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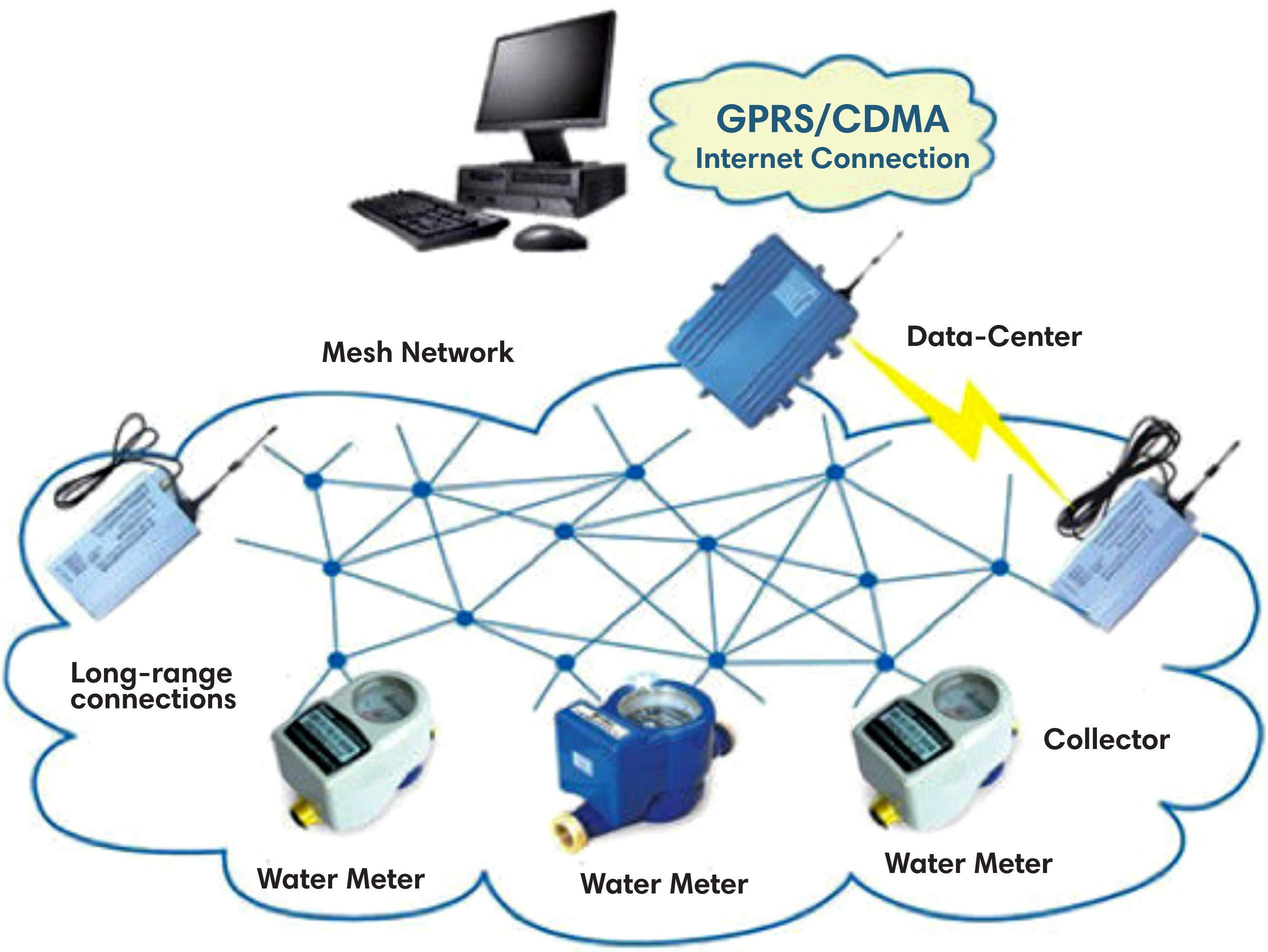
Atal Mission for Rejuvenation and Urban Transformation

Ministry of Housing and Urban Affairs
Government of India

# Advisory on
# Water Meters, Instrumentation & SCADA




Central Public Health and Environmental Engineering Organisation (CPHEEO)

Ministry of Housing and Urban Affairs
Government of India

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दुर्गा शंकर मिश्र
सचिव
**Durga Shanker Mishra**
Secretary

सत्यमेव जयते

भारत सरकार
आवासन और शहरी कार्य मंत्रालय
निर्माण भवन, नई दिल्ली–110011
Government of India
Ministry of Housing and Urban Affairs
Nirman Bhawan, New Delhi-110011

## FOREWORD

Ministry of Housing and Urban Affairs has constituted an Expert Committee under the chairmanship of Adviser (PHEE), CPHEEO to prepare various advisories on latest technologies and best practices in water supply & waste water sector to facilitate implementation of Jal Jeevan Missions for both urban and rural areas.

Water meters play a vital role in managing water resources in any water supply system and crystallize the centrality of information systems in improving the management of the public water supply service. It is also a management tool linked directly to consumption and billing of water based on quantity of usage. It helps in better understanding and evaluation of water demand and further assists in setting up priorities in terms of investments in water sector.

Non-revenue Water (NRW) is an issue with almost all water supply utilities in India. It includes physical & commercial losses and free authorized water for which payment is not collected. The average NRW in India is about 38%, which is above the global average range of 30% to 35%, as reported by the World Bank. The data obtained from an upright metering system facilitates in the estimation of water losses/leakage in any water supply system and identify its location. Digital technologies such as smart water meters have been effective in curbing water loss and reducing NRW globally.

This Advisory on Water Meters and its Application is prepared with an aim to encourage and empower the engineers working in State Public Health Engineering Departments (PHEDs)/Parastatals/Boards/Urban Local Bodies (ULBs) etc. to select appropriate meters based on their applications and use data measured by water meters in order to understand the water demand patterns in the system and to project future demands. They must also ensure that there is universal metering of all existing domestic and non-domestic connections and all new connections must be metered. Further, all water supply sources, treatment plants, and water distribution stations should have functional flow meters alongside consumer end metering. The concept of District Metering Areas (DMA) and smart metering should be encouraged. This Advisory will support and boost the objective of 'Make in India' initiatives.

I congratulate all the concerned officers of the Ministry, the Chairman & all the Members of the Expert Committee, officers of CPHEEO, who have been involved in the preparation of this Advisory on Water Meters and SCADA.

**(Durga Shanker Mishra)**

New Delhi
24th June, 2020

**Office Address:** Room No. 122 'C' Wing, Nirman Bhawan, New Delhi-110011
Tel.: 011-23062377, 23061179; Fax: 011-23061459; Email: secyurban@nic.in
Website: www.mohua.gov.in

डी॰ तारा, आई.ए.स.
संयुक्त सचिव
D. Thara, I.A.S.
Joint Secretary

भारत सरकार
आवासन और शहरी कार्य मंत्रालय
GOVERNMENT OF INDIA
MINISTRY OF HOUSING AND URBAN AFFAIRS

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## PREFACE

Water meters and flow meters are indispensable for understanding the quantity of water being distributed in a system and its usage. These meters are used to measure quantity of water entering a water supply system, from different sources such as water sources, water treatment plants or bulk water suppliers. Meters in the distribution network measure where the water is transported to, and finally, consumer meters are used to measure how much water is delivered to each metered consumer in the system.

A good water meter must record the entire water passing through it, being capable of recording even slight discharges and should be able to work efficiently at all the pressures in the mains. The data facilitates water manager in effective decision making based on capital investments, maintenance, staffing and various other aspects of the water supply systems. It also facilitates municipal/ hydraulic engineers to identify unauthorized / illegal connections by comparing the water meter readings at the point of release of water with the readings at consumer end. An increase in revenue generation for water utilities through improved billing efficiency, enhanced water conservation and resource optimization is a major driver for installing water meters.

I take this opportunity to congratulate the Chairman and all the Members of Expert Committee for bringing out this Advisory on Water Meters, Instrumentation and SCADA.

**(D. Thara)**

Office: 144-C, Nirman Bhawan, New Delhi-110011, Phone: 011-23061444, 23061991
Email: tharad@ias.nic.in, Website: www.mohua.gov.in

**Dr. M. Dhinadhayalan**
Adviser (PHEE),
CPHEEO
Tel.(O) : 91-11-23061926
Fax : 91-11-23062559
E-mail : adviser-phee-muha@gov.in

भारत सरकार
आवासन और शहरी कार्य मंत्रालय
निर्माण भवन
GOVERNMENT OF INDIA
MINISTRY OF HOUSING AND URBAN AFFAIRS
NIRMAN BHAWAN
नई दिल्ली-110011, तारीख 20
New Delhi-110011, dated the 20

# EXECUTIVE SUMMARY

A water meter is a device that measures the volume of water that passes through it. A water meter consists 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 having passed through the meter, and (iv) an indicator to display the meter reading. Water meters are classified as mechanical, electromagnetic and ultrasonic water meter.

Mechanical meters have moving parts that detect the flow, such as a piston or impeller and make up the vast majority of meters used in water distribution systems. Electromagnetic and ultrasonic meters have no moving parts but detect the flow through the meter using electromagnetic waves and ultrasound waves respectively. These meters are used in special cases, such as in very large pipes and/or where a high accuracy metering is required. Sizing and detailed description of various other meters is provided in the advisory.

A chapter on Water Meters, Instrumentation, Telemetry and SCADA is already existing in the Manual on O&M of Water Supply Systems, 2005, published by this Ministry. Publication of this advisory is an effort to put holistically together all relevant information including recent developments and trends in the water meters and flow meters along with their usages based upon experiences at one place to assist States/UTs in selection of appropriate meters.

