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CHAPTER 13: WATER METERS

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CHAPTER 13: WATER METERS

13.1 Introduction

Water meter is an instrument for measurement of quantity of water delivered to a consumer and also can serve the purpose of monitoring the efficiency of water distribution system. The water meters are the final link between a consumer and the water authority to ensure equitable distribution of water and financial sustainability of the project. A water supply project is designed for a period of 30 years. It is important to have a metering system to match the project life. Water meter plays an important role in transforming an intermittent water distribution system to 24X7 water supply system to implement 'Drink from Tap' initiative. 100% metering is required for demand management, water conservation and financial sustainability through cost recovery. Without 100% metering 24X7 water supply system may not be possible.

Water meters can be classified as Water meter or Flow meter. A water meter measures the volume (quantity) of water that passes through the meter and a flow meter measures the rate of flow at which the water passes through the meter. But with technological advancement, this distinction is getting inexistent more and more. Now with proper accessories and attachments, rate of flow can be measured with the water meter and quantity of flow can be assessed with flow meter as well.

The flow meters are installed at the crucial points of the water supply system such as Source, WTP, Transmission mains, Feeder mains, Inlet to Service Reservoirs, Entry point to DMAs etc. Water meters are installed at the consumer end for the purpose of measuring the quantity of water delivered to the consumer and billing for the same

At present it is observed that the most of the consumer water meters are not functional at majority of the local bodies. The main causes for the present status may include:

- Though water meters are installed at the consumer connections, the local bodies do not have manpower for meter reading. Consequently, the local bodies continue with fixed rate billing system and the meters are not read. (*One Instrumentation Engineering Corollary: Any instrument will continue to work only if someone looks at it at regular interval*).
- In many cities/towns due to lack of manpower/funds, casual untrained labourers or other local body staff are deployed for meter reading. This results in erroneous reading and billing discrepancies.
- Procurement of water meter by the consumer at his own cost results in procurement of cheapest water meter available in the market. Mostly 'Class A Single Jet Mechanical water meter'. These meters have poor accuracy and very short life. Very often these meters fail within a few months of installation.
- Fluctuations in pressure and flow under the present intermittent water supply system causes wear and tear and result in failure of intricate moving parts of these low cost water meters.
- Under the intermittent supply system, initial expulsion of air before beginning of water flow and suction of air after the supply stops, results in over or under

billing.

- Tampering and theft: The meters are susceptible to tampering and fraud. Some customers may attempt to tamper with their water meter or steal water by bypassing the meter.
- Inadequate maintenance: With no single agency responsible for procurement and installation and maintenance of water meters, local facility for testing or repairing of the water meters does not exist in any of the cities/towns. .
- Water utilities can implement regular maintenance and repair programs for water meters, take anti-tampering measures to prevent theft and misuse of water, and use modern and accurate metering technology. Additionally, efforts can be made to raise awareness among customers about the importance of paying for their water usage and the negative consequences of tampering with meters.

The challenge of regular maintenance and ensuring good quality meters can be overcome by adopting policy of procuring and maintaining the meters by water utility. The cost may either be included in the project cost or recovered from the consumer. In the second case, the consumers will have a sense of ownership on the meters and will try to maintain the meter and meter boxes. By this it is possible to ensure that the water meters' function throughout project life. Metering policy as discussed in Part A Chapter 2 to be referred

Management of water resources in a system is a function of the measurement of quantity of water at source and its effective usage. They are indispensable for understanding the quantity of water being distributed in a system and its usage. Flow meters are used to measure the quantity of water entering into water supply systems, from different sources such as water works, water treatment plants, or bulk water suppliers. Water meters are used to measure the quantity of water that is delivered to each metered consumer in the system.

Metering helps to assess accurately the water produced and distributed and strike a water balance. An adequately metered DMA based water distribution system will result in identification of water losses through leaks or unauthorised /illegal connections.

The data obtained from an upright metering system also allows water managers to make a decision matrix on capital investments, maintenance, staffing, and various other aspects of the water supply systems. Therefore, water metering is an excellent application of the principle "to measure, is to know". The knowledge of how much water is being used in the water distribution system is the key element in controlling the water loss and revenue loss thereof.

The water tariffs based on the quantity of consumption can be used for increasing the income of water supply agency, cross-subsidizing needy consumers, and managing water consumption. A tariff policy cannot be implemented without a well-established metering system. It is very essential in water supply system for installing a metering system in the cities/ULBs.

Water meter and flow meters consist of four basic components: (i) a sensor to detect the flow, (ii) a transducer to transmit the flow signal, (iii) a counter to keep track of the total volume of water passed, and (iv) an indicator to display the meter reading.

The following points indicate that how water meter is different from flow meter:

(i) It is a quantity meter and not a rate of flow meter;
(ii) Water meter is always specified in two accuracies i.e. lower range and upper range whereas a flow meter is specified in a single range accuracy;
(iii) The upper range and lower range accuracies are 2% and 5% of the actual quantity, respectively for the water meter whereas it is variable for flow meter i.e. ± 0.5% and ±5% as per the customer’s requirement; and
(iv) Importance is not given for repeatability and linearity in the case of water meter whereas importance is given in the case of flow meter because the accuracy of flow meter performance is related to linearity and repeatability.

13.2 Sizing of Water Meters

The nominal sizes of domestic water meters vary from 15 mm to 50 mm as per {IS 779: 1994 (Reaffirmed 2015)} and bulk water meter is 50 mm & above as per {IS 2373: 1981 (Reaffirmed 2017)}. Sizing of water meter is done keeping in view the guidelines given in Indian standard {IS 2401: 1973} and {ISO 4064 Part-II: 2014}.

In general, main considerations are as follows:

(i) Water meter should be selected according to the rate of flow and need not match the size of water main;
(ii) The maximum flow should not exceed the rated maximum; of the selected meter size.
(iii) The nominal flow should be closer to the nominal flow rating;
(iv) The minimum flow measured should be within the minimum starting flow of the meter;
(v) Low head loss, long operating flow range, less bulky and robust meter should be preferred.

13.3 Classification of Water Meters

13.3.1 Water meters are classified based on the purpose for which they are used.

a. Water meter: Measuring quantity of water for billing

b. Flow meter: Measuring rate of flow and quantity of water for monitoring and management of water supply system.

13.3.2 Water meters are classified based on the measuring technology used, most common ones are

(a) Mechanical
  (i) Single jet
  (ii) Multi jet
  (iii) Woltman

- (b) Electromagnetic
  - (i) Full bore
  - (ii) Insertion
- (c) Ultrasonic
  - (i) Clamp on
  - (ii) Insertion
  - (iii) Full bore

All the above classes of meters can also be classified based on the meter reading method used as:

(a) *Manual*
Meters manually read by the meter reader onsite and recorded

(b) *Automatic Meter Reading (AMR)*
Meter read and recorded by electronic devices carried by a meter reader walking / driving along the route at fixed intervals

(c) *Advanced Metering Infrastructure (AMI)*
Automatic transmission of the meter data to the centralised data centre at pre-determined intervals with no human intervention

The most prominent and widely used flow meter for bulk flow measurement is the full bore, inline electromagnetic flow meter. Traditionally, for household connections mechanical Class B Multi jet meters were used, however, with advancements in technology progressive water boards are opting for AMR water meters, especially for high consumption customers. Due to the various advantages, they offer like reduction of cycle time for billing and better customer service. Water flow meters are broadly classified into (i) Bulk flow and (ii) Domestic meters based on usage, as shown in Figure 13.1.

Figure 13.1: Classification of Water Flow Meter based on consumer category

Water meters can also be classified based on Metrological Characteristics as given in ISO 4064-3 Standard. The water meter metering classification is divided according to the water meter transitional flow rate (Q2) and the minimum flow rate (Q1), which indicates the sensitivity of the water meter as shown in Table 13.1 below. The old regulations are classified according to Class A water meter, Class B water meter, Class C water meter, and Class D water meter, and Class D is the highest level {RS Components, Northants, (2003)}. The Water meter Classification- According to ISO 4064-3 Standard is shown in Table 13.2 below.

At present, Class A water meter has to be withdrawn from the mainstream market, and use of Class B water meter is to be encouraged. The Class C water meter has high measurement accuracy and ability to read at low flow; but is too costly and not readily available in Indian Markets. There are limited manufacturers of Class C meters in India and are mostly imported. Class D water meters are meant for process industries.

Table 13.1: Water meter Classification- According to ISO 4064-3 Standard

Size		Ratio	Q_4 Overload flow	Q_3 Nominal Flow	Q_2 transitional flow	Q_1 Min flow	Min reading	Max reading
DN(mm)	Inch		m^3/hr		L/h		m^3	
15	1/2"	80	3.125	2.5	50.000	31.250	0.001	999999
		160			25.000	15.625		
		250			16.000	10.000		
		400			10.000	6.250		
		500			8.000	5.000		
		630			6.35	3.968		
		800			5.000	3.125		
20	3/4"	80	5.00	4.00	80.000	50.000	0.001	999999
		160			40.000	25.000		
		250			25.600	16.000		
		400			16.000	10.000		
		500			12.800	8.000		
		630			10.16	6.349		
		800			8.000	5.000		
25	1"	80	7.875	6.3	126.000	78.750	0.001	999999
		160			63.000	39.375		
		250			40.320	25.200		
		400			25.200	15.750		
		500			20.160	12.600		
		630			16.00	10.000		
		800			12.600	7.875		
32	1 1/4"	80	12.5	10	200.000	125.000	0.001	999999
		160			100.000	62.500		
		250			64.000	40.000		
		400			40.000	25.000		
		500			32.000	20.000		
		630			25.40	15.873		
		800			20.000	12.500		
40	1 1/2"	80	20	16	320.000	200.000	0.001	999999
		160			160.000	100.000		
		250			102.400	64.000		
		400			64.000	40.000		
		500			51.200	32.000		
		630			40.63	25.397		
		800			32.000	20.000		
50	2"	80	25	20	400.000	250.000	0.001	999999
		160			200.000	125.000		
		250			128.000	80.000		
		400			80.000	50.000		
		500			64.000	40.000		
		630			50.79	31.746		
		800			40.000	25.000		

Q1- lowest flow rate; Q2-transitional flow rate; Q3- permanent flow or nominal flow rate; Q4- highest flow rate

13.4 Detailed Description of Meters and Applications

Mechanical meters have moving parts that detect the flow, such as a piston or impeller. They make up the vast majority of meters used in water distribution systems specially to measure consumption and billing purpose at the domestic level. Electromagnetic and ultrasonic meters have no moving parts but detect the flow through the meter using electromagnetic waves and ultrasound waves, respectively.

Mechanical water meter like the single jet, multi-jet, piston type, and electromagnetic and ultrasonic meters are used for domestic purposes. The preferred diameter size for domestic metering is 15 mm to 40 mm depending on the rate of flow to the consumer. Bulk water meters are used to measure high water consumption for billing /water audit purposes by bulk consumers like commercial complexes, industries, etc. Generally, Woltman water meters (mechanical type), electromagnetic and ultrasonic water meter are used for system flow measurement. .. Sub-classification of different meters are shown in Figure 13.2 as under:

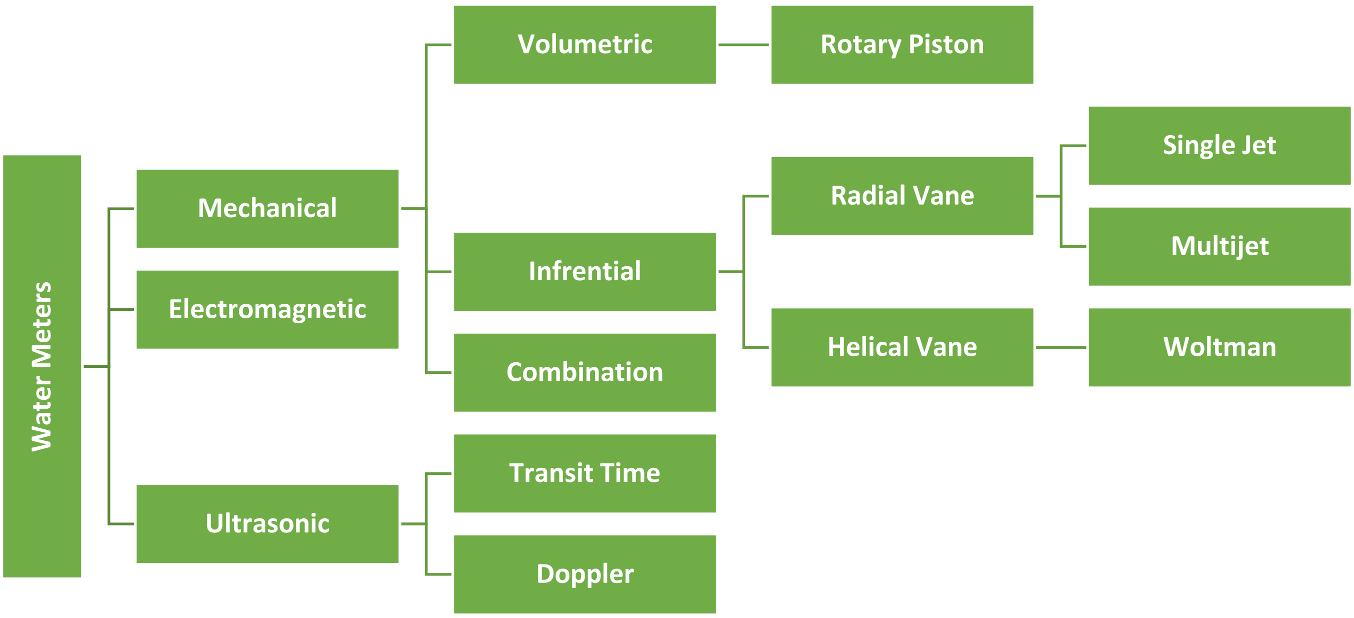


Figure 13.2: Sub-classification of different meters

Comparison of Mechanical, Electromagnetic and Ultrasonic Meters are given in Table 13.2 below.

