Pacific Northwest
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Water Metering Best Practices

February 2022

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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
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Acronyms and Abbreviations

AMI	advanced metering infrastructure
AMR	advanced meter reading
AWWA	American Water Works Association
DOE	Department of Energy
EPA	Environmental Protection Agency
FM	Factory Mutual
gpm	gallons per minute
ID	internal diameter
IT	information technology
mg/l	milligrams per liter
NIST	National Institute of Standards and Technology
NPD	nominal pipe diameter
OMB	Office of Management and Budget
O&M	Operations & Maintenance
PD	positive displacement
TDR	turndown ratio
UL	Underwriter's Laboratories
WUI	water use intensity

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1.0 Introduction

Managing water-efficient facilities and operations can be enhanced by the application of water meters and timely analysis of the reported data. These actions provide critical information for facility managers to analyze water use, identify trends and operational issues that can help target water efficiency measures.

Intended Audience:
Operations and Maintenance (O&M) and Building Management staff to provide a general introduction and overview of water meters.

The recommendations in these best practices are designed to supplement those of the manufacturer and design professionals. As a rule, these best practices will first defer to the manufacturer's recommendations on installation and maintenance.

Federal agencies are required to meter buildings for water per the Energy Act of 2020, codified in 42 U.S.C. § 8253(e), which directs agencies to meet the following water metering requirements:

- By October 1, 2022, in accordance with U.S. Department of Energy (DOE) guidance, all federal buildings shall, for the purposes of efficient use of water and reduction in the cost water in such buildings, be metered.
- Each agency shall use, to the maximum extent practicable, advanced meters or advanced metering devices that provide data at least daily and that measure at least hourly consumption of water in the federal buildings of the agency.
- Meter data shall be incorporated into federal water tracking systems (e.g. ISO 50001, Energy Management Information Systems) and made available to federal facility managers.

These best practices provide further technical information to select the appropriate water meters on buildings that have been identified and to understand how data can be used and analyzed to improve water management.

Find additional information and resources on federal water metering on the Federal Energy Management Program water metering resources website

Basic Terms:

Standard meters cumulatively measure and record aggregated usage data that are periodically retrieved for use in customer billing or energy management. A meter that is not an advanced meter is considered a standard meter.

Advanced meters measure and record water consumption data hourly or more frequently and transmit measurements over a communication network to a central collection point.

Advanced Metering Infrastructure (AMI) is an integrated network of advanced meters, communications, and data management systems.

Advanced Meter Reading (AMR) is a predecessor to AMI. AMR refers to individual advanced meters that transmit readings over short distances without the need for manual logging.

Find more definitions in the Glossary

These best practices focus on agency-owned building-level metering and addresses water meters for applications such as irrigation, cooling towers, vehicle wash, laundry, commercial cooking, recreation, and other water-intensive end uses.

Many federal facilities have water meters that are owned and managed by a private utility that supplies water to the site. These utility water meters typically measure water for an entire campus, not at the building-level or application level. Therefore, many federal buildings and water-intensive applications (e.g., irrigation) are not metered. Further, commonly available water meter selection resources focus on private utility operations and revenue recovery, not on facility water efficiency and O&M.

These best practices aim to guide facility managers in understanding these key issues to help increase the use of water metering:

- Water meter selection and installation
- Water meter technology options
- Data analytics and validation

Metering Cost Effectiveness:
Water reduction and operational improvements drive the cost effectiveness of water meters. A properly selected meter may have a higher upfront cost but will last longer and reduce operations & maintenance issues. Although meters do not save water directly, they provide data to inform performance improvements and cost reductions from:

- Water leaks in distribution system or equipment
- Operational issues such as open valves or malfunctioning equipment
- Water-intensive buildings that are good candidates for water efficiency upgrades

The Federal Metering Guidance discusses the practicability of installing advanced meters. It provides agencies with the option to forego advanced meters on buildings where costs could prohibit accomplishment of agency mission and project objectives. A forthcoming best practice on life-cycle cost analysis for advanced metering will help agencies make these determinations.

Find more information water metering use cases in the Data Analytics Section.

2.0 Meter Selection and Installation

The following information provides best practices on selecting and installing water meters.

2.1 Selection Considerations

Selecting the appropriate water meter technology/type and size requires identifying and addressing the unique requirements of each application. The primary considerations include:

Meter Size: The appropriate meter size for an application depends on the anticipated flow range (minimum, maximum, and continuous duty), as well as the other considerations listed here. The American Water Works Association (AWWA) oversees water meter specifications, including testing criteria, selection, installation, and maintenance guidelines. Per AWWA standards, threads on meter bodies are typically listed as one nominal iron-pipe size (NPS) larger than the nominal size of the meter inlet internal diameter (ID). Meter sizes indicated throughout these best practices refer to the flow capacity of the meter body ID, not the nominal pipe size they are connected to. Manufacturer product data sheets will list meter characteristics similar to those noted in Table 1 specific to their sizing ranges.

Water Demand Profile: A building's water demand profiles the range of flow rates expected or observed throughout a time period, typically a week. For some buildings or applications, water consumption is consistent with little variation, while other buildings may experience large swings in water use. It is pertinent to select a meter that can operate in the expected *extended low-flow* and *maximum continuous duty* ranges of the building or application.

Accuracy: Some applications may require highly accurate meter readings (laboratory equipment), while others may not require such high performance (irrigation). Accuracy is a function of the meter type, meter size, and the water volume and velocity flowing through it. The *turndown ratio (TDR)* is a metric that compares a meter's highest rated flow range to its lowest. An oversized meter will not accurately measure low flows, making it harder to detect problems at a building level. Meter accuracy also can be affected by improper installation. This is especially true for turbine and compound meters that require flow conditioning for a uniform swirl-free flow profile in the pipe immediately upstream of the meter.

Determining the Water Demand Profile:
To select the right meter type and size, determine the building or application *flow range* and estimate percentages for each:

1. Low flows (0.25 gpm–30 gpm)
2. High flows (30 gpm–1000+ gpm)
3. Maximum continuous duty (varies)

Temporary data logging may be required to collect water use profile data (minimum of 7 days). The existing meter (typically utility owned) must be tested for valid data logging.

Turndown Ratio is a metric used to estimate the range of accurate flow measurement that can be expected from a meter. Some meters (orifice) have very low TDRs meaning the meter does not accurately measure large variations in flow rate. Therefore, orifice meters should only be used on applications with very little variation in flow rate. It is common for the TDR to decrease as pipe diameter decreases, and it will vary among manufacturers.

Flow Range is the minimum and maximum flow rates measured accurately. This metric refers to entire meter categories, not individual meters. To estimate flow ranges for individual meters, consider the TDR and desired accuracy of the maximum or minimum flow rate of the building or application.

An example is a system with a max flow of 1,000 gpm and a meter with a TDR of 5:1, thus the lowest flow rate accurately measured would be:

1,000 gpm / 5 = 200 gpm

Alternatively, a system with a max flow of 1500 gpm and a meter with a TDR of 30:1 would have a min flow rate accuracy of:

1,500 gpm / 30 = 50 gpm

Pressure Loss: All meters impart a pressure loss to the system from friction through the flow path of the device. Some meters (electronic and propeller) impart minimal drag on the water flow, while others (venturi) depend on water pressure to register measurements. Undersized meters may have a large pressure drop, however larger meters may not measure low-flows as accurately and have cost and installation disadvantages. Determine the building or application acceptable pressure loss and select a meter that fits within this pressure range or provide provisions to compensate for proper system operation, such as a booster pump.

