to 200,000 | 3½ |
| 200,000 to 500,000 | 3¼ |
| 500,000 to 750,000 | 3 |
| 750,000 to 1,000,000 | 2¾ |
| 1,000,000 and over | 2½ |

All railroad companies using the following quantities of metered water, except for station, depot and office purposes, which shall be charged for at domestic rates, shall pay as follows, at a daily average per month:

| | Cents per 1000 Gallons. |
|---|---|
| Daily average less than 10,000 gallons | 8 |
| Daily average 10,000 to 15,000 gallons | 7 |
| 15,000 to 25,000 | 6½ |
| 25,000 to 35,000 | 6 |
| 35,000 to 50,000 | 5 |
| 50,000 to 75,000 | 4¾ |

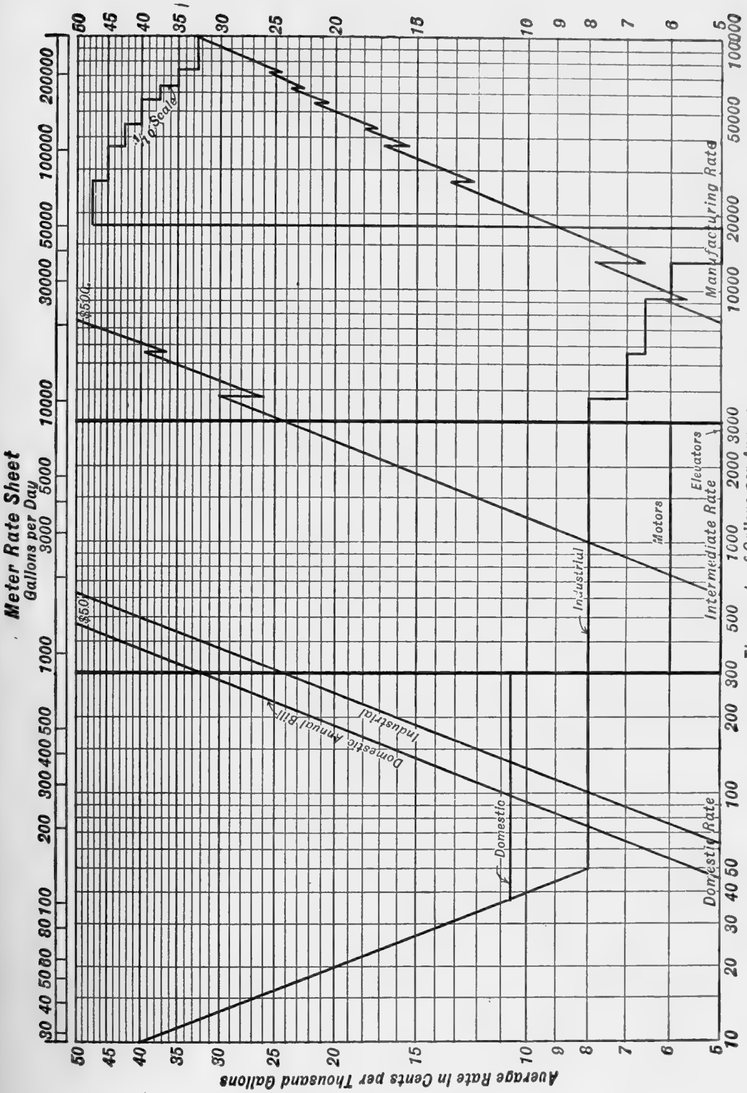


FIG. 7.—Showing Meter Rates in Harrisburg, Pa.

| | | Cents per 1000 Gallons. |
|---|---|---|
| Daily average | 75,000 to 100,000 gallons | $4\frac{1}{2}$ |
| | 100,000 to 125,000 | $4\frac{1}{4}$ |
| | 125,000 to 150,000 | 4 |
| | 150,000 to 175,000 | $3\frac{3}{4}$ |
| | 175,000 to 200,000 | $3\frac{1}{2}$ |
| | 200,000 gallons and over | $3\frac{1}{4}$ |

**Hotel Rates.** All hotels and restaurants using the following quantities of metered water shall pay as follows at a daily average rate per quarter:

Daily average, less than 5000 gallons, 8 cents per 1000 gallons.

Daily average over 5000 gallons, manufacturers' rate.

**Elevators.** Elevators, per 1000 gallons, 5 cents.

**Motors.** Motors, except for bottling establishments, per 1000 gallons, 6 cents.

(Plotted in Fig. 7.)

## Hartford, Conn.

(Water Works Pay for Service and Meter)

For the first 3000 cubic feet or less per day, 12 cents per 100 cubic feet.

All over the first 3000 cubic feet per day at the rate of 6 cents per 100 cubic feet.

(Plotted in Fig. 8.)

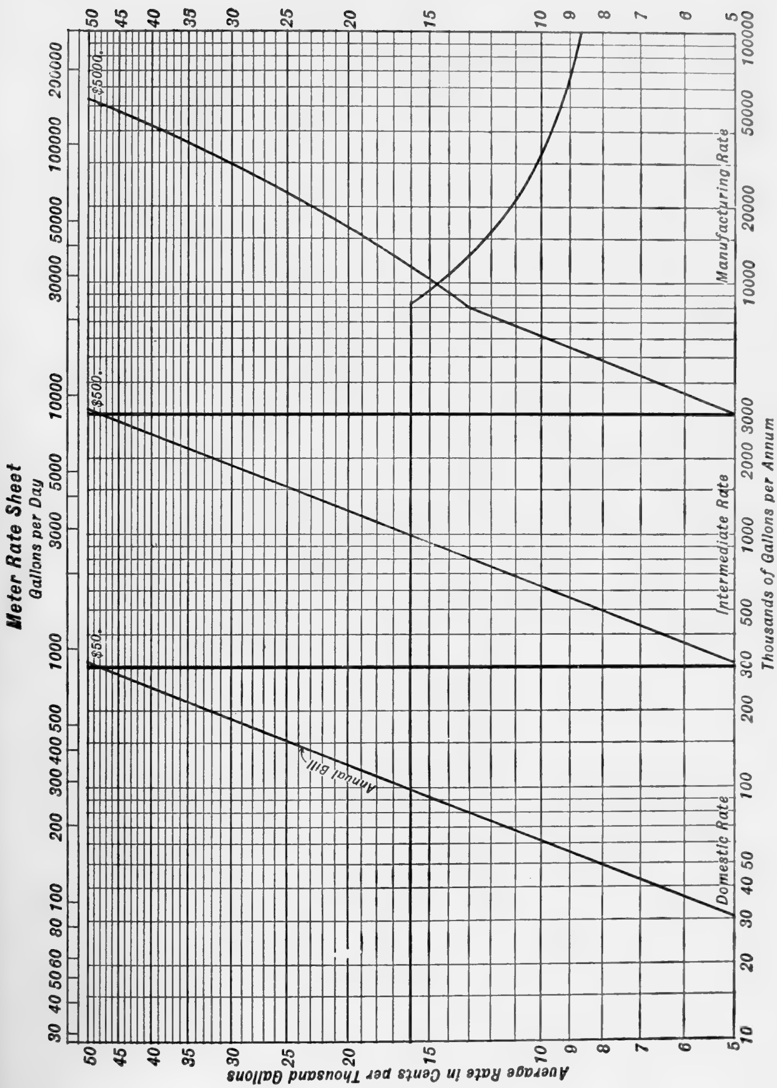


FIG. 8.—Showing Meter Rates in Hartford, Conn.

## Madison, Wisconsin

(Water Works Pay for Service and Meter)

(1) Service charge:

| | | |
|---|---|---|
| 1. | $\frac{5}{8}$-inch meter, one consumer on meter six months | $1.50 |
| 2. | $\frac{3}{4}$ | 1.75 |
| 3. | 1 | 2.00 |
| 4. | $1\frac{1}{4}$ | 2.75 |
| 5. | 2 | 3.75 |
| 6. | 3 | 6.00 |
| 7. | 4 | 10.00 |

For each additional consumer on the same meter, $1.00.

Each dwelling, flat, suite, store, tenant, etc., shall be regarded as one consumer in determining the service charge.

(2) Output charge:

1. Up to and including 75,000 cubic feet (in six months), 6 cents per 100 cubic feet.
2. For quantities in excess of 75,000 cubic feet in six months, 5 cents per 100 cubic feet.

(Plotted in Fig. 2, p. 29.)

## Oak Park, Illinois

(Taker Pays for Service and Meter)

Class I. A minimum charge of $1.75 per quarter, not exceeding $7 per year, shall be made, entitling the consumer to use 9000 gallons per quarter. A charge of 18 cents shall be made for each additional 1000 gallons payable quarterly.

Class II. A charge of 17 cents per 1000 gallons shall be made to consumers of 100,000 to 200,000 gallons per month, payable monthly.

Class III. A charge of 16 cents per 1000 gallons shall be made to consumers of 200,000 to 600,000 gallons per month, payable monthly.

Class IV. A charge of 15 cents per 1000 gallons shall be made to consumers of over 600,000 gallons per month, payable monthly.

(Plotted in Fig. 16, p. 62.)

### Philadelphia, Penna.

(Taker Pays for Service Meter, and for Distribution Pipe in Street)

MINIMUM METER RATES AND QUANTITIES OF WATER ALLOWED THEREFOR

| | | |
|---|---|---|
| For ½-inch ferrule | $8.00 minimum | 8,000 cubic feet |
| ⅝ | 12.00 | 12,000 |
| ¾ | 18.00 | 18,000 |
| 1 | 32.00 | 32,000 |
| 1¼ | 50.00 | 50,000 |
| 1½ | 75.00 | 75,000 |
| 2 | 130.00 | 130,000 |
| 3 | 290.00 | 290,000 |
| 4 | 515.00 | 515,000 |
| 6 | 1150.00 | 1,150,000 |

All water in excess of the quantity hereinabove fixed for any metered connection shall be charged for at the rate of forty (40) cents per one thousand (1000) cubic feet.

(Plotted in Fig. 9.)

It may be noted in connection with this that the whole cost of the mains in the streets is assessed against the abutters when the pipes are laid. With this system of charging for mains lower rates per 1000 cubic feet naturally result than would otherwise be possible.

It is also to be noted that the size of the tap or ferrule is made the basis of the service charge instead of the customary size of meter.

Mr. Carleton E. Davis, Chief of the Bureau of Water, Philadelphia, states that each minimum is composed of an interest and sinking fund contribution ($5.00 for the ½-inch ferrule, $8.00 for the ⅝-inch ferrule, etc.), plus the cost at 40 cents per 1000 cubic feet of the volume of water that is allowed for the minimum charge, and that this schedule in effect creates a wholesale rate, but it is peculiar in that the wholesale rate can be enjoyed as fully by the smallest concern doing business as by its largest competitor. All that is necessary is that sufficient water at the uniform rate of 40 cents per 1000 cubic feet shall be drawn through any one connection in order that the interest and sinking fund contribution from that connection shall be practically absorbed in the charge for water. As that contribution is proportional to the carrying capacity of the several connections, the smallest has the same ability to absorb its contribution as the largest.

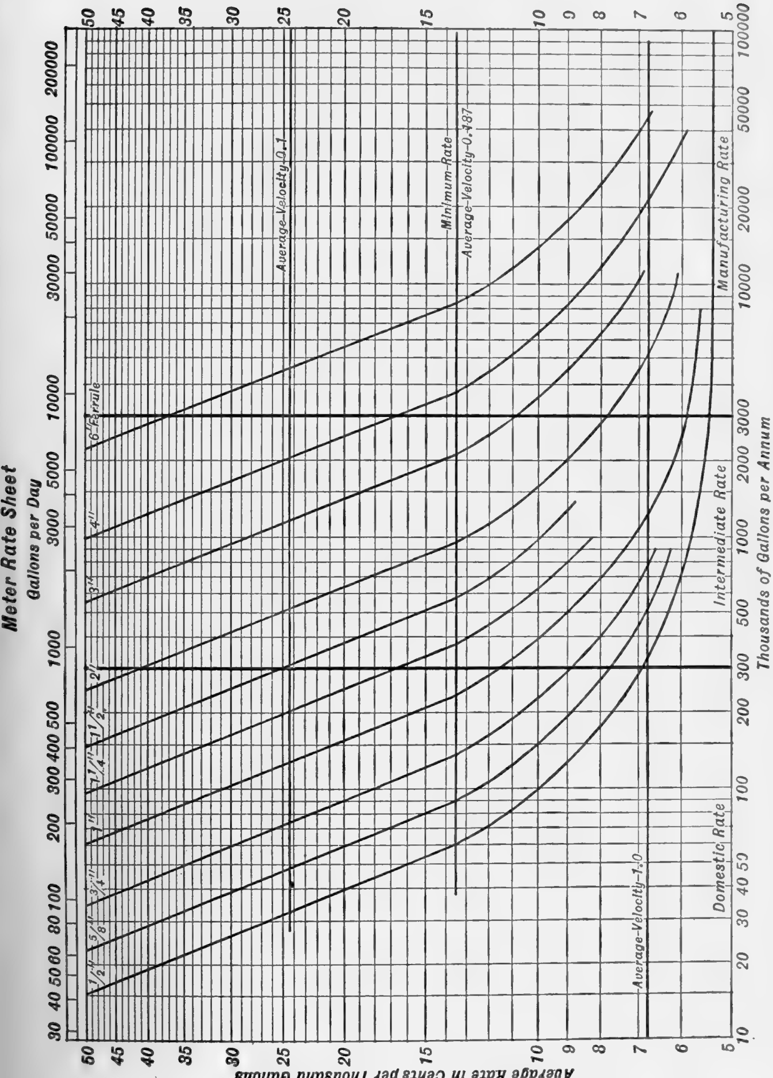


FIG. 9.—Showing Meter Rates in Philadelphia. (Service Charge Based on Size of Ferrule).

## SYRACUSE, N. Y.

(Water Works Pay for Service. Taker Pays for Meter)

At least $4.00 per annum must be paid for each family supplied, who will be allowed 3600 cubic feet of water; any excess to be paid for at the rate shown below as governed by monthly consumption. The minimum charge for any service is $4.00 per annum.

Monthly meter rates, in cubic feet

| | |
|---|---|
| 6,000 or less | 11 cents per 100 |
| 6,000 to 8,300 inclusive, lump sum | $6.60 |
| 8,300 to 16,000 | 8 cents per 100 |
| 16,000 to 21,300 inclusive, lump sum | $12.80 |
| 21,300 to 35,000 | 6 cents per 100 |
| 35,000 to 46,700 inclusive, lump sum | $21.00 |
| 46,700 or more | 4½ cents per 100 |

(Plotted in Fig. 10, p. 58.)

## WESTON, MASS.

(Water Works Pay for Service and Meter)

$18.00 for 35,000 gallons or less per year.
35 cents per 1000 gallons for all above 35,000 to 100,000.
30 cents per 1000 gallons for all above 100,000.
(Plotted in Fig. 12, p. 58.)

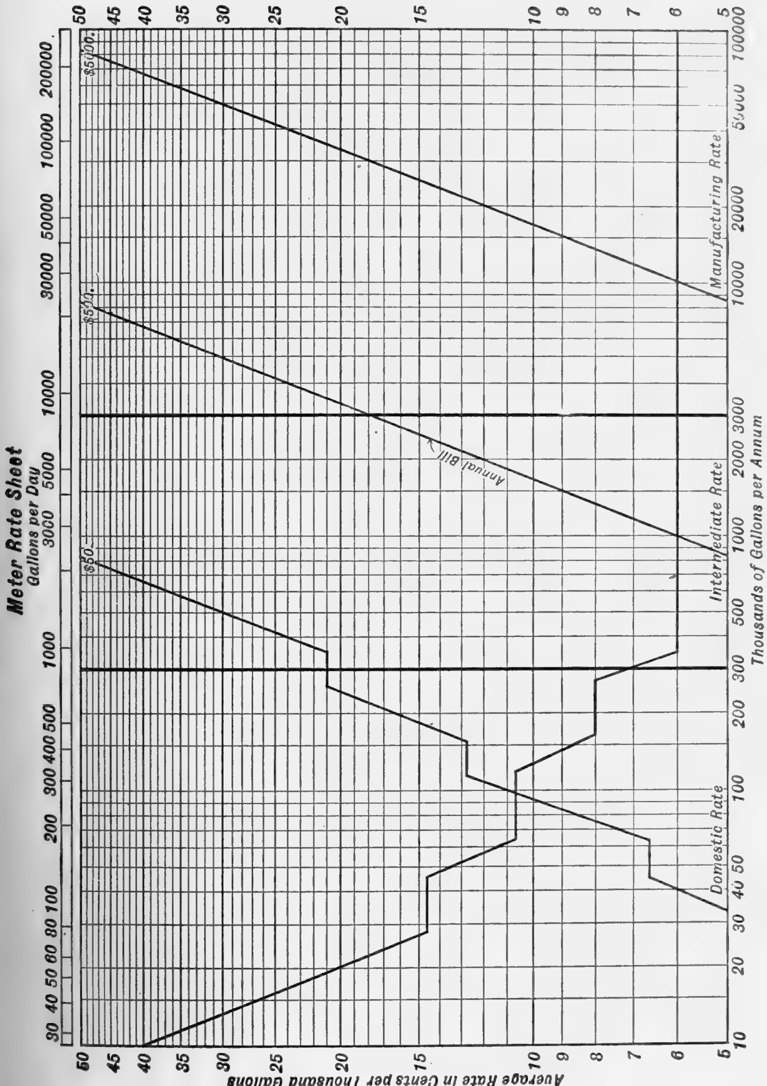


FIG. 10.—Showing Meter Rates in Syracuse, N. Y.

### Winnipeg, Manitoba

(Water Works Pay for Service and Meter)

Water rates are collected quarterly in advance. A discount of 5 per cent is allowed if the rates are paid on or before the 18th of the first month of each quarter.

Frontage Tax: Upon streets wherein the water mains have been placed a frontage rate of 4 cents per foot is charged, and may be imposed irrespective of whether such real property is vacant or not connected with the water main.

Water according to meter rate, 23 cents per 1000 gallons, subject to special discount, as follows:

A single consumer using in respect of any one building 200,000 gallons and less than 400,000 per quarter is entitled to a discount of 5 per cent.

A single consumer using in respect of any one building 400,000 gallons and less than 600,000 gallons per quarter is entitled to a discount of 10 per cent.

A single consumer using in respect to any one building 600,000 gallons and less than 800,000 gallons per quarter is entitled to a discount of 15 per cent.

A single consumer using in respect to any one building 800,000 gallons or upwards per quarter is entitled to a discount of 20 per cent.

In no case, however, shall the amount charged be higher than the minimum paid by consumers in the next highest class.

(The Imperial gallon used in this schedule is 1.2 U. S. gallons.)

(Plotted in Fig. 11.)

### Other Rates

In Figs. 12 to 19 are plotted the meter rates for some fifty American cities. Where these cities have separate rates for manufacturing, commercial and domestic purposes, the domestic rate is shown for the smaller quantities and the manufacturing rate or commercial rate for the larger quantities; in other words, the line is intended to represent the most common meter rate for takers of each class. The rates were selected from those readily available to the author, and completeness has not been attempted. The rates represented are sufficiently numerous, however, to give a very fair idea of the variety and range of meter rates in use in American cities.

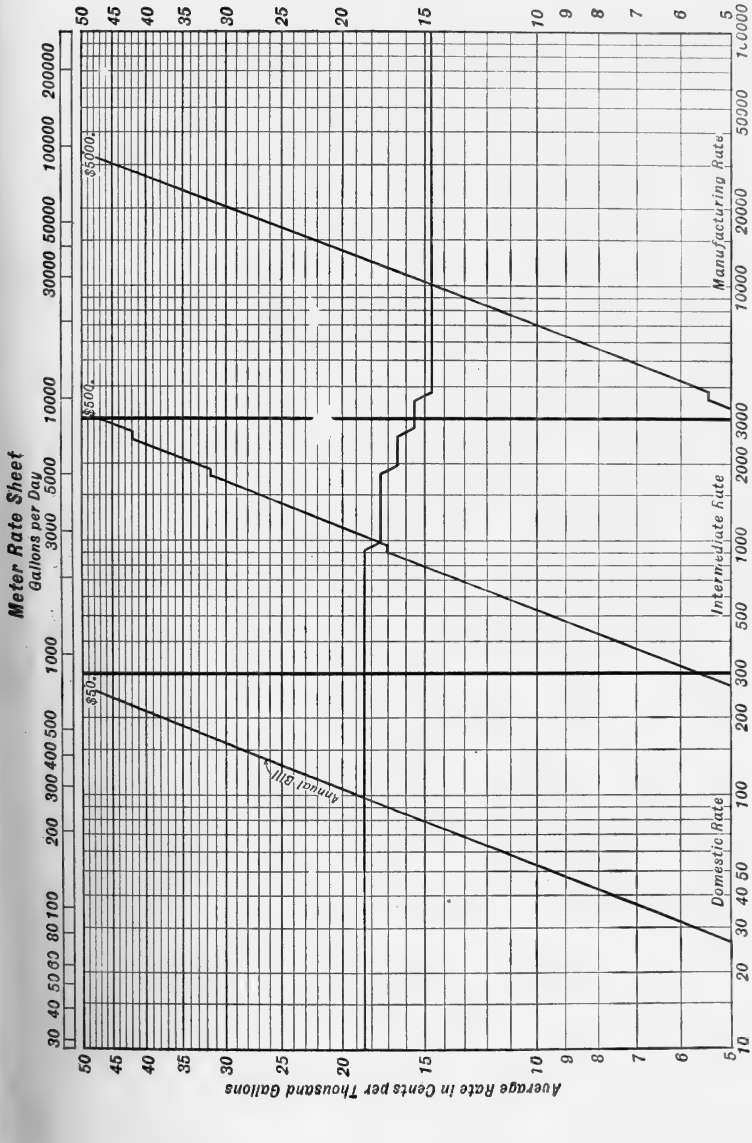


FIG. 11.—Showing Meter Rates in Winnipeg, Canada. (These rates are calculated for U. S. gallons in place of the Imperial gallons actually used.)

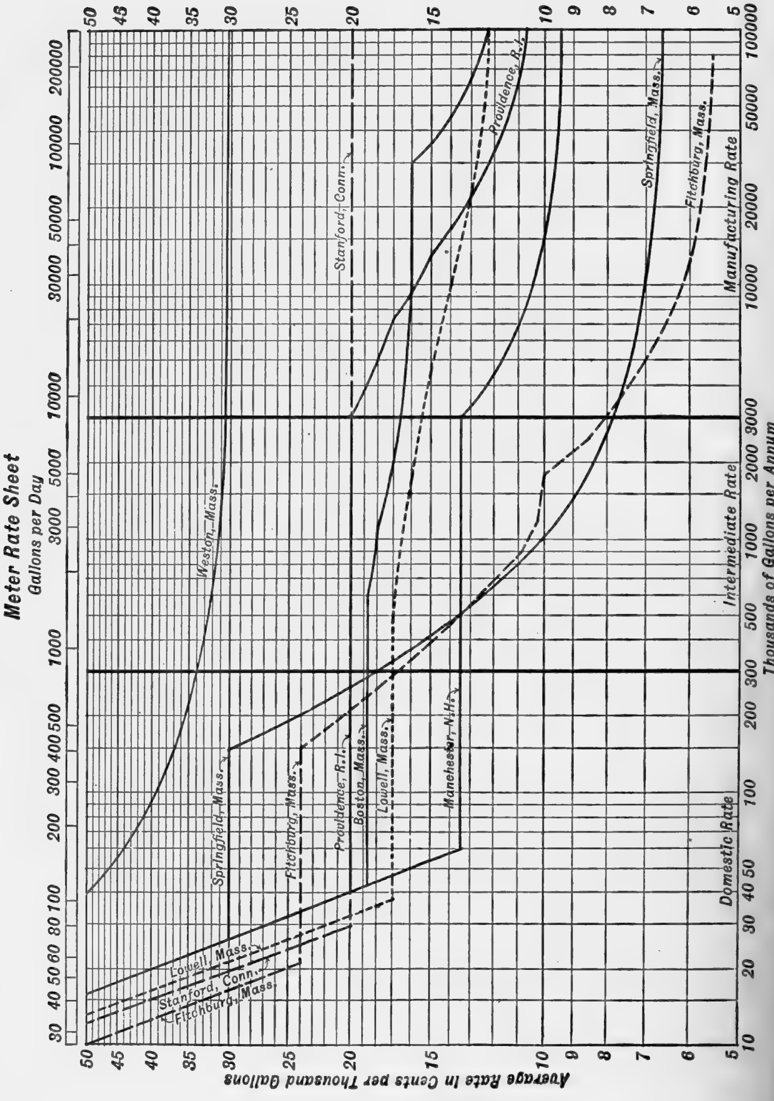


FIG. 12.—Showing Meter Rates in Some Cities in New England.

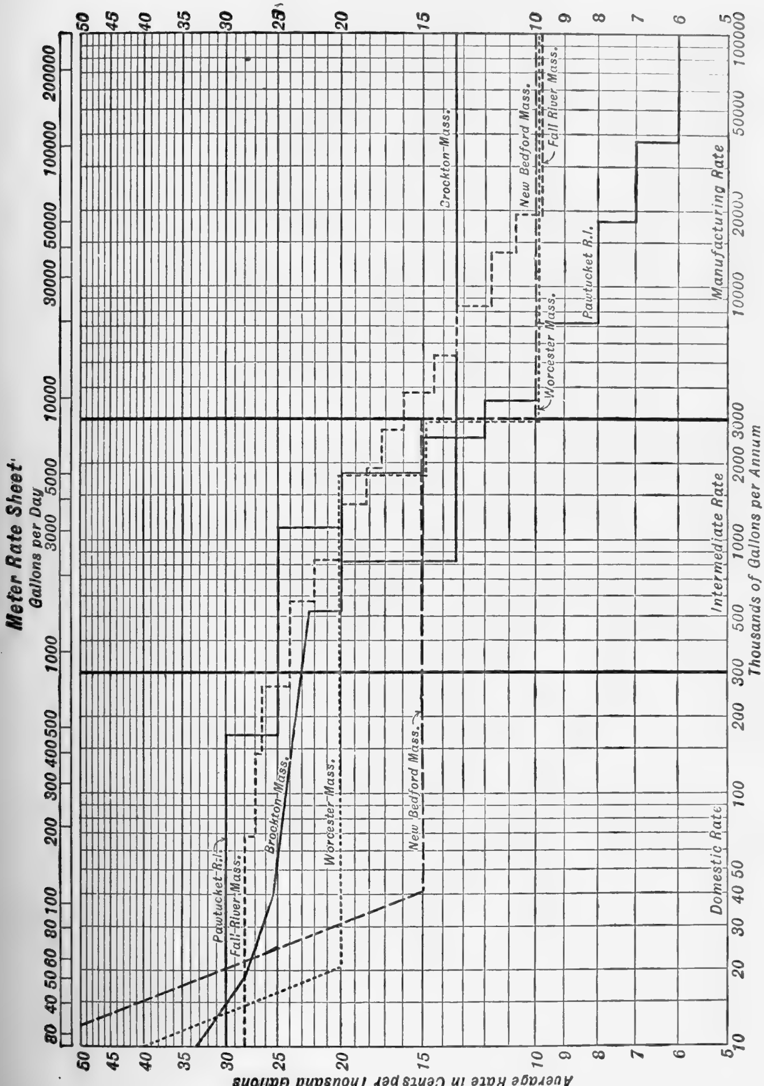


FIG. 13.—Showing Meter Rates in Some Other New England Cities.

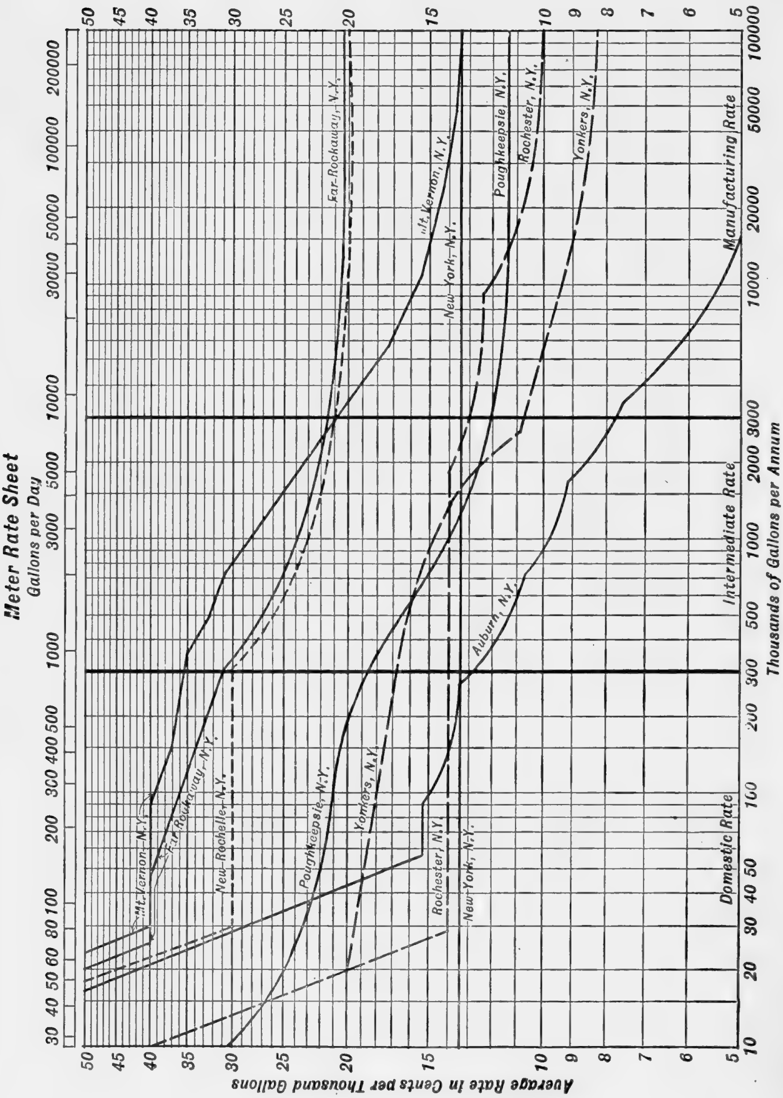


FIG. 14.—Showing Meter Rates in Some Cities in the State of New York.

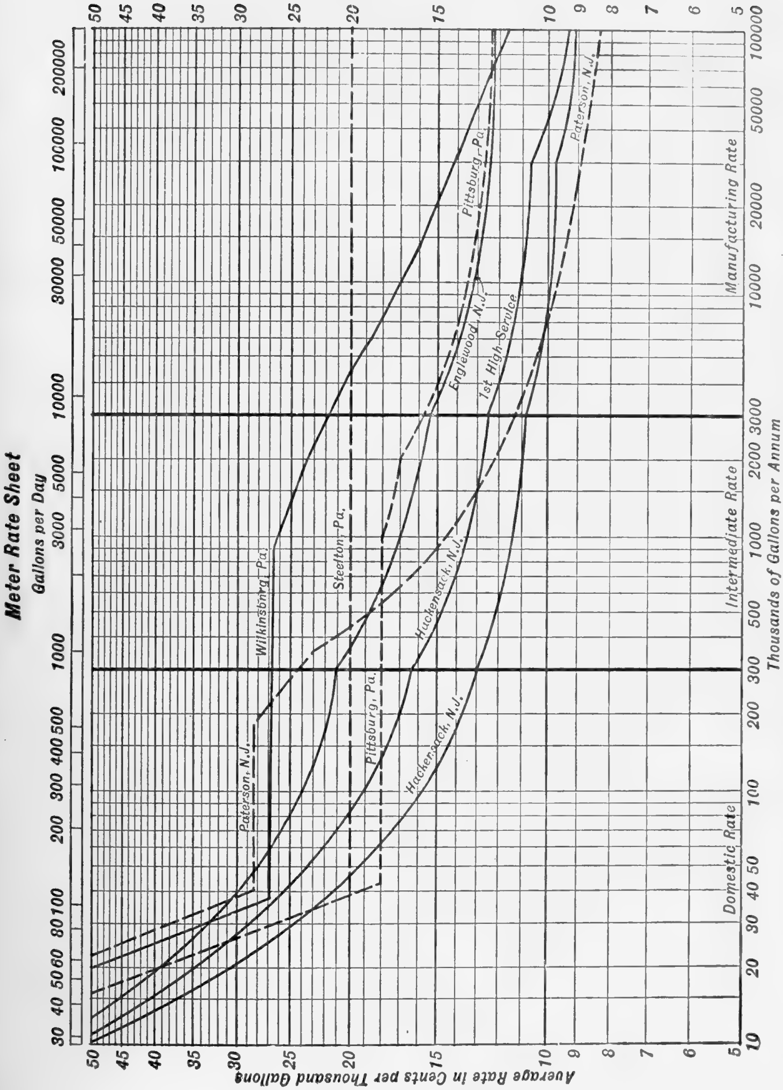


FIG. 15.—Showing Meter Rates in Some Cities New Jersey and Pennsylvania.

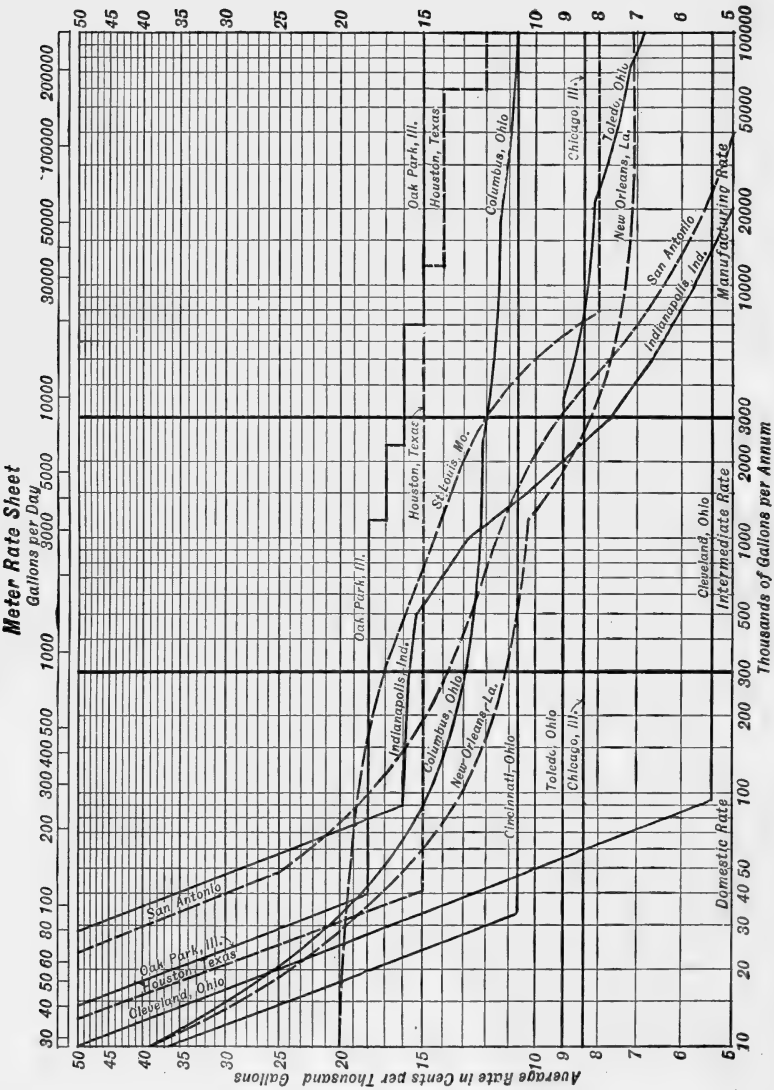


FIG. 16.—Showing Meter Rates in Some Cities in the Middle West.