The Electromagnetic meters are two types – Full bore and Insertion;

- The full bore electromagnetic meters are sturdy, more accurate; but are costly. It is difficult to install a full bore electromagnetic flow meter in a functioning live water main.
- The insertion type electromagnetic flowmeter is easy to install in a functioning live water main and are comparatively less costly. But they are susceptible for tampering and are less accurate.

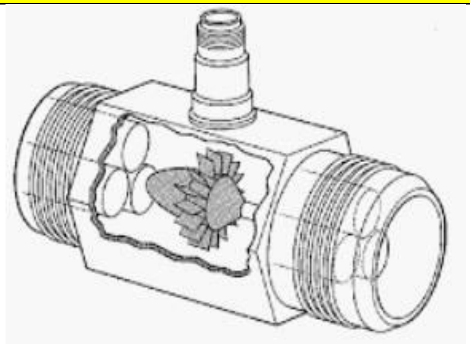
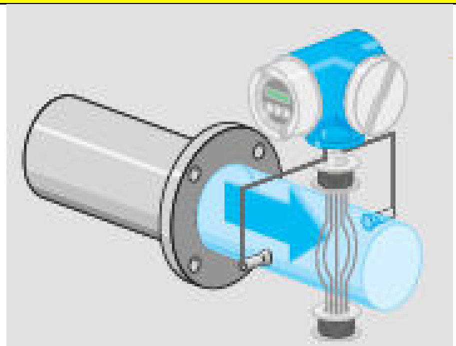
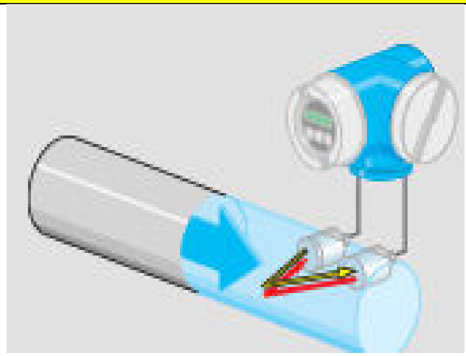
The Ultrasonic meters have three types - Clamp on, full bore and insertion.

- Clamp on ultrasonic flow meters are portable and used for temporary flow measurement in an existing water supply system and also for rough assessment of the functioning of other fixed flow meters. They are less accurate ad low repeatability.
- Full bore ultrasonic flow meters are sturdy, more accurate; but are costly. It is difficult to install a full bore flowmeter in a functioning live water supply system.
- Insertion type ultrasonic flow meters are more common and used in large diameter water mains as they are less costly than any other flow meter.

Table 13.2: Comparison of Mechanical, Electromagnetic and Ultrasonic Meters

S.No.	Attributes	Mechanical meters	Electromagnetic meters	Ultrasonic meters
1.	**Working principle**	Paddle Wheel, Turbine or mechanical with moving counter	Electromagnetic induction principle Faraday's Law measurement	Ultrasonic Measurement principle Time of Flight measurement
2.	**Build**	(i) Moving parts are present (ii) Mechanically & Magnetically coupled meter (iii) Dry/ Wet Dial meter	(i) No moving parts (ii) Sensor in-built (iii) Dry Dial meter (iv) Can be inline type threaded/ flanged end. (v) Insertion type is also available	(i) No moving parts. (ii) Sensor in-built (iii) Dry Dial meter (iv) Can be inline type threaded/ flanged end. (v) Insertion type is also available (vi) Clamp on type can be used as portable meters
3.	**Available sizes**	15mm – 500mm	15mm - 3000mm	15mm - 4000mm
4.	**Application**	Domestic meter: 15mm to 40mm Bulk meter (Woltman): 50mm to 500mm or more	Domestic meter: 15mm to 40mm Bulk meter: 50 mm to 3000 mm or more	Domestic meter: 15mm to 40mm Bulk meter: 50 mm to 4000 mm or more
5.	**Standards**	ISO 4064 / IS 2373/ IS 779	ISO 4064 and OIML R49	ISO 4064 and OIML R49
6.	**Water quality**	Suitable for potable water. Highly critical with suspended particles as it clogs the moving parts.	Suitable for potable water. No impact of particles.	Suitable for potable water. Highly critical with suspended impurity & turbidity as it deposits on the sensor face.
7.	**Accuracy**	Better than +/- 2% for Upper flow range and +/- 5% for lower flow range	Better than +/- 2% for Upper flow range and +/- 5% for lower flow range	Better than +/- 2% for Upper flow range and +/- 5% for lower flow range
8.	**Installation orientation**	Good performance under horizontal installation..	Good performance under horizontal, Vertical and inclined installation.	Good performance under horizontal, Vertical and inclined installation.
9.	**Periodic maintenance**	Very high as it has a lot of moving parts and wear & tear is a regular issue. There is no indication of wear and tear as no warning available other than the high-pressure drop.	Less and the expected life of the meter is a minimum of 10 years. Hence the cost of ownership is very less.	Less and the expected life of the meter is a minimum of 10 years. Hence the cost of ownership is very less.
10.	**IP-68 Sensor availability**	Available but a lot of failure due to moving parts	Yes	Yes
11.	**Operating**	Poor	Good	Good

S.No.	Attributes	Mechanical meters	Electromagnetic meters	Ultrasonic meters
	accuracy at low flow			
12.	**Cost**	Low initial cost but the high cost of maintenance due to moving parts and more frequent replacements like jamming of rotating wheels, counters, etc.	Cost increases with diameter in case of full bore option. Cost of Insertion type option are moderate.	Moderate.
13.	**Advantages**	(i) Suitable for higher flows (ii) Can sustain hostile flow conditions (iii) External & internal regulator facilitates easy calibration (iv) Robust construction (v) Easy local Maintenance. (vi) With proper attachment (Pulse units) can be used for Automatic meter reading or SCADA applications. (vii) Life of meter is low – less than five years.	(i) Suitable for wide range of flows (very low to high flows) (ii) Less sensitive to flow disturbances. (iii) Ready for Automatic Meter reading for water SCADA compliant (iv) Do not measure the air in the pipe (v) Can be installed in any Orientation. (vi) Life of meter 10 to 15 yrs. (vii) Low Maintenance required (viii) U0D0 – Meter works accurately with zero upstream and downstream length for installation	(i) Suitable for wide range of flows (low to high flows) (ii) Less sensitive to flow disturbances. (iii) Ready for Automatic Meter reading for water SCADA compliant (iv) Do not measure the air in the pipe (v) Can be installed in any Orientation. (vi) Life of meter 10 to 15 yrs. (vii) Low Maintenance required. (viii) U0D0 – Meter works accurately with zero upstream and downstream length for installation
14.	**Disadvantages**	(i) Less sensitive to low flow (ii) Approach conditioning piping is required (iii) Limited to higher flows. (iv) Bush leak problems (v) Meter measures air. (vi) Brass body meter – prone to theft (vii) A strainer or dirt box has to be provided upstream of the water meter.	(i) Costlier than mechanical meters (ii) Water must be free from solid dirt particles	(i) Costlier than mechanical meters (ii) Water must be free from solid dirt particles. (iii) Ultrasonic sensors need to be cleaned periodically.

S.No.	Attributes	Mechanical meters	Electromagnetic meters	Ultrasonic meters
15.	**Representation**			

13.5 Mechanical Meters

Mechanical meters are further classified in three categories i.e. volumetric, inferential, and combination meters.

13.5.1 Volumetric Meters

Volumetric meters directly measure the volume of flow passing through them. Most volumetric meters use a rotating disk to measure the flow and are known as rotating piston meters. For application of volumetric meters, the TDS level in water should be lower than 200 ppm.

13.5.1.1 Rotary Piston Meters

Rotary piston meters are positive displacement meters that use a rotating cylindrical piston to measure 'packets' of water moving from the inlet to the outlet of the meter.

Figure 13.3: Rotary Piston Meters

Positive displacement meters are popular for their accuracy, long life, and moderate cost and are used for most domestic applications. Rotating piston meters are sensitive to sand and/or other suspended solids in the water that get clogged between the piston and chamber wall, thereby clogged the meter. These meters are also sensitive to low flows and are particularly suitable for applications where the water flow rates are low or where frequent on-site leakage occurs. Rotary Piston Meter is shown in Figure 13.3.

The main disadvantages of rotating piston meters are:

(i) being sensitive to suspended solids in the water;
(ii) prone to relatively high-pressure losses; and
(iii) bulky and expensive than other meter types

13.5.2 Inferential Meters

Inferential meters do not measure the volume of water passing through them directly but infer the volumetric flow rate from the velocity of the water.

Two categories of inferential meters commonly used are:

(i) Meters using a radial vane impeller and
(ii) Meters using a helical vane impeller

Radial vane impeller meters are further classified into a single jet and multi-jet meters. Helical vane impeller meters are also called Woltman meters and use a propeller-like vane to increase the water velocity. Multi-jet meters are widely accepted in countries such as Brazil, Malaysia, Indonesia, India, Vietnam, etc., where the water supply system is intermittent.

13.5.2.1 Single Jet Mechanical Water Meters

Single jet mechanical meters are inferential meters consisting of an impeller with radial vanes (also called a fan wheel) and use a single flow stream or jet to move the sensor. The rotational speed of the impeller is converted into a flow rate, which is registered on the meter. It is critical to precisely control the path of water through the single jet meter to obtain accurate readings. Thus, the inside portion of the single jet meter has to be manufactured to strict tolerances. The meters are prone to fail due to clogging by floating threads, yarns etc in water. Single jet water meter and its cross-sectional view is shown below in Figure 13.4.

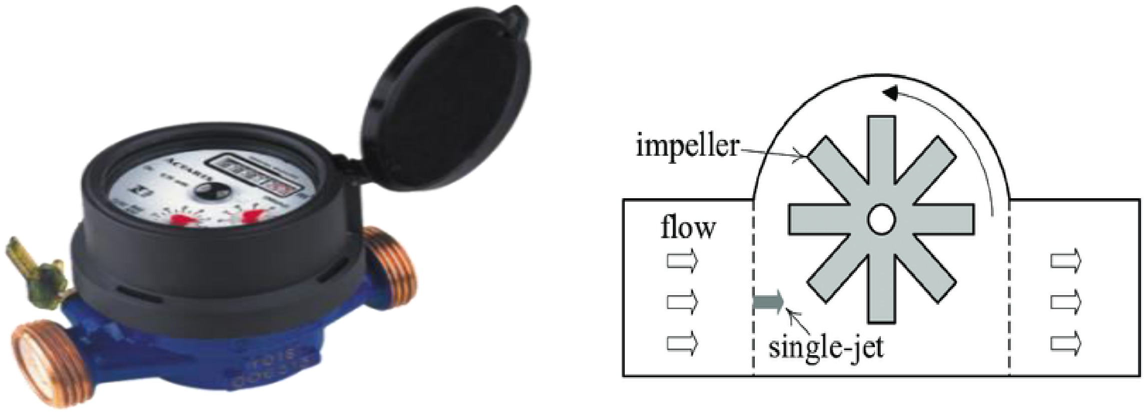


Figure 13.4: Single jet water meter and its cross-sectional view

The accuracy of single jet meters reduces due to wear in the moving parts with continuous usage over a period of time. In particular, the starting flow and accuracy of metering at low flow rates may deteriorate, and thus older meters tend to under-register at low flow rates. At higher flow rates, the error can be positive or negative and may be exacerbated by sediments or deposits accumulating inside the meter. Air moving through the meter will also be registered as water, and thus can lead to over-register of water flow. Traditionally the metering chamber is made out of brass, but plastics are also becoming popular. The composite body (engineered plastics) for water meters makes it economical. Brass chambers make the single jet meter expensive, especially in larger diameters. Single jet meters are thus mostly used in the size range of 15 mm to 40 mm.

Advantages of brass chambers for water meters:

(i) Steady water meter;
(ii) Protects the register can inside;
(iii) No health hazards;
(iv) Scrapped and re-use;
(v) End connection installation.

Disadvantages of brass chambers for water meters:

(i) Makes water meter heavier;
(ii) Increase the cost of manufacturing by 5-6%;
(iii) Prone to theft, due to the high value of scrap;
(iv) Drift in accuracy over the period of time;
(v) Installation restriction horizontal position only.

13.5.2.2 Multi-jet Mechanical Water Meters

Multi-jet Mechanical Water meters are inferential water meters that use an impeller with radial vanes. The operation of multi-jet meters is similar to that of single jet meters, except that multi-jet meters use several jets to drive the impeller at multiple points. This implies that the forces applied on the impeller are better balanced than in single jet meters, thereby reducing wear on the moving parts and provides greater durability.