Location: Meters can be located indoors or outdoors, with each option having advantages and disadvantages. For example, indoor installations provide protection from the elements and added security but may take-up a significant footprint in the mechanical or water entry room. Outdoor installations may free up valuable indoor space, but the location of the underground meter vault may interfere with vehicle or foot traffic. Other considerations include access for reading and maintenance, meter harmonics/vibrations local drainage, and freeze protection for outdoor applications.

Available space: The space required for meter installation depends on the type, size, and required accessories such as straight lengths of pipe, strainers, control valves, test ports, etc., that make up the “meter set.” Allow sufficient space around the meter set to permit access for reading, testing, calibration and maintenance.

Networking and Cybersecurity: As AMI is increasingly integrated with federal IT networks, advanced meters introduce new entry points for potential cybersecurity breaches. Close coordination between agencies’ facility operations and IT personnel is essential to ensure that potential vulnerabilities are addressed and that AMI systems are operating in accordance with federal information cyber security policies.

Communication and data management systems: Communications and interoperability between meters and other data acquisition systems are critical. Confirm meter communication options are appropriate and compatible with existing information technology (IT) systems and cybersecurity protocols. Current AMI and AMR technology allows for remote data readings minimizing previous disadvantages of indoor or outdoor installations. Confirm cybersecurity requirements with the appropriate federal agency’s meter acquisition policy, if applicable.

Cost: Initial costs vary by meter technology and size. A small turbine meter will be less expensive than an equivalent sized compound meter. An ultrasonic meter (newer technology) may be slightly more expensive to a comparable compound meter but may have other benefits such as reduced footprint and maintenance. Procurement and installation should be balanced with operations and maintenance for the application. A low-cost meter not well suited to the application may cost more in operations and maintenance. Conversely, a more expensive compound meter may not be appropriate for an application where a less expensive disk meter may suffice. In certain cases, high costs could mean advanced metering is not practicable at some Federal buildings. See the Federal Metering Guidance for an explanation of practicability of advanced metering in appropriate buildings.

2.2 Installation Considerations

The following rules of thumb provide general guidelines for meter installations. Refer to the meter manufacturer's installation recommendations for specific requirements.

- Install the meter in the proper orientation. Some meter types (electronic) can be installed in any orientation, while most others must be installed horizontally.
- Locate meter so it is readily accessible for reading, servicing, calibrating and/or testing.
- Provide high-quality shutoff valves and connections so the meter can be removed from service without negatively affecting operations.
- Provide a bypass to allow for testing and routine maintenance without interrupting service.
- Provide for permanent electrical grounding not connected to the meter to prevent accidental shock to operations personnel.
- Provide protection from freezing and other conditions that could damage the meter set.
- Provide proper wiring connection to AMI/AMR or building controller system in accordance with individual federal agency IT and/or AMI/AMR requirements.
- For outdoor installations, confirm that soil conditions, groundwater level, frost line, and meter vault depth and clearances are appropriate.

Pipe fittings and valves close to the meter introduce turbulence in water flow, which decreases the accuracy of most meters. The guidelines listed below and as illustrated in Figure 1 can assist in providing the best flow and measurement accuracy through the meter.

A. ***Straight Pipe*: **Compound and turbine meters require a minimum length of 5 pipe diameters upstream and downstream of the meter for optimum performance. For example, a pipe 3" in diameter would require 15" of straight pipe both upstream and downstream of the meter.

B. ***Strainer*: **Water that contains sediments or contaminants can damage or interfere with the internal components of most water meter types. Although some meters include internal strainers, installations without an appropriate external strainer may require a minimum of 10 pipe diameters of straight pipe upstream of meter.

C. ***Valves*: **Valves disturb water flow, thus interfering with the water flow profile.

   - Install full open butterfly or gate valves a minimum of 5 pipe diameters from meter and strainer upstream and 5 pipe diameters downstream.
   - Install check valves at least 5 pipe diameters downstream of the meter. Install pressure reducing valves at least 5 pipe diameters downstream of meter. Never install check valves or pressure reducing valves within 5 pipe diameters downstream of the meter.

D. ***Other*: **Components such as backflow devices, pumps, and test ports.

   - Install backflow devices at least 5 pipe diameters upstream of the meter.
   - Install test ports at least 2 pipe diameters upstream and downstream of the meter.
   - Never install valves on the suction side of a pump near a meter.

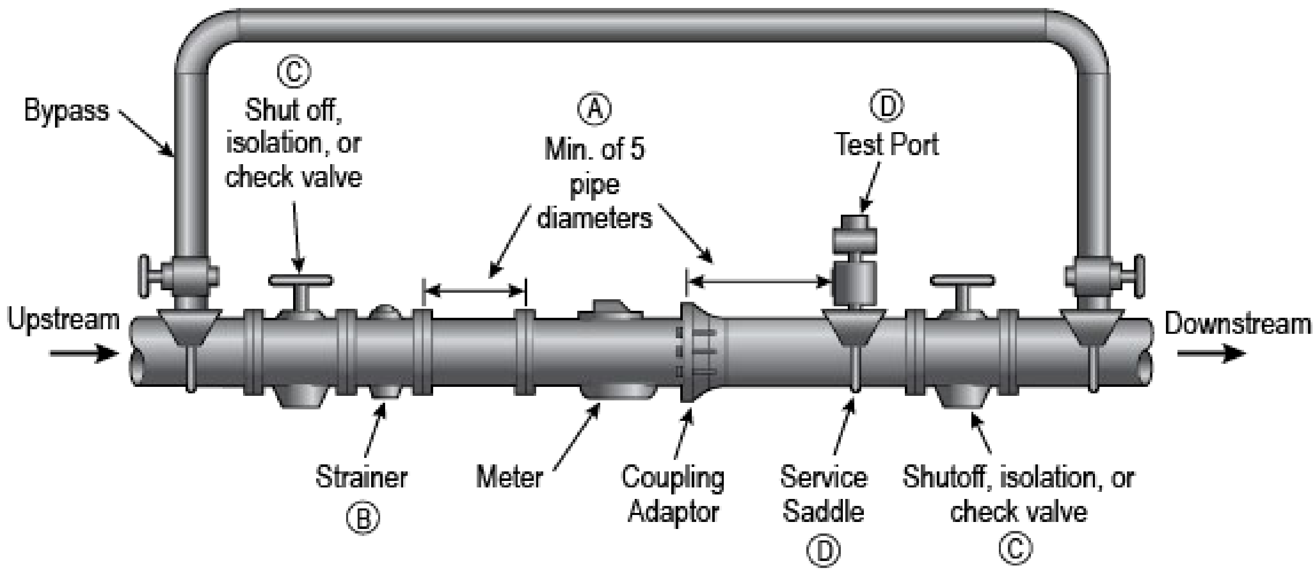


Figure 1. Recommended Installation for Turbine and Compound Meters

2.3 Testing and Calibration

Most water meters, other than electronic types, contain moving parts that wear out over time, reducing accuracy and reliability. To avoid wear-related problems, it is recommended that meters be tested for accuracy in accordance with manufacturer's recommendations or applicable American Water Works Association test procedures for the meter type. General practices for maintaining different sized meters are listed below and provided by meter type in Table 1.

– Meter sizes between 5/8" and 1" should be tested every 10 years.

– Meter sizes between 1" and 4" should be tested every 5 years.

– Meter sizes above 4" should be tested annually.

Refer to the National Institute of Standards and Technology (NIST) Fluid Metrology Calibration Services website for more information https://www.nist.gov/pml/sensor-science/fluid-metrology/fluid-metrology-calibration-services-liquid-flow

3.0 Water Meter Technology Overview

The single function of a water meter is to convert the physical flow of water into a measurement of volume. While the process used to make this measurement varies, all water meters share these basic components:

- A coupling connection to the water line. Flanges and union threaded ends are the most commonly used connections.
- A metering element that reacts proportionately to flowing water. This could be an impeller, a nutating disc, or an electrical signal.
- A register that converts the incoming signal, pulse, or mechanical movement into a measurement of volume. In advanced meters, the register often is connected to an AMR/AMI system that transmits readings, often by radio frequency.

