CALIBRATION

It consists of comparing the meter reading with the reading obtained from a standard of higher accuracy than the test meter and with established uncertainty. The standard may be a reference master meter or a complete test stand which themselves are traceable back to more fundamental measures of mass, time and volume, usually held at the National Measurement Institute (e.g NMIM-SIRIM)

Calibration is typically performed in a laboratory at several different flow rates and sometimes at different densities or temperature.

When a calibration is performed, the meter's calibration factors are determined.

Purpose of Calibration

Water Meter Calibration

"To ensure that the water meter is performing as designed and that it meets the necessary performance requirements put in place by the national legal metrology organization"

Why Calibrate

- A water meter is subject to wear and deterioration and, over a period of time, loses its peak efficiency
- Protect individual customer against over-registration
- Protect customers (as a group) against inequity of under-registration and higher water rates
- Protect water utility from revenue loss caused by under-registration

CALIBRATION OF LIQUID FLOWMETERS

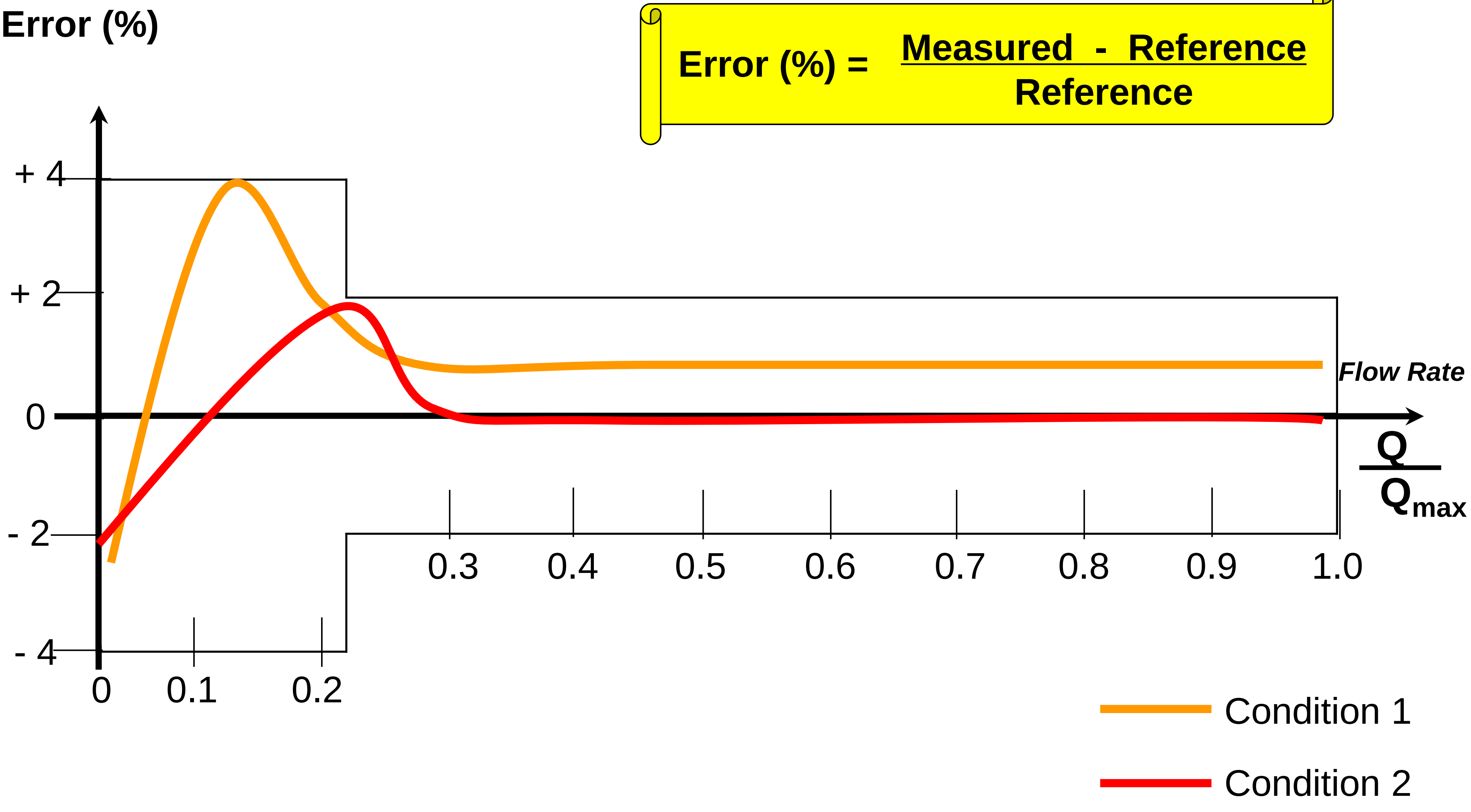
To establish a meter factor, the indicated volume of fluid that passes through a meter is compared to the true volume measured in a container of known size, or in a master meter (called provers as described in the earlier section).