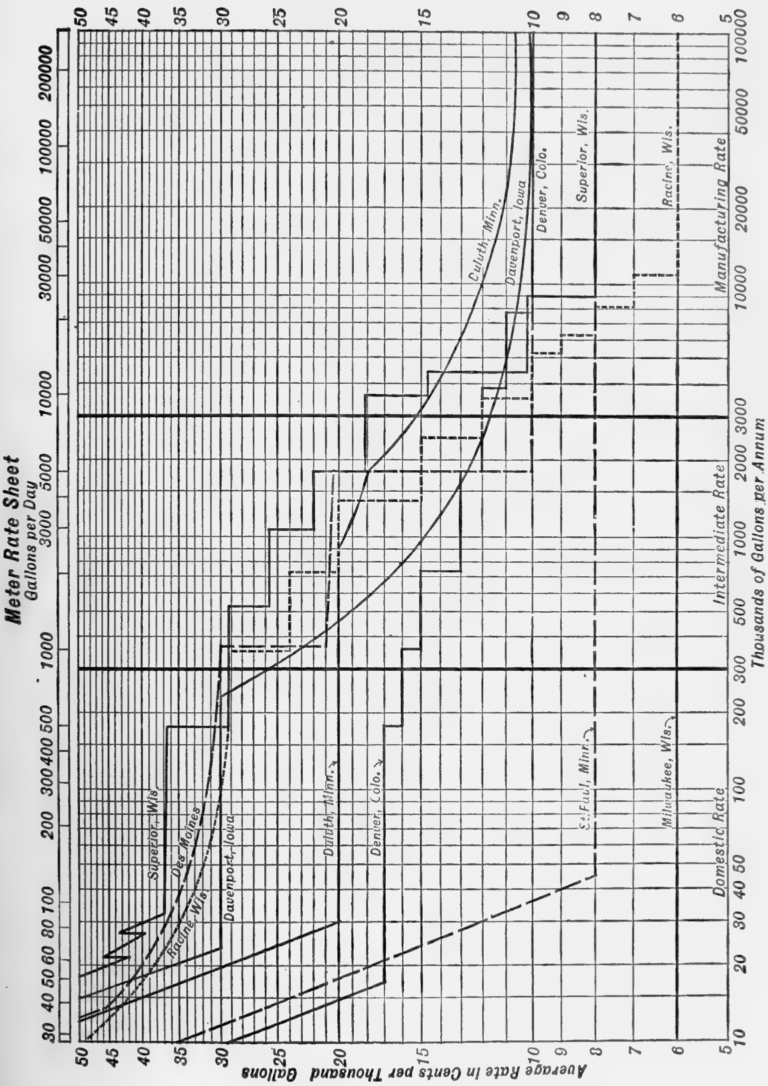


FIG. 17.—Showing Meter Rates of Some Cities in the Northwest.

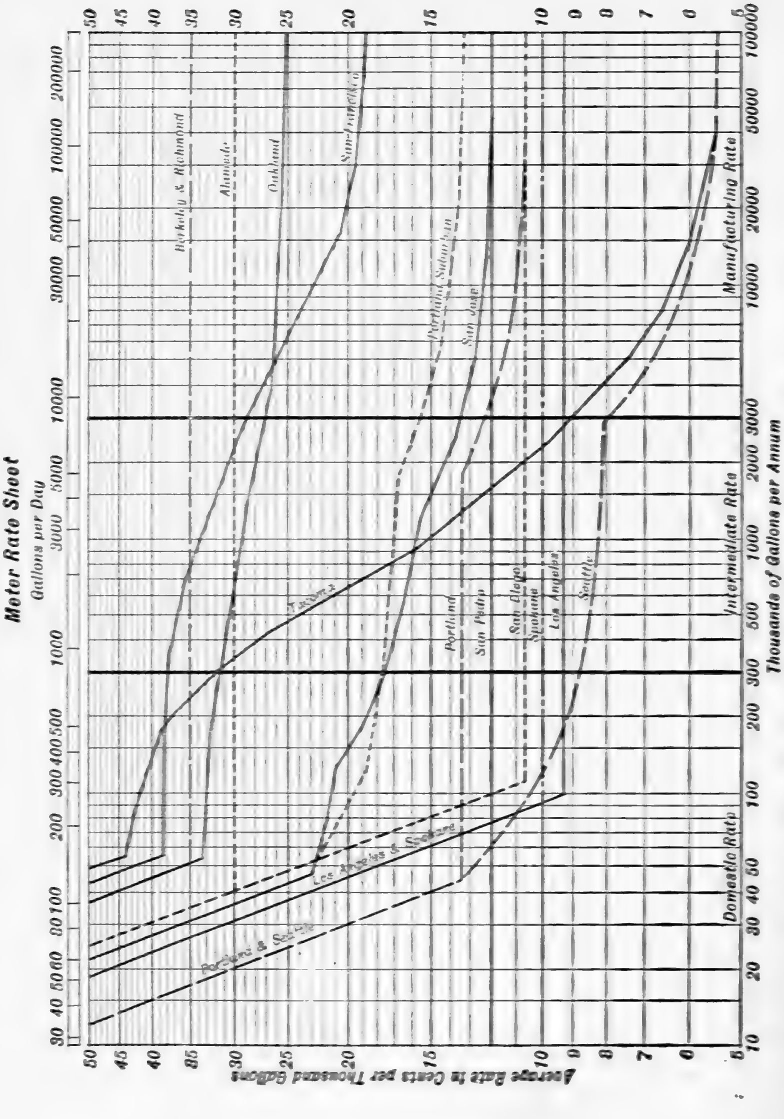


FIG. 18.—Showing Meter Rates in Some Pacific Coast Cities.

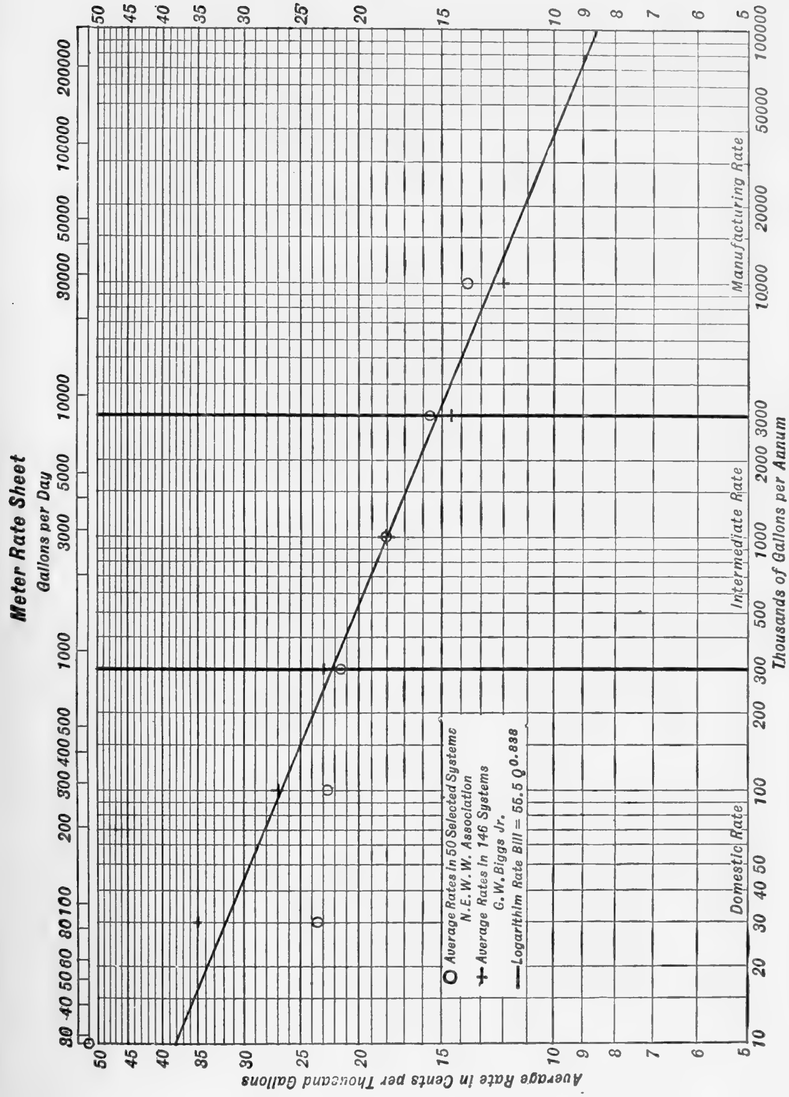


FIG. 19.—Showing a Logarithmic Rate in Comparison with Average Rates now in Force.

# CHAPTER V

## THE NEW ENGLAND WATER WORKS ASSOCIATION FORM OF RATE

No one shall draw water without a writing from Caesar, and no one shall draw more than has been granted.—Frontinus.*

This form of rate, drawn by the committee composed of Charles R. Bettes, Philander Betts, A. E. Blackmer, A. W. Cuddeback, James L. Tighe, and the writer, was presented to the Association in preliminary form on September 9, 1914, in final form on March 8, 1916, and it was adopted by vote of the Association after extended discussion on November 6, 1916.

The committee state that in preparing the schedule it was the intention to embody the most useful features of the Coffin report to the Association which preceded it by ten years and which it recognized as excellent in principle; but the new form is arranged to diverge less from current practice so that it may be adopted with a minimum disturbance to existing rates and conditions. The committee suggested that the form be considered as an ideal to be approached whenever meter rates are being revised and to be incorporated in whole or in part as might be found feasible or advantageous in such new rates.

The schedule recognizes the principle of the sliding scale and provides three rates. These rates are not fixed, but are left to be determined for each case as may be necessary to provide the required revenue.

The quantities of water per annum, per quarter or per month to which the three rates are applicable are defined and are made uniform by the schedule.

In addition a service charge is provided. The service charge

* Water Supply of Rome, translated by Clemens Herschel, 1899, p. 75.

was an essential feature of the earlier Coffin schedule, but the service charge in the present schedule rests upon a different basis and one which the committee believed would more readily lend itself to meet existing conditions. The schedule is given in alternate forms, according as gallons or cubic feet are used and as the unit of time is annual, quarterly or monthly.

The schedules, with the addition of a place for service charges for larger services in accord with the Committee's later report, are as follows:

### QUANTITIES IN GALLONS: ACCOUNTS ANNUALLY

For each service there shall be a charge for the service and meter, per annum, as follows:

| | | |
|---|---|---|
| For a service with a | 5/8-inch meter........................... | $ |
| | 3/4 ........................... | |
| | 1 ........................... | |
| | 1½ ........................... | |
| | 2 ........................... | |
| | 3 ........................... | |
| | 4 ........................... | |
| | 6 ........................... | |

In addition thereto, for all water drawn there shall be charged:

| | Cents per 1000 Gallons. |
|---|---|
| For the first 300,000 gallons of water per annum, or any part thereof, the Domestic rate of.......................... | |
| For water in excess of 300,000 gallons and under 3,000,000 gallons per annum, the Intermediate rate of.................. | |
| For water in excess of 3,000,000 gallons per annum, the Manufacturing rate of........................................ | |

### QUANTITIES IN GALLONS: BILLS QUARTERLY

For each service there shall be a charge for the service and meter, per quarter, as follows:

| | | |
|---|---|---|
| For a service with a | 5/8-inch meter........................... | $ |
| | 3/4 ........................... | |
| | 1 ........................... | |
| | 1½ ........................... | |
| | 2 ........................... | |
| | 3 ........................... | |
| | 4 ........................... | |
| | 6 ........................... | |

| | Cents per 1000 Gallons. |
|---|---|
| In addition thereto, for all water drawn there shall be charged: | |
| For the first 75,000 gallons of water per quarter, or any part thereof, the Domestic rate of........................ | |
| For water in excess of 75,000 gallons and under 750,000 gallons per quarter, the Intermediate rate of...................... | |
| For water in excess of 750,000 gallons per quarter, the Manufacturing rate of.................................... | |

## QUANTITIES IN GALLONS: BILLS MONTHLY

For each service there shall be a charge for the service and meter, per month, as follows:

| | |
|---|---|
| For a service with a 5/8-inch meter.......................... | $ |
| 3/4 .......................... | |
| 1 .......................... | |
| 1½ .......................... | |
| 2 .......................... | |
| 3 .......................... | |
| 4 .......................... | |
| 6 .......................... | |

| | Cost per 1000 Gallons |
|---|---|
| In addition thereto, for all water drawn there shall be charged: | |
| For the first 25,000 gallons of water per month, or any part thereof, the Domestic rate of.............................. | |
| For water in excess of 25,000 gallons and under 250,000 gallons per month, the Intermediate rate of...................... | |
| For water in excess of 250,000 gallons per month, the Manufacturing rate of.................................... | |

## QUANTITIES IN CUBIC FEET: BILLS QUARTERLY

For each service there shall be a charge for the service and meter, per quarter, as follows:

| | |
|---|---|
| For a service with a 5/8-inch meter.......................... | $ |
| 3/4 .......................... | |
| 1 .......................... | |
| 1½ .......................... | |
| 2 .......................... | |
| 3 .......................... | |
| 4 .......................... | |
| 6 .......................... | |

| | Cents per 100 Cubic Feet. |
|---|---|
| In addition thereto, for all water drawn there shall be charged: | |
| For the first 10,000 cubic feet of water per quarter, or any part thereof, the Domestic rate of.......................... | |
| For water in excess of 10,000 cubic feet and under 100,000 cubic feet per quarter, the Intermediate rate of................. | |
| For water in excess of 100,000 cubic feet per quarter, the Manufacturing rate of.................................... | |

QUANTITIES IN CUBIC FEET: BILLS MONTHLY

For each service there shall be a charge for the service and meter, per month, as follows:

| | | |
|---|---|---|
| For a service with a | $\frac{5}{8}$-inch meter.......................... | $ |
| | $\frac{3}{4}$ .......................... | |
| | 1 .......................... | |
| | $1\frac{1}{2}$ .......................... | |
| | 2 .......................... | |
| | 3 .......................... | |
| | 4 .......................... | |
| | 6 .......................... | |

In addition thereto, for all water drawn there shall be charged:

| | Cents per 100 Cubic Feet. |
|---|---|
| For the first 3300 cubic feet of water per month, or any part thereof, the Domestic rate of .......................... | |
| For water in excess of 3300 cubic feet and under 33,300 cubic feet per month, the Intermediate rate of.......................... | |
| For water in excess of 33,300 cubic feet per month, the Manufacturing rate of.......................... | |

A typical meter rate in this form is shown graphically in Fig. 21, p. 179.

The following paragraphs, rearranged and slightly edited, are from the Committee's report.

The prices to be written in the schedule should be fixed in each case by the authorities to meet local conditions and to produce the required revenue. The Committee suggests, however, that the methods of determining the service charge and the rates for each class of water should follow those outlined by it.

For a domestic service with $\frac{5}{8}$-inch meter, the ordinary service charge may properly be about $3 per annum where service and meter are paid for by the taker; $4 where the meter is furnished by the works, and $5 or $6 where both meter and service pipe are paid for by the works, the lower figure being used where the average cost of the service pipe is under $15, and the higher where it is greater than $15. The above charges, however, are subject to modification, depending upon local conditions. These matters will be taken up in detail for both the $\frac{5}{8}$-inch and larger meters in Chapter VII.

The price per 1000 gallons or per 100 cubic feet should be in most cases an even number of cents, omitting fractions, and the domestic rates and manufacturing rate should be first fixed; the manufacturing rate should very seldom be less than half the domestic rate, and for the intermediate rate the price should be the nearest cent midway between the average and the mean proportional of the domestic rate and the manufacturing rate. In other words, it will ordinarily be half way between the two, or half way between the two less one half cent.

A uniform rate for all quantities may be made by fixing the same price for water for domestic purposes and for manufacturing purposes, and in this event the whole schedule may be simplified.

The Committee limited its study to quantities under ten million gallons per annum (with average annual charges of about $1300) because this limit is high enough to include all but a very few of the largest takers. Special considerations often control the rates made to those using more than this amount of water. These considerations are always of local character, and the Committee did not think it necessary to extent its study to existing rates for larger quantities.

It suggests tentatively that if it is thought necessary to make a fourth and lower rate that it be called a *special rate* and that it be made to apply only to quantities in excess of 30,000,000 gallons per annum or 82,000 gallons per day.

**Committee's Alternate Procedure.** There is also an alternate procedure suggested for use where there is local objection to the service charge. This procedure was not recommended and it is not part of the adopted schedule. It may nevertheless have some interest. Under it the amount that would otherwise be used as the service charge is ascertained and this amount is applied as a loading to a small amount of water first sold from each service, thus making in effect a fourth and higher rate for use only where no service charge is made. This alternate and less desirable procedure is described further as follows:

The amount that would be a fair service is computed by the method described in Chapter VII. This amount is divided by sixty and the result to the nearest even cent is added to the domestic rate, and this new rate (which may be called a loaded or maximum rate) is applied to the first 60,000 gallons of water per annum drawn from each service. If cubic feet are used, the amount is divided by eighty, and the result to the nearest even cent is added to the domestic rate per 100 cubic feet, and the increased rate is applied to the first 8000 cubic feet per annum used from each service. In connection therewith, a minimum rate must be established. This minimum rate may be about $3 more than the computed service charge. This double procedure of loading the rate for the first quantity of water sold from each service and of establishing a minimum rate will accomplish in a rough way the general purpose of the service charge. It is less satisfactory because it is less fair as between the various small consumers drawing quantities of water that will be affected by it. It is as fair to the works and to the larger consumers because the loading of the first quantity of water sold by the method described will produce a sum nearly equal in the aggregate to that which would otherwise be directly charged for the service.

The Committee further recommends that where the same works supply water in different services under conditions which impose substantially greater relative expense in one or more such services as compared with others, by reason of high service pumping or otherwise, that it is just and equitable that discriminations be made and that for water sold in such districts the additional cost may be approximately ascertained and an added price may be charged for water sold in such districts.

For example, to one of the schedules as drawn above might be added the words:

For all water sold in the high service district the charges shall be —— cents per 1000 gallons (or per 100 cubic feet) greater than those in the above schedule.

The Committee recommended that statistics of sales of water by meter be classified in the following form. (The actual statistics of the Belmont, Mass., water works, from the annual report for 1916, probably the first to be published in the recommended form, are filled in.)

This form shows all the underlying data. From them the amount of water that would be sold under each of the three

FORM FOR STATISTICS

STATISTICS OF BELMONT, MASS., WATER WORKS FOR YEAR 1916

| | Services Coming Entirely under Domestic Rates, that is, Averaging Less than 820 Gallons per Day. | Services Coming under Intermediate Rates, that is, Averaging between 820 to 8200 Gallons per Day. | Services Securing Manufacturing Rates, that is, Using an Average of More than 8200 Gallons per Day. | Total. |
|---|---|---|---|---|
| Number of services | 1,448 | 123 | 8 | 1,579 |
| Total amount of water supplied to these services, millions of gallons | 72.2 | 40.0 | 13.5 | 125.7 |
| Total amount of revenue derived from these services, dollars | 18,057 | 8,178 | 2,142 | 29,977 |

classes can be found. A close estimate of the amount of revenue produced by sales under any schedule of rates in the form used by the Committee can then be made.

**As to the Kind of Takers that are Classified as Manufacturing.** The term manufacturing is used simply for the purpose of classification and has no other significance. The following is a tabular statement of consumers so classified in a commercial city having relatively little manufacturing:

| | Combined Average Sales, Gallons Daily. | Gallons per Capita Daily. |
|---|---|---|
| 27 hotels | 985,000 | 1.98 |
| 22 industrial establishments | 970,000 | 1.94 |
| 13 electric company stations | 824,000 | 1.65 |
| 16 railroad services (3 railroads) | 752,000 | 1.51 |
| 12 breweries | 493,000 | 0.98 |
| 9 public buildings | 396,000 | 0.79 |
| 13 hospitals | 413,000 | 0.83 |
| 2 suburban water companies | 379,000 | 0.76 |
| 11 office buildings | 197,000 | 0.39 |
| 7 parks | 154,000 | 0.31 |
| 4 clubs | 152,000 | 0.31 |
| 7 restaurants | 108,000 | 0.22 |
| 5 laundries | 101,000 | 0.20 |
| 5 apartment houses | 64,000 | 0.13 |
| Miscellaneous and not classified | 500,000 | 1.00 |
| Total | 6,488,000 | 13.00 |

It is estimated roughly that the aggregate amount of water from local sources in quantities that would be classed as manufacturing (over 8200 gallons daily each) is approximately equal to another 13 gallons per capita. In other words, the public water works get about half of the wholesale business in this particular city.

# CHAPTER VI

## THE MINIMUM RATE

It was important for sanitary reasons that no person should be restricted in the liberal use of water and therefore a minimum rate was fixed so that no temptation should exist to lessen the real use of water.—J. Herbert Shedd, Jour. N.E.W.W. Assn., Vol. XVIII, 1904, p. 7.

It is common practice at the present time to establish a minimum charge for each service. This is collected in any event, whether water is drawn or not. The amounts of these minimum charges have been fixed by considerations of various kinds.

The effect of the minimum is to require that all those takers who use less water than the quantity of water represented by it shall pay the same annual bill. In other words the amount of water registered by the meters ceases to be important within the limit covered by the minimum.

There are two reasons for the minimum:

First, the desire to get a certain necessary revenue from each service even where no water is drawn or where the quantities are too small to be remunerative at the rates that are collected for larger quantities;

Second, the desire to offer an inducement to people living in the smaller houses not to economize in the use of water below the point which is supposed to be necessary for their health.

An excellent statement in regard to the reasons for minimum rate by Mr. J. Herbert Shedd, who as city engineer had the management of the water works of Providence, which was one of the earliest cities of considerable size to require the general use of meters, is as follows: *

When the rates were fixed, the price for measured water was the common one, at that time in New England, of three cents per hundred gallons, and it was thought that $10 per year would pay, at that rate, for all the

* Jour. N.E.W.W. Assn., Vol. XVIII, 1904, p. 7.

water that would be legitimately used by an ordinary family. It was important for sanitary reasons that no person should be restricted in the liberal use of water, and therefore a minimum rate was fixed so that no temptation should exist to lessen the real use of water, but only to prevent waste. The minimum charge of $10 per year was therefore fixed for all who took *measured* water. That this was a fair estimate was proved by experience. Fifteen years after the delivery of water began (in Providence) about one-half of all the families supplied by meter were paying the minimum rate, which entitled them to 91.32 gallons of water per family per day, or, upon the basis of five persons per family, to 18.26 gallons per capita. It was noticed for many years that a large portion of the families supplied by meter did not draw more than about $5 worth per year. It is to be remembered that the poorer people are excluded from this list. They were generally supplied by one faucet at $6 per year. It was only those who were supplied with extra fixtures for their convenience who had an object in paying for and maintaining a meter, and they could have no selfish incentive to save the water within the value of $10 per year. They used all they wanted, but they did not waste the water.

**Amount of Water Furnished for the Minimum.** Running rapidly through 66 meter rates now before me, selected without reference to this consideration, it is found that the average amount allowed daily under the minimum rate is 120 gallons per day; the median is 105; 80 per cent of the results come between 55 and 170 gallons per day. The extremes are 40 and 300 gallons per day.

**As to the Sanitary Conditions.** The minimum rate as usually carried out is a clumsy and inefficient means of securing an ample supply for everyone. If every family of five lived in its own little house and had its own meter, the arrangement would not be so bad. But people who live in one family houses are not the ones who most need looking after. Sanitary conditions are more likely to be defective in tenement houses, and the minimum as ordinarily applied does not mean very much as applied to them. To extend the sanitary principle of the minimum to them in an adequate way, it would be necessary to make a minimum for every house, making it large enough in each case to cover the bill at the rates that are fixed for a supply of 20 gallons or some other quantity for every man, woman and child living in it. In some cases this has been attempted in a rough way.

But the number of people living in any given tenement house is neither constant nor easily determined by the water department for the purpose of fixing rates, and the administrative difficulty of the procedure is, to say the least, rather great. Even then there is no assurance that the water will be divided among the various inhabitants of such a tenement house so that each would have a sufficient share.

Some other form of regulation, such, for instance, as a provision that each tenement should be provided with certain fixtures for the free use of tenants would seem to be sufficient, and much more practical in their enforcement.

Such matters are in the field of the health department. There is no adequate reason why the water department should be expected to enforce conditions having only a sanitary bearing, and no direct relation to its ordinary business.

So far as the minimum is established for the purpose of meeting sanitary consideration, it is to be noted that it substitutes a new and entirely different basis for fixing meter rates from that which is used in all the rest of the discussion; that is to say, because of this consideration rates are artificially modified in a way that is otherwise inequitable for the purpose of inducing people to use a certain amount of water thought to be necessary for their well-being. The water rates are thus used to enforce a kind of sanitary policing. When this happens the fundamental ideas of the cost of the service and the value of the service are lost sight of.

The questions must be considered as to whether there is any sanitary reason for modifying water rates in this way, and whether the practice when adopted is really efficient in promoting sanitary conditions.

No doubt in years gone by much importance has been attached to this consideration. It has been used perhaps chiefly to meet the arguments of those opposed to the use of meters, who urged that motives of economy would induce some of the smaller takers to stint themselves in the use of water to a point that would be injurious to their health.

While it may be that there is some ground for this fear, practical experience in American cities which have done away with the minimum rate does not suggest that the practice is a necessary one from a sanitary standpoint at the present time. Certainly it would seem that very much less weight should be now given to this argument than probably was given to it many years ago, at the time, for instance, when the Providence water meter rates were first fixed.

**Minimum from the Standpoint of Revenue.** A certain revenue is necessary to run a water works plant, and it is proper that each taker should contribute his proper share of that cost. If no provision for a minimum or its equivalent is made, many takers will use so little water that, at rates that are naturally established and that are proper when considerable quantities of water are drawn, the bills will be so small that the services will not be remunerative, or, in other words, the takers will not pay their fair proportion of the cost of the service.

The fact, which will be developed later, that domestic water meters do not register all of the water that is drawn, must also be taken into account, because it is quite possible that with only small quantities of water drawn the unregistered proportion is greater, and if there were no minimum the taker would get off without payment or with but an inadequate payment. It is therefore necessary that some arrangement be made that will insure some substantial payment from each taker, even though the quantity of water registered is very small.

The minimum is the commonest method now in use of insuring this result. From the standpoint of accomplishing this direct result, the minimum is satisfactory. From the standpoint of distributing the assessments as nearly as may be in proportion to the cost of the service, the minimum rate is badly adapted to the service. For instance, in Providence some years ago, following Mr. Shedd's statement, one-half of the total number of domestic takers used less water than corresponded to the minimum rate. Of this one-half of the takers each one paid precisely the same amount, namely $10 per annum. All the differences that there were in the conditions of service among half of the consumers were eliminated from consideration in the bills by the method of minimum rates. It is a matter of experience that the conditions and cost of service for that half of the domestic takers using the smallest quantities of water are not uniform. Instead there are very considerable divergences that might well be taken into account in fixing the rates.

The minimum introduces irregularities into the charges for different quantities that cannot be justified. Under it a service using 100 gallons per day pays no more than a service taking 20 gallons per day, but it is obvious that it costs more to supply it and there is a presumption that the service has greater value to the taker. Certainly on the ordinary basis of distributing the burden according to cost and value of the service, a taker drawing 100 gallons per day should pay somewhat more than one drawing only 20 gallons per day.

On the other hand, where the service and meter are furnished by the works, as is now common, and is rapidly becoming still more common, and when the costs of maintaining the service pipe and meter and of reading the meter and billing are taken into account, the water-works system frequently realizes a smaller absolute return from those consumers taking amounts of water near the limit represented by the minimum than it does for either smaller or larger takers.

To illustrate: If the annual cost to the department for the service pipe and meter and of reading the meter and billing and collecting and all incidental expenses, but not including water, is $4, and if the minimum rate is $8, then from a consumer using the exact amount of water permitted under the minimum rate the collections are $8, the direct expenses are $4, and the amount left to the water works which may be considered as income from the sale of water is $4. If another consumer uses twice as much water and pays $16, the expenses for a similar service will be the same or $4, and the net income to the works from the sale of water is $12, or three times as much. The return from twice as much water is three times as great. In other words a consumer using the smaller quantity of water, which is the maximum amount permitted under the minimum, gets his water at two-thirds of the cost per 1000 gallons net that is paid by a taker who uses twice as much.

On the other hand, with the same assumptions, if a third taker uses only one-half of the quantity of water that is permitted under the minimum rate, that is to say $4 worth, he will pay the same amount for this as one drawing the maximum quantity permitted under the minimum, and the works will realize twice as much per 1000 gallons from the sale of the smaller quantity as from the sale of the whole amount permitted under the minimum.

Such irregularities under meter rates now in force are very common and they represent a substantial injustice between different classes of small takers.

**The Multiple Minimum.** When a minimum is used for small meters, the same amount may also be used for larger meters, but it is common and advisable to use larger amounts for the larger-sized meters. Amounts larger by 50 per cent then those suggested for service charges in the following chapter may be considered.

Another variation is to have a series of minimums graded according to the number of families or the size of the house, or or according to the number of fixtures. Such scales fortunately are not common. They represent a combination of flat rate schedules and meter rates and are sometimes useful to steady and insure revenue during the trying period of transition from flat rates to meter rates.

The minimum rate as now commonly used represents important ideas that cannot be ignored, but in the form in which it is commonly used it brings about inequalities and injustices in the charges.

**Method of Ascertaining the Proper Minimum Rate.** From the standpoint of sanitary conditions, the minimum rate is that amount which at the rates otherwise adopted will pay for the quantity of water that it is desired from a sanitary standpoint that each taker shall use.

From the standpoint of furnishing adequate revenue, the minimum rate is ordinarily a matter rather of experience than of calculation.

When used to steady and insure revenue during the period of change from flat rates to meter rates, the minimum should ordinarily be somewhat less than the old flat rates, thus giving each taker a chance to secure some reduction in his bill, if his use of water is low enough to warrant it.

The amount of the minimum rate will always be greater than the amount of a suitable service charge. The amount by which it is greater will normally be the estimated worth of a minimum daily draft of water, as for example, 50 or 100 gallons per day.

Mr. Leonard Metcalf writes of an unusual case where out of 3200 domestic services, there were 2500 families supplied by these services in excess of the one family normally attributable to a service, there being many cases of not only 2, 3, 4 and 5 families per service, but even as high as 10, 11, 12, 13 and 14 families per service in a population over 80 per cent of which was foreign and the per capita consumption of flat rate basis without meters being about 225 gallons per day. Under the circumstances he stated that he found it necessary to establish a family charge of $3 per family for each family in excess of one served by a single service, and a service charge of $5, thus making the family charge vary from $5 to a little over $3 in households with from one to fourteen families served by one service. For this minimum charge he gave no water. In estimating probable revenue figured the value of the water on the basis of the estimated registerable consumption of approximately 15 gallons per capita per day for the domestic services.

## CHAPTER VII

### THE SERVICE CHARGE

It is a mistake to assume that water companies have but one thing to sell, and that is water. They have two things to sell: one is water, and it is easy to measure that; the other is security against fire, and it seems to me that that should be paid for as willingly as any other form of security. It should be paid for as willingly as a premium on an insurance policy. —F. N. Connet, Jour. N.E.W.W. Assn., Vol. XV, 1901, p. 428.

The service charge is a charge for the privilege of having a service, and does not include the use of any water. As commonly used, it is a device for separating some of the expenses of maintaining the individual service which have nothing to do with the delivery of water, and of keeping them separate, and of charging them to each customer as a separate item in his bill. Otherwise these expenses go into the general expense account and must be distributed among the customers in some other and less equitable manner.

The service charge is an alternative for the minimum rate. It is less generally used, but its use is increasing. It represents a more logical and more just arrangement. Under the service charge a specific amount is collected for the service and meter. This amount is collected regardless of whether any water is drawn or not. If water is drawn it is charged for, and the amount charged for water is added to the amount of the service charge.

The amount realized by the Water Works Department from service charges forms a part of its income and the amount to be raised by water sales is reduced by a corresponding amount.

With the minimum rate this is true to a partial and ordinarily comparatively slight extent, namely, to the extent that the amount collected for minimums exceeds the amount that would otherwise be collected for the water quantities under the meter rates. The amount collected by the department from service charges may be expected to be greater than the amount resulting from the excess collections under the minimum rates, and consequently the amounts to be raised by the meter rates will be reduced by a substantial amount. This means that the rates per 1000 gallons will be lower where service charges are used than where the minimum rate system is followed.

For water sold at wholesale at manufacturing rates the prices per 1000 gallons may be less by 1 or 2 cents more or less, depending upon whether the service charges are higher or lower and upon other conditions of service, while for the smaller takers at domestic rates the difference may be and probably ordinarily will be at least several cents per 1000 gallons.

While the service charge is separately collected and is in addition to the amount collected for water rates, it is not to be supposed that water rates will average higher where service charges are used or that any more money will be collected in the aggregate. Some popular opposition to the service charge grows out of the erroneous idea that the service charge is an additional charge and means higher rates. As a matter of fact it is simply a different way of distributing the burden and of changing it to correspond more nearly with the costs. As an illustration a brief comparison of the two systems may be shown by the following table:

ANNUAL BILLS

| | With a Minimum Rate of $8 per Annum and Water at 22 cents per 1000 Gallons. | With Service Charge of $5 per Annum and with Water at 15 cents per 1000 Gallons. |
|---|---|---|
| Customer taking no water | $ 8.00 | $ 5.00 |
| Customer taking 60 gallons per day, representing about the minimum full domestic consumption | 8.00 | 8.27 |
| Customer taking 100 gallons per day, being about the average domestic consumption | 8.00 | 10.47 |
| Customer taking 200 gallons per day, being above the average | 16.00 | 15.95 |
| Total charges for four takers | $40.00 | $39.69 |

The total charges in the four cases are about the same, but the distribution is different.

With the service charge the rates per 1000 gallons are less and in the aggregate they are less by an amount that corresponds to the total amount that is realized from the service charges. There is a collection from each service in any event, whether water is drawn or not, which prevents its becoming a loss to the department, and in this respect the service charge serves the same function as that performed by the minimum rate.

If the charge is properly adjusted to the cost of the service, the use of the service charge straightens out the irregularities of the minimum charge system and provides a more accurate adjustment of the bill to the cost and probable value of the service to each taker.

There has been some little discussion of the principle that should be followed in determining the amount of service charge. Some have held that the service charge in the aggregate should suffice to pay the interest and depreciation on the entire water works plant. This principle has been sometimes followed, but when this has been done it sometimes results in placing a heavy and unfair burden upon the smallest consumers. This phase of the matter will be referred to again in Chapter XIV.

The method for estimating fair service charges used by the Committee of the New England Water Works Association leads to more moderate amounts, and as a general method it is believed to be safe.

The following development of the procedure for both small and large services is taken almost in full from the several reports of the Committee.

**Method of Calculating the Amount of the Service Charge for a $\frac{5}{8}$-inch Meter.*** The service charge may be naturally made up of several parts. The Committee suggests that the procedure to be followed in determining the amount of the service charge be as follows:

First, that the average amount of money invested by the works in the service pipe and meter be ascertained. Where the

* Jour. N.E.W.W. Assn., September, 1914, pp. 203–205.

works furnish the service pipe to the curb line, and the meter, the normal cost seems to be about $25 per service. Where the taker pays for the service pipe and the works furnish the meter, the normal cost seems to be about $10 for a $\frac{5}{8}$-inch meter in position. The Committee suggests that 10 per cent of this cost be taken as the first part of the service charge. That is to say, that $2.50 per annum be used where both service and meter are paid for by the works; $1.00 per annum where the meter only is furnished by the works, and that this part of the charge disappear where both pipe and meter are paid for by the taker. The Committee believes that on the whole 10 per cent is a fair allowance for the depreciation in the service pipe and meter, and for the interest on the money invested in them. The structures are not long-lived, and occasional repairs are needed. A reasonably approximate figure is sufficiently close, and 10 per cent is used in this way.