This section describes a variety of water meters available on the market. Table 1 provides a general comparison of key attributes that can be useful in the selection process, with the most common meter types encountered in building applications shown at the top.

This section of describes five categories of water meters:

- Positive displacement
- Velocity
- Compound
- Electronic
- Differential pressure

Table 1. Meter Characteristics[1]

Meter Type	Meter Category	Cost	Flow Range (gpm)	Turn Down Ratio (High to Low)	Meter Size Range	Pressure Drop	Applications	Testing Frequency
Water Meters Applicable for Most Building Applications								
Nutating Disk	Positive Displacement	$	0.25 to 400	3:1 to 20:1	5/8" to 2"	Low	Single Family Residential, Small Commercial,	10-15 years
Turbine Class II	Velocity	$$	4 to 12,000	20:1 to 50:1	¼" to 20"	Medium	Large Office, Irrigation, Education, Hospitals	Annual
Ultrasonic	Electronic	$$ to $$$	0.05 to 10,000	100:1	5/8" to 120"	Low	Single Family Residential, Multifamily Residential, Hospital, Commercial, Irrigation	1-5 years
Electro-magnetic	Electronic	$$ to $$$	0.1 to 100,000+	400:1	½" to 72"	Low	Single Family Residential, Multifamily Residential, Hospital, Commercial, Irrigation	1-5years
Compound Class II	Compound	$ to $$	0.25 to 4,500	100:1 to 1,000:1	2 to 8"	High	Multifamily Residential, Hospital, Commercial, Education, Irrigation	1-5 years
Water Meters for Other Applications								
Oscillating Piston	Positive Displacement	$	0.4 to 5	3:1 to 10:1	5/8" to 2"	Low	Process, Viscous fluids	5-10 years
Multi-Jet	Velocity	$	0.25 to 160	15:1 to 40:1	5/8" to 2"	Medium	Small Commercial	5-10 years
Single-Jet	Velocity	$	0.25 to 1000	40:1 to 300:1	5/8" to 2"	Medium	Education, Hospitals	5-10 years
Vortex Shedding	Velocity	$$	0.6 to 100,000+	10:1 to 20:1	¼ to 12"	High	Irrigation	1-5 years
Propeller	Velocity	$ to $$	40 to 100,000+	10:1	2 to 72"	Low	Irrigation	1-5 years
Venturi	Differential Pressure	$$	0.25 to100,000+	<5:1	¼" to 84"	High	Process, Boilers, High Volume, Low Variability	Annual
Orifice	Differential Pressure	$	0 to 25	<5:1	¼" to 24"	High	Process, Steam, High Volume, Low Variability	Annual
Fire Service	Compound	$$	2.5 to 7,000	10:1 to 20:1	3" to 12"	N/A	Per local fire safety codes	Annual

[1] Information obtained from AWWA Water Meters Manual 6 and Manual 22, as well as a selection of manufacturer and industry data to compile typical ranges for each criteria.

3.1 Positive Displacement Meters

Description: Positive displacement (PD) meters directly measure water volume by monitoring how often a fixed volume measuring chamber is filled with and emptied of water.

Types: There are two main categories of PD meters: 1) nutating disk and 2) oscillating piston.

- **Nutating disk** meters have a disk on a sliding ball guided by a thrust roller. The movement of water into the fixed volume measuring chamber causes the disk to nutate, or wobble, on its axis. The thrust roller is connected to a magnetic coupling at the register.

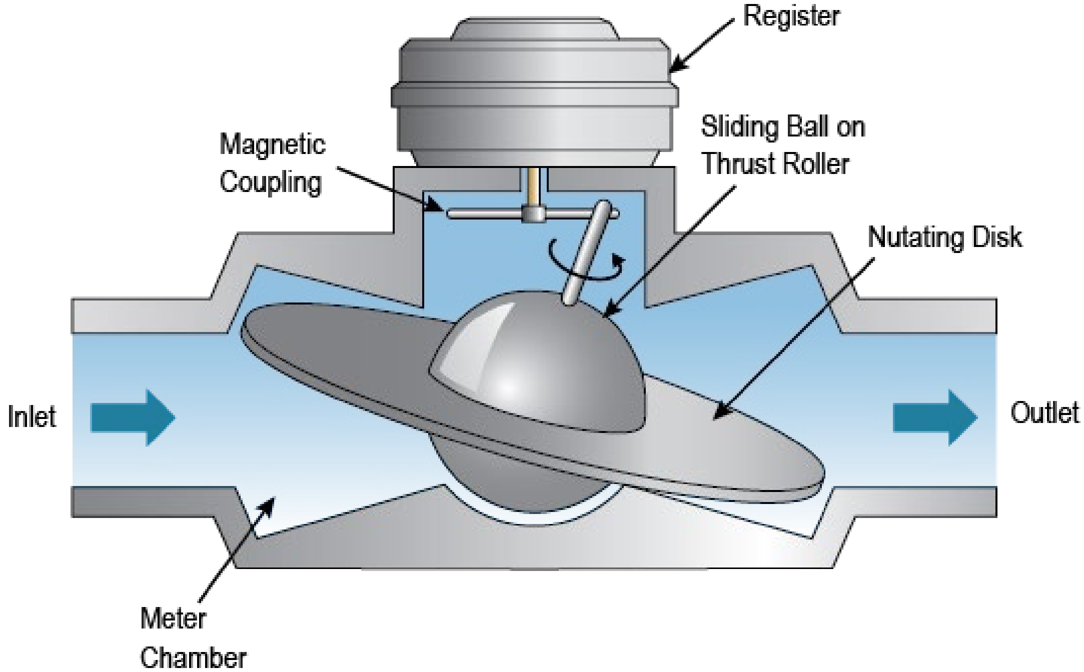


Figure 2. Example of a Nutating Disk Positive Displacement Meter

- **Oscillating piston** meters have a precision-machined measurement chamber containing a circular piston constrained to oscillate in one plane only. The rotation of the piston within a circular groove is transmitted to the register either mechanically or magnetically.

Applications: PD meters are well suited for smaller systems with low flow rates, up to 400 gpm. Common PD meter sizes range from $^{5}/_{8}$" to 2". Nutating disk meters are the most common type of PD meter used in building applications. Oscillating piston meters are ideal for use with viscous fluids such as in vehicle maintenance and food and beverage applications.

Selection Tips: PD meters are very accurate for low-flow rates. Pressure drop through the meter is modest, and meter maintenance is minimal. Smaller low-occupancy buildings are ideal candidates for these meters, as are low-flow applications. PD meters operate best when installed horizontally. PD meters are small and do not require straight lengths of pipe upstream or downstream of the meter and are well suited for environments where space is limited. As the measuring mechanism is not designed for higher flows, buildings or applications that experience periodic high flow rates should consider a compound meter. PD meters are less expensive than comparable turbine or compound meters.

3.2 Velocity Meters

Description: Velocity meters measure water velocity and convert the measurement into a volume. An impeller spins at a rate proportional to the water flow, or in the case of a vortex shedding meter, volume is interpreted through flow-induced vortices.

Types: There are four main categories of velocity meters: 1) turbine, 2) single-jet and multi-jet, 3) vortex shedding, and 4) propellor.