Temperature and pressure correction is then applied.

$$Meter\ Factor\,(MF) = \frac{true\ volume}{indicated\ volume} = \frac{\begin{bmatrix} volume\ of\ liquid\ in\ the\ prover \\ corrected\ to\ standard\ conditions \end{bmatrix}}{\begin{bmatrix} meter\ reading\ corrected \\ to\ standard\ conditions \end{bmatrix}}$$

TYPICAL CALIBRATION CURVE

$$\text{Error (\%)} = \frac{\text{Measured} - \text{Reference}}{\text{Reference}}$$



FLOW METER PERFORMANCE CHARACTERISTICS

Accuracy - The closeness of the agreement between the result of a measurement and the true value of the quantity being measured.

Repeatability - ability of a flowmeter to indicate the same reading each time the same flow condition exist

Linearity - constancy of the meter factor over a specified flowrate range.

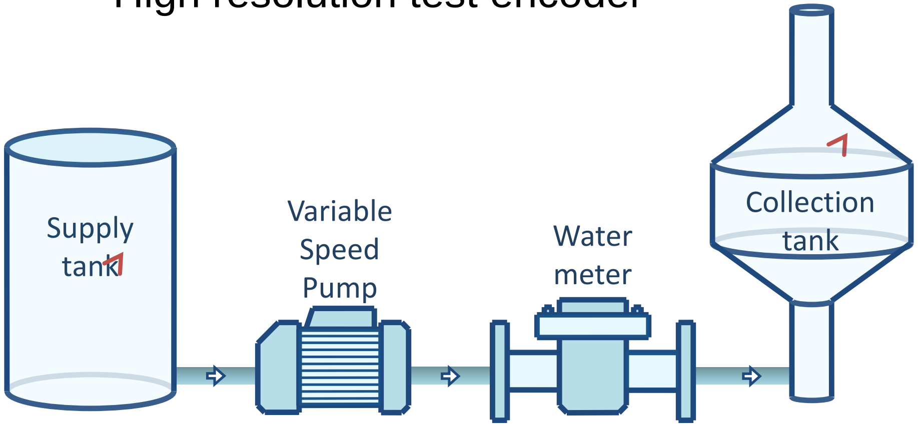
Rangeability - the ratio of the maximum to minimum flowrates specified by the meter's linearity. Rangeability is frequently termed as turndown ratio.

Resolution - measure of the smallest increment of total flow that can be individually recognized

Calibration Equipment

- Test Bench
  - Single or multi-meter
- Reference Standard (Calibration Method)
  - **Volumetric**
  - **Gravimetric**
  - **Reference Meter**
- Water supply
  - Flow through
  - Re-circulating reservoir
  - Pump
  - Gravity feed
- Inlet valve

- Quick-acting valve on discharge side
- Flow regulating valve
- Device for determining flow rate
- Pressure gauge
- Temperature gauge
- High resolution test encoder



Reference Standards (Calibration Methods)

- Volumetric
  - Test Tank
  - Narrow-neck Prover
- Gravimetric
- Master or Reference Meter
- Displacement Prover
  - Piston Prover
  - Pipe Prover
- On-site or Portable Testing

VOLUMETRIC METHODS

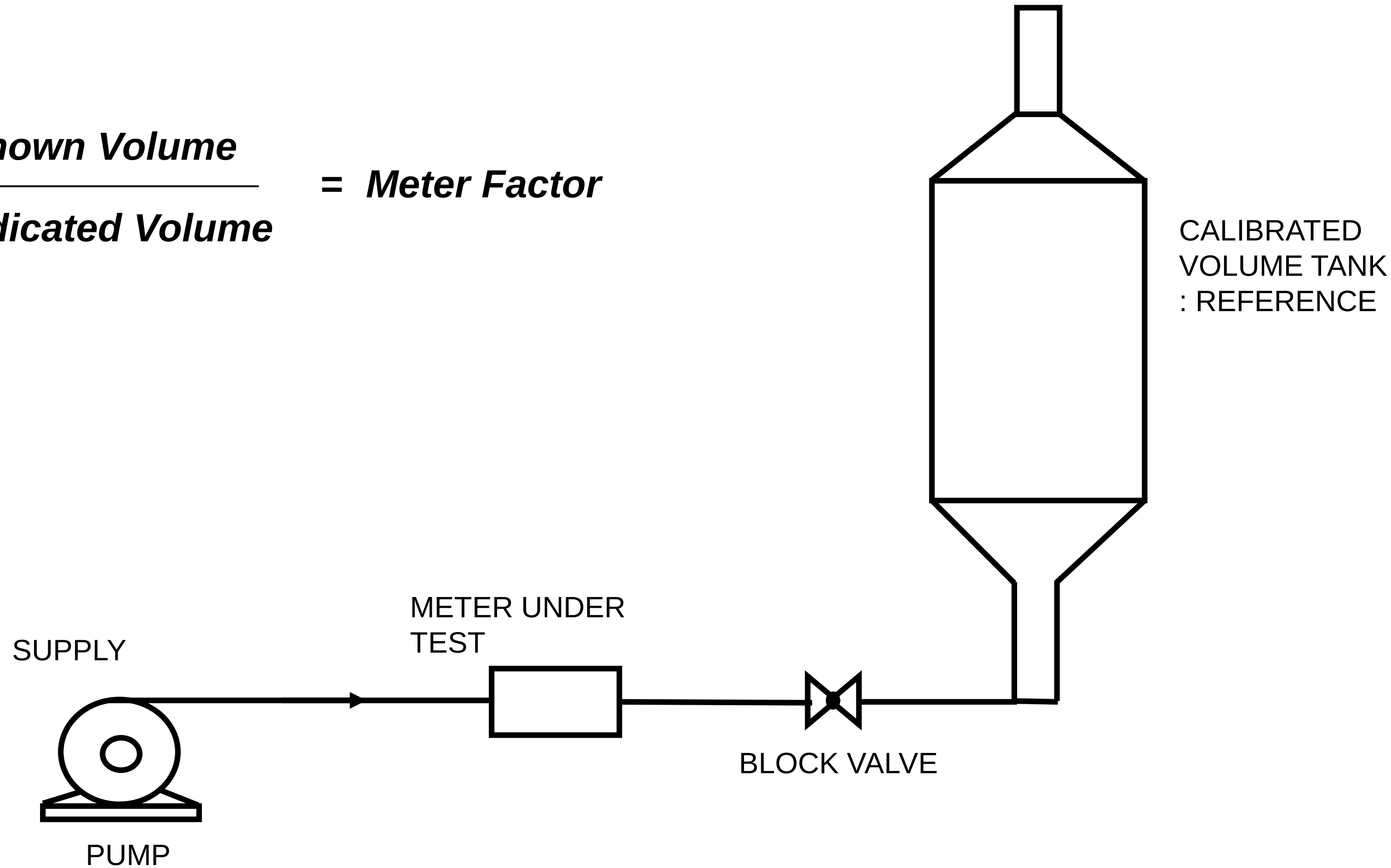
In volumetric method of calibration, a standard volume is collected in a measured time.

