Asia-Pacific
Economic Cooperation

Asia-Pacific
Legal Metrology
Forum

Water Meter Testing

APEC / APLMF Training Courses in Legal Metrology

September 23 – 26, 2008
Hanoi, Vietnam

Measurement Canada
An Agency of Industry Canada

Mesures Canada
Un organisme d'Industrie Canada

Canada

Definition

Water Meter Testing

"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 Test Meters?

- 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

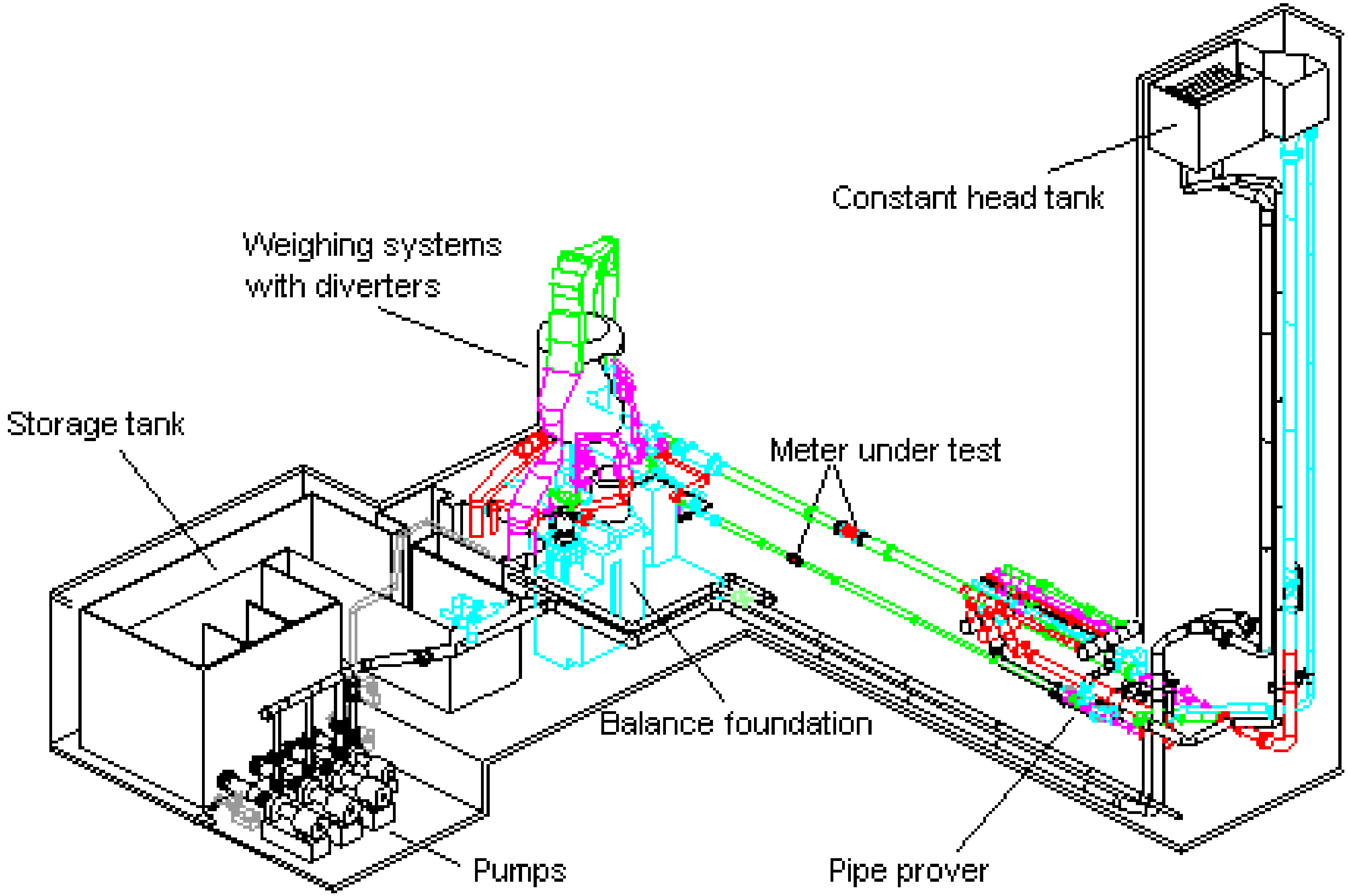
Factors Affecting Accuracy

- Turbidity of the water
- Chemical build-up in the measuring chamber
- Rates of flow
- Total quantity metered
- Age of meter
- Type of meter installed
- Poor installation practices

Test Equipment

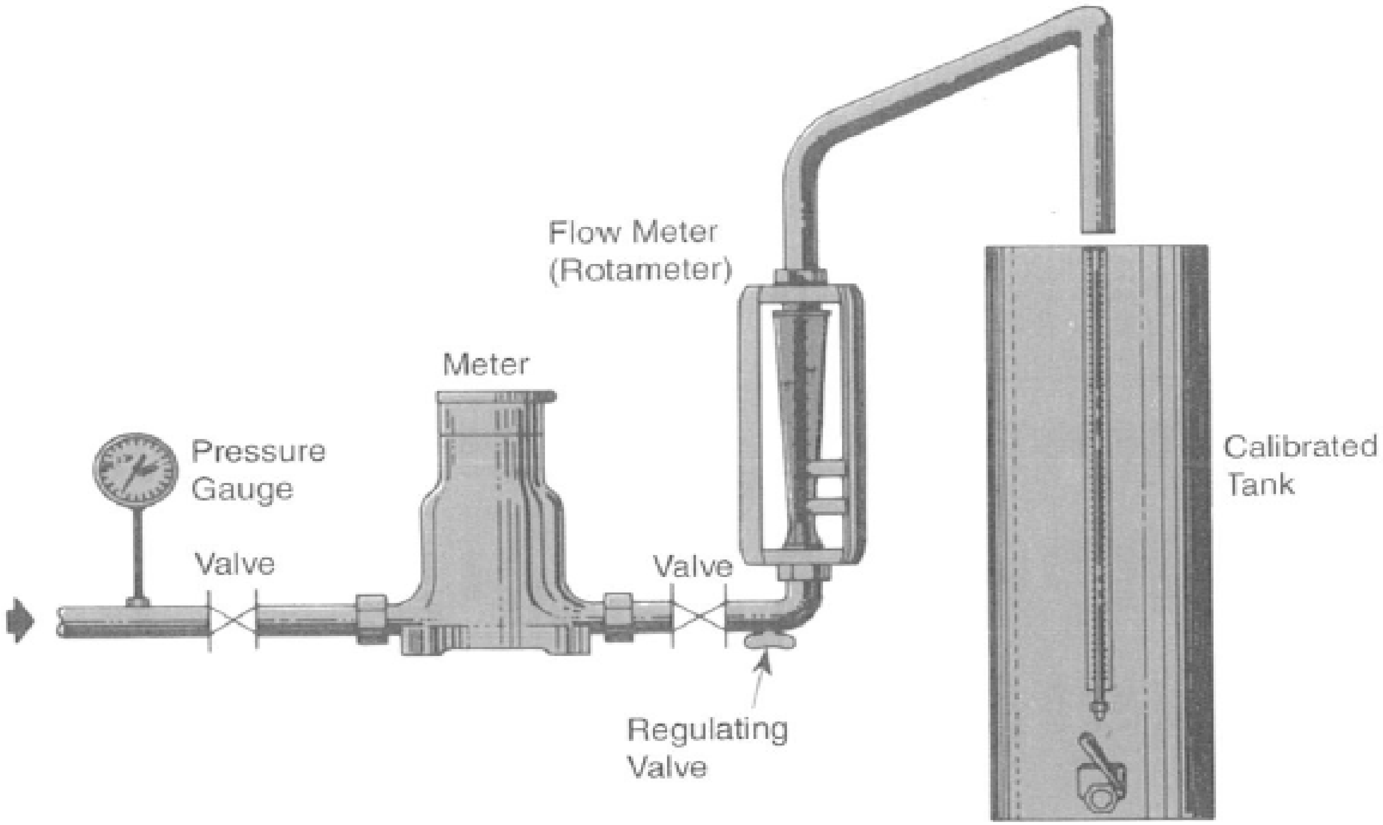
- Test Bench
  - Single or multi-meter
- Automated Test Controller
- Comparative Standard (Test Method)
  - Volumetric
  - Gravimetric
  - Reference Meter
- Water supply
  - Flow through
  - Re-circulating reservoir
  - Pump
  - Gravity feed
- Inlet valve
- Flow disturbance devices
- Quick-acting valve on discharge side
- Flow regulating valve
- Device for determining flow rate
- Pressure gauge
- Temperature gauge
- High resolution test encoder

Water Meter
Test Facility



PTB
Braunschweig, Germany

Water Meter
Test Station



General - Layout

Single Meter Test Bench

- One position only
- Used primarily for large meters
- Found in small meter shops