- **Turbine** meters use an impeller connected by a gear set to the register to measure the water flow. There are two classes of turbine meters. Class I turbine meters have the impeller axis perpendicular to the water flow, tend to be older designs and thus are less widely used. Class II turbine meters have the impeller axis parallel to the water flow and are smaller than Class I meters.

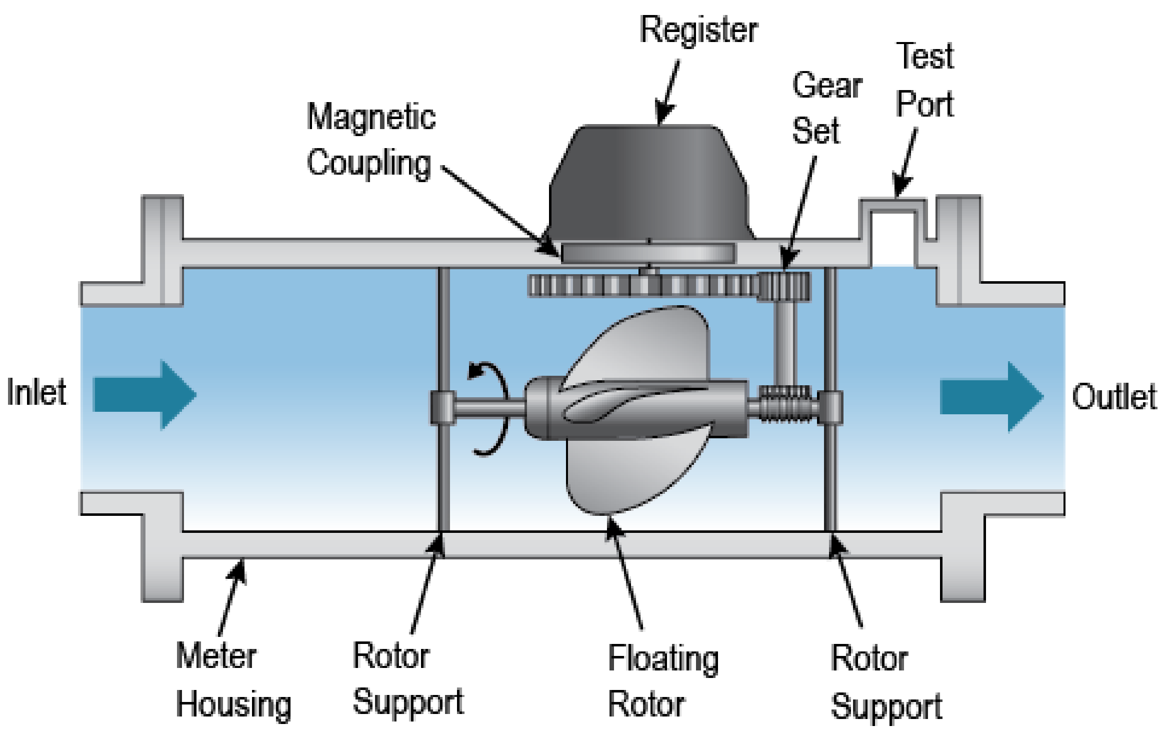


Figure 3. Example of Class II Turbine Meter

- **Single-jet and multi-jet** meters concentrate the flow of water into several columns directed at the periphery of an impeller. Single-jet meters have one jet directed tangentially to the impeller. Measurements are taken in a similar manner as turbine meters.

– **Vortex shedding** meters are unique as they induce vortices in the flowing water and use the frequency at which these occur to measure the flow rate and infer the volume.

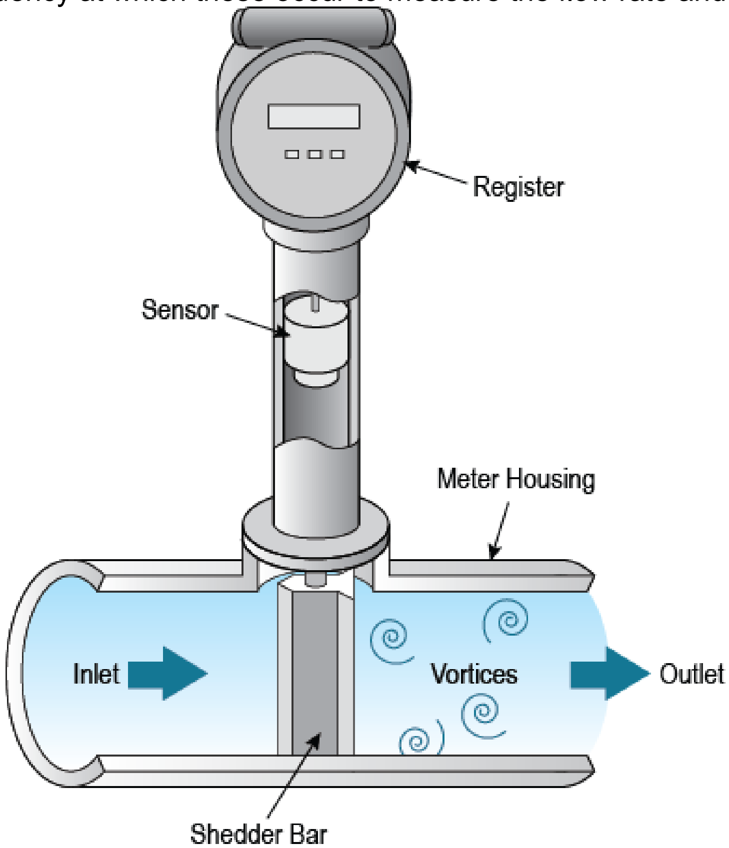


Figure 4. Example of Vortex Shedding Meter

– **Propeller** meters have a “pinwheel” (rotor) in the flow stream that spins on a horizontal axle geared to a register. The rotor spins proportionally to the fluid velocity with minimal pressure drop. This meter type can measure high-velocity turbulent flows and can be used in water in which particulates are present without significantly affecting the meter components.

Applications

– **Turbine** meters should range in size from ¼“ to 20” and work best in high-flow applications, thus should be considered for high-occupancy facilities and end uses where flow rates are greater than 50 gpm.

– **Single- and multi-jet** meters range in size from $^{5}/_{8}$” to 2” and cover a wider range of flow rates ranging from 2–30 gpm.

– **Vortex shedding** meters range in size from ¼“ to 12”. They are less common in potable water applications as low flow rates are not accurately measured, although they can be appropriate for end uses with continuous moderate to high flow rates such as boiler feed water, chilled or hot water systems, corrosive fluids, or where moving parts are not desired.

– **Propeller** meters range in size from 2” to 72” and are most appropriate for high-flow end uses containing sediments such as irrigation mains.

Selection Tips

Acceptable flow rates vary from meter-to-meter in this category; consult manufacturer data sheets to help select the appropriate meter. Avoid installing turbine meters in buildings or end-uses in which frequent low-flow rates are experienced as accuracy in these ranges tends to be poor; PD or multi/single-jet meters would be choices for that application. Turbine meters need fully established relatively steady flow profile upstream of the meter. A strainer should be installed upstream of the turbine meter to remove debris that can impact accuracy and reduce the life of the meter. Many turbine meters require an adequate length of straight pipe installed before and after the meter (typically 10x and 5x nominal diameter, respectively) otherwise accuracy will be affected. Vortex meters should be avoided in applications where intermittent low-flow occurs due to the possibility of under measurement.

3.3 Compound Meters

Description: This meter type uses a combination of both high- and low-flow metering devices for facilities that see a wide variation of water flow rates throughout a given time period. Compound meters typically include both turbine and positive displacement (disk) meters as one unit. When water usage is low, the PD meter is active and registers usage until flow increases above a threshold when the turbine meter registers usage. Accuracy is affected by the *changeover point*, which is the flow rate at which the meter transfers from the high to low-flow measurements.