Since a liquid, unlike a gas, may be contained within an open vessel, one very convenient way of calibrating liquid flowmeters is to use as a reference a calibrated tank.

One of the volumetric calibration techniques, called start-stop methods, is as shown schematically in the following slide.

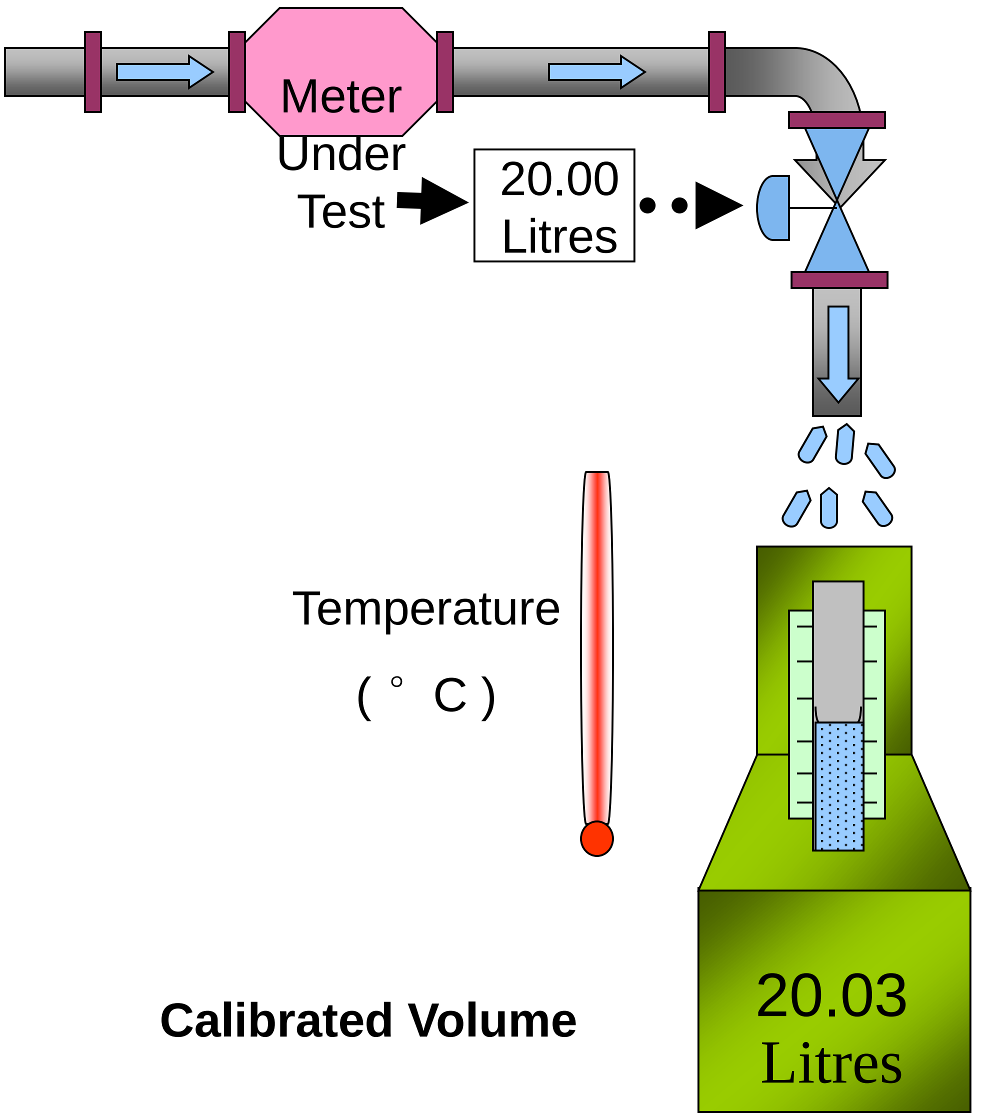
CALIBRATION OF LIQUID FLOWMETERS - VOLUMETRIC METHOD

$$\frac{\textit{Known Volume}}{\textit{Indicated Volume}} = \textit{Meter Factor}$$