They are similar in construction to that of single jet meters although multi-jet meters tend to be slightly larger in overall size. Multi-jet meters are fitted with removable strainers on the inlet side of the meter, to facilitate the cleaning of the same. A second internal strainer often covers the openings of the metering chamber. The internal strainer, if clogged, can affect the accuracy of the meter, thereby causing over-registration of the flow. Multi jet water meter and its cross sectional view is shown in Figure 13.5.

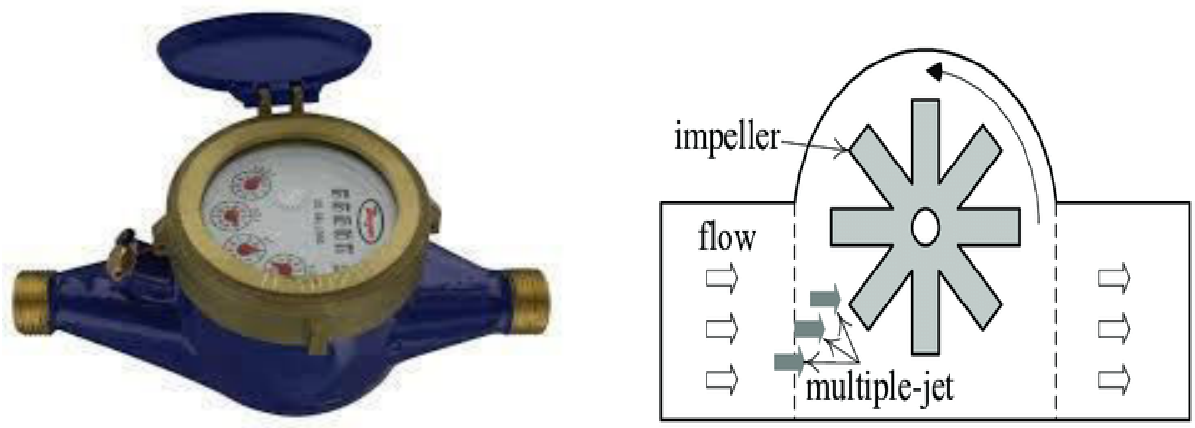


Figure 13.5: Multi jet water meter and its cross-sectional view

They normally use an internal bypass with a regulating screw to adjust the flow passing through the impeller. This allows the manufacturer to adjust the meter's error curve to achieve the best accuracy before sealing the meter to prevent meter tampering. Traditionally the metering chamber is made out of brass, but plastics are also becoming popular. The composite body (engineered plastics) for water meters makes it economical

Multi-jet meters use reliable and tested metering technology and normally have long working lives due to the balanced forces on the impeller. They are not sensitive to the velocity profile in the pipe and are tolerant of small suspended solids in the water.

The disadvantages of multi-jet meters are:

(i) Sensitivity to the installation position, thereby affecting accuracy;
(ii) Often bulkier than single jet meters;
(iii) Not being sensitive to low flow rates;
(iv) Starting flow rate can deteriorate significantly with time;
(v) Accuracy may be significantly affected by clogs in jet openings if any;
(vi) A brass body prone to theft, due to the high value of scrap;
(vii) Meter life 3-4 years.

13.5.2.3 Woltman Meter

The Woltman meter is an inferential meter that uses an impeller with helical vanes, which resembles a fan or boat's propeller. As water flows over the helical vanes, it causes the impeller to rotate, and the rotation is then transmitted to the dial via reduction gearing.

There are two different types of Woltman meters, Horizontal turbine and Vertical turbine. Horizontal Woltman meters have their inlets and outlets directly in line with the pipeline, and the axle of the helical vane is parallel to the flow. Water flows directly through the meter with minimal disturbances by the meter body. Horizontal Woltman meters are used in a large range of pipe sizes, typically having a diameter between 40 mm and 600 mm. Vertical Woltman water meter is designed for industrial and irrigation applications in sizes 50mm and 200mm for the cold meter. Both Vertical turbine and Horizontal turbine are shown in the Figure 13.6 and Figure 13.7 respectively.

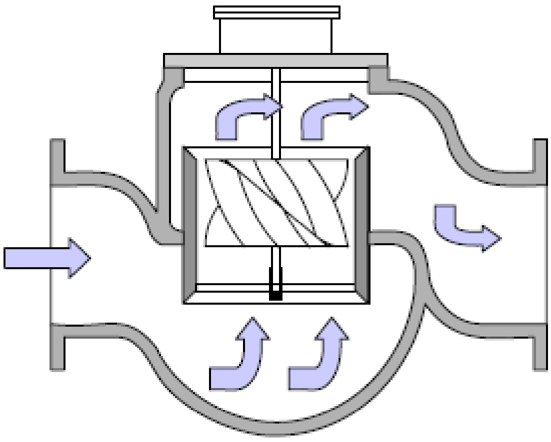


Figure 13.6: Vertical Turbine

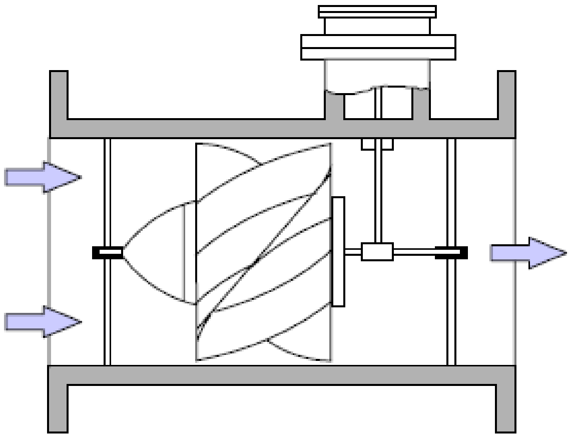


Figure 13.7: Horizontal Turbine

Woltman meters are affected by flow distortions or changes in meter dimensions that may interfere with the way water passes through the meter. The meters prone to be affected by floating materials such as yarn, roots etc. Deposits in the meter can cause over-registration at medium flows and under-registration at low flows.

Figure 13.8: Woltman Meter

All Woltman meters have dry, sealed dials. The easy passage of water through Horizontal Woltman meters reduces pressure loss through the meter. However, since the transducer needs to turn the circular movement of the impeller through 90 degrees to connect it to the counter, greater torque is required, which reduces the meter's sensitivity to low flows. Another limitation of Woltman meters is that they are sensitive to disturbances in the flow passing through them. Bends or valves close to a Horizontal Woltman meter can affect the meter's accuracy. Spiralling flow, caused by two successive bends in different planes, is particularly unfavourable for their accuracy. Woltman meter is shown in Figure 13.8.

13.5.3 Combination Meters

They do not use a specific mechanism to measure the flow but are made up of two meters of different diameters that are combined to measure a wide range of flow.

Figure 13.9: Combination Meter

They are generally used to measure high flow rates with extremely widespread flow profiles and also to measure very small flow rates for leakage detection and are ideal for fire service pipes. Combination Meter is shown in Figure 13.9.

13.6 Electromagnetic Water Meters

Electromagnetic or Magflow water meters' function on the principle of electromagnetism, called Faraday's Induction Law, to measure the velocity of the water passing through it. In an electromagnetic meter, a magnetic field is created across the pipe. When water, which is an electrical conductor, moves through the magnetic field, a voltage is induced which is detected by electrodes in the body of the meter. The voltage is directly proportional to the flow velocity, which allows the flow rate to be calculated. Domestic Electromagnetic meter DN15 to DN40 is shown in Figure 13.10 and Bulk Electromagnetic meter DN50 to DN300 is shown in Figure 13.11. They are available in two models – a. Full bore and b. Insertion type. Insertion type can be used in retrofitting existing large diameter pipelines

Figure 13.10: Domestic Electromagnetic meter DN15 to DN40

Figure 13.11: Bulk Electromagnetic meter DN50 to DN300

The voltage is measured by two electrodes placed at right angles to the magnetic field. The sensor measurement is transmitted via an electric signal to an electronic counter, which converts the velocity readings to volume. The volume of consumption and/or flow rate is normally displayed on an LCD screen, but can also be obtained as an electronic signal to a telemetry system or flow logger.

Electromagnetic meters are accurate within their measuring range. Electromagnetic flow meters are generally accurate in the range from 0.3m/s to 10m/s and their accuracies are normally stated as a sum of the percentage of the reading and percentage of the full-scale value. Most electromagnetic flow meters are configured for a fixed flow velocity range, typically from 0.5 m/s to 10 m/s. These meter is only able to measure flow in the defined velocity range, and thus it is important to select the correct meter for a given situation. Typical accuracy values range from 0.5% to 0.1% but decrease at low flow rates. Electromagnetic Water Meters accuracy is defined as +/- 5% for lower operating flow range and +/- 2% for upper operating flow range (as per ISO 4064 Standard).

Advantages of electromagnetic meters are as follows:

(i) No obstruction to flow;
(ii) No pressure loss;
(iii) No moving parts subject to wear, therefore there is hardly any maintenance
(iv) Highly accurate and immune to variations in fluid density, pressure, viscosity, or temperature;
(v) Measures only water, no air;
(vi) No drift in accuracy over the product life;
(vii) Composite body, not prone to theft;
(viii) Very good low flow; and

(ix) Meter life more than 10 years R800 metrology Class D meters.

(x) No need for strainers or dirt- boxes.

13.7 . The Electromagnetic Domestic meters operates on battery and battery life is minimum 10 years.Ultrasonic Water Meters

Ultrasonic flow meters utilize the properties and behaviour of sound waves passing through moving water. The ultrasonic meters are of two types depending on different working mechanisms viz, Transit time meters and Doppler meters. The ultrasonic meters are also available as clamp-on, insertion type and inline type.

13.7.1 Transit Time Ultrasonic Flow Meters

Transit time ultrasonic flow meters are based on the phenomenon that sound waves slow down when moving through the water against the flow, and speed up when they move with the flow. A transit time ultrasonic meter has two sound transducers mounted at opposite sides of the pipe at an angle to the flow. Each of these sound transducers will in turn transmit an ultrasound signal to the other transducer. The differences in the transit times of the signals determine the flow velocity and flow rate. Domestic Ultrasonic Meter DN15 to DN40 is shown in Figure 13.12 and Bulk Ultrasonic Meter DN50 to DN300 is shown in Figure 13.13.

Figure 13.12: Domestic Ultrasonic Meter DN15 to DN40

Figure 13.13: Bulk Ultrasonic Meter DN50 to DN300

The accuracy of the transit time ultrasonic meters depends on the ability of the meter to accurately measure the time taken by the ultrasound signal to travel between the sound transducers. Larger pipes have longer path lengths and thus the speed of the signal, and the flow rate can be measured with higher accuracy. Transit time meters work better in clean fluids and thus are ideal for drinking water pipes. They measure the average velocity of fluid but are sensitive to the velocity profile in a pipe. In some cases, multi-beam devices are used to improve meter accuracy.

Permanently installed transit time meters are often called wetted transducer meters since their sound transducers are in direct contact with the fluid. These meters are very reliable. Ultrasonic flow meters typically have relative errors between 0.25% and 1%. They can be used on pipes ranging from 10 mm to greater than 2 m in diameter, although they are not often used on small diameter water pipes. The ideal flow velocity range for good accuracy is 0.5 to 10 m/s. Ultrasonic Water Meters accuracy is defined as +/- 5% for lower operating flow range and +/- 2% for upper operating flow range (as per ISO 4064 Standard).

The In-line type meter, IP 68 Protection class is constructed as a vacuum chamber of moulded composite material or suitable metal body. Thus, the electronics are fully protected against penetration of water. Water consumption is measured electronically, as a volume, using the ultrasound signal. Through two ultrasonic transducers, an audio signal is sent with and against the flow direction. The ultrasonic signal traveling with the flow will be the first to reach the opposite transducer, while the signal running against the flow will be received a little later. The time difference, between the two signals, can be converted into flow velocity, and thereby also into a volume. The measuring principle is called 'bidirectional ultrasound technique based on the transit time method', which is a proven, long-term stable and accurate measuring principle.

Clamp-on transit time meters use sound transducers that are clamped externally onto the walls of a pipe to provide portable non-intrusive flow measurement. Practically, they can be used on any pipe material including metals, plastics, fibre, cement and lined or coated pipes. A disadvantage of Ultrasonic flow meter is that the ultrasonic pulses must traverse pipe walls and coatings, and therefore the thicknesses and acoustic properties of these elements must be known. Deposits on the inside pipe surface can affect signal strength and performance. Disadvantage of Ultrasonic Water Meters is that air in the liquid, turbulence, deposits on the sensors and water hammer (pressure transients) affects the performance. Besides, the ultrasonic water meters operate on battery and battery life is minimum of 10 .

Modern clamp-on meters incorporate microprocessors that allow mounting positions and calibration factors to be calculated for each application and can provide accuracies of 0.5 % to 2 %. The advantages of transit time flow meters include high accuracy and reliability, which makes them cost-effective for use in large pipes. The clamp-on version of the meter is easy to install without the need to shut down the pipe. However, transit time flow meters are sensitive to distortions in the velocity profile of a pipe, require an electricity supply, and are not suitable for dirty waters.

13.7.2 Doppler Ultrasonic Flowmeters

Doppler ultrasonic water meters’ function based on the Doppler Effect, which is the measure of the change in the frequency of a sound wave when it is reflected back from a moving object. Doppler ultrasonic flowmeters create a soundwave in a moving fluid, which upon contact with dirt particles or air bubbles, reflects back towards the origin of the signal. The reflected ultrasound waves are detected by a receiver, and the change in the wave frequency is measured. This shift can then be related to the velocity and thus flow rate of the water. Doppler Ultrasonic Flowmeters is shown in Figure 13.14.

