fire-service strainers as part of the metering package. Fire-service-rated strainers must be installed upstream of the meter.

When the piping installation, by necessity, creates a flow swirl in the upstream piping, a flow straightener should be used. At least two types are available: one type incorporates a concentric tube bundle, and the other uses a system of vanes. Either type of straightener can be installed integrally in the meter or immediately upstream. If a flow straightener is not used, the run of straight pipe immediately upstream of the meter should be increased at a minimum of 10 pipe diameters.

Caution should be exercised to avoid entrained air in the meter piping. This is most critical during meter startup when large slugs of entrained air could cause damage to the meter's internal measuring mechanism. Slowly filling the meter piping with a small bleed valve is good practice with the upstream isolation valve open and the downstream isolation valve closed. If possible, the small air-bleed valve should be located at a high point in the surrounding meter piping. The test opening, if valved, is used for this function.

The installation guidelines described are considered good practices for any meter installation and are repeated again in this section because of their importance in turbine meter installations. Figure 4-6 illustrates many of the suggested installation criteria for class I and class II turbine meters.

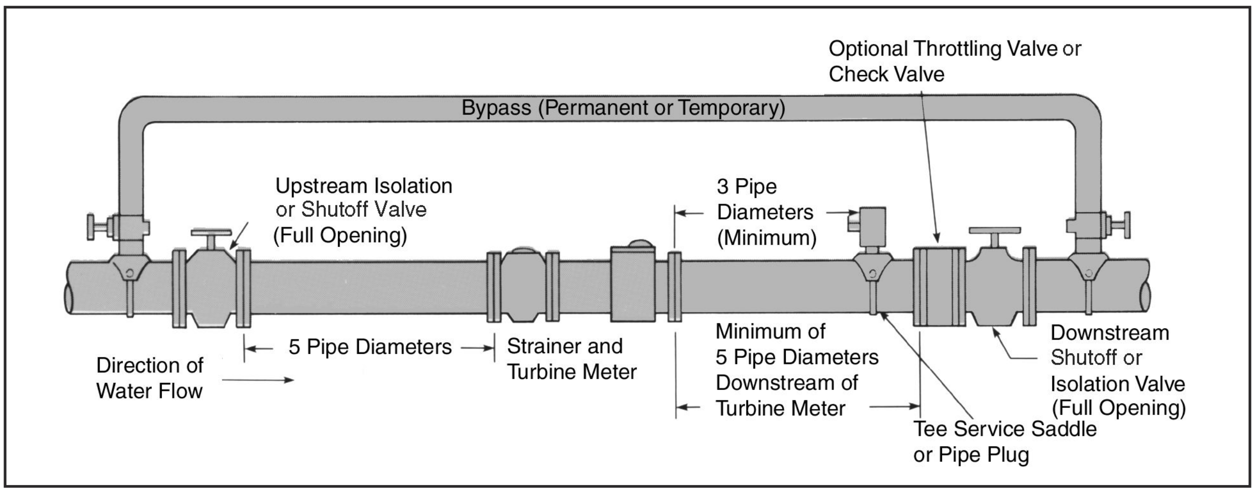


Figure 4-6 Optimum turbine meter installation

This page intentionally blank.

Chapter 5

Testing of Meters—Test Procedures and Equipment

INTRODUCTION

A water meter, like any other mechanical device, is subject to wear and deterioration and, over a period of time, loses its peak efficiency. How long water meters retain their overall accuracy depends on many factors, such as the quality of the water being measured, rates of flow and total quantity, and chemical buildup and abrasive materials carried by the water. The only way to determine whether a specific meter is operating efficiently is to test it. Establishing a meter maintenance program used to be very difficult, as it involves repetitive testing. Recent introduction of modern testing equipment reduces testing time and improves accuracy. From the individual customer's viewpoint, meters should be tested to protect the customer against meter inaccuracy that could result in overcharges from over-registration. This matter is also of concern to utility management. Experience shows, however, that the greater concern of a water utility should be the inequities and revenue loss that result from under-registration of meters.