STATIC VOLUMETRIC FLOW SYSTEM : START-STOP METHOD

CALIBRATION PRINCIPLES - Volumetric Technique



Mass = Volume x Density

Volumetric calibration facility for liquid flowmeter

Narrow-Neck Prover

- Older technology (aka: onion tank)
- Standing-start-and-finish-method
- Better sensitivity due to narrow-neck
- Errors reading sight glass – meniscus
- Careful to maintain proper drain times
- Aware of effect of coefficient of expansion
- Careful about spilling if meter is under-registering
- Can be costly and difficult to re-certify

GRAVIMETRIC METHODS

In gravimetric systems, time and weight are measured. Since mass is a primary unit of measurement a big advantage is may be gained, by applying this method. There are several arrangement used, as described in the following slides.

GRAVIMETRIC START-STOP METHODS

This method is essentially the same as that described for volumetric systems above, except that a weight tank and constant level device replace the volumetric tank. The basic elements of the system are shown in the next slide.

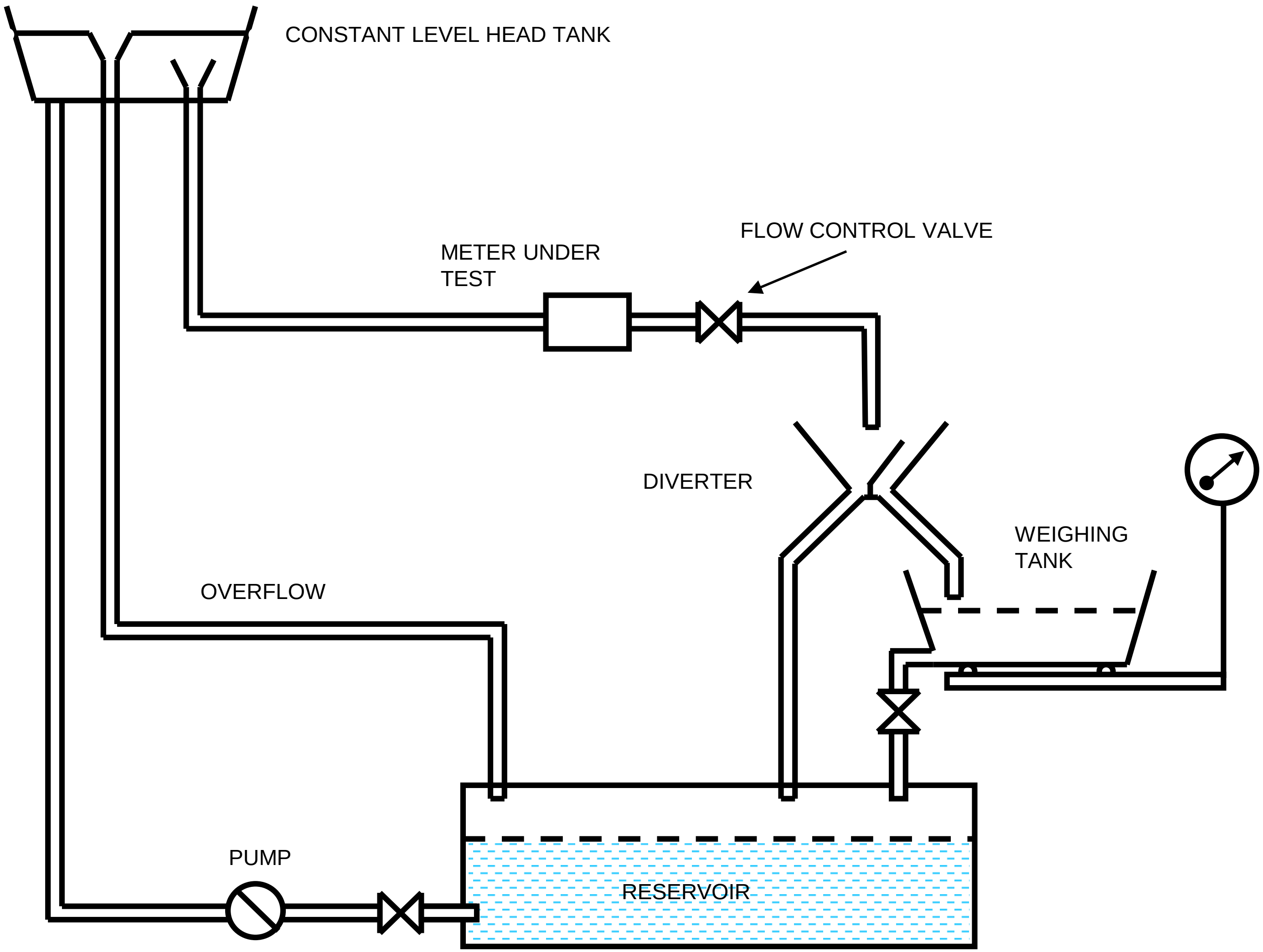
CALIBRATION OF LIQUID FLOWMETERS - GRAVIMETRIC METHOD