Types: There are three main types of compound meters: 1) series, 2) parallel, and 3) fire-service.

- **Series** compound meters operate simultaneously with a ratcheting mechanism so only one meter registers flow at a time.
- **Parallel** compound meters operate one at a time and transition by an automatic bypass.
- **Fire service** compound meters are specialty types listed by Underwriters Laboratories (UL) and/or Factory Mutual Global (FM) for fire service applications. This type of meter complies with applicable fire and life safety codes and standards.

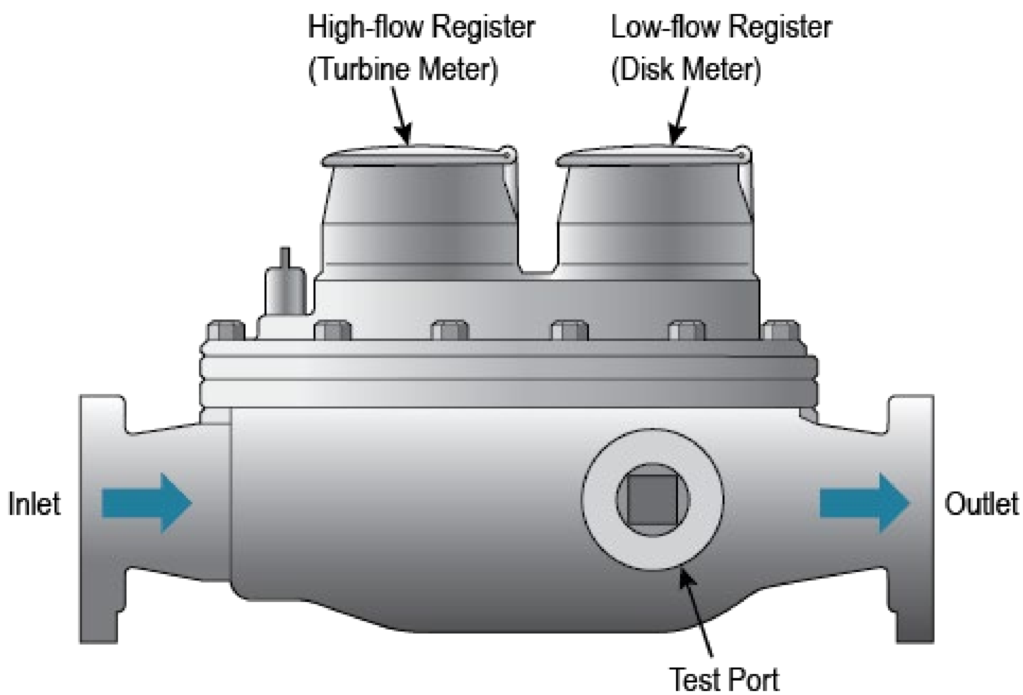


Figure 5. Example of a High-Low Compound Meter

Applications: These units have a large TDRs and are widely used in buildings and applications with large water flow rate variations. Common compound meter sizes range from 2” to 8”.

Selection Tips: Observe the use patterns (water demand profile) of your facility to minimize the time spent operating at the changeover point. Also consider the space needed to accommodate manufacturer’s recommended strainer and straight-pipe requirements. Compound meters ranging in size from 2” to 8”. When use is intermittent and shows significant variation, a compound meter should be considered. Because they require two meters per application, compound meters tend to be relatively expensive compared to a similar size turbine or PD meter.

3.4 Electronic Meters

Description: Electronic meters measure water velocity from an electrical charge or signal and converts that measurement to a volume measurement. The measurement is proportional to the velocity, which is used to calculate the volume of water. Some electronic meters may include pressure and temperature sensors. Because the flow is through an open pipe with no moving parts, they can be installed minimal to zero straight runs of pipe (depending on manufacture’s installation instructions), there is very little pressure drop and minimal maintenance required.

Types: There are two main types of electronic meters: 1) electromagnetic and 2) ultrasonic.

- **Electromagnetic** meters operate by sending a magnetic field through the water flow to induce an electrical current that is proportional to the flow rate moving through the field.

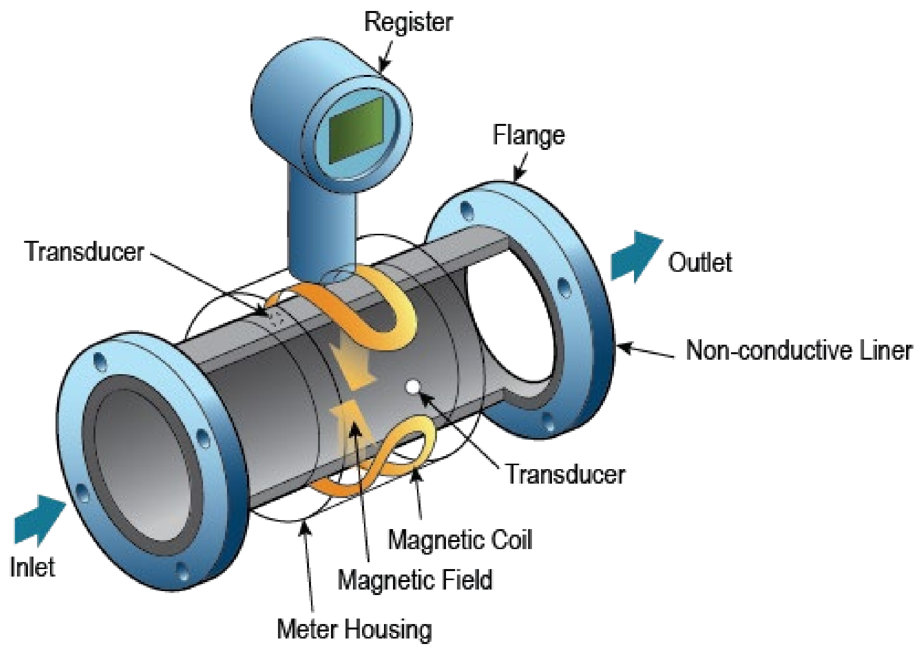


Figure 6. Example of an Electromagnetic Meter

- **Ultrasonic** meters come in two varieties: 1) doppler and 2) transit-time.
  - Doppler meters send and receive high-frequency sound waves through the fluid. The sound waves are reflected off particles suspended in the fluid and sensed by the metering unit. A shift in frequency is interpreted to arrive at the total water flow.
  - Transit-time meters send an ultrasonic signal through the water, both in the direction of flow and in the reverse direction. The difference in travel time is proportional to the velocity of the flow. These meters are commonly found in non-invasive, clamp-on units that are easy to install on the outside of the pipe.