The figures mentioned for cost of service and meter are believed to be representative, but they should be increased or decreased according to the ascertained average costs under local conditions. Round figures should be used in all cases as a matter of convenience, and because precision is unnecessary, and because it cannot be reached in most cases. For meters larger than five-eighths domestic size, correspondingly larger figures should be used.

Second, a sum per annum representing approximately the cost of reading the meters, keeping the meter records, making bills, and collecting the money. The amount of this item depends upon the frequency upon which meters are read, and upon local conditions; for ordinary domestic services where meters are read once a quarter, $1 per annum may be a sufficient allowance. This figure may also be used without substantial injustice for services of all sizes, because when meters are read monthly the quantities are usually larger and the cost of meter reading becomes an inappreciable fraction of the bill.

Third, an amount which will represent the approximate average value to the works of the water that passes a domestic meter without being registered. The normal service of a domestic meter for one day may be assumed to consist of passing 200 gallons of water, more or less, in about two hours, the whole time being made up of many short intervals during the day. During the remaining twenty-two hours no water will ordinarily be flowing. If the service pipe and plumbing are perfectly tight, no water will pass during those twenty-two hours; if there is a leak of such size that the water lost by it will turn the meter, then the meter will register the flow throughout the twenty-four hours, and all the water passing will be recorded, except that there may be some slip in the meter at a low rate. If there is a leak in the service or plumbing which allows water to escape, but in amount so small that it does not serve to move the disc or piston of the meter, then the amount of water lost by such leakage in the twenty-two hours when the piston or disc is not moving will be entirely unrecorded. Probably no meter in ordinary service will register a flow of less than 100 gallons in twenty-two hours. Many meters in actual service will allow much larger quantities to pass without registering. It is probable that the plumbing in every house has leaks at times, through defective washers in the faucets or automatic valves which permit the loss of water in amounts too small to be recorded. In some houses such loss is always taking place. In the aggregate the amount of this unrecorded leakage from plumbing is large. It probably furnishes the greatest single reason why the amount of water registered by meters never approximates closely the total quantity of water furnished by the system.

Water lost in this way is running at a steady rate throughout the twenty-four hours, and increases but slightly the peak load of the plant. It can, therefore, be supplied at the lowest relative cost, and for the purpose of this estimate should be reckoned at the lowest rate charged for any water that is sold.

The amount lost per service will range from nothing to 100 gallons per day, and occasionally to much larger quantities. Assuming an average of 50 gallons per day per service at a minimum price of 10 cents per 1000 gallons, the value of water so lost amounts to $1.82 per service per annum.

There are no adequate data upon which this loss can be computed, and the Committee sees no way of securing such data at this time. Nevertheless it believes that the matter is an important one and that a substantial allowance should be made for such losses. It suggests for the present the use of $2 per annum for this item.

Upon this basis the service charge will amount to the sum of these parts, namely, first, 10 per cent of the average investment of the works in service pipe and meter; second, $1 per annum for reading meters, billing and collecting; third, $2 per annum for probable value of unregistered water. For a domestic service with $\frac{5}{8}$-inch meter, the ordinary service charge may properly be $3, where service and meter are paid for by the taker; $4 where the meter is furnished by the works; and $5 or $6 where both meter and service pipe are paid for by the works, the lower figure being used where the average cost of a service pipe is under $15, the higher where it is greater than $15.

The figures used in the above paragraphs should be considered only as general approximations, to be modified to meet established local conditions, or upon more complete data. The Committee suggests that the *method* is of first importance and should be first discussed and settled, and that the values to be then used under it should always be selected with reference to the conditions in each plant for which a service charge is to be established.

**Service Charges for Large Meters.** Service charges for large meters should be based in a general way upon their carrying capacity. The carrying capacities of different meters of the same size vary greatly, and it is no easy matter to get a general basis that will be sufficiently accurate at all points. The Committee considers in a general way that a 2-inch meter is equivalent in discharging capacity to ten $\frac{5}{8}$-inch meters, and it takes a 2-inch meter as the starting point for the discussion.

Comparison may be made on the basis of areas, that is, by the squares of the diameters. In the case of larger meters, this is nearly accurate. In the case of smaller ones, the diameters used to designate the meters are understood to be nominal and may differ somewhat from the exact figures. Nevertheless, the areas computed from these diameters do give something of an idea of the relative capacities.

The relative carrying capacities of disc meters at a fixed loss of head, as given in the American Civil Engineers' Pocket Book, page 967, may be used. It is of course understood that different makes of meters vary a good deal in their capacities. The figures mentioned were compiled by the chairman of this Committee some years ago, after receiving returns from various manufacturers of meters and examining records of experiments by a number of members of the association, and they were selected as being representative of the different sizes. Round figures were used, and they are to be taken as a general indication only.

The maximum normal amount of water supplied by each size, as deduced by this Committee from the returns made to it in the inquiry with reference to waste prevention, may also be used. The figures obtained in this way represent only a limited amount of data, but that is the best of its kind now available to the Committee. There are some irregularities in the scale. For instance, 2- and 4-inch meters are distinctly more popular and are used in larger relative numbers than some of the intermediate sizes, and in fixing the normal capacity of meters the influence of the tendency must be discounted to reach the fair relative capacities.

The relative capacities of meters of several sizes calculated in each of these three ways, taking the capacity of a 2-inch meter as ten in each case, are as follows:

| Size of Meter. | Ratio of Areas. | Ratio of Carrying Capacities of Meters at Fixed Loss of Head. | Ratio of Maximum Normal Outputs Indicated by Committee's Statistics. | Ratio Used for this Discussion. |
|---|---|---|---|---|
| 5/8 | 0.98 | 1.14 | 0.93 | 1.0 |
| 3/4 | 1.41 | 1.85 | 1.59 | 1.7 |
| 1 | 2.50 | 3.20 | 2.71 | 3 |
| 1½ | 5.62 | 6.25 | 3.60 | 6 |
| 2 | 10.00 | 10.00 | 10.00 | 10 |
| 3 | 22.50 | 20.80 | 18.40 | 20 |
| 4 | 40.00 | 35.00 | 53.00 | 30 |
| 6 | 90.00 | 62.50 | ............ | 60 |

**Service Charges Deduced from These Rates.** In the preliminary report of this Committee of September 9, 1914, it was suggested that the service charge for a $\frac{5}{8}$-inch meter would be made up of three parts, namely:

First, 10 per cent of the average investment of the works in the service pipe and meter.

Second, $1 per annum for reading meters, billing and collecting.

Third, $2 per annum for the probable value of unregistered water.

The item in this calculation for a large meter corresponding to the $2 per annum in the above schedule "for the probable value of unregistered water" must also cover any cost to the system that there may be in the extension of mains and other facilities that will be necessary in connection with the use of large service connections, and any value that there may be to the taker in having large quantities of water available instantly for any purpose.

With reference to the amount of water under-registered by large meters it is interesting to note that in the experiments made by F. C. Kimball, at Knoxville, presented to this Association on September 10, 1903, that of nine 6-inch meters furnished by their makers for test, only three were able to register a flow of 4500 gallons per day. In other words, in a majority of new 6-inch meters, 4500 gallons per day would pass entirely without registration. At 10 cents per thousand gallons, such an amount of leakage continuously for a year amounts to $164; and if on an average of 6-inch meters the leakage amounts to one-half this quantity, it amounts to $82 per annum.

The possibility of loss of this quantity of water, and in some cases of a much greater quantity, is not to be taken as the sole ground for the service charge. Nevertheless the facts that such losses are possible; that such losses do exist in many or most services; that the works have to furnish the water that is so lost; that the water costs money, and that the value of the water lost must be made up in some way, are among the substantial elements that must be considered in arriving at an equitable service charge.

Following the matter further, the service charges for larger meters are reached as follows:

| Size of Meter. | Relative Capacity. | $2 per Unit of Capacity. | Service Charge being $2 per Unit of Capacity with $1 Added. | Round Figure to be Used. |
|---|---|---|---|---|
| 5/8 | 1 | $2 | $3 | $3 |
| 3/4 | 1.7 | 3.40 | 4.40 | 5 |
| 1 | 3 | 6 | 7 | 7 |
| 1½ | 6 | 12 | 13 | 12 |
| 2 | 10 | 20 | 21 | 20 |
| 3 | 20 | 40 | 41 | 40 |
| 4 | 30 | 60 | 61 | 60 |
| 6 | 60 | 120 | 121 | 120 |

It is interesting to see how much per thousand gallons the application of these service charges would amount to for quantities of water that may be taken as the normal outputs for meters of the different sizes.

Taking annual quantities and smoothing the figures a little by taking into account both the actual performance as indicated by the Committee's returns and the possible performance as indicated by the relative capacities of the meters, we have the following tabular statement:

| Size of Meter. | Service Charge. | Greatest Normal Quantity per Annum Thousands of Gallons. 8% Load Factor | Least Normal Quantity per Annum Thousands of Gallons. | Service Charge in Cents per Thousand Gallons for Greatest Normal Quantity. | Service Charge in Cents per Thousand Gallons for Least Normal Quantity. |
|---|---|---|---|---|---|
| 5/8 | 3 | 300 | 0 | 1.00 | |
| 3/4 | 5 | 500 | 300 | 1.00 | 1.67 |
| 1 | 7 | 900 | 500 | 0.78 | 1.40 |
| 1½ | 12 | 1,800 | 900 | 0.67 | 1.33 |
| 2 | 20 | 3,000 | 1800 | 0.67 | 1.11 |
| 3 | 40 | 6,000 | 3000 | 0.67 | 1.33 |
| 4 | 60 | 9,000 | 6000 | 0.67 | 1.00 |
| 6 | 120 | 18,000 | 9000 | 0.67 | 1.33 |

This indicates that for the $\frac{5}{8}$-inch meter on the largest services normally handled by meters of this size, the service charge will amount to 1 cent per 1000 gallons. With one-sixth of this amount passing, which perhaps approximately represents the average work of a $\frac{5}{8}$-inch meter, the service charge is equivalent to about 6 cents per 1000 gallons. The table shows the corresponding figures for all the sizes. For the larger meters the service charge ranges from $\frac{2}{3}$ of a cent per 1000 gallons for meters working to the ordinary limit of their capacity, increasing to an average of about $1\frac{1}{3}$ cents per 1000 gallons for meters passing the smallest normal quantity which is taken as equal to the greatest normal quantity handled by a meter of the next smaller size. In other words, in a general way for manufacturing meters the service charges adjusted in this way would vary between $\frac{2}{3}$ of a cent and $1\frac{1}{3}$ cents and probably would average about 1 cent per 1000 gallons for meters working at normal capacity.

In connection therewith a manufacturing rate would naturally be selected about 1 cent per 1000 gallons less than would be used if these service charges were not to be collected.

With this procedure followed, the water works could always let the taker select the size of meter. If the taker selected a large one, the works would be insured of a return for it commensurate with its cost and with the probable general cost of supplying the extra mains and connections required in connection therewith and of standing the extra losses of water by leakage and under-registration that also must be anticipated. In other words, the water works plant would have no objection to the installation of large meters in any number if the takers were willing to pay for them. This the Committee believes is a logical condition for the best interests of the business. It can only be secured by the use of an adequate service charge.

If any taker has a meter which is worked to the limit of its capacity, that is to say, one that is supplying more than the ordinary maximum assumed for that size of meter, the effect would be that such a taker would get automatically a small discount on his bill, because the service charge for that meter would be applied to the larger quantity of water drawn through it. On the other hand, if a meter considerably larger than needed, or than is usual for the quantity drawn, were used, the service charge would amount to more per 1000 gallons than the normal amount, and the taker would be paying something extra for the extra capacity required and furnished to him by the works.

The use of such service charges would tend to discourage the use of unnecessarily large service connections and meters, and this is a desirable condition. On the other hand, with a 1-cent reduction in the manufacturing rates, there is no increase in bills in case of a normally busy meter.

The Committee suggests further that the service charge always be reckoned on the size of meter and not on the size of service pipe, thus giving an opportunity to one who has put in a meter that is too large to substitute a smaller one and get the benefit of the smaller service charge without having to change his service pipe. This arrangement also permits the use of a larger service pipe than is needed to anticipate reduction of carrying capacity by corrosion through a long term of years, without requiring the use of an unnecessarily large meter, with payment therefor.

The figures above mentioned in no case include 10 per cent of the cost of the service and meter as far as paid for by the works and included by the Committee as part of the service charge on $\frac{5}{8}$-inch meters, and this allowance should be added wherever the customer does not pay the first cost of the service and meter.*

**Meter Rent.** In some works a charge is made for the rent of meters furnished and owned by the department. Where such a charge is made it is in reality a service charge and it must be so classified. The service charge as now used ordinarily covers meter rent and much more, so that the meter rent represents only a fraction of the amount of what may be considered the normal service charge.

Cases may be found where meter rents are used in connection with a minimum rate, but with this minor exception

* Jour. N.E.W.W. Assoc., Vol. XXX, 1916, p. 467.

the service charge is not used in connection with a minimum rate.

**Intermediate Sizes of Meters.** There is a recent tendency to make intermediate sizes of meters in small sizes, and special types in large sizes which may have either greater or smaller relative capacities than the ordinary ones. There are also special kinds of large meters that have much less resistance.

The question of adjusting service charges to such special types of meters is obviously a difficult one. In principle, service charges should be rated somewhat according to the capacity of the meters; but on the other hand they must be rated along simple general lines, and it would seem best in general to classify special meters under that one of the classes used in this chapter to which such meters most nearly approach. There may be cases where an extra class will be necessary, but the need of it should be clearly shown before extending the classification.

The practical problem may be presented of what is to be done with a meter called of a certain size but really having the capacity of the next larger size or some approximation thereto. The general adoption of the service charge plan would offer some inducement to the taker if possible to find and use such a meter.

The best way of meeting this condition would seem to be to establish some standard limit of capacity for each of the various sizes, and if any particular type of meter exceeded the limit set for that size, it would then be classified as of the next larger size. No attempts will be made to set such standard limits at this time, but the matter is suggested as one that may have to be met by water works men as the business develops.

# CHAPTER VIII

## MINIMUM RATE BASED ON FRONTAGE

The frontage of the lot affects materially the total length of the piping system. Therefore there seems no other element which can serve so well and so justly as the measure of the constant yearly assessment as the length of frontage of the property.—Committee on Meter Rates, Freeman C. Coffin, Chairman, Jour. N.E.W.W. Assn., Vol. XIX, 1905, p. 325.

The minimum charge as outlined by the report of the Committee on Meter Rates of 1916 reflects solely the costs to the works in connection with the service and meter for which a service charge is made. The Committee did not include as part of its service charge any part of the expenses growing out of the distribution of water through the pipes in the streets. Service charges have been otherwise proposed and used which are greater relatively than those proposed by the Committee and which do reflect in part the cost of distribution.

In rates that have been suggested by decisions of the Wisconsin, Pennsylvania and New Jersey Public Service Commissions, service charges according to the size of meter have been suggested, sufficient to carry in addition to the direct costs of the service a part of the general cost of the distribution of the water.

The Coffin Committee on Meter Rates * made a suggestion of great merit in this connection. This suggestion has received less practical consideration than it deserves, but the underlying idea is reflected to some extent in water rates in use in a number of large cities of this country.

The idea was that the service charge should be based on the frontage of the property.

The method, in the words of the Committee, is as follows:

* Jour. N.E.W.W. Assn., Vol. XIX, p. 322, 1905.

### The Assessment Method

By this method the rates will be assessed as follows: A constant sum will be assessed each year upon each property based upon the frontage of the lot on one street, and without regard to the amount of water used. In addition to this assessment, a certain price per 100 cubic feet or 1000 gallons will be charged for all water used through the meter.

### Frontage Assessment

There are certain expenses of a water-works system which must be met as long as the works are operated, which are affected but little, if at all, by the amount of water used. These expenses should be met by a revenue which is also independent of the amount of water used. The total amount of such expense is dependent more upon the length of the piping system than upon any other element of the plant. The amount of water used affects the capacity of the pumping plant, but not in direct proportion, and in many works not at all. The requirement for fire protection fixes the pumping capacity. The amount used affects the capacity of the supply, but not necessarily its distance from the center of distribution.

The frontage of the lot affects materially the total length of the piping system. Therefore there seems no other element which can serve so well and so justly as the measure of constant yearly assessment as the length of frontage of the property. It is not material to the method how the frontage which shall be assessed is determined. It is probable that a municipality can assess all property, both that built upon, and vacant lots, while a company can only assess upon existing houses and their lots. It would seem to be fair that all buildings should be assessed, whether occupied or not. This, however, is not essential to the method. If vacant lots were not assessed, some limit to the amount of land to be assessed with each building would be necessary; for instance, each lot might be assessed upon a length not exceeding twice or three times the width facing the street, of the building upon it. A corner lot might be assessed upon one street only, or, as in the case of sewers, a certain frontage of the second street might be exempt. These details are not essential to the principle, and should be decided by the conditions of each case.

The exact proportion of the total annual expense of maintenance which should be assessed in this way is not essential. It seems to the Committee, however, that it would be substantially just if, in ordinary cases, one-half of the total amount to be raised were assessed upon frontage and the balance raised by meter rates based upon the total consumption. The price per 100 cubic feet, or 1000 gallons, in any place would then depend upon the total consumption. Taking the average place, it might be about 7½ cents per 100 cubic feet, or ten cents per 1000 gallons, based upon the water that would be measured through the meters. . . .

It is believed that this method will allow the use of meters on services with only a single faucet, and also in large houses in which little water is used, with substantial justice and with satisfactory results in revenue to the department. Aside from occasional exceptions, houses with a single faucet are small and on narrow lots, while large, well-plumbed houses generally have greater frontage. These different classes of property would bear their proportion of fixed charge in a fairly equitable manner. As long as each pays its fair proportion of fixed charges, there is no reason why a single faucet using large quantities of water should not pay for it, and on the other hand, why a large, fully plumbed house should pay for water which it does not use.

This method seems to be very well adapted for summer and winter resorts, where there is a great fluctuation in the use of water. Those consumers who actually use water for only a few months in the year must pay the fixed charges for the entire year through the assessments, and if they use a very large quantity of water during their short stay, pay for that at meter rates.

While places of this sort need metering as a means of water waste prevention more than any other places, it is very difficult to meter them under the methods of fixture rates now in use. The transient consumers, while using large quantities of water for a short time, do not use enough in the whole year to exceed the ordinary minimum rate, and thus, while making it exceedingly difficult and costly to supply them while in town, do not do their share (under ordinary meter rates) toward supporting the works, the fixed charges of which are tremendously increased by their requirements.

This class of consumers would be reached through the frontage assessment, and in such places the portion of the entire annual cost which was assessed upon frontage could be larger than in places with more normal conditions.

The whole report, and also the excellent discussion by members of the association that follows, is worthy of careful study. The members of the Committee were Freeman C. Coffin, Caleb Mills Saville, Henry V. Macksey, Frank E. Merrill and Charles F. Knowlton. The report was presented September 13, 1905, with unusual modesty; for the Committee states that it submits its report "with a profound sense of its inadequacy." It does not speak of its propositions as recommendations, but rather as suggestions of a somewhat tentative character that may be of some present value.

While the form of rate suggested in this report has not been directly adopted, the underlying principle of a service charge substantial in amount and independent of the amount of water drawn, as set forth in this report, is sound and has received increasing recognition.

In a large measure this report was the beginning of a rational system of meter rates for water in America.

**Application of the Method.** In a water-works system the number of services ordinarily ranges from 50 to 200 per mile, according to the size and density of population. Jordan, Gray & Ulrich,* in collecting statistics from 108 American systems in 1913, found 93 per mile. The last collection of statistics by the New England Water Works Association,† representing 44 systems, in the year 1914 shows 98 per mile. The records of some fourteen systems that have been appraised by the writer, and for which full statistics are available, show an average of 108 services per mile.

Taking into account that these reports represent systems all over the country, the closeness with which the figures agree is rather striking and indicates a normal figure of about 95 to 100 services per mile, or about 55 feet of main pipe for each service.

The average size of pipe in the streets is seldom less than 6 inches and rarely more than 8 inches, and the cost of the distribution system to each service will lie somewhere between the cost of 55 feet of 6-inch pipe and 55 feet of 8-inch pipe, with a proportionate part for gates and all other auxiliary and special costs of the system.

In a general way the cost to the distribution system per service at prices that prevailed up to 1916, may be taken as in the neighborhood of $100. The annual cost, including interest, depreciation and the maintenance of the distribution system, depending upon many local conditions, would ordinarily be between $6 and $10 per service, but with many figures outside these limits.

A part of the cost of this annual cost of distribution is ordinarily assigned to fire service, and the money representing

* Proc. Am. W.W. Assn., 1914, p. 231.

† Jour. N.E.W.W. Assn., Vol. XXIV, 1910, p. 440.

this part of it is raised in some other way than by means of water rates. After this is ascertained and deducted, the remainder of the cost of distribution may be taken to be a part of the service charge.

Under the procedure suggested by the Coffin report, the amount so found instead of being assessed as so much per service was to be assessed as so much per front foot of lot. By this means takers who occupied properties with long frontages would pay a higher water rate. This is fair from the standpoint of the cost of the additional length of pipe necessary because of their properties. The charge was to be made for frontage on a pipe even though no water was taken. In this way the increase in value in unoccupied property held for speculative purposes is made to pay tribute in some measure to the water department for the increased value given to it by the water service.

So far as has come to the attention of the writer, only one American city has adopted rates in the form recommended by the Coffin Committee. That city is Winnipeg, in Canada. The Winnipeg rates are found on page 56.

### Assessing Abutters for Distribution Pipes

The underlying idea of the Coffin report has been carried out by a number of cities, but in a different way from that suggested by the Committee. The cities referred to are Philadelphia, Milwaukee, St. Paul, Seattle and Los Angeles. There may be others, but these are the ones that have come to the attention of the writer. In these the cost of extending the water pipes is assessed on the owners of the property which the pipe passes. This method was in use in the cities mentioned long before the Coffin report was written.

There are variations in the procedure in the different cities with regard to this, and the procedure has not been carried out uniformly throughout the entire histories of all of these works. So far as it has been followed, the cost of the distribution system is assessed on the takers when they are first provided with water. That part of the capital cost of the plant represented by pipes in the streets in front of these properties is paid by the abutters at the start and the works never bear the burden of it. Where this is done the investment in works is correspondingly reduced and the water rates will normally be lower than they otherwise would be. In effect the takers own the distribution system and cannot be expected to pay a return upon its value and so get their water cheaper.

This system differs only from that recommended by the Coffin Committee, in that the assessment is paid once for all by the taker when the pipe is first laid instead of being paid as an annual service charge computed to cover interest and depreciation, or a part of them, on the value of the pipe. The cost of operation, taxes and other expenses is, of course, left to be provided for in some other way, but in general so far as the distribution of cost among different classes of consumers is concerned, it is the same as that outlined in the Coffin report.

This general method of assessing the cost of distribution has a great deal of merit, especially where rates are being adopted for an entirely new system. The radical departure from common practice has probably been the principal reason for limiting its use and this will probably continue to be a bar to its general adoption. It is especially important in any general study of water rates in American cities that this method be kept clearly in mind, however, because in those cases where it is used the water rates are much lower than they otherwise would be, and comparison of water rates in cities following this system with water rates in cities following the more common method cannot be properly made.

## CHAPTER IX

### COMPARISON OF SERVICE CHARGE, MINIMUM RATE, THE UNIFORM RATE, AND THE COMMITTEE'S ALTERNATE PROCEDURE BY MEANS OF AN EXAMPLE

This comparison is made in both tabular form and graphically. The tabular form will perhaps bring out the fundamental differences in the rates more clearly than could be done by any amount of discussion.

In that which follows only domestic services as defined by the Committee on Meter Rates, that is to say, services taking less than 820 gallons of water per day, are considered. To make the computation, twenty rates of draft are assumed to represent the whole range of quantities taken by such domestic consumers.

In selecting the twenty representative rates of draft the statistics of the Committee on Water Rates were used as a basis and a graphical plotting was used. Each quantity is selected to represent five per cent of the whole number of domestic takers. The quantities ascertained in this way probably represent nearly ordinary practice, although precision is not to be expected. The average daily quantity for all twenty is 152 gallons per service.

For these twenty rates of draft the annual bills are calculated by each of the methods that is to be compared. The first comparison is made with a service charge of $5 and a further charge of 20 cents per 1000 gallons for all water drawn. Applying this to each of the twenty quantities, it is found that the total computed collections would amount to $321.46, or $16.07 per service. The amount of collections per service is normal for a representative water works plant.

In the next place the uniform meter rate is calculated that would produce exactly the same revenue. The rate is ascertained by dividing the $321.46 by the total annual quantity for the twenty services, 110,738 gallons, and amounts to 29.03 cents per 1000 gallons. The exact figure is used so that the results will check.

A calculation is then made for a rate with an $8 minimum. Preliminary trial shows that the minimum applies to the first nine terms, and deducting the revenue resulting from this minimum from $321.46 and dividing the remainder by the aggregate quantity for the remaining eleven terms gives a required price of 25.87 cents per 1000 gallons. Applying this to the remaining terms the process is checked and the revenue is found to be the same as in the other cases.

In the next column the rates are calculated which if used in the Committee's Alternate Procedure would produce exactly the same total revenue. The calculation in this case is a little more complicated and is reached by two or three approximations. It is found that the rates will be 29.04 cents per 1000 gallons for the first 60,000 gallons and 20.71 cents for all larger quantities.

These rates then would produce identical total revenues for all domestic consumers for the assumed quantities. As the quantities were selected somewhat carefully to represent a normal plant, the comparative figures should give a very good idea of what the comparative rates would need to be used to give equal revenues in any case.

The rates that produce equal revenues are as follows:

Uniform rate without service charge or minimum, 29.03 cents per 1000 gallons.

Uniform rate with service charge, $5 and 20 cents per 1000 gallons.

Uniform rate with minimum rate, $8 and 25.85 cents per 1000 gallons.

Committee's alternate procedure of minimum rate and sliding scale, $8 and 29.04 cents for the first 60,000 gallons, and 20.71 cents for larger quantities.

The twenty quantities and the annual bills by the four methods are as follows:

| Serial No. of Services, Each Taken to Represent 5 Per Cent of the Whole Number of Domestic Takers, Arranged in the Order of Magnitude. | Daily Quantity in Gallons. | Annual Quantity in Gallons. | Service Charge of $5 and 20 Cents per 1000 Gallons. | Uniform Rate 29.03 Cents per 1000 Gallons. | Minimum Rate $8 25.87 1000 Gallons. | Alternate Procedure $8 Minimum, 29.04 and 20.71 Cents per 1000 Gallons. |
|---|---|---|---|---|---|---|
| 1 | 0 | 0 | $5.00 | $0.00 | $8.00 | $8.00 |
| 2 | 15 | 5,470 | 6.09 | 1.59 | 8.00 | 8.00 |
| 3 | 28 | 10,220 | 7.04 | 2.97 | 8.00 | 8.00 |
| 4 | 36 | 13,140 | 7.63 | 3.81 | 8.00 | 8.00 |
| 5 | 45 | 16,420 | 8.28 | 4.77 | 8.00 | 8.00 |
| 6 | 53 | 19,350 | 8.87 | 5.62 | 8.00 | 8.00 |
| 7 | 61 | 22,260 | 9.45 | 6.46 | 8.00 | 8.00 |
| 8 | 71 | 25,910 | 10.18 | 7.52 | 8.00 | 8.00 |
| 9 | 83 | 30,290 | 11.06 | 8.79 | 8.00 | 8.79 |
| 10 | 95 | 34,680 | 11.94 | 10.07 | 8.97 | 10.07 |
| 11 | 108 | 39,420 | 12.88 | 11.44 | 10.20 | 11.45 |
| 12 | 122 | 44,530 | 13.90 | 12.93 | 11.52 | 12.93 |
| 13 | 139 | 50,730 | 15.15 | 14.73 | 13.12 | 14.73 |
| 14 | 160 | 58,400 | 16.68 | 16.95 | 15.10 | 16.96 |
| 15 | 188 | 68,620 | 18.72 | 19.92 | 17.75 | 19.20 |
| 16 | 220 | 80,300 | 21.06 | 23.31 | 20.77 | 21.62 |
| 17 | 260 | 94,900 | 23.98 | 27.55 | 24.55 | 24.65 |
| 18 | 320 | 116,800 | 28.36 | 33.91 | 30.21 | 29.18 |
| 19 | 420 | 153,300 | 35.66 | 44.50 | 39.66 | 36.74 |
| 20 | 610 | 222,640 | 49.53 | 64.63 | 57.60 | 51.10 |
| Sum........... | 3034 | 110,738 | 321.46 | 321.47 | 321.45 | 321.42 |

The four rate scales plotted in the ordinary way, but showing domestic takers only, are shown in Fig. 20.

If we take the rates calculated for the service charge and a rate of 20 cents per 1000 gallons as representing what the bills fairly ought to be in each case and find the differences for each of the twenty takers under the three other methods of calculation, the average differences are found to be as follows:

| | |
|---|---|
| Uniform rate. | $3.68 |
| Uniform rate with a minimum | 2.07 |
| Committee's alternate procedure. | 1.14 |
| Service charge | 0 |

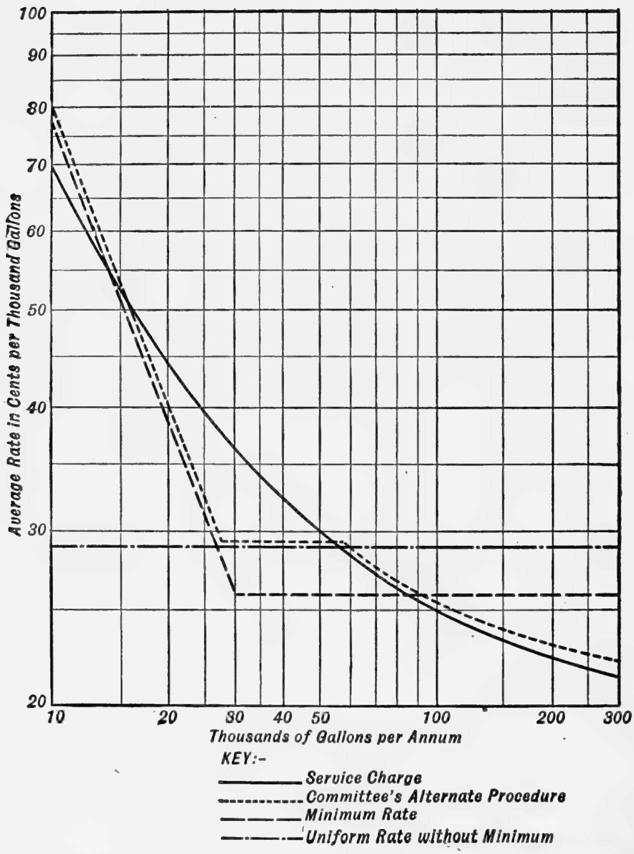


FIG. 20.—Showing Four Kinds of Meter Rates Arranged to Produce the Same Total Income from all Domestic Takers.

The gain in uniformity with each successive step as compared with the preceding one is noteworthy, but the procedure of a service charge is much better than any of the others and is as simple and easy as any in application.

It may not be amiss to repeat for emphasis that for normal conditions equal revenue will be obtained from all domestic takers by these rates:

(*a*) A rate of 29 cents per 1000 gallons, with no minimum.

(*b*) A rate of 26 cents per 1000 gallons, with an $8 minimum.

(*c*) A rate of 20 cents per 1000 gallons, with a $5 service charge.

Similar differences will be found for other ordinary rates.

# CHAPTER X

## AS TO SERVICES AND METERS

As the practice of furnishing, setting and repairing water meters, by the department rather than the consumer, increases, the public prejudice against meters will also decrease.—M. N. Baker, Editorial, Engineering News, Vol. XLV, 1901, p. 285.

By service is meant every connection with the main pipes in a water-works system placed for the purpose of supplying takers. All services may be classified into three divisions:

*First:* Dead services, being services that may have been used, but that have been discontinued and for which there is no probability of further use. All services should be classed as dead where there is not a definite prospect of resumption of use within a reasonable time.

*Second:* Live services, including all services in actual use and those temporarily out of service, as where water is shut off from houses that are not rented.

*Third:* Reserve services, including all services which have not yet been used. These are mainly services which have been placed in anticipation of future business, as, for instance, in advance of paving when a street is to be improved.

For the purpose of comparing systems with each other, of finding the proportion of services to population, the amount of water sold and unaccounted for per service, the number of live services should always be taken as the basis of statement. All services in the first and third classes should be excluded.

Live services may be further subdivided into services in use each of which is represented by a bill for the current accounting period, and services that are shut off, being services to houses temporarily vacant and where the water is shut off and where there is no bill for the current accounting period.

The distinction between services in use and shut off is sometimes hard to draw with precision and it is not necessary in case of difficulty to attempt an exact classification.

With the service charge system, as far as it is feasible, the service charge should run on continuously with all live services. If the house is empty, the service charge only is paid and there is no bill for water because no water is drawn. With this system carried out, the distinction between services in use and services shut off would disappear as a bookkeeping proposition.

Only in the case of works owned by a company which deals with tenants to a considerable extent and cannot collect the service charges when the house is vacant does this distinction become important. In that case the service charges must be made higher by a percentage that will make the returns from services in use equal to what they might otherwise be on all live services. Information from two water companies for a limited period indicates that on an average 8 or 9 per cent of live services do not appear in the bills for any one accounting period. The percentage obviously will vary with different systems and in different years and also with the length of the accounting period.

**Multiple Services.** It frequently happens that a single taker has a number of meters or services, and the questions arise as to how these are to be counted and as to whether the meter rates on a sliding scale are to be applied to the quantity drawn through each service or meter separately, or whether the quantities may be consolidated before applying the rate. With the uniform rate it makes no difference which is done. With the sliding scale there is an advantage to the taker in the latter practice. It is difficult to make invariable rules that will cover all such cases, but in general the following principles should govern.

*First*, where meters are set in batteries or where there are several connections to different mains from the same establishment, all connecting with the same interior pipe system, for the purpose of securing greater capacity or greater certainty of service, the whole should be treated as a single service and the readings of all the meters should be added up and the rate applied to the total quantity of water.

*Second*, where any taker requires two or more services because water is used in different buildings, or in different parts of the same building, or because he wishes to have a separate record of water used in different parts of his establishment, and in general wherever separate services are required because the taker needs water in different places or in separate services, then each meter should be classed as one service and billed separately and without regard to any other services that the same owner may have.

**Ownership of Services and Meters.** There is a difference in practice among the water-works systems of the United States with reference to the ownership of the service pipe to the street line and the meter. The pipe on the land of the taker is paid for by the taker in all cases; in other words, the taker provides the pipe beyond the street line and takes care of it.

The cost of the service pipe and meter is a substantial one and it makes some difference with meter rates whether the cost of it is paid by the works or by the taker.

From information relating to 150 systems collected by the New England Water Works Association Committee on Meter Rates in 1914, about half the systems in New England and the other half scattered over the United States, it appears that in 46 per cent of the systems the service pipe is furnished and paid for by the works; in the remaining 54 per cent of the systems it is paid for by the taker upon installation. Of these same systems, 77 per cent furnished the meter, while 23 per cent required the taker to furnish it.

The tendency in recent years had been for the works to furnish more service pipes and more meters than formerly. With respect to the meter there is no question but what it is the best policy for the works to furnish it and to own it. This is the only method that gives the works the full control of the meter, with power to take it out and test it and replace it with a new meter, or repair it whenever the conditions of service make it desirable.

The advantage of this procedure and the disadvantages of having the meters owned by the takers are so great and so well known to all practical water works superintendents that there should be no question upon this point. The works ought to own the meters in all cases.