GRAVIMETRIC WITH FLYING START-STOP METHODS – STATIC WEIGHING

In this method, the flow through the meter is not interrupted while the calibration is being carried out. This requires a diverter arrangement such as the one shown in next slide. The diverter causes the flow through the meter to bypass the weigh tank during periods of flowrate change. It then diverts steady flow for a measured time into the weigh tank.

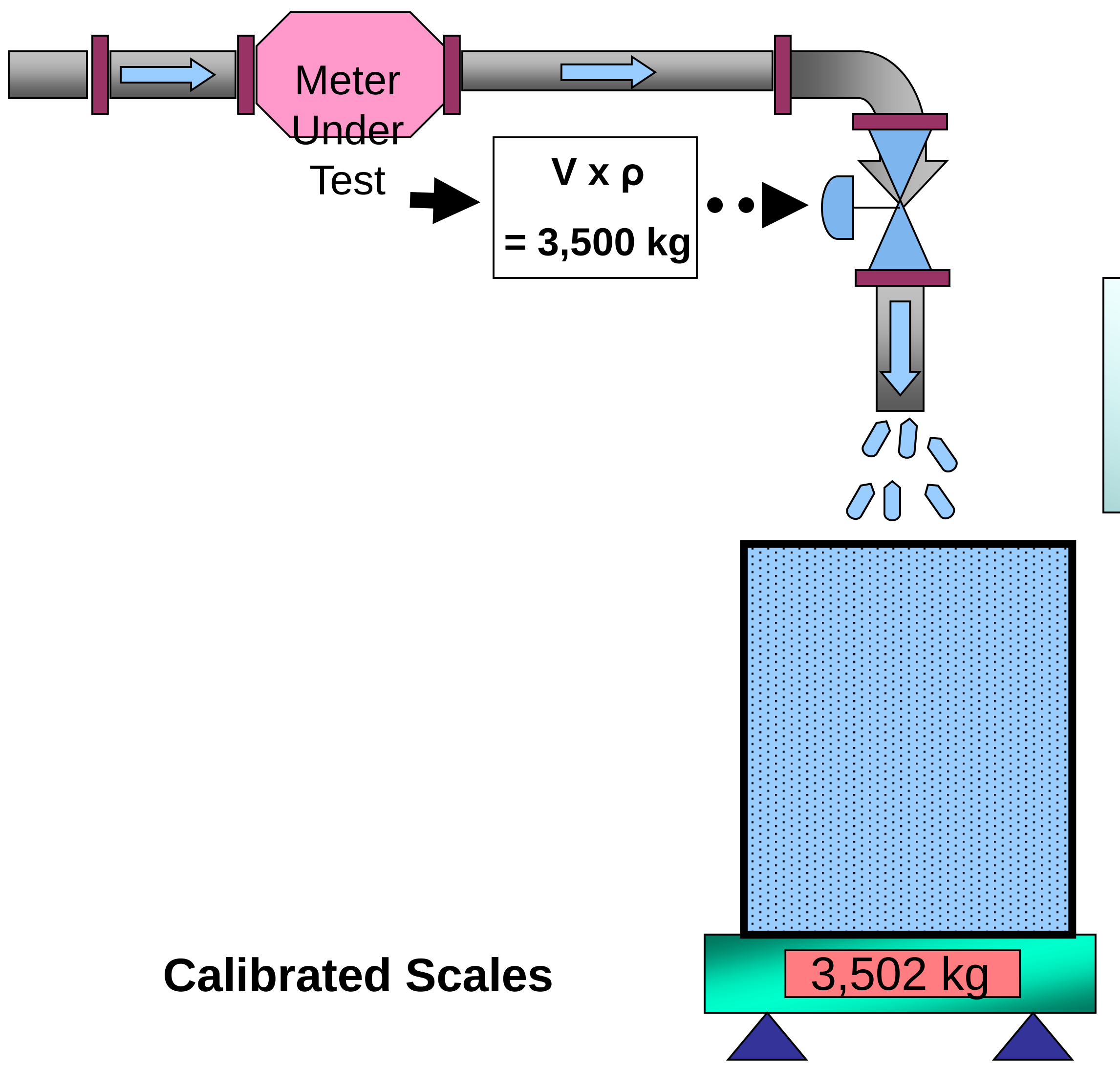
The method is particularly suitable for calibrating meters which might be affected by starting and stopping the flow, such as pressure difference device and vortex meters.