They can only be used for water that contains particles or air bubbles, and thus they are more suitable for dirty water applications such as raw water. A drawback of Doppler meter is that fluid particles in the water sometimes move slower than the water itself, or are concentrated in parts of the pipe with lower velocities (e.g. close to the sides or bottom of the pipe), which can result in a measurement error of 10% or more. They are also sensitive to disturbances in the velocity profile and require an electrical supply. While they are not suitable as billing meters, they can be cost-effective as flow monitors if measurement accuracy is not critical.

Figure 13.14: Doppler Ultrasonic Flow meter

13.7.3 Sensor Based Flow Meter

Remote flow meter, for use on gravity fed and pressurized piped water systems, is designed to monitor functionality and performances of water supply networks. The pipe flow meter utilizes the Ultrasonic flow meter, microprocessor, and a body trace chip to monitor water usage on piped systems. The sensor has a plastic enclosure waterproof, anti-explosion, heat and cold resistant and utilizes food-compliant plastic.

After installation on the water pipe, when the water tap is opened, the flow of water passing through the sensor results in the rotation of the internal turbine. The energy of the fluid passing through it moves a rotor that have magnets on his blades; the volume of the water is registered by monitoring the speed of the rotation of the magnets passing by a metal point. This information is then transformed in digital data by the microprocessor, and the data sent by the sim card embedded in the sensor. The sensor transmits hourly flow data that can be uploaded on cloud platforms. Dashboards have to be designed according to the user needs. This is an advance technology and may be applied in water supply systems.

13.8 Installation & Testing of Water Meters

13.8.1 Installation of Water Meters

In order to ensure proper working of the meters, BIS has given guidelines in IS-2401:1973 and ISO 4064:2014 Part 5 for their installation as per the drawing given in it. At the same time following guidelines should be borne in mind while installing the meters.

(i) The water meter being a delicate instrument shall be handled with great care. Rough handling including jerks or fall is likely to damage it and affects its accuracy;

(ii) The meter shall be installed at a spot where it is readily accessible. To avoid damages and overrun of the meter due to intermittent water supply system, it is always advisable to install the meter, such that the top of the meter is below the level of the communication pipes so that meter always contains water, even when during non-supply hours. Also, the minimum straight length condition as per the manufacturer's specification shall be followed;

(iii) The meter shall preferably be housed in a chamber with the lid for protection; it should never be buried underground nor installed in the open nor under a water tap so that water may not directly fall on the meter. It should be installed inside inspection pits, built out of bricks or concrete, and covered with the lid. It should not be suspended;

(iv) The meter shall be installed so that the longitudinal axis is horizontal and the flow of water should be in the direction shown by the arrow cast on the body;

(v) Before connecting the meter to the water pipe, it should be thoroughly cleaned by installing in the place of the water meter a pipe of suitable length and diameter and letting the passage of a fair amount of water flow through the pipework to avoid the formation of air pockets. It is advisable that the level of the pipeline where the meter is proposed to be installed should be checked by a spirit level;

(vi) Before fitting the meter to the pipeline check the unions nuts in the tail pieces and then insert the washers. Thereafter screw the tail pieces on the pipes and install the meter in between the nuts by screwing. To avoid its tilting during operation, the meter should be kept fixed with suitable non-metallic clamps. Care should be taken that the washer does not obstruct the inlet and outlet flow of water;

(vii) The protective lid should normally be kept closed and should be opened only for reading the dial;

(viii) The meter shall not run with free discharge to the atmosphere. Some resistance should be given in the downside of the meter if static pressure on the main exceeds 10 m head;

(ix) A meter shall be located where it is not liable to get the severe shock of water hammer which might break the system of the meter;

(x) Owing to the fine clearance in the working parts of the meters they are not suitable for measuring water containing sand or similar foreign matter and in such cases a filter or dirt box of the adequate effective area shall be fitted on the upstream side of the meter. It should be noted that the normal strainer fitted inside a meter is not a filter and does not prevent the entry of small particles, such as sand;

(xi) Where intermittent supply is likely to be encountered the meter may be provided with a suitable air valve before the meter in order to reduce inaccuracy and to protect the meter from being damaged. At higher altitude, if the meter is installed as above, the problem will be eliminated;

(xii) Every user expects a problem-free installation of the meter and thereafter only accurate reading. Regular monitoring is desirable in order to avoid failures;

(xiii) The meter is installed in the pipeline using flanged or threaded connections giving due consideration for conditioning sections. It should be seen that stress-free installation is carried out in the pipeline;

(xiv) It is essential to install the flowmeter co-axially to the pipeline without protruding any packing or gasket into the water flow stream. In the case of ultrasonic flow meter, the probes are welded on the pipeline which requires care to see that no projection is protruding in the pipeline;

(xv) Installation in 'U' shape is essential for intermittent water supply;

(xvi) Flow meters should be provided with battery backup in order to retain integrator reading during the failure of electric supply.

13.8.2 Testing and Calibration of Water Meters

The testing & calibration of a water meter is essential before putting it into use as it is a statutory requirement. It is also essential to test it periodically in order to ascertain its performance as during the course of meter working it is likely that its accuracy of measurement may deteriorate beyond acceptable limits. Calibration consists of comparing the meter reading with the reading obtained from a standard of higher accuracy than the test meter and with established uncertainty. Calibration is usually done in a laboratory at a variety of flow rates, as well as varied densities and temperatures. The calibration factors of the meter are determined during calibration.

All types of Meters shall be designed, manufactured, and calibrated as per standard ISO/IEC 17025: 2005 (Reaffirmed 2017). Meters shall also have an actual flow rate & totalized value for effective water management purposes. The accuracy shall be ± 0.5% of reading for flow meters. The accuracy of Water meter +/- 5% for lower operating flow range and +/- 2% for upper operating flow range (as per ISO 4064 Standard).

The supplier shall have full ISO 9000 series accreditation and fully traceable calibration methods. The suppliers shall also have a testing facility in India so that methodology and procedures can be verified. Each meter shall be wet calibrated with 2-point calibration to verify performance in accordance with the specification & submit the report for the same. The testing facility shall be duly accredited in accordance with ISO/IEC 17025: 2005 (Reaffirmed 2017) standards. Suppliers must upload/attach the certificate of ISO/IEC 17025 from flow meter manufacturer as a mandatory requirement of this enquiry/tender which is duly accredited according to ISO/IEC 17025: 2005 (Reaffirmed 2017) facilities in India.

The sensors for flow meter shall be as per DVGW / ISO standard lengths (ISO 13359:1998) so that interchangeability can be carried out for the applicable flow meter sizes. The sensor shall also have built-in grounding and empty pipe detection electrodes of SS 316 for detecting partial flow conditions & efficient operation purposes. The liner material shall be Polyurethane (PU) or Hard Rubber suitable for media/ application/ service. The appropriate certificate for drinking water approval shall be a part of it and the same shall be uploaded or attached while bidding as a mandatory requirement of this tender. The sensor & transmitter shall be capable of working in a tropical environment. The meter body shall be available in flanged or with custom connectors as specified in the datasheets.

The sensors shall be rated IP 68. The transmitter shall be rated IP 67 in line with local operating conditions. Installations shall be made with cables and /or conduits that guarantee the integrity of the system under all operational conditions. The transmitter/converter shall be the wall-mounted type with a 2-line display for the indication of an actual flow rate & totalized value. A glass window within the protection enclosure with optical switches shall be provided for local reading purposes. The non-corrosive, polycarbonate housing material of the enclosure shall be sufficient to guarantee five years of operational life. Magnetic flow meters should be supplied with built-in software features to analyse and continuously monitor the health of the sensor, display errors in text format. The transmitter should be capable of performing the verification program on-demand or on request without taking meter off the line or without any additional external hardware/accessories;

The transmitter shall be capable of being fully programmable. It shall have a set-up menu so that all relevant parameters may be user-set from the self-prompting driven menu. The transmitter shall have three (3) totalizer units and shall have one (1) scalable pulse output & one (1) current i.e. 4-20mA HART output. The current output shall be galvanically isolated. It shall be fitted with switched-mode power supply capability 0-250V or 24 DC and 45-65Hz to cope with power transients without damage. The totalizer value shall be protected by Electrically Erasable Programmable Read-only Memory (EEPROM) during a power outage and utilizes an overflow counter.

The transmitter shall be having the facility of indicating electrical conductivity measurement. It shall be possible to separate the sensor and transmitters up to 300 meters without the need for signal boosters or amplifiers. The pulsed DC type flow sensors shall normally be installed remotely from the transmitters and are to be subject to harsh environmental conditions. At some locations, underground chambers shall be used and, in such cases, the operation under fully submerged conditions may occur. Thus, in either case, a full IP68 design is necessary. The sensor shall, therefore, be made from SS 304 materials with flanges of up to PN10 rating from carbon steel as per EN 1092-1, suitably treated for the application. The sensor coil housing shall be powder coated cast aluminium with NEMA 4X rating (IP 68) or painted steel. The paint shall be of durable anti-corrosion grade. The tube liner shall be suitable for media/application/service;

The manufacturer shall have a full system of local offices in India and full- service capability in the metro-cities throughout the country. Full contact details for key personnel, both national and local shall be furnished on request. The supplier shall provide evidence of at least five years of involvement in the manufacturing of meters worldwide. The water flow meter manufacturer /supplier shall provide full data on each meter required, including optimizing and sizing programs calculation sheet. The proposed flow meter model number by the manufacturer shall be available on their official website with a complete technical catalogue or operating manual for flow meter (sensor /transmitter). The official latest meter sizing program shall be available on the official website of the flow meter supplier. The proposed model code shall be available and acceptable globally;

A meter suspected to be malfunctioning is also tested for its accuracy of the measurement. The testing is done as per {IS 6784: 1996 (Reaffirmed 2017)} / {ISO 4064-2014 part III}. A faulty meter, if found to be repairable, is repaired and tested and calibrated for its accuracy before installation. To establish a meter factor, the indicated volume of fluid that passes through a meter is compared to the true volume measured in a container of known size, or a master meter. Temperature and pressure correction are then applied.

The metering accuracy testing is carried out at as per {IS 779: 1994 (Reaffirmed 2015) / {ISO 4064-2014} Q_{min}/Q1, Q_t/Q2 & Q_n/Q3 separately.

Where;

Q_1: Minimum flow rate at which the meter is required to give indication within the maximum permissible error tolerance. It is as mentioned in IS779 and is determined in terms of numerical value of meter designation in case of ISO 4064. Q1 value is derived from the ratio i.e., Q1 = Q3 / ratio.

Q2: The transitional flow rate at which the maximum permissible error of the water meter changes in value. Q2 is 1.6 times of Q1

Q3: Permanent flow rate as mentioned in ISO 4064-2014 for each size of the meter.

Q4: The Overload flow rate at which the meter is required to operate in a satisfactory manner for short periods of time without deterioration. Q4 is 1.25 times of Q3

Dynamic Ratio – Q3 / Q1

The accuracy of water meter is divided into two zones i.e. (i) lower measurable limit in which ±5% accuracy from minimum flow/Q1 to transitional flow/Q2 (exclusive) and (ii) upper measurable limit in which ±2% accuracy from transitional flow/Q2 (inclusive) to maximum flow/Q4.

Procedure for Conducting the Test

Water meter is fixed on a test bench horizontally or vertically or in any other position for which it is designed and with the direction of flow as indicated by the arrow on its body. By adjusting the position of regulating valve on the upstream side, the rate of flow is adjusted. At the desired rate of flow, the difference in pressure gauge readings fitted on the upstream and downstream side of the water meter is noted. The flow is now stopped with regulating valve and the measuring chamber is emptied and zero water levels on the manometer attached to the measuring chamber are correctly adjusted. The initial reading of the water meter from its recording dial is noted. Now the flow at the set rate is passed through the water meter and the discharge is collected in the measuring chamber. After passing the desired quantity of water through the meter, the flow is once again stopped. The discharge as recorded by the measuring chamber is noted. The final reading of the water meter is noted. The difference between the initial and final readings of water meter gives the discharge figure recorded by the water meter. Now the discharge recorded by measuring tank is treated as ideal. The discharge recorded by water meter is compared with this ideal discharge. If the quantity recorded by water meter is more than the ideal, the meter is called running fast or vice versa. The difference in the quantity recorded by the meter from the ideal quantity is considered as an error. This error is expressed in percentage.

If the limits of error for the meter exceed as specified in the IS concerned, the meter is readjusted by the regulator if it is available in the meter. A change in position of the regulating screw will displace the error curve (calibration curve) in parallel to the former position. With the closing of the regulating orifice, the curve will shift upward while opening the same will lower the curve. If the curve does not get into an acceptable limit the meter is not used. Some of the organizations are accepting accuracy limit for repaired water meter double the value of new water meters at respective zones i.e. for upper zone accuracy is ±4% & for lower zone accuracy is ±10%.

Flow calibration is essential to

(i) Confirm performance of flowmeter
(ii) Quality control
(iii) Comply with statutory or legal requirements
(iv) Provide traceability of measurement and confidence in resultant data.

The calibration is normally carried in the flow laboratory with the help of one of the following methods.