With respect to the ownership of services, there are no correspondingly strong reasons for ownership by the works. It is principally a matter of finance. If the works furnish the service pipes they are entitled to earn a return upon the amounts invested in them and the water rates will be higher than they otherwise would be. If the taker pays for the service pipes, in the natural course of events he will enjoy a rate that is lower by an amount corresponding to the annual value of the investment in his service pipe.

In comparing meter rates of different systems, especially when comparing the rates for small quantities of water, it is necessary to take into account this divergence of practice with reference to service pipes in some way. The annual interest and depreciation on the value of the service pipe and meter is large enough in proportion to the amount of business done by a small service to make it a matter that cannot be overlooked.

The Committee on Water Rates decided to make an allowance for these differences in conditions which would bring all the water rates on the same basis. The Committee's procedure was:

> To deduct 10 per cent of the average cost to the works of each service from the amount computed by the schedule for each quantity. This course is followed and . . . the annual rates that follow are thus reduced by an amount equal to 10 per cent of the works' contribution to the cost of each service. Obviously in applying any rates deduced from these figures to a particular case, it will be necessary to add one-tenth of the corresponding contribution to the works to the cost of services in that plant.*

And the Committee later on carried 10 per cent of the cost of the service and meter, as far as that cost was borne by the works, into the service charge.

The 10 per cent used in this calculation is an approximate round figure, believed by the members of the Committee to be

* Jour. N.E.W.W. Assn., Vol. XXVIII, 1914, p. 203.

about right for ordinary average conditions. Obviously somewhat varying percentages might be used to meet local conditions, if such a refinement were necessary. The 10 per cent may be assumed to be made up of 6 per cent for interest and 4 per cent for depreciation and repairs, the depreciation being less as the repairs are greater, or to be made up of 5 per cent for interest and 5 per cent for repairs and depreciation.

The mean cost of a service and $\frac{5}{8}$-inch meter in 81 systems reported to the Committee was $26.30, the median was $25.40, and 80 per cent of the terms fall between $17.60 and $34.60. In a similar way the cost of the service and meter, as far as borne by the works amounts to an average of $14.75; the median is $15 and 80 per cent of the terms fall between 0 and $25.50 per service.

On the face of the returns, 56 per cent of the combined cost of services and meters are borne by the works, the remaining 44 per cent being collected from the takers at the outset.

These data relate to conditions before the war and do not reflect costs in 1917.

**Cost of Large Services and Meters.** The above relates only to services supplied with meters $\frac{5}{8}$-inch in diameter. The cost for larger services and meters increases rapidly with the diameter. It also varies greatly with local conditions, such as frost and depth of cover, whether the meters may be set in cellars or must be set in special vaults outside, and other local matters.

**Metering Water for Public Purposes.** Water-works systems supply public uses, as, for instance, drinking fountains; water required for flushing sewers; water required for public buildings, including city halls, schoolhouses, etc.; water used for sprinkling streets. They also supply semi-public uses, such as private schools, churches, educational and charitable institutions.

In many cases water is supplied for public purposes without charge and for semi-public purposes at reduced rates, and where water is not charged for it has frequently happened that meters have not been applied.

The only satisfactory way to conduct a water department on the meter system is to meter every service whether public or private and whether the water is paid for or not. Good business management requires that all water should be paid for.

For all use of water in public buildings, for street sprinkling, sewer flushing and public fountains, useful or ornamental, the municipality should pay the same rates as any private consumer for like service, the water department being conducted strictly as a business enterprise.—J. C. Chase, Jour. N.E.W.W. Assn., Vol. XVII, 1903, p. 175.

Even where works are owned by the city, other city departments using water should pay for what they use. Their appropriation should be made sufficient to make this possible. The water works department is entitled to the revenue as part of its just earnings, and to require that certain takers be furnished without charge, or at less than cost, simply means that other takers must pay higher rates.

Only a few American cities have actually followed this practice, but it is to be highly commended, and on its merits it ought to be everywhere adopted.

Most American water departments have supplied water without charge to other city departments, and the water departments have had to pay dearly for this generosity. For other city departments receiving water without cost and without limit are the most incorrigible wasters of water. The loss of water, which is equivalent to loss of revenue, and to increased operating expenses to keep up the supply, is a direct hardship on the water departments. Further the loss is not limited to the direct loss. The example of public waste of water is irreconcilable with demands for private suppression of waste, and the public is not slow to see the point and act on it.

The only adequate way to stop this abuse is to meter the water to each department and collect for it at current rates from the appropriations for that department.

It need only be suggested that no successful commercial or manufacturing business is operated without making charges between different stores, factories and departments, and the necessity for such charges is certainly not less in city business.—Hazen, "Clean Water," p. 167.

Where it is required by law or by custom that certain services should be furnished without charge there is a procedure that has been sometimes used with the best of results. This consists in making a formal estimate of the amount of water reasonably needed for each such service, and notifying those responsible for it of the estimates; the service is metered and thereafter water to the extent of the estimate is furnished without charge, but water in excess of the estimate is charged at the usual rates, or perhaps at the manufacturing or wholesale rate. The amount estimated is usually so many gallons per capita daily for each person. Thus 75 gallons per person may be estimated for a hospital or 15 gallons per person for a school, for school days only. The following rules illustrating this method are from the regulations of the water department of Columbus, Ohio.

*Free Water.* Water will be furnished free of charge under conditions made compulsory by the laws of the State of Ohio.

*Free Water to be Metered.* All services to which water is supplied free of charge must have meters.

*Maximum Allowed.* The following average daily per capita allowance of free water, based on the average number of inmates and attendants, shall be granted as a maximum free of charge to such institutions, to wit:

Hospitals, 75 gallons per capita; asylums and other charitable institutions devoted to the relief of the poor, the aged, the infirm or destitute persons, or orphan children, 40 gallons per capita per day. Police stations and jails, work houses, fire engine houses, public bath houses and other public buildings, parks and other public grounds, as may be estimated by the Superintendent of the Water Department.

*Pay for Consumption above Maximum.* All such institutions as enumerated in the foregoing shall pay for all water used or that passes through meters that supplies such institutions, etc., at the city meter rate, for all consumption above such maximum.

The Superintendent of the Water Department shall determine as closely as possible the average daily population of such institutions for the collection period, to the end that free water may be distributed as is provided by law for such institutions, but that waste, and the use of water for power purposes, may be prevented, save as payment therefor may be made.

For some public uses it is not practicable to meter the water. Such uses are temporary ones, as, for instance, flushing sewers through hose from hydrants, but in all cases it is possible to make a more or less close estimate of the quantity of water that is used. For instance, in drawing water from hydrants the amount of opening and the pressures and the recorded time of flow give a basis for at least a fairly approximate calculation.

In street sprinkling the number of carts and the number of times that they are filled, with the known capacity of each cart, gives an approximate basis of calculation.

Knowledge of the amount of water used for public purposes is also necessary in order to make a correct balance sheet of quantities for the system and to show what the loss and unaccounted for water really is. Correct knowledge upon these points goes to the heart of a correct application of the meter system and to a fair adjustment of meter rates.

The use of meters should be insisted upon on public services, even where it is not possible to make charges for the water. Meters have been installed under these conditions frequently in America. One conspicuous case was metering all the public buildings in Washington even though the government as owner of the water works does not permit any charges to be made for the water. In this and other cases publicity of the results and an unwillingness of those in charge to have the buildings in their control use excessive amounts of water has led to overhauling of fixtures, the suppression of many leaks and the stopping of unwarranted drafts, and even though no pecuniary reward followed the restriction of waste, the actual consumptions have been greatly reduced.

**As to the Size of the Meter.** Practice in regard to determining the size of the meter is divided. Sometimes the size of meter is determined by the area of floor space in the building supplied.* In this case the determination is made by the department and the customer has nothing to say about it.

When the customer furnishes the meter, he sometimes is allowed to use any size that he selects. This condition is unfortunate, as the taker is not ordinarily well posted and frequently selects a size that is not appropriate to his use.

Where the service pipe is of material that corrodes and loses its carrying capacity, such as wrought iron and steel, galvanized or otherwise coated, the meter should be of a smaller size than the service pipe. For other than the smallest size of domestic meters, it would also appear a wise provision to make

* W. W. Brush, Proc. Am. W.W. Assn., 1912, p. 35.

the settings as far as possible so that if the meter first installed proved to be too large or too small, another size could be readily substituted for it without undue disturbance of conditions.

In some cities the use of meters in batteries is common; that is to say, a considerable number of meters, perhaps 2 inches in size, are set in parallel and as many of them are connected all the time as the business requires. This has the advantage that the meters can be taken out in detail for inspection and repair without disturbing the service.

John Thomson, whose wide experience as a designer and maker of meters qualified him to speak with authority, stated: *

> Probably three-fourths of the meters in public use to-day are considerably underworked; that is, if proper judgment could be depended upon in selecting the capacity of the meter to do the duty to be performed, still more compact and less expensive nominal sizes might be the result.
>
> The opinion then expressed has been but strengthened by experience meantime gained; and while there is no more exasperating and inexcusable fault than to set a meter so as to be damaged by over-running, a fault promptly made evident, but little is ever said or known regarding the opposite condition, that is, under-running, which prevails to a much larger extent than is generally supposed. The reason for the latter is probably too often due to the greater convenience of measuring the diameter of the pipe, to which the contemplated attachment is to be made, rather than measuring the quantity which the pipe can deliver.
>
> The writer believes that there is but one reliable and satisfactory method for practically determining the proper maximum capacity of a meter to be applied to a service, namely, to insert a meter in circuit, open all the valves or faucets and time the operation of the meter for one, five or ten minutes. Thus, if a $\frac{3}{4}$-inch meter has been set and its full delivery is only, say, $1\frac{1}{2}$ cubic feet a minute, then in the majority of cases a $\frac{5}{8}$-inch meter would satisfactorily replace it and so on through the range of sizes.

The Committee on Meter Rates examined its statistics to ascertain how much water was ordinarily passed by meters of different sizes. This study rested on the fundamental assumption that the largest meter in any system supplies that service in the system from which most water is drawn; and that all the other services are to be assigned to the meters of the several sizes in the order of their outputs. This is not strictly correct,

* Jour. N.E.W.W. Assn., Vol. VIII, 1894, p. 63.

but for practical purposes it may not be much in error, because there are bound to be as many larger meters coming under any given limit as there are smaller meters exceeding it. There will be some variations both ways, but in the aggregate these will balance.

The limits that were found were as follows:

| Size of Meter. | No. of Systems Represented in the Calculation of this Item. | Cubic Feet per Quarter. | Gallons Daily. | Load Factor, Per Cent. |
|---|---|---|---|---|
| $\frac{5}{8}$ | 11 | 8,600 | 705 | 6.9 |
| $\frac{3}{4}$ | 11 | 15,000 | 1200 | 6.9 |
| 1 | 12 | 25,000 | 2050 | 6.6 |
| $1\frac{1}{2}$ | 9 | 33,500 | 2740 | 4.4 |
| 2 | 11 | 92,000 | 7580 | 7.4 |

Examined in this way, it appears that the normal maximum output for one $\frac{5}{8}$-inch meter (data for 11 systems) is 705 gallons per day. In other words, averaged by systems there are as many $\frac{5}{8}$-inch meters as there are services from which less than 705 gallons per day are drawn. The average output from all the $\frac{5}{8}$-inch meters is considerably less than this. Averaged by systems, it seems to be about 116 gallons per day. The 705 gallons per day, or 8600 cubic feet per quarter, is the normal maximum limit for output of a meter of this size.

Different systems vary rather widely in the maximum limits for $\frac{5}{8}$-inch meters, quantities ranging from 220 to 1370 gallons daily being found. This difference is to be attributed principally to the divergence in practice with reference to the use of $\frac{3}{4}$-inch meters on the larger domestic services.

The classification of quantities is not available for some of the systems using the largest proportion of $\frac{3}{4}$-inch meters, and, if these statistics were available and were included, it is probable that it would lower considerably the average limit for the $\frac{5}{8}$-inch meter probably to between 300 and 400 gallons daily. There is a similar but less marked variation at the line between the $1\frac{1}{2}$-inch and the 2-inch meters.

The detailed figures show considerable divergence of practice with reference to the amounts of water that meters of all sizes will handle, but the divergence with respect to the line of division between $\frac{5}{8}$-inch and $\frac{3}{4}$-inch meters is much greater than elsewhere. An interesting and profitable subject for discussion would be the question as to whether it is better to use a $\frac{5}{8}$-inch meter or a $\frac{3}{4}$-inch meter for service drawing from 300 to 1000 gallons per day. Such a discussion would tend to establish the principles that should govern, and it might aid in reaching a more logical and scientific method of determining the size of meters required for various services.

It is of course true that services are occasionally found which require water at a certain rate, and where that rate determines the size of meter even though the total aggregate draft is small; but it would seem as though, generally speaking, some relation between the normal rate of draft and the size of meter in the larger domestic services might be found.

The New Orleans annual reports for the years 1913 and 1914, George G. Earl, general superintendent, show the average daily drafts of water by meter sizes. These with similar data collected by the author for the Spring Valley Water Company at San Francisco for the year 1916 are as follows:

AVERAGE DAILY DRAFT PER SERVICE, IN GALLONS

| Size of Meter, Inches. | Average Daily Draft per Meter in Gallons. | | | Load Factors. | | |
|---|---|---|---|---|---|---|
| | New Orleans 1913 | New Orleans 1914 | San Francisco 1916 | New Orleans 1913 | New Orleans 1914 | San Francisco 1916 |
| $\frac{5}{8}$ | 148 | 162 | ........ | 1.44 | 1.58 | |
| $\frac{3}{4}$ | 370 | 410 | 890 | 2.12 | 2.35 | 5.11 |
| 1 | 1120 | 1,100 | 1720 | 3.65 | 3.59 | 5.60 |
| $1\frac{1}{2}$ | 2400 | 3,100 | 2890 | 3.91 | 5.04 | 4.70 |
| 2 | 6100 | 6,500 | 6700 | 5.96 | 6.35 | 6.54 |
| 3 | ........ | 33,800 | ........ | ........ | 16.50 | |
| 4 | ........ | 8,350 | ........ | ........ | 2.72 | |
| 6 | ........ | 9,850 | ........ | ........ | 1.60 | |
| 8 | ........ | 47,500 | ........ | ........ | 4.64 | |

### As to the Capacity and Resistance of Meters

The importance of the loss of head cannot be overestimated. Upon one hand the consumer usually objects to any appreciable lowering of the efficiency of his service pipe as a water carrier, and on the other hand the water department desires to set as small a meter as possible in order to reduce the expense. With meters showing a small loss of head, it is often possible to set meters of a smaller size than the service pipe, which would not be wise with meters showing a large loss of head. It is economy to put the meter department in the hands of a competent engineer who is posted on the flow of water, and who will not always insist on setting a meter of the same size as the pipe when one much smaller is ample for the work. During the past year a number of places have been found having 4-inch services where a 1-inch or 1½-inch meter was ample to measure all the water used. —J. Waldo Smith, Trans. Am. Soc. C.E., 41, 1899, p. 360.

The most commonly used kinds of meters in the United States are:

(1) Disc meters, consisting of an oscillating disc in a case moved by the water and communicating the motion which represents a certain volume of water to a gear train which indicates the amount on a dial, and

(2) Rotary meters, being meters in which an irregular or cylindrical drum rolls in a rotary manner in the interior of a case.

Other types, used mainly for large services, are

(3) Compound meters for large sizes are a combination of two meters, a small one to register small flows and a large one to register large flows, with an automatic appliance for shifting the flow from one to the other.

(4) Inferential meters, consisting of a wheel or other discs moved by the flowing water, by impact and without positive displacement. There are many variations of this type.

With a great majority of water meters the frictional resistance increases as the square of the quantity passing. In other words, the resistance is always a certain number of times as great as the head that would theoretically produce the velocity of the entering water.

Water meters are usually arranged to handle satisfactorily all the quantities of water that are likely to pass through a pipe of the size represented. They may even pass more than this when installed on pipe of larger diameter.

Manufacturers' ratings of the capacities of meters have been somewhat arbitrary and are usually higher than the limits of ordinary practice. Recently the practice has been adopted of stating capacities as the quantities that will pass under 25 pounds loss of head in the meter.

Different types of meters vary greatly in frictional resistance. The following table shows approximate representative figures for the sizes of meters in common use.

CAPACITY AND RESISTANCE OF WATER METERS

| Nominal Size of Meter, Inches. | Manufacturers' Rating, Gallons per Minute for Loss of Head of 25 Pounds. | Moderate Rating Used in Computing Capacities about 5 Pounds Loss of Head. | | | | Number of Feet of Straight Pipe Having about the Same Resistance at All Velocities as the Meter. |
|---|---|---|---|---|---|---|
| | | Gallons per Minute. | Millions of Gallons per Annum. | Millions of Cubic Feet per Annum. | Velocity in Pipe of Exact Diameter. | |
| $\frac{5}{8}$ | 21 | 7.11 | 3.74 | 0.50 | 7.439 | 12 |
| $\frac{3}{4}$ | 35 | 12.09 | 6.36 | 0.85 | 8.783 | 12 |
| 1 | 62 | 21.33 | 11.22 | 1.50 | 8.717 | 16 |
| $1\frac{1}{2}$ | 100 | 42.67 | 22.44 | 3 | 7.748 | 40 |
| 2 | 160 | 71.7 | 37.40 | 5 | 7.264 | 60 |
| 3 | 390 | 142.2 | 74.81 | 10 | 6.458 | 100 |
| 4 | 570 | 213.3 | 112.21 | 75 | 5.449 | 200 |
| 6 | 1000 | 426.7 | 224.42 | 30 | 4.843 | 500 |

There is considerable variation in the frictional resistance of meters of different makes and also in meters from the same factory at different times, and the above is to be taken only as a general approximate indication. These capacities have been used for another purpose in Chapter IV, p. 34.

It is further to be noted that there is a recent tendency to introduce intermediate and odd sizes of meters and meters of special capacities.

**Load Factor.** In that which follows, the percentage which the actual average sales from any meter is of the moderate rating in the above table will be referred to as the "load factor." Thus a 2-inch meter passing 1,000,000 gallons of water per annum, must run at the moderate rating $\frac{1}{37.4}$ or 2.67 per cent of the time; and its load factor is thus 2.67 per cent.

For a large water-works system for 1916, where there was an opportunity to examine in considerable detail the records of the meters, the following conditions with respect to load factors were found.

Of 3567 meters, ¾-inch and over, 224 or 6.3 per cent of the whole number, carry a load of less than 0.1 per cent, or one-thousandth of their normal capacity. These meters are mainly 2 inches and over and are practically all on services used only for fire purposes and not for furnishing water. Excluding these, those that remain do supply water for ordinary uses and the following conditions were found:

| Load Factor. | Per Cent of Whole Number of Meters, Excluding Those Used Only for Fire Services. |
|---|---|
| Under 1 per cent..... | 14 |
| 1 to 2 per cent...... | 19 |
| 2 to 4 " " ...... | 25 |
| 4 to 8 " " ...... | 22 |
| 8 to 16 " " ...... | 13 |
| 16 to 32 " " ...... | 5 |
| Over 32 per cent..... | 2 |

The average load factor for all of these meters was 6.5 per cent.

The load factors for the sizes taken separately differed little and the figures for all may be taken as applying substantially to each size ¾ inch and over.

The size of meter that is used in each case depends more upon the whim of the taker and the idea of the superintendent or foreman who sets it than upon any logical consideration of the business. The variations found in this example are too large for a sound business basis and should be reduced.

Most of the meters that run on very high load factors are on services supplying water through tanks, and in such cases, as far as the service is satisfactory, there is no reason for changing; in fact, generally speaking, the taker can be counted upon to object if his meter is too small and to demand a larger one. On the other hand, a meter much larger than is necessary may be allowed to continue for a long time, and because of its greater slip with small quantities much water may be passed without registration.

In a tentative way it may be suggested that wherever any meter $\frac{3}{4}$ inch and over in size is running on less than a 2 per cent load factor that the local conditions be inspected to see if a smaller meter will answer as well and if so to change it. The substituted meter may be in general of such size that the load factor will be between 4 and 8 per cent, this being the most common range. This procedure is suggested tentatively, and in case considerable savings are made by it, it may afterwards be extended to meters running on higher load factors.

## CHAPTER XI

## AS TO THE WATER THAT CANNOT BE ACCOUNTED FOR

Even in fully metered systems about 20 per cent of the total water supply is unaccounted for by sale to consumers.—F. A. Barbour, Jour. New England W.W. Assn., Vol. XXX, 1916, p. 440.

There is always a substantial percentage of the water that cannot be accounted for by meters. The table on page 20 is taken from the statistics compiled by the Committee on Water Rates.*

These records from 29 systems, mainly for the year 1915, after allowing for all the water sold and measured, or otherwise accurately estimated, show an amount that cannot be accounted for of 130 gallons per service daily.

The water not accounted for averaged 27.0 per cent of the total output. For the several systems, it ranges from 12 to 49 per cent. Nine systems, or nearly one-third of the whole number, showed more than 80 per cent accounted for, and 4 systems, or one-seventh of the whole number reporting, showed more than 85 per cent of the water accounted for.

The amounts not accounted for per service vary from 11 gallons to 385 gallons daily. For 7 systems, or one-fourth of the number reporting, the water not accounted for was less than 50 gallons per service, while for 2 systems less than 40 gallons per service is reported.

**Where the Water is Lost.** The water that is not accounted for is made up of various sources of loss. Included among these are the following:

1. Leakage from the mains in the streets.

2. Leakage from the service pipes between the mains and the meters.

* Jour. N.E.W.W. Assn., Vol. XXX, 1916, p. 454.

| System. | No. of Services. | Millions Gallons Daily. Total Output. | Recorded by Meters. | Otherwise Accurately Estimated. | Not Accounted For. | Unaccounted for Water. Per Cent of Output. | Per Service Gallons Daily. | Per ⅝-inch Unit of Service Gallons Daily. |
|---|---|---|---|---|---|---|---|---|
| Cleveland | 94,881 | 78.23 | 61.59 | 5.12 | 11.52 | 14.7 | 122 | 85 |
| Peoples Water Co | 61,325 | 16.06 | 12.75 | ... | 3.28 | 20.4 | 53 | 48 |
| New Orleans | 51,093 | 25.10 | 15.90 | ... | 9.20 | 36.7 | 180 | 113 |
| Seattle | 41,831 | 30.00 | 22.90 | ... | 7.10 | 23.6 | 177 | 87 |
| Atlanta | 29,733 | 16.99 | 12.30 | 2.55 | 2.14 | 12.6 | 72 | 59 |
| Syracuse | 26,870 | 19.50 | 10.75 | 0.03 | 8.72 | 44.7 | 325 | 237 |
| New Bedford | 14,138 | 7.65 | 6.54 | 0.07 | 1.04 | 13.6 | 74 | 47 |
| Springfield, Mass. | 13,529 | 10.60 | 7.95 | ... | 2.65 | 25.0 | 192 | 89 |
| Houston | 11,652 | 4.86 | 2.81 | ... | 2.05 | 42.2 | 176 | 118 |
| Springfield, Pa | 11,614 | 5.163 | 3.547 | 0.264 | 1.353 | 26.3 | 116 | 85 |
| Yonkers, N. Y | 9,842 | 8.310 | 5.560 | 1.470 | 1.260 | 15.4 | 130 | 90 |
| Brockton, Mass. | 9,416 | 2.830 | 2.140 | ... | 0.690 | 24.4 | 73 | 59 |
| Malden, Mass. | 8,052 | 2.243 | 1.410 | ... | 0.833 | 37.0 | 103 | 93 |
| Oak Park, Ill | 6,998 | 2.060 | 1.700 | 0.060 | 0.300 | 14.6 | 43 | 37 |
| New Rochelle, N. Y. | 6,676 | 3.500 | 1.878 | ... | 1.622 | 46.4 | 243 | 189 |
| Poughkeepsie, N. Y. | 5,157 | 2.410 | 1.431 | 0.220 | 0.759 | 31.5 | 147 | 118 |
| Chelsea, Mass. | 4,748 | 3.060 | 2.210 | ... | 0.850 | 27.7 | 179 | 144 |
| Monmouth, N. J. | 3,991 | 0.738 | 0.527 | ... | 0.211 | 28.6 | 53 | 45 |
| Woonsocket, R. I. | 3,905 | 1.820 | 1.490 | 0.020 | 0.310 | 17.0 | 79 | 47 |
| Western N. Y. Water Co. | 3,845 | 6.500 | 5.020 | ... | 1.480 | 22.7 | 385 | 174 |
| Meridian, Miss. | 3,921 | 2.850 | 1.560 | 0.710 | 0.580 | 20.3 | 160 | 131 |
| Winthrop, Mass. | 2,783 | 0.698 | 0.566 | 0.002 | 0.130 | 18.6 | 47 | 37 |
| Miami, Fla | 2,497 | 1.220 | 0.624 | ... | 0.596 | 48.9 | 239 | 198 |
| Milton, Mass. | 2,002 | 0.340 | 0.289 | ... | 0.051 | 15.0 | 26 | 14 |
| Wellesley, Mass. | 1,550 | 0.470 | 0.267 | ... | 0.201 | 42.8 | 130 | 106 |
| Belmont, Mass. | 1,328 | 0.400 | 0.316 | ... | 0.084 | 21.0 | 63 | |
| Middleboro, Mass. | 1,127 | 0.330 | 0.199 | ... | 0.131 | 39.7 | 116 | 104 |
| Duxbury, Mass. | 281 | 0.047 | 0.030 | ... | 0.017 | 35.1 | 59 | 58 |
| Addison, N. J. | 254 | 0.019 | 0.016 | ... | 0.003 | 15.3 | 11 | 11 |
| Average | ..... | .... | .... | ... | .... | 27.0 | 130 | 94 |

3. Under-registration of meters.

4. Water used for various purposes, not registered or estimated, as, for instance, water used for flushing sewers.

5. Loss by seepage and evaporation from service reservoirs.

The Committee had no means of distributing the total loss among the different sources of loss, but stated its belief that under-registration of meters accounts for a substantial part of the total loss in systems where the pipes and service pipes have been carefully and systematically followed up for leakage and where there have been no considerable uses of water for flushing sewers and similar uses without record being made of it.

As can be ascertained from the statistics which follow, meters on about half (48 per cent) of the total number of services pass less than 100 gallons per day. (Fig. 22, p. 197.)

There are few meters in use at the present time that will register a steady flow of as little as 100 gallons per day.

If the amount of water now shown by that half of all meters which pass the smallest quantities of water were to pass at a uniform rate, it would all pass as leakage without moving the pistons or discs of the meters and would fail to be recorded.

It is recorded in part because that part which is recorded is drawn at higher rates, but whenever there is leakage in plumbing, so that the leak amounts to less than 100 gallons per day, more or less according to the sensitiveness of the meter, the amount of water so lost by leakage will pass without being registered. The water that is registered probably is all drawn during, at most, one or two hours per day, and during the remaining twenty-two or twenty-three hours there will be no registration of whatever water is lost by leakage in the plumbing.

Some of the large-size meters will pass much larger quantities without registering.

The above statistics are the most complete and up-to-date now available. Considerable labor is required to prepare the records, and data from many large completely metered systems are not available.

**Fall River Experience.** One of the earliest of the completely metered systems, and one in which waste has been most persistently suppressed through a long period of years, is Fall River. The statistics for Fall River,* presented by Mr. R. D. Chase in very convenient form, are as follows:

| Purpose. | Gallons per Capita. | Per Cent of Total. |
|---|---|---|
| Sold—manufacturing purposes | 6.46 | 13.20 |
| Sold—domestic purposes | 21.48 | 44.00 |
| Schoolhouses | 2.02 | 4.14 |
| Public buildings | 1.37 | 2.81 |
| Parks and cemeteries | 1.19 | 2.44 |
| Street watering | 2.74 | 5.65 |
| Flushing sewers | .46 | .94 |
| Puddling trenches | .32 | .65 |
| Fires | .53 | 1.09 |
| Maintenance water department | 4.12 | 8.45 |
| Overflow waste—back to lake | .70 | 1.43 |
| Unaccounted for | 7.41 | 15.20 |
| Total | 48.80 | |

Based on population of 122,231, May 1, 1914.

| Year. | Daily Average Consumption, M.G.P.D. | Daily Average per Capita, Gallons. | Amount Gallons. | Sold per Capita, Per Cent of to Total. | Amount Unaccounted for Per Capita. | |
|---|---|---|---|---|---|---|
| | | | | | Gallons. | Per Cent of to Total. |
| 1905 | 4.40 | 41.34 | 24.65 | 59.75 | 6.46 | 15.65 |
| 1906 | 4.47 | 41.49 | 24.79 | 59.80 | 6.02 | 14.62 |
| 1907 | 4.94 | 43.93 | 25.79 | 58.75 | 7.56 | 17.25 |
| 1908 | 4.96 | 43.48 | 27.25 | 62.80 | 6.26 | 14.44 |
| 1909 | 5.34 | 46.40 | 25.00 | 59.00 | 5.84 | 12.60 |
| 1910 | 5.20 | 43.59 | 25.90 | 59.40 | 5.04 | 11.55 |
| 1911 | 5.17 | 44.09 | 26.30 | 59.75 | 6.24 | 14.15 |
| 1912 | 5.33 | 46.23 | 28.19 | 61.00 | 4.97 | 11.78 |
| 1913 | 5.63 | 47.04 | 28.10 | 59.70 | 5.62 | 11.94 |
| 1914 | 5.96 | 48.80 | 27.95 | 57.25 | 7.41 | 15.20 |

**European Experience.** American cities in general have not paid as much attention to the suppression of waste and the complete accounting for all water supplied as have some European cities, where the meter system was adopted long ago and where a larger percentage of water is accounted for.

* N.E.W.W. Assn., Vol. XXX, p. 391, 1916.

There are a number of reasons for this. In some cases the meters have been less efficient. Whether this has been generally so, present evidence is not sufficient to determine. In Germany particularly the number of services per thousand of population is less, large blocks in which many families live all served by a single service being common, and this, no doubt, tends to reduce the loss by under-registration of meters.

Water also has been more valuable relatively in Europe, and through a long term of years means of detecting and stopping waste have been persistently followed up.

Statistics with remarkable completeness are available for German water-works system before the war. The table on p. 124 shows the largest water-works systems, with their outputs of water and the proportion of the same recorded by meters.*

Not all of these cities were completely metered, but data are not at hand to show what percentages of the taps were unmetered. Comparison with similar data for American cities shows strikingly the greater percentage of water that is accounted for.

**Washington, D. C., Experience.** The Water Department of the District of Columbia started a campaign against water waste about 1906. The work was planned on a comprehensive scale and has been followed up diligently, and is probably the most thorough work that has been done in this line. A record has been kept of the various leaks which have been found and remedied and these have been classified in the table which follows.

This table is particularly interesting, as it shows the large quantities of water that may escape from a system without making themselves evident at the surface. It is clear from the last column of the table, too, that larger leaks were found during the early years of the work, and as these have been remedied and as the efficiency of the force employed on waste investigations has increased, smaller leaks have been found and remedied.

Another point of importance that may be noted is that the

* XXIII Statistical Compilation of Water Works Statistics for the year 1912, R. Oldenbourg, Munich.

TABLE SHOWING THE LARGEST WATER-WORKS SYSTEMS IN GERMANY FOR THE YEARS 1911–12, WITH THE PROPORTION OF FLOW RECORDED BY METERS

| Name of System. | Approximate Population. | Average Output Million Gallons per Day. | Average Output Gallons per Capita Daily. | Percentage of Total Output Recorded by Meters. |
|---|---|---|---|---|
| Gelsenkirchen * | 800,000 | 59.5 | 75 | 96.2 |
| Berlin | 2,173,958 | 54.5 | 25 | 92.6 |
| Essen | .......... | 44.4 | | |
| Vienna (Austria) | 2,032,900 | 41.4 | 20 | 71.5 |
| Munich | 604,000 | 36.2 | 60 | 89.9 |
| Hamburg | 948,000 | 35.2 | 37 | 97.0 |
| Schoneburg † | 832,000 | 26.3 | 32 | 82.1 |
| Dortmund | 360,829 | 24.1 | 67 | 73.3 |
| Frankfort | 427,900 | 19.5 | 46 | |
| Cologne | 463,800 | 18.8 | 41 | 73.8 |
| Dresden | 542,600 | 16.6 | 31 | 72.5 |
| Bochum | 210,000 | 15.7 | 75 | 89.0 |
| Dusseldorf | 372,600 | 15.0 | 40 | 89.0 |
| Essen-an-der-Rhur | 304,021 | 14.5 | 48 | 75.9 |
| Breslau | 527,909 | 12.5 | 24 | 78.6 |
| Charlottenburg | 314,100 | 12.0 | 38 | 81.1 |
| Hanover | 392,405 | 11.5 | 29 | 82.5 |
| Leipzig | 600,639 | 11.4 | 19 | 86.1 |
| Bremen | 258,000 | 10.4 | 40 | |
| Nuremberg | 339,250 | 8.6 | 25 | 84.8 |
| Elberfeld | 206,000 | 8.6 | 42 | 100.0 |
| Stuttgart | 292,324 | 8.3 | 28 | |
| Marienberg | 261,717 | 7.4 | 28 | 76.3 |
| Königsberg | 251,174 | 5.10 | 20 | 70.2 |
| Stettin | 238,769 | 4.34 | 18 | 81.1 |
| Kiel | 214,365 | 3.95 | 19 | 82.9 |
| Chemnitz | 292,952 | 3.86 | 13 | 76.5 |
| Average | .......... | .......... | 36 | 82.7 |

* Water works for the northern Westphalian coal fields.

† Charlottenburg Water Co., supplying 36 suburban communities about Berlin.

SUMMARY OF LEAKS FOUND IN WASTE SURVEYS IN WASHINGTON, D. C.

| | Year. | Number Found. | Waste in Gals. per Day. | |
|---|---|---|---|---|
| | | | Total. | Per Leak. |
| Abandoned services and taps | 1910 | 11 | 305,075 | 27,700 |
| | 1911 | 4 | 173,583 | 43,400 |
| | 1912 | 12 | 174,184 | 14,500 |
| | 1913 | 15 | 180,900 | 12,050 |
| | 1914 | 8 | 101,700 | 12,700 |
| | 1915 | 8 | 54,700 | 6,840 |
| | 1916 | ....... | 115,450 | |
| Broken iron services | 1910 | 204 | 2,438,000 | 11,950 |
| | 1911 | 142 | 1,508,898 | 10,600 |
| | 1912 | 325 | 2,329,751 | 7,170 |
| | 1913 | 311 | 1,988,840 | 6,400 |
| | 1914 | 166 | 924,000 | 5,560 |
| | 1915 | 183 | 861,950 | 4,700 |
| | 1916 | 113 | 449,440 | 4,000 |
| Broken lead services | 1910 | 87 | 1,201,878 | 13,800 |
| | 1911 | 94 | 1,237,644 | 13,160 |
| | 1912 | 134 | 976,720 | 7,300 |
| | 1913 | 59 | 394,000 | 6,680 |
| | 1914 | 74 | 471,000 | 6,360 |
| | 1915 | 58 | 254,100 | 4,380 |
| | 1916 | ....... | 201,380 | |
| Broken wiped joints | 1910 | 74 | 710,145 | 9,600 |
| | 1911 | 70 | 666,730 | 9,500 |
| | 1912 | 109 | 438,055 | 4,020 |
| | 1913 | 64 | 282,300 | 4,400 |
| | 1914 | 49 | 237,000 | 4,840 |
| | 1915 | 48 | 213,500 | 4,450 |
| | 1916 | ....... | 342,490 | |
| Leaking joints on mains | 1910 | 92 | 1,034,227 | 11,240 |
| | 1911 | 184 | 2,562,461 | 13,900 |
| | 1912 | 75 | 746,305 | 9,950 |
| | 1913 | 104 | 962,310 | 9,250 |
| | 1914 | 93 | 596,800 | 6,420 |
| | 1915 | 45 | 368,800 | 8,200 |
| | 1916 | 161 | 607,350 | 6,000 |
| Broken mains | 1910 | 2 | 332,000 | 166,000 |
| | 1911 | 1 | 15,900 | 15,900 |
| | 1912 | 1 | 7,000 | 7,000 |
| | 1913 | 3 | 103,300 | 34,400 |
| | 1914 | 2 | 62,200 | 31,100 |
| | 1915 | 0 | 0 | |
| | 1916 | ....... | 142,800 | |

leakage from broken mains, or defective joints on the mains, is relatively small when compared with the leakage due to defects in service pipes.