CALIBRATION OF LIQUID FLOWMETERS - GRAVIMETRIC METHOD



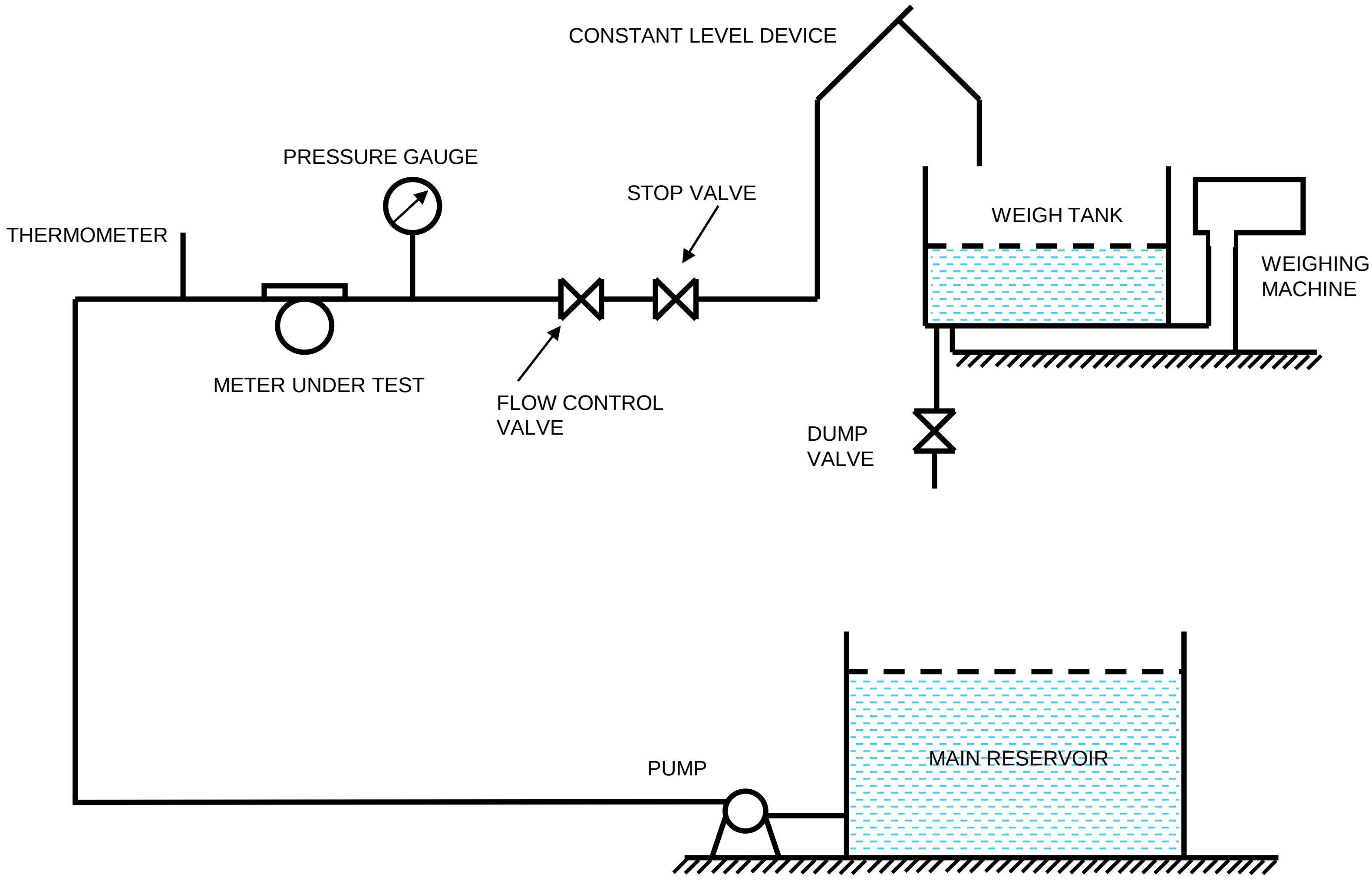
GRAVIMETRIC FLYING START-STOP CALIBRATION FACILITY - USING A CONSTANT LEVEL HEAD TANK