Details of various types of flow meters such as Differential Pressure/Head Flow Meter, Linear Flow Meter, Variable Area Flow Meter (Rotameter) etc., along with their advantages and disadvantages are described in the advisory. The guidelines for installing, measures for repairs, maintenance & trouble shooting of water meters have been mentioned in the advisory.

There are many online instrumentation devices other than flow meters and water meters which are used for measurement of level, liquid parameters like turbidity, pH etc. These instruments provide more accuracy & are integral part of any SCADA system and help to mitigate the challenges in the current water supply system.

I would like to convey my gratitude to Shri. Shubhanshu Dixit, Superintending Engineer (Tech.), PHED, Jaipur, Govt. of Rajasthan & Members of the Expert Committee for providing technical support in preparation of the Advisory. I would also like to extend my sincere thanks to all the Members of the Expert Committee & the Officers of CPHEEO for reviewing the Advisory and supporting staff for their effective coordination in completing the task. I would also like to extend my appreciation to Ms. Chaitra Devoor, Assistant Adviser(PHE) for her untiring efforts in completing the Advisory.

**(Dr. M. Dhinadhayalan)**
Adviser (PHEE) & Chairman of the Expert Committee

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# 1.0 INTRODUCTION

A water meter is a scientific instrument for accurate measurement of quantity of water distributed to the consumer and efficient management of urban water supply. It provides real-time data on the volume of water being consumed by a consumer (residential or bulk), thereby encouraging the consumer to use water more efficiently. Flow meters are the instruments installed for the measurements of the volume of water consumed or discharged from the source of water like a river or bore well or dam/reservoir to Water Treatment Plant (WTP) and subsequent to the District Metering Areas (DMA). Based on the requirement, some of the other features like pressure, turbidity, and water quality parameters can also be measured by the flow meter.

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, and water meters are used to measure the quantity of water that is delivered to each metered consumer in the system.

Therefore, metering fulfils the need to know accurately the water produced and distributed by clear understanding of water balance. A well-placed metering system in the water distribution network shall also assist technical staff in identifying the location where water loss /leakage is observed by comparing the water meter readings at the point of release of water with the readings at the consumer end. By estimating the level of water losses in a water supply system, unauthorized/ illegal connections can also be identified.

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. However, a tariff policy cannot be implemented without a well-established metering system. Therefore, 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 flow rate meter;
(ii) Water meter is a mechanical or electromagnetic or ultrasonic device whereas flow meter may be mechanical or an electronic device;
(iii) 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;
(iv) 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
(v) 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.

## 2.0 SIZING OF WATER METERS

The nominal sizes of domestic water meters are varying from 15 mm to 50 mm as per {IS 779: 1994 (Reaffirmed 2015)} and bulk water meter is varying between 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 flow to be measured and not necessarily to suit a certain size of water main;
(ii) The maximum flow should not exceed the maximum flow rating;
(iii) The nominal flow should not be greater than 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.

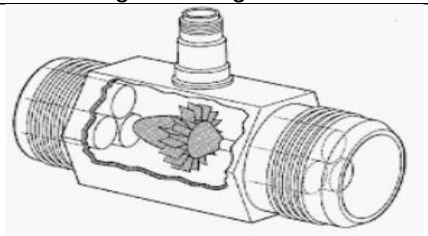
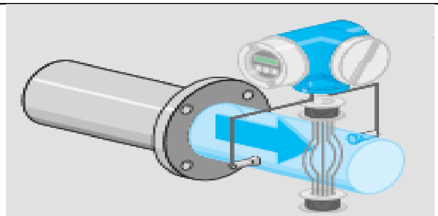
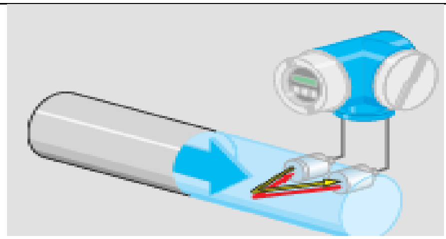
## 3.0 CLASSIFICATION OF WATER METERS

Water meters are generally classified based on the different mechanisms used by the water meter to measure the flow of water passing through it. These are mechanical water meter, electromagnetic water meter and ultrasonic water meter. Based on the usage, it is classified as a domestic meter or bulk meter. The classification and features of various types of water meters are discussed in Table 3.1.

## Table 3.1: Classification of Water 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<br>(ii) Mechanically & Magnetically coupled meter<br>(iii) Dry/ Wet Dial meter | (i) No moving parts<br>(ii) Sensor in-build<br>(iii) Dry Dial meter | (i) No moving parts.<br>(ii) Sensor in-build<br>(iii) Dry Dial meter<br>(iv) Can be clamped on or inserted in the pipe |
| 3. | **Available sizes** | 15mm – 500mm | 15mm - 3000mm | 15mm - 4000mm |
| 4. | **Application** | Preferred diameter size Domestic meter: 15mm to 40mm<br>Bulk meter (Woltman): 50mm to 500mm | Preferred diameter size: Domestic meter: 15mm to 40mm<br>Bulk meter:<br>50 mm to 3000 mm | Preferred diameter size: Domestic meter: 15mm to 40mm<br>Bulk meter:<br>50 mm to 4000 mm |
| 5. | **IS Code** | IS 4064 / 2373/ 779 | IS 4064 | IS 4064 |
| 6. | **Water conductivity & quality of water** | Conductivity not necessary but highly critical with suspended impurity as it clogs the moving parts. | Only Conductive Fluids | Conductivity not necessary but highly critical with suspended impurity & turbidity as it deposits on the sensor face. |
| 7. | **Accuracy** | > 2%+ to 5%+ | ± 0.5% or better | ~ 0.5% to 2% |
| 8. | **Field accuracy** | Practically impossible due to wear & tear of moving parts, chocking of strainer & filter, etc. | Achievable | Achievable, but depends on a lot of variable factors and installation. Generally, field accuracy is not as good as other flowmeters |
| 9. | **Wet calibration** | Possible | Possible | Possible if clamped and not possible if its inserted |
| 10. | **Flow tube available** | It has flow meter with the compulsory requirement of inlet filter /strainer | Yes | Yes, for clamp-on and since, sensors are installed at the site by making holes in the running pipe in insertion type, no flow tube is available. |
| 11. | **Installation perfection** | Good but precision is based on-site layout and human error. | Good | Good, but not so good |
| 12. | **Field check** | Not Possible | Possible | Possible |
| 13. | **Regular** | Very high as it regularly chocks with | Less | Less if clamped on but Regular |

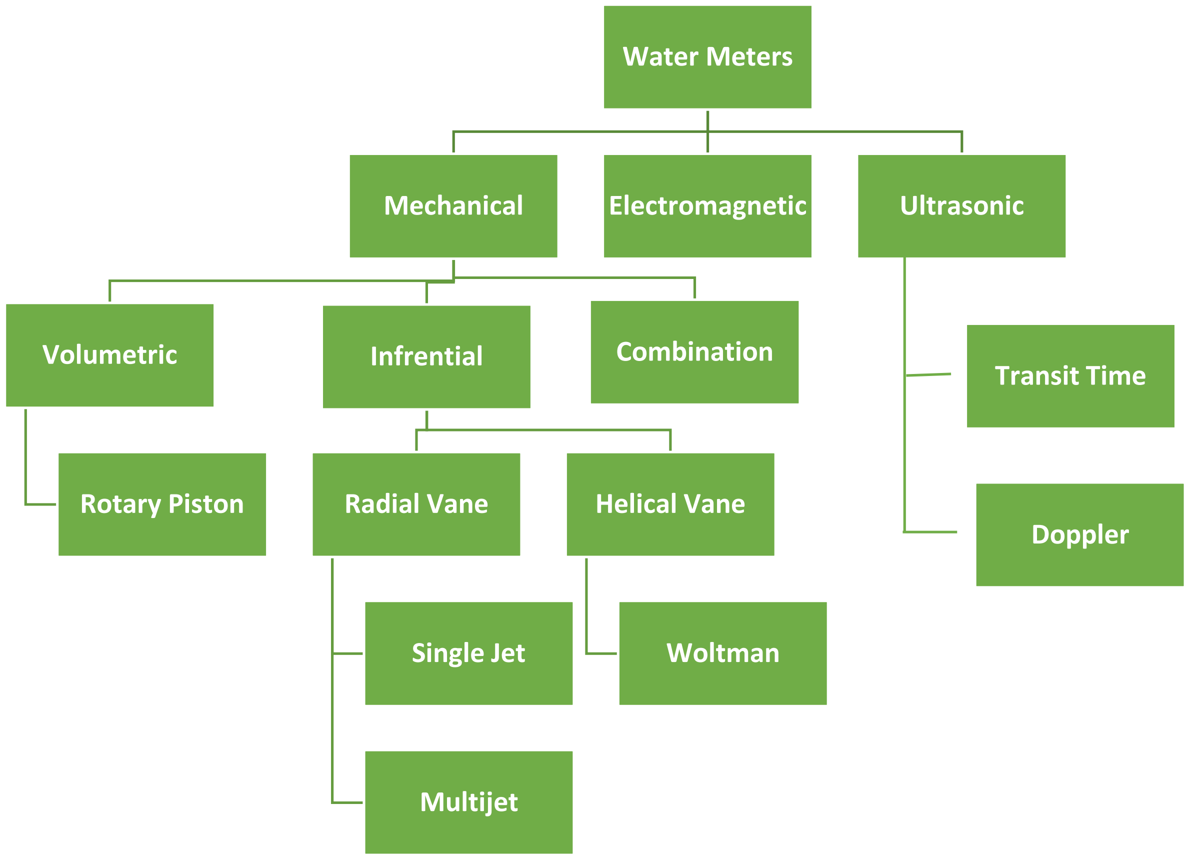
| S.No. | Attributes | Mechanical meters | Electromagnetic meters | Ultrasonic meters |
|---|---|---|---|---|
| | **maintenance required.** | the suspended solids. | | cleaning of sensor is essential if inserted |
| 14. | **Periodic maintenance** | Very high as it has a lot of moving parts and wear & tear is a regular issue. We do not come to know wear and tear as no warning available other than the high-pressure drop. | Less & replacement of the sensor is a remote possibility due to its rugged construction. The expected life of the sensor is a minimum of 10 years. Hence the cost of ownership is very less. | Very Less & Very easy without any shutdown in case of clamp on. But insertion requires regular cleaning of the sensor and reduces signal strength due to irreversible deposition. The estimated life of the sensor is only 2-3 years & requires replacement. |
| 15. | **Replacement / Removal of the sensor** | Possible & requires very frequently. Generally, meters & dial requires replacement. The estimated life is only within 1 year. | Difficult / Time consuming & requires shutdown. | Easy and can be done without disturbing the process. |
| 16. | **IP-68 Sensor availability** | Available but a lot of failure due to moving parts. | Yes | Yes |
| 17. | **Wet calibration facility at the manufacturer's place** | Yes | Yes | Yes |
| 18. | **Verification of accuracy at site** | Not Possible. | Possible | Possible for clamp on, but insertion type, Wet calibration not possible |
| 19. | **Lining** | No lining but has moving parts like a turbine, paddlewheel, etc. | PU lining available. | Food grade coating with Drinking water certificate available for clamp on. No lining is required for insertion as it is installed in the running pipes |
| 20. | **Operating at low velocity** | Poor | Good | Moderate |
| 21. | **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. | Moderate.<br>The sensors are clamped over the outer surface of pipe for diameters from DN500 to DN4000 |