If each distribution system were examined with the thoroughness which has characterized the Washington work, considerable leakage could be found and eliminated, and the total consumptions reduced and the percentages of water accounted for substantially increased in a great many cities.

## CHAPTER XII

## LEAKAGE FROM STREET MAINS

But a considerable quantity of water is lost through leaks in the conduit which is not readily seen on account of the depth at which the conduit is located.—Frontinus, "Water Supply of Rome," Translation by Clemens Herschel, 1899, p. 41.

Hundred of thousands of microscopic leaks at the main pipe joints, each of which individually is too small to attract notice or to warrant the expense of a remedy, but which in the aggregate amount to a very noteworthy quantity.—John R. Freeman, Report on New York Water Supply, 1900, p. 58.

At first thought leakage from street mains seems to be a little outside of the question of meter rates, but it is one of the matters that is closely connected with it and that always has to be taken into account.

The percentage of the total output that can be accounted for by meter, even under the best American practice, is disappointing. The meter rates have to be higher than they otherwise would be because of this shortage. This is a very practical matter and one that must be fully understood in order that disastrous errors may not be made in fixing meter rates. Information as to the division of the water that cannot be accounted for among the various possible sources of loss is disappointingly meager.

It is proposed in this chapter to take up first a very brief résumé of what is known about the leakage from street mains, to be followed by a brief statement of the best methods of locating and stopping this leakage.

It is easy to see why there is so little definite information as to the leakage from street mains. As soon as a main is laid, service connections are made, and water begins to be drawn for various purposes as soon as it is turned on. There is ordinarily a demand for the use of the pipe even before it is laid, and there is no time to be used in testing.

Afterward it is possib e to isolate a certain section of pipe at any time and to find out how much water is going into it, but the amount so found represents both leakage from the pipe and water drawn through the services.

Making the observation between one and four o'clock in the morning in a residence street, during which time the use of water is presumably very small, gives an indication of leakage, because very nearly the whole flow at that hour is leakage.

Shutting off the stop-cocks on each individual service adds greatly to the difficulty of the experiment, and also to the value of the results obtained. Even after this is done there remains some uncertainty as to whether the observed loss of water is from the pipe itself or from the service pipes between the main and the shut-off cocks, and it may be that some abandoned and forgotten service pipe with a partially closed end is discharging water to a sewer.

Tests of new lines before service connections are made have occasionally been possible and some information has been collected in regard to them. Such information is useful, but it is hardly to be taken as a guide in estimating leakage from old mains. There are slight movements of the pipes at times because of temperature changes and for other reasons, and these tend to open joints, and there is more likelihood of leaks in the joints of old pipes than is the case with new ones.

On the other hand, one engaged in the water-works business has occasion to see from time to time pieces of pipes in services under pressure and joints between successive lengths of pipe. Such occasional inspections do now and then show leakage. The frequency with which joints that leak are found depends most of all upon the conscientious care with which the pipes have been laid and the joints caulked. If the work has been badly done, leakages may be common. It is the writer's experience that in well-laid old systems leakages from pipe joints are not common. The great majority of joints that come to his attention are completely tight. Where leaks do exist they are usually of considerable size, such as are produced by some movement of the pipe and opening of the joint, either by settlement or by often repeated temperature changes.

**Evidence and Opinions as to the Amount of Leakage from Street Mains.** Mr. Dexter Brackett, of Boston, who had given the subject of waste of water as much as attention as any American Engineer, stated that:

> The waste from street mains and services is much larger than is generally supposed. It is often said that no leak of any magnitude is likely to occur without showing on the surface of the ground, but broken 4-inch and 6-inch pipes and service pipes running 1000 gallons per hour have been discovered in Boston which gave no indication at the surface, and which had evidently been wasting water for years.—Trans. Am. Soc. C.E., Vol. XXXIV, p. 196, 1895.

Not long after, Mr. Brackett had an opportunity to test the leakage of a system of pipes laid by the Metropolitan Water Board for the supply of Boston and its suburbs. These tests were made soon after the pipes were laid. These pipes were large connecting pipes, serving for the distribution of water in a wholesale manner only, and there were no service connections from them and the opportunity for testing was much more favorable than occurs in ordinary water works development. The tests of leakage are summarized in the following table:

| Inside Diameter of Pipe in Inches. | Sum of Lengths Tested. | | Average Leakage Found per Lineal Foot of Pipe in Gallons per Twenty-four Hours. | Average Leakage per Lineal Foot of Lead Joints in Gallons per Twenty-four Hours. |
|---|---|---|---|---|
| | Feet. | Miles. | | |
| 48 | 116,563 | 22.0 | 3.7 | 3.16 |
| 42 | 11,744 | 2.2 | 2.5 | 2.43 |
| 36 | 25,663 | 4.9 | 2.9 | 3.19 |
| 30 | 7,287 | 1.4 | 0.6 | 0.81 |
| 24 | 20,553 | 3.9 | 2.1 | 3.44 |
| 20 | 40,231 | 7.6 | 3.6 | 7.00 |
| 16 | 49,903 | 9.4 | 1.9 | 4.65 |

The total length of the different sizes tested was 271,944 feet, and the average leakage per lineal foot of lead joint for twenty-four hours was 3 gallons.

These tests of Mr. Brackett's have been often used as a basis for estimating the probable leakage from cast-iron pipe systems, as, for example, the table in the American Civil Engineers' Pocket Book, Third Edition, p. 956.

Mr. H. F. Dunham stated, in commenting on Mr. Brackett's data:

> The speaker found in making tests of entire pipe systems where the mains ranged from 16 to 4 inches in diameter, and a pressure of 50 pounds per square inch was maintained, that the quantity of water escaping did not exceed 1 gallon per minute per mile of street main. These tests were made when the pipe systems were new and before the introduction of service pipes. They did not include such breaks as would immediately appear on the surface, but did include some leaks from porous castings, faulty joints and imperfectly packed gates that were noticed subsequently. The quantity was determined by plunger displacement.—Trans. Am. Soc. C.E., Vol. XXXIV, p. 204, 1895.

One gallon per minute amounts to 1440 gallons per twenty-four hours. Assuming that the average size of pipe is between 6 and 8 inches, this indicates only about half of the rate of leakage shown by Mr. Brackett's test.

A statement in regard to leakage from pipe mains by Emil Kuichling, for many years Engineer of the Rochester Water Works, and an engineer with unusual powers of observation, has been widely quoted.

> It should be understood that the leakage here referred to is limited to that which does not show on the surface of the ground, and the individual components of which cannot be detected by the most careful inspection. Loss by wilful waste on the part of consumers and by breakage of pipes is distinctly excluded from present consideration, since the former may be corrected by the use of meters, and the escape of a comparatively large quantity of water at a single point generally renders itself manifest after a short time. The inquiry may therefore be restricted to the loss due to the sweating or slight dripping of the pipe joints, valves of fire hydrants, stuffing-boxes of stop-valves, badly ground taps and curb cocks, and defective joints in service pipes.
>
> From close observation of thousands of water pipe joints and fixtures in various localities, both when first laid and after having been in use for years, the author has reached the conclusion that a discharge of one drop per second from each joint, five drops from each hydrant and stop-valve,

and three drops from each service pipe, including tap and curb cock, represents a fair measure of the average undiscoverable leakage in a well-constructed distributing system. As the size of a drop of water, however, depends upon the form and magnitude of the surface from which it falls, a number of experiments were made by the author to determine the weight and volume of 100 drops falling from a cast-iron surface similar to that of a pipe socket, from which it was found that one such drop per second is equivalent to about 3 gallons per day. On this basis, and with the assumption that on the average there are 504 pipe joints, 12 hydrants, 10 stop-valves and 100 service pipes per mile of distributing pipe, the leakage will amount to 2742 gallons per mile per day, or in round figures, say from 2500 to 3000 gallons per mile per day.—Trans. Am. Soc. C.E., Vol. XXXVIII, p. 18, 1897.

Mr. Kuichling's results check closely those of Mr. Brackett for a leakage of from 2500 to 3000 gallons per day per mile of pipe and correspond approximately with Mr. Brackett's allowance for 6-inch pipe, and the average size of pipe in the distribution system referred to by Mr. Kuichling was probably not far from this size.

Mr. Charles F. Loweth, an engineer of St. Paul, in discussing Mr. Kuichling's paper, stated:

The estimate in the paper (Kuichling's) of from 2500 to 3000 gallons of leakage per day per mile of pipe, in a well-constructed distribution system, he believes is excessive. As a result of testing several new pipe systems, in most cases before any service connections were made, the writer has come to the conclusion that the leakage can be kept within 60 to 80 gallons per inch mile of pipe per twenty-four hours, or 600 to 800 gallons per mile of 10-inch pipe line per day.

For several years past he has specified a leakage test for all new pipe systems or extensions. The permissible leakage has been limited to from 60 to 80 gallons per day for each inch-mile of pipe, depending upon the pressure, and inclusive of hydrants and valves, and a liquidated damage clause added to cover any excess leakage over this amount. His observation has been that honest and experienced workmen can readily keep the leakage within this limit, especially when warned beforehand that their work will be tested. A comparatively small amount of negligence, however, will result in a considerable excessive leakage.—Trans. Am. Soc. C.E., Vol. XXXVIII, p. 30, 1897.

In closing the discussion Mr. Kuichling stated in regard to this:

While this quantity (that mentioned by Mr. Loweth) may be ample under the conditions stated, it is certainly too small after the system is several years old, and the lead joints have been strained by settlements and by repeated expansions and contractions of the pipes due to changes of temperature; also after the packing in the stuffing-boxes of stop-valves is partly decayed, the valves of fire hydrants damaged by use, and the tightness of the plugs in taps and curb cocks impaired by frequent handling or shock from water-ram in house pipes and mains. All these elements must be taken into account after the work of construction is finished, and hence a much different standard is applicable to old pipe systems than to new contract work.

The leakage from old or abandoned services may be important and it is practically impossible experimentally to separate this loss from the loss from the street pipes. Mr. J. J. R. Croes, in reporting to the Merchants Association, in 1900, on the Water Supply of the City of New York, stated:

There is much leakage underground from bad joints, breaks and defective stoppage of disused services. There are on the 850 miles of mains in New York City at least 18,000 old service taps which have been discontinued and more or less imperfectly plugged up. There is a great loss of water from these old taps. Thousands of them are leaking continuously; some but a mere dribble, but others carrying off into the sub-soil and into the sewers thousands of gallons daily each. Sometimes the leakage from one of them increases sufficiently to come to the surface of the ground, and the water appears as a spring in the pavement of the street or sometimes flows off into vacant lots. If the underground channels become obstructed, the water will rise to the surface and the leak will be reported. Every increase of pressure in the pipes increases the leakage from these old taps, and attention is called to them. The number of leaks which showed themselves, when the pressure on the mains was kept down on account of scarcity of water between 1883 and 1889, was about 700 annually. After the new aqueduct was finished, and the pressure was increased, the number of leaking services reported was over 1000 annually; and last year (1899) after the full pressure had been turned on downtown by the laying of the additional mains down Fifth Avenue and Elm Street, there were 2500 such leaks that made themselves manifest. . . . The mains themselves also leak largely. There are at least 500,000 joints in the main pipes underground, and from many of them water is escaping. . . . Cases of leakage are constantly occurring in which the source is traced to corroded cast-iron mains. For several years the average amount of old pipe which has had to be taken up and replaced has been about 2 miles annually, but the deterioration and consequent leakage from the old pipes is progressing more rapidly than the work of replacing the pipes.—Report on the Water Supply of the City of New York, Merchants Association, April 15, 1900, p. 119.

At about the same time, Mr. John R. Freeman, in reporting on the Water Supply of New York, mentions these matters and gives two additional pieces of evidence. The first is a test of the Providence special high pressure fire pipe system.* The system when tested was about three years old, and consisted of 5.57 miles of pipe mainly 16 inches in diameter, under an average pressure of 114 pounds, in the business section of the city. It has no service connections of any description. The test was made by Mr. Otis F. Clapp, City Engineer, on June 10, 1900, by putting a small water meter on a by-pass around the main gates supplying the system. The test showed a leakage at the rate of 2487 gallons per twenty-four hours, which, as Mr. Freeman computes, is equal to a leakage of 0.22 gallon per foot of leaded joint per twenty-four hours, or about one-fifteenth of the amount found by Mr. Brackett. It is to be noted that this was special high pressure fire service pipe and the joints were probably made with greater care then is the rule in ordinary water-works systems.

The second test reported by Mr. Freeman is of the pipe system at Milton, Mass. This was made by measuring the minimum night flow in a residential community and assuming that two-thirds of the night flow was from cast-iron mains and one-third from house fixtures. There were 2 miles of 4-inch pipe; 18 miles of 6-inch; 5 miles of 8-inch; 3 miles of 10-inch; 4 miles of 12-inch; a total of 32 miles, and a total length of leaded pipe joint not far from 37,000 feet. The total population served was about 6500, and there were 818 service pipes. On this basis leakage amounted to 1.3 gallons per twenty-four hours per foot of leaded joint. As the division of the loss between pipe and services is estimated, this is only of significance as being a case where the total loss is unusually low.

Mr. E. G. Bradbury, discussing the matter at a much more

* Freeman's Report on New York Water Supply, p. 60.

recent date, goes into the leakage from street pipes and shows the financial loss by such leakage. He states:

> By the method of open-trench inspection it is possible to make a new system practically bottle-tight. The measured leakage in 5.5 miles of 6 to 12-inch pipe laid and thus tested by the writer at Grandview Heights, a suburb of Columbus, Ohio, amounted to 2.3 gallons per mile daily, or 0.31 gallon per inch mile.—Jour. N.E.W.W. Assn., Vol. XXVIII, p. 317, 1914.

At Akron, Ohio, tests of pipes laid by contract by Mr. Bradbury ranged from 23 to 135 gallons daily per inch mile and averaged 83 gallons, and for pipe laid by the water works on force account ranged from 59 to 133 and averaged 62 gallons daily per inch mile.

The question of testing pipe under full pressure or more than full pressure in the open trench before it is backfilled is one that has a decided bearing upon the amount of leakage. Mr. Clarence Goldsmith stated in regard to this:

> There is one city which, I think, is a preeminent example. That is Atlanta, Ga., where all the lines laid are tested at 300 pounds before they are filled in. That rule is strictly adhered to. When I first talked to the superintendent, Mr. William Rapp, with regard to this, I was a little skeptical. He was then laying a 20-inch line through the heart of the city, and held every joint of that line open, and subjected it to 300-pound pressure. The pressure was maintained for one hour, and every joint was gone over carefully. Of course, there were a few spits of water, but the test showed a very good job indeed, and the superintendent assured me that every pipe in Atlanta is subjected to such a test.—Jour. N.E.W.W. Assn., Vol. XXVIII, p. 328, 1914.

Mr. Dexter Brackett in discussion stated that in his experience it was seldom feasible to allow pipes to remain uncovered for a sufficient length of time in city streets to allow them to be thoroughly tested out before the trenches were refilled. Mr. Bradbury suggested, however, that it would often pay to use more gates in the city streets, so as to permit the pipe to be tested in shorter sections, and that the added tightness secured would justify the cost of the additional gates.

Mr. Arthur H. Smith * gave a test of a new water-works

*Jour. N.E.W.W. Assn., Vol. XXX, p. 5, 1916.

system at Medway, Mass., where the leakage from about 11 miles of pipe ranging from 6 to 12 inches in diameter amounted to 1.58 gallons per lineal foot of lead joint daily.

In discussion, Caleb M. Saville, Engineer of the Hartford Water Works, reported a leakage on test of 7½ miles of 42-inch cast iron supply main, to which there were no service connections, amounting to about 0.7 gallon daily per foot of lead joint.

Mr. Spear, Department Engineer of the Board of Water Supply of New York, reported that in the main conduit lines laid recently by the Board the leakage had ranged from less than 1 to about 2 gallons daily per lineal foot of pipe joint.

Mr. Killam reported a test of a new line laid by the Boston Metropolitan Water Board, about a mile long, 20-inch pipe, leakage equal to 0.6 gallon daily for each foot of pipe joint.

Mr. Hawley, Engineer of the Wilkinsburg, Pa., water works, stated that it was his experience "after seeing many miles of pipe uncovered for the purpose of replacement with larger pipe, that a large percentage of joints are absolutely tight. Most of the leakage is caused by a few large leaks; some is from stuffing-boxes on gate valves, which obviously has no relation to diameter of pipe per length of joint. I mention this so that those who have not given the matter consideration will not conclude that a general leakage is to be expected."

Mr. E. S. Martin, Superintendent of Water Works at Springfield, stated that on account of changes in grades of streets, he had to relay and lower about a mile of 30-inch pipe and in the whole length he did not find half a dozen joints that were even sweating. This pipe was laid about 1892 and was therefore over twenty years old.

**Methods of Finding and Stopping Leakage from Street Mains.** Foremost is to be mentioned conscientious care in extending the pipe system. Testing pipes under full pressure, or if possible, more than full pressure, before backfilling is most important. It can usually be done except in the central and congested parts of cities where street conditions do not make it advisable to leave the trenches open long enough for it to be done.

Well-made joints and careful caulking by skilled caulkers are of the first importance. Testing pipes for leakage before backfilling is one of the best ways of educating caulkers, and in a system where the pipes are ordinarily so tested the caulkers will learn to make joints that are always tight.

There are several variations in the type of joint and in the materials that are used in making it, and there are possibilities of improving these. These matters, however, cannot be discussed in this place.

In an old system of pipes there are bound to be many leaks underground. Most of these leaks are so small that it will not pay to spend the money to locate them and to dig up the pipe and to correct them by caulking or otherwise; but there are also many larger leaks and it is frequently possible to locate some of these, and the water that may be saved by stopping them is well worth the cost. Some of the largest leaks will show at the surface of the ground, but there is a great difference in systems in this respect. If the soil is clayey and impervious, even a small leak will force its way to the top and will make a wet place that can be detected by one who knows the significance of such a spot. On the other hand, with a dry gravelly soil, large quantities of water may be lost without showing at the surface.

This is one of the reasons for differences in leakage in different systems, and it is not to be expected that quite the same degree of tightness will be realized in pipes laid in an open pervious soil as in an impervious one.

Looking for leaks in an old pipe system is ordinarily best carried out during the time of minimum consumption, that is, between the hours of one and five a.m. In a strictly residential community, the figures obtained at this time are a very good index of existing conditions. If there are industrial all-night users, the night figures are of little value.

The underlying principle of test is to let the water supplying the whole system or some part of the system go through a water meter and to shut off parts of the pipes that are supplied in detail and observe how the rate of flow is affected. In this way a measurement of the whole minimum night flow for the district is obtained as well as some idea of how that minimum is distributed among the different parts of it.

Mr. Dexter Brackett * was a pioneer in investigations of this kind. He used the English device called the Deacon meter. This was used on parts of the distribution system which were shut off by closing gates until the whole district was supplied through one pipe on which the Deacon meter was placed.

The writer has found that a rough preliminary idea but often of value could be obtained by tests on the whole of a small system in the early morning hours with the aid of a Venturi meter provided with a good manometer, or even in some cases by counting the revolutions of a pump, while the gates on different parts of the system were being operated.

More recently the pitometer † has come into general use for waste detection. The pitometer serves as a very delicate water meter. It can be conveniently attached to a water pipe by tapping and without cutting the pipe or interrupting the flow of water.

All these methods serve to locate these stretches of pipe between gates in which there are relatively large leaks. For a closer and more detailed examination of the pipe system better results can be obtained by shutting off all the gates on the pipe in one block and supplying that block through a hose reaching between two hydrants, one attached to the pipe that is shut off and one attached to the pipe outside. On this line of hose a meter is placed. Small disc meters have sometimes been used for this service. Small Venturi meters with manometers ‡ give immediate indications without waiting for the time to elapse necessary for a record to be made by a disc meter. The use of standard orifices in place of the Venturi meters would simplify the apparatus and a series of such orifices with graded diameters in interchangeable discs could be arranged to accommodate any variation in flow that might be found.

In experimenting in this way it must be borne in mind that

* Trans. Am. Soc. C.E., Vol. XXXIV, p. 185, 1895.

† Edward S. Cole, Proc. Am. W.W. Assn., p. 136, 1907.

‡ Eng. News, Vol. LXXV, p. 1160, 1916.

there is a possibility of leakage through the gates in the mains and that such leakage will tend to reduce the apparent leakage in the system. It is therefore necessary that every attention should be given to the gates to make sure that they are properly seated and to ascertain as far as possible that they are tight. Also, that the remaining leakage is made up in part of leakage from the main pipe and in part from defective or abandoned services, and there is no certainty of finding out which is which.

Examinations of this kind carefully carried out night after night by competent observers will locate those blocks in a system in which the greatest leakage from street mains occur, and if this is followed up by further examinations of the pipes in the day time for evidences of leakage and by digging out and recaulking those pipes in which leakage is greatest, the loss can be reduced. In any system where the pipe has been carefully and conscientiously laid, it is to be normally expected that the pipe in a great majority of blocks will be comparatively tight After some of the worst sections have been located and corrected it will not pay to go further.

**As to the Total Amount of Water Lost from Pipes in the Streets.** The most convenient basis for comparison with the rest of the discussion is the average amount of water lost per service. Most of the data are in terms of pipe sizes and lengths, and a basis of comparison must be first found.

For the purpose of this discussion 95 services per mile may be taken. This is the figure reached in Chapter VIII, p. 96.

The average size of pipe in the streets in a water works system ordinarily ranges from about 6 inches for the smallest systems to about 8 inches in larger systems. For the largest cities the size exceeds 8 inches, and there is an upward tendency in the average.

For sixteen representative systems of companies for which complete information is available the average size is about 7 inches.

For the purpose of this discussion 8 inches may be taken as the normal average size of pipes in the streets. The normal leakage is to be taken as the leakage to be reasonably expected on an average from pipes that have been in use for a considerable term of years under average conditions and excluding all large leaks of such size that it might reasonably be anticipated that they would be discovered by a proper system of investigation and stopped.

Following Dexter Brackett's basis, leakage at a rate of 3 gallons per twenty-four hours per lineal foot of lead joint under 100 pounds pressure may reasonably be anticipated. For 8-inch pipe that amounts to 3420 gallons per mile. Probably the average pressure is less than 100 pounds, and this figure would be somewhat reduced, perhaps to 3000 gallons daily per mile. With 95 services per mile, the average loss is then equivalent to 32 gallons per service daily.

The following calculation is made in very general terms to give an idea of the significance of this leakage with reference to the finances of the whole system and not with any idea of reaching precision.

If the water lost is worth 10 cents per 1000 gallons, which may be taken as about the average wholesale rate, this loss amounts to $1.17 per service per annum. If the investment in the street pipes amounts to an average of $100 per service, and if the interest on the investment (or the profit to a company) and the depreciation and the repairs and maintenance amount to an average of 8 per cent of the first cost, then the total annual cost of maintaining the pipes to supply one service on an average is 8 per cent of $100, or $8. The water normally lost by leakage as estimated above adds 15 per cent to this to make up the whole cost of distribution. In other words pipe leakage adds 15 per cent more or less to the average cost of distributing the water.

# CHAPTER XIII

## UNDER-REGISTRATION OF METERS

A thoroughly serviceable meter should have great sensitiveness, but need not have a very high degree of accuracy.—Emil Kuichling, Trans. Am. Soc., C.E., Vol. XXV, p. 68, 1891.

The physical difficulties of making a water meter that will record all the water that passes it are apparently very much greater than the corresponding difficulties in getting an accurate gas meter or an accurate electric meter.

There has been much discussion as to the probable average amount of under-registration of meters in actual service. Actual data are almost impossible to get. It would take a line of specially designed experiments to throw light adequately upon this matter, and as far as the writer knows, such experiments have never been undertaken in any adequate way.

Without being able to prove it, it is the writer's idea that probably the under-registration of meters is the most important of the reasons why the whole output of water cannot be accounted for. The statement of Mr. Kuichling in regard to the conditions of twenty years ago is still in the main directly applicable.*

The average amount of water not accounted for as shown by returns to the Committee on Meter Rates for completely metered systems amounted, on an average, to 130 gallons per service daily, as stated in Chapter XI, and of this only 32 gallons, more or less, is fairly to be assigned to probable leakage from street mains.

**Kinds of Water Meters.** An illuminating statement as to water meters was made by John Thomson,† a meter inventor

* Chapter II, p. 8.

† Trans. Am. Soc. C.E., Vol. XXV, p. 40, 1891.

and a meter manufacturer. This reflects the state of the art as it had developed up to that time. It would be interesting if a corresponding up-to-date statement of meter practice could be made by someone as competent to speak as John Thomson was at the time this paper was presented. Unfortunately, no such statement is available. However, many of the underlying principles of meter construction remain the same in 1917 as they were in 1891.

The type of water meter sold and used in greatest numbers in American cities consists of a hard rubber disc rotating in a bronze casting. This is called the disc meter. In another type called a rotary meter, the rotating member is fluted prism and in outline it fits as it revolves with the openings in the bronze case. In a disc meter water may flow between the edge of the disc and the inside of the bronze casing against which it oscillates. In the rotary meter the moving part rolls or turns upon each part of the outside case in succession and presumably fits tightly upon it, but water may flow between the ends of the moving parts and the bronze faces above and below. In both types the fit between the rubber and the bronze is made to be as close as circumstances permit. It is closer now than it used to be. Years ago when unfiltered river water was used in many American cities, the clearance had to be arranged with reference to the particles of grit. With clear filtered water this clearance can be reduced and the amount of slippage is decreased. The rates of expansion of rubber and bronze with changes of temperature are not the same and some inequalities grow out of this difference. There is bound to be some wear of the moving parts in the course of time and the effect of this wear is to increase the spaces through which water may pass without moving the meter. In large meters the amount of water that will pass before the meter begins to move may be considerable.

It is possible to make new meters that will show but little slip. John Thomson stated: *

* Trans. Am. Soc., C.E., Vol. XLI, p. 354, 1899.

It is entirely feasible, and has frequently been carried out in practice, when required, to produce disc meters of the $\frac{5}{8}$ and $\frac{3}{4}$-inch sizes that will indicate from 50 to 75 per cent of the quantity discharged when the rate of flow is as low as $\frac{1}{10}$ cubic foot per hour.

This rate of flow is equal to only 18 gallons per twenty-four hours.

G. Bechmann, Engineer of the Paris Water Works, stated: *

At Paris the regulations in force require that the registration must be comparatively exact, that is to say, with a tolerance not exceeding 20 per cent for even very small outputs not exceeding from $\frac{1}{1500}$ to $\frac{1}{8000}$ of the maximum ordinary capacity as well as the full registration of larger quantities. These conditions rigorously and strictly enforced have limited somewhat the number of kinds of meters that could be used.

It is common water works experience that old meters brought into the shop after having been in service some years are less sensitive and require larger flows to move them.

In tests made by J. Waldo Smith,† seven $\frac{5}{8}$-inch meters when new, purchased in the open market from well-known makers, commenced to register with flows ranging from 19 to 390 gallons per twenty-four hours, with an average of 123 gallons as the minimum amount that would move the register. After making various tests and after finally standing four months connected up under pressure without being run, the amount of flow that was required to start registration in the five of the meters that were still serviceable averaged 440 gallons per twenty-four hours and in no case was it under 300 gallons.

**Meters with Packing.** In Europe, meters which measure as a result of the movement of a piston provided with an adequate and approximately water-tight packing, have been extensively used, and the art of constructing such meters has reached a considerable state of development. Such meters are much more expensive than the disc and rotary meters that have been commonly used in America.

It may be that the use of some form of a packed meter will ultimately prove advantageous in America. At any rate, the

* "Distributions D'Eau," Paris, p. 440, 1888.

† Trans. Am. Soc. C.E., Vol. XLI, p. 359, 1899.

matter is one worthy of discussion. The cost of a packed meter would be much greater than the cost of the meters that are in common use.

**Devices for Increasing the Accuracy of Large Meters.** Large meters are frequently required on services because of the occasional requirement of large capacity, even though the ordinary rate of use is small. For instance, a 6-inch meter may be put on a 6-inch pipe line, and the 6-inch size may be required because the amount of water represented by it must be available for fire service, although the amount of water required for ordinary use would be passed by a 2-inch pipe and meter. In such a case, the registration of the 6-inch meter will be much below the truth, because its moving parts are too large to be moved by the ordinary flows.

Detector meters have come into common use for this service. They consist of a small meter and a large by-pass connected in such a way that when the difference in pressure on the two sides of the meter exceeds a certain amount it will open a valve and make the full capacity of the pipe available. The detector meter is arranged to give a record of the fact that the by-pass has been opened, although it does not record accurately the quantity of water that has passed through it.

The compound meter differs from the detector meter in that an effort is made to record all quantities of water that pass. The larger quantities are recorded by a larger meter, the smaller quantities by a small meter, and an automatic arrangement shifts the flow from one to the other, according to its amount. Compound meters were in use in Europe many years ago. They have been introduced in numbers in the United States only in the last few years, but their use is rapidly increasing.

There is a great difference in the quality and accuracy of water meters. Meters can be manufactured at low prices that will on test record large flows in a fairly satisfactory manner, but which do not have either the durability to retain their accuracy or the delicacy to record the low flows. Under sharp competition there is always a temptation for manufacturers to cut the quality of the workmanship and to sell at lower prices meters that are deficient in the qualities that make for continued accuracy.

**Present Testing Methods.** It has been American practice to test meters by streams of water flowing through circular openings of various sizes. Usually the smallest sized opening has been $\frac{1}{32}$-inch, representing under an ordinary working pressure about 500 gallons of water per day. In most cases meters are not tested on smaller water quantities than this. In other cases tests with a $\frac{1}{64}$-inch opening, corresponding to a flow of about 125 gallons per day, have been made. It is very rare indeed that tests with lower flows have been made.

When Mr. Kuichling's statement * is remembered in connection with these testing limits, the large opportunity for passage of water without registration as a steady flow at low rates is apparent.

This condition would certainly be improved if methods of testing were perfected by which the registration of meters at still lower rates of flow could be rapidly determined and recorded, for instance, if an instrument were available which would allow a number of successive quantities of water to pass, the quantities being otherwise measured, and these quantities were made to pass through a meter, a record could be made of the first quantity that caused the moving parts to revolve and that would then become a matter of record.

John Thomson presented a paper to the New England Water Works Association, called "Is the Game Worth the Candle?" † in which he suggested that, in order to facilitate the business of introducing meters, that the standard of test should be reduced with a view to decreasing the cost of manufacture of meters. The discussion of this proposition by the water works superintendents who were present was not favorable.

Looking at the matter from the standpoint of twenty years after, the question may fairly be raised whether the time has not come for more rigorous specifications for meters, and for requiring mechanical construction that in the case of a clear

* Chapter II, p. 8.

† Jour. N.E.W.W. Assn., Vol. VIII, p. 58, 1893.

filtered or ground water will give a record of smaller flows than can be shown by meters now commonly used.

The use of compound meters for large services and the improvements that are being rapidly made in the design of such meters is rapidly bringing about a better condition with respect to the larger consumers. But it must always be borne in mind that the representative domestic consumer is one whose meter records about 100 gallons per day. On the best available evidence, the actual average quantity of water drawn is considerably more than 100 gallons per day, possibly as much as 150 gallons per day. The average meter records that part of it which flows at relatively high rates of draft, amounting in all to about 100 gallons per day, and it fails to record the drop-by-drop leaks from water-closets and fixtures, amounting to some very substantial quantity, but varying from house to house and also from system average to system average; so that whether as a general average it amounts to 50 gallons per day, as the Committee on Meter Rates suggested that it might, or to a larger or a smaller quantity, cannot be certainly determined.

### Testing Meters at Low Rates of Flow

It is obvious that testing meters, especially domestic meters, at low rates of flow goes to the heart of the under-registration problem. Testing meters at ordinary rates has been brought to a state of perfection where little can be suggested to improve it, but testing meters at low rates has been neglected.

It has been neglected perhaps primarily because of the difficulty of making tests with the equipment that has been available. It may be fairly supposed that if a rapid and easy method of making tests of the performance of meters at low flows were available, that information would soon be collected as to the performance of different kinds of meters when new and after certain periods of service, and this would certainly react upon the manufacturers and tend to beneficial improvements.

The following outline is suggested of a simple apparatus to permit tests of this kind to be made with rapidity and all needed accuracy.

This is based upon the idea of measuring small quantities of water in a graduate or glass measuring vessel, by the ordinary laboratory method, aided by the discharge through standard orifices as a secondary method to permit more rapid comparison, and upon counting the revolutions of the primary moving part in the meter for a short period to get the rate of flow that is indicated by the meter. In this way indications of performance can be obtained almost at once, and running a meter for a long interval to permit sufficient water to pass to be accurately weighed on the large scales ordinarily used in testing and to be registered accurately on the dial of the meter will be unnecessary.

The water to be used for test will be drawn from the ordinary pipe system. Directly beyond the shut-off gate would be a connection to a pipe running up to a spout or to a sink on a floor above, whose sole function is to reduce and steady the pressure and to eliminate the effects of water-ram. With very steady pipe pressure this may be unnecessary. Ordinarily a little water will escape through this pipe and the pressure beyond this point will be steady, and will only correspond to the elevation of the outlet.

The water should then be taken through a simple pressure filter, which need be only a rough strainer, to stop any sediment which otherwise might interfere with the subsequent operations.

This may be followed by a coil in a tank used to control the temperature of the water used for experiment. Not much is known about the effect of temperature upon the performance of meters, but the viscosity of water at the freezing-point is twice as great as it is at summer heat; there are probably unequal temperature expansions in the rubber and the metal in the meters; and it would be interesting, and perhaps profitable, to try out the performance throughout the temperature range of practical work. For this purpose the coil may be packed with ice, or surrounded with water into which a little steam is drawn to produce the desired temperature. A pressure gauge at this point is desirable.

The water would next go through a controlling gate. This should be a simple and substantial mechanism, so that by turn-ing it the flow can be increased or decreased as desired. It should be all of metal free from leather or rubber packing, so that when once placed the flow of water through it will not change until the control is moved.

The water should then go to a standard orifice placed in an enlargement of the pipe. A mercury manometer, connected with the water on either side of the orifice, would show the pressure upon it. Several orifices of different diameters would be required to measure the range in quantities to be handled, the diameter of each orifice being perhaps 50 per cent greater than the next smaller one. The rating of the orifices would be done in the course of regular work and would not need to be provided for in advance. A rapid method of shifting the orifices is desirable. It may be that a series of them could be cut in a disc which would be revolved on packing without appreciable leakage, and so that the orifice could be almost instantly changed by revolving the disc.

The water would then go through the meter to be tested, or, if desired, through a series of them.

After passing the meters, the water would be discharged into the air, or could be carried, if desired, to a weighing tank to be used for checking up the higher rates of flow.