(i) Gravimetric
(ii) Volumetric
(iii) Prover
(iv) Master or reference meter
(v) Tow tank – current meter calibration

There are two philosophies of flow meter calibration. One is that it is better to have a fixed calibration system with all the associated technical back up and with the flow meters being brought to the calibration system, the other favours calibrating in situ leaving the flow meters in their installed condition and using a portable calibrator. The former will generally provide the more accurate calibration but the latter has the advantage that site-specific effects such as proximity to hydraulic disturbances can be taken into account. It is necessary to decide carefully to adopt the option.

There is often no choice but to carry out in situ calibration where:

(i) Flow cannot be shut off
(ii) Site-specific conditions have to be accounted for
(iii) The meter is so large that removal, transport, and testing costs would be prohibitive.

The major constraint with the in-situ calibration technique is that the high accuracy laboratory calibration cannot be matched in the field and accuracies of ± 2% to ± 5% is all that can be achieved and such field tests are called confidence checks rather than absolute calibrations. Such checks are often the precursor to the removal of flow meter for laboratory calibration or replacement.

For field tests following methods can be used:

(i) Clamp on devices
(ii) Thermodynamic method
(iii) Velocity area methods (insertion meters)
(iv) Tracer methods
(v) Flow simulators

Normally the manufacturers of the flowmeters provide laboratory calibration of the flow meters in their works. Some of the Government agencies also provide laboratory calibration vis. Fluid Control Research Institute (FCRI), Palakkad, Central Water & Power Research Station (CWPRS), Pune and Institute for Design of Electrical Measuring Instruments (IDEMI), Mumbai.

Point Calibration Test

All the meters manufactured shall be tested/ calibrated for accuracy at Q1, Q2 & Q3 flow rates & shall meet the acceptance criteria of errors less than the MPE, as per ISO4064 standard.

Calibration consists of comparing the meter reading with the reading obtained from a standard of higher accuracy than the test meter and with established uncertainty. The standard may be a reference master meter or a complete test bench which are traceable back to more fundamental measures of mass, time and volume. Test Report Format is as under:

Meter Serial Number	3 Point Accuracy Test			Date of testing
	Q1 (%)	Q2 (%)	Q3 (%)	

Lot Acceptance Test: Meter Testing from first lot of meters

Sample meters shall be sent to approved laboratory from the first lot of meters based on the below IS779 sampling plan for conducting the below tests.

1. Accuracy Test at Q1, Q2, 0.35(Q2 +Q3), 0.7(Q2 + Q3), Q3 and Q4 as per ISO4064 standard
2. Pressure Loss Test
3. Static Pressure Test
4. AMR Communication Test with the meter
5. IP68 Test on 2 sample meters
6. Life cycle test on 3 sample meters

Table 13.3: IS779 Sampling plan for Sample Size and Criteria for Acceptance

Size of the lot	Size of First Sample	Acceptance Number	Rejection Number	Size of Second Sample	Size of Cumulative Sample	Cumulative Acceptance Number
Upto 50	5	0	1	-	-	-
51-150	13	0	2	13	26	1
151-280	20	0	3	20	40	3
281-500	32	1	3	32	64	4
501-1200	50	2	5	50	100	6
1201-3200	80	3	6	80	160	9
3201-10000	125	5	9	125	250	12
10001-35000	200	7	11	200	400	18
35001 and over	315	11	16	315	630	26

Certificates to be provided with the meters during QAP Approval

All the below certificates shall be submitted during QAP approval process.

1. MID (Module B+D or Module H) Certificate
2. MAP & the endurance certificate from approved laboratory for each size
3. IP-68 Certificate from FCRI for the model of meters
4. Certificate of Approval of Model as per Legal Metrology Act
5. ISO17025 certificate

Setting up a Test facility

The Supplier shall setup a test facility in the utility premises to Test accuracy, pressure loss & static pressure of water meters to attend customer grievance.

13.8.3 Trend of Replacement of Water Meters

At present, there is no specific Indian certification process of validating the accuracy of water meters or flow meter. In general, if a water meter goes out of order due to any physical damage or non-operation of the registration device and is beyond economical repair, it should be replaced with immediate effect. In the Indian context, the performance of water meter or flow meter depends upon:

(i) The quality of water meter produced by the manufacturer and it differs from manufacturer to manufacturer;
(ii) The design of pipeline & fittings in line with the meter;

(iii) The workmanship & care when handling and installing the meter;
(iv) The pattern of water passing through the meter;
(v) The type of supply of water whether it is continuous or intermittent;
(vi) The meter maintenance, testing;
(vii) The proper selection of meter; and
(viii) Installation procedure as per {ISO 4064:2014 Part 5} to be followed

The performance of a water meter is required to be watched continuously with suitable history sheets. Any abnormality noticed needs immediate action. Timely removed faulty meter, & especially mechanical type meter, prevents cascade and cumulative damages.

Looking at the number of transactions involved, bulk meters shall be given priority in replacements. Based on the experience gained for a specification work, a well-planned programme for periodical meter testing, servicing, repairs and replacement wherever necessary shall be designed.

13.9 Flow Meters

The flow meter is the device used for measurement flow rate and quantity of liquids passing through a conduit. This device differs on the type of liquid conductive or non-conductive, and also have the other related aspects of the principle of operation. In water supply, mechanical, electromagnetic, or ultrasonic types of flowmeters are used. However, those are segregated depending on various points i.e., working principle, conductivity of liquid and its quality, the basic and overall accuracy of the flowmeter, calibration possibility, field or online, etc. The supply and delivery manufacturer should have ISO quality standard (IS 9001:2015) certification and flow meter testing confirming to ISO 17025: 2005 (Reaffirmed 2017). There are installation standards that need to be adopted for different flow meters. Figure 13.15 shows Electromagnetic flow meter, Figure 13.16 shows Ultrasonic Insertion flow meter, and Figure 13.17 shows Ultrasonic Clamp-on flow meter.

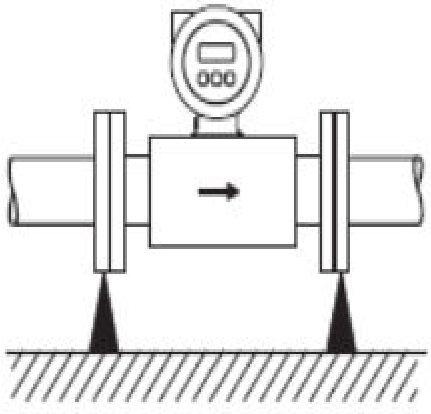


Figure 13.15: Electromagnetic flow meter

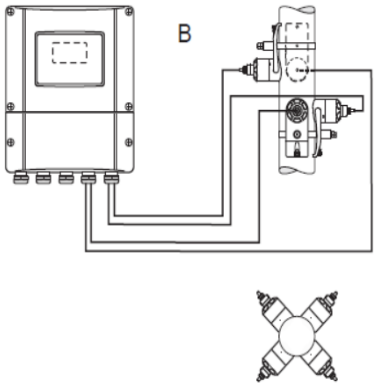


Figure 13.16: Ultrasonic Insertion flow meter

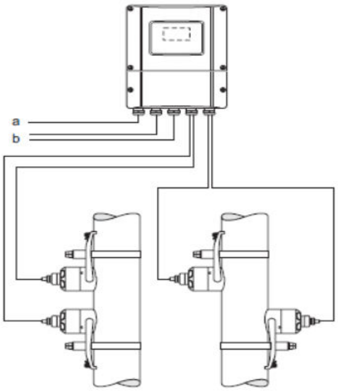


Figure 13.17: Ultrasonic Clamp-on flow meter

13.9.1 Methods for Metering Flow

Various methods are available for the metering flow rate and total flow. Each method has its own specific characteristics, which are directed towards individual installation requirements. In the water industry flow rate meter is termed as the flow meter and the total flow meter is termed as the water meter. A wide range of standard terms is used to describe the essential performance characteristics of instruments and sensors. Some of these terms are as follows.

13.9.1.1 Accuracy

It is defined as the difference between the reading of an instrument and the true value of the measured variable expressed as a percentage of either full scale or true value of the measured variable i.e. either in terms of full scale or flow rate of the flow meter. As far as possible the accuracy should be selected in terms of percentage of flow rate as it remains constant within the rangeability irrespective of variation in flow rate.

13.9.1.2 Range

The difference between the maximum and minimum values of the physical output over which an instrument is designed to operate normally.

13.9.1.3 Rangeability/Turndown Ratio

Describes the relationship between the range and the minimum quantity that can be measured.

13.9.1.4 Linearity

The degree to which the calibration curve of a device matches a straight line.

13.9.1.5 Resolution

The error associated with the ability to resolve the output signal to the smallest measurable unit.

13.9.1.6 Repeatability

The quantity which characterizes the ability of a measuring instrument to give identical indications or responses for repeated applications of the same value of the quantity measured under stated conditions of use.

13.9.2 Types of Flow Meter

In water works, normally, the following types of flow meters are used. These are classified with their advantages and disadvantages as described in the Table 13.4.

Table 13.4: Types of Flow Meters

S. No.	Types of Flow Meter	Advantages	Disadvantages
A	**Differential Pressure/Head Flow Meter**		
1.	Orifice Flow Meter	i. It can be used for all fluids except for some exceptions ii. No moving parts iii. Flow rate, indication, integration is easily obtained iv. It can be fitted in any configuration of the pipeline v. Suitable for any pipe diameter vi. The signal can be transmitted to long distance vii. Good accuracy viii. Suitable for extreme temperature and pressure ix. Calculation possibilities for unusual situations	i. Rangeability 4: 1 ii. Energy cost in terms of head loss iii. Ideal conditions are required for good accuracy iv. Suitable for a particular range of Reynolds number v. Accuracy in terms of span vi. Minimum slope for tapping piping has to be maintained i.e. 1:10 vii. Very long conditioning section required viii. Intensive maintenance required ix. Edge sharpness of the orifice must be assured. x. It requires isolation of pipeline during installation xi. Significant loss of head across the meter
2.	Venturi Meter	Advantages are similar to orifice flow meter, and less pressure loss compared to orifice meter and hence less energy cost.	Advantages are similar to Orifice flow meter metined at Sr. No. i, iii, iv, v, vi & x in addition to the high capital

S. No.	Types of Flow Meter	Advantages	Disadvantages
			cost.
3.	Pitot Tube	i. As mentioned under orifice flow meter except at Sr. No. vii. ii. It does not require isolation of pipeline for installation and comparatively capital cost of the flow meter is less. iii. Head loss is also less.	As mentioned under orifice flow meter at Sr. No. i, iii, v, vi, vii with addition of inferiority in accuracy as it being point velocity measurement.
4.	Annubar (Average Pitot Tube)	Similar as mentioned under pitot tube in addition to higher accuracy	Similar as mentioned under pitot tube except for inferiority in accuracy i.e. accuracy improves due to averaging of multi-ported pressures.
B	**Linear Flow Meter**		
1(a)	Turbine Wheel Flow Meter (Full Bore or Inline)	i. Excellent accuracy, linearity, and repeatability ii. Usable at extreme temperature and pressure	i. Suitable only for low viscosity ii. Moving parts and hence wear and tear iii. Sensitive to contamination iv. Flow profile sensitive and needs conditioning section v. Affected by overloading, the danger of over speeding vi. Sensitive to vibration vii. Isolation of pipeline is required for installation.
1(b)	Turbine Wheel Flow Meter (Insertion Type)	i. Isolation of pipeline is not required ii. Low cost	i. Inferior accuracy because of point velocity measurement ii. Suspended impurities can clog it. iii. In addition to the above, the disadvantages mentioned under the Turbine wheel flow meter (full bore) are also applicable.
2	**Variable Area Flow Meter (Rotameter)**		
	Variable	i. Inexpensive	i. It requires vertical

S. No.	Types of Flow Meter	Advantages	Disadvantages
	Area Flow Meter (Rotameter)	ii. No power supply required for local indication iii. No conditioning section iv. Easy maintenance	installation ii. Affected by the density and temperature of the fluid iii. Affected by vibration and pulsation
3	**Vortex Flow Meter**		
3(a)	Full Bore or Inline Type	i. No moving part ii. Robust construction iii. Unaffected by temperature, pressure and density changes	i. Conditioning of long approached section ii. Span limitation due to viscosity iii. Shedding rate is nonlinear between 2000 and 10000 Reynolds's number iv. Available up to 400 mm size due to constraints of sensitivity v. Isolation of pipeline is required for installation
3(b)	Insertion Vortex Flow Meter	i. Isolation of pipeline for installation is not required ii. Less costly than that of full bore iii. In addition to the above, the advantages mentioned under full bore vortex flow meter are also applicable.	i. Inferior accuracy due to point velocity measurement ii. In addition to the above, the disadvantages mentioned under full bore vortex meter are applicable except at Sr. No. V.
4	**Magnetic Flow Meter**		
4(a)	Full Bore (Inline) Flow Meter	i. Unobstructed flow passage ii. No moving parts iii. No additional pressure drop iv. Unaffected by changes in temperature, density, viscosity, electrical conductivity v. Flow range setting can be optimized vi. Suitable for water containing suspended solids vii. Short conditioning section is required as it is insensitive to flow profile viii. Measures flow both the	i. Air or gas inclusion causes the error ii. Minimum required conductivity of fluid 0.5 ms/cm. iii. Isolation of pipeline is required for installation iv. Vacuum creation may detach inner liner

S. No.	Types of Flow Meter	Advantages	Disadvantages
		directions ix. Un- affected by contamination and deposit x. Minimum maintenance xi. Good linearity xii. The smaller diameter flow meter can be used on a bigger diameter pipe with the help of reducers having angle not more than 16 degrees.	
4(b)	Insertion Magnetic Flow Meter	i. Less costly than that of full bore ii. No isolation of pipe line for installation iii. Advantages mentioned under Sr. Nos. ii, iv, v, vi, viii, ix, x, xi of full bore (inline) magnetic flow meter is applicable.	i. Inferior accuracy due to point velocity measurement ii. Long conditioning section is required iii. Sensitive to vibration iv. Periodic cleaning of the electrode is required
5	**Ultrasonic Flow Meter**		
5(a)	Doppler Type Ultrasonic Flow Meter	i. Unobstructed flow passage ii. No moving parts iii. No pressure drop iv. Measures flow in both directions v. Installations of individual elements in existing pipe lines possible vi. Minimum maintenance vii. Economical for large diameter pipe viii. Suitable for turbid water	i. Not suitable for clear water ii. Accuracy is inferior iii.
5(b)	Transit Time (Time of Flight) Ultrasonic Flow Meter	i. Advantages mentioned under Sr. nos. i, ii, iii, iv, v, vi, vii of Doppler type are applicable ii. Accuracy is improved in multipath iii. Accuracy is superior in insertion (wetted type) than that of clamp type.	i. It requires long conditioning section ii. Not suitable for turbid water or carrying air/gas bubbles.