| S.No. | Attributes | Mechanical meters | Electromagnetic meters | Ultrasonic meters |
|---|---|---|---|---|
| 22. | **Advantages** | (i) Suitable for higher flows<br>(ii) Can sustain hostile flow conditions<br>(iii) External & internal regulator facilitates easy calibration<br>(iv) Less Pressure loss<br>(v) Robust construction<br>(vi) Easy Maintenance | (i) Most sensitive 15 mm to 50 mm as per IS 779: 1994 and 15 mm to 100 mm as per ISO 4064<br>(ii) Less sensitive to flow disturbances and ready for Automatic Meter reading for water SCADA compliant<br>(iii) Straight reading cyclometer<br>(iv) Do not measure the air in the pipe<br>(v) No Orientation issue.<br>(vi) Life of meter 10 to 15 yrs. | (i) Most sensitive 15 mm to 50 mm as per IS 779:1994 and 15 mm to 100 mm as per ISO 4064<br>(ii) Less sensitive to flow disturbances and ready for Automatic Meter reading for water SCADA compliant<br>(iii) Straight reading cyclometer<br>(iv) Do not measure the air in the pipe<br>(v) No Orientation issue.<br>(vi) Life of meter 10 to 15 yrs. |
| 23. | **Disadvantages** | (i) Less sensitive to low flow<br>(ii) Approach conditioning piping is required<br>(iii) Not available in metrological classes in BIS.<br>(iv) Limited to higher flows.<br>(v) Multi pointer meter (Analogue type)<br>(vi) Bush leak problems<br>(vii) Air escape holes create a problem during submergence. | (i) Costlier than mechanical meters<br>(ii) Water must be free from solid dirt particles | (i) Costlier than mechanical meters<br>(ii) Water must be free from solid dirt particles |
| 24. | **Representation** |  |  |  |

# 4.0 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. They are mostly for bulk metering, such as in very large pipes and/or where a high accuracy metering is required like DMA measurement.

Mechanical water meter like the single jet, multijet, piston type, and electromagnetic and ultrasonic meters are used for domestic purposes. The preferred diameter size for domestic metering is 15mm to 40mm. 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 is used for bulk metering. The preferred diameter size for bulk metering is 50mm to 150mm. Sub classification of different meters are as under:



## 4.1 Mechanical Meters

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

### 4.1.1 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.

#### 4.1.1.1 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. 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.

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

### 4.1.2 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 multijet (also known as multiple jets) meters. Helical vane impeller meters are also called Woltman meters and use a propeller-like vane to increase the water velocity. Multijet meters are widely accepted in countries such as Brazil, Malaysia, Indonesia, India, Vietnam, etc., where the water supply system is intermittent.

### 4.1.2.1 Single Jet Meters

Single jet 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 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.

### 4.1.2.2 Multijet Meters

Multijet meters are inferential water meters that use an impeller with radial vanes. The operation of multijet meters is similar to that of single jet meters, except that multijet 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 multijet meters tend to be slightly larger in overall size. Multijet 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.

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.

Multijet 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 multijet 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.

### 4.1.2.3 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 (WP) and Vertical (WS). 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.

Woltman meters are affected by flow distortions or changes in meter dimensions that may interfere with the way water passes through the meter. Deposits in the meter can cause over-registration at medium flows and under-registration at low flows. 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. Spiraling flow, caused by two successive bends in different planes, is particularly unfavourable for their accuracy.

### 4.1.3 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. 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.

## 4.2 Electromagnetic Water Meters

Electromagnetic or Magflow water meters' functions 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

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 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 (generally 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 meters are configured for a fixed flow velocity range, typically from 0.5 m/s to 10 m/s. The 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.

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.

The accuracy of electromagnetic meters can however be affected by deposits forming on the electrodes, air in the liquid, turbulence, and to an extent by, water hammer (pressure transients). These meters are also susceptible to damage from lightning strikes if installed outside without canopy. Besides, the electromagnetic meters also need an electrical connection or batteries to operate.

## 4.3 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 and insertion type.

### 4.3.1 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 | 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 and 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.

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, fiber, cement and lined or coated pipes. A disadvantage 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.

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.

### 4.3.2 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.

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.

### 4.3.3 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.

# 5.0 INSTALLATION & TESTING OF WATER METERS

## 5.1 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, so that the top of the meter is below the level of the communication pipes so that meters always contains water, when there is no supply in the line. Also, the minimum straight length condition as per the drawing shall be observed;

(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 rotation during the 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 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.

## 5.2 Testing and Calibration of Water Meters

(i) 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;

(ii) Full bore bi-directional electromagnetic flow 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;

(iii) 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. Bidders 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;

(iv) The sensors 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;

(v) 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;

(vi) 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;

(vii) 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 EEPROM during a power outage and utilizes an overflow counter;

(viii) 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;

(ix) 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;

(x) 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;

(xi) 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;

(xii) 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.

The metering accuracy testing is carried out at as per {IS 779: 1994 (Reaffirmed 2015)} Qmin/Q1, Qt/Q2 & Qn/Q3 separately. Where,

Qmin/Q1: Minimum/Lowest flow rate at which the meter is required to indicate within the maximum permissible error tolerance. It is as mentioned in {IS 779: 1994 (Reaffirmed 2015)} and is determined in terms of the numerical value of meter designation in the case of {ISO 4064:2014}.

Qt/Q2: The flow rate at which the maximum permissible error of the water meter changes in value.

Qn/Q3: Half the maximum flow rate Q max/nominal flow rate.

Qmax/Q4: The highest flow rate at which the meter is required to operate in a satisfactory manner for short periods of time without deterioration.

The accuracy of water meter is divided into two zones i.e. (1) Lower measurable limit in which ±5% accuracy from minimum flow/Q1 to transitional flow/Q2 (exclusive) and (2) Upper measurable limit in which ±2% accuracy from transitional flow/Q2 (inclusive) to maximum flow/Q4.

### 5.2.1 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), Palghat, Central Water & Power Research Station (CWPRS), Pune and Institute for Design of Electrical Measuring Instruments (IDEMI), Mumbai.

# 6.0 REPAIRS, MAINTENANCE & TROUBLESHOOTING OF WATER METERS

## 6.1 Introduction

The water meters are mechanical devices, which normally deteriorate in performance over time. The fact that a meter does not show outward signs of any damage and has a register that appears to be turning does not mean that the meter is performing in a satisfactory way. It is necessary to ascertain preventive care for water meter after proper installation.

The 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/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.

The orifice, Pitot tube, Venturi & Annubar flowmeters 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 the sharpness of the edge as in the case of its deterioration or damage the flowmeter reading may vary up to 20%.

The Ultrasonic and Electromagnetic water meters' accuracy performance is assured for the life of the product. They are generally self-monitored and 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' recommendations.

Turbine meter should be checked for bearing wear out periodically as the 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. In an intermittent water supply, the corrosion rate of the pipe increases due to chlorine and air. The formation of incrustation & subsequent descaling effect flowmeter working especially differential pressure type, turbine meters.

### 6.1.1 Preventive Maintenance

(i) Proper handling, storage, and transportation of water meters
(ii) To clean the dirt box or strainer wherever installed
(iii) To replace the gaskets, if any
(iv) To clean the chamber in which the meter is installed and keep free from flooding, & seepage
(v) To remove the meter for further internal repair/replacement if it does not show the correct reading pattern

### 6.1.2 Breakdown Maintenance

The only basic breakdowns observed during the periodical inspection are replacement of broken glass, lid, and fallen wiper wherever provided. If a meter found not working, then it shall be removed immediately and sent to the meter service workshop. In meter workshops normally following steps are performed to carry out the repairs.

(i) Disassembling of water meters including strainer, measuring unit, regulator, registering the device, etc;
(ii) Clean all disassembled spare parts in detergent solution in warm water;
(iii) Inspect the cleaned parts and replace worn parts and gaskets, if any;
(iv) Inspect the meter body spur threads and cover threads;
(v) Inspect the sealing surface on the meter body and paint the meter body, if necessary;
(vi) Inspect the vane wheel shaft pinion, bearing & pivot;
(vii) Inspect the vane wheel chamber;
(viii) Reassemble the water meter properly after reconditioning;
(ix) Calibrate & test the repaired water meter for leakage & accuracy as per IS 6784: 1996 (Reaffirmed 2017);
(x) Make entry in the life register of that water meter for keeping history records.