CALIBRATION PRINCIPLES - Gravimetric Technique



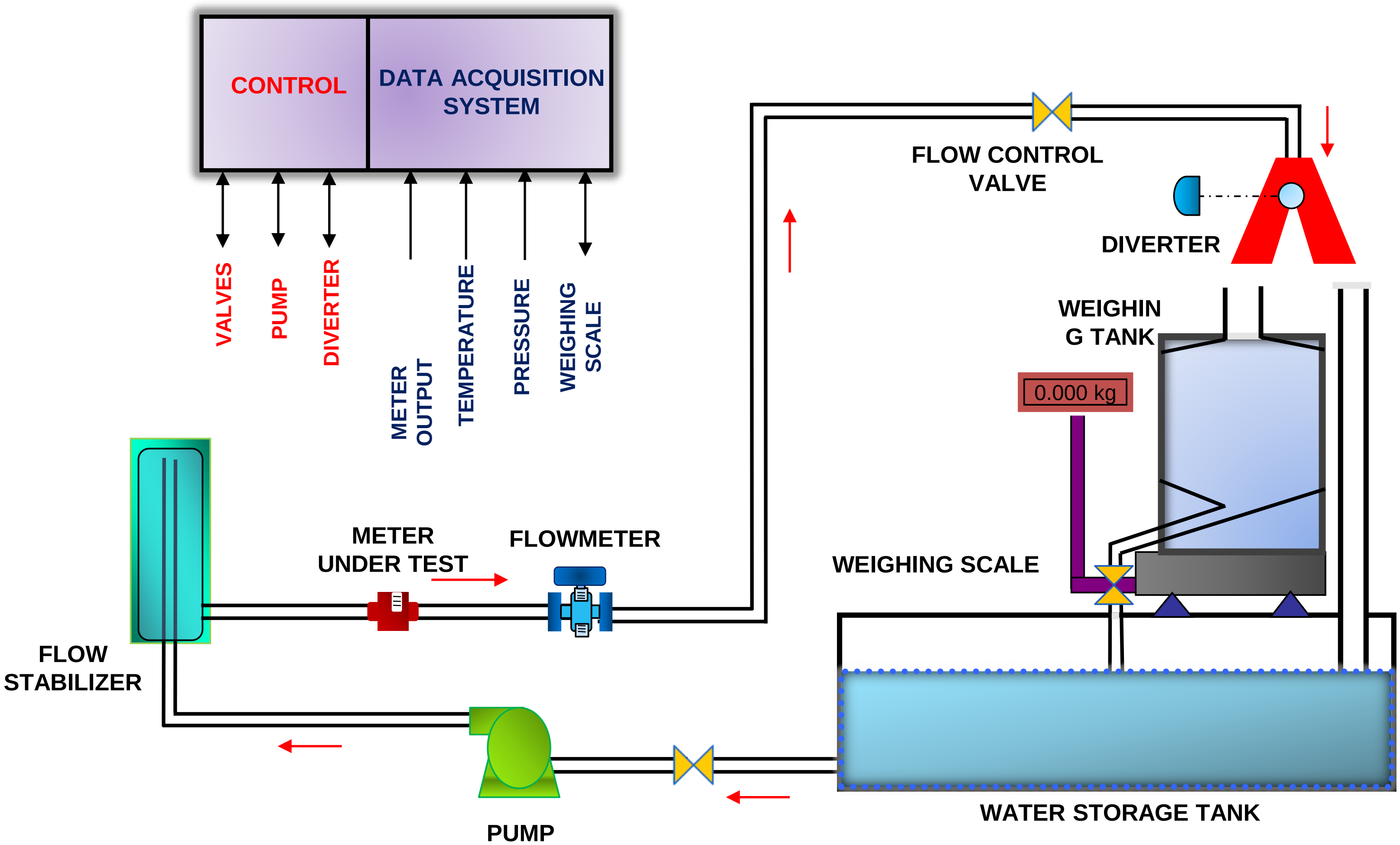
$$\text{Volume} = \frac{\text{Mass}}{\text{Density}}$$

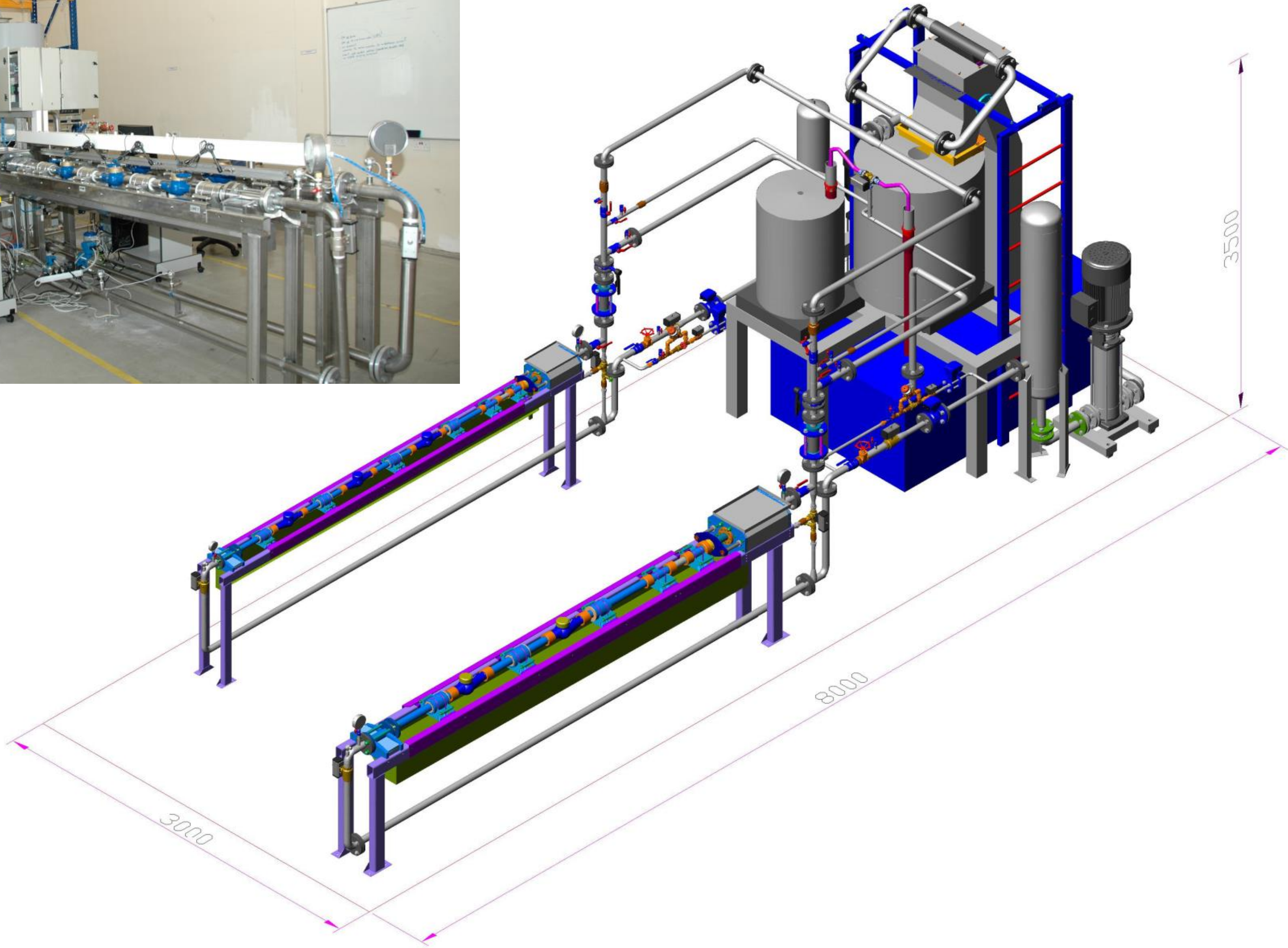
CALIBRATION OF LIQUID FLOWMETERS - GRAVIMETRIC METHOD