The economic advantage of meter maintenance programs has been recorded in many articles, but most of these programs have represented concentrated efforts to rehabilitate meters after a long period of nonmaintenance. These programs are of little value in answering the question of how often meters should be tested. Unfortunately, there can be no single answer, as the economic result depends on factors such as rates charged for water; the effects of waters of different qualities on meters; and the cost of removing, testing, repairing, and installing meters. A proper economic balance should be attained. If meters are not adequately maintained, the utility loses revenue. Conversely, if the cost of a meter maintenance program is more than the loss of revenue incurred if the meters were not tested, the overall result is economic waste, and the utility's customers incur the unnecessary expense. Because modern water meters are technically more advanced than those that were produced just a few years ago, meters of today may no longer be disposable. Electronic registers and AMR systems are too valuable to throw away or ignore maintenance.

ACCURACY LIMITS

Accuracy limits are established to ensure that water meters record as accurately as possible. Meters have an inherent variation of 2 to 3 percent in registration over the entire range of flows. As an example, a ⅝-in. (15-mm) water meter in good condition will register within the following limits: 95 percent or higher at ¼-gpm (0.06-m^3/h) flow, a rise to a maximum of 101.5 percent at 2 gpm (0.45 m^3/h) (usually 10 percent of rated meter capacity), and then a falling off on a flat curve to not less than 98.5 percent at 20 gpm (4.5 m^3/h). This is the rated meter capacity for a ⅝-in. (15-mm) meter (refer to Figure 5-1 for an illustration of a typical accuracy curve).

It may not be economically feasible to repair older meters to meet the accuracy requirements for new meters. The water utility should carefully weigh all costs to make a specific determination. For this reason, separate accuracy limits are shown in Table 5-3 for new, rebuilt, and repaired meters on the minimum flow test. The limits set for repaired meters represent those that require good meter-shop procedures. Meter repair work is not acceptable if repaired meters do not register at least 90 percent on this test. Older meters may not be repairable to modern standards or advanced register systems. A higher accuracy percentage is recommended for desirable shop-quality standards and may be a requirement of the state, provincial, or federal regulatory agencies.

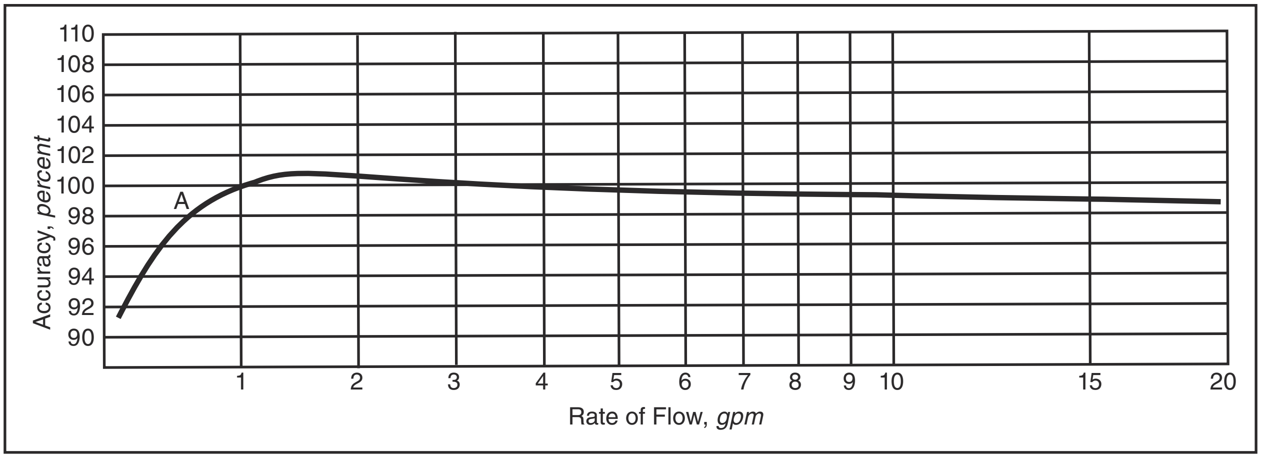
In many cases, meter manufacturers have provided revenue-maintenance programs in the form of replacement measuring-chamber assemblies and modern register assemblies, wherein the accuracy of the repaired meter can be restored to the same level as that of a new meter. The reality is that most repaired meter standards are not acceptable to most modern utility meter shops due to the importance of revenue protection. The practice of repairing meters to new meter standards is becoming standard practice.