Single Meter Test Bench

Large Meter Test Bench
MARS Company
USA

Single Meter Test Bench

Small Meter Test Bench
City of Brandon
Canada

Single Meter Test Bench

testing large meters
Badger Meter
USA

Single Meter Test Bench

China

Multi- Meter Test Bench

- Advantage of testing more than one meter at the same time
- Meters are mounted in-series and/or in parallel
- Many different configurations, (stock or custom built)
  Ex:
  - 2 rows (24 position) – small meters
  - 2 rows (3 position) -intermediate meters, (5 position) - small meters
  - Single row (5 position)
- Caution about high pressure loss at Q3 or Q4

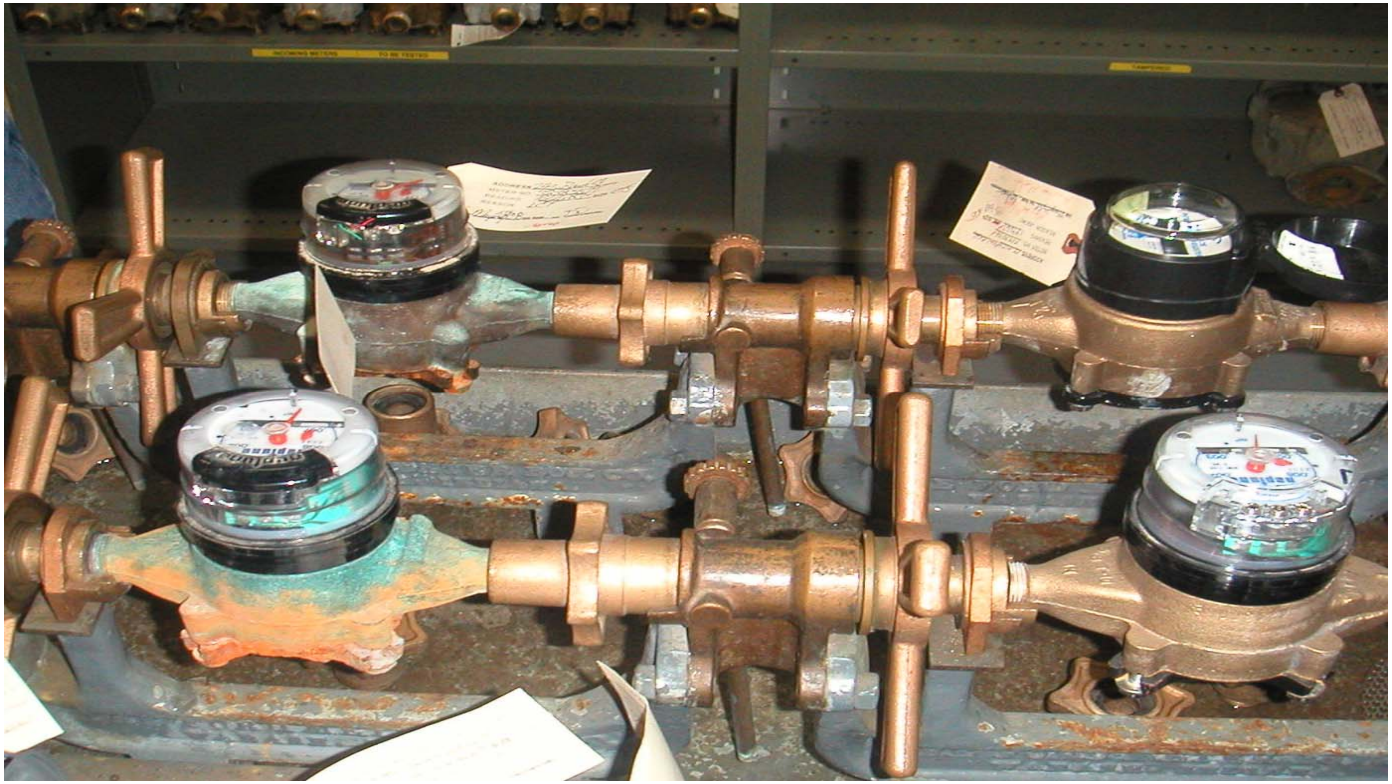
Multi- Meter Test Bench

WRc-NSF
Wales, UK

Multi- Meter Test Bench

MARS Company
USA

Multi- Meter Test Bench



City of Ottawa
Canada

Multi- Meter Test Bench

Coulter Meter Service
Ingersoll, Canada

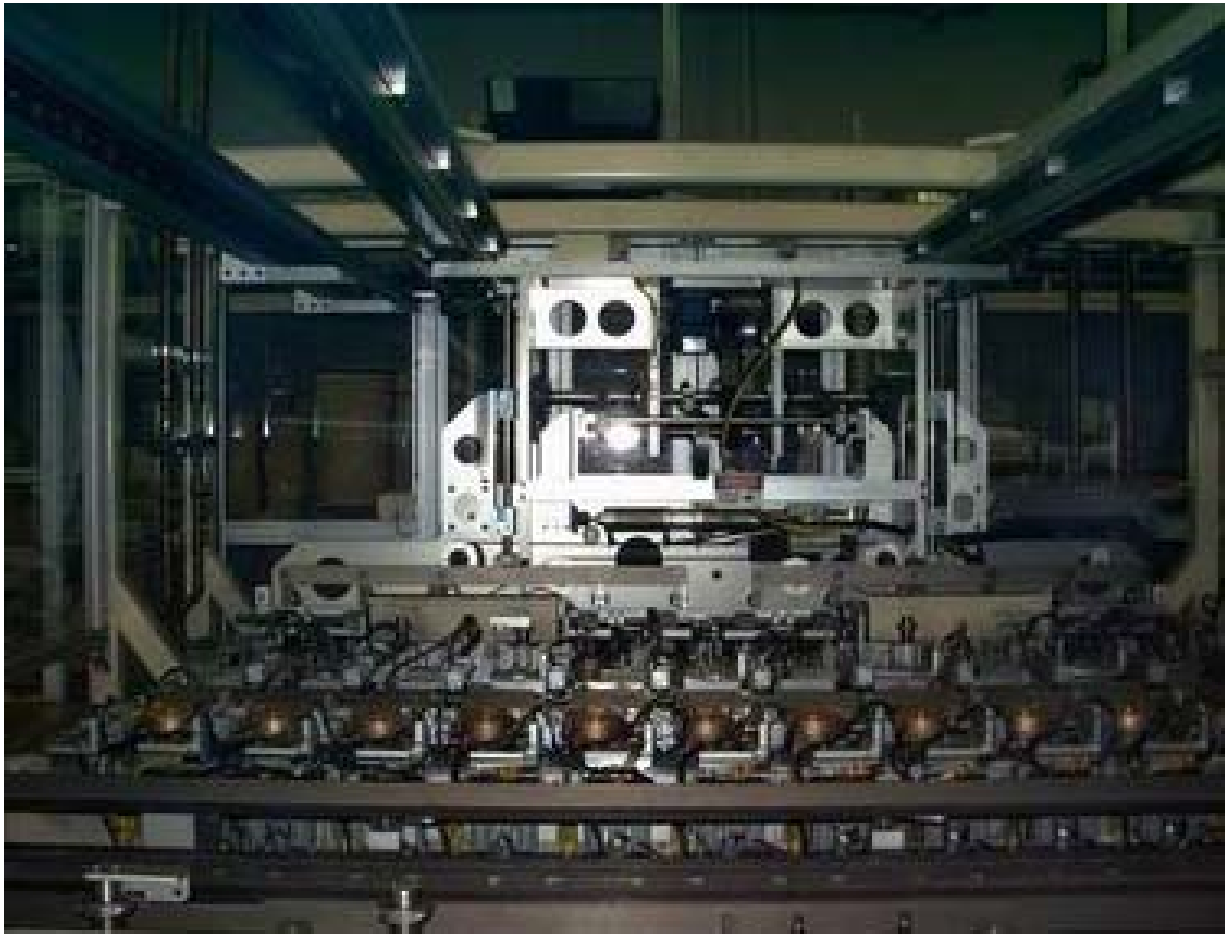
Multi- Meter Test Bench

Force Technology
Denmark

Multi- Meter Test Bench

Neptune TG
USA

Multi- Meter Test Bench



Badger Meter
USA

Automated Test Controller

- Many test stations are Operator controlled
  - Reads meter and quantity of volume delivered
  - Determines and regulates flow rate
  - Observes and records pressure and temperature
- Automated test controller (full or partial)
  - Reads meter
  - Determines quantity delivered
  - Monitor and controls flow
  - Monitors pressure and temperature
  - Calculates errors
  - Prints or stores test results