13.9.3 Installation & Maintenance of Flow Meters

13.9.3.1 Installation of Flow Meters

Every user expects a problem-free installation of the meter and thereafter only accurate reading. Regular monitoring is desirable in order to avoid failures.

The meter is installed in the pipeline using flanged or threaded connections giving due consideration for conditioning sections. It should be seen that stress-free installation is carried out in pipeline. It is essential to install the flowmeter co-axially to the pipeline without protruding any packing or gasket into the water flow stream. In the case of ultrasonic meter, the probes are welded on the pipeline which requires care to see that no projection is protruding in the pipeline. In this case onsite calibration is essential. Wherever converters are used with primary elements it should be observed that the connection between them should be protected against lightning strokes and any other interference signal.

The installation on the functioning water supply systems requires shutting down the water supply. This necessitates shortest installation time. The installations are strictly carried out as per manufacturers' recommendations.

In the case of differential pressure type flow meter, the impulse piping requires special care in respect of slope and protection. Similarly, long disturbance free straight sections should be provided for uniformity. Installation should be vibration free as moving parts in the flowmeter wherever present will get worn out in addition to the effect on overall accuracy of the flowmeter. Installation in 'U' shape is essential for intermittent water supply.

Flow meters should be provided with battery backup in order to retain integrator reading during failure of electric supply.

13.9.3.2 Maintenance of Flow Meters

Modern development in the flowmeter measurement is that in most of the equipment a self- diagnosing facility is provided with which the maintenance staff monitors the health of the equipment. A number of instruments are enunciating the error conditions.

As long as orifice, Pitot tube, Venturi & Annubar flowmeters are concerned they require regular purging of impulse piping. Similarly, the transducers require periodical checking of zero and range setting. For the orifice, it is essential to check sharpness of the edge as in the case of its deterioration or damage the flowmeter reading may vary upto 20%.

Ultrasonic flowmeter and Magnetic flowmeters being self-diagnosing , they give information regarding deviation in accuracy or failure of probe or electrode. Whenever cleaning of probes or electrodes is required, those should be cleaned as per manufacturers' recommendation.

Turbine meter should be checked for bearing wear out periodically as presence of air in the liquid may damage the bearing because of over speeding.

Where deposits are to be expected in any flowmeter, the same should be regularly inspected and cleaned as per the experience gained during the course of time. As these deposits affect the accuracy of the measurement, Vortex meter, Magnetic flowmeter, Ultrasonic flowmeter, may show erroneous reading in the presence of deposits. Average Accuracies of Various Flow Meters are given in Table 13.5. In an intermittent water supply, the corrosion rate of the pipe increases due to chlorine and air. The formation of incrustation & subsequent descaling affect flowmeter working especially differential pressure type, turbine meters.

Table 13.5: Average Accuracies of Various Flow Meters

Sr. No.	Type of flow meter	Accuracy %
1.	Square edge orifice	±1S
2.	Venturi	±1S
3.	Pitot	±2S
4.	Annubar	±1S
5.	Turbine	±0.5R
6.	Rotameter	±2S
7.	Vortex	±1R
8.	Magnetic	±0.5R
9.	Doppler	±2S
10.	Transit time	±1R

Legends: S: in terms of full scale; R: in terms of flow rate.

Table 13.6 gives broad areas of Application of Flow Meter for Liquid

Table 13.6: Broad Areas of Application of Flow Meter for Liquid

Sr. No.	Type of flow meter	A	B	C	D
1.	Orifice	0	(+)	0	0
2.	Venturi	0		0	0
3.	Variable Area	0	0		
4.	Annubar	0		0	0
5.	Turbine	0		0	(*)
6.	Insertion turbine	0		0	0
7.	Vortex	0			
8.	Insertion Vortex	0		0	0
9.	Electro Magnetic	0	0	0	0
10.	Insertion Electro Magnetic	0		0	0
11.	Doppler	0		(+)	(+)
12.	Transit time	0	(+)	0	0

Legends: 0: Suitable, generally applicable; C: Large liquid flows (> 1.7 x 10^4 L /min.); (+) is worth considering, sometimes applicable; (*) is worth considering, limited availability or tends to be expensive; D: Large water pipes (> 500 mm dia); A blank indicates unsuitable; liquids (temp.>200^0C) not applicable; A: General liquid application (< 50 CP); B: Low liquid flows (<2 L /min)

Table 13.7: Performance Factors of Flow Meter

Sr. No.	Type of the flow meter	Linearity %	Repeatability (%)	Rangeability	Pressure drop at maximum flow	Flow parameter measured
1.	Orifice	0.25% FS to 1% FS	± 0.2% FS	3 or 4:1	3-4	R
2.	Venturi	0.25% FS to 1% FS	± 0.2% FS	3 or 4:1	2	R
3.	Variable area	±1% FS to ±5% FS	± 0.5% FS to ± 1% FS	1% FS	10:1	3R
4.	Annubar	0.5% R to 1% R	± 0.05% R to ± 0.2% R	4 to 10:1	1/2	Vm
5.	Turbine	± 0.15% R to ± 1% R	± 0.02% R to ± 0.5% R	5 to 10:1	3	R
6.	Insertion Turbine	± 0.25% R to ± 5% R	± 0.1% R to ± 2% R	10 to 40:1	1-2	Vp
7.	Vortex	± 1% R	± 0.1% R to ± 1% R	4 to 40:1	3	R
8.	Insertion Vortex	± 2% R	± 0.1% R	15 to 30:1	1	Vp
9.	Electro Magnetic	± 0.2% R to ± 1% R	± 0.1% R to ± 0.2% FS	10 to 100:1	1	R
10.	Insertion Elec. Mag.	± 2.5% R to ± 4% R	± 0.1% R	10:1	1	Vp
11.	Doppler	No data	± 0.2% FS	5 to 25:1	1	Vm, R
12.	Transit time	± 0.2% R to ± 1% R	± 0.2% R to ± 1% FS	10 to 300:1	1	R

Legends: R: Flowrate, Vp : Point velocity, NS: Not specified; T: Volume flow; % R: Percentage flowrate; 1: Low; Vm: Mean velocity; % FS : Percentage full scale; 5: High

Table 13.8: Installation Constraints for Flow Meter

Sr. No.	Type	Orientation	Direction	Quoted range of upstream lengths	Quoted range of minimum downstream	Pipe Diameter (mm)
1.	Orifice	H, VU,VD,I	U,B	5D/80D	2D/8D	6 to 2600
2.	Venturi	H,VU,VD,I	U	0.5D/29D	4D	>6
3.	Variable area	VU	U	0D	0D	2 to 150
4.	Annubar	H, VU,VD,I	U,B	2D/25D	2D/4D	>25
5.	Turbine	H, VU,VD,I	U,B	5D/20D	3D/10D	5 to 600
6.	Insertion turbine	H, VU,VD,I	U,B	10D/80D	5D/10D	>75
7.	Vortex	H, VU,VD,I	U	1D/40D	5D	12 to 400
8.	Insertion Vortex	H, VU,VD,I	U	20D	5D	>200
9.	Electromagnetic	H, VU,VD,I	U,B	0D/10D	0D/5D	2 to 3000
10.	Insertion magnetic	H, VU,VD,I	U,B	25D	5D	>100
11.	Ultrasonic - Doppler	H, VU,VD,I	U,B	10D	5D	>25
12.	Ultrasonic-Transit time	H, VU,VD,I	U,B	0D/50D	2D/5D	>4

Legends: H: Horizontal flow; U: Unidirectional flow; VU: Upward vertical flow; B: Bidirectional flow; VD: Downward vertical flow; D: Inner diameter of pipe; I: Inclined flow.

Table 13.9: Fluid Property Constraints for Flow Meter

Sr. No.	Type	Maximum pressure (bar)	Temperature Range (˚C)	Minimum Reynold's number	More than one phase (Gas or liquid)
1.	Orifice	400	<650	3×10^4	P
2.	Venturi	400	<650	10^5	P
3.	Variable area	700	-80 to + 400	No data	N
4.	Annubar	400	<540	10^4	N
5.	Turbine	3500	-260 to +530	10^4	N
6.	Insertion Turbine	70 to 250	-50 to +430	10^4	N
7.	Vortex	260	-200 to +430	2×10^4	P
8.	Insertion Vortex	70	- 30 to +150	5×10^3	N
9.	Electromagnetic	300	-60 to +220	No limit	S/P
10.	Elect. Insertion	20	+5 to +25	No data	N
11.	Ultrasonic-Doppler	Pipe pressure	-20 to +80	5×10^3	S
12.	Ultrasonic-Transit time	200	-200 to +250	5×10^3	N/P

Legends: S: Suitable; P: Possible; N: Not suitable

Table 13.10: Economic Factors of Flow Meters

Type	Installation cost	Calibration cost	Operation cost	Maintenance cost	Spares cost
Orifice	2-4	1	3	2	1
Venturi	4	1-4	2	3	3
Variable area	1-3	2	2	1	1
Annubar	2	3	2	2	2
Turbine	3	4	3	4	4
Insertion Turbine	2	3	2	2	3
Vortex	3	3	3	3	3
Insertion Vortex	2	3	2	3	3
Electromagnetic	3	3	1	3	3
Insertion ..Electromagnetic	2	3	2	3	2
Ultrasonic-Doppler	1-3	1	1	3	2

Ultrasonic-Transit time (time of flight)	1-3	3	1	3	2

Legends: 1: Low; 5: High

The installation methods for various types of flow meters along with its maintenance and service is discussed in Table 13.11.

Table 13.11: Installation & Maintenance of Flow Meters

Type	Installation	Pipeline ahead of meter	Maintenance during operation	Self-Monitoring	Service
Turbine meter	Flanged connections electrical installation	Conditioning section	Maintenance free, monitor, possible foreign lubrication	Not possible	—
Vortex meter	Flanged connections or water installation, electrical	Conditioning section installation	Maintenance free	Error monitoring	Electronic monitor functions and test values
Differential pressure Meters	Primary in flanges, impulse piping, convertor power supply	Long conditioning sections	Regular monitoring	Not possible	Direct measurement at primary
Variable area meter	Flanged or threaded connections	No restrictions	Maintenance free	Constant appearance	—
Electromagnetic flow meter	Flanged connections, electrical connections	No conditioning section	Maintenance free	Monitoring with error announcements	Electronic control functions & test simulator
Ultrasonic meter	Flanged connections or welding nipples, electrical installation.	Long conditioning section	Maintenance free	Signals for signal loss	-

13.9.4 Problems Encountered in Flow Meter Performance

There are many problems which are encountered during the life of the flow meter. Some of the common performance-related issues/problems that are encountered during its operation due to some causes along with remedial action are discussed in Table 13.13.