**Table 6.1: Troubleshooting of water meter**

| Sr. No. | Trouble | Cause | Remedy |
|---|---|---|---|
| 1. | Meter reads in reverse direction | Might have been installed in the reverse direction | Check the arrow on the meter body and install the meter properly, if necessary |
| 2. | Meter not recording | Impeller to register link broken | Remove the meter for servicing and repairs |
| 3. | Continuously moving pointer/ digit rotates but no change in the indicator | Pointer and drum link missing<br>Drum defect | Remove the meter for servicing and repairs<br>Remove the meter for servicing and repairs |
| 4. | Dial/glass foggy | Climatic condition | Wait for climate change, if it is the rainy season |
| 5. | Meter suspected to be slow or fast | Inlet flow disturbance, missing internally def ective, deteriorated magnets in case of magnetic meter | Clean the external filter/dirt box where provided and the in-built strainer.<br>Ensure full open condition of the upstream valve. If doubt persists, remove meter for testing, servicing & repair |
| 6. | Bush/gland leakage | Gland deformity | Remove meter for testing and servicing |
| 7. | Regulator, head, body leakage | Regular washer damaged, loose screw | Remove the meter and repair |
| 8. | Physical damage to meter including broken seal | Improper installation | Remove meter for testing, servicing, and repair, physical protection arrangement be made |
| 9. | No water available past the water meter even though the inlet side is charged | Semi positive/positive displacement meter with jammed piston | Meter is acting as a stop valve. Remove it for inspection, servicing and repair |

In the case of smaller size of water meters, it is advisable to check cost-benefit ratio before getting them repaired.

## 6.2 Prevention of Tampering of Water Meters

In order to prevent tampering, the following precautions should be taken:

(i) The water meters shall be installed properly in the chamber with lock and key or in the C.I. covers with lock and key to avoid tampering;

(ii) The water meters must be sealed properly;

(iii) The water meter shall not allow reversible flow; it should register flow in forward directions only;

(iv) The water meter dials should be easily readable without confusions;
(v) The lid, glass of water meters must be made up of tough materials as per IS 779: 1994 (Reaffirmed 2015) and shall be replaced timely;
(vi) The wiper or dial as far as possible is avoided;
(vii) In the case of magnetically coupled meters, the proper material to shield magnets must be provided to avoid the tampering of such meter by outside magnets in the vicinity of the meter;
(viii) Periodical inspection/checking at the site is essential to ensure the proper working of the meter;
(ix) Special sealing arrangements may be necessary and provided for bulk meters whereby unauthorized removal of the meter from the connection can be detected.

Inspite of the above, to tackle the problems of tampering suitable penalty provisions/clauses shall be there in the rules or the water supply agreement with the consumer. This will also discourage the consumer tendencies of neglecting water meter safety.

## 6.3 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:

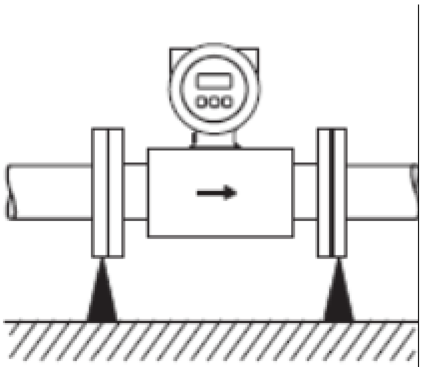
(i) The quality of water meter produced by the manufacturer and it differs from manufacturer to manufacturer;
(ii) The design of pipeline & fittings in line with the meter;
(iii) The workmanship & care when handling and installing the meter;
(iv) The pattern of water passing through the meter;
(v) The 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.

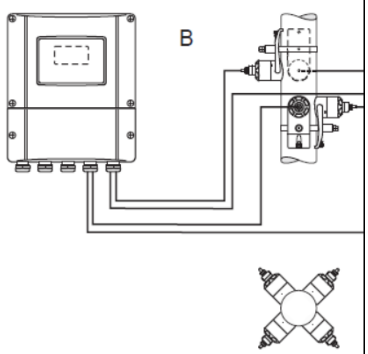
Looking at the number of transactions involved, bulk meters shall be given priority in replacements. Based on the experience gained for a specification work, a well-planned programme for periodical meter testing, servicing, repairs and replacement wherever necessary shall be designed.

# 7.0 FLOW METERS

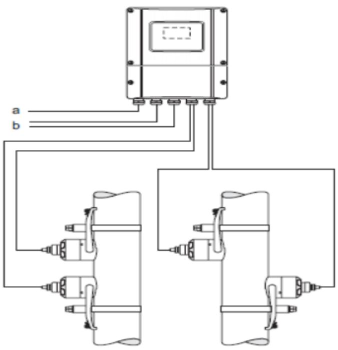
The flow meter is the device used for the measurement of liquids in closed conduits. This device differs on the type of liquid conductive or non-conductive, and also have the other related aspects of the principle of operation. In water supply, mechanical, electromagnetic, or ultrasonic types of flowmeters 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.



Electromagnetic flow meter




Ultrasonic Insertion flow meter




Ultrasonic Clamp-on flow meter

## 7.1 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.

### 7.1.1 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.

### 7.1.2 Range

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

### 7.1.3 Rangeability/Turndown Ratio

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

### 7.1.4 Linearity

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

### 7.1.5 Resolution

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

### 7.1.6 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.

## 7.2 Types of Flow Meter

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

**Table 7.1: Types of Flow Meters**

| Sr. 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<br>ii. No moving parts<br>iii. Flow rate, indication, integration is easily obtained<br>iv. It can be fitted in any configuration of the pipeline<br>v. Suitable for any pipe diameter<br>vi. The signal can be transmitted to long distance<br>vii. Good accuracy | i. Rangeability 4: 1<br>ii. Energy cost in terms of head loss<br>iii. Ideal conditions are required for good accuracy<br>iv. Suitable for a particular range of Reynolds number<br>v. Accuracy in terms of span |

| Sr. No. | Types of Flow Meter | Advantages | Disadvantages |
|---|---|---|---|
| | | viii. Suitable for extreme temperature and pressure<br>ix. Calculation possibilities for unusual situations | vi. Minimum slope for tapping piping has to be maintained i.e. 1:10<br>vii. Very long conditioning section required<br>viii. Intensive maintenance required<br>ix. Edge sharpness of the orifice must be assured.<br>x. It requires isolation of pipeline during installation |
| 2. | Venturi Meter | Advantages are similar to orifice flow meter, and less pressure loss 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 cost. |
| 3. | Pitot Tube | i. As mentioned under orifice flow meter except at Sr. No. vii.<br>ii. It does not require isolation of pipeline for installation and comparatively capital cost of the flow meter is less.<br>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** | | |
| 1a | Turbine Wheel Flow Meter (Full Bore or Inline) | i. Excellent accuracy, linearity, and repeatability<br>ii. Usable at extreme temperature and pressure | i. Suitable for only for low viscosity<br>ii. Moving parts and hence wear<br>iii. Sensitive to contamination<br>iv. Flow profile sensitive and needs conditioning section<br>v. Affected by overloading, the danger of over speeding<br>vi. Sensitive to vibration<br>vii. Isolation of pipeline is required for installation. |
| 1b | Turbine Wheel Flow Meter (Insertion Type) | i. Isolation of pipeline is not required<br>ii. Low cost | i. Inferior accuracy because of point velocity measurement<br>ii. Suspended impurities can clog it. |

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

| Sr. No. | Types of Flow Meter | Advantages | Disadvantages |
|---|---|---|---|
| | | ix. Un- affected by contamination and deposit<br>x. Minimum maintenance<br>xi. Good linearity<br>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. | |
| 4b | Insertion Magnetic Flow Meter | i. Less costly than that of full bore<br>ii. No isolation of pipe line for installation<br>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<br>ii. Long conditioning section is required<br>iii. Sensitive to vibration<br>iv. Periodic cleaning of the electrode is required |
| **5** | **Ultrasonic Flow Meter** | | |
| 5a | Doppler Type Ultrasonic Flow Meter | i. Unobstructed flow passage<br>ii. No moving parts<br>iii. No pressure drop<br>iv. Measures flow in both directions<br>v. Installations of individual elements in existing pipe lines possible<br>vi. Minimum maintenance<br>vii. Economical for large diameter pipe<br>viii. Suitable for turbid water | i. Not suitable for clear water<br>ii. Accuracy is inferior<br>iii. It requires a long conditioning section |
| 5b | 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<br>ii. Accuracy is improved in multipath<br>iii. Accuracy is superior in insertion (wetted type) than that of clamp type. | i. It requires long conditioning section<br>ii. Not suitable for turbid water or carrying air/gas bubbles. |

## 7.3 Installation & Maintenance of Flow Meters

### 7.3.1 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 existing water supply 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.

### 7.3.2 Maintenance of Flow Meters

Modern development in the flowmeter measurement is that in most of the equipment a self- monitoring 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-monitoring, 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. 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 7.2: 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 7.3: 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.>$200^0$C) not applicable; A: General liquid application (< 50 CP); B: Low liquid flows (<2 L /min)

## Table 7.4: 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 7.5: 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. | Doppler | H, VU,VD,I | U,B | 10D | 5D | >25 |
| 12. | 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 7.6: 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 | $3 \times 10^4$ | 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 | $2 \times 10^4$ | P |
| 8. | Insertion Vortex | 70 | - 30 to +150 | $5 \times 10^3$ | N |
| 9. | Electromagnetic | 300 | -60 to +220 | No limit | S/P |
| 10. | Elect. Insertion | 20 | +5 to +25 | No data | N |
| 11. | Doppler | Pipe pressure | -20 to +80 | $5 \times 10^3$ | S |
| 12. | Transit time | 200 | -200 to +250 | $5 \times 10^3$ | N/P |

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

### Table 7.7: 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 Ele. Mag. | 2 | 3 | 2 | 3 | 2 |
| Doppler | 1-3 | 1 | 1 | 3 | 2 |
| 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 7.8.