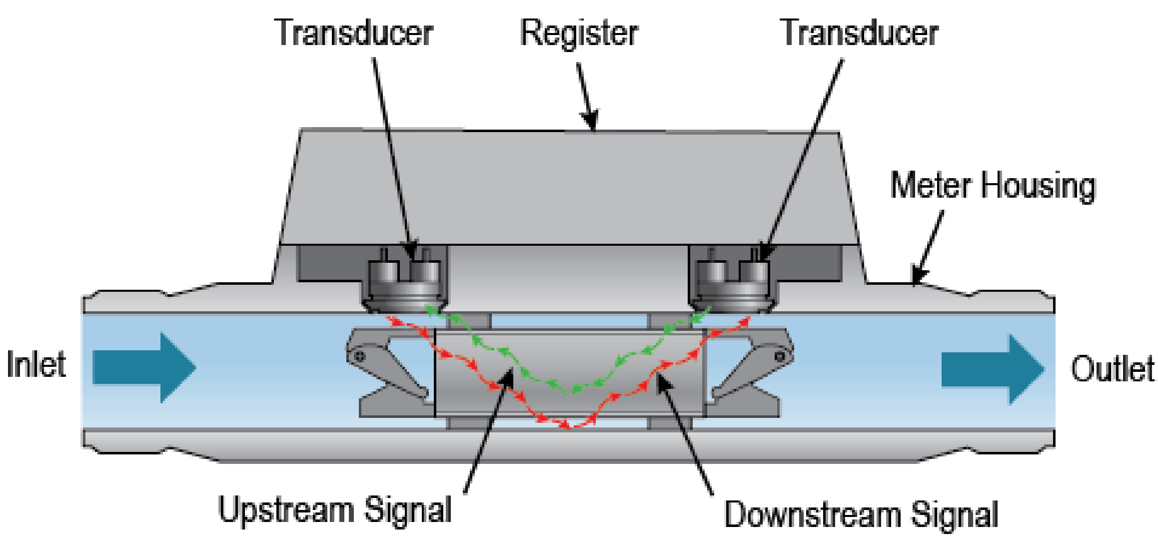


Figure 7. Example of Ultrasonic Transit-Time Meter

Applications: Electronic meters also have high TDRs, making them suitable for variable flow applications. These units are commonly used in water lines that contain contaminants, due to the lack of moving parts and obstructions in the meter cylinder. Common electronic meter sizes range from ½" to 72". Ultrasonic meter common sizes range from 5/8" to 120". The maintenance required for electronic meters is low, making them ideal for remote locations and areas where workspace is limited. The accuracy and sizing ranges are greater than those of their mechanical counterparts, making them ideal for unique metering purposes where accuracy is of utmost importance.

Selection Tips: Avoid using for water that contains magnetic (iron) particles or air bubbles as these factors can affect meter accuracy. It is also critical to have a reliable source of power. The cost of electronic meters is decreasing as the market matures. The cost of a small electronic meter may be on par with a comparable turbine meter, with added benefits of low pressure drop and excellent low flow capabilities.

3.5 Differential Pressure Meters

Description: Differential pressure meters work by restricting water flow into the meter and measuring the difference in pressure at the inlet and outlet. The differences in pressure are proportional and used to measure velocity which is then inferred into a volumetric number.

Types: There are two types of differential pressure meters" 1) Venturi and 2) orifice plates.

- **Venturi** meters restrict water flow by gradually decreasing the tube diameter as the water flow approaches the middle of the meter. The meter takes two measurements, at the inlet of the meter and near the narrowest section of the meter. The difference in pressure is proportional to the rate of flow.

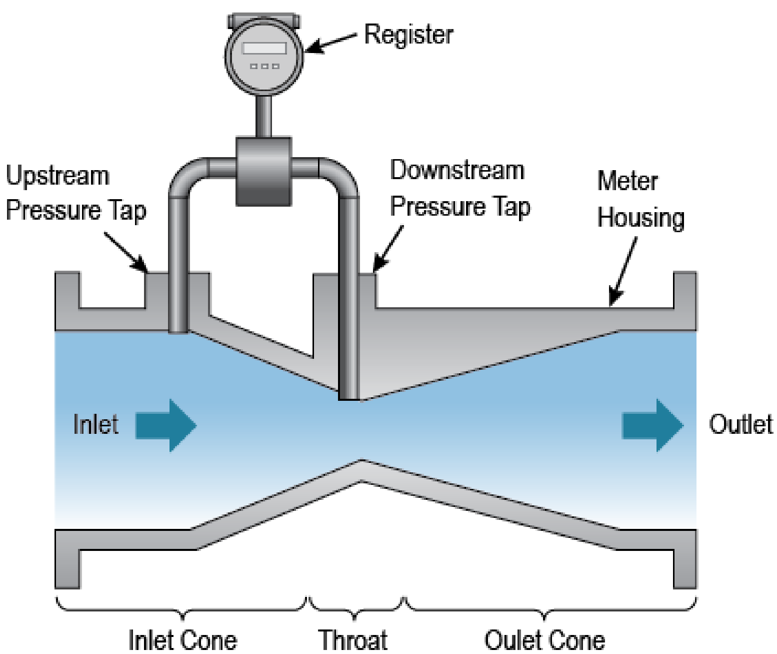


Figure 8. Example of Venturi Meter

– **Orifice plate** meters rely on a precisely manufactured plate inserted between two flanges to restrict water flow and induce a pressure drop. Suspended particles—regardless of size—abrade the plate over time and enlarge the orifice. This process diminishes the accuracy of the meter. It is imperative that orifice plates be inspected regularly to prevent the occurrence of excessive wear. The frequency at which inspections should occur will depend on water quality and use of the water line.

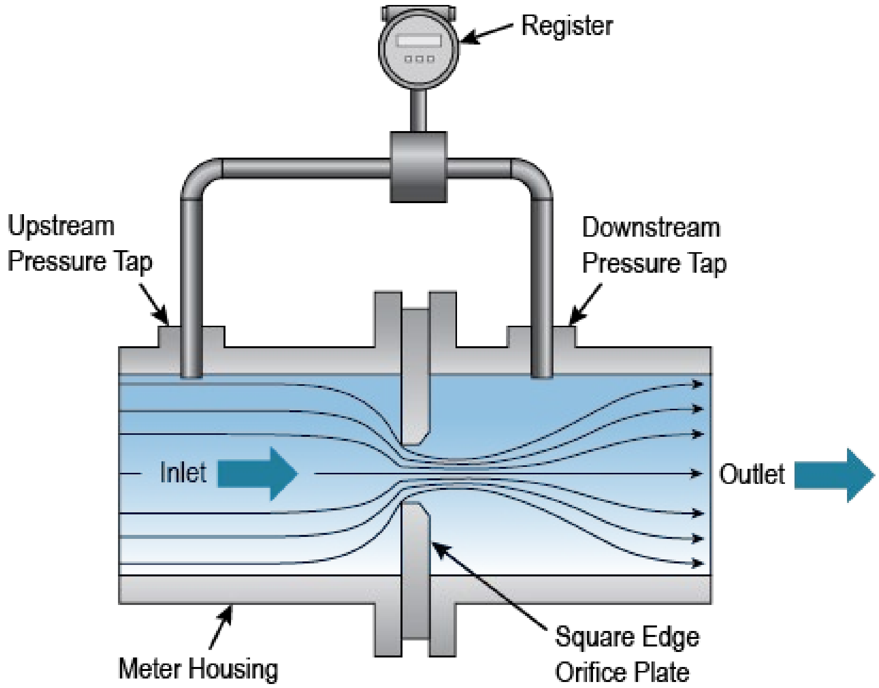


Figure 9. Example of Orifice Plate Meter

Applications: Differential pressure meters are used on large water lines in high-flow applications in which variations in flow rate are low. This meter type is most commonly found in larger water distribution systems.

Selection Tips: Differential pressure meters require sufficient space for flow conditioning straight pipe runs installed upstream and downstream of the meter. They are typically less expensive than other types of meters. Common differential pressure meter sizes range from ¼” to 84”. Maintenance, regular testing and calibration, and replacements of orifice plates are all required to attain accurate readings. Costs of differential pressure meters are comparable to the costs of turbine meters.

4.0 Data Analytics and Validation

The purpose of installing advanced water meters at federal buildings is to collect data to analyze and act upon. Detailed water use data measured hourly or more frequently and displayed in water tracking systems can be used by agencies to identify operational issues and select conservation measures to reduce water use. The importance of metering can be summed up in the energy manager's maxim: ***You can't manage what you don't measure.***

Advanced meters are one component of an agency's AMI, which includes an integrated network of advanced meters, communications networks, and energy management information systems. All of these components work together to transform readings at the meter into actionable data for the user.