Table 13.13: Common Problems Encountered in Flow Meter Performance

Sr. No.	Problems	Causes	Flowmeter	Remedial Action
1.	Erratic reading	Operated below lower range having limited rangeability of flow meter	Differential pressure (DP) type	Replace flow meter
		Operated below lower range having limited rangeability of flow meter	Linear flow meter	Change range setting
		Less static pressure	D.P. type	Remove air trap
		Clogged impulse piping	D.P. type	Clear the choke up
		Air trapped in impulse piping	D.P. type	Remove air trap
		Frequent air trap in impulse piping	D.P. type	Change impulse piping slope to minimum 1: 10, If still the problem persists change the flow meter
		Damaged impulse piping	D.P. type	Rectify impulse piping
2.	Unsteady reading : (oscillating)	β ratio of more than 0.65	D.P. type	Redesign orifice
		Pulsating flow	D.P. & Linear type	Condition the flow
3.	Inaccurate reading	Pipeline internally incrusted	D.P. & Linear type	Clean the internal surface of pipeline
		Scaling is formed at tapping points	D.P. type	Clean the tapping points
		Orifice edge gets blunt	D.P. type	Replace orifice plate
		Flow meter downstream is opened within the range of 50 times dia pipe length	D.P. type	Extend the downstream pipeline beyond 50 times dia length
		Unsymmetrical formation of vena contra due to the large diameter of the throat in relation to static pressure	D.P. (orifice type)	Redesign the orifice
		Mismatch between flow meter & pipeline	D.P. & Linear type	Remove the mismatch
		Absence of sufficient conditioned approach pipeline	D.P. & Linear type	Provide sufficient conditional approach pipeline
		Foreign particles such as pieces of concrete, bricks, debris. etc. are gathered at upstream of the orifice	D.P. (Orifice)	Remove them
		Flanged coupling used with flow meter leaking	D.P. & Linear type	Rectify the leakage
		The pipeline may not be	D.P. &	Replace the pipe length

Sr. No.	Problems	Causes	Flowmeter	Remedial Action
		cylindrical within the range of 0.3% of the diameter of the pipe	Linear type	of 2 times dia immediate upstream of the flow meter
		Pipeline partially filled	D.P. & Linear type	Install valve downstream of the flow meter for throttling

13.10 Automated Meter Management

The Water Supply managers generally monitor levels in service reservoirs, pressures, flows in a distribution system (DMAs), water quality to supply safe and sufficient drinking water by manual readings. The manager usually use the telephone line or GSM unit to gather the data, use his discretion gained with experience, and take decisions to ensure that the system is operating with the required efficiency. Manual collection of data and analysis is an outdated practice and may not be helpful in large undertakings if water utilities have to aim at enhanced customer service by improving water quality and service level with reduced costs.

Meters are very crucial in managing the flows for equitable water supply throughout the network. The DMA based management ensures that the flows are matching the demand and supply adjusted accordingly.

The GIS, Telemetry, SCADA and Digital Twin Technology helps in efficiently runing the water supply system with real-time information, analysing the data with Digital Twins and thus to maintain continuous 24x7 supply to implement 'Drink from Tap'. The details of the above systems in explained in details in Chapter 14: Automation of Part A of this Manual.

13.10.1 Meter Reading Systems

Water meter is a cash register of a water supply authority. Consumption-based water rates require periodic reading of meters except in remote or automated meter reading of meters. Except in remote or automated meter reading these readings are usually done by meter readers visiting consumers premises one by one and noting down the indicator reading by the meter. These readings are recorded manually in books or on cards and later keyed manually to a customer accounting or billing system. In some cases, meter readers use Handheld Data Entry Terminals to record meter readings. Data from these devices are transferred electronically to a billing system. In other cases, the key entry has been replaced by mark-sense card readers or optical scanners.

The environment of meter reading usually is not favourable to the meter reader as most of the water meters are installed in the underground chamber; these chambers are filled in many cases with water, reptiles, or insects. Often access to these meters is also obstructed when these meters are installed in the consumers' premises. Sometimes manual work is involved in opening the chamber covers.

Some consumers connect their electrical earth terminal to water utility pipe which endangers the safety of the meter reader. If during the meter reading visit, the consumer premises are not accessible, the meter reader will have to visit it again which increases the cost of meter reading.

The solution to the above difficulties is to install an automatic system to read meters and process the results by computer. Because of development in integrated circuit technology and low powered radio transreceivers, this system to some extent is simplified.

The data can be captured by the meter readers from the meter in one of the following ways.

(i) Manual entry into meter books;
(ii) Manual entry into the portable Handheld Entry Terminals or recorders;
(iii) Direct electronic entry from meter registers either into portable data terminals or display units from which readings are transcribed in the field;
(iv) Telemetry link through radio, telephone.

13.10.2 Automatic Meter Reading (AMR)

AMR is a technology that automatically collects and transfers metering data to a central database for analysis and billing purposes, generally called “Smart Meters”. Data on detailed water usage can be collected at regular intervals (for example, every 30 minutes) and can be read remotely via an automated process. The usage data can later be sent to the utility’s management and billing system. Readings from AMR can be obtained by a simple walk-by or drive-by method, where the meter reader cruises down the street automatically downloading the meter data. Alternatively, the AMR through a one-way or two-way communication with the utility can transfer reading data. Figure 13.18 represents Automatic Meter Reading (AMR).

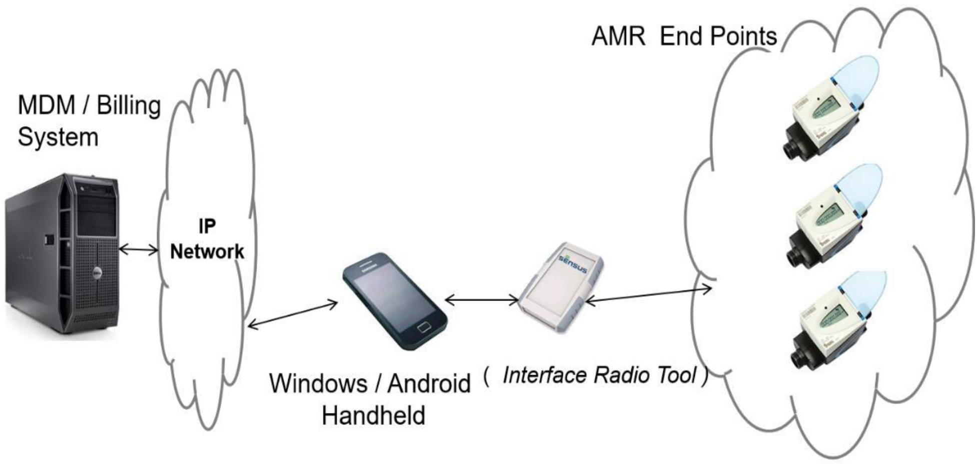


Figure 13.18: Representation of Automatic Meter Reading (AMR)

AMR does not require an extensive installation plan or significant maintenance, because the units that comprise AMR are not part of a larger physical network. It is a fixed system that can offer improved customer service through frequent readings and the ability to detect leaks and tampering. There is also an opportunity for additional data collection such as GPS surveys, time-of-day rate systems, and system modelling. However, since AMR is fixed, it requires employee drive-by visits, often conducted on monthly basis. Because of the drive-by visits, AMR can be much safer for meter readers since readers are not required to enter properties, which in turn reduces the likelihood of injury. AMR systems can take reads as frequently as every 15 minutes; however, the collected data will not be available until weeks after it is registered. As a result, any problems in the system may go unnoticed for a significant period unless the utility retains a full staff of meter readers to collect data more frequently. Maintaining or increasing the number of staff is likely to impact operational expenses.

Benefits ascribed to the installation of an AMR system:

(i) Increased revenue from previously unaccounted water;
(ii) Reduced meter reading costs including both regular cycle reading and special reads;
(iii) Reduction in security issues ;
(iv) Increased customer service;
(v) Identifying and locating losses (customer and system);
(vi) Theft detection;
(vii) Efficient billing;
(viii) Improved cash flow;
(ix) Conservation/Efficiency improvements;
(x) Provide outage management and detection;
(xi) Intangible benefits;
(xii) No human error.

An AMR system can provide:

(i) Readings as frequently as every 15 minutes or more, accurate and timely billing;
(ii) Improved work efficiency and safety;
(iii) Generate reports of unusual or outstanding events;
(iv) Tamper and reverse-flow alarms;
(v) Drastic reduction of estimated readings;
(vi) Utility-side leak detection by data collection and analysis;
(vii) Can estimate apparent & real losses in a water network.

Many utilities have used the AMR system as a stepping-stone between standard metering and Advanced Metering Interface (AMI) systems. Some utilities made changes as technology became available, while other utilities made system decisions for financial reasons, and a few other utilities wanted to try out the technology before committing to an AMI system. However, if the goal is to eventually have a full AMI system, then it is smart to explore the cost-effectiveness of growing from AMR to AMI. A slow transition may lead to setbacks or delays on the road to a complete AMI system and be more expensive.

AMR metering technology can:

(i) Store and record data at regular intervals up to 180 data points;
(ii) Readings can be retrieved in a drive-by – walk-by or fixed network mode;
(iii) The utility can conduct daily water balance and estimate NRW;
(iv) Moreover, smart meters or AMR technology can perform the following:

a) 24 hours' index
b) Leakage alarm (at consumer end)
c) Backflow alarm
d) Tamper alarm
e) End of battery life indicator
f) Water Intelligence Alarms (backed up by additional analytical tool/software)

- Meter oversized
- Meter undersized
- Meter stopped
- Peak flow
- AMR data, if continuously analyzed on data intelligent platforms like Digital Twins can help in finding leaks & water theft in distribution networks which reduces manpower & operational cost
- Hydraulic modelling simulations
- NRW Monitoring

13.10.3 Remote Register Meters

This system consists of a coiled spring mechanism wound by the register gears in the meter. A small generator is attached to the spring which trips and upwind when the meter reaches a certain consumption increment. The spinning of the generator sends an electrical pulse to the remote display unit installed outside. This system is known as electro-mechanical remote registering. The place of this system is being taken by electronically encoded remote registering. In this type, small printed circuit boards are installed between counter wheels of meter register, wiper blades attached to the counter wheels contact discrete positions on the PCBs corresponding to meter reading digits. A small microprocessor determines the positions of the wiper blades on PCB and converts in serially coded output. Similarly, non-contact type optical-encoded sensing technology is also being used.

In order to collect the data from the site Hand held Data Entry Terminal (HDET) is used. This unit consists of a programmable microprocessor-based unit, with memory, keypad, display unit, and battery power supply. It has an interface part so that necessary meter reading route instructions can be down loaded to the unit from a host computer and the meter readings themselves uploaded. The meter reader follows the HDET's instructions.

In a remote electronic meter reading system, the output from the encoded register meter is captured through a probe attached to HDET. For reading a meter the probe is connected to a receptacle on the outside of consumer's premises.

Presently there are five different systems of automatic meter reading which are as follows: -

1. **Telephone dial outbound:** In this system, a meter interface unit is installed on the phone line in the consumer's premises. The utility begins reading by calling a central office access unit which in turn connected to the meter interface unit through the telephone line. This access is available through dialling i.e., the meter reading is carried out on demand.
2. **Telephone dial inbound:** In this system meter interface unit dials the utility's computer at the predetermined time and transmits the latest reading.
3. **Bi-directional telephone dial-in/ out bound:** It is the combination of two earlier systems. With this system, it is possible to read meters at will or to send instructions from the utility control centre to the meter interface unit as necessary.
4. **Cable Television:** In this system at cable hardware end station on the address, the signal is injected for Meter Interface Units (MIU). All MIUS monitor the signals and the unit corresponds to a particular address respond and data is transmitted through the cable.
5. **Radio:** In this system, a radio frequency transmitter is installed at the meter and the receiver is either located at a fixed location or movable through the vehicle. The dialogues between transmitters and receivers are taking place either in predetermined time or on demand.

Some of the accrued advantages of automatic water metering are as follows:

(i) Improvement in the efficiency of meter reading;
(ii) Reduced operating cost;
(iii) Skipping of access problems of meter reading;
(iv) Estimated billing not necessary;
(v) Tampering of meter can be detected;
(vi) Back up to customer information services.

13.10.4 Advanced Metering Interface (AMI)

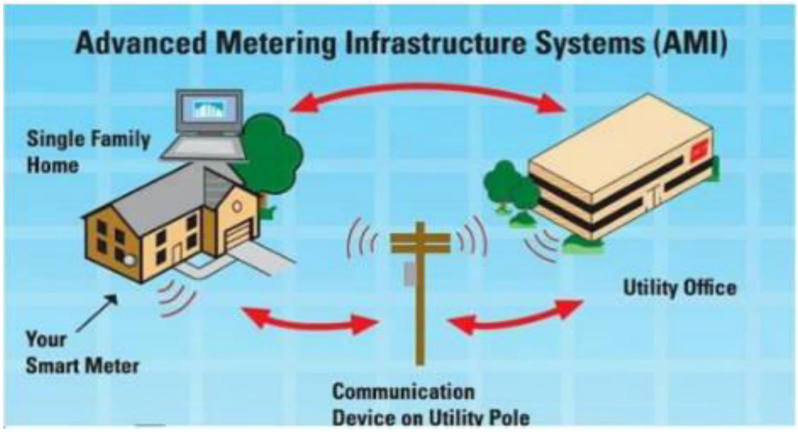


Figure 13.19: Advanced Metering Interface (AMI)

AMI comprises of smart meters and adds two-way communication between the meter and utility, and between the meter and consumer. This implies that in addition to providing readings, the meter can also receive (and often act on) instructions sent from the utility or consumer. Figure 13.19 and Figure 13.20 shows Advanced Metering Interface (AMI).

AMI is more complex than AMR and requires a large physical network. AMI performs the function of data collection similar to an AMR system; however, instead of holding the collected data until a meter reader can collect it, AMI relays the data to the owner of the meter in real-time. Because AMI can relay data in real-time and has a physical network, it has additional features.