**Table 7.8: 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 | - |

## 7.4 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 7.9.

**Table 7.9: Common Problems Encountered in Flow Meter Performance**

| Sr. No. | Problems | Causes | Flowmeter | Remedial Action |
|---|---|---|---|---|
| 1. | Erractic reading | Operated below lower range having limited rangeability of flow meter | Differential pressure 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 contract 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 cylindrical within the range of 0.3% of the diameter of the pipe | D.P. & Linear type | Replace the pipe length 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 |

# 8.0 ONLINE MEASUREMENT INSTRUMENTATION

## 8.1 Level Measurement

### 8.1.1 Introduction

Whenever water parameters are considered, both water quantity and water quality must be given equal weightage. Instrumentation facilitates the coordination of various water parameters, which are essential for the optimization of water supply & treatment plants. One of the important parameters amongst them is water level measurement, which is carried out at various locations viz water reservoir, inlet chamber, open channel, alum feeding tank, lime tank, filter beds, air vessel, sump well, etc.

This measurement is accomplished in waterworks by following two ways:

A. Direct Method
B. Inferential Method

**Direct Method** – Their merits, demerits as well as uses are given in brief below:

**Table 8.1: Direct Method of Level measurement**

| Hook Type Level Indicator | Sight Glass | Float Type Indicator |
|---|---|---|
| **Advantages** | | |
| i. Low cost<br>ii. Simple | i. Inexpensive<br>ii. Corrosion resistive<br>iii. Simple | i. The level can be read at a convenient place<br>ii. Operates over large temperature range<br>iii. Very accurate |
| **Disadvantages** | | |
| i. Only local reading<br>ii. Human error may be encountered in reading | i. Only local reading<br>ii. Accuracy and readability depends on the cleanliness of glass and fluid<br>iii. It is fragile | i. They are tailored to tank geometry<br>ii. Requires a certain amount of mechanical equipment |
| **Uses** | | |
| i. Inlet channel level | i. Filter bed level<br>ii. Reservoir level<br>iii. Head loss in the filter | i. Filter bed<br>ii. Final water reservoir<br>iii. Sump well<br>iv. Lime tank |

**Inferential Method** – Some specifications of the recent level transmitters as mentioned below:

**Table 8.2: Inferential Method of Level measurement**

| Hydrostatic Pressure Gauge Type & Pressure Bulb Type | Displacer Level Type | Electrical Method (Capacitance Type) | Ultrasonic |
|---|---|---|---|
| **Advantages** | | | |
| i. Easy maintenance<br>ii. Simple to adjust<br>iii. With pressure, bulb type remote reading possible<br>iv. Reasonably accurate | i. Excellent accuracy<br>ii. Possible at remote places | i. Good accuracy<br>ii. Possible at remote places<br>iii. Very sensitive<br>iv. Suitable for highly corrosive media | i. Good accuracy<br>ii. Possible at remote places<br>iii. Suitable for liquid as well as bulk products |
| **Disadvantages** | | | |
| i. The instrument must be installed at base reference level for gauge type<br>ii. Pressure bulb type relatively costly | i. Limited range<br>ii. High cost<br>iii. Requires stilling chamber<br>iv. Requires a significant amount of mechanical equipment | i. Affected by dirt & other contaminants<br>ii. Affected by temperature | i. Affected by foam<br>ii. Not suitable for high temperature & pressure |
| **Uses** | | | |
| i. Delivery head of the pump (pressure gauge type)<br>ii. Clear or raw water reservoir<br>iii. Sump level | i. Clear water reservoir<br>ii. Raw water reservoir | i. Raw water reservoir<br>ii. Clear water reservoir | i. Raw water as well as clear water level i.e. inlet channel sump level etc.<br>ii. Lime tank<br>iii. Sludge level |

### 8.1.2 Maintenance of Level Measuring Instruments

**Sight Glasses**

- After closing top and bottom valves remove the glass and clean with soap water using the brush. Clean with fresh water. Assemble the parts again in proper order.

**Float Operated Instrument**

- Guide cable wound round a pulley should be lubricated. Other moving parts should also be lubricated;
- Zero setting should be checked. Float should be checked from a corrosion point of view.

**Hydrostatic Pressure Instruments (Pressure Gauge Type)**

- Check for Zero settings after disconnecting from the system and purging out;
- Check for the leakages from the connection after reconnecting it.

**Pressure Bulb Type**

- Check for zero settings. Check for air leakages from the bulb by applying soap water;
- Check coupling from a corrosion point of view;
- Clean the bulb with fresh water;
- Check for the correctness of the signal by moving the bulb in the water.

**Displacer, Electrical or Ultrasonic Instrument**

- Clean the instrument and check for zero and range setting as per manufacturer recommendations.

## 8.2 Pressure Measurement

In the water supply network pressure, parameter plays a very important role to get sufficient water to the consumers. Similarly, in flow measurement by differential pressure type flow meter, differential pressure measurement across the primary element is the main physical parameter to interlink with flowing fluid. This pressure or differential pressure measurement is accomplished with the help of following methods in water works:

A. Manometers
B. Elastic Pressure Transducer
C. Electrical Pressure Transducer

The advantages and disadvantages of the instrument of pressure measurement normally used in waterworks are given below:

## A. Manometers

**Table 8.3: Types of Manometers**

|

| U Tube Manometers | Well Type Manometers | Inclined Manometers |
|---|---|---|
| **Advantages** | | |
| i. Simplest<br>ii. Low cost | i. Zero reference setting is possible<br>ii. Low cost | i. More sensitive<br>ii. Low cost |
| **Disadvantages** | | |
| i. No fixed reference<br>ii. Large & bulky<br>iii. Need for levelling<br>iv. No over range protection | i. Accuracy inferior to U tube manometer<br>ii. Large & bulky<br>iii. Need for levelling<br>iv. No over range protection | i. Large & bulky<br>ii. Need for levelling<br>iii. No over range protection |
| **Uses** | | |
| i. For measurement of differential pressure in D.P. type flow meter & calibration of D.P. type transducers | i. For calibration of D.P. type flow meters & measurement of differential pressure in D.P. type flow meter | i. For measurement of very small pressure differences |

## B. Elastic Pressure Transducer: Commonly used

Bourdon tube type pressure gauge:

**Advantages**

(i) Low Cost
(ii) Simple construction
(iii) Time tested in applications
(iv) Availability in a wide range
(v) Adaptability to electronic instruments
(vi) High accuracy in relation to cost

**Disadvantages**

(i) Low spring gradient below 3 $kg/cm^2$
(ii) Susceptibility to shock and vibration
(iii) Susceptibility to hysteresis
(iv) Accuracy in terms of full-scale deflection

**Uses**

(i) Pump delivery & suction
(ii) Water supply distribution network
(iii) Air receivers
(iv) Chlorinators

(v) Pump cooling water

**C. Electrical Pressure Transducer**

In this category following types are there:

(i) Strain gauge pressure transducer
(ii) Potentiometric pressure transducer
(iii) Capacitive pressure transducer
(iv) Variable reluctance pressure transducer
(v) Piezo electric pressure transducer

The advantages & disadvantages of electrical pressure transducers commonly used in water works are as follows:

**Table 8.4: Advantages & Disadvantages of Electrical Pressure Transducers**

| Potentiometric Transducer | Capacitive Pressure Transducer | Variable Reluctance Type |
|---|---|---|
| **Advantages** | | |
| i. Widely used in Industry as these are simpler and less expensive<br>ii. Easy compatibility with the requirement | i. Short response time<br>ii. Vibration-proof<br>iii. Extremely sensitive<br>iv. It can measure static as well as dynamic changes | i. Excellent linearly<br>ii. Good repeatability<br>iii. Low hysteresis<br>iv. High sensitivity |
| **Disadvantages** | | |
| i. Finite resolution<br>ii. Wear out early<br>iii. Noise signal is generated | i. Sensitivity changes with temperature | i. Relatively large size<br>ii. More nos. of components<br>iii. More maintenance |
| **Uses** | | |
| i. Where less accuracy is required | i. Distribution network<br>ii. In process instrumentation | i. Distribution network<br>ii. In process instrumentation |

## 8.2.1 Calibration of Pressure Measuring Instruments

Pressure instrument calibration is the process of adjusting the instruments output signal to match a known range of pressure. All instruments tend to drift from their last setting. This is because springs stretch, electronic components undergo slight changes on the atomic level, and other working parts sag, bend or lose their elasticity. The calibration procedure includes zero, span, and linearity adjustments. The pressure is varied with the help of a pneumatic calibrator so as to give desired pressures to the instrument. The settings are carried out on the instrument for zero and span adjustment on the basis of applied pressures. For carrying out linearity setting various pressures between zero and maximum range of the instruments are applied and adjusted the output of the measuring instrument with the help of controls provided in the instrument.

In the case of pressure gauges, the calibration is carried out by means of dead weight tester.

In absence of a pneumatic calibrator, the air can be supplied to the instrument with proper pressure regulator, and pressure is measured with the help of a manometer so as to calibrate the instrument.

The calibration should be checked every 3, 6 or 12 months depending upon the use and accuracy expected, as per the manufacturer's recommendation and latest ISO standards.