Automated Test Controller

Gravimetric System Test Bench Console
MARS Company
USA

Automated Test Controller

Test Bench Console
WRc-NSF
Wales, UK

Automated Test Controller

Test Bench Console
Force Technology
Denmark

Comparative Standards Tests Methods

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

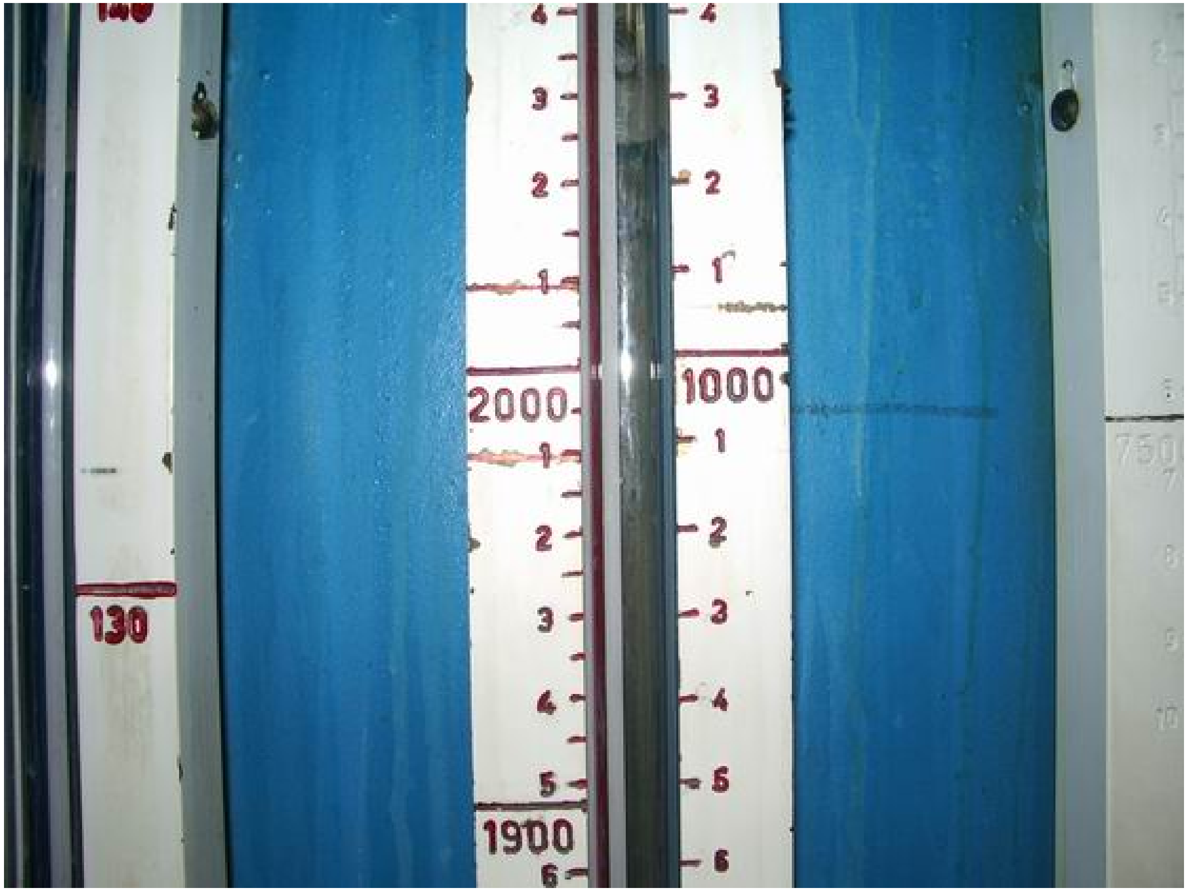
Volumetric – Test Tank

- Older technology
- Standing-start-and-finish method
- Poor sensitivity if large diameter tank
- Errors reading sight glass – meniscus
- Careful to maintain proper drain times
- Aware of effect of coefficient of expansion
- Best use is for calibrating meter to zero error
- Can be costly and difficult to re-certify