The ordinary basis of measurement would be to collect the water passing the meter in a glass graduate. Those used for laboratory use, having capacities of 100, 200, 500 and 1000 cubic centimeters, are suitable. The water would be caught for one minute, or for some other short interval of time, long enough to allow the time to be accurately ascertained with a stop-watch. The volume that passed in the interval would be read directly in the graduate. The flow in cubic centimeters per minute is then ascertained. The slide rule would naturally be used for all calculations. One U. S. gallon contains 3785 cubic centimeters and 1 gallon per twenty-four hours is equal to 2.63 cubic centimeters per minte. Dividing the number of cubic centimeters per minute by 2.63, therefore, gives the rate of flow in gallons per twenty-four hours.

With any given orifice the rate of discharge will increase as the square root of the pressure shown by the manometer. The formula $Q=C\sqrt{H}$ may be used where $H$ is the pressure on the manometer in inches. The value of $C$ is to be ascertained by making a number of experiments at different rates, reading the manometer and measuring the water collected in a certain time interval in a graduate. After several experiments to ascertain the value of $C$ have been made with consistent results, it will be unnecessary to collect the water from the discharge in the graduate each time, but instead the simple reading of the manometer can be used with a slide rule calculation to show the rate of flow.

Each orifice will have its own formula and must be rated. The rating once established should be checked periodically, because it may be changed by slight corrosion of the metal or by incrustations upon it due to deposits from the water. This will depend upon the character of the water and also upon the metal. No chances should be taken. The rating can be so rapidly and easily made that it should be repeated often enough to insure accuracy.

The record of the meter is to be ascertained by taking off the top so that the spindle can be seen. These spindles revolve with comparative rapidity. For instance, in a certain domestic meter in common use, the spindle makes 433 turns for each cubic foot of water passed, or 58 turns per gallon. If the meter indicates a discharge of 100 gallons per twenty-four hours, the spindle will turn once in fifteen seconds. The time of revolution may be taken with a stop-watch if the revolution is slow. Better, the time of several revolutions may be taken, and in case the velocity is greater, the number of revolutions in one minute or some other interval of time may be counted. The number of turns to a gallon for each type of meter can be ascertained from the manufacturer, or it can be ascertained by an examination of the gear train, counting the several teeth and making the appropriate calculation.

In making a test a meter would be connected up in the apparatus, the shut-off gate opened far enough to furnish as much water as needed (deficiency will be indicated by less than full pressure on the pressure gauge, which should always show a constant reading) and the throttling gate slowly opened until the moving parts of the meter commence to revolve. It would then be closed down until they stop, and then opened, watching the manometer closely, as far as possible without again starting them. The manometer reading and the corresponding quantity should be then entered in the record as the quantity that will pass with no registration. The controlling valve should then be opened until the moving parts move very slowly, the observation repeated, but this time with the addition of a record of the rate at which the meter is recording. Opening it further, the operation should be repeated at a number of points as may be indicated by experience.

In making up the record in tabular form, it is suggested that the slip should be calculated in every case; that is to say, the difference between the actual quantity of water passing and the quantity indicated by the meter.

For plotting, logarithmic paper should be used, and a 4-inch or 5-inch base will be sufficient. The quantity in gallons per day should be shown in one direction and against this should be plotted the amount of slip ascertained for those quantities.

This method of testing involves the use of the slide rule for rapid calculation, but there are no greater difficulties in the calculations or in making records than are common in hydraulic and laboratory work. With such equipment once installed and tested out, it would seem possible to put a meter through all of its paces and ascertain substantially what it is capable of doing at low rates in a very few minutes.

Testing old meters of various types after they have seen some years of service will be most likely to be productive of useful ideas as to types and materials giving continued successful registration.

The following is a suggestion for a further specification for meters in connection with these tests:

" The slip of the meter at low rates shall not exceed — gallons per twenty-four hours. When the moving parts are stationary and water is allowed to flow through the meter at a slowly increasing rate, the moving parts shall start to move before this quantity is reached and thereafter at no point shall the indicated quantity fall below the actual quantity by more than the amount specified. Meters shall be subject to this test at any temperature between 35° and 75° F."

The number of gallons that could be specified per day will have to be ascertained by practical experience. There is a tendency at the present time to manufacture and sell an increasing number of types of meters and of variations of old types and with variations in the materials that are used, and some such addition to the specifications and to the ordinary meter tests is much needed.

## CHAPTER XIV

## AS TO WHETHER THE SCALE SHOULD SLIDE OR NOT *

It is an important question of public policy whether exceptionally low rates shall be made for large service not otherwise available, which would result in large additions to income and some net profit.—Thos. W. D. Worthen, Jour. N.E.W.W. Assn., 1917, Vol. XXXI, p. 134.

The sliding scales now in use in American Water Works systems have largely come down to us from early times. The forms and sometimes the rates themselves were established to meet conditions that existed only in those earlier days. In part they were framed to meet conditions which have ceased to exist and they embody features that would hardly be otherwise adopted at the present time.

In the first place, the idea to be kept first in mind in establishing a system of meter rates is to distribute the total burden of the service among all the takers as equitably as it can reasonably be done. We are not concerned in this discussion as to that most important question of how much revenue is to be raised. We will limit ourselves strictly for the present to the distribution of the amount that is raised equitably among the different takers.

In the second place, the actual cost of furnishing service to various kinds of takers is to be taken as the ordinary guide in establishing the relative amounts of charge. This cost is not necessarily to be taken as the sole guide in fixing rates, but among all the things that may be taken into account it is by far the most important.

* The substance of this chapter was presented as an oral statement to the Penna. Water Works Assn. at its meeting Oct. 19, 1916, and to the N.E.W.W. Assn. at its meeting Nov. 8, 1916.

Years ago rates for metered water and for many other services were established upon somewhat different principles from those which will naturally govern at this time. To illustrate: A railroad man of wide experience stated, perhaps twenty-five years ago, that it was the policy of his road to make operating expenses on everything that it touched and to make profits where profits could be made. That was a sound principle with reference to conditions that obtained at one time, and it was a principle that largely governed in making many of the early rates for metered water. Many of these early rates are still in effect.

In considering the question of meter rates, one of the first matters to be thought of is the effect of the rates as applied to the smaller domestic consumers. In completely metered systems at the present time approximately one-half of all consumers use less than 100 gallons of water per day. Although the amount of water used by this 50 per cent of the consumers is often a relatively small part of the total output, pipes and services and meters have to be maintained for them and rates must be established that will insure that these small takers bear a fair proportion and only a fair proportion of the total cost of supporting the system.

The first point in fixing a meter rate schedule is to make certain that a consumer taking 100 gallons per day or less will pay a bill which is a reasonable one from the standpoint of the cost of the service. It is also desirable that the charge should be a reasonable one as compared with the fixture rates which were earlier in force and which are commonly replaced by the meter rates.

The average amount of water taken by each manufacturing and industrial consumer from the returns of the committee of the New England Water Works Association is over 30,000 gallons per day. It is obvious that where a single customer takes 30,000 gallons per day, the cost of distribution is less and it is possible for the works to sell the water at a lower price per 1000 gallons than it can be sold for to domestic consumers taking only 100 gallons of water per day.

It is this obvious difference in conditions that first suggested and led to the sliding scale.

Let us take for consideration the case of a small town which has recently built a water works plant. The amount of water required could not be ascertained with certainty in advance, and in any event it is wise to build works to anticipate a considerable amount of future growth The result is that the plant when first built has a capacity that is necessarily considerably greater than sufficient to furnish the quantity of water for which there is a remunerative market.

Let us take concrete quantities, because they are easier to talk about. Assume that the works have been built to supply two million gallons of water per day year in and year out. These works start in business and get what business they can, and at the end of the second year, when most of the business readily within reach has been secured and connected, it is found that the amount of water sold is only half a million gallons per day. Three-fourths of the capacity of the system is still in reserve and unutilized.

Under these conditions it is hard to make the business pay its way. It is running behind and there is something of a deficit in the interest payments and the deficit is beginning to be embarrassing.

There is a factory in town that as yet has not taken water. It has a supply of its own for manufacturing purposes and that supply is so readily obtained that there is no hope of selling to it water from the public works at the rates that have been adopted. If a rate could be made that was sufficiently low, there would be a chance to do business.

What naturally happens? The superintendent of the water works and the manager of the factory get together, estimates are made of the cost to the factory of supplying itself with water, various matters are taken into account, and a contract is made to sell some of the surplus water to the factory at a rate which the factory can afford to pay. The price of water under this contract is a mere fraction of the cost of water to the small takers, but the amount paid for water under the contract adds to the net income of the plant. A market is found for water that could not otherwise be sold. The money received under the contract makes up the deficit on the interest and helps the works out of a tight place. So far, the contract is all to the good and is advantageous to everyone; but the low rate that is made in this way to meet competition of another supply and to secure much needed revenue to meet an urgent early deficit is very persistent. The chances are that either the rate itself, or some other rate not very greatly higher than it will be continued through a long term of years and extending into a time when general water supply conditions have wholly changed.

If we can look at this same plant say ten or twenty years afterward, when the town has grown and business has grown, and nearly the whole of the two million gallons of daily plant capacity has been sold, we shall find that the time is approaching when the plant must be extended to meet increasing business, and it must be extended sooner because of the water that is supplied to that factory.

If the matter is carried to its logical conclusion and it is found that it is necessary to build the new works five years sooner than they would otherwise be necessary because of that supply to the factory then logically the water rates charged to the factory should carry the whole interest charge on the new plant during the five years interval. That, of course, cannot be done. But the illustration does represent a real substantial condition that must be taken into account in considering equitable prices for water for manufacturing purposes through a term of years.

In the case that we are assuming, the contract that was advantageous at the start, at the end of ten or twenty years has ceased to be an asset to the works; it has become instead a serious liability.

Considering that plant from the time when it first becomes apparent that additional capacity will be required to maintain the business, the conditions with respect to equitable meter rates are very different from what they were in the early days when the special rate was made.

The question to be considered now is whether the sliding scale that originated in the way that has just been illustrated and which was undoubtedly necessary for early conditions, has outlived its usefulness and should be discarded and be replaced by the uniform rate.

The writer has been trying to think out the answer to this question. In doing this, he has taken from his office files records of a number of water works plants that have been valued and for which full statistics of operation are available. A number of representative plants have been selected from different parts of the country. In each case the gross income for the plant for the year in which the study is made is taken as a starting point. The question as to whether that gross income was too much or too little need not be considered at this time. The only question considered is the distribution of it equitably among the different classes of takers.

There are various ways in which the cost of maintaining a water works plant may be classified. Several systems of distribution have been presented to the water works associations in recent years. It cannot be said that one way is right and that other ways are wrong, but it is now suggested that the following classification which is a little different from those which have been proposed may be helpful in this connection. Under it the whole annual budget is divided into three parts, as follows:

First, the cost of supplying water, including all the costs that there are up to the point where the water is delivered under pressure at a reasonably central point. This includes interest (or a proportional part of the net profits) on the whole investment or worth of the supply works and of the land held for use in connection with the supply; the depreciation on those works, all operating expenses, and taxes and a pro rata division of general expenses of all kinds than cannot otherwise be assigned to a part of the service.

Second, the cost of distribution made up in the same way and including all the costs that there are for pipes in the streets and distributing reservoirs, and the care of the pipes and the work that is done to prevent and stop leakage, and the value of whatever water may be lost as leakage from the pipes in the streets.

Third, the service cost, including the costs of service pipes and meters as far as they are borne by the water works department, and all the costs of reading meters, billing, collecting and general office expenses, and the value of whatever water may be lost as leakage or as under-registration of meters.

The distribution in the cases that have been taken is comparatively easy, because they represent plants at times when valuations were made and when the costs or values of each part of the plant have been carefully estimated in detail, and these figures serve as a basis for distribution of the interests (or profits) and depreciation charges.

Distribution of most of the operating expenses is comparatively easy, but after most of the items have been disposed of, some items remain, such as a part of the taxes, salaries of general officers, etc., which are not associated particularly with any one of the three parts, and the best that can be done with these is to divide them pro rata in proportion to the amounts of the items that can be directly distributed. When this is done, the whole cost of the water service will have been divided into the three parts.

Let us now see what is to be done with these three parts. How shall they be distributed in the form of bills among the water takers? It will be more convenient to take them up in a different order from that in which they were first mentioned.

Let us consider first the service cost. This includes the interest on the investment in each service pipe and meter; the operating expenses, including repairs; meter reading; the office expenses and cost of collections. It may also include the value of the average amount of water lost per service or failing to be recorded by the meters.

The easiest, simplest and fairest way of handling all of this part of the cost is to distribute it on the services as service charges. As between the large meters and the small meters it should be distributed somewhat in proportion to the carrying capacity of the meters, so that the larger services will carry a proportionately larger amount. This distribution is a fairly simple and definite proposition and it can be worked out in a way that is fair and equitable to every taker. There seems to be no question of the procedure so far.

To take up next the first division of the cost of the water delivered at the central point. The cost per 1000 gallons may be ascertained by dividing the total annual cost by the total annual output. The result is a price per million gallons or per thousand gallons. This price is the basis of the meter rate. It is not the whole of the meter rate but it is the first part of it, and it is a part that ought to go with every drop of water that is sold, and so far as the meter rate is made up of it, it ought to go in exactly the same measure with every bit of water; that is, the smallest taker should contribute just as much to the price of water wholesale as the manufacturer and no more. This step in the procedure also is simple and definite and there seems to be no question about its soundness.

This leaves the second item in our classification to be disposed of. This is the cost of distributing the water in the streets including the value of the water lost by leakage from the mains. This is much harder to handle. It amounts to quite a large part of the whole cost of supplying water. Where the source of supply is near at hand and cheap, it is often much the largest part of the whole cost. Where the source of supply is remote and costly, it is smaller relatively, but it is always an important part of the whole cost.

In the first place, a subdivision of this cost of distribution may be made. Some of it represents the cost of furnishing fire protection; the rest of it represents the cost of distributing water to consumers. Fire protection is furnished by practically every American water-works system. Furnishing fire protection is an important function of the plant. The value of fire protection is very great. The cost of furnishing fire protection is a substantial part of the whole cost of furnishing water. Perhaps on an average it amounts to one-third of the whole cost in American cities, but this is not to be taken as a fixed or definite ratio.

The method of ascertaining the approximate cost of the fire service, from the data that are best suited to general use, is that proposed by Messrs. Metcalf, Kuichling and Hawley.*

This method is one of several that has been proposed, but I

* Proc. Am. W.W. Assn., p. 55, 1911.

think it is the fairest and best adapted for general use. Even so, the results reached by it are not to be taken as conclusive, but rather as an aid to judgment.

For the systems selected for study, examined in this way, this method indicates that from one-fourth as a minimum to three-fourths as a maximum of the whole cost of distribution should be taken as the cost of fire service. The percentage of the cost of distribution assignable to fire service is higher in small systems than in large ones. It is also higher in systems where buildings in the city are largely of wood than where they are of brick and stone. It is higher as the town or city is compactly built, and a scattered or rambling town is safer from fire and needs less fire protection.

In each of the cases which I have considered there is a record of the amount actually paid for fire service for that year. In every case the amount of money that was so paid is less and usually much less than the estimated fair value of the service. However that may be, it cannot usually be assumed in fixing meter rates that inequalities in the amounts paid for fire service under contracts will be readjusted. Whatever amount is received for fire service is to be credited to what appears to be the whole cost of distribution, and whether that amount is too much or too little, it is to be subtracted. All the remaining cost of the distribution must be raised in some way from the water takers.

As a practical matter, this means that a part, and often a considerable part, of the cost of the fire service is actually contributed by the water takers, and if the takers pay by meter rates, then the meter rates must be made large enough to cover that part of the value of the fire service.

So far as fire service cost is carried in this way, there is no doubt that meter rates are a crude, inequitable way of distributing it, but even so, it is one way of distributing it, and any other way that is in practical use also involves some inequalities.

For instance, if the value of the fire service is paid to the water works with money raised by taxation, then the tax is assessed in proportion to the valuation of the property. Under this method, if a person puts up a fireproof building, he will pay on the value of the building for fire protection, although he has little use for it, while his neighbor who puts up at half the cost a building of corresponding size that is a fire-trap, gets off with half the tax, although he is the one that makes the heavy demand upon the system for fire protection and who ought to pay most heavily for it. That, however, is a side issue at the present time and we need not be detained by it. For our present purpose it is only necessary to keep in mind that a substantial part of the cost of the fire service must be carried in some way by the meter rates.

That leaves us with all the rest of the cost of the distribution and that obviously should and must be carried by the water rates. The question remains as to how it is to be best applied.

One way is to divide the whole amount by the whole quantity of water that is sold in the course of a year. If this is done a price is found per 1000 gallons which represents the average cost of distributing water to all customers, large and small, and if this amount is added to the wholesale cost of the water it produces a price per 1000 gallons which can be applied to all quantities as a uniform rate and that will produce the required revenue.

But before doing this we must bear in mind that approximately half of the whole number of takers use 100 gallons per day of water, or less, and that less than 1 per cent of takers are industrial establishments using an average of 30,000 gallons per day each, more or less. The cost of distributing water in large quantities at wholesale to railroads and factories and to places centrally located is a great deal less than the average cost of distributing water in small quantities to all the small customers, and it is fair to recognize in some way this difference in cost of distribution.

Another way of handling the matter is to put the whole of this part of the distribution cost on the service charge. That view has been warmly supported by some of those who have studied the question. It can be backed by the idea that the pipes in the streets are required in any event to give the required capacity and that the size and cost of these pipes is practically unaffected within reasonable limits by changes in the rate of draft by takers.

From a theoretical standpoint, there is a great deal to be said in favor of this proposition of putting the cost of the distribution so far as it is not charged to fire service, on the service charges. If it could be carried out in a simple and equitable manner the writer would be quite content to see it disposed of in that way.

If that were to be undertaken the most natural way of distributing it, and the only one that seems to be readily available, is to distribute it in the manner which has already been mentioned for distributing that part of the gross income which represents the cost of taking care of the services; that is to say, by dividing it among the meters, but taking into account the size of the meters so that the larger meters will pay a greater relative proportion of it.

As far as the takers who use the, larger meters are concerned, this method may not be unjust. It is true that it results in a very high service charge, but in connection therewith the price per 1000 gallons may be less than it would otherwise be, and the high service charge is offset by the lower price per 1000 gallons. If the larger meters only were concerned, we could let it go, but when we come to the smaller meters an obstacle is found.

On the whole number of services in the system, 90 per cent more or less are served by $\frac{5}{8}$-inch meters. There are very practical reasons why it is not worth while to vary the size of those $\frac{5}{8}$-inch meters according to the amount of business done by each service; that is to say, we find that 90 per cent of the whole number of services, more or less, are supplied by meters of the same size, and under the proposed arrangement every one of these would be assessed the same relatively high service charge.

Now, these 90 per cent of the services do not represent equality of conditions. On the other hand, they represent a very wide range of conditions. The range is between the smallest houses that there are and some of the larger residences and small business establishments. Some of these $\frac{5}{8}$-inch meters are on services that handle twenty times as much water as is handled by others, and these services represent also presumably twenty times as much business and worth of service to the taker.

To divide the whole distribution cost in this way and to apply it in the form of service charges results in an amount of loading on the services of the smallest customers that is not fair to them.

The takers that use 100 gallons of water per day or less, are particularly referred to, and these make up in a general way one-half of the whole number of takers. Following out this system makes these smaller takers carry a part of the load that ought to be carried by the larger takers.

As a practical matter, after giving the subject considerable study, the writer does not believe that it is advisable, even if it is practicable, to put the whole of that load, or even the greater part of it, on the service charge, when the service charge is calculated in this way.

It is true some other method of computing the service charge might be found that would permit the loading to be carried with less injustice. For instance, the service charge might be based on the width of the lot. This method was suggested and recommended by an earlier committee of the New England Water Works Association eleven years ago, of which the late Freeman C. Coffin was Chairman.*

On the other hand, it does not seem fair to distribute the whole cost of distribution evenly on all of the water that is sold because of the inequalities in conditions of service between large consumers and small ones. To do that by the adoption of the uniform rate means raising the manufacturing rate above the amount which is really fair to large takers. The manufacturers are then made to stand the brunt of the deficiency in income that results from supplying small houses at less than cost.

So the question still remains as to where the cost of distribution is to be placed. It must go somewhere. The way in which it is actually carried by most American water-works systems at the present time is by putting it, or a part of it, as a loading

* Jour. N.E.W.W. Assn., Vol. XIX, p. 322, 1905.

on the first quantity of water that is sold from each service. In other words, instead of putting it equally on all the water, it is divided unequally. Some of it, of course, should go with all the water, because there is some cost of distribution in all cases, and the manufacturers ought to pay a part, but not in proportion to the volumes of water that they take.

When this method is followed we have the sliding scale. The difference in distribution cost furnishes a rational reason for the use of the sliding scale, and perhaps it is the only rational reason that can be assigned for its use at this time.

The calculations that have been made from the examples from water-works systems taken from our office files will not be presented in detail. One of them is given as an illustration of the method of analysis and computation, in Chapter XVII, p. 182. As a result of that study as far as it has proceeded at the present time, it seems very clear to the writer that sliding scales of the kind that have been and still are in use, where the ratios between the rates charged for water to the smallest consumers and those charged for water to the largest manufacturing estabsishments, reach 3 to 1 and even 5 to 1 and more, cannot be justified. They are a relic of conditions that are gone, and rates that have grown out of conditions that have gone ought to be discontinued. But, on the other hand, a sliding scale having a ratio of perhaps 1.50 to 1.00, that is to say, a scale of rates under which domestic consumers are charged 50 per cent more per 1000 gallons than is paid by manufacturing takers, has good, substantial reason for its existence, and it is not by any means clear that such a sliding scale ought to be discarded.

As a result of the rapid study it appears to the writer that this ratio of 1.5 to 1 or at most 2.0 to 1 is all that is justified by existing conditions in the plants that have been taken for study, but other cases will undoubtedly be found representing more nearly the condition of a new plant with large surplus capacity, like that used above as an illustration, where a wider ratio may be desirable.

For example, Mr. Leonard Metcalf writes of a case where it was impossible to adhere to the suggestion that the domestic rate be but twice the commercial rate, and the Commission agreed with us that it would be disastrous to the community if the rate should be so changed as to increase materially the industrial service rate which is now approximately six cents per thousand gallons, compared with the thirty-three cent rate per thousand gallons upon the domestic service. To have materially raised the manufacturing rate would unquestionably have involved the loss of the service of the large steel mills, one of which, for instance, is now paying $10,000 annual revenue, which business shows the company a profit over the cost of the service, and the loss of which would increase the domestic consumers' burden.

**Suggested Procedure.** The following outline, in very general terms, may be helpful in cases where detailed calculations like those described in the following chapters are not feasible, and as an aid in checking such calculations after they have been made.

Where the cost of the distribution system, or a large part of it, is assessed upon the abutters when pipes are laid, as is done in Philadelphia, Milwaukee, St. Paul, Seattle and Los Angeles, then there appears to be no reason for using the sliding scale, and a uniform rate should be used.

Where the distribution system is paid for by the water department in the usual way, a moderate amount of slide in the scale seems to produce rates that are most equitable to all. Where the water itself is more than usually expensive, either because of costly works for storage, or transportation, or because of pumping and purification expenses, the amount of slide will be relatively small. Where the source of supply is near at hand, and cheap, and water is delivered at less than average expense, the cost of distribution becomes the principal part of the whole cost of furnishing water, and the amount of slide will be relatively great.

In the former cases slides in ratios ranging from 1 to 1.3 to 1 to 1.6, in the latter cases from 1.0 to 1.5 to 1 to 2.0, more or less, would seem to be about the ranges that on present evidence would include the greatest number of cases.

When rates are drawn up in this way, if it appears that the manufacturing rate is considerably greater than the rates that are actually paid by the largest consumers, the question may be considered as to whether enforcing such rates would have the result that one or more large consumers would get other supplies and cease to take water from the plant.

It may often happen that the best thing for an overloaded plant is to have one or more such customers secure other supplies. The question of all the effects of such loss deserves careful consideration in each case.

If there is likelihood of the loss of business, and if the loss of business is undesirable, then the question of what rates must be made to retain the business is to be considered. The first matter to be determined will be the probable cost to such large takers of making other adequate arrangements for maintaining their service. There may be some advantages to them in having their service from the plant, and it may be presumed that they will pay a somewhat greater annual bill than the estimated annual cost of securing an independent supply. The rate that can be actually secured may be a matter of negotiation in the end. There are many local factors that will have to be taken into account.

If it is decided that a lower rate is warranted to meet existing conditions, it is not necessary to lower the manufacturing rate in the three-scale rate to a level that will hold the business. A better procedure is to make a special rate, applying only to quantities in excess of 82,000 gallons per day, 30,000,000 gallons per annum, or 1,000,000 cubic feet per quarter, and to make this rate as low as may be necessary to hold the business that it is considered necessary and desirable to hold.

The new rates of the Hackensack Water Company, found on page 44, show the use of the special rate for this purpose.

## CHAPTER XV

### THE THREE-CHARGE RATE

Theoretically this is the most complete and satisfactory type of rate, but it involves so many practical difficulties in application that it has been adopted by comparatively few companies. Thos. W. D. Worthen, Jour. N.E.W.W. Assn., Vol. XXXI, p. 177, 1917.

The form of rate adopted by the New England Water Works Association, which has been under discussion in the preceding chapters, is sometimes called a two-charge rate, that is to say, each bill is made up of two parts; first, a service charge and, second, a charge for water. This is distinguished from the old or one-charge rate in which the charge for water only constituted the whole bill. In distinction to these we have now to consider the Three-charge Rate.

Under this system the costs of maintaining the water service are classified under three heads instead of under two. In discussing this matter before the American Water Works Association, Mr. Halford Erickson, Chairman of the Wisconsin Railroad Commission * after developing at considerable length the conditions to be met, stated:

The operating expense of a water utility, then, may be said to be influenced by three principal elements: the demand which the plant must meet, or the capacity which is required; the amount of water pumped, or the output, and the number of consumers supplied. For the sake of convenience these may be referred to as capacity, output and consumer costs.

Mr. Erickson, after discussing the classification, further suggests that for a typical water works plant, the capacity expense would amount to about 38 per cent; the consumer expense to about 18 per cent; and the output expense to about 44 per cent of the total operating expenses.

* Proc. Am. W.W. Assn., p. 56, 1913.

This threefold division has also been frequently used by writers in the last years.*

Classified in this way, the consumer charges vary with the frequency of filling rather than with the quantities taken. They cover such expenses as the care and reading of meters, billing, postage, collections, etc. The second, or demand charges, vary with the size of installation or capacity for taking water, while the third, or output charges, are the only ones that vary with the actual quantities of water drawn.

This threefold classification was probably first used in connection with the supply of electric current. It may be accepted as a logical division of the expense of supplying water, but some of the conditions of the water service are different from those of electric services, and as a practical matter the rates may not work out in quite the same way.

With an electrical equipment there is absolutely no storage of power. The electricity must be generated and carried and distributed second for second to meet the requirements of the consumers, and the absolute peak loads must be met by every part of the equipment. Peak loads in the electrical business are high with reference to the main output, and also irregular, in that they come at different times and are frequently of short duration. The cost of furnishing and keeping the equipment ready for service to meet these peaks is a very important part of the whole cost of the electric service.

With a water-works system, on the other hand, and especially when domestic consumers only are considered, the peak loads are much less marked in amount and they occur with a considerable degree of regularity each day. In a great many, probably in a majority of water-works systems, there is a standpipe or service reservoir connected with the distribution system, and this meets or helps to meet and carry these peak loads.

The amount of storage required to cover all such peak loads growing out of variations in domestic water supply service is relatively small; and the cost of furnishing it is hardly an appreciable element in the whole cost of supplying water. For

* Philander Betts, Jour. N.E.W.W. Assn., Vol. XXX, p. 376, 1916.

all the domestic services in a system the average rate of output is probably not over 2 or 3 per cent of the combined capacities of the services and meters. Practically speaking, it makes no difference to the water-works system whether an individual consumer draws 5 gallons of water in one minute or in ten minutes. It does perhaps make a very little difference whether it is drawn during those hours of the day when heavy drafts are common or in the hours when the normal use is light.

The peak loads in a water-works system resulting from domestic service are at most only a small fraction of the loads that have to be provided for in connection with fire service. The pipes in the streets, the reservoirs, the pumps, or whatever appliances are depended to furnish the water to meet the peaks must always have capacity greatly in excess of the domestic peak load to meet fire service.

Further, ordinarily these pipes, reservoirs and pumps are built to meet a certain amount of anticipated future growth, and until otherwise required that margin is also available to meet peak loads.

On the other hand, it is undoubtedly a fact, when the analysis is carried to a logical conclusion, that the capacity in all these structures that must be provided is somewhat greater because of the domestic peak loads. While the proportion is relatively small, it is one of the elements that influence cost, and the cost of the service is somewhat greater because of these fluctuations.

The situation differs from the electric situation in the relative importance of the peaks. In the electrical business these peaks are large and meeting them is costly to the works. In the water works business they are relatively small and easily provided for. Under these conditions, the demand charges for domestic water consumers become so small relatively that it is hardly necessary to try to separate them, and they may be more conveniently and with all needed accuracy divided into the two remaining classes. That is to say, they may be divided between the service charge and the output charge.

This is the method that has been followed by the New

England Water Works Association in its adopted schedule of rates.

This method may be less appropriate for large services, that is to say, for services 4 inches and 6 inches in diameter and larger, used for railroad and manufacturing purposes. Rapid fluctuations in rate of draft from such services are often troublesome to small water-works systems, and a consideration of this condition would logically lead to placing higher service charges on these large services than would otherwise be used.

It is further to be noted that if any very large part of the whole cost were to be classified as capacity charges and were to be assessed among the services in proportion to the sizes of the services or meters, that the same conditions that were discussed in Chapter XIV with reference to the undesirability of high service charges, would be met. Ninety per cent more or less of all the consumers are supplied by meters and services of the same size. The fact that all of these services are of the same size is a matter of practical economy and convenience and does not represent equality of conditions among all these takers. To assess a considerable part of the whole cost of the service upon the consumers in proportion to the size of meters would mean that these differences in conditions among all those consumers, except the 10 per cent, more or less, that use meters of larger size, would be ignored. All the others would be put upon the same basis, and this condition, from the standpoint of the conditions of service, is not equitable between the larger and smaller consumers in this class.

In classifying pumping station expenses, it has sometimes been thought that the output charge should include only the cost of fuel and labor needed in operation and that the capacity charge should include all the capital charges on the investment in such works. This view is based on the idea that increased output means increased operating expense, but no increased equipment. As long as the pumping station and other supply works have considerable reserve capacity and are not extended to meet increasing output, this classification seems to have merit, but whenever the amount of output comes so near to the capacity of the plant that a sufficient reserve capacity is no longer available, it becomes necessary to build additions, and in that event, the additions are needed to take care of the added quantities of water that are drawn.

If the particular time in the course of development when new works are required is taken for especial consideration, it is then found that the additional quantity of water drawn represents a great increase in capital outlay needed to secure it.

In the whole period of development two conditions are thus presented: the first runs through some years when increased capacity is not required to furnish an additional quantity of water; and the second begins and covers the period when additional capacity and investment are required to furnish perhaps a rather moderate increase in output.

Taking both of these considerations into account, and averaging the conditions right through, the additional quantity of water, great or small, will cost about as much in proportion as the main output.

There may be reasons for temporarily adopting the other classification, especially in the case of a new plant for which business is being secured slowly and with difficulty. In the normal water works operation, the writer believes that every bit of the cost of production of water, whether operating expenses or capital charges, should be carried in the output cost.

If this is always done, there remains to be separately accounted for as output charge under this general procedure only so much of the additional cost of the pipes and reservoirs as is not chargeable to fire service. That will probably be relatively small in amount and may logically be handled as part of the service charge. That may be done so far at least as will not increase the service charges above an amount that is otherwise fair to the smallest takers.

## CHAPTER XVI

## MAKING THE RATE SCHEDULE

Selling water by guess has now few advocates among the water works engineers and superintendents.—M. N. Baker, Editorial, Engineering News, April 18, XLV, p. 285, 1901.

The problem presented is to select a rational and just system of water rates to produce a given amount of revenue. No detailed discussion of the amount of revenue to be produced will be here undertaken.

To supply water at cost, the revenue produced must be sufficient to pay all operating expenses of every description, including the general administration, and this includes, in the case of works owned by cities, a proportionate part of the general expenses of the city government and of the city buildings, a fair allowance for depreciation on all property used, all taxes and charges of every kind, and in addition a return on the value of the plant at the rate at which money can actually be borrowed for the enterprise.

In the case of plants owned and managed by cities, the effort is most often to fix rates at cost. In other cases they are fixed at less than cost and only sufficient to pay operating expenses and interest on so much debt as exists. Where the works are owned by private companies, a profit must be earned, over and above cost, to make the business go.

The measure of a fair profit is that it must be sufficient to insure all necessary capital for extending the plant as may be needed to serve an increasing business. Halford Erickson, late Chairman of the Wisconsin Railroad Commission,* states:

Public interest requires that the rates should be high enough to cover the cost of adequate service, and to bring the necessary capital and the best managing ability into the public utility field.

* Proc. Am. W.W. Assn., p. 51, 1913.

Thomas W. D. Worthen, of the Public Service Commission of New Hampshire, states: *

> The amount of return should be such as to provide for the cost of economical and efficient operation, taxes and depreciation, a fair net return on the fair value of the property devoted to public use, and a proper margin for the successful conduct of the business. Exceptional efficiency of management should receive consideration and encouragement.

President Wilson, speaking of prices to be paid for commodities by the Government in July, 1917, used words which well apply in the water works business. He said:

> By a just and reasonable price I mean a price which will sustain the industries concerned in a high state of efficiency, provide a living for those who conduct them, enable them to pay good wages, and make possible the expansion of their enterprises which will from time to time become necessary. . . . We could not wisely or reasonably do less than pay such prices.

In the case of some publicly owned plants, the present practice is to make rates only sufficient to meet the operating charges and interest on the outstanding bonds; and where bonds originally issued have been retired and the present bonded indebtedness represents much less than the value of the plant, rates so made are less than cost.

When water is sold at less than cost, it means that part of the cost is taken from the accumulations from taxes or water rates of the past, or else that the deficiency is carried forward to be met by future rates. It also ordinarily means that the business cannot be permanently conducted at those rates, because sooner or later extensions will be required; money must be secured to build them; and charges upon the additions will have to be met.

There is a difference of opinion as to what should be done in such cases. The writer believes that water should not be sold for less than cost.† He believes that surplus earnings that result because of the previous retirement of bonds should first be devoted to the extension of the plant. This policy systematically followed will result in constantly increasing surplus

* Jour. N.E.W.W. Assn., Vol. XXXI, p. 170, 1917.

† See "Clean Water and How to Get It," 1907, Chapter XVIII.

revenue, and ultimately part of the surplus should be dedicated to other non-productive public purposes, such as supplying libraries, hospitals and parks. This policy has been followed to a limited extent by American cities.

The rates should further be arranged to represent as nearly as possible average requirements for a reasonable period, say five to ten years in the future, but in general they should be sufficient to meet average conditions; that is to say, it would be unwise to adopt a rate schedule recognizing only the condition of a largely over-built plant, if that condition exists, because the condition is temporary and will soon disappear with increasing business. On the other hand, a schedule adapted only to the conditions of a plant fast reaching, or which has already reached, the limit of its capacity, would be unwise even when those conditions exist, because extensions will presumably be soon made, and then the conditions will be changed to those of a plant that is temporarily over-built.

If each of these two kinds of conditions were considered by itself, wide divergency in forms of rates would result. In the case of an under-built or inadequate plant the service charges would be reduced or might even entirely disappear, and the uniform meter rate would be selected; while with the over-built plant the service charges would be relatively large, the sliding scale would be selected, the amount of slide would be liberal, and the price per thousand gallons to large takers would be reduced to a low amount.