Determining Accuracy Limits for Meter Types

A weighted average meter accuracy can be calculated, based on accuracy test results at various flow rates and an assumed model for actual consumption patterns in the field. For example, one such weighting function for residual meter applications is the algebraic sum of 15 percent of the low flow results, 70 percent of the intermediate flow results, and 15 percent of the maximum flow results. For typical turbine-meter applications, a different weighting function such as 10 percent of the low flow results, 65 percent of the intermediate flow results, and 25 percent of the maximum flow results might be used. For compound and fire-service compound-type meters, the weighted average meter accuracy might be one-third of the algebraic sum of the accuracy results at the maximum test-flow rate of the main-line meter and the maximum and intermediate test-flow rates of the bypass meter.

Accuracy Limits for Removal From Service

Meters with unacceptable accuracies (as defined by regulatory agencies or by internal concerns over unaccounted-for water or revenue losses) should be repaired or replaced. Table 5-1 provides an example of recommended accuracy limits. Determining the optimum number of years a meter should remain in service between tests is achieved by testing 5 percent of those meters next scheduled or past due for periodic testing under



Highest registration occurs at approximately 7 to 10 percent of maximum capacity.

Figure 5-1 A typical accuracy curve for a ⅝-in. (15-mm) meter

an existing testing schedule. If the results of these tests fall within the accuracies shown in Table 5-1, it is assumed that the remaining meters will produce the same average test results. This procedure should be followed each year until the test results indicate that a longer time interval between tests would still produce results compliant with the accuracy limits in Table 5-1. At this time, the remaining meters should be removed and tested as part of the periodic test program. At this point the optimum number of years for periodic testing can be determined. As long as all factors remain unchanged, it can be assumed that the periodic testing period will remain constant. Table 5-2 contains testing intervals for many states. A more aggressive program can result in significant annual savings.

Statistical sample testing in a meter distribution system is an alternative method for determining the optimum number of years a meter should remain in service, especially residential meters ⅝ in. (15 mm) through 1 in. (25 mm) in size. Sample testing is a cost-effective management approach to determine the variables affecting meter performance and to monitor the overall accuracy of the metering system. Using established statistical methods, a random selection of meters determined by the year the meter was installed will provide data on the entire metering system. Weighting the statistical sample information with the system demand information determines the service-life decision.

The sample-test database, sorted by the purchase year and by the consumption rate, can be used to identify or window groups of meters with similar accuracy problems. This information will be used as a criteria to select changeout based on performance rather than age or type. Maintenance programs are an excellent opportunity to upgrade meters with new technology. This ensures that the money used to exchange meters is spent on the poorest performing meters within the system.

Calibration

The information in this section is provided for historical purposes, as mechanical-drive meters with gear-train technology are no longer manufactured.

In a mechanical-drive meter and in many magnetic-drive meters, the gear train includes two changeable gears allowing the ratio between the motion of the measuring element and the register to be adjusted for maximum accuracy of registration. Changed gears are no substitute for good meter-repair standards. Gearing changes

Table 5-1 Accuracy limits for compliance with guidelines

Meter Type (all sizes)	Accuracy Limits as Found by Testing *percent*	
	Normal Test Flow Rates	Minimum Test Flow Rates
Displacement	96–102	90–102
Multijet	96–102	90–104
Singlejet	96–102	90–104
Fluidic oscillator	96–102	90–102
Propeller and turbine	96–103	Not applicable
Compound and fire service	95–104	Not applicable

should be based on tests made at the high point on the performance curve to ensure that the meter registers near optimum accuracy.