SIMPLE GRAVIMETRIC FLOW CALIBRATION SYSTEM

NMIM-SIRIM Water Meter Calibration Facility





NMIM-SIRIM WATER METER CALIBRATION FACILITY

Gravimetric Method

Operation

- Usually standing-start-and-finish method
- Uses a vessel and a highly accurate electronic scale or mass comparator
- Weigh the amount of water that has passed through the meter
- Convert the weighed value to a volume based on the density of the measured water
- Primary standard - test weights used to verify the accuracy of the weighing device

Advantages

- Compensate for water temperature, pressure and gravitational effect
- Relatively easy to recalibrate weighing device
- Reduce operator error – easy to read indicator (no sight glass meniscus)
- Easy to incorporate into fully automated system
- Tank does not have to be drained between successive runs

Master or Reference Meter Method

The simplest and simple way to calibrate meters is to check its performance against another meter. The latter must has been calibrated and traceable to known standards and is usually refers as reference or master meters. The reference meter must obviously be of higher quality than the meter to be calibrated and the location of the one must not be such as to affected the performance of the other in the test line.

Reference master meter method are used in inter laboratory transfer standards which sometimes also used to check the calibration stand itself. Positive displacement meter type make excellent transfer reference meters due to its wide working range, good repeatability and insensitivity to installation effect.

Master or Reference Meter Method

Operation

- A highly accurate reference meter is placed in-series with the meter being tested
- A volume of water is passed through both meters (usually standing-start-and-stop method)
- The amount of volume displayed on both meter’s indicating devices are compared
- Reference meters are periodically certified against a primary standard
- Frequency
  - Time
  - Volume
  - Condition of water

Advantages

- Flow through metering so no need to capture a volume of water.
  - Save space
  - No need for test tanks
  - Saves time
- Reduce operator error – easy to read indicator
- Easy to incorporate into fully automated system reading

Disadvantages

- Need to recalibrate meter regularly
- Best if two reference meters are used in-line (3 way comparison)

CALIBRATION RIG DESIGN CONSIDERATION

The calibration rig shall be so designed and constructed that the performance of the rig itself shall not contribute significantly to the test error.

Thus, high standards of rig maintenance, adequate structural strength to prevent vibration of the meter, the rig and its accessories, are necessary

Major Factors Affecting Measurement Errors

- Variations and Uncertainty in Measuring:
  - Supply Pressure
  - Flowrate
  - Temperature

Supply Pressure

- Shall be maintained at a constant value
- Considerations for small meters at test flowrates ≤ 0.1 Q3
  - Gravity feed (constant head)
  - Pressurized tank
  - Variable speed pump
- During test shall not vary more than 10 %
- The maximum uncertainty (k = 2) in the measurement of pressure shall be 5 % of the measured value
- Pressure at the entrance to the meter shall not exceed the maximum admissible pressure for the meter

Flow Rate

- Shall be maintained constant throughout the test at the chosen value

- The relative variation in the flowrate during each test (not including starting and stopping) shall not exceed:
  - ± 2.5 % from Q1 to Q2 (not inclusive)
  - ± 5.0 % from Q2 (inclusive) to Q4.

- The flowrate value is the actual volume passed during the test divided by the time.

Temperature

- **During a test, the temperature of the water shall not change by more than 5 ºC**

- **The maximum uncertainty in the measurement of temperature shall not exceed 1 ºC**

Water Meter Calibration

Questions or Comments