National Measurement System

Custody Transfer Flow Metering

Alick MacGillivray

Consultant

National Measurement Office

NPL National Physical Laboratory

LGC Setting standards in analytical science

nel technology for life

National Measurement System

Contents

nel technology for life

Introductory slides:

- Why is measurement important?
- The UK National Measurement Office (NMO) and the National Measurement System (NMS)

Main presentation:

- Custody Transfer
- Meter Types
- Meter Proving
- Density Determination
- Secondary Instrumentation

National Measurement System

Why is measurement important?

nel technology for life

Each year in the UK

£342 BILLION

worth of goods, gas and electricity

are sold on the basis of the **measurement** of their quantity to consumers.

National Measurement System

National Measurement System

“The NMS is responsible for stimulating good measurement practice and enabling business to make accurate and traceable measurements, for the benefit of the nation”

National Measurement System

NEL

nel technology for life

- UK National Standards for Flow Measurement
  - Oil
  - Water
  - Gas
  - Multiphase
- Research
- Joint Industry Projects
- Flow measurement consultancy

National Measurement System

nel technology for life

MAIN PRESENTATION

CUSTODY TRANSFER FLOW METERING

National Measurement System

Why Measure?

nel technology for life

- Taxation or custody transfer
- Allocation
- Reservoir management
- Well testing
- Meeting specifications or requirements
- Environmental reporting

National Measurement System

What is Custody Transfer?

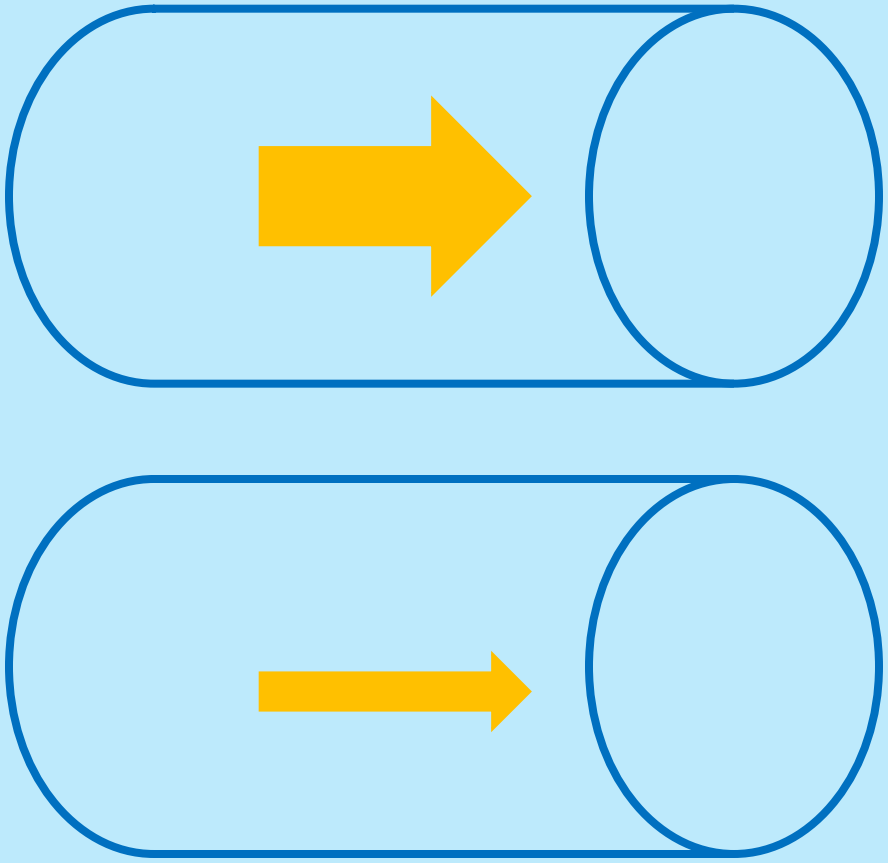
nel technology for life

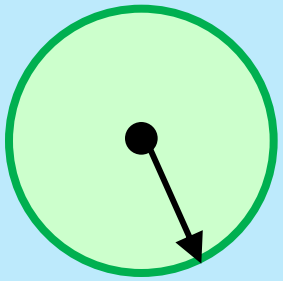
- Transactions involving transporting a fluid from one operator to another.
- Metering point where the fluid is being measured for **sale** from one party to another.
- **Accuracy is of great importance** to both the company delivering the material and the eventual recipient

National Measurement System

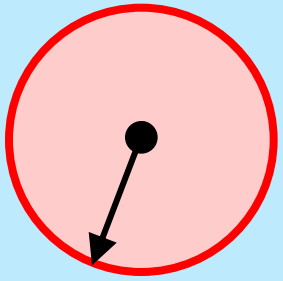
Turn Down Ratio

nel technology for life





Max Flow



Min Flow

Ratio of max flow to min flow in effective range

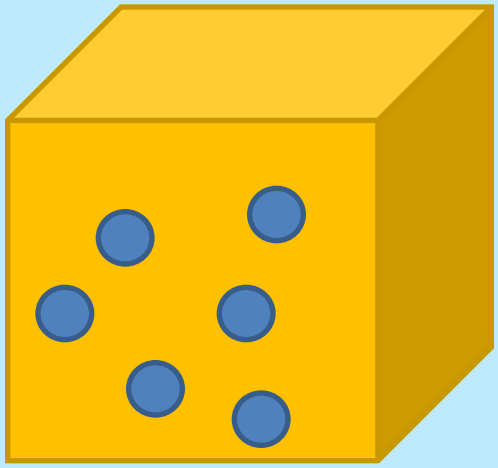
National Measurement System

Gross Standard Volume

nel technology for life

Gross Standard Volume (GSV)

The total volume of petroleum liquids, sediment and water at standard temperature and pressure



National Measurement System

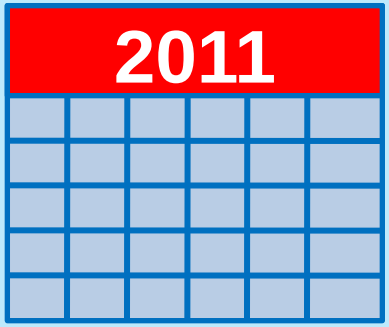
Some Facts

nel technology for life

88 Million barrels of Oil per day

The total cost was approximately

$9.9 Billion



Uncertainty was

0.25%

Financial exposure

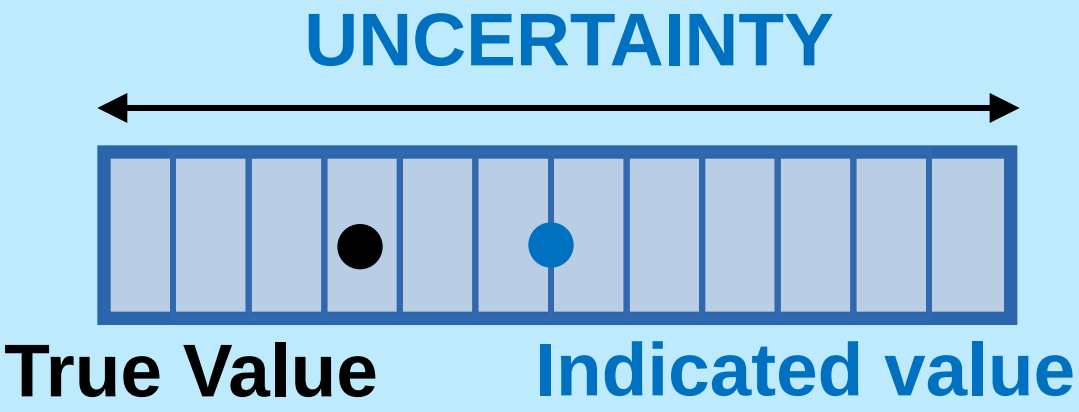
$25 Million per day

National Measurement System

What is uncertainty?

nel technology for life

An **INTERVAL** either side of the measurement result within which we expect the true value to lie (with a given confidence)



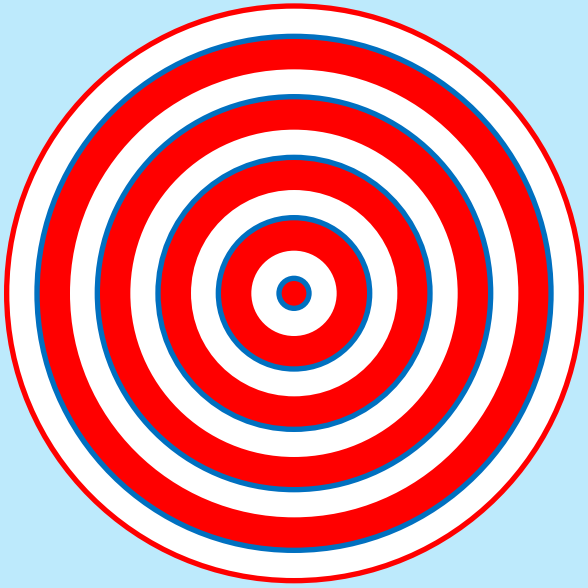
National Measurement System

Uncertainty Targets

nel technology for life

For Custody Transfer (Fiscal) metering the following uncertainty limits are typical (quoted at 95% confidence) for gross standard volume (GSV)

LIQUID
0.25%



GAS
1.0%

National Measurement System

Typical Components

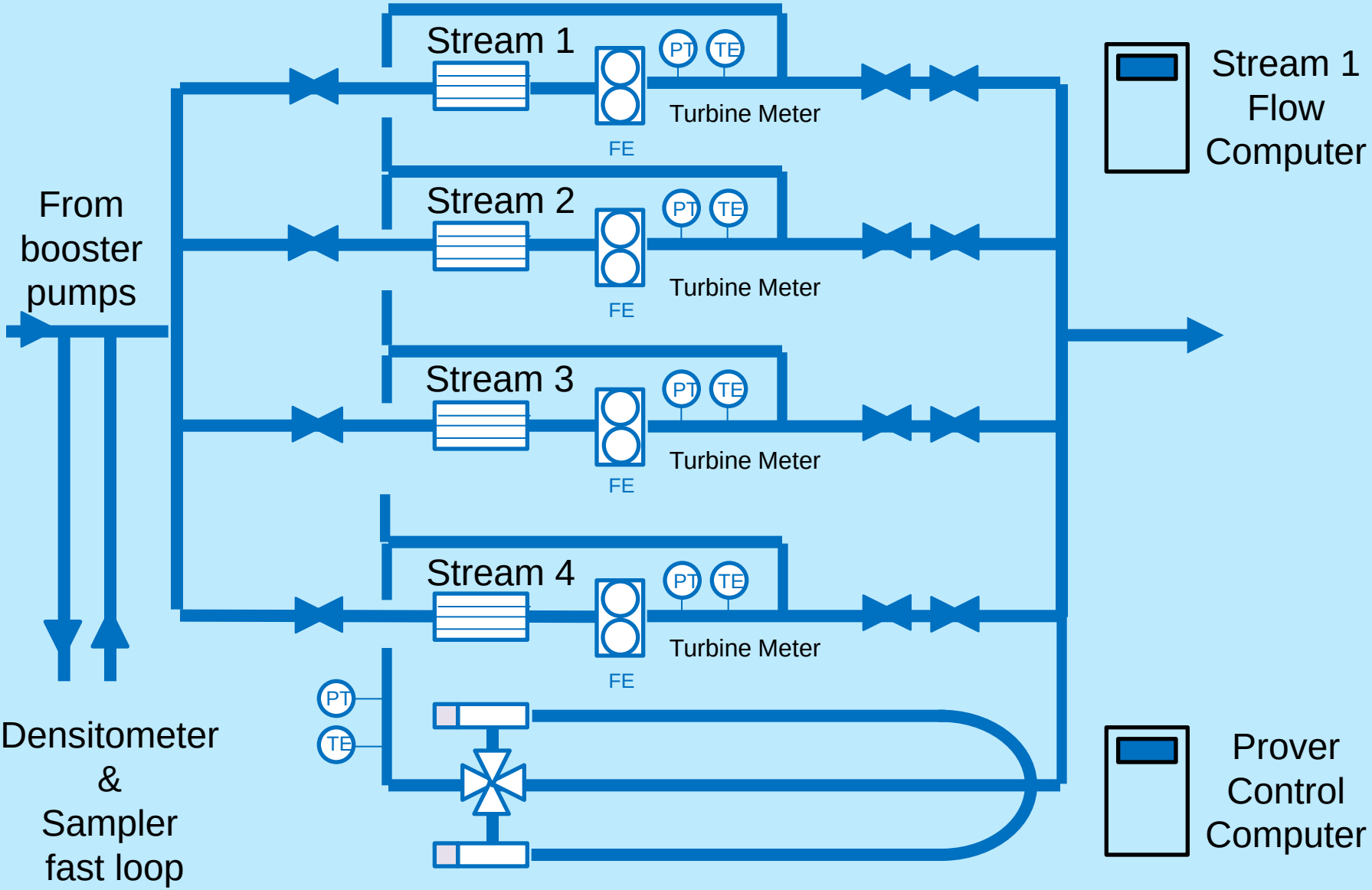
nel technology for life

- When metering to low uncertainty: a meter placed in a line is NOT enough.
- Other components are required to reduce uncertainty
- The components include:
  - A meter prover
  - Density measurement instruments
  - Sampling systems
  - Composition measurement for gas
  - Temperature measurement
  - Pressure measurement
  - Flow conditioning
  - Flow computers

National Measurement System

Oil Export Meter Package

nel technology for life

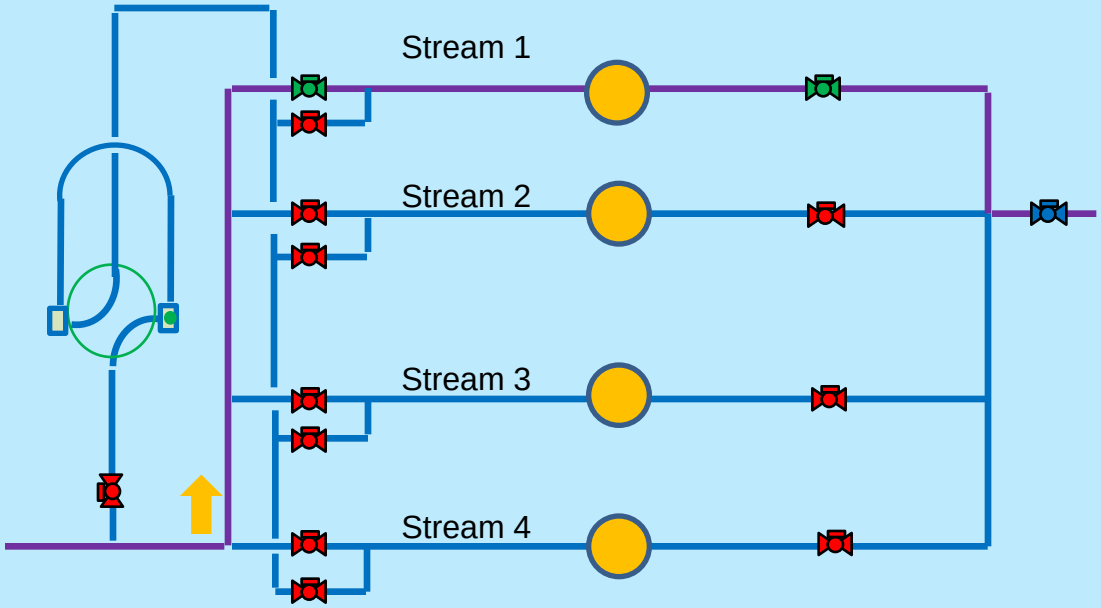


METER TYPES

Meter Types

The main meter types used in Custody transfer metering are:

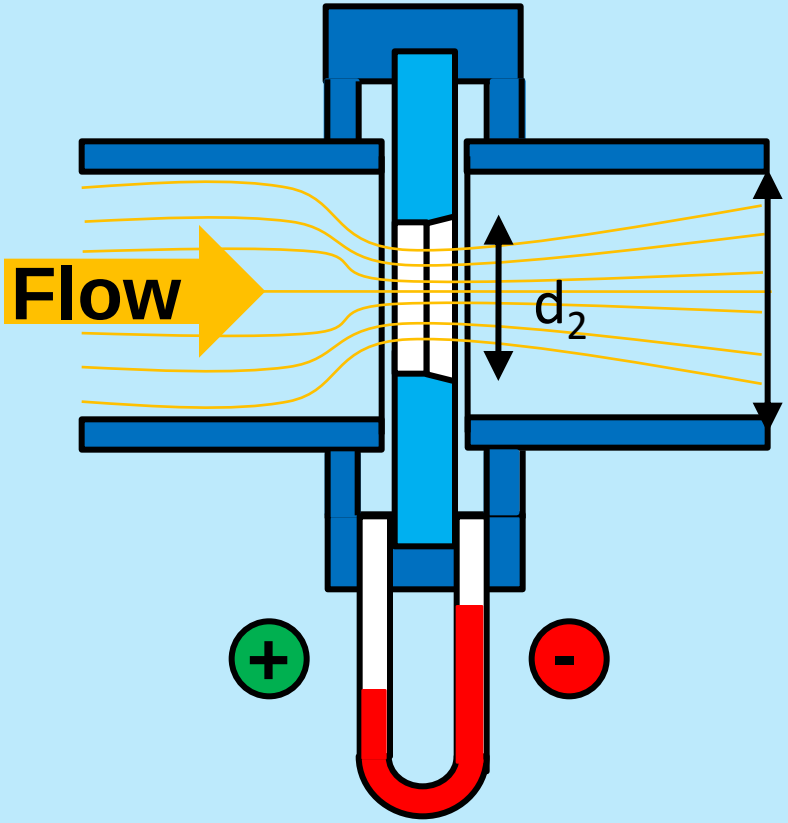
- Orifice plates
- Turbine meters
- Positive displacement meters
- Ultrasonic meters
- Coriolis meters



National Measurement System

Orifice Meters

nel technology for life

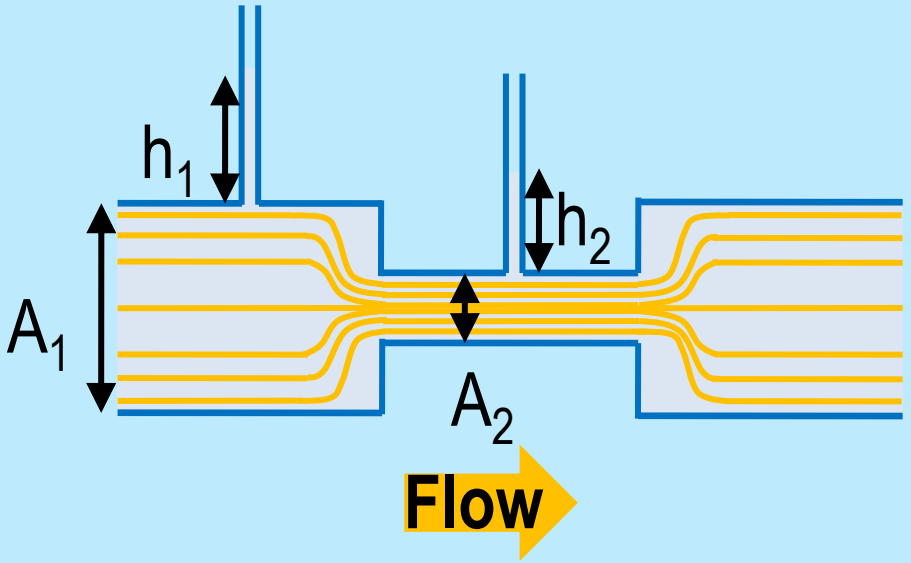


- Most common type of Δp meter
- Machined plate held between two pipes
- Plate has a hole in the centre
- Medium uncertainty
- Low turndown
- Gas and liquid flow

Orifice Meters

Advantages

- Low cost
- Easy to install
- Comprehensive Standards



Disadvantages

- High Pressure Loss
- Erosion to edges causes error
- Very sensitive to upstream installation (especially large beta devices)

Turbine Meters

- Free rotating rotor with flow in pipe
- Rotor has multiple blades
- Rotor driven by flow
- Flowrate proportional to rotor speed
- Count the rotations – total fluid volume
- Medium uncertainty
- Medium turndown
- Versatile (measures natural gas and crude oil)

National Measurement System

Turbine Meters

nel technology for life

Advantages

- Very good repeatability
- Easy to install
- Average cost

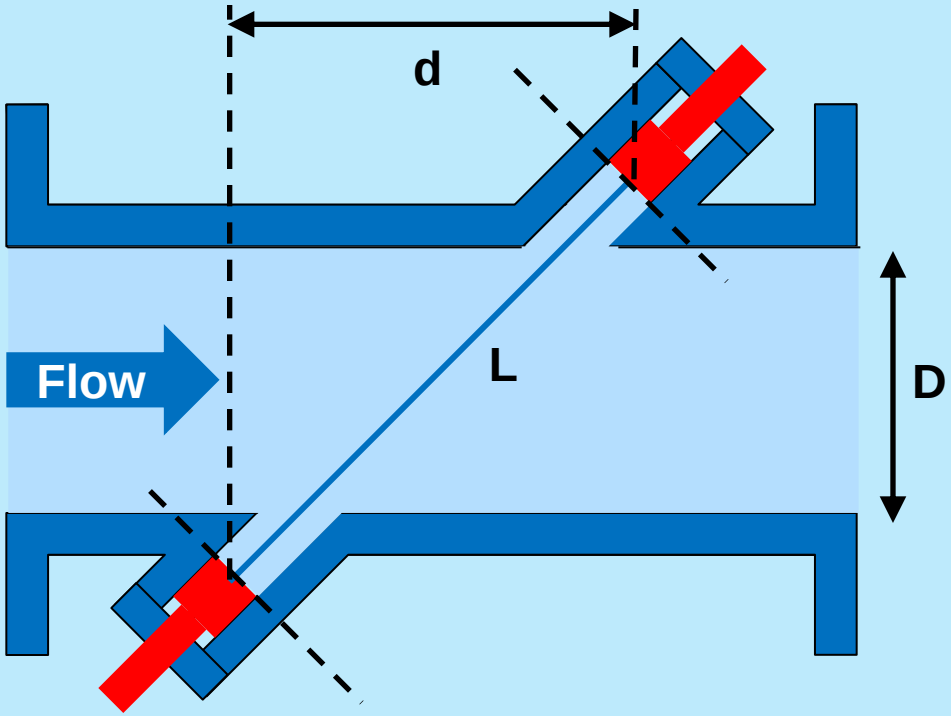
Disadvantages

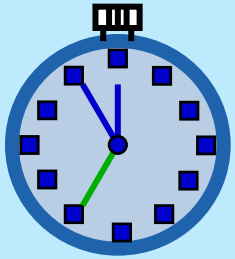
- Susceptible to mechanical damage
- Installation effects
- Bearing wear
- Can be blocked by contaminants

National Measurement System

Ultrasonic Meters

nel technology for life





- Speed of propagation of the ultrasonic signal depends on the speed of the fluid through which it travels
- Analogous to a boat travelling with or against the current
- Very low uncertainty
- High turndown

National Measurement System

Ultrasonic Meters

nel technology for life

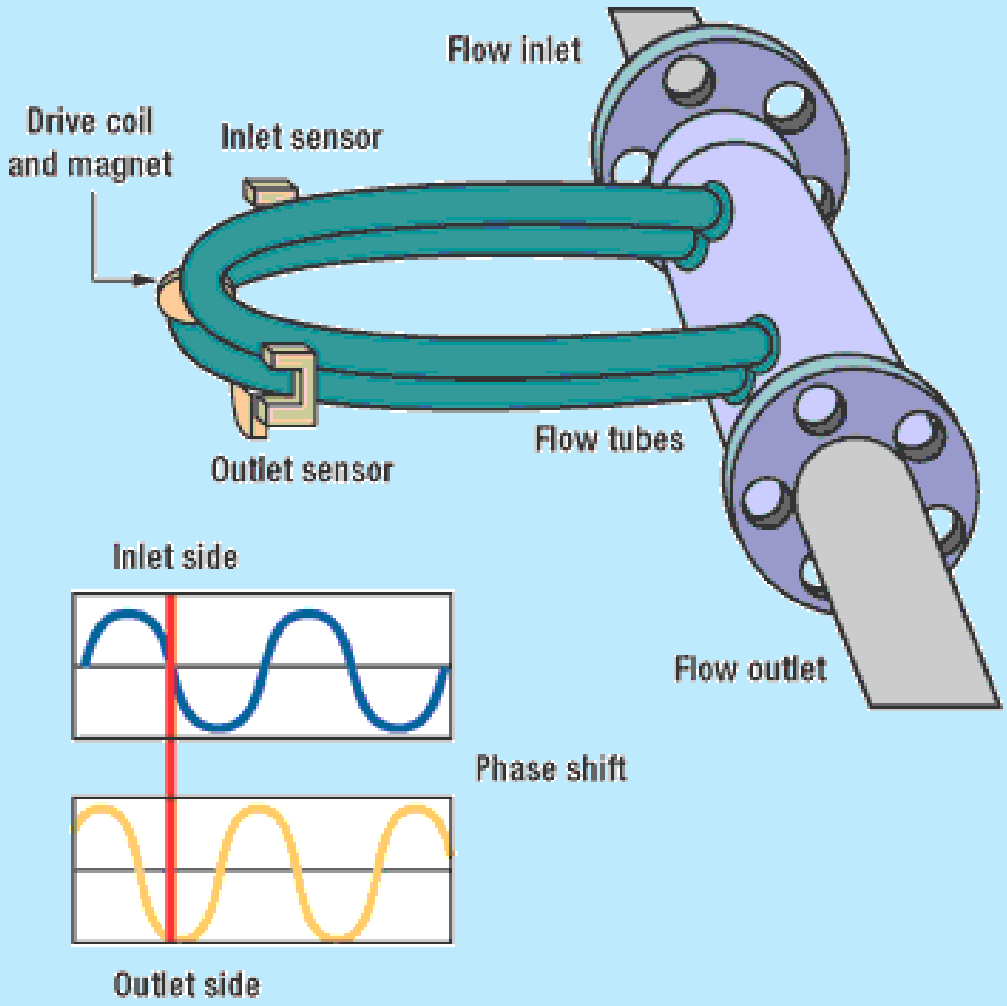
Advantages

- Non-intrusive and non-invasive
- No moving parts
- Diagnostic and secondary measurements
- Bi-directional measurement

Disadvantages

- Expensive
- Susceptible to installation effects
- Deposition in transducer ports

Coriolis Meters



- Tubes vibrate at natural frequency
- Frequency gives a measure of fluid density
- Flow causes twist
- Twist causes phase difference
- Can measure phase difference very accurately
- Difference proportional to mass flow

National Measurement System

Coriolis Meters

nel technology for life

Advantages

- Insensitive to fluid Parameters (density, viscosity)
- Non-invasive
- High accuracy
- High Turn-down

Disadvantages

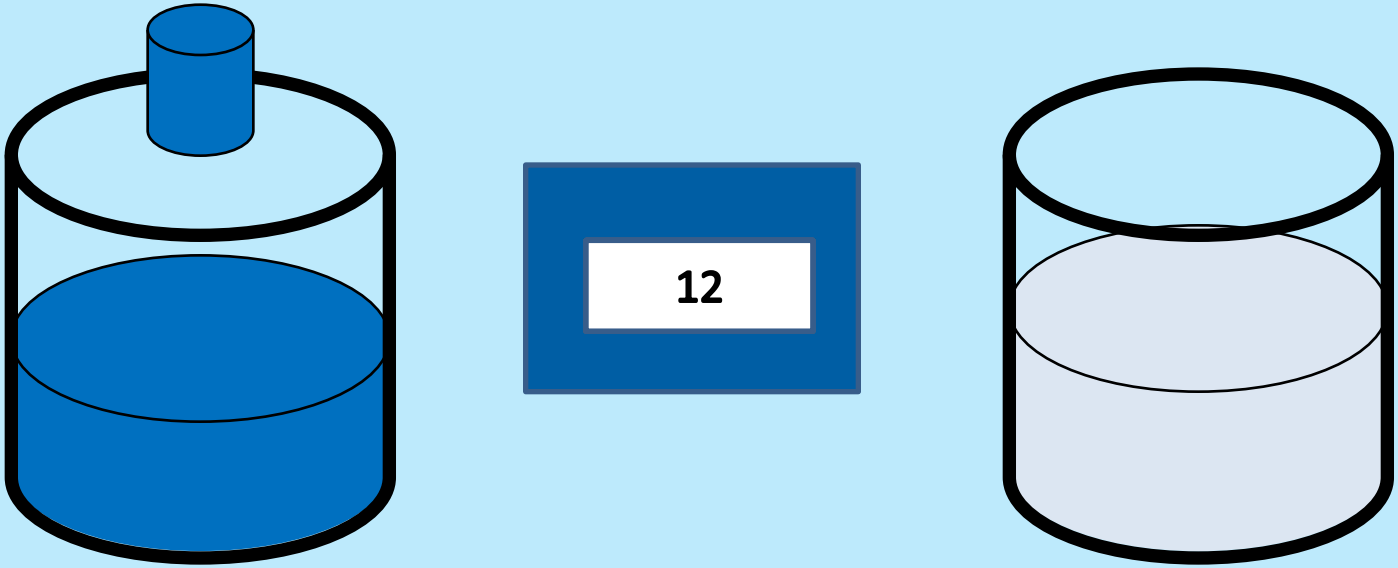
- Zero Stability
- Limited Size
- High Cost
- Vibration and stress effects
- Introduces pressure drop

National Measurement System

Positive Displacement

nel technology for life

- Fluid mechanically displaces component to measure flow
- Like repeatedly filling a bucket to a fixed level
  - Time the rate at which the bucket is being filled
  - Total number of buckets for total volume



National Measurement System

Positive Displacement

nel technology for life

Advantages

- Accurate
- Repeatable
- Fast response
- A direct method
- Good for batching
- Insensitive to installation effects

Disadvantages

- Susceptible to mechanical damage
- Bulky and complicated
- Expensive

National Measurement System

nel technology for life

METER PROVING

National Measurement System

Meter Proving

nel technology for life

- It's the same as calibration but:
  - Done on-site
  - Usually more often
- Often included as part of liquid metering systems
- Compares the meter's registered throughput to a known reference volume
- Types of prover:
  - Pipe provers
  - Tank provers
  - Compact provers
  - Master meters

National Measurement System

Meter Proving

nel technology for life

- Meter proved on a number of consecutive runs
- Meter must show repeatability below given tolerance
- Maintenance is important
- Temperature variations can cause problems
  - Fluid can be different temperature to prover
  - Allow time to stabilise if possible

National Measurement System

Pipe Provers

nel technology for life

- Basically a length of pipe, part of whose internal volume has been determined accurately
  - Capable of calibrating meters with pulsed output
- Provers used where lab calibration not possible
  - The known volume is contained in a specific length of pipe between two detector switches
  - Number of meter pulses (or volume) is then counted between a displacer tripping first one switch then a second

National Measurement System

Types of Pipe Prover

nel technology for life

There are four main classifications of pipe provers

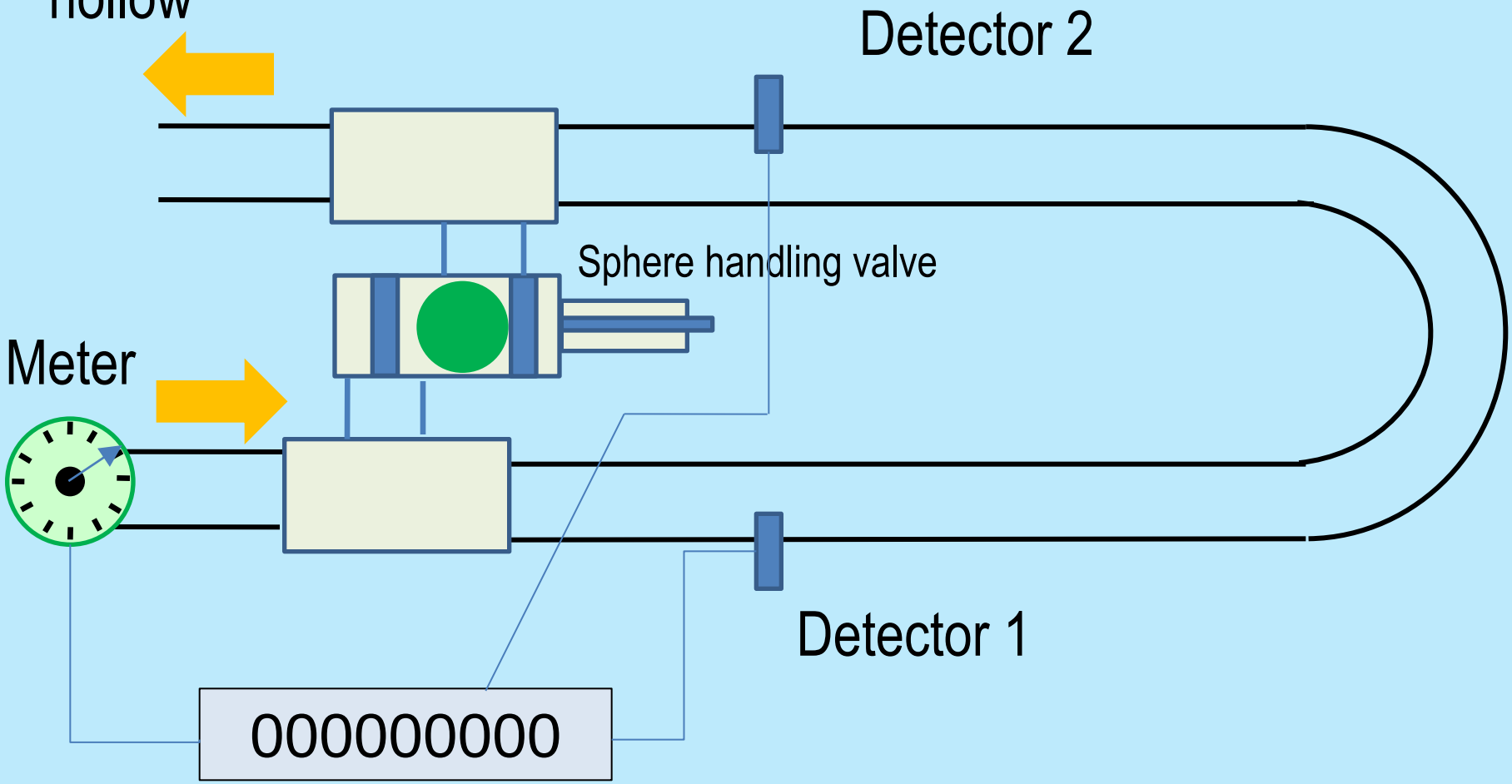
- Uni-directional ball provers
- Bi-directional ball provers
- Piston provers
- Compact provers

National Measurement System

Uni-directional Ball Provers

nel technology for life

- Displacer travels in ONE direction along the pipe
- Displacer is a elastomer (neoprene, polyurethane etc which is hollow



National Measurement System

Master Meters

nel technology for life

- A Master Meter is simply a meter that has been proven against displacement or tank provers
- By running the master meter in series with the meter being proved a comparison can be made
- Reliable and repeatable
- Does not adversely alter the flow profile
- Positive displacement used for years:
  - When checking petrol pumps
- Ultrasonic used as master meters
  - No pressure drop through the line

National Measurement System

Master Meter Z Configuration

nel technology for life

- Configuration to allows one meter to act as duty meter while the other is used as the master
- The master meter and duty meter to be tested in series
- It has compact design – normally uses less space than a prover

National Measurement System

nel technology for life

DENSITY DETERMINATION

National Measurement System

Density Determination

nel technology for life

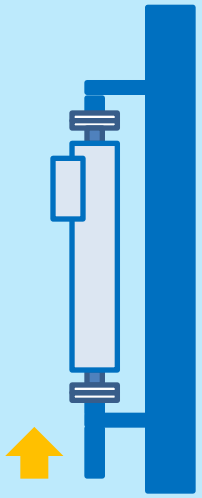
- Density measurement is a fundamental requirement for upstream oil and gas production
- The most commonly used technique is an oscillatory densitometer
- Oscillatory densitometers are very good devices provided that they are
  - Installed correctly
  - Calibrated properly

National Measurement System

Density Determination

nel technology for life

- Densitometer: Spring Mass Oscillating System
  - Vibrating test section
  - Fluid contained in it
- As liquid density changes
  - Changes the total vibrating mass
  - Detected by a change in the resonant frequency
- Resonant frequency depends on the stiffness and the mass of the element.

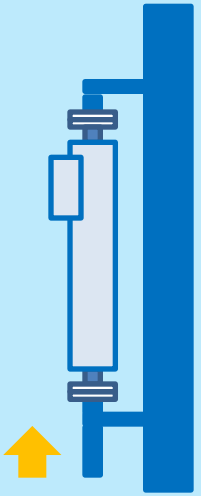


National Measurement System

Density Determination

nel technology for life

- The stiffness depends on k factor constants
- These are used with the oscillation period to calculate the density of the fluid
- Density is measured at a reference temperature and pressure



National Measurement System

Density Determination

nel technology for life

Advantages

- Simple and easily automated
- Can be used over a wide temperature and pressure range
- Can be used in-line
- Commercially available
- Potentially very accurate ± 0.1%

Disadvantages

- Expensive to purchase
- Careful calibration required - NEL

National Measurement System

Fluid Sampling

nel technology for life

When taking a crude oil sample

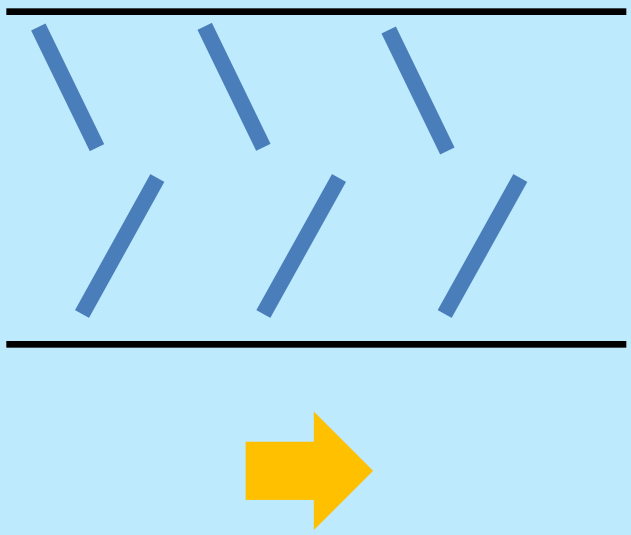
- Fluids must be completely mixed
- Flow must remain representative and stable throughout sampling period
- Sample analysed must be the same as that sampled
- Each sub-division must have exactly the same composition as original sample

National Measurement System

Static Mixer

nel technology for life

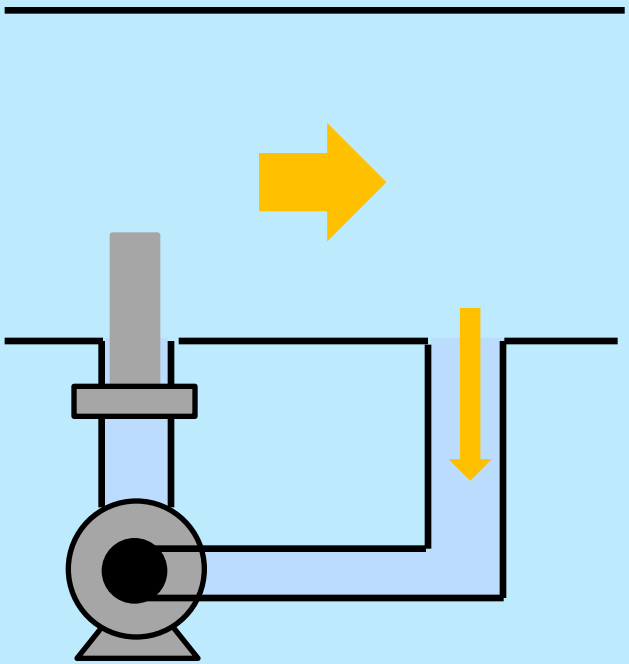
- A static mixer is a device for the continuous mixing of fluids.
  - Normally the fluids to be mixed are liquid, but static mixers can also be used to mix gas streams
  - Situated in the pipe in which the fluid is flowing