To be useful for analysis, water use should be measured at short, regular intervals, and data should be accurate and complete.

Measurement Interval: Federal law requires advanced meters installed on federal buildings to measure at least hourly consumption of energy and water. Depending on the application, more frequent measurement (e.g., 15-minute intervals) may be desirable. High-resolution interval data enables water managers to see variable usage patterns at their facility throughout the day and look for periods of unexpectedly high or low water use

Data Accuracy: As discussed in the **Error! Reference source not found.** section, advanced meters must be appropriately sized and properly configured to accurately measure water flow. Inaccurate data can lead to unreliable conclusions.

Data Completeness: There are techniques for interpolating missing data over short intervals (i.e., 1–2 hours); however, filling longer gaps with estimated values reduces the reliability of the data. Complete or near-complete data is desirable for understanding water performance at the building.

4.1 Supporting Data Sources

Combining water meter data with specific information about a building leads to the greatest insight and the most value for the investment. Common supporting data sources include:

Real property data: Dimensions such as building size, age, and use type provide context as to whether water use is within the expected range at expected times of day.

Equipment inventories: Descriptions of water-consuming equipment in the building can help explain unexpected patterns, such as unusually high levels of water use due to single-pass cooling.

Weather data: Outdoor environmental factors such as temperature and rainfall can provide another check as to whether a building is overusing water. For example, regular irrigation during wet months often is wasteful and presents an opportunity for savings.

Utility bills and rate schedules: Billing documents from the local utility can be analyzed in combination with water use data to project and verify cost savings from retrofits and operational improvements.

Maintenance records: These records are important documents that explain repairs and replacements on water-using equipment. Savings from maintenance often can be quantified using water meter data.

4.2 Water Use Intensity

Water use intensity (WUI) is a metric that normalizes water use by a building's total floor area. WUI can be used to directly compare rates of water use across buildings of different sizes. The metric is usually calculated as:

$$\frac{Water\ use\ (gallons)}{Total\ building\ area\ (gross\ square\ feet)}$$

The WUI metric can be calculated over any time period; although, for benchmarking purposes, total water use usually is summed monthly or annually.

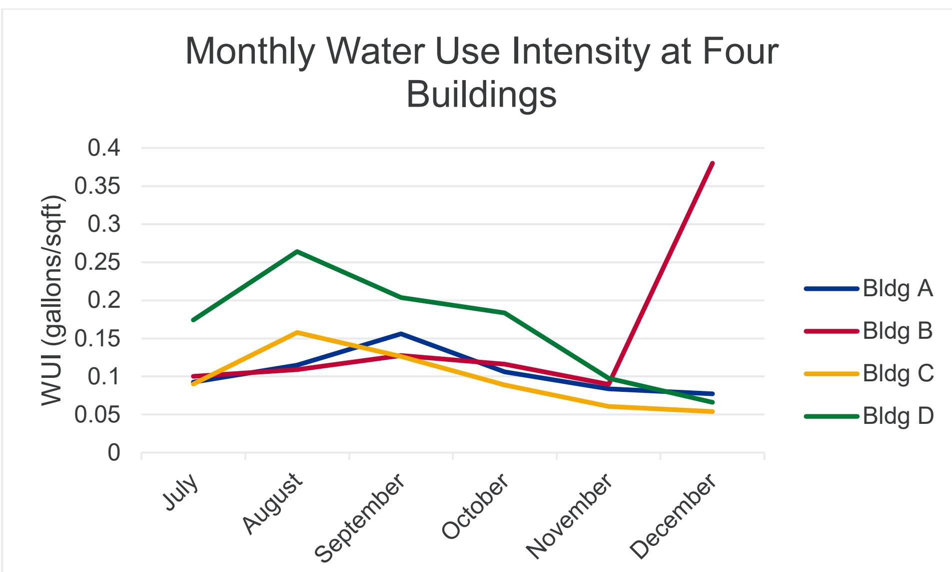
Note: Per the Energy Act of 2020, the US DOE, in consultation with the Office of Management and Budget (OMB) and the US Environmental Protection Agency (EPA), is developing new performance metrics requirements for data centers, in which WUI is being considered.

4.3 Use Cases

The following examples illustrate some typical use cases for water meter interval data.

4.3.1 Benchmarking Monthly WUI for Similar Buildings

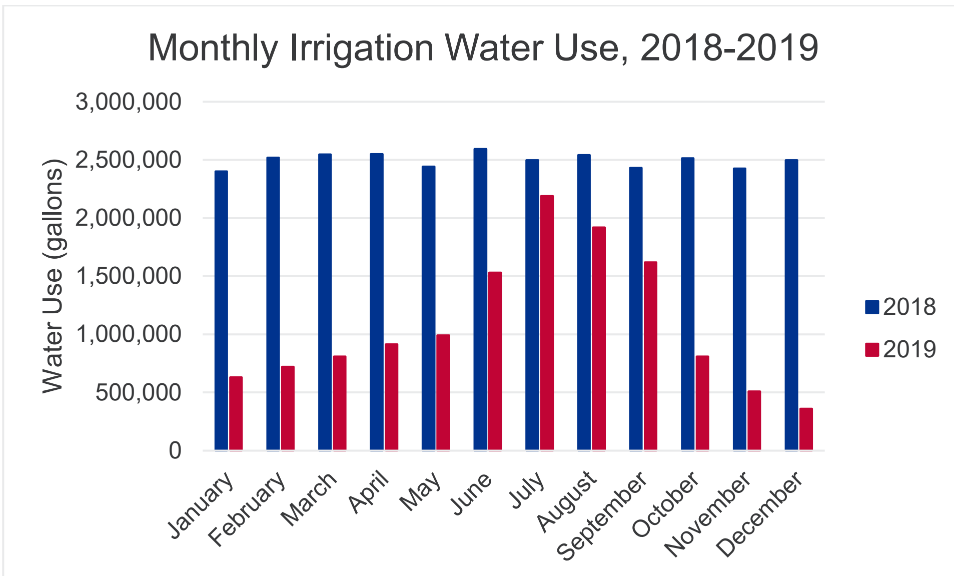
Situation: A regional energy and water manager monitors monthly water use for a portfolio of buildings. She compares monthly WUI for four similar buildings and notices that water use at Building B has increased substantially in December, while it is trending downward for the winter at the other three buildings.



Outcome: The water manager reviewed the 15-minute interval data and saw that at 3:30 PM on December 4, baseline water use at the facility increased rapidly from zero to approximately 130 gallons every 15 minutes. She placed a call to the facility manager on-site, who discovered that a faucet had been left running in a seldom-used utility closet. The facility manager closed the faucet and the following month water use decreased by almost 20,000 gallons.