Maintenance of pressure instruments is essential for their proper working and accurate reading. It also improves the life and reliability of the instruments.

### 8.2.2 Preventive Maintenance

The manufacturer of the instrument gives the instructions in the manual supplied along with the instruments. These instructions explain how to maintain the instrument. Generally, these consist of the following categories:

**1. Visual Inspection**

Any damage to piping or wiring of the instrument observed should be immediately rectified. It avoids the entry of foreign bodies into the system and further damage to the instrument.

**2. Venting or Blow down**

Liquid lines are generally clogged subsequently if those are not vented periodically. Similarly, air or gas in the liquid columns gives wrong readings. In order to avoid such incidents, it is essential to blow down the instrument piping periodically on the basis of experience gained in the field.

**3. Cleaning and Lubrication**

Instruments with mechanical linkages undergo wear and misalignment. Dirt may clog the linkages, causing the mechanism to become less flexible. If not attended these kinds of faults, the instrument may breakdown subsequently. This clogging can be removed by cleaning, and the working of the instrument can be improved by lubrication as per manufacturer's recommendations. Dust can be removed from the panels as well as from the instruments with the help of an air blower. If auto test facility is provided on the instrument by the manufacturer the same can be used to check the performance of the instrument daily. If any kind of fault occurs, in such instrument, the same is identified and displayed by the instrument itself.

**Table 8.5: A Typical Troubleshooting Chart for Pressure & Level Measuring Instrument (Electronic Transmitter Type)**

| Fault | Possible Causes | Corrective Action |
|---|---|---|
| Low output or Zero output or High output or Erratic output | Power Supply | Check the output of power supply |
| | | Check for short and multiple grounds |
| | | Check polarity of connections |
| | | Check loop impedance |
| | Pressure tapping | Check the pressure connection |
| | | Check for leakage or blockage |
| | | Check for entrapped air or gas in the line |
| | Transmitter | Check for shorts in sensor leads |
| | | Check connector to transmitter |
| | | Check for amplifier assembly by replacing it with the spare one |
| | Sensing element | Check the sensing element for its working by gently tapping it |
| Tapping by hand gently the mechanism sensor does not respond | Mechanical | Check mechanical linkage |
| | | Check for dirt finding |
| | | Excessive wear, misalignment |
| | | For dirt clean and lubricate as per manufactures recommendations |
| | | Realign mechanical parts if necessary |
| | | For wear replace the worn-out components |
| | Electrical | Replace electrical/ electronic subassemblies and perform calibration |

**Table 8.6: Typical Specification for Online Measurement of Pressure**

| | |
|---|---|
| Specifications | Pressure Range 0 to 10 / 20 / 50 / 100 Kg/cm$^2$ g |
| Process Temperature Range | -20 to +125°C |
| Output Signal | 4 to 20 mA with superimposed digital communication protocol HART, 2-wire |
| Signal Range | 4 to 20 mA HART |
| Signal on Alarm | As per NAMUR NE 43<br>• 4 to 20 mA HART<br>Options: Max. alarm: can be set from 21 to 23 mA (factory setting: 22 mA)<br>• Hold measured value: last measured value is held |

| | |
|---|---|
| | • Min. alarm: 3.6 mA |
| Resolution | Current output: 1 microAmp<br>Display: can be set (setting at the factory: presentation of the maximum accuracy of the transmitter) |
| Response Time | <250 ms |
| Damping | Via local display, handheld terminal or PC with the operating program, continuous from 0 to 999 s<br>Additionally, for HART: via DIP switch on the electronic insert, switch position "on" = value set in the 2 Sec As default |
| Supply Voltage | 11.5 to 45 V DC |
| Residual Ripple | No influence on 4 to 20 mA signal up to ± 5 % residual ripple within the permitted voltage range [according to<br>HART hardware specification HCF_SPEC-54<br>(DIN IEC 60381-1) |
| Influence of Power Supply | < 0.0006% of URL/1 V |
| Reference Accuracy | ± 0.075% of the set Span |
| Climate Class | Class 4K4H (air temperature: –20 to 55°C / –4 to +131°F, relative humidity: 4 to 100%) satisfied as per<br>DIN EN 60721-3-4 – Seal Capsuled electronics. |
| Housing | Die Cast Alu. Housing |
| Diaphragm Material | Ceramic Dry measuring cell, Capacitive measuring cell |
| Display Operation | 3 Key Push button for configuration without HART COMMUNICATOR. A 4-line liquid crystal display (LCD) is used for display and operation |
| Long Term Stability | ± 0.25% URL/year for 1 year, 5 year |
| Turn Down | 100:1 |

### 8.2.3 Radar Level Transmitters

They provide a non-contact type of level measurement in case of liquids in a metal tank. They make use of EM i.e. electromagnetic waves usually in the microwave X-band range which is near about 10 GHz. Hence, they can be also known as microwave level measurement devices. However, there are some differences between radar and microwave types. They are:

(i) Power levels in the case of radar systems are about 0.01 $mW/cm^2$ whereas, in the case of microwave systems, these levels range from 0.1 to 5 $mW/cm^2$

(ii) Microwaves can work at higher energy levels; hence they are competent enough to endure extra coating as compared to radar level detectors

A radar level detector includes:

(i) A transmitter with an inbuilt solid-state oscillator
(ii) A radar antenna
(iii) A receiver along with a signal processor and an operator interface

The operation of all radar level detectors involves sending microwave beams emitted by a sensor to the surface of the liquid in a tank. The electromagnetic waves after hitting the fluid's surface return back to the sensor which is mounted at the top of the tank or vessel. The time taken by the signal to return back i.e. Time of Flight (TOF) is then determined to measure the level of fluid in the tank.

**Table 8.7: Radar Level Transmitter**

| **Radar – Microwave type level transmitter** | **Service: Raw Water (Non-Contact Type)** |
|---|---|
| **Transmitter** | |
| Type | Microwave level measurement |
| Principle | Pulse Time of Flight |
| Output | 4-20 mA HART Current |
| Housing | Die-Cast Aluminium |
| Electromagnetic compatibility | Interference Immunity to EN 61326, Annex A (Industrial) and NAMUR |
| Ingress protection | IP65 / IP 66 / IP 67 |
| Accuracy | ±3 mm |
| Area classification | Non-Hazardous |
| Display | 4-line LCD Display. Menu guided operation. Display of Envelope Curve. |
| Configuration | Using the keypad on display |
| **Sensor** | |
| Range | Liquids 0 to 5m and 0 to 10m depending on Tank size |
| Temperature range | -40°C ... +80°C |
| Max pressure | 3 bar abs |
| Materials | Sensor: PVDF Seal: EPDM |
| Antenna seal | FKM Viton |
| Process connection | Threaded or universal flange dependent on model selection |
| Degree of protection | IP65 |

## 8.3 Water Quality Parameter Monitoring

In water works, various treatment processes are carried out to supply potable water. The parameters of the water which are normally used for monitoring are as follows:

(i) Turbidity
(ii) pH

(iii) Residual Chlorine

These parameters are monitored either by means of on-line instruments or by analytical laboratory instruments or both. Their relative advantages and disadvantages are as follows:

### 8.3.1 Turbidity Meter

**Table 8.8: Advantages and Disadvantages of Turbidity Meter**

| Online | Laboratory Type |
|---|---|
| **Advantages** | |
| i. Turbidity continuously monitored<br>ii. Can be hooked up for automation<br>iii. Can be set for giving an alarm if minimum and maximum limits of turbidity are exceeded.<br>iv. Human error in sampling is eliminated | i. Low cost<br>ii. Simple to use<br>iii. Portable<br>iv. Easy maintenance |
| **Disadvantages** | |
| i. High cost<br>ii. High maintenance is required<br>iii. Periodical calibration is required<br>iv. It is not portable | i. Does not monitor continuously<br>ii. Human error may encounter<br>iii. Low accuracy |
| **Maintenance** | |
| i. Clean chamber & lense with fresh water<br>ii. Microprocessor based instrument has a self-calibration facility which is useful for periodical calibration<br>iii. Clean sources of light | i. Clean sampling tube with fresh water<br>ii. Bulb, standard sample tubes and lense should be cleaned with soft cotton<br>iii. Calibrate before carrying out the measurement<br>iv. Calibrate with standard samples of 100 NTU, 10 NTU & 1 NTU or calibrate with formazin standard solution |

#### 8.3.1.1 Typical Specification for Online Measurement of Turbidity

Online sensor based on Nephelometric 90 degree scattering light method as per ISO 7027. The sensor must be an easy plug and play with digital communication based on inductive energy transfer with IP68 rating suitable for measuring range 0 to 9999 FNU /NTU with an accuracy of <2% of measured value or 0.1 FNU/NTU. The sensor shall store on-board all the calibration data and other diagnostic information. The sensor must have provision to store at least 5 user calibration points. The offered transmitter shall be 4 wire digital with the possibility of connecting multiple sensor inputs for additional parameters – referred to as multichannel /multi parameter type. The transmitter shall be suitable for outdoor installation with IP66/67 rating.