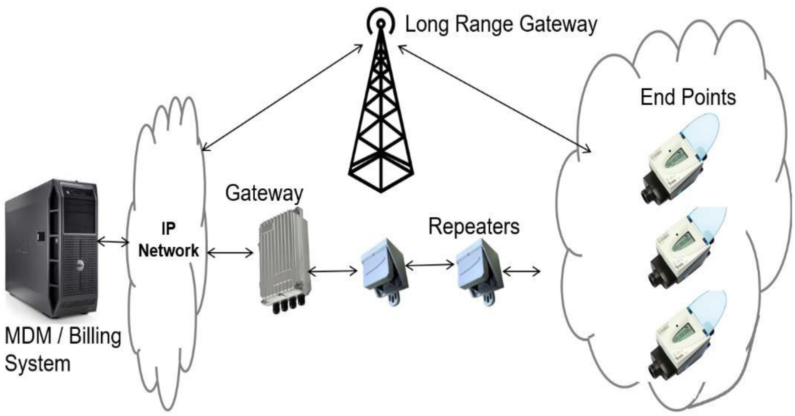


Figure 13.20: Representation of Advanced Metering Interface (AMI)

An AMI system can perform the functions of an AMR system as well as:

(i) Daily, hourly, or 15-minute read increments without reading staff;
(ii) Improved customer service;
(iii) Customer web portals;
(iv) Quick and accurate replies to inquiries;
(v) Faster resolution of billing disputes;
(vi) Select billing date;

(vii) Real-time diagnostic operation and maintenance reports;
(viii) Targeted data collection and report generation;
(ix) Operational updates for the collector, repeaters, and endpoints;
(x) Faster leak detection in water network with analytical module.

Data is transmitted in AMI systems in the following ways: one-way, two-way, and quasi two-way. The most appropriate option will largely depend on how much data is collected and the requirement of the utility.

13.10.5 Methods of Data Transmission

Radio Technologies: Because of its reliability and cost-effectiveness, radio frequency (RF) is the most common communication technology for AMI/AMR systems. Antennas or transmitters are attached to the meter or register, and data is transmitted from the meters and the data collectors by RF.

Non-Radio Technologies: Non Radio technologies for data transmission include power lines, cable, cellular, satellite, telephone, GSM / GPRS, LoRA WAN , LAN, NBIOT, IIOT, Optical Fibre Cable, etc.

Meter Data Management: Meter Data Management (MDM) is a common platform where any smart meter can directly communicate & report meter reading data, alarms, tamper alerts, etc. to the user. The MDM is a cloud-based application capable to communicate with smart meters via different communication protocols. In the case of non-communicating meters, users can use android applications to collect data and send it through a mobile network to MDM to analyze, visualize and check the accuracy.

13.10.6 Data Collected in SCADA/ Smart Metering System/ Digital Twin System

SCADA systems will have probes/ sensors which will sense and generate signals for the level, pressure, and flow in a given unit and transmit the signals for storage and analysis on the computer. The signals are transmitted by radio, by telephone, microwave satellite or fibre-optic transmission systems. SCADA systems can include the network diagrams of the distribution system of which detailed sketches of a particular area can be viewed by the operator if necessary to observe the current operating data such as flow, pressure, level, or residual chlorine.

SCADA systems in Water distribution are programmed for the collection and processing of the following information.

(i) To monitor levels in service reservoirs, pressures and flows in a distribution system;
(ii) To monitor and store data on levels in SRs, or flows/quantity of delivered into SR or pressures of the distribution system and generate alarms for threshold values of levels, flows and pressures to initiate operation of valves and pumps;
(iii) To monitor and store data on the operation of pumps such as voltage,

amperes, energy consumed, operating times and down times of pumps;

(iv) To measure and record chlorine residuals and generate alarms at thresh hold values of residual chlorine in the distribution systems.

13.10.7 Analysis of Data from SCADA/Smart Metering

SCADA systems can be designed to analyze the data and provide daily, weekly, monthly, and or annual reports or schedules. It also helps in monitoring the inventories on spare parts and plan requirement of spares. Responses for different scenarios such as seasonal changes or any emergencies can be programmed into SCADA. The information stored in the SCADA can be easily retrieved and analyzed. Typical information that could be generated in the system includes consumption patterns linked to the weather conditions, plots on pressures against flows, electrical energy consumption linked to consumer demands, record on system leaks, record on pump failures, areas with fewer chlorine residuals, etc.

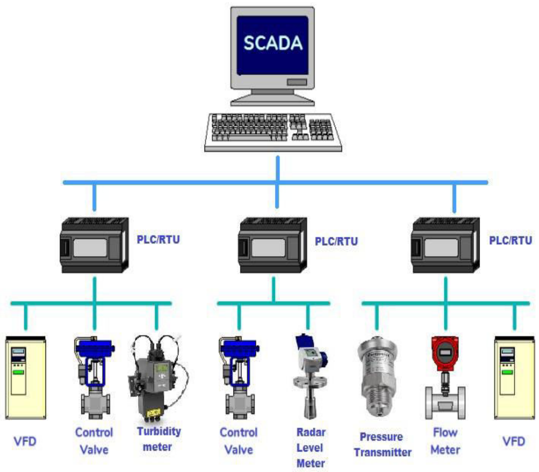


Figure 13.21: SCADA System Architecture

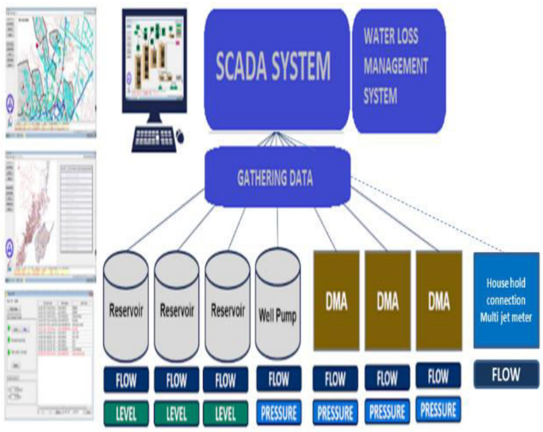


Figure 13.22: SCADA System Dashboard

13.10.8 Limitations of SCADA/Smart Metering/Communication

Before installing a SCADA, the utility staff should visit facilities with SCADA and discuss with the utility managers and then decide the scope of SCADA to be provided in their utility. The objective of SCADA should be to make the job of operator easier, more efficient, and safer to make their facilities performance more reliable and cost-effective. There is no doubt that SCADA enables better capacity utilization and help in improved service levels at low operating cost. SCADA designing calls for careful planning and requires a phased implementation, particularly dependent on appropriate training of utility staff and their willingness to adopt the new technology.

The availability of power supply is very essential to the efficient functioning of the system. Wherever possible the RTU for flow meter or pressure sensor and water quality like pH, turbidity, residual chlorine is provided power from electricity mains via a battery that acts as a buffer in case of mains failure. There may be metering locations for flow and pressure sensors without any source of power close by. In such cases, solar power may be one alternative. Initially installations at such locations may operate well but they are always subject to poor after-sales service by vendors, vandalism, and theft.

Ultimate improvement in the water supply distribution system cannot be achieved through the advanced application of technology like SCADA or Digital Twin System. The utility staff should have reached a reasonable level of managerial capabilities even with conventional methods of monitoring and control by adopting a holistic approach when the SCADA may further enhance their capabilities, but SCADA by itself is not the answer for poor or inefficient management.

13.10.9 Conclusion

The present field measurement market which caters to the water quantity and quality is open and there are many new technologies available based on the requirement of the purchaser. If the right instrumentation for measurement and control like a water meter, flow meter, etc. are selected and installed properly, the maintenance cost, manpower cost, etc. will get reduced drastically and accuracy also will be maintained.

It is also pertinent to mention that there is no data available in the country regarding the quantity of water drawn or abstracted from the source or treated in a treatment plant or consumed by consumers. As the precious water resources are getting scarce and depleted day by day, it is essential to adopt technologies for ensuring proper measurement, maintaining quality and conservation. By adapting the necessary field instrumentation devices, water balance, NRW, UFW, etc. can be known and necessary steps may be taken for better management of water. The reduction of NRW has to be the focus of utilities. The correct and accurate measurement of inputs and outputs need to be given due weightage and importance in all waterworks installations for effective and productive utilization of precious potable water resources and water audit and effective energy audit of any water utility.

Subsequently, the revenue generated by water usage billing is very essential for the sustenance of any water supply project and the utility which is involved in its operation and maintenance.

Table 13.17 **Applicable Standards for Water Meters & Flow Meters (National & International Standards)**

Sr. No.	Standard / Reference	Title/Description
General		
1	BS: 7405:1991 confirmed year: 2017	Selection and application of flow meters for the measurement of fluid flow in closed conduits
2	BS: 5792:1980 Replaced by: BS EN ISO 20456:2019	Specification for Electro Magnetic flow meters
3	BS EN ISO: 6817:1997 Replaced by: BS EN ISO 20456:2019	Measurement of conductive liquid flow in closed conduits - Method using Electromagnetic flow meters
4	ISO Recommendation: R-541: 1967(E) Replaced by: ISO 5167-1:2003	Measurement of fluid flow by means of orifice plates and nozzles
5	ISO 9104:1991/ Revised by: ISO 20456:2017 BS 7526: 1991	Measurement of fluid flow in closed conduits — Method of evaluating the performance of electromagnetic flow meters for liquids
6	BS: 6199: 1991/ ISO 9368:1990 Confirmed Year:1998	Measurement of liquid flow in closed conduits by using weighing and volumetric methods
7	IS: 4477 Part-2: 1975 Reaffirmed Year : 2016	Methods of measurement of fluid flow by means of Venturi meters: Part-2 Compressible Liquids
8	IS 2951 Part I: 1965 Reaffirmed Year : 2017	Recommendations for estimation of flow of liquids in closed conduits Part I : Head loss in straight pipes due to frictional resistance
9	IS 14615 Part I: 1999 : 2018	Measurement of fluid flow by means of pressure differential devices — Part I : Orifice plates, nozzles and venturi tubes inserted in circular cross-section conduits running full
10	IS 9115: 1979 Reaffirmed Year : 2017	Method for estimation of incompressible fluid flow in closed conduits by Bend meters
11	IS 779: 1994 Reaffirmed Year : 2015	Water meters (Domestic type) – Specification (Sixth revision)
12	IS 2373: 1981 Reaffirmed Year: 2017	Specifications for water meters (Bulk type) (Third revision)
13	IS 6784: 1996 Reaffirmed Year : 2017	Methods for Performance Testing of Water Meters
14	BS 5728	Measurement of flow of cold potable water in closed conduits Part-I (1979): Specification for single meters

Sr. No.	Standard / Reference	Title/Description
		Part-II (1980): Specification for installation requirements for single meters Part-III (1997): Methods for determining principal characteristics of single meters
15	ISO: 4064:2014 Confirmed Year: 2019	Water meters for cold potable water and hot water Part-1: Metrological and technical requirements Part-2: Test methods and equipment Part-5: Installation requirements
16	AWWA Manual 6	Water Meters - Selection, Installation, Testing and Maintenance
Closed Pipe Flow Measurements		
1	ISO 1088: 2007 Confirmed Year: 2020	Velocity-area methods using current-meters — Collection and processing of data for determination of uncertainties in flow measurement
2	ISO 3354: 2008 Confirmed Year: 2017	Velocity-area method using current-meters in full conduits and under regular flow conditions
3	ISO 4006: 1991 Confirmed Year: 2019	Measurement of fluid flow in closed conduits — Vocabulary and symbols
4	ISO 4064-1: 2005 Replaced by: ISO 4064-1:2014	Measurement of water flow in fully charged closed conduits — Meters for cold potable water and hot water — Part 1: Specifications
5	ISO 4064-2: 2014 Confirmed Year: 2019	Water meters for cold potable water and hot water — Part 2: Test methods
6	ISO 4064-5: 2014 Confirmed Year: 2019	Water meters for cold potable water and hot water — Part 5: Installation requirements
7	ISO 4185: 1980 Confirmed Year: 2019	Measurement of liquid flow in closed conduits — Weighing method
8	ISO 5167-1: 2003 Confirmed Year: 2014 Status: Current	Flow Measurement via Differential Pressure Methods: General
9	ISO 5167-2: 2003 Confirmed Year: 2014	Flow Measurement via Differential Pressure Methods: Orifices
10	ISO 5167-3: 2003 Confirmed Year: 2014	Flow Measurement via Differential Pressure Methods: Nozzles
11	ISO 5167-4: 2003 Confirmed Year: 2014	Flow Measurement via Differential Pressure Methods: Venturis
12	ISO 5168: 2005 Reaffirmed 2015	Measurement of fluid flow — Procedures for the evaluation of uncertainties
13	ISO 6416: 2004 Revised by ISO 6416:2017	Measurement of discharge by ultrasonic (acoustic) method
14	ISO/TR 9464: 2008 Confirmed Year: 2019	Guidelines for the use of ISO 5167
15	ISO 6817: 1992	Closed Pipe Flow Measurements:

Sr. No.	Standard / Reference	Title/Description
	Replaced by: ISO 20456:2017	Electromagnetic Flowmeters
16	ISO 8316: 1987 Confirmed Year: 2019	Flow Measurement by Volumetric Tank Collection Method
17	ISO 9104: 1991 Replaced by: ISO 20456:2017	Methods of evaluating the performance of electromagnetic flow-meters for liquids
18	ISO/TR 9824: 2007	Measurement of Free Surface Flow in Closed Conduits
19	ISO 11631: 1998 Confirmed Year: 2014	Methods for Specifying Flowmeter Performance
20	ISO/NP 12242: 2012	Measurement of fluid flow in closed conduits — Ultrasonic transit-time meters for liquid
21	ISO 13359: 1998 Replaced by: ISO 20456:2017	Flanged Electromagnetic Flowmeters: Overall length
22	ISO/TS 25377: 2007 Confirmed Year: 2013	Hydrometric Uncertainty Guidance (HUG)