Volumetric – Test Tank

Different size tanks for various test quantities
Badger Meter
USA

Volumetric – Test Tank



Sight Glass
Two readings - tanks are manifolded
Badger Meter
USA

Volumetric – Test Tank

Scotiatech
Halifax, Canada

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

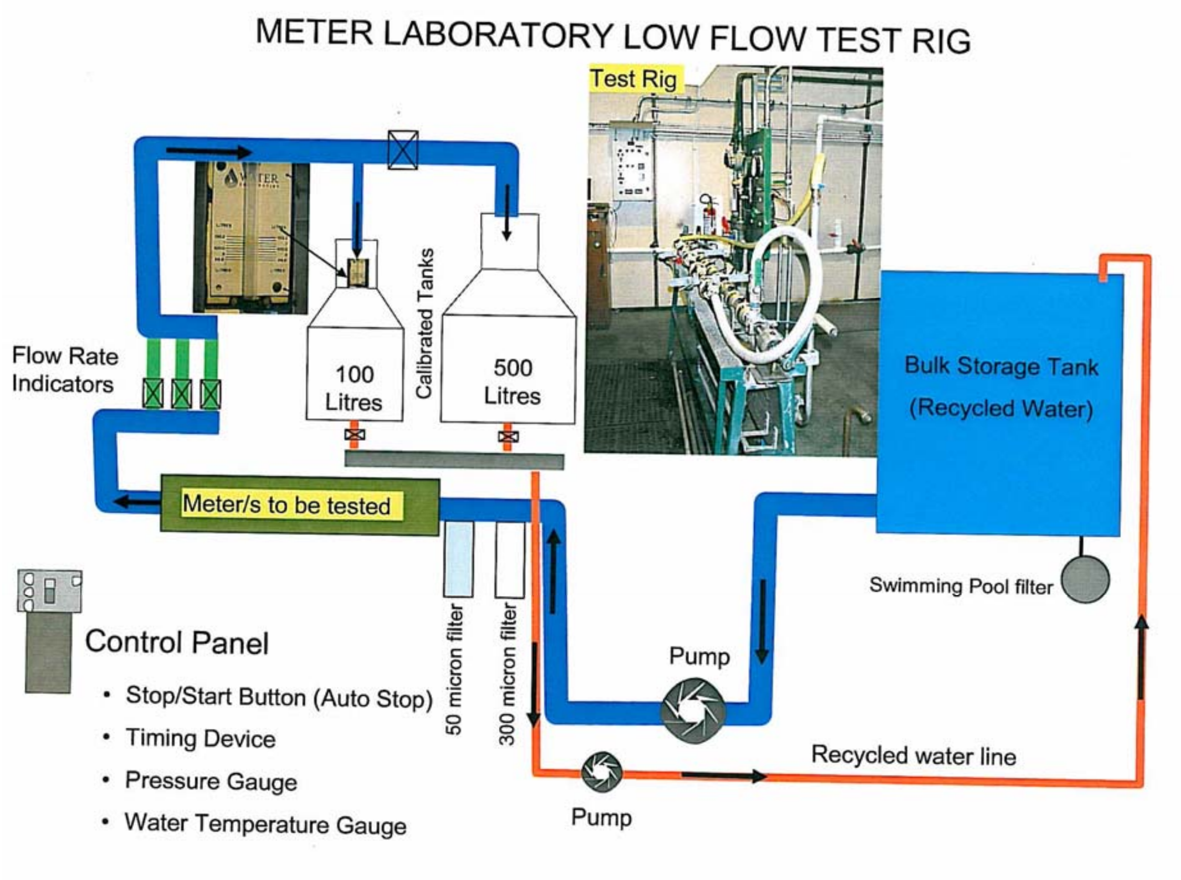
Narrow-Neck Prover

City of Halifax
Canada

Narrow-Neck Prover

Measurement Canada Certification Sticker
City of Halifax
Canada

Narrow-Neck Prover
Test Station



Water Corporation
Australia

Gravimetric

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

Gravimetric

City of Bellville
Canada

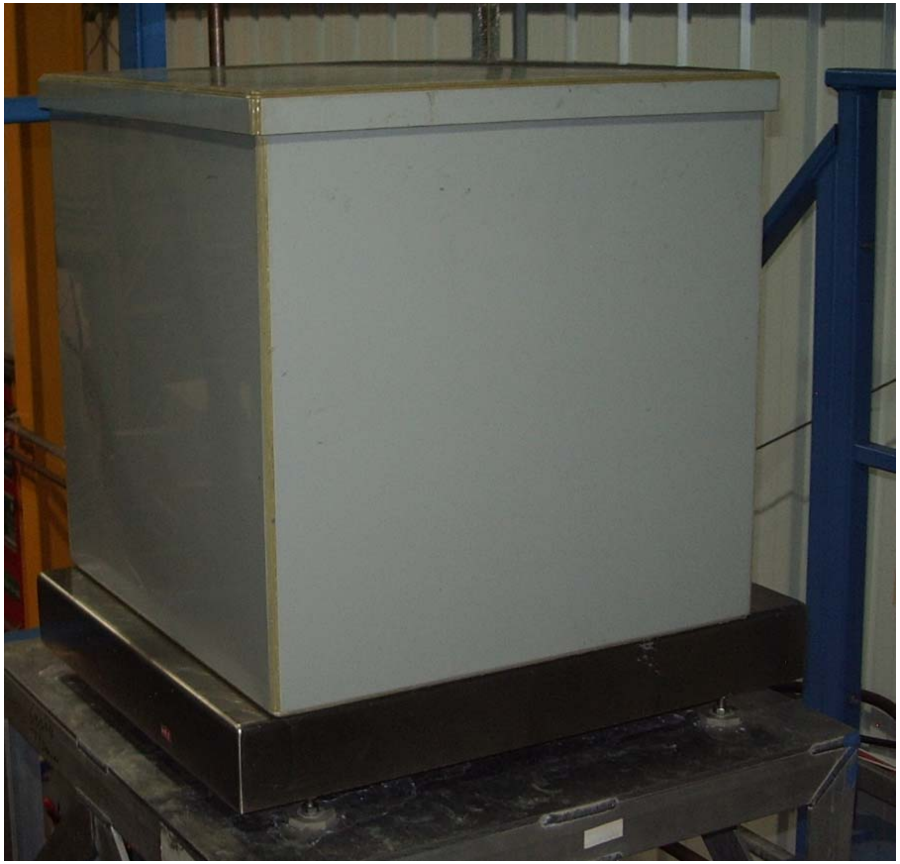
Gravimetric

Badger Meter
USA

Gravimetric

WRc-NSF
Wales, UK

Gravimetric



WRc-NSF
Wales, UK

Gravimetric

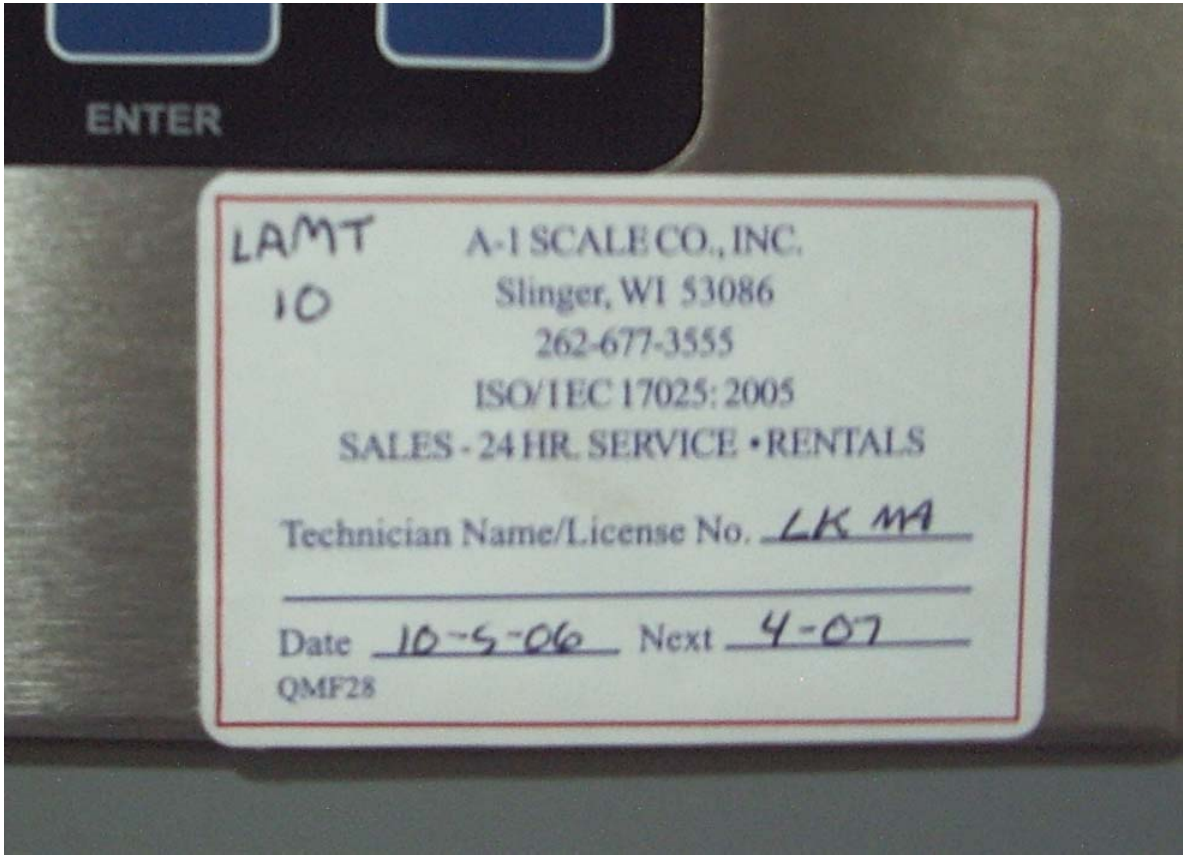
Load Cells
Badger Meter
USA

Gravimetric

Digital Indicator
City of Ottawa
Ottawa, Canada

Digital Indicator
WRc-NSF
Wales, UK

Gravimetric



Scale Inspection Sticker
Badger Meter
USA

Gravimetric

Test Weights
WRc-NSF
Wales, UK

Gravimetric

Hooks for Test Weights
Badger Meter
USA

Master or Reference Meter

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

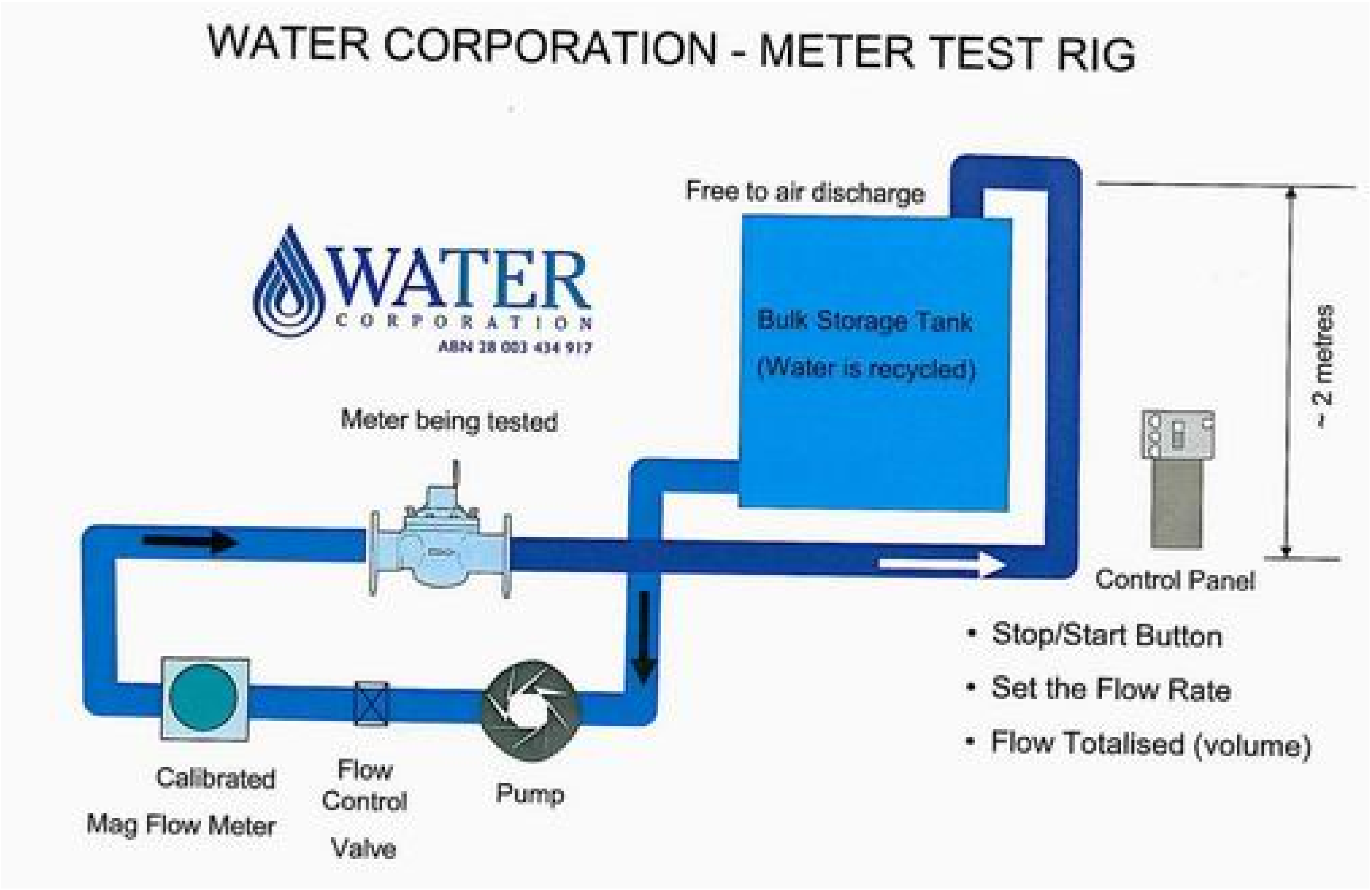
Advantages

- 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)