**Table 8.9: Online Turbidity Meter**

| Turbidity Measurement | |
|---|---|
| **Transmitter** | |
| Type | Turbidity and suspended solids transmitter |
| Principle | Nephelometric measuring principle 90° NIR scattered light according to ISO EN 27027 |
| Output | 4-20 mA HART current |
| Supply voltage | 100 / 115 / 230 V AC +10 / –15%, 48 ... 62 Hz ; 24 V AC/DC +20 / –15% |
| Material | Field Housing: ABS PC Non-corrosive type |
| Display | LC display, two lines, with status indicators |
| Electromagnetic compatibility | interference emission and interference immunity acc. to EN 61326-1:1998 |
| Protection class of field housing | IP 65 |
| Ambient temperature | – 20 to 60 °C |
| Self-Diagnostic feature | Required |
| **Sensor** | |
| Measurement range | 0 – 9999 FNU / 0 - 3000 ppm / 0 – 3.0 g/L |
| Material | Sensor shaft : PVC / PPS GF40 Optical window : sapphire Cable : TPEO |
| Max Process temperature | 50°C |
| Max Process pressure | 10 bar |
| Temperature sensor | Integrated NTC temperature sensor |
| Connection | Fixed cable connection |
| Ingress protection | IP68 |
| Additional Certifications | Calibration certification |
| Resolution | 0.001 FNU, 0.01 ppm, 0.1 g/l, 0.1% |
| Measurement error | <2% of meas. value (min. 0.02 FNU) |

## 8.3.2 pH Meter

**Table 8.10: Advantages and Disadvantages of pH Meter**

| Online | Laboratory Type |
|---|---|
| **Advantages** | |
| i. Continuously monitored<br>ii. Can be hooked up for automation<br>iii. Can be set for giving alarm for specified limits<br>iv. Human error in sampling is eliminated | i. Low cost<br>ii. Simple to use<br>iii. Portable<br>iv. Easy maintenance |
| **Disadvantages** | |
| i. High cost<br>ii. Periodical calibration is required<br>iii. High maintenance cost (replacement of electrodes)<br>iv. It is not portable | i. Does not monitor continuously<br>ii. Human error may encounter<br>iii. Low accuracy |

| Online | Laboratory Type |
|---|---|
| **Maintenance** | |
| i. Clean electrode with soap water or clean with 5% concentrated $H_2S0_4$ and 6% concentrated $H_20_2$<br>ii. Calibrate periodically with a standard solution of pH 4 and pH 7<br>iii. Replace electrodes if dried up | i. Clean sampling electrode with distilled water<br>ii. Calibrate the instrument with three standards samples i.e. pH 4, pH 7 & pH 9.2<br>iii. Prepare standard samples from readily available capsules<br>iv. Calibration may last from 4 days to 7 days |

### 8.3.2.1 Typical Specification for Online Measurement of pH

Online pH sensor is based on potentiometric measurement using a glass sensor. The sensor shall have digital communication based on inductive energy transfer. The sensor shall have inbuilt memory to store calibration data and other additional diagnostic information. The offered transmitter shall be 4 wire digital with the possibility of connecting multiple sensor inputs for additional parameters – referred to as multichannel /multi parameter type. The transmitter shall be suitable for outdoor installation with IP66/67 rating.

**Table 8.11: Online pH Meter**

| Transmitter | |
|---|---|
| Type | Glass electrode |
| Principle | Glass electrode with dirt repellent PTFE diaphragm |
| Output | 4-20 mA HART current |
| Supply voltage | 100 / 115 / 230 V AC +10 / –15%, 48...62 Hz ; 24 V AC/DC +20 /–15% |
| Material | Field Housing : ABS Polycarbonate non corrosive |
| Display | LC display, two lines, with status indicators |
| Electromagnetic compatibility | Interference emission and interference immunity acc. to EN 61326: 1997 / A1: 1998 |
| Protection class of field housing | IP 68 |
| Ambient temperature | –20 ... +60 °C |
| Diagnostic feature | Required |
| **Sensor** | |
| Measurement range | pH 0 - 14 |
| Material | Glass |
| Max Process temperature | 130°C |
| Max Process pressure | 6bar |
| Temperature sensor | NTC / Pt100 |
| Connection | Inductive digital connection with Transmitter |
| Ingres protection | IP68 |
| Additional Certifications | FM, ATEX, CSA |
| Resolution | pH 0.01, Temp 0.1°C |

| | |
|---|---|
| Measurement Error | ± 0.5% of Measuring range |

## 8.3.3 Residual Chlorine Meter

**Table 8.12: Advantages and Disadvantages of Chlorine Meter**

| Online | Laboratory Type (Lovibond Type) |
|---|---|
| **Advantages** | |
| i. Continuously monitored<br>ii. Can be hooked up for automation<br>iii. Can be set for giving alarm for specified limits<br>iv. Human error in sampling is eliminated | i. Low cost<br>ii. Simple to use<br>iii. Portable<br>iv. Easy maintenance |
| **Disadvantages** | |
| i. High cost<br>ii. Periodical calibration is required<br>iii. High maintenance cost (replacement of membrane)<br>iv. It is not portable<br>v. It requires electricity of battery or solar | i. Does not monitor continuously<br>ii. Human error in sampling may encounter<br>iii. Low accuracy |
| **Maintenance** | |
| i. Clean membrane if it gets clogged<br>ii. If the membrane is damaged replace it with the new one<br>iii. Fill up/ DPD membrane /electrolyte if necessary<br>iv. Calibrate it using Potentiometric electrode | i. Clean tubes with distilled water<br>ii. Calibration is not required as it is a comparator |

### 8.3.3.1 Typical Specification for Online Measurement of Chlorine

Online chlorine analyzer is based on Amperometric / membrane-based measurement of active chlorine converted to free chlorine by means of pH compensation. The sensor shall have digital communication based on inductive energy transfer which will withstand moisture, corrosion, and ensures reliable data transmission. Complete measuring system includes chlorine sensor, pH sensor with suitable flow assembly for mounting these sensors along with the transmitter. The offered transmitter must be IP65, Interference emission & immunity as per EN 61326-1:2006.

**Table 8.13: Online Chlorine Meter**

| Transmitter | |
|---|---|
| Type | Free chlorine |
| Principle | Amperometric measurement of free chlorine |
| Output | 4-20 mA HART current |
| Supply voltage | 100 / 115 / 230 V AC +10 / –15%, 48 ... 62 Hz ;<br>24 V AC/DC +20 / –15% |
| Material | Field housing: ABS PC Fr |
| Display | LC display, two lines with status indicators |

| Transmitter | |
|---|---|
| Electromagnetic compatibility | Interference emission and interference immunity acc. to ISO EN 61326: 1997 / A1: 1998 |
| Protection class of field housing | IP 65 |
| Ambient temperature | -20….+60ºC |
| **Sensor** | |
| Measurement range | 0.01 – 5ppm free chlorine |
| Material | Sensor Shaft: PVC |
| | Membrane: PTFE |
| | Membrane cap: PBT (GF30); PVDF |
| Process temperature | +2ºC…..+45ºC |
| Max process pressure | 1 bar |
| Temperature sensor | NTC/ Pt100 |
| Connection | Inductive digital connection with transmitter |
| Ingress protection | IP 68 |
| Resolution | 0.01 mg/l |
| Measurement error | ±0.5% of measuring range |

# 9.0 TELEMETRY AND SCADA SYSTEMS

## 9.1 Manual Monitoring

Normally, the managers of O&M of water utilities monitored levels in service reservoirs, pressures, and flows in a distribution system and on the operation of pumps such as hours of pumping and failure of pumps and monitored water quality by measuring residual chlorine. The manager usually used the telephone line or wireless like VSAT or GPRS / GSM unit to gather the data, used his discretion gained with experience, and took 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. This is possible if the management acquires operational data at a very high cost.

## 9.2 Telemetry

The inspection, monitoring, and control of O&M of a water utility can be automated partially through telemetry. Telemetry enables regular monitoring of the above data on a real-time basis and the data is provided to anyone in the organization who can review the data and make a decision. In a telemetry system probes/sensors will be used which will sense and generate signals for the level, pressure, flow, and water quality like pH, turbidity, residual chlorines in a given unit and transmit the signals by radio/by telephone, VSAT, GSM / GPRS. Normally radio link is used and telephone line with the modem is used as spare communication. Microwave satellite or fiber-optic transmission systems are also used for data transmission. The water pumping stations may communicate via a cable buried with the pipe. However, there may be locations where the main power may not be available and hence solar panels with a battery charger are used to power the remote terminal unit (RTU) and the radio, VSAT, GSM / GPRS. In urban areas, RTUs can communicate on cell phones and or packed radio networks. For remote locations satellite technology is also available.

### 9.2.1 Data for Collection by Telemetry

The data includes levels in service reservoirs, pressures and flows in a distribution system, flows/quantity and water quality like pH, turbidity, residual chlorines of delivery into an SR and data on the operation of pumps such as voltage, amperes, energy consumed, operating times and downtimes of pumps and chlorine residuals. In a telemetry system up-to-the-minute real-time information is gathered from a remote terminal unit located at the water treatment plant, reservoir, flow meter, pumping station, etc. and transmitted to a central control station where the information is updated, displayed and stored manually or automatically.

### 9.2.2 Processing Data from Telemetry

The meter readings from reservoirs are useful information for managing the distribution system and help in preventing overflow from reservoirs. However, the effectiveness of telemetry in pumping operations is dependent on the reliability of instrumentation for measuring flows, pressures, KWh meters, etc. Standard practice is to calculate pump efficiency and water audit calculations on a monthly basis. Telemetry can also be used to supervise a water hammer protection system wherein the pump failures are linked to initiate measures to prevent the occurrence of water hammer.

## 9.3 SCADA Systems

Instead of manual review of data collected by telemetry and initiating action manually, if telemetry is extended to include actions based on the data for remote control of pumps and other equipment then such a system is known as SCADA. Supervisory Control and Data Acquisition (SCADA) is a computer-aided system that collects, stores, and analyses the data on all aspects of O&M. It gives a better understanding of what is happening in terms of water quantity or water quality which is sourced and supplied. SCADA can do any activity like on/off any equipment or start /stop.

The operating personnel can retrieve the data and control their operations and sometimes the system itself is programmed to control the operations on the basis of the acquired data. SCADA enhances the efficiency of the O&M personnel who are better informed about the system and hence are in full control of the operations. Whether in a telemetry system or a SCADA system up-to-the-minute real-time information is gathered from the remote terminal unit located at the water treatment plant, reservoir, flow meter, pumping station, etc. and transmitted to a central control station where the information is updated, displayed and stored manually or automatically. In a SCADA system, the information is linked to a supervisory system for local display, alarm annunciation, etc. which may be linked to remote control of pumping operations or operation of valves, etc.