A well-balanced schedule is one that takes into account both of these conditions and provides a division between large and small takers that will represent average conditions through a term of years, with both of these general conditions alternating with each other.

**Fire Service.** The first step after ascertaining the gross revenue to be raised is to deduct from it the amount that can be realized from fire service. The fair value of the fire service to the community is one thing; the amount that can actually be realized from it is another.

The methods of estimating the value of fire service have been mentioned in Chapter XIV. For the present purpose, in most cases, the study may be limited to ascertaining what is or what can be reasonably charged for fire service and deducting this from the gross revenue that must be obtained.

The question of revenue from private fire service is a mooted and difficult question. It is claimed on one hand that private fire service is only an extension of public fire service, and that when public fire service is paid for by taxation such additional facilities as are furnished in the works of large manufacturing establishments are really covered by the taxes on those plants and that no further charges should be made.

On the other hand, it is claimed that private fire protection in yards of manufacturing establishments puts the water works to large additional outlays in providing capacity to furnish large quantities of water that may be needed in a bad fire, and also to furnish the quantities of water that are sometimes lost by leakage or otherwise from such pipe systems, and that very substantial annual payments should be required for furnishing such facilities.

This matter will not be discussed further at this time. If such collections are made or can be made under the proposed schedule, all such amounts should be deducted from the gross revenue otherwise needed. The remainder is the amount that must be raised by the proposed rates.

The problem then remains of distributing the gross revenue, less the amounts received from fire protection, among all the takers. This procedure will be taken up by the use of an example of an actual system.

**Example.** The plant selected for this study is a small one, with 5191 services, nearly all of them metered. Waste has been persistently hunted for years, and the per capita consumption is unusually low.

The meter rates are in the jump scale form with a minimum. It is sometimes possible to get a lower bill by drawing more water. The rates for the largest consumers are too low, and for certain intermediate ones too high. The schedule, however, is fixed by contract; has successfully withstood legal attacks;

and is a good revenue producer. It is certain that it will not soon be changed, but we may, nevertheless, see what could be done to improve it.

An analysis of the records for a certain year shows that 4839 of the services drew less than 300,000 gallons each Under the proposed classification * all water drawn by them would come under the Domestic Rate. These services drew in the aggregate 150 million gallons of water, an average of 85 gallons per day for each service.

Among the larger services there were 99 drawing larger quantities but less than 3,000,000 gallons each, and therefore coming under the Intermediate Rate. These drew, in all, 47.7 million gallons, an average of 1320 gallons per day for each service. Of this amount, 300,000 gallons from each service during the year, or 29.7 million gallons, would be charged at the Domestic Rate. The remaining 18 million gallons drawn by these 99 services would be charged at the Intermediate Rate.

There were, further, 20 services drawing over 3,000,000 gallons each, and so coming under the Manufacturing Rate. The total draft by these was 143.3 million gallons, an average of 19,700 gallons daily for each service. Of the whole quantity drawn by these 20 services, 6 million gallons would be charged at the Domestic Rate, 54 million gallons at the Intermediate Rate, and the remaining 83.3 million gallons at the Manufacturing Rate. These quantities may be brought together in tabular form as follows:

| Class. | Number of Services. | Average Daily Draft per Service. Gallons. | Total Annual Draft, Millions of Gallons. | Classified for Payments. | | |
|---|---|---|---|---|---|---|
| | | | | Domestic. | Intermediate. | Manufacturing. |
| Domestic | 4939 | 85 | 150.19 | 150.19 | | |
| Intermediate | 99 | 1,320 | 47.70 | 29.70 | 18.00 | |
| Manufacturing | 20 | 19,700 | 143.30 | 6.00 | 54.00 | 83.30 |
| Total | 4958 | 188 | 341.19 | 185.89 | 72.00 | 83.30 |
| Per cent | ...... | ....... | 100.0 | 54.49 | 21.10 | 24.41 |

* Chapter V, p. 66.

The service charge for the local conditions, computed by the methods suggested and at the average figures by the Committee on Meter Rates, are as follows:

| Size of Meter. | Number of Meters in Use at End of Year. | Service Charge as Developed in Chapter VII. | In Addition 10 Per Cent of Cost of Services and Meters as Far as Paid by Works. | Total Service Charge per Meter. | Total Amount per Annum. |
|---|---|---|---|---|---|
| 6 | 4 | $120.00 | $50.00 | $170.00 | $680.00 |
| 4 | 0 | 60.00 | 25.00 | 85.00 | |
| 3 | 3 | 40.00 | 13.00 | 53.00 | 159.00 |
| 2 | 24 | 20.00 | 8.00 | 28.00 | 672.00 |
| 1½ | 7 | 12.00 | 5.50 | 17.50 | 122.00 |
| 1 | 32 | 7.00 | 3.70 | 10.70 | 342.00 |
| ¾ | 67 | 5.00 | 3.00 | 8.00 | 536.00 |
| ⅝ | 5054 | 3.00 | 2.50 | 5.50 | 27,797.00 |
| Total from service charges.. | | | ............ | ............ | $30,308.00 |

The actual revenue from the sale of water was $91,226. Deducting the amount $30,308, that would have been raised by service charges if they had been in effect, leaves a balance of $60,918 to be charged for water. The average price that must be collected is then $60,918 ÷ 341,190,000 gallons, or 17.855 cents per 1000 gallons.

The slide in the present scale exceeds the 2 to 1 ratio which the Committee of the New England Water Works Association suggests as the ordinary maximum. In finding new rates, it is proposed to reduce the amount of slide to the 2 to 1 limit. Probably a detailed analysis would suggest a scale with less slide than this; but in view of the fact that takers are used to a scale with a wide slide ratio and that a minimum disturbance of present conditions is desirable, the slide will not be further reduced at this time.

The rates for the three classes are then computed in tabular form as follows:

| Class. | Percentage of Total Quantities. | Relative Rate. | Product. | Ratio of Required Rate to Average Rate. | Required Rate, Average Being 17.855. |
|---|---|---|---|---|---|
| Manufacturers.... | 24.41 | 1.00 | 24.41 | 0.609(2) | 10.87 |
| Intermediate...... | 21.10 | 1.46(1) | 30.81 | 0.889(3) | 15.87 |
| Domestic......... | 54.49 | 2.00 | 108.98 | 1.218(4) | 21.75 |
| Total...... | 100.00 | ........ | 164.20 | | |

(1) One-half way between the mean and the mean proportional of the Manufacturing = Domestic rates.

(2) $= \frac{1.00}{1.642}$ (3) $= \frac{1.46}{1.642}$ (4) $= \frac{2.00}{1.642}$

As cubic feet are used, the corresponding values are found to be 8.13, 11.87 and 16.27 cents per 100 cubic feet.

A discount of 10 per cent for cash is allowed, and it is desired to raise these rates in such measure that when 90 per cent of all the bills are paid promptly so as to secure this cash discount, the collection will produce the desired revenue.

For $1.00 billed on this basis, 0.91 will be collected, and all the rates thus far reached must be divided by 0.91 to obtain the rates to be used.

The calculation is made in tabular form below and shows the new rates that must be used to maintain the revenue with this discount.

The service charge for a $\frac{5}{8}$-inch meter, first found at $5.50, is increased to $6.04 per annum, but as billing is done monthly, the round figure of .50 cents per month, equal to $6.00 per year, is used. In the same way round figures are used for the ones first calculated for all the items of the schedule, and the ones selected are entered in the next column of the table.

The fifth column shows the number of units to be billed under each class. In the case of the quantities these are converted from the gallons given above to cubic feet to correspond with the billing basis.

Multiplication then shows the amount to be derived from each item. The sum of the products amounts to $100,320. Deducting from this nine-tenths of the 10 per cent cash discount leaves $91,212 as the probable collection under the new schedule.

This checks exactly (within $66) with the actual collections. If there were a discrepancy, it might indicate an error in the computation or a difference growing out of the use of approximate round figures. In the latter case, the question of where the necessary adjustment could be best made would be taken up and a revised schedule made.

| Unit. | Charge as Computed. | Charge to Yield Net Revenue with 10 Per Cent Discount for Cash Availed of by 90 Per Cent of Takers (÷0.91). | Approximate Round Figure. | Number of Units to which this Rate Will Apply. | Total Annual Revenue Produced. |
|---|---|---|---|---|---|
| 6-inch service....... | $170.00 | $186.80 | 180.00 | 5 | 720 |
| 4 ....... | 85.00 | 93.40 | 90.00 | 0 | |
| 3 ....... | 53.00 | 58.25 | 60.00 | 3 | 180 |
| 2 ....... | 28.00 | 30.77 | 30.00 | 24 | 720 |
| 1½ ....... | 17.50 | 19.23 | 18.00 | 7 | 126 |
| 1 ....... | 10.70 | 11.76 | 12.00 | 32 | 384 |
| ¾ ....... | 8.00 | 8.79 | 9.00 | 67 | 604 |
| ⅝ ....... | 5.50 | 6.04 | 6.00 | 5054 | 30,324 |
| Domestic water..... | 16.27 cents | 17.88 cents | 18. | 248.500 | 44.730 |
| Intermediate water.. | 11.87 | 13.04 | 13 | 96.250 | 12.512 |
| Manufacturing water | 8.13 | 8.93 | 9 | 111.350 | 10.021 |
| Sum.............. | ......... | ......... | ......... | ......... | 100.320 |
| Less 10 per cent discount from 90 per cent of takers............... | | | | | 9.028 |
| Probable net proceeds of rates................................ | | | | | 91.292 |
| Actual collections at present rates............................ | | | | | $91.226 |

As the bills are rendered monthly, the schedule with the blanks filled in will be as follows:

For each service there shall be a charge for the service and meter per month as follows:

| | |
|---|---|
| For $\frac{5}{8}$-inch meter | $0.50 |
| $\frac{3}{4}$ | .75 |
| 1 | 1.00 |
| 1½ | 1.50 |
| 2 | 2.50 |
| 3 | 5.00 |
| 4 | 7.50 |
| 6 | 15.00 |

In addition thereto, for all water drawn there shall be charged:

| | Per 100 Cu. Ft. |
|---|---|
| For the first 3300 cubic feet of water per month, or any part thereof, the Domestic rate of | 18 cents |
| For water in excess of 3300 cubic feet and under 33,300 cubic feet per month, the Intermediate rate of | 13 |
| For water in excess of 33,300 cubic feet per month, the Manufacturing rate of | 9 |

A 10% discount for cash payment on or before the 15th of each month will be allowed.

The rates of the present schedule are shown in Fig. 21 as a dotted line, and the rates for the new schedule are shown as a solid line. For the new rates two lines are shown: first, a light line showing the base rate without service charges; and second, a heavier line showing the rates including average service charges. In this case the average service charges were computed by the method given on page 32. For the Domestic Rates the service charge for a $\frac{5}{8}$-inch meter, $6 per annum, less 9 per cent discount for cash, is $5.46. This amounts to 54.6 cents per 1000 gallons per annum when 10,000 gallons are drawn, and less in proportion as the quantities are greater until at the limit for this class it amounts to 1.82 cents per 1000 gallons for a draft of 300,000 gallons.

The Intermediate and Manufacturing Classes are taken together. They include 119 takers using 191,000,000 gallons.

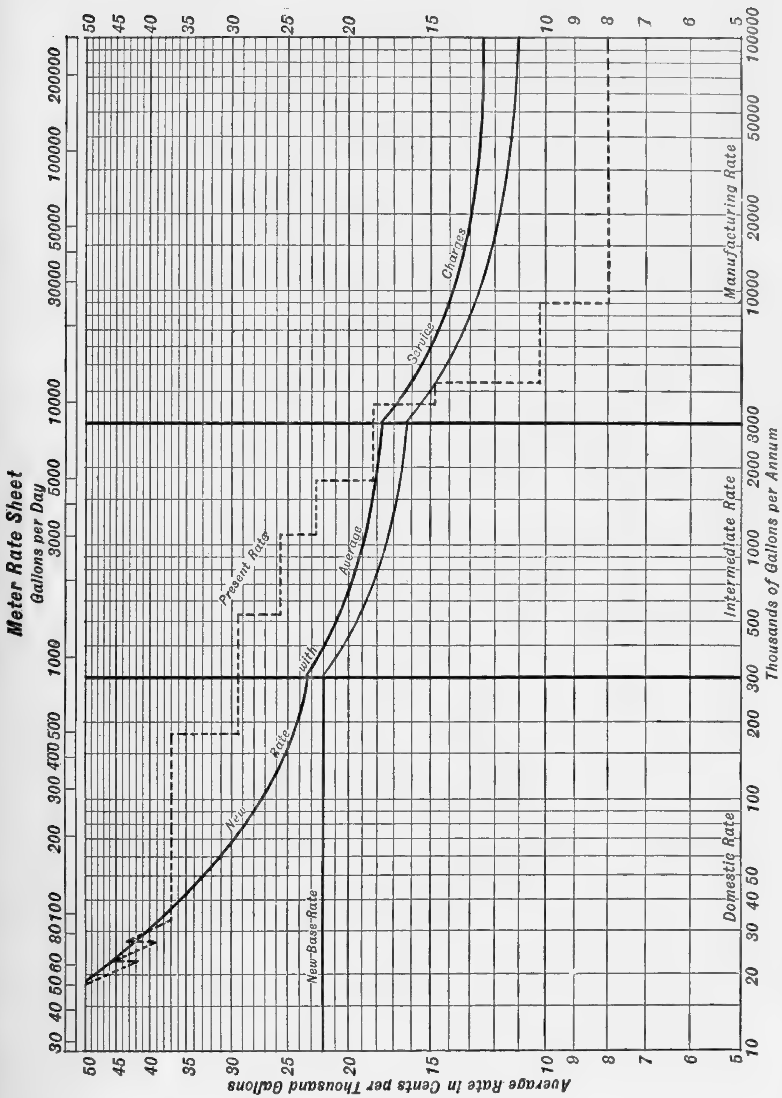


FIG. 21.—Showing Present Rates in a Certain System, Add Proposed Rates to Yield Equal Revenues.

The service charges, as in the above table for these takers, will be approximately as follows:

| | |
|---|---|
| 71 meters 1 inch and over in size | $2130 |
| 48 ¾-inch meters to make up total number @ 9 | 432 |
| Total | $2562 |
| Deduct 9% cash discount | 231 |
| Net service charge | $2331 |

The service charges for all large takers thus produce $2331, with total sales of 191,000,000 gallons, and it therefore increases the price by the quotient, or 1.22 cents per 1000 gallons. This amount is used in making the diagram.

At the 300,000 gallons per annum line where the two methods of calculation meet, the two amounts do not quite agree. There is a computed difference of 0.6 cent per 1000 gallons. Actually there is no sharp line of division in the distribution of meters among the larger or smaller takers. Some takers classed as intermediate are supplied through ⅝-inch meters, and some takers classed as domestic are supplied through larger meters. These variations cannot and need not be taken into account. The difference is divided and the two are made to meet at the 300,000 gallon line.

This plotting shows clearly just which classes of consumers would have their rates raised and which would have their rates lowered. It is interesting to note that consumers drawing from 50 to 150 gallons per day on an average, being two-thirds of the whole number, would not be greatly affected by the change.

It may be that under the new rates the increase to some manufacturing takers will induce greater economy in the use of water, or possibly will lead to the use of more well or other water for purposes for which it is fitted, and, on the other hand, the reduction in rates to those who use intermediate quantities may lead to some new business. If the changes were more radical, their effect upon probable consumption would have to be carefully considered, and perhaps some slight modifications made in some of the rates as a factor of safety against harmful loss of revenue growing out of these conditions.

There is a further comparison that may be made and that has some interest in this case. In Chapter III is given a representative rate in the form proposed by the Committee* that in a general way is found to correspond approximately with average practice of American cities that have adopted the meter system. If this schedule had been in effect at the plant in question during the past year, the charges under it would have been as follows:

| | |
|---|---|
| Service charges for 4958 services at \$4.20 (=\$3.00+\$1.20) | \$20,700 |
| Add approximately for larger services 10 per cent........ | 2,070 |
| 185.7 million gallons of water at 21 cents............... | 39,100 |
| 72 million gallons of water at 16 cents.................. | 11,500 |
| 83.3 million gallons of water at 11 cents............... | 9,200 |
| Total revenue at this rate.......................... | \$82,570 |

The actual revenue from the sale of water was \$91,226, which is 10.2 per cent more than the sum that would have been produced by the above mentioned rates. It is thus ascertained that the actual rates of this company produced a revenue that is about 10 per cent greater than the average or representative rate as above defined would have done.

* Jour. N.E.W.W. Assn., Vol. XXVIII, p. 212, 1914.

# CHAPTER XVII

## A MORE DETAILED ANALYSIS

Let our aim be a generous use of water, but no waste, and each man to pay for what he gets.—Hazen, "Clean Water," p. 153, 1907.

In this chapter an effort will be made to illustrate by means of a typical case the principles described in Chapter XIV and their application to a particular rate problem. The figures that follow represent an actual plant at the time of valuation and classification of the accounts by a very well qualified accountant, and the figures and the values used in that examination will be used. However, the case is used here as an example only and some liberties will be taken with the statistics to make it better serve the purpose of illustration.

The estimated cost of reproduction of the entire plant, classified into the three divisions, is as follows:

| | | |
|---|---|---|
| Supply works | $520,923 = | 23% |
| Distribution system | 1,524,951 = | 68 |
| Services | 202,669 = | 9 |
| Total | $2,248,543 = | 100% |

There were 14,200 services, all of which were metered. The consumption was 5.05 million gallons per day, being 56 gallons per capita for a population of 89,000. The gross income was $305,000. The net earnings, after deducting all operating expenses, taxes and depreciation, amounted to $149,907, equal to 6.68 per cent of $2,248,543, the estimated cost of reproduction.

The water registered by the meters was 75 per cent of the output, equal to 3.78 million gallons per day. The remainder of the water is assumed for this purpose to be accounted for as follows:

| | Million Gallons Daily. |
|---|---|
| Leakage from mains taken on the basis found in the American Civil Engineers' Pocket Book (Section 10, Art. 20) | 0.51 |
| Fire use and unavoidable losses, 2 per cent | 0.10 |
| Leakage from services and under-registration of meters | 0.66 |
| Sold | 3.78 |
| Total output | 5.05 |

CLASSIFICATION OF WATER SALES

| Class. | Number of Services. | Average Daily Draft per Service Gallons. | Total Annual Draft Thousands of Gallons. | Classified for Payment. | | |
|---|---|---|---|---|---|---|
| | | | | Domestic. | Inter-mediate. | Manufac-turing. |
| Domestic | 13,813 | 155 | 781,000 | 781,000 | | |
| Intermediate | 355 | 1,760 | 227,000 | 106,400 | 120,600 | |
| Manufacturing | 32 | 31,700 | 372,000 | 9,600 | 86,400 | 276,000 |
| Total | 14,200 | ........ | 1,380,000 | 897,000 | 207,000 | 276,000 |
| Per Cent of Total | ........ | ........ | ........ | 65.0 | 15.0 | 20.0 |

The greater part of the operating expenses and taxes could be classified definitely into the three classes relating to source of supply, distribution and services, but for some of the taxes and general operating expenses there was no basis of classification, and these items were distributed pro rata in proportion to the items that could be directly distributed.

The annual cost of maintaining the system and supplying water may be classified as follows:

| | | |
|---|---|---|
| *Cost of Water:* | | |
| Property, $520,923 @ 6.68 per cent | $34,700 | |
| Operation and taxes | 72,693 | |
| Depreciation | 7,000 | |
| Total | $114,393 | |
| 114,393 ÷ 5.05 ÷ 365 = $62.20 per million galllons = 6.22 cents per thousand gallons. | | |
| Sold at this rate, 3.78 mgd. amounts to, per annum | | $86,000 |

| | | |
|---|---|---|
| Brought forward | | $86,000 |
| *Cost of Distribution:* | | |
| Property, $1,524,915 @ 6.68 per cent | $101,800 | |
| Operation and taxes | 41,136 | |
| Depreciation | 10,000 | |
| Value of water lost, including fire service, etc., 0.61 ×365×$62.20 | 13,800 | |
| | | $166,736 |
| *Cost of Services:* | | |
| Property, $202,699 @ 6.68 per cent | $13,500 | |
| Operation and taxes | 19,760 | |
| Depreciation | 4,000 | |
| Water lost by under-registration of meters, 0.66×365×$62.20 | 15,000 | |
| | | $52,260 |
| Total annual cost of system | | $304,996 |

This checks the gross income actually received for the last year.

**Fire Service.** The population supplied and protected is 89,000.

Following the rule in the American Civil Engineers' Pocket Book (page 948), the plant capacity to be dedicated to fire service is $\sqrt{89}$, or 9.45 million gallons per day.

The average output is 5.05 million gallons per day. The amount of plant capacity dedicated to peak loads of ordinary consumption, exclusive of fire service, is 70 gallons per capita, equal to 6.22 million gallons per day. The total plant capacity required for ordinary use, exclusive of fire service, is the sum of these two items, or 11.27 million gallons per day.

These estimates are made without regard to the actual plant capacity, which may be somewhat less than the sum of these items, because a part of the reserve for ordinary peak loads is available also for fire service; or, on the other hand, it may be greater because some growth has been anticipated in construction. These figures mean that if a plant were provided for fire service only, it would need to have a capacity of 9.45 million gallons per day, and a plant provided to supply water for use, and with no provision for fire service, would need to have a capacity of 11.27 million gallons per day. The cost of distribution assignable to fire service and to other use would be in proportion to these figures, and this proves to be 46 per cent for fire service and 54 per cent for ordinary use.

Applying this figure, the cost of fire service is taken as 46 per cent of the whole cost of distribution which was found above to be $166,736. This is $76,670 per annum, equal to $0.86 per capita per annum, and to 21.9 per cent of the gross income. This is taken as representing the whole fair value of the fire service in this case.

There was actually received from the city out of money raised by the tax levy for fire service the sum of $51,208. Deducting this from the fair value of the service, there remain $25,522 of fire service cost not paid for from the tax levy and which must be raised in some way from the meter takers. This amounts to 1.84 cents per 1000 gallons for the whole quantity of water sold. This represents that part of the cost of fire service which must be loaded in some way upon meter rates.

The cost of distribution for all other purposes amounts to 54 per cent of the total cost of distribution, or $90,060 per annum.

The quantity of water used for manufacturing purposes is relatively low. About 20 per cent of the whole output would be charged at the manufacturing rate under the proposed schedule and an additional 15 per cent under the intermediate rate; 65 per cent of the entire output is to be charged at the domestic rate.

For the water used for manufacturing purposes, the cost of distribution will be much less than the average for all. Without going into details in this particular case, and which details would be somewhat uncertain and speculative in any case, it is assumed for this purpose that the cost of distributing water to the manufacturers is one-half on an average the cost of distributing water to all takers. The cost of distributing water to manufacturers will then be $\frac{1}{2} \times \$90{,}060 \div 365 \div 3.780 = 3.27$ cents per 1000 gallons.

The additional cost of distributing water to intermediate and domestic takers, 65 per cent domestic, and taking one-half of the 15 per cent intermediate, making $72\frac{1}{2}$ per cent in all, would be as follows:

One-half of \$90,060 ÷ 0.725 ÷ 3.780 ÷ 365 = 4.50 cents per 1000 gallons.

The manufacturing rate will then be made up as follows:

| | Cents. |
|---|---|
| Cost of water | 6.22 |
| Part of fire service carried by meter rates | 1.84 |
| Distribution of water for manufacturing purposes at one-half the average cost | 3.27 |
| Sum, being manufacturing rate per 1000 gallons | 11.33 |
| Add for domestic rate the balance of the cost of distribution | 4.50 |
| Total domestic rate | 15.83 |

The slide in this scale is in the ratio of 1 to 1.40.

The intermediate rate will be found to be 13.48 by the rule suggested by the Committee that it be one-half way between the average, which is 13.58, and the mean proportional, which is 13.38.

For the service charge the sum of \$52,260 is to be divided among 14,200 services, making an average of \$3.68 per service. This being a private company no service charge can be collected where services are shut off. Assuming 8 per cent of the services are shut off on an average, this will have to be increased to \$4.00 to cover this loss.

The application of these rates should produce the same gross revenue as was actually received under the old scale.

As a practical matter, the fractions reached in the above computation are not to be recommended for use. Instead, approximate round figures producing substantially the same amount of gross revenue, would be preferred. For the three rates, 16, 13 and 11 cents may be used. This will need to be checked by the preparation of a full trial schedule, which may be afterward adjusted to produce the required amount.

Such a schedule in outline is as follows:

| | |
|---|---|
| Service charges | $ 52.260 |
| Fire service collections | 51.208 |
| 276 mg., at 11 cents, manufacturing rate | 30.360 |
| 207 mg., at 13 cents, intermediate rate | 26.910 |
| 897 mg., at 16 cents, domestic rate | 143.520 |
| | $304.258 |

This checks within one-fourth of one per cent the present amount of revenue and the proposed rates may be accepted as equivalent to the present ones, but as giving a more rational distribution of the burden among the different classes of takers.

**Further Adjustment of the Manufacturing Rate.** In the above calculation the manufacturing rate carries one-half of the whole average cost of distribution of water, but those takers classed as manufacturing pay on an average more than this proportion of the cost of distribution, because the first part of the water that each draws is charged at the domestic rate and a further quantity is charged at the intermediate rate.

It is possible to make the calculation so that the whole quantity of water sold to manufacturing takers will carry only one-half of the average cost of distribution. This may be most conveniently done algebraically.

Let $D$ = the domestic rate,

$M$ = the manufacturing rate,

$\frac{D+M}{2}$ = the intermediate rate (not exactly but closely enough for this calculation).

The average sale price for all manufacturing water is to be 11.33 cents per 1000 gallons. Referring to the quantities that make up the total draft of those to be billed at the manufacturing rate, stated on page 183, this may be put in the form of an equation.

$$9600\ D + 86{,}400\ \frac{M+D}{2} + 276{,}000\ M = 372{,}000 \times 11.33, \text{ or}$$

$$52{,}800\ D + 319{,}200\ M = \$42{,}300$$

The equation for total revenue will be

$$897{,}000\ D+207{,}000\ \frac{M+D}{2}+276{,}000\ M+\$52{,}260\ \text{(service charges)}$$
$$+\$51{,}208\ \text{(hydrant rentals)} = \$304{,}969\ \text{(gross revenue)},$$
$$\text{or}\ 1{,}000{,}500\ D+379{,}500\ M=\$201{,}501.$$

Solving these we find

$$M=10.60$$
$$D=16.15.$$

The ratio of slide is 1 to 1.52.

There is a decrease by this calculation of about 7 per cent in the manufacturing rate and an increase of about 2 per cent in the domestic rate, as compared with those reached by the first calculation.

If the large takers were all grouped so as to be reached by relatively little distribution piping the proportion of the whole average distribution cost charged to them might be reduced from the one-half in the above calculation to one-fourth or to some other proportion.

It is evident that the whole process is not one that can be made to lead to exact results. In any case, many matters in connection with it are, and must remain, matters of judgment. Considerations, some of them elsewhere discussed, may make a greater or a less degree of slide desirable.

The value of the method is as an aid to intelligent judgment as to the amount of slide that will be most equitable to all classes of consumers, and no effort should be made to carry it further than that.

# CHAPTER XVIII

## FIXING METER RATES FOR A SYSTEM NOT YET METERED

Frequently a utility was saddled with rates made for the purpose of securing customers or favorable influence, or under pressure of various kinds.—Thos. W. D. Worthen, N.E.W.W. Assn. Jour., Vol. XXXI, p. 168, 1917.

In the two cases given above, the meter system was already well established and the necessary underlying data to make the calculation of the financial effect of a new schedule was available. In these cases it was simply a matter of computation to a find what rates in the new schedule are required to produce the identical revenue that is now received, and obviously it is equally easy to see what change in those rates would be required to produce any desired increase or decrease in that revenue.

In many cases it is necessary to establish a system of meter rates for a system that either is not metered or is but incompletely metered. The underlying data are not at hand to make a close calculation. The desired or necessary amount of revenue is known, but the problem of finding what revenue any given set of rates will produce can be solved only by actual trial.

This case is a very common one, and obviously it presents a more difficult problem. The best that can be done is to study the statistics of completely metered systems as comparable as may be with the system in question and to apply the results, but to supplement this study by any local data that may be available, especially by data in reference to the probable consumptions of water by the larger takers, and on the basis of these estimates find the rates that are necessary to produce the required revenue.

**Rate for a Partially Metered System.** It is difficult to discuss rates for a partially metered system. The only basis that can always be used with safety, and that is always fair, starts with the assumption that a meter rate that is fair for a completely metered system is also fair in a partially metered system. All the estimates and calculations are made for the probable results as they would be if the system were completely metered.

**Margin of Safety.** As this calculation is at best an uncertain one, in making it a margin of safety should always be allowed; that is to say, when the rates are fixed they should be fixed to produce a somewhat greater amount of revenue than is indicated by the estimates.

The amount of margin depends upon the exigencies of the case, but in a general way a 5 to 10 per cent margin will be considered as a reasonable one. If the estimates prove to be sound, the revenue will exceed expectations by 5 to 10 per cent, and as soon as that fact is sufficiently ascertained by experience, the rates, or some of them, may be reduced. If the sales of water fall below expectations, no harm will be done up to the point where the deficiency in sales cuts out the margin that is allowed. If, on the other hand, the rates prove more productive than is expected, the reduction in rates may come sooner and may be greater.

Too much revenue means a relatively light hardship on the takers for a few years. Too little revenue may mean disaster to the system. It is much easier to reduce rates than to increase them, and a fair margin of safety to cover the uncertainties in the calculation is essential.

**Basis of Estimate.** The number of live services in every water-works system is known This is the starting point. The amount of water that can be sold to them must first be estimated.

Statistics were collected by the Committee on Meter Rates for thirty-five completely metered systems.* Some of the data are to be found on page 120. From these it appears that the average sales per service were 359 gallons daily, but amounts

* Jour. N.E.W.W. Assn., Vol. XXX, p. 453, 1916.

ranging from 63 gallons to 1300 gallons were found in the various reporting systems.

If one looks through the list of cities and picks out those as comparable as may be in population, location and amount of manufacturing, with the one under discussion, a figure can be selected which multiplied by the number of services will give a first and very rough approximation of the amount of water that can probably be sold. The amount of water used for industrial and other uses from wells or other local sources must be considered in making such comparison.

A second approximation may be undertaken by subdividing all the takers into three classes, following the classification of the New England Water Works Association.

Taking it up in this way in more detail, the second estimate should be rather more accurate than the first one. This is particularly true if, as often happens, some of the larger takers are already metered, and information can be substituted for estimates for a part of the schedule.

The statistics collected by the Committee on Meter Rates, arranged to facilitate use in this way, are shown below.

**Domestic Services.** In the first table are shown the domestic consumers; that is to say, all those taking less than an average of 820 gallons daily, or 10,000 cubic feet per quarter.

The table shows for each system, first, the total number of services, to give an idea of the size of the plant; second, the percentage of services classified as domestic; third, the average amount of water sold for each domestic service in gallons daily; fourth, the total daily sales from the services classed as domestic, reckoned on the whole number of services in the system.

DATA AS TO DOMESTIC TAKERS

| | Whole Number of Services. | Per Cent of Takers Classed as Domestic. | Average Gallons Daily Sold per Service. | Gallons Daily per Service Reckoned on the Whole Number of Services. |
|---|---|---|---|---|
| Cleveland | 94,881 | 90.00 | 192 | 173 |
| Seattle | 41,831 | 90.95 | | |
| Springfield, Mass | 13,529 | 85.00 | 198 | 168 |
| Malden, Mass. | 8,052 | 98.62 | 129 | 127 |
| Oak Park, Ill | 6,998 | 97.72 | 175 | 171 |
| Poughkeepsie, N. Y. | 5,157 | 96.65 | | |
| Fitchburg, Mass. | 4,852 | 95.14 | 141 | 134 |
| Chelsea, Mass. | 4,748 | 94.15 | 249 | 234 |
| Western N. Y. Water Co. | 3,843 | 95.45 | 119 | 114 |
| Meridian, Mass | 3,921 | 95.50 | | |
| Winthrop, Miss. | 2,783 | 98.30 | 174 | 171 |
| Miami, Fla | 2,497 | 96.68 | 137 | 132 |
| Belmont, Mass. | 1,328 | 97.13 | 171 | 166 |
| Addison, N. J | 254 | 100.00 | 63 | 63 |
| Average | ........ | 95.09 | 159 | 150 |

With these figures as a guide, an estimate may be made of the probable sales under the domestic classification in the proposed system. The average results will, of course, be considered, but the peculiarities of the system for which estimate is being made should be considered.

**Intermediate Services.** We pass now to intermediate services, representing larger takers, namely, those using between 820 and 8200 gallons per service daily. In the following table statistics for these services are arranged in the same way as the domestic takers and in addition a division of the amount of water is made as it would be classed under the proposed meter rate schedule; that is to say, the first 820 gallons daily from each service is classed under the domestic rate, and only that which follows is classed at the intermediate rate.

DATA AS TO INTERMEDIATE TAKERS

| | Per Cent of Whole Number of Takers. | Average Sold per Service Gallons Daily. | Gallons Daily Charged at | | Gallons Daily for Whole Number of Services. | | |
|---|---|---|---|---|---|---|---|
| | | | Domestic Rate. | Inter-mediate Rate. | Total. | Domestic Rate. | Inter-mediate Rate. |
| Cleveland | 9.00 | | | | | | |
| Seattle | 8.23 | | | | | | |
| Springfield, Mass. | 13.90 | | | | | | |
| Malden, Mass. | 1.26 | 1790 | 820 | 970 | 22 | 10 | 12 |
| Oak Park, Ill. | 2.14 | 1520 | 820 | 700 | 32 | 17 | 15 |
| Poughkeepsie, N. Y. | 3.08 | | | | | | |
| Fitchburg, Mass. | 3.71 | 1945 | 820 | 1135 | 74 | 31 | 43 |
| Chelsea, Mass. | 5.41 | 1738 | 820 | 918 | 94 | 44 | 50 |
| Western N. Y. Water Co. | 3.28 | 1870 | 820 | 1050 | 61 | 27 | 34 |
| Meridian, Miss. | 4.20 | | | | | | |
| Winthrop, Mass. | 1.62 | 1450 | 820 | 630 | 23 | 13 | 10 |
| Miami, Fla. | 3.12 | 1975 | 820 | 1155 | 62 | 26 | 36 |
| Belmont, Mass. | 2.80 | 1680 | 820 | 860 | 47 | 23 | 24 |
| Addison, N. J. | 0 | | | | | | |
| Averages | 4.37 | 1750 | 820 | 930 | 77 | 36 | 41 |

It will be noted that there is less variation in the average amounts of water sold per service for the intermediate services than for either the domestic or manufacturing services. This is natural, as the intermediate comes between the two limits, and extreme values at either end are thus excluded.