Master or Reference Meter
Test Station



Water Corporation
Australia

Master or Reference Meter

Large Meter Test Station
In-take and Out-take lines
Coulter Meter Service

Large Meter Test Station
200 mm (8”) Turbine Meter
Coulter Meter Service

Master or Reference Meter

Four Reference
Electromagnetic Flowmeters
Coulter Meter Service

Digital Indicators
Electromagnetic Flowmeters
Coulter Meter Service

Master or Reference Meter

200 mm (8”) Reference
Electromagnetic Flowmeter
(Fast Flow Tests)
Coulter Meter Service

50 mm (2”) & 13 mm (1/2”) Reference
Electromagnetic Flowmeter
(Intermediate and Slow Flow Tests)
Coulter Meter Service

Master or Reference Meter

Turbine Reference Meters
Neptune Technology Group
USA

Master or Reference Meter

Reference Mag Meter Remote Display
Badger Meter
USA

Master or Reference Meter

Test Scale Used with Reference Mag Meter
Badger Meter
USA

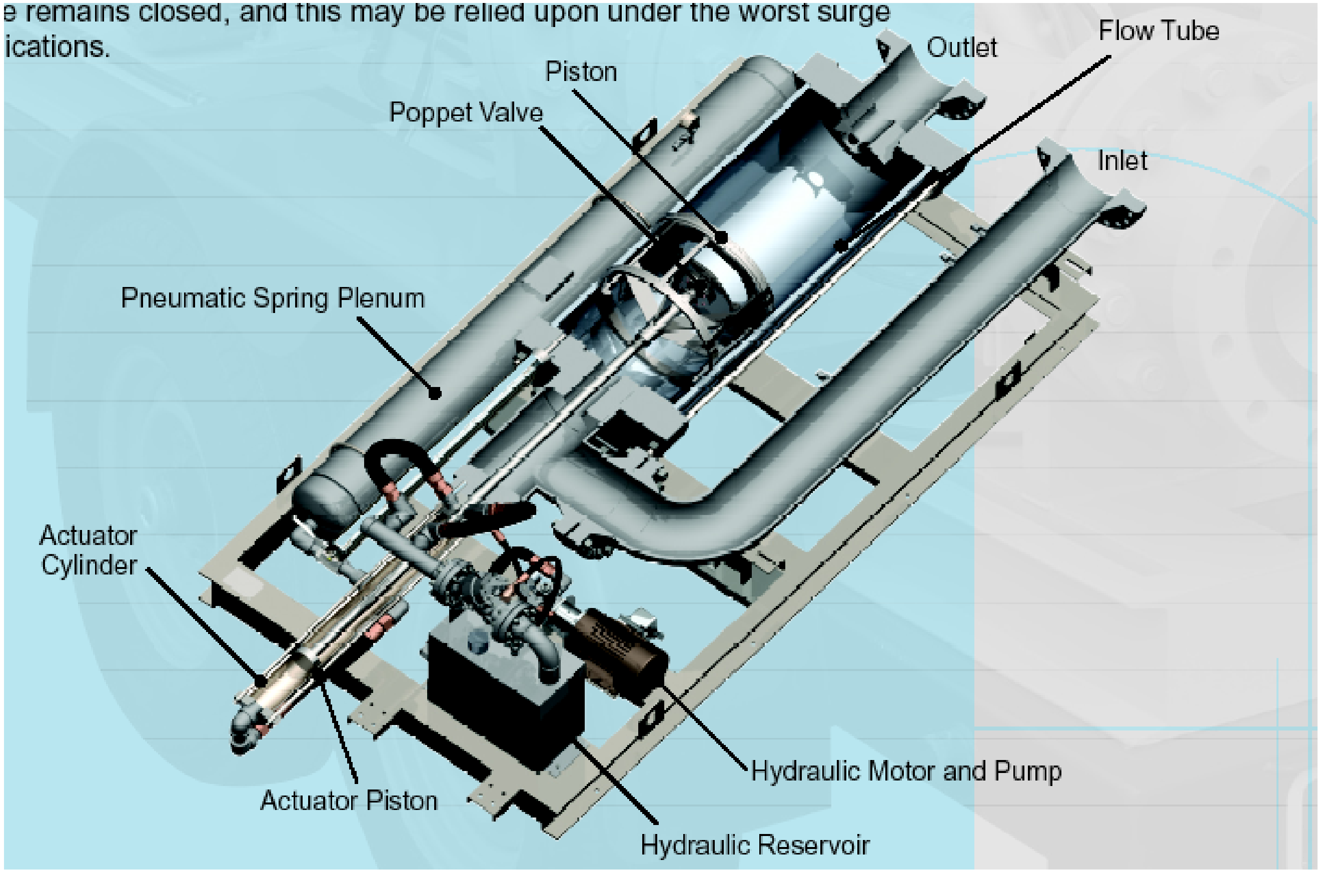
Displacement Provers

"Displacement provers operate on the principle of the repeatable displacement of a known volume of liquid from a calibrated section of pipe between two detectors."

Compact (Piston) Prover

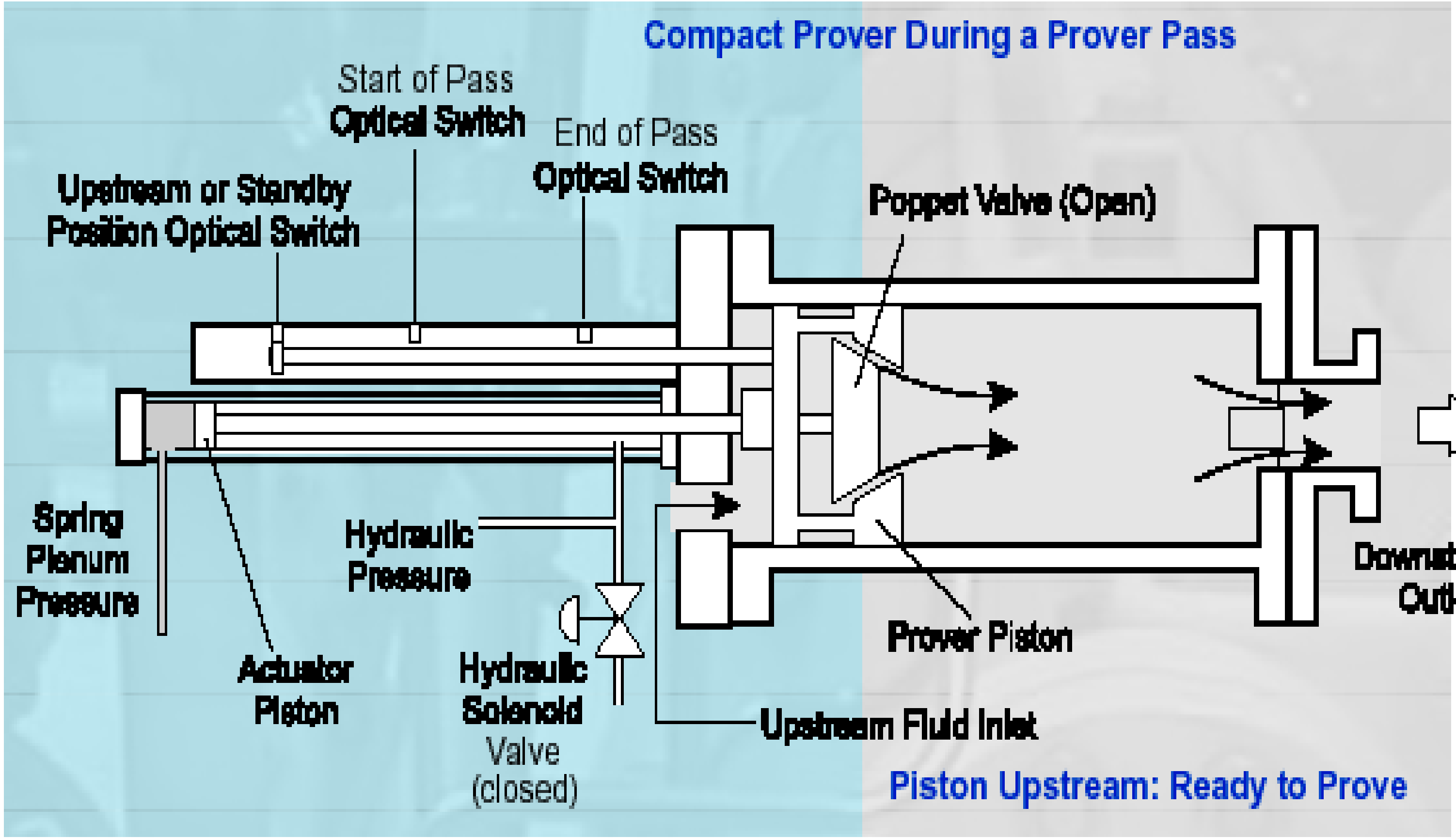
- Flying-Start-and-Finish Method
- Utilizes a piston that travels through a measurement section
- Displaces a known volume of liquid
- Piston travel is detected with sensors
- Pulse interpolation allows for less than 10,000 pulses per pass
- Reliable proving with smaller volumes

Compact (Piston) Prover



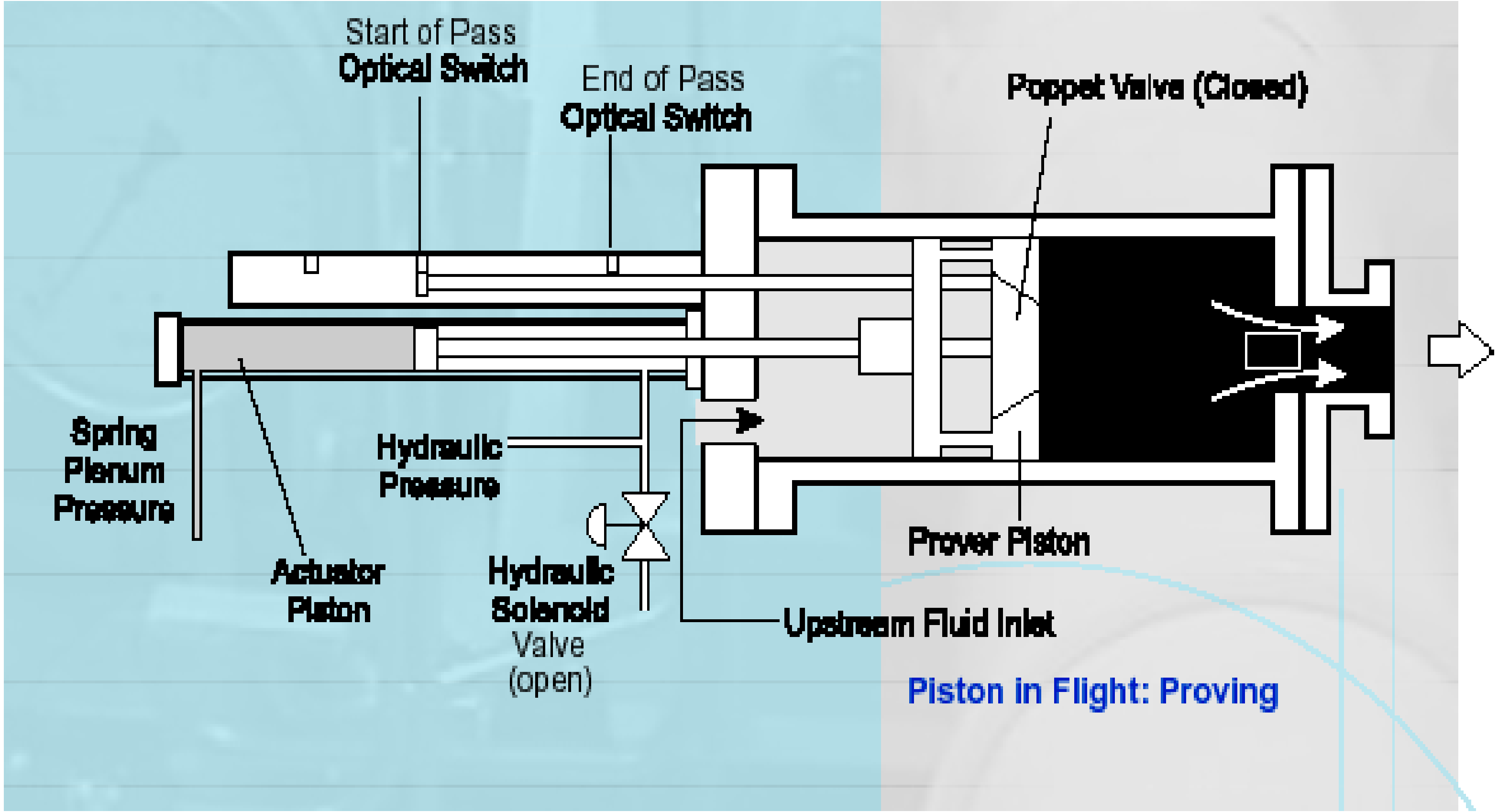
Brooks Compact Prover

Compact (Piston) Prover



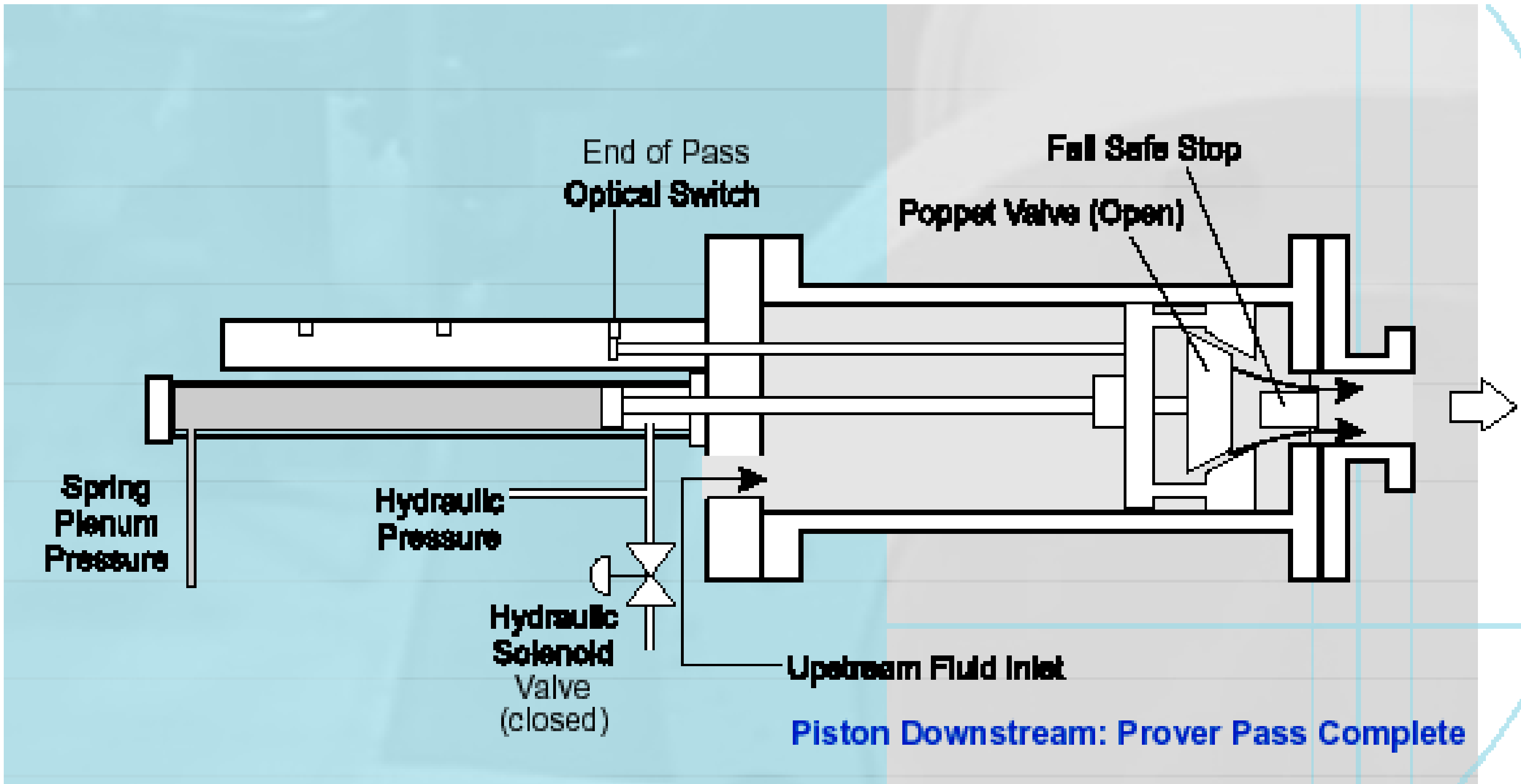
Brooks Compact Prover

Compact (Piston) Prover



Brooks Compact Prover

Compact (Piston) Prover



Brooks Compact Prover

Compact (Piston) Prover

Brooks Compact Prover
PTB
Germany

Pipe Prover

- Closed circuit system
- Usually Flying-Start-and-Finish Method
- Composed of a section of pipe of constant size
- A displacer (ex. ball or sphere) passes a start and a stop detector
- The volume between these two detectors is known (determined by water draw calibration)
- Pulses received from the meter under test are counted while the displacer moves between the start and stop detectors
- As the volume between these two detectors is known the pulses per litre of product can be deduced

Pipe Prover

Badger Meter
USA

On-site or Portable Testing

Operation

- Customer meter is tested on-site
- Standing-start-and-stop method
- A portable reference meter is used (in-series)
- Primary standard – reference meter is periodically certified with a traceable standard

Advantages

- No need to remove meter for testing
- No need for installing loaner meter or providing unmetered condition while regular meter is at test shop
- Test may show meter errors due to installation – not seen at meter shop

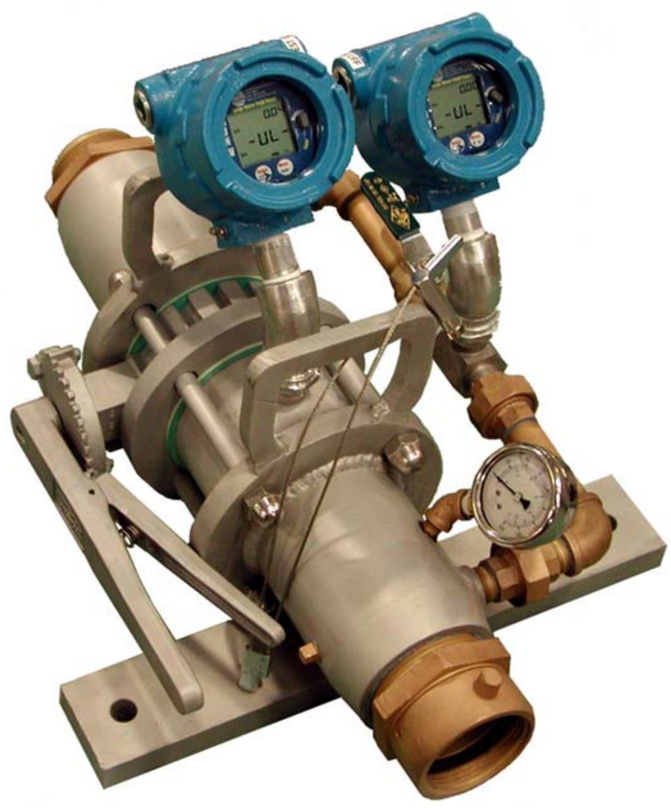
Disadvantages

- Large meters are not tested at Q3
- Need an outlet for discharged water
- Difficult to perform if no provisions have been made for on-site testing

On-site or Portable Testing

Residential Meter Tester
MARS Company
USA

On-site or Portable Testing



MARS Company
USA

On-site or Portable Testing

City of Belleville
Canada

On-site or Portable Testing

ScotiaTech Canada

On-site or Portable Testing

City of Windsor
Canada

On-site or Portable Testing

MARS Company
USA

Water Supply

Flow Through

- Water is only used once, discharged to sewer
- Supplied by pump or gravity feed
- Expensive if water is treated or purchased from independent sources
- Waste - environmentally unfriendly
- Difficult to control temperature

Re-circulation

- Closed system
- Tanks is used to store water used for test (above or below ground)
- Pump circulates water
- Water temperature can be controlled (heaters & chillers)
- Water has to be monitored for contamination

Water Supply

Pump Supplied

- Pump is used to supply water to test bench
- Allows for varying test pressures (variable speed pump)
- Can be expensive if high energy costs

Gravity Feed

- Water is stored in tower or tank that is above the test station
- Pressure will be dependent on distance of the drop
- Allows for constant head pressure
- Not good if need for varying test pressures

Re-circulation Tanks

6,000 litre tank
Coulter Meter Service
Canada

Re-circulation Tanks

Tanks and Chiller
WRc-NSF
Wales, UK

Water Supply- Pump Supplied

Badger Meter
USA

Water Supply- Gravity Feed

National Research Council
Ottawa, Canada

Water Supply- Gravity Feed

National Research Council
Ottawa, Canada

Flow Disturbance Devices

- Introduce flow disturbances upstream of meter
- Ex. (ISO 4064 Part 3, Annex B)

Flow Rate
Determining Device

- Rotameter
- In-line meter
- Stop watch

Rotameter

"A device used to measure fluid flow, in which a float rises in a tapered vertical tube to a height dependent on the rate of flow through the tube"

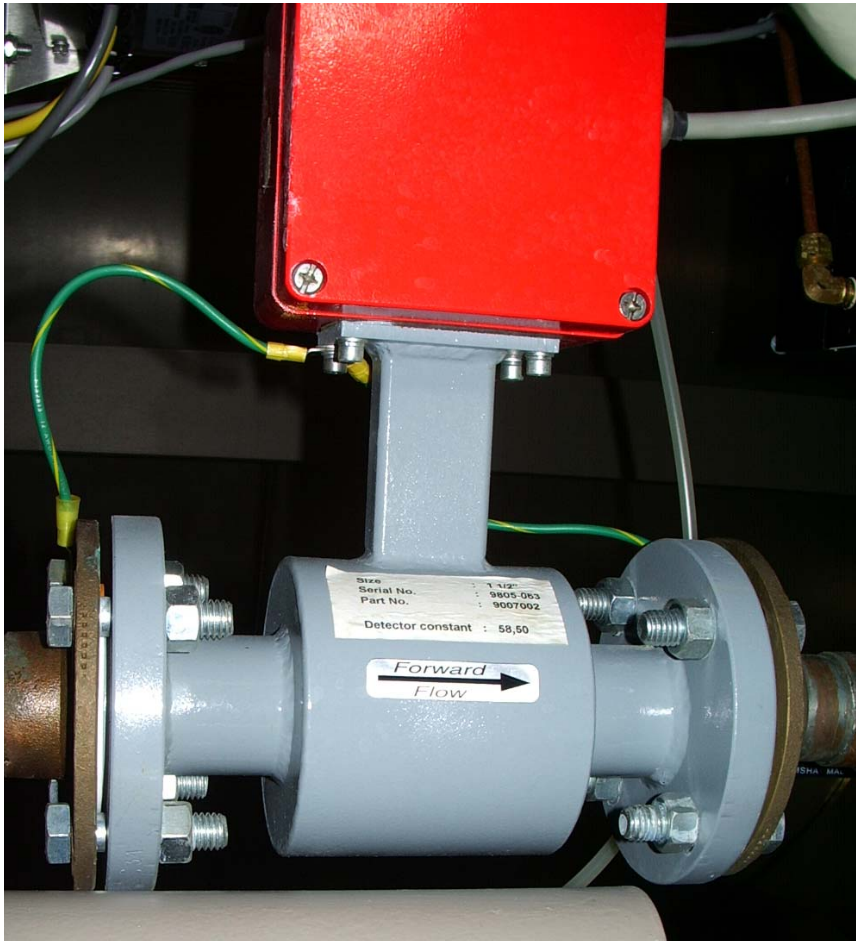
Rotameter

City of Kitchener
Canada

Rotameter

City of Belleville
Canada

In-line Meter

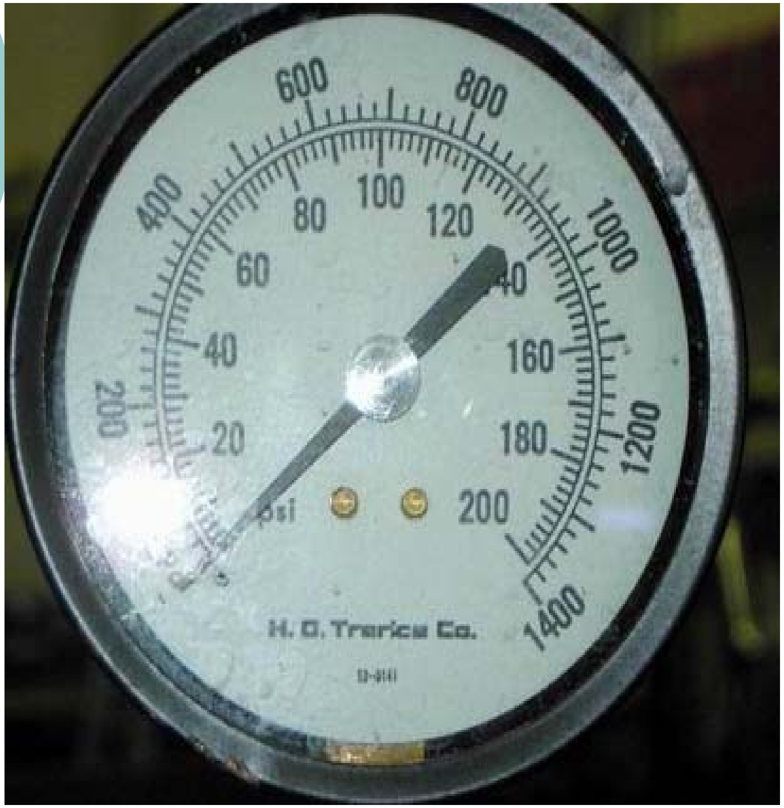


Badger Meter
USA

In-line Meter

WRc-NSF
Wales, UK

Pressure Gauge



City of Windsor
Canada

Badger Meter
USA

Pressure Gauge

NeptuneTG
USA

Pressure Gauge

WRc-NSF
Wales, UK

Temperature Gauge

Neptune TG
USA

Temperature Gauge

PTB
Germany

High Resolution Test Encoder

- Device which replaces mechanical indicating device during testing
- Provides a high number of output pulses
- When used with high resolution test equipment allows for a relatively small amount of test volume
- Result is faster test times