## 9.4 Smart Communication

The smart data and communication is more of revenue model and having better control over NRW (Non-Revenue Water or UFW – Unaccounted for flow of water)

### 9.4.1 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.

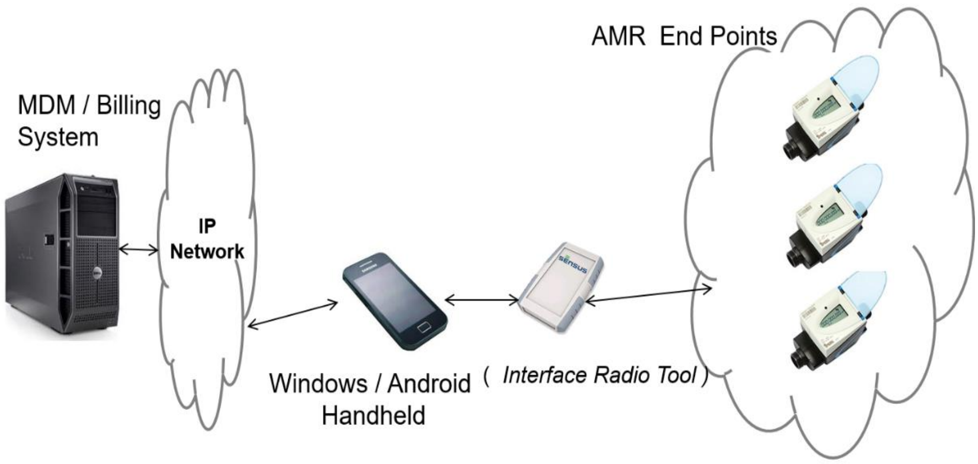
The solution to the above difficulties is to install an automatic system to read meters and process the results by computer. Because of development in integrated circuit technology and low powered radio trans receivers, this system to some extent is simplified.

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.

### 9.4.2 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.




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 - Reduced GHG;
(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 AMI and AMR System Primer 5;
(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 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 platform can help in finding leaks & water theft in distribution networks which reduces manpower & operational cost
   - Hydraulic modelling simulations

### 9.4.3 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.

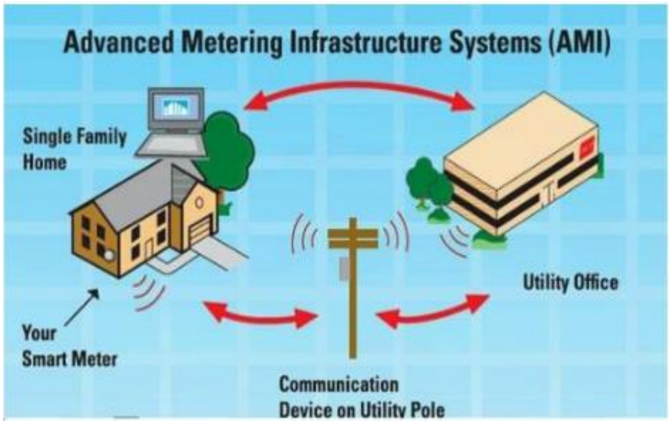
5. **Radio:** In this system, a radio frequency transmitter is installed at the meter and the receiver is either located at a fixed location or movable through the vehicle. The dialogues between transmitters and receivers are taking place either in predetermined time or on demand.

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

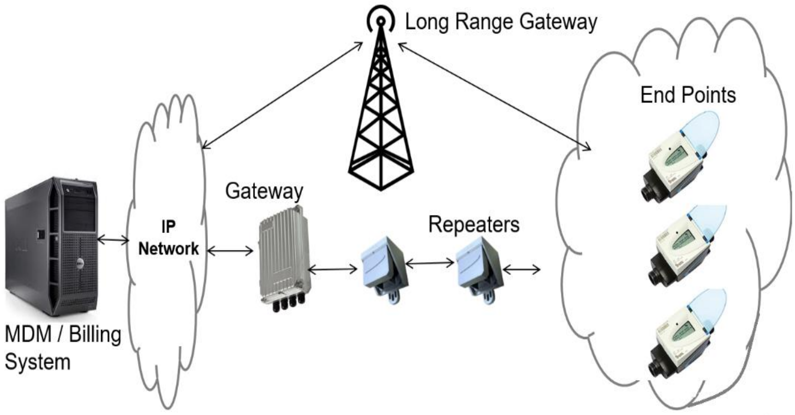
(i) Improvement in the efficiency of meter reading;
(ii) Reduced operating cost;
(iii) Skipping of access problems of meter reading;
(iv) Estimated billing not necessary;
(v) Tampering of meter can be detected;
(vi) Back up to customer information services.

### 9.4.4 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.




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.




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.

## 9.5 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 Fiber Cable, etc.

## 9.6 Data Collected in SCADA/ Smart Metering 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 fiber-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.

## 9.7 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.

## 9.8 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. 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.

# 10.0 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 adopting 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 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.

## 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<br>Replaced by: BS EN ISO 20456:2019 | Specification for Electro Magnetic flow meters |
| 3 | BS EN ISO: 6817:1997<br>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)<br>Replaced by: ISO 5167-1:2003 | Measurement of fluid flow by means of orifice plates and nozzles |
| 5 | ISO 9104:1991/<br>Revised by: ISO 20456:2017<br>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/<br>ISO 9368:1990<br>Confirmed Year:1998 | Measurement of liquid flow in closed conduits by using weighing and volumetric methods |
| 7 | IS: 4477 Part-2: 1975<br>Reaffirmed Year : 2016 | Methods of measurement of fluid flow by means of Venturi meters: Part-2 Compressible Liquids |
| 8 | IS 2951 Part I: 1965<br>Reaffirmed Year : 2017 | Recommendations for estimation of flow of liquids in closed conduits<br>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<br>Reaffirmed Year : 2017 | Method for estimation of incompressible fluid flow in closed conduits by Bend meters |
| 11 | IS 779: 1994<br>Reaffirmed Year : 2015 | Water meters (Domestic type) – Specification (Sixth revision) |
| 12 | IS 2373: 1981<br>Reaffirmed Year: 2017 | Specifications for water meters (Bulk type) (Third revision) |
| 13 | IS 6784: 1996<br>Reaffirmed Year : 2017 | Methods for Performance Testing of Water Meters |
| 14 | BS 5728 | Measurement of flow of cold potable water in closed conduits |

| Sr. No. | Standard / Reference | Title/Description |
|---|---|---|
| | | Part-I (1979): Specification for single meters<br>Part-II (1980): Specification for installation requirements for single meters<br>Part-III (1997): Methods for determining principal characteristics of single meters |
| 15 | ISO: 4064:2014<br>Confirmed Year: 2019 | Water meters for cold potable water and hot water<br>Part-1: Metrological and technical requirements<br>Part-2: Test methods and equipment<br>Part-5: Installation requirements |
| 16 | AWWA Manual 6 | Water Meters - Selection, Installation, Testing and Maintenance |
| **Closed Pipe Flow Measurements** | | |
| 1 | ISO 1088: 2007<br>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<br>Confirmed Year: 2017 | Velocity-area method using current-meters in full conduits and under regular flow conditions |
| 3 | ISO 4006: 1991<br>Confirmed Year: 2019 | Measurement of fluid flow in closed conduits — Vocabulary and symbols |
| 4 | ISO 4064-1: 2005<br>Replaced by:<br>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<br>Confirmed Year: 2019 | Water meters for cold potable water and hot water — Part 2: Test methods |
| 6 | ISO 4064-5: 2014<br>Confirmed Year: 2019 | Water meters for cold potable water and hot water — Part 5: Installation requirements |
| 7 | ISO 4185: 1980<br>Confirmed Year: 2019 | Measurement of liquid flow in closed conduits — Weighing method |
| 8 | ISO 5167-1: 2003<br>Confirmed Year: 2014<br>Status: Current | Flow Measurement via Differential Pressure Methods: General |
| 9 | ISO 5167-2: 2003<br>Confirmed Year: 2014 | Flow Measurement via Differential Pressure Methods: Orifices |
| 10 | ISO 5167-3: 2003<br>Confirmed Year: 2014 | Flow Measurement via Differential Pressure Methods: Nozzles |
| 11 | ISO 5167-4: 2003<br>Confirmed Year: 2014 | Flow Measurement via Differential Pressure Methods: Venturis |
| 12 | ISO 5168: 2005<br>Reaffirmed 2015 | Measurement of fluid flow — Procedures for the evaluation of uncertainties |
| 13 | ISO 6416: 2004<br>Revised by<br>ISO 6416:2017 | Measurement of discharge by ultrasonic (acoustic) method |
| 14 | ISO/TR 9464: 2008 | Guidelines for the use of ISO 5167 |

| Sr. No. | Standard / Reference | Title/Description |
|---|---|---|
| | Confirmed Year: 2019 | |
| 15 | ISO 6817: 1992<br>Replaced by:<br>ISO 20456:2017 | Closed Pipe Flow Measurements: Electromagnetic Flowmeters |
| 16 | ISO 8316: 1987<br>Confirmed Year: 2019 | Flow Measurement by Volumetric Tank Collection Method |
| 17 | ISO 9104: 1991<br>Replaced by:<br>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<br>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<br>Replaced by:<br>ISO 20456:2017 | Flanged Electromagnetic Flowmeters: Overall length |
| 22 | ISO/TS 25377: 2007<br>Confirmed Year: 2013 | Hydrometric Uncertainty Guidance (HUG) |

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