**Manufacturing Services.** For the larger customers taking more than 8200 gallons per day on an average, statistics of other plants are much less serviceable, because variations between different plants are much greater. A consideration of the statistics available may, however, be helpful in at least a suggestive way. The statistics available made up in the same way and with a corresponding classification, are as follows:

## DATA AS TO MANUFACTURING TAKERS

| | Per Cent of Whole Number Takers. | Average Sold per Service Gallons Daily. | Gallons Daily Charged. | | | Gallons Daily for Whole Number of Services. | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Charged. | | |
| | | | Domestic. | Inter-mediate. | Manufac-turing. | Total. | Domestic. | Inter-mediate. | Manufac-turing. |
| Cleveland | 1.000 | | | | | | | | |
| Seattle | 0.780 | | | | | | | | |
| Providence | 0.450 | | | | | | | | |
| Springfield, Mass. | 1.100 | | | | | | | | |
| Brockton, Mass. | 0.064 | | | | | | | | |
| Malden, Mass. | 0.124 | 26.600 | 820 | 7380 | 18.400 | 33 | 1 | 9 | 23 |
| Oak Park, Ill. | 0.129 | 30.000 | 820 | 7380 | 21.800 | 39 | 1 | 10 | 28 |
| Poughkeepsie, N. Y. | 0.270 | | | | | | | | |
| Fitchburg, Mass. | 1.090 | 30.800 | 820 | 7380 | 22.600 | 335 | 9 | 80 | 246 |
| Chelsea, Mass. | 0.442 | 31.300 | 820 | 7380 | 23.100 | 139 | 4 | 33 | 102 |
| Western N. Y. Water Co. | 1.270 | 89.000 | 820 | 7380 | 80.800 | 1124 | 10 | 94 | 1020 |
| Meridian, Miss. | 3.000 | | | | | | | | |
| Winthrop, Mass. | 0.080 | 12.500 | 820 | 7380 | 4.300 | 10 | 1 | 6 | 3 |
| Miami, Fla. | 0.020 | 28.000 | 820 | 7380 | 19.800 | 6 | 0 | 2 | 4 |
| Belmont, Mass. | 0.075 | 37.700 | 820 | 7380 | 29.500 | 29 | 1 | 6 | 22 |
| Averages | 0.461 | 35.700 | 820 | 7380 | 27.500 | 165 | 4 | 34 | 127 |

The averages in this table are largely affected by records of one system which does what is in reality largely a wholesale business, with sale of water to large takers classed as manufacturing that is much greater than in any of the other systems represented. Aside from this there are wide variations according to the industries and local sources of supply in the areas served by the respective systems. As the statistics are comparatively limited, representing only eight systems (the number of services without the quantities being shown for seven others), they cannot be expected to serve as a basis for estimates that will stand tests. The data are much less adequate than those for domestic and intermediate takers.

Bringing together the averages from three tables, we have in the following a summary of the average results indicated by the statistics, arranged in convenient form:

| Class. | Per Cent Whole Number of Takers. | Average Sales per Service. | Sales per Service Reckoned on Whole Number of Services. | | | |
|---|---|---|---|---|---|---|
| | | | Total. | Classed as | | |
| | | | | Domestic. | Intermediate. | Manufacturing. |
| Domestic........ | 95.09 | 159 | 150 | 150 | | |
| Intermediate.... | 4.37 | 1,750 | 77 | 36 | 41 | |
| Manufacturing.. | 0.461 | 35,700 | 165 | 4 | 34 | 127 |
| Total.... | ......... | ......... | 392 | 190 | 75 | 127 |

**Further Classification.** In the collection of statistics, the Committee of the New England Water Works Association further subdivided each of the three main classes into two or three sub-classes, making eight classes in all. If full statistics for each of these subdivisions were available from all completely metered systems, something that in water works would correspond to a life-line in life insurance could be prepared that would have considerable value in making estimates of this kind. Owing to the limited number of returns received too much significance is not to be attached to this. However, the following brief summary may be helpful:

Thirty-five systems reported. These systems had 524,636 services and 520,719 meters. They were thus almost completely metered.

The daily output, estimating roughly, for three systems where sales are reported, but not the total output, is about 300 million gallons, or 575 gallons per service daily. Of this quantity about 140 gallons per service is not accounted for.

The following table gives an approximate distribution indicated by the data received, arranged by total numbers in each class, for those systems for which reasonably complete reports were available.

| Range in Quantities, Gallons Daily per Service. | Average Daily Quantities Sold per Service. | Per Cent of Total Number of Services Coming in This Class. | Per Cent of Total Output. | Total Output, Gallons per Day from 100 Services. |
|---|---|---|---|---|
| 0– 82 | 51 | 29.420 | 3.41 | 1,500 |
| 82– 246 | 146 | 47.865 | 15.91 | 7,000 |
| 246– 820 | 385 | 16.755 | 14.63 | 6,440 |
| 820– 2,460 | 1,300 | 3.594 | 10.59 | 4,660 |
| 2,460– 8,200 | 4,070 | 1.807 | 16.64 | 7,320 |
| 8,200– 24,600 | 12,700 | 0.356 | 10.27 | 4,520 |
| 24,600– 82,000 | 42,300 | 0.071 | 16.37 | 7,200 |
| 82,000–246,000 | 120,000 | 0.024 | 6.52 | 2,870 |
| Over 246,000 | 311,000 | 0.008 | 5.66 | 2,490 |
| Total....... | 440 | 100.000 | 100.00 | 44,000 |

These figures were made up by approximate methods, with a few doubtful returns excluded. They are believed to represent the distribution fairly well and they check the total very well, for they show 440 gallons per service on an average sold, and adding the 140 gallons per service not accounted for, which is the average from the total number, makes 580 gallons per service. This checks approximately the 575 gallons first found.

The data represented by the above brief statement have been otherwise arranged and are plotted on a diagram which is presented herewith (Fig. 22). This diagram shows the percentage of the total number of consumers taking more than various quantities of water daily, arranged in a number of different ways. A dotted line shows them averaged by the gross numbers in the systems for which the statistics were reasonably complete. A broken line shows them averaged by systems, which, as above noted, gives one small system the same relative weight in the average as one large one. Three other solid lines show the figures arranged in the order of size, the middle one being the medium, so selected that half the results fall below it and half above it, while the two lines marked as the normal 10 per cent limit and the normal 90 per cent limit are the lines which include 80 per cent of all the results. Ten per

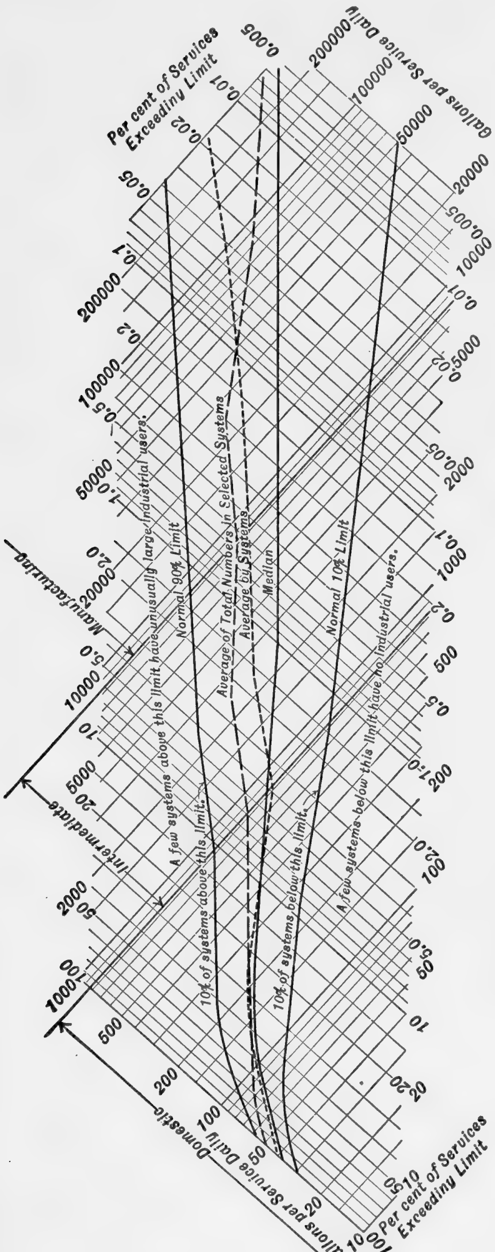


FIG. 21.—Showing Classification of Takers by the Average Daily Quantities that are Drawn.
(From Jour. N.E.W.W. Assoc., Vol. XXX, p. 462).

cent of the results fall outside of these limits on either side, representing, on the one hand, systems in which manufacturing and large users are unusually developed, and, on the other hand, small systems in which there are no such uses.

The distribution of the whole output among meters of different sizes, estimated by the aid of graphical and roughly approximate methods, is shown by the following table:

| Size of Meter. Inches. | Per Cent of Total Number of Services. | Mean Quantity per Meter, Gallons per Day. | Total Quantity per 100 Services, Gallons Daily. | Per Cent of Total Quantity of Water Sold. |
|---|---|---|---|---|
| $\frac{5}{8}$ | 84.546 | 116 | 9,870 | 22.38 |
| $\frac{3}{4}$ | 11.228 | 580 | 6,500 | 14.82 |
| 1 | 2.225 | 1,700 | 3,780 | 8.59 |
| $1\frac{1}{2}$ | 0.616 | 2,380 | 1,470 | 3.34 |
| 2 | 0.783 | 5,500 | 4,300 | 9.77 |
| 3 | 0.369 | 10,000 | 3,690 | 8.39 |
| 4 | 0.218 | 20,000 | 4,360 | 9.91 |
| 6 | 0.104 | 70,000 | 7,280 | 16.55 |
| Larger........ | 0.011 | 250,000 | 2,750 | 6.25 |
| | 100 | 440 | 44,000 | 100 |

**Service Charges.** An estimate must first be made of the number of meters of the different sizes that will be employed.

It may be assumed that all domestic takers using less than an average of 820 gallons per day may be supplied with $\frac{5}{8}$-inch meters, but on the other hand, it may be that some of them having fixtures requiring that water be drawn rapidly, will prefer to pay the added service charge and use a $\frac{3}{4}$ inch meter; for larger takers it may be assumed that the average maximum limit of output of each size of meter will correspond to an 8 per cent load factor and will be as follows:

| Size of Meter | Average Gallons per Day. | Gallons per Annum. | Cubic Feet per Quarter. |
|---|---|---|---|
| ⅝ inch | 820 | 300,000 | 10,000 |
| ¾ | 1,370 | 500,000 | 16,700 |
| 1 | 2,460 | 900,000 | 30,000 |
| 1½ | 4,920 | 1,800,000 | 60,000 |
| 2 | 8,200 | 3,000,000 | 100,000 |
| 3 | 16,400 | 6,000,000 | 200,000 |
| 4 | 24,600 | 9,000,000 | 300,000 |
| 6 | 49,500 | 18,000,000 | 600,000 |

From this table and the estimated outputs in the several classes, a rough idea of the required number of meters of various sizes may be made.

The total number of meters in 33 completely metered systems * may also be of service in making the estimate.

| Size of Meter, Inches. | Total Number of Meters in 33 Systems. | Percentage of Total Number. |
|---|---|---|
| ⅝ | 423,231 | 84.546 |
| ¾ | 57,406 | 11.226 |
| 1 | 11,378 | 2.225 |
| 1½ | 3,148 | 0.616 |
| 2 | 4,005 | 0.783 |
| 3 | 1,374 | 0.269 |
| 4 | 1,115 | 0.218 |
| 6 | 533 | 0.104 |
| 8 | 46 | 0.009 |
| 10 and 12 | 8 | 0.002 |
| | 511,240 | 100.000 |

The service charges selected may then be applied to the estimates and the total amount to be probably realized from service charges may be ascertained.

When the calculation has gone thus far, the rest follows the method given in Chapter XVI. The only difference is that it rests on estimates instead of upon ascertained facts, and when it is completed an addition of the amount allowed as a margin of safety must be made.

**Example.** It is desired to make an estimate of the necessary data for a city with a population of 45,000 having 8000 services

* Jour. N.E.W.W. Assn., Vol. XXX, p. 460, 1916.

and with a consumption at the present time of 7 million gallons per day, equal to 155 gallons per capita.

A few of the larger manufacturing services only are now metered.

From a consideration of the above data and comparison of the city in question with some of the others that seem to be more or less similar to it, the following rough estimate is made:

| | Estimated Per Cent of Total Number of Services. | Estimated Number of Services. |
|---|---|---|
| Manufacturing | 0.4 | 32 |
| Intermediate | 3.6 | 288 |
| Domestic | 96.0 | 7680 |

On the manufacturing services there are already 27 meters, the records of which are available, leaving only 5 for which estimates must be made. There is little to guide in estimating the probable intermediate and domestic sales per meter and the average for the data given above is used. Made up in this way, we have:

| | Gallons per Day. |
|---|---|
| Manufacturing uses records, 27 meters, actual records | 774,000 |
| Five others estimated to range from 8200 to 16,000, averaging 12,000 | 60,000 |
| 288 intermediate meters estimated to average 1750 gallons | 504,000 |
| 7680 domestic meters estimated to average 159 gallons | 1,220,000 |
| Total estimated daily sales | 2,558,000 |
| After meters have been in service for some years and all leakage that can be stopped has been stopped until the system is brought to the average tightness of completely metered systems, the unaccounted for water would probably amount to 130 gallons per service daily, a total of | 1,040,000 |
| Total probable daily consumption, when completely metered, but on basis of last year's population and business | 3,598,000 |

This indicates sales of 2.56 million gallons per day and an output of 3.59 million gallons per day, equal to 80 gallons per capita, or about one-half of the present rate of output.

So great an immediate reduction is not to be anticipated, and a consumption between that and the present consumption for a few years must be anticipated. However, the extra quantity is to be expected in water that cannot be accounted for and not in amounts sold, and the figures as reached may be used for the estimate.

The schedule of quantities sold under each of the rates can be estimated as in Chapter XVI, in tabular form.

| Rate. | Number of Services. | Total Sales. | Under What Rate Charged. | | |
|---|---|---|---|---|---|
| | | | Domestic. | Intermediate. | Manufacturing. |
| Domestic | 7680 | 1170 | 1170 | | |
| Intermediate | 288 | 504 | 236 | 268 | |
| Manufacturing | 32 | 834 | 26 | 236 | 572 |
| Total thousands of gallons daily | ...... | 2508 | 1432 | 504 | 572 |
| Total million gallons per annum | ...... | 916 | 522 | 184 | 210 |
| Per cent | ...... | 100.0 | 57.0 | 20.1 | 22.9 |

These figures may be used in the study of the required rates as above described. It will be safer, however, before making the calculation to diminish the amounts estimated for domestic and intermediate sales by from 5 to 10 per cent on account of the uncertainty of the basis of the estimate. As the manufacturing takers are already nearly all metered there is less uncertainty in regard to them and no reduction need be made.

The whole estimated quantities will be reduced by this procedure by about 6 per cent and the rates will be made proportionately higher because of it. There will be then a chance that after the rates have been tried out in actual practice, more revenue will be produced than is needed and that they may be reduced.

**Statistics.** In trying to make estimates of probable sales under the meter system for a system not yet metered, the following statistics of systems that are completely metered or nearly so, may be helpful. They will at least give an idea of local variations that are to be expected, and of the range within which results may be expected.

CONSUMPTION AND SALES OF WATER IN WATER-WORKS SYSTEMS THAT ARE COMPLETELY METERED, OR NEARLY SO

Compiled from Annual or Special Reports

| Place. | Year. | Population. | Number of Services. | Total Output. Average Daily Quantity Million Gallons. | Gallons per Capita Daily. | Gallons per Service Daily. | Per Cent Water Accounted For. |
|---|---|---|---|---|---|---|---|
| Atlanta, Ga. | 1915 | 154,839 | 29,733 | 16.990 | 109 | 572 | 87 |
| Attleboro, Mass. | 1916 | 18,100 | 2,965 | 0.971 | 54 | 327 | 56 |
| Belmont, Mass. | 1916 | 8,600 | 1,574 | 0.448 | 52 | 285 | 79 |
| Brockton, Mass. | 1915 | 65,746 | 9,416 | 2.830 | 43 | 300 | 76 |
| Chelsea, Mass. | 1915 | 32,452 | 4,746 | 3.060 | 94 | 745 | 73 |
| Cleveland, Ohio | 1915 | 656,975 | 94,881 | 72.230 | 118 | 825 | 85 |
| Columbus, Ohio | 1915 | 202,000 | 33,975 | 16.987 | 84 | 500 | 64 |
| Dubuque, Iowa | 1915 | 33,494 | 4,623 | 2.615 | 78 | 516 | |
| East Bay Water Co. (Oakland, Berkley, etc) | 1916 | 328,000 | 65,600 | 18.067 | 55 | 275 | 75 |
| Fall River, Mass. | 1913 | 119,014 | 9,251 | 5.635 | 47 | 610 | |
| Framingham, Mass. | 1916 | 14,500 | 2,508 | 0.865 | 60 | 344 | 81 |
| Hartford, Conn. | 1915 | 145,000 | 14,482 | 9.500 | 66 | 655 | |
| Houston, Texas | 1915 | 78,800 | 11,652 | 4.860 | 62 | 418 | 58 |
| Lincoln, Neb. | 1916 | 55,000 | 11,158 | 3.570 | 65 | 320 | |
| Malden, Mass. | 1915 | 50,067 | 8,052 | 2.243 | 45 | 279 | 63 |
| Madison, Wis. | 1912 | 27,000 | 5,500 | 1.953 | 72 | 356 | |
| Meridian, Miss. | 1915 | 23,285 | 3,921 | 2.850 | 122 | 725 | 80 |
| Miami, Fla. | 1915 | ....... | 2,497 | 1.220 | .... | 489 | 51 |
| Middleboro, Mass. | .... | 8,214 | 1,127 | 0.330 | 40 | 293 | 60 |
| Milton, Mass. | 1916 | 8,933 | 1,965 | 0.371 | 42 | 189 | 81 |
| Milwaukee, Wis. | 1916 | 465,000 | 63,914 | 54.885 | 118 | 858 | 72 |
| New Bedford, Mass. | 1916 | 111,120 | 15,350 | 8.531 | 77 | 556 | 85 |
| New Britain, Conn. | 1916 | 52,000 | 5,201 | 3.392 | 65 | 652 | |
| New Orleans, Va. | 1915 | 366,484 | 51,093 | 25.100 | 69 | 490 | 63 |
| New Rochelle, N. Y. | 1915 | 28,867 | 6,676 | 3.500 | 122 | 524 | |
| Newton, Mass. | 1915 | 43,600 | 9,286 | 2.830 | 65 | 305 | 65 |
| Oak Park, Ill. | 1915 | 26,000 | 6,998 | 2.060 | 79 | 295 | 54 |

CONSUMPTION AND SALES OF WATER IN WATER-WORKS SYSTEMS—*Continued*

| Place. | Year. | Population. | Number of Services. | Total Output. Average Daily Quantity Million Gallons. | Gallons per Capita Daily. | Gallons per Service Daily. | Per Cent Water Accounted For. |
|---|---|---|---|---|---|---|---|
| Omaha, Neb. | 1915 | 175,000 | 30,133 | 16.284 | 93 | 542 | |
| Pasadena, Cala. | 1916 | 46,000 | 12,532 | 4.760 | 104 | 380 | 85 |
| Pawtucket, R. I. | 1915 | 97,175 | 12,198 | 7.336 | 75 | 554 | |
| Poughkeepsie, N. Y. | 1915 | 32,714 | 5,157 | 2.410 | 74 | 467 | 68 |
| Providence, R. I. | 1915 | 278,727 | 31,506 | 17.194 | 62 | 545 | 70 |
| San Diego, Cala. | 1914 | 100,000 | 14,642 | 7.960 | 80 | 543 | |
| Seattle, Wash. | 1916 | 330,000 | 44,000 | 30.000 | 91 | 682 | 98 |
| Springfield, Mass. | 1916 | 104,572 | 14,852 | 11.260 | 108 | 756 | 71 |
| Springfield, Pa. | 1915 | ....... | 11,614 | 5.163 | .... | 444 | 74 |
| Sioux City, Ia. | 1916 | 65,000 | 8,737 | 3.416 | 53 | 391 | |
| Syracuse, N. Y. | 1915 | 152,534 | 26,870 | 19.500 | 128 | 728 | 55 |
| Toledo, Ohio. | 1915 | 190,300 | 38,060 | 15.503 | 81 | 407 | 85 |
| Wellesley, Mass. | 1915 | 5,413 | 1,550 | 0.470 | 87 | 303 | 57 |
| W. N. Y. W. Co. (Suburbs of Buffalo) | 1915 | ....... | 3,843 | 6.500 | .... | 1600 | 77 |
| Wilmington, Del. | 1915 | 95,000 | 21,306 | 9.730 | 102 | 457 | 64 |
| Winchendon, Mass. | 1916 | 5,908 | 1,017 | 0.214 | 36 | 210 | 49 |
| Winnipeg, Canada. | 1915 | 136,035 | 29,287 | 8.500 | 63 | 290 | |
| Winthrop, Mass. | 1916 | 13,325 | 2,972 | 0.707 | 53 | 238 | 81 |
| Woonsocket, R. I. | 1915 | 38,125 | 3,905 | 1.820 | 48 | 468 | 83 |
| Worcester, Mass. | 1915 | 169,299 | 20,425 | 12.614 | 75 | 617 | 72 |
| Yonkers, N. Y. | 1914 | 90,948 | 9,842 | 8.310 | 92 | 847 | 85 |

# CHAPTER XIX

## HIGHER RATES IN HIGH SERVICE DISTRICTS

The committee further recommends that where the same works supply water in different services under conditions which impose substantially greater relative expense in one or more such services as compared with others, by reason of high service pumping or otherwise, that it is just and equitable that discriminations be made; and that for water sold in such districts the additional cost may be approximately ascertained and an added price may be charged for water sold in such districts.—Report Committee on Meter Rates, Jour. N.E.W.W. Assn., Vol. XXX, p. 363, 1916.

The common practice in America is to make precisely the same charges for water served from the high service systems as is made for water from low service pipes. The man on the top of the hill, having high service water, pays no more than the man in the valley, although to supply him costs ordinarily from 2 to 5 cents more per 1000 gallons, and where the high service districts are small or high or isolated, the extra cost may greatly exceed these figures.

Cases are not uncommon where the cost of pumping alone for a small high service district exceeds the whole gross revenue derived from it.

There is no good reason for equality of charge when there is such clearly defined difference in cost of service. The present method is unfair to those who take water upon the low ground. They have to pay their share, which is often a large share, of the extra cost of supplying water to their neighbors who live on higher ground, and this is the more unfair to them, as the hill sites are usually more desirable for residences, and those who live on the hills are well able to pay the added cost which their service entails upon the water department.

It seems rational and wise to charge more for high service water than for low service water and to establish the differential carefully at so many cents per 1000 gallons, arranged to pay as nearly as it can be computed the additional cost of supplying water in the high service districts. The differential should be subject to revision from time to time, as the conditions of service change. Often it would be higher at first with few takers, and less as the output from a given district increased.

The same principle applies to districts separated by long distances or by physical obstacles, such as difficult and expensive river crossings. As an illustration, there is no reason why New York City should sell water at the same price per 1000 gallons in the northern part of the city, where the water enters, and in Staten Island, the most remote point that is reached. If the price charged is a fair one in the Bronx, it is inadequate in Staten Island. The cost of transportation for many miles through the city and under the East River and under the Narrows is an important part of the cost of water delivered on Staten Island. The price of water was formerly much higher in Staten Island than in other parts of the city, and equalizing the rates throughout the city in reality means that water takers in the northern parts of the city must all pay more so that people on Staten Island may have water at less than cost.

It is not necessary to pursue the matter to extremes. If that were done, it would result in unduly complicated rates and no corresponding advantage would be secured. But wherever any water-works system is divided by natural barriers or conditions, so that some parts of it are fairly distinct from other parts, and so that the differences in cost of service in the several parts can be ascertained with some degree of definiteness, and where these differences are substantial, it would seem to be in the interests of justice and equity to establish approximate differentials in rates between those districts.

The principle of higher charges for high service water has been recognized in the new rates fixed by the New Jersey Board of Public Utilities Commission, for the Hackensack Water Company. The area served was divided into three districts, for which rates were graded according to the difficulty and estimated expense of the service. These rates are given in Chapter IV, page 44, and are shown graphically in Fig. 15, page 61.

It may be noted that Mr. Philander Betts, Engineer of the Commission, was a member of the Committee on Rates of the New England Water Works Association, and that Mr. Weston E. Fuller, a partner of the author, had to do with the arrangement, as engineer of one of the interested parties.

## Rates for Special Seasons

Some water-works systems are subject to wide fluctuations in the quantity of water that is available at different times, and in the demand for it. There are periods when the water required to meet the consumption is much harder to get than at other times. Sometimes a great increase in population supplied at certain seasons of the year causes a relative shortage, as, for instance, at summer resorts. It may happen that the capacity of a plant on the seashore must be arranged to meet a rate of output that is only required for a few weeks in August. During the remainder of the year the load factor is much below normal.

The periodical reduction in the capacity of sources at dry times is often a limiting condition. Some months of the year are drier than others, and many water-works systems, having upland supplies, are capable of less output during the dry season in late Summer and early Fall than at other times. Then, again, some years are drier than others, and a system that has sufficient water through nine years may fail with the greater drought of the tenth. It often happens that expensive additions to supply works are required to prevent a shortage of water that is not to be anticipated oftener than once in ten or even twenty years and then only for a few weeks.

In both of these cases it would be logical to charge higher rates per thousand gallons for water during those periods when there is difficulty in maintaining the supply, and to provide for which the capacity of the supply works must be larger than would otherwise be needed.

For summer resorts, the collection of a higher rate per thousand gallons during the three months' period that includes the heaviest rate of draft may be considered. This has been rarely done in American practice. From the standpoint of the cost of the service and in the endeavor to distribute the burden where it can best be carried, this practice might well be extended.

Raising water rates at times of drought, when it is hard to get enough water to maintain the service, has never been practiced, as far as known. The practical objection to doing this is that periods of drought are irregular in the times of their recurrence, and to charge additional rates when they do come would introduce an undesirable element of uncertainty in the calculations of both the takers as to the amounts that they would have to pay and of the works as to the amounts that they could count on collecting.

Such changes in rates would not be welcomed by either party, and practically it is better to make all of the takers pay such rates all the time as are needed to provide sufficient works to give reasonable assurance against shortage at any time.

On the other hand, some abuses have grown up at times of unusual drought, and it may be that some advantageous regulation beyond that contained in the ordinary rate schedule may be undertaken. For instance, it was found in a certain small water-works system, with which the author had to do, that at very dry times the consumption increased to what seemed an abnormal amount. Some increase in consumption at dry times is to be expected, but in this case the increase was greater than could be readily accounted for. Investigation showed that the abnormal increase was due to the railroad draft. The railroads ordinarily obtained most of the water which they used from other and cheaper sources along their lines, but they always bought a certain amount from this system. At the time of drought, the other sources failed to yield their ordinary amounts and increased quantities were drawn from this water-works system. A relatively small water-works system was thus called upon to make up the deficiency in supply in sources ordinarily used within a radius of many miles.

From the ordinary point of view the railroads, being regular customers, were entitled to buy at regular rates all the water that they needed; but to provide for this and similar occasions in the future, it was necessary to build a large addition to the plant. If the railroads had bought corresponding quantities all the year round, the established rates would have been sufficient to pay for the cost of getting the additional water, but as they bought large quantities only in exceptionally dry times, it was obvious that water sold only at such times would have to bring a very high price per 1000 gallons to make the business carry itself.

It seems to be a safe general rule that emergency supplies furnished at very dry times only, then taking the place of other supplies normally used, are fairly worth much more per thousand gallons than the amount which is a fair price for the same water when it is taken by regular customers all the year round. It ought not to be expected or required that any waterworks system shall furnish emergency supplies at regular rates to new customers, or that any old customer in a case like that cited should be allowed to greatly increase his draft in periods of stresss.

In such cases it would seem to be fair to provide that the railroads and any other takers could only draw the usual amount of water at the regular prices, and that if additional quantities were to be drawn, that they should be permitted by the works only to the extent that they were available from time to time, and at prices subject to special arrangement, and adequate to meet the greatly increased cost of furnishing water under such conditions.

## CHAPTER XX

## COMPETITION OF LOCAL SOURCES OF SUPPLY

A large consumer is profitable at any rate which produces a result that will add to the net revenue of the plant even though the rate is below the average.—John N. Chester, Jour. Am. W.W. Assn., 1917, p. 317.

A Public water-supply system is commonly supposed to be a monopoly, and therefore not subject to competition. As a matter of fact, the monopoly is seldom complete. The competition of private local sources of supply is often keen, and it makes an important difference in revenue and rates.

There are some urban communities where the local sources of supply in private ownership, in the aggregate, do more business than the public works. In almost every community there are some local sources of supply. The greatest variations in the amounts, qualities and costs of these are found. Even when their quality is not such as to permit their continued use for domestic purposes they continue to be used for the various purposes for which they are suitable. Ordinarily such local water is cheaper than water from the public works, and the continued use and competition of these local supplies has been, and still is, an important element in fixing rates.

The peculiarities and irregularities in old meter rate schedules are as often due to this condition as to any other.

**Kinds of Local Supplies.** Both underground and surface waters are used. Surface waters are drawn from lakes, streams or local reservoirs. These are ordinarily deficient in sanitary quality and are not suitable for domestic use, but they are frequently soft and well adapted for manufacturing purposes, for boiler feed water, for washing and for irrigating purposes on suburban and country properties.

Ground water supplies are drawn from the underlying soil and are to be had only where that soil is porous. If the soil is clay, or if granite or other impervious rock comes near the surface, there is not much ground water to be had. But, if there are deep beds of sand, gravel, or sandstone, or other pervious material, ground water supplies are found. The interstices of the material serve as a natural reservoir to hold the water that reaches them from the rainfall, and to make it available at all seasons to those who provide themselves with the wells and pumps that are necessary to utilize it.

Many large cities are built over underground reservoirs in such water bearing materials, and the quantities of water that may be drawn from them under favorable conditions are very large.

Ground waters drawn from fine-grained materials are usually of better sanitary quality than surface waters. Where the population is not too dense in suburban and outlying districts the quality of the water obtained from wells is often excellent. As the population in the neighborhood of the wells increases the water becomes less desirable in quality, although there are occasional exceptional conditions under which good water is obtained even in the centers of cities. After the water is no longer suitable in quality for domestic use it may continue to be used for other purposes.

Underground waters are usually harder than surface waters and less desirable for boilers, washing and many industrial uses; their field of usefulness is thus restricted; but, where they are much cheaper, there are many uses which may be served by them.

A public water supply may feel the competition of well waters at times with nearly all classes of consumers. For the small houses, people who have good wells and who have been, and are, dependent upon them are slow to take water from the public supply. This has been the experience in many American cities, and especially in the smaller towns, and it is always surprising to find how many people there are who will not willingly take water from the public works where the old wells are reasonably satisfactory.

In larger houses where more water is used the difficulty in pumping is the chief obstacle to the continued use of well water, and it is this difficulty which is often the determining factor in securing the introduction of water from the public works. The convenience of having the water in the pipes under pressure more than compensates for the rates that are collected. On the other hand, in recent years improvements in small automatic electrically driven pumps, with the general presence of electric current at moderate rates available for driving them, have made it possible to continue the use of well waters in many large houses in outlying or suburban districts where the ground water is of good sanitary quality.

With industrial establishments the cost of pumping is often of controlling importance. If a separate pumping station has to be maintained and additional men must be employed to operate it, the operating cost will be considerable and will not be warranted unless the consumption of water is rather large. Most industrial establishments, however, have steam plants always in service. When the pumping can be done in the establishment, the pump being located in some convenient corner and looked after by men otherwise employed, the cost of pumping is low relatively, and if a supply of local water is readily available it may pay to pump it, even though the quantities used are not very great.

The cost at which water from the public works is supplied is an important element in determining the extent of use of local supplies. If water from the public works is from a nearby lake, and is supplied at a very low cost per thousand gallons, there is less inducement to use local supplies. If, on the other hand, the water of the public supply is brought from costly impounding reservoirs at a great distance, and necessarily costs much more per thousand gallons, there is inducement to continue and extend the use of local sources of supply.

**Amount of Local Supplies.** Exact statistics are difficult to secure. It was estimated many years ago that at Berlin, Germany, the use of water from local sources, that is, from wells in the gravel under the city, exceeded the output of the public works.

Careful and fairly detailed canvasses of private pumping plants in Hartford, Conn., and St. Paul, Minn., in recent years have indicated that the local sources of supply in those cities equalled or exceeded the total output of the public works. Even in San Francisco, where the city is on the end of a peninsula, and with relatively low rainfall, the conditions for local supplies would seem most unfavorable, a careful canvass by the City Engineer's office in 1913, showed 700 wells in use with a combined daily output equal to 18 gallons per capita daily for the whole population of the city.

In the manufacturing cities in New England there are no doubt cases where the amount of water used from the rivers for industrial purposes is several times as great as the public supply.

On the other hand, if the local sources of supply are smaller in volume and are difficult and expensive of development, the amount used from them may be comparatively small. For instance, at Springfield, Mass., the sand on which the city is built is too fine in grain size to permit a free flow of water to wells, and the ground water table is too far below the surface to permit economical pumping, and as a result most of the industrial users are supplied from the public works. The per capita output of the Springfield system is much greater than it is at Hartford, Conn. This does not mean that the total consumption of water in Springfield is greater than it is in Hartford. It simply means that the public works get a greater percentage of the business.

For these reasons comparison of the outputs per capita, or per service, in different water-works systems have much less significance than would appear at first thought. A very low per capita consumption at St. Paul and in some of the New England manufacturing cities simply means that local supplies are abundant and cheap, and are used to a great extent, and that fact is reflected in the low relative output of the public works.

**The Relative Quality of Water is Frequently Controlling.** If the public supply of water is not a good sanitary quality, or is not attractive in appearance and taste, many people will get a well supply of their own, even if it costs them much more than water from the public supply. On the other hand, if the local sources of supply are not of good character they will not be used for domestic purposes even though they are cheaper.

The competition of the local sources of supply is a very real one in many cases. The water works plant instead of supplying all the water that a community uses only supplies that part of it that cannot be advantageously taken from local sources.

It does not make much difference whether the water plant is owned by a water company or by a city. In either case the superintendent of the water works is aware of the local sources of water supply and of their uses. He wants to get the business, and there is always a temptation to lower the water rates at any point in the schedule that will make them tempting to any class of prospective consumers. There is a temptation to lower the water rates to a point that will secure the business, even though other rates have to be raised to produce the necessary income.

In going after this business estimates are sometimes made of the cost of water, which take into account only the operating expenses, and not the charges on the capital that is invested in the supply works. If such a partial estimate is taken as a starting point, and water rates are made which are based upon it, they do not reflect the whole cost of the water, and business secured under them will not be profitable in the long run.

Business obtained on this basis is only advantageous, if at all, during the period when the load factor on the whole plant is low. It ceases to be advantageous and becomes a drag as soon as the business begins to approach the capacity of the plant.

The idea that the cost of water can be calculated from operating expenses only is obviously wrong, but it keeps coming up in one community after another as rate schedules are discussed and made, and competitive rates are constantly being made that are based upon it. By competitive rates are meant rates fixed with reference to getting business that would otherwise be supplied by water from local sources. The practical effect is to bring about the use of rate scales having more slide than can otherwise be justified. Up to a certain point there may be merit in this procedure. There may be reasons why it is worth while to seek and get certain lines of business even at some sacrifice. On the other hand, it is easy to overdo the matter. There is no good reason why many of the local supplies that are good and fit for the service demanded of them should not be permanently continued in use. If the water from them is really cheaper than water can be sold from the water works plant at remunerative rates it is best for all that they be continued in service.

There is no use trying to make rates so low that all of these supplies can be displaced. To do this does injustice to those other takers who cannot so easily secure independent supplies, and who thus are not in a position to secure the advantage of competitive rates.

The plant, as a whole, must be made to pay its way, and making rates below cost to some customers necessarily means that excessive rates must be charged to others.

The whole question of local supplies presents endless variations. It is of fundamental importance in considering the statistics of the water-supply business in different communities for differences in the amounts of output per capita and of revenue per capita are often accounted for in whole or in part by these differences in local supplies that are available and that are used.

In the past efforts to meet this natural competition have been one of the most potent influences in bringing about the adoption of unbalanced and unreasonable meter rate schedules.

# INDEX