The following description demonstrates how the displacement of water in the measuring chamber is transmitted to the meter register and converted to standard units of measure. Although the maximum speed of ⅝-in. (15-mm) meters is limited to 435 piston revolutions or nutations/ft^3 (15,400 rev/m^3) by 1995 AWWA standards, most meters have measuring speeds considerably below this maximum. Furthermore, meters are manufactured with three to five gear-reduction stages. In the example that follows, a composite figure of element's speed of 310 nutations/ft^3 (10,950 rev/m^3) is used in combination with a four-gear reduction train.

The volume of the measuring-chamber assembly of this composite meter is, therefore, approximately 1/310 ft^3, and 310 revolutions of the disc spindle are required to cause the smallest hand of the meter register to make one complete revolution and record 1 ft^3.

The intermediate gear train consists of four sets of reduction pinions and gears; each driving pinion has seven teeth and each driven gear has 28 teeth. The meter design (or trial) gears for registration in cubic feet consists of a driver gear with 24 teeth and a driven gear with 29 teeth.

In any gear train, the change in speed is the product of the number of teeth of the driver gears divided by the number of teeth of the driven gears. Therefore, in this meter, the reduction of the 310 revolutions of the disc spindle to one revolution of the 1-ft^3 index of the register is done as follows:

$$310 \times \frac{7}{28} \times \frac{7}{28} \times \frac{7}{28} \times \frac{7}{28} \times \frac{24}{29} = \frac{7{,}440}{7{,}424}$$

= 100.215% (Curve A in Figure 5-1)

This same meter geared for registration in gallons requires only a different set of change gears. For example, if a 24-tooth driver gear and 39-tooth driven gear are used, and the number of revolutions of the disc spindle are increased from 310 to 413⅓, an increase of one third, as 10 gal equals 1.3368 ft^3, then

$$413\frac{1}{3} \times \frac{7}{28} \times \frac{7}{28} \times \frac{7}{28} \times \frac{7}{28} \times \frac{24}{39} = \frac{9{,}920}{9{,}984}$$

= 99.359%

Thus, the smallest index of the meter register records 10 gal for each complete revolution.

These examples show that one basic design is used for meters recording in various units of measure by mere substitution of the change gears and register dial plate. This feature is of value from a production cost standpoint but is not the only reason for changing gears. These gears are also used to compensate for differences in meter accuracy resulting from manufacturing tolerances, wear, or other service conditions.

Multijet Meters—Calibration Device

Contrary to the positive-displacement meters, where the ratio between the register and the measuring chamber is changed mechanically, in some multijet meters, changes are made hydraulically, whereas in other multijet designs, the accuracy can be adjusted mechanically.

In some models, calibration is done by a variable-port regulating device incorporated along an internal bypass channel in the meter. Usually the device will be in the form of a screw, accessible from the outside without the need to disassemble the meter or the register and protected by a sealed plug.

Turbine Meters—Calibration Device

Some turbine meter designs have an adjusting vane that can be used for a simple hydraulic calibration. Adjustment is done with a screwdriver. Changing the position of the adjusting vane will affect the entire accuracy curve, but it might not shift the whole curve by the same amount.

TESTING NEW METERS

All new meters should be tested for accuracy of registration at flow rates and test-flow quantities in accordance with Table 5-3 before they are placed in service. This procedure ensures the water utility that the new meter is accurate and that a complete history is available when the meter is eventually brought back to the maintenance shop for inspection or maintenance, or if a customer challenges the meter's accuracy.

During the procurement process, specifications that require the manufacturer to provide certified meter test results are advantageous. Certified test results may easily be transferred to a database thus establishing the complete history of a meter. The database can be referenced for inspection or maintenance work, or to address customer concerns. A statistical sample testing of new meter shipments to verify accuracy and to maintain confidence in manufacturer test results is an efficient cost alternative to testing every new meter.