4.3.2 Identifying Landscape Irrigation Improvements

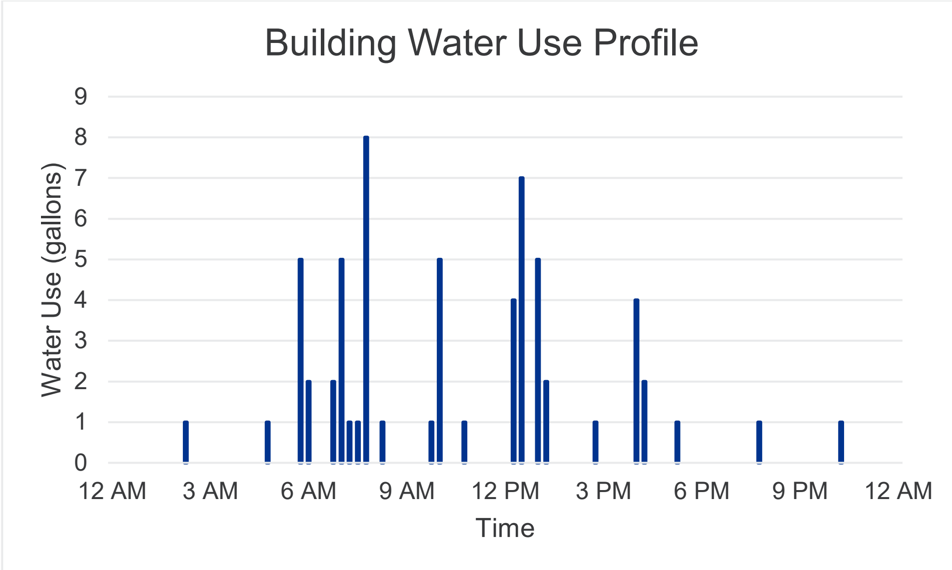
Situation: A facility grounds manager in Texas reviews a graph of landscape irrigation water use over the previous month and sees that a consistent amount of water is used at the same time each day. Further investigation reveals that the irrigation system is controlled by a clock timer, leading to a significant overuse of water throughout the year, particularly in the winter months. By implementing weather-based irrigation controllers, which adjust the timing and duration of irrigation based on locally forecasted weather conditions, the site could save water and money.



Outcome: The following year after installing the weather-based irrigation controllers, the site reduced irrigation water use by 57%, saving nearly 17 million gallons of water. Data from the advanced water meter was instrumental in first identifying the problem of over-watering and then demonstrating the savings from installing the controllers.

4.3.3 Identifying a Plumbing Leak

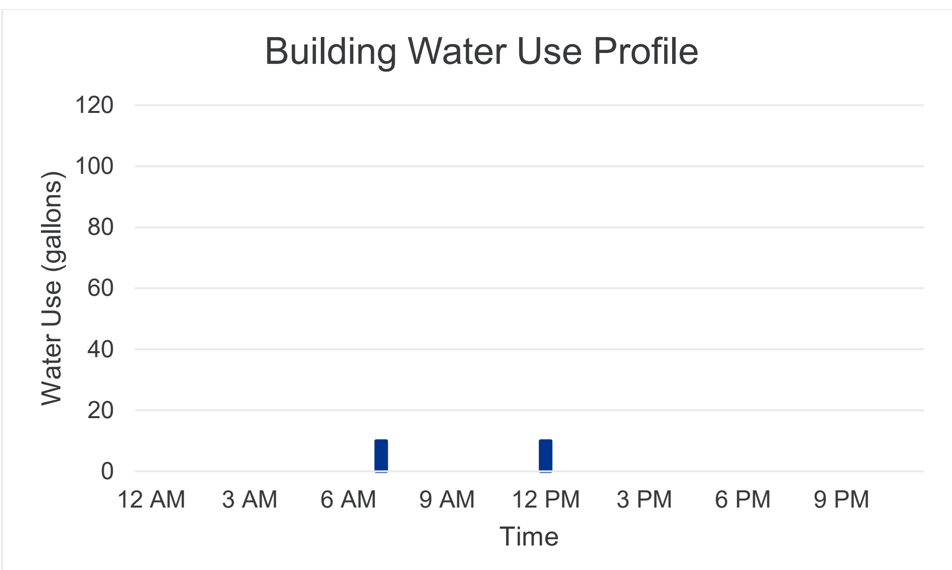
Situation: A building operator reviews a plot of water use over the previous 24 hours and notices a suspicious pattern of regular water use at night. The graph below shows one gallon pulses at intervals of 2 hours which reveals use during unoccupied periods.



Outcome: The water use observed at regular intervals during the night, when the building is unoccupied, raised the suspicion of a small but continuous water leak. Visual inspection of the fixtures in the men's restroom confirmed the leak's location. Leaks can be difficult to recognize during the day when water normally flows but during unoccupied periods when no flow is expected, regular pulses of the same magnitude and frequency are a common sign that there is a leak in the system.

4.3.4 Improper Configuration of a Meter at a Building with Low Water Use

Situation: A facility manager reviews water use data at a campus building for the prior 24-hour period. The time series graph reveals little interpretable information, beyond the fact that the building appears to have used a total of 20 gallons of water during that time.



Outcome: The meter is not properly configured to record the relatively low rates of water use in this building. The water meter has a pulse kit that is configured to report consumption in 10-gallon increments; however, because water use is low at this building, the kit should have been configured to pulse at 1-gallon increments or less. That configuration would have provided better data resolution, showing water use at times where the meter is currently reporting zero use.

Appendix A – Glossary

Advanced meter: An advanced meter records energy or water consumption data hourly or more frequently and provides for daily or more frequent transmittal of measurements over a communication network to a central data collection point. Advanced meters usually are able to record other physical quantities in addition to consumption. Related to an advanced meter, an advanced metering device is an electronic meter with built-in metering and communication capabilities, or a separate electronic device coupled to a standard meter that enables communication to the on-site automated metering infrastructure.

Advanced Metering Infrastructure (AMI): An integrated network of advanced meters, communications networks, and data management systems. Advanced metering infrastructure can refer broadly to an agency's entire portfolio of advanced meters and related assets (referred to in this document as the agency's "AMI system") or more narrowly to the assets at a particular site or building.

Advanced Meter Reading (AMR): The predecessor and contemporary to AMI, AMR refers to individual advanced meters that transmit readings over short distances without the need for manual logging of information. The key difference between AMR and AMI falls in the method of data collection. AMR relies solely on vehicles or personnel equipped with remote meter-reading devices to collect data from the roadside, as opposed to data being automatically transmitted to a data management system. As such, readings occur less frequently and are less useful for diagnostic purposes.

Changeover point: The point at which a compound meter's operations transition from one meter to the other is known as the changeover point. Applications with flows near this operating point should consider a meter that can accommodate the changeover point range.

Extended low-flow: Low flow at which the meter manufacturer guarantees minimum accuracy of ±3% or 97%–103%

Flow range: A general range of flow rates that the meter measures accurately. This information refers to entire meter categories, not individual meters.

Maximum continuous duty: The flow rate where meter can be run continuously without degrading meter operation.

Pressure range: The amount of water pressure the meter can safely handle without being damaged or give inaccurate readings. This is important to consider when evaluating the pressure available from the main line and the pressure requirements of the building or application.

Sizing range: Sizing range refers to the range of line sizes available for a type of meter. This dimension refers to the internal diameter of the tube. It is important to be aware of this, as installing the correct meter may involve adapters to reduce the line size.

Standard meter: An electromechanical or solid-state meter or phase controller that cumulatively measures and records aggregated usage data that are periodically retrieved for use in customer billing or energy management. A meter that is not an advanced meter is considered a standard meter under this guidance.

Turndown ratio (TDR): TDR compares a meters highest rated flow to its lowest rated flow. This ratio is specific to individual meters and the ranges provided by the manufacturer. It is useful when evaluating system requirements and meter capabilities, as some meters have flow ranges that make them better suited for specific use patterns. TDR tends to decrease in smaller sized lines and increase in larger sized line.

Water-intensive buildings: Buildings with high water-using equipment such as chiller plants, steam plants, industrial buildings, manufacturing machinery and buildings, data centers, lodging, food service, food sales, recreation centers, vehicle wash stations, inpatient health care and hospitals, prisons, vehicle care, laboratories, and irrigation pump houses.

Water Use Intensity (WUI): A metric that normalizes water use by the total floor area of a building. WUI can be used to directly compare rates of water use across buildings of different sizes.

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