High Resolution Test Encoder

Neptune TG
USA

High Resolution Test Encoder

Calibration & Certification
Neptune TG
USA

High Resolution Test Encoder

Badger Meter
USA

High Resolution Test Encoder

Badger Meter
USA

High Resolution Test Encoder

Badger Meter
USA

Standing-Start-and-Finish Method

- The meter is read when the registration is stationary
- Flow is established by opening a valve
- The flow rate is determined
- The flow rate is adjusted (if required)
- The minimum test quantity is delivered
- Flow is stopped by closing a valve
- The meter is read when the registration is stationary

Standing-Start-and-Finish Method

- Ensure that only 1/50 of the (by volume) run takes place at start up and shut-down.
- If there is any doubt with target flow rates or start-up and shut-down times:
  - To increase the volume of the test
  - To increase the duration of the test

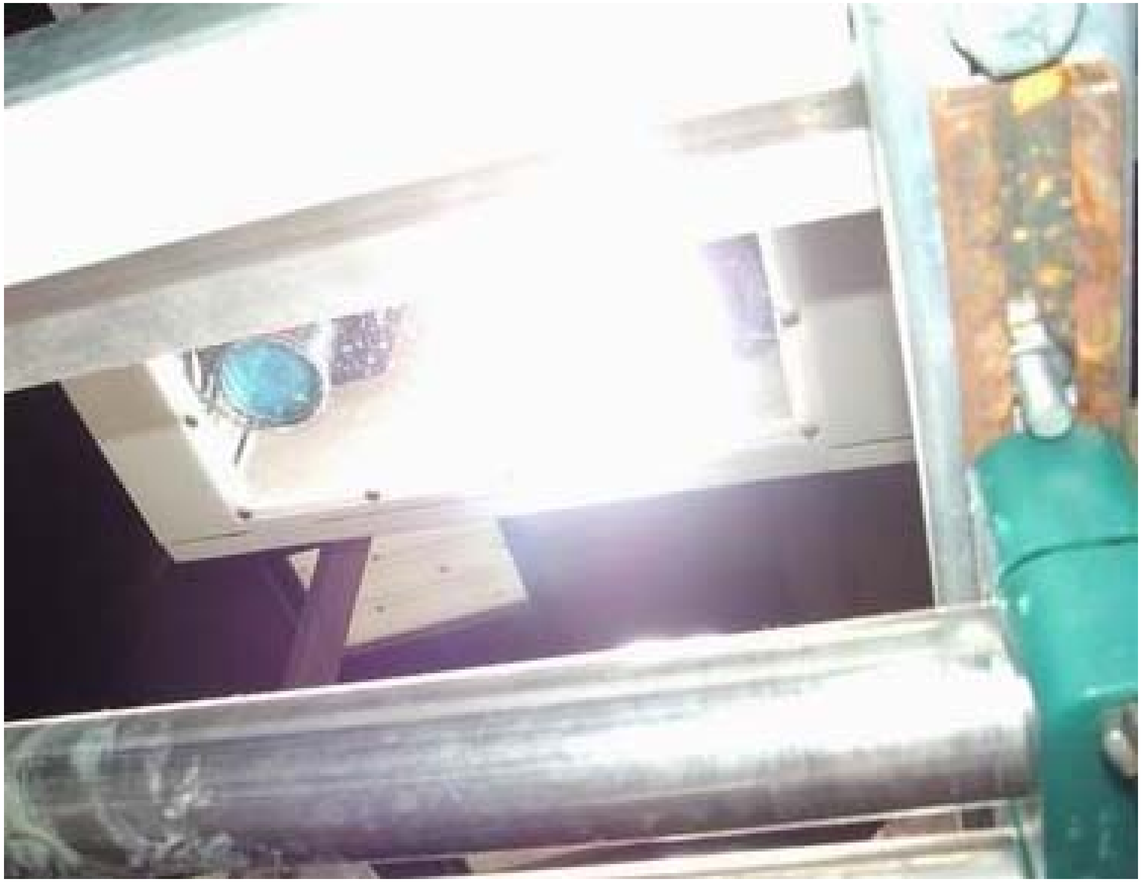
Flying-Start-and-Finish Method

- The measurement is carried out when flow conditions have stabilized
- A switch diverts the flow into a test standard at the beginning of the measurement and diverts it away at the end
- The meter is read whilst in motion (pulse output)
- The reading of the meter is synchronized with the movement of the flow switch.
- The uncertainty introduced by the flow switching will be considered negligible if the time involved is less than 1/50 of the total time of the test.

Flying-Start-and-Finish Method

PTB Test Facility
Braunschweig, Germany

Flying-Start-and-Finish Method



WRc-NSF
Wales, UK

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:
  - $\pm$ 2.5 % from Q1 to Q2 (not inclusive)
  - $\pm$ 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

Uncertainty of Measurement

- The uncertainty of this measurement, is influenced by a number of general factors:
  - Measurement uncertainty of the test standard or test equipment
  - Any variations between the volume seen by the meter and that seen by the test standard or test equipment
  - Testing process errors (stability metering conditions, meter cyclic effect, error of the measured metering conditions , etc)
  - Meter output resolution

Minimum Test Quantity

"The minimum quantity of water that must pass through the meter to ensure that there is a high level of confidence that the results of the test are accurate"

Minimum Test Quantity Calculations

- Assume that the combined measurement uncertainty of the first three factors (Uref) = 0.125%.
- For testing of water meters, two readings are taken (start of test run and end of test run)
- the uncertainty due to the resolution of the indicating device (e) is based on a triangular distribution of ± e (GUM).

  U res = e /√6 = .41e

- Ures (%) = .41e * 100 / TQ , (TQ - test quantity)

Minimum Test Quantity Calculations (cont:)

- The uncertainty of the measured meter error (Umeter) is calculated using this formula:

  $(\text{Umeter error } \%)^2 = (\text{Ures } \%)^2 + (\text{Uref } \%)^2$

- Ratio between the meter MPE (maximum permissible error) and the expanded meter error measurement uncertainty (k) = 2, OIML recommends:

  Type Approval: 5:1

  Initial Verification: 3:1

- $2 * \text{Umeter error } (\%) \leq \text{MPE}/5$ (ex. Type Approval)

  $\text{Umeter error } (\%) = \text{MPE}/10$ (ex. Type Approval)

Minimum Test Quantity Calculations (cont:)

- With the equations shown, the minimum test quantity can be calculated using this formula:

- $TQ\ min = 0.41\ e \div \sqrt{\ ((MPE/10)^{2} - (.125)^{2})}$

Minimum Test Quantity
Example # 1

Meter resolution (e) = 1 litre (0.001 m^3)

Flow Rate = Q3

MPE = $\pm$ 2 %

K=2

Type Approval Testing: 5 to 1 Ratio

$$TQ\ min = 0.41\ e \div \sqrt{\left((MPE/10)^2 - (.125)^2 \right)}$$

$$TQ\ min = 0.41 \times 1 \div \sqrt{\left((2/10)^2 - (.125)^2 \right)}$$

TQ min = 262.61 litre

Minimum Test Quantity
Example # 2

Meter resolution (e) = 1 litre (0.001 m^3)

Flow Rate = 1.1 Q1

MPE = $\pm$ 5 %

K=2

Type Approval Testing: 5 to 1 Ratio

TQ min = 0.41 e ÷ √ ($(MPE/10)^2 - (.125)^2$)

TQ min = 0.41 x 1 ÷ √ ($(5/10)^2 - (.125)^2$)

TQ min = 84.68 litre

Minimum Test Quantity
Example # 3

Meter resolution (e) = 1 litre (0.001 m^3)

Flow Rate = 0.9 Q3

MPE = $\pm$ 2 %

K=2

Initial Verification: 3 to 1 Ratio

$$TQ\ min = 0.41\ e \div \sqrt{\left((MPE/6)^2 - (.125)^2 \right)}$$

$$TQ\ min = 0.41 \times 1 \div \sqrt{\left((2/6)^2 - (.125)^2 \right)}$$

TQ min = 132.68 litre

Minimum Test Quantity
Example # 4

Meter resolution (e) = 1 litre (0.001 m^3)

Flow Rate = 1.1 Q1

MPE = ± 5 %

K=2

Initial Verification: 3 to 1 Ratio

$$TQ\ min = 0.41\ e \div \sqrt{\left((MPE/6)^2 - (.125)^2 \right)}$$

$$TQ\ min = 0.41 \times 1 \div \sqrt{\left((5/6)^2 - (.125)^2 \right)}$$

TQ min = 49.76 litre

Minimum Test Quantity
Summary Table

Example	Inspection Type	Meter Resolution (Litre)	Flow Rate	MPE	K= Value	Uncertainty Ratio	TQ Min (Litre)
#1	Type Approval	1 litre	0.9 Q3	± 2 %	2	5 : 1	263
# 2	Type Approval	1 litre	1.1 Q1	± 5 %	2	5 : 1	85
# 3	Initial Verification	1 litre	0.9 Q3	± 2 %	2	3 : 1	133
# 4	Initial Verification	1 litre	1.1 Q1	± 5 %	2	3 : 1	50

Water Meter Testing

Questions or Comments