Program Coordination

To start a program of periodic testing, it is necessary to set an arbitrary time in which to complete the work. Also, it is desirable to select a period of years that coincides with the best estimate of the frequency with which meters should be tested. In this way, the work load is leveled out, and approximately the same number of meters will be due for testing each time. If, for example, a utility with 10,000 meters in service sets up a program for testing meters on a 10-year cycle, the utility has to remove approximately 900 meters each year. This amount is less than 10 percent of the number in service, as there are always meters that will not remain in service for the full period but will be removed for other reasons.

In order to provide for even work flow, both in the changing of meters and the shop work, the number of orders required should be prepared on a daily basis. Assuming

250 working days in a year, in order to complete the periodic testing of 900 meters per year, the testing of approximately four meters each day would be necessary in addition to other required work. If, therefore, four orders are written each day, the progress of the program may be reviewed at any time by a count of the number of incomplete orders for changing meters for periodic test and a check to see if the shop work is completed without a backlog of meters.

Although the testing of 10,000 meters may seem a staggering job, it is surprising that once the work is started on a systematic basis, the additional work is absorbed and soon becomes routine. As actual test results of meters removed from service are accumulated, experience is obtained as to how long it takes, on the average, for meters to lose sensitivity on the low flows. The length of time meters are permitted to remain in service can be adjusted on the basis of known results.

Large Meters

It is generally considered advisable to provide for more frequent testing of large meters, because an error in their registration affects revenue to a much greater extent. Furthermore, current and compound meters may under- or over-register to a much greater degree than positive-displacement meters.

If enough 3-in. (80-mm) and larger meters are installed, the repair and testing of these larger meters may be delegated to one particular person or crew. They will develop special skills that are necessary for the effective maintenance of larger meters. A survey of the largest utilities in the United States determined that the testing period for the larger meters is conducted on a yearly basis. However, the surprisingly large variation in test periods indicates a need for close study of this important policy. In any meter-testing program, accurate and readily available records are essential. A formal, ongoing meter record program should be established as an initial step in the program. Electronic data processing has proven to be a highly effective tool in maintaining an effective meter record program.

When any testing program is considered, some general observations are pertinent. An initial service period should be assumed, whether it is 30, 25, 20 years, or less. Older meters and those carrying the heaviest volume should be given priority, because volume measured is definitely related to meter wear. Magnetic-drive meters should have a longer maintenance period than mechanical-drive meters.

Probably the best advice that can be given regarding a meter testing program is to be alert to and study all phases of the metering field; there is no substitute for experience in determining the best procedure for any one utility. Although a metered system is the best known for equitably spreading the cost of water service, serious inequities and injustices can occur unless all meters are maintained at a high, uniform level of efficiency and unless every reasonable effort is made to prevent inequities from occurring.

Test Procedures

No phase of water-utility operation has been handled in so many different ways as the testing of water meters. The closest approach to standard test procedures has been the accuracy requirements contained in the AWWA meter standards and AWWA Manual M6, and these have been widely used as a basis for establishing individual testing methods. With the exception of specific rates set forth for testing meters on a minimum flow, the specifications make no provision for the number of different rates of flow on which meters should be tested; what these various rates of flow should be; or the quantities of water to be used in running such tests. It is understandable that the meter specifications do not contain these provisions, as the accuracy requirements are primarily a warranty to the buyer that meters purchased in accordance with the specifications will register within certain accuracy limits. The confusion and wide variance in testing procedures result from the fact that the testing of water meters in ordinary shop practice is primarily concerned with meters that are not new but that have been removed from service and repaired. Each individual has had to begin with the information available and develop testing procedures. Under such circumstances, it is not difficult to understand the reason for the widely divergent procedures that have developed over the years, many of which do not produce reasonable answers on overall operational ability of the meters tested.

Although many state regulatory commissions have adopted regulations concerning frequency of meter tests, it should be noted that any arbitrary time interval applied to several localities, each with its own unique local conditions, is not economically feasible for all. Table 5-2, compiled in 1995 and showing data as of 1994, lists these regulations. It must be recognized, however, that the very existence of such regulations has often resulted in better maintenance of meters. It is inexplicable why meter maintenance is, in too many instances, considered of secondary importance. Only when meters are formally recognized as the only means by which revenue is equitably obtained to operate the water system will the necessary time and study be given to the question of how often it is necessary to test meters for the most efficient and economic results.

Table 5-3 includes recommended data for testing cold-water meters by the use of the volumetric method, using volumetric tanks, or the gravimetric method, using weight scales. Accuracy standards for new meters are contained in the latest editions of the following AWWA standards: C700, C701, C702, C703, C704, C708, C710, C712, and C713.

The primary reason for meter tests is to ensure that the cost of water service is equitably distributed among all customers. Unless all meters register within defined limits of accuracy, equitable cost distribution does not occur. For this reason, regulatory commissions have established definitive meter-accuracy requirements and the frequency of tests for water meters. A review of such commission requirements indicates that each agency varies slightly in test frequencies, so it is important to be familiar with local regulations.

In addition, loss of revenue to the water utility will occur if the meters are not maintained efficiently. Unfortunately, meters may under-register for long periods without complete stoppage. It is necessary to test meters periodically to minimize this loss of revenue. The accuracy of displacement meters, inferential meters, multijet or current meters, is also subject to change while they are in service, and they may either under- or over-register. The period of time for which water meters retain overall accuracy is variable and depends on the characteristics, quality, and volume of the water being measured. The rates charged for water service also have a distinct bearing on how frequently meters should be tested. It is difficult to determine the economic balance between the cost of more frequent testing and potential loss in revenue caused by meter under-registration. Proper meter tests are necessary, however, in any such evaluation. Unless meter-testing procedures reflect overall operational ability and the same procedures are followed consistently, changes in meter accuracy after periods of service cannot be determined.

Finally, it would be advantageous if everyone spoke the same language. Many seminars are held annually on meter department operation and test procedures, but no common ground can be found for comparison unless the results are based on one method or standard.

Table 5-2 State public service commission regulations for periodic testing of water meters as of Nov. 30, 1994*

State	Effective Year	Rule Number	Meter Size in. (mm)								Meter Size in. (mm)				
			⅝ (15)	¾ (20)	1 (25)	1½ (40)	2 (50)	3 (80)	4 (100)	6 or larger (150)	⅝ (15)	¾ (20)	1 (25)	1½ (40)	2 (50)
			Interval Between Tests *Years*								Registration Between Tests *1,000 ft³* (28me)				
Alabama	(2)	W-17	10	8	6	4	4	3	2	1					
Alaska	1986	6.02	10	8	6	4	4	4	4	4	200	300	400		
Arizona (1)															
Arkansas															
California (3)	1967	103	20	20	15	10	10	10	10	10					
Colorado†	1949	21	5	5	5	4	4	3	2	1					
Connecticut	1966	16-11-88	8	8	8	4	4	3	2	1					
Delaware	1980	2076	15	15	10	10	3	3	3	1					
Florida															
Georgia (1)															
Hawaii															
Idaho (1)															
Illinois	1975	I.A.C.83 Part 600	6	6	4	4	4	4	4	4	100	300	300		
Indiana	1988	170 LAC 6-1	10	10	8	6	4	4	4	4	100	150	300		
Iowa (4)	1986	21.6(10)													
Kansas (1)															
Kentucky	1992	KAR 5:066	10	10	10	4	4	2	1	1					
Louisiana (1)															
Maine (3)	1987	Chap. 620	8	8	8	6	6	4	2	1	100	150	300		
Maryland	1968	6.9.2	10	8	6	4	4	2	2	1					
Massachusetts (1)															
Michigan (5)	1963	R460.13601	10	8	6						100	150	300		
Minnesota (1)															
Mississippi (1)															
Missouri	1968	42	10	6	4	4	4	4	4	4	200	300	400		
Montana	(2)	9	10	10	10	10	10	10	10	10					
Nebraska (1)															
Nevada (1)															
New Hampshire (2)		605.04(6)	10	10	4	4	4	2	1	1					
New Jersey	(2)	14:9-3.2	10	8	6	4	4	4	4	4	750	1,000 (6)	2,000 (6)		
New Mexico (1)															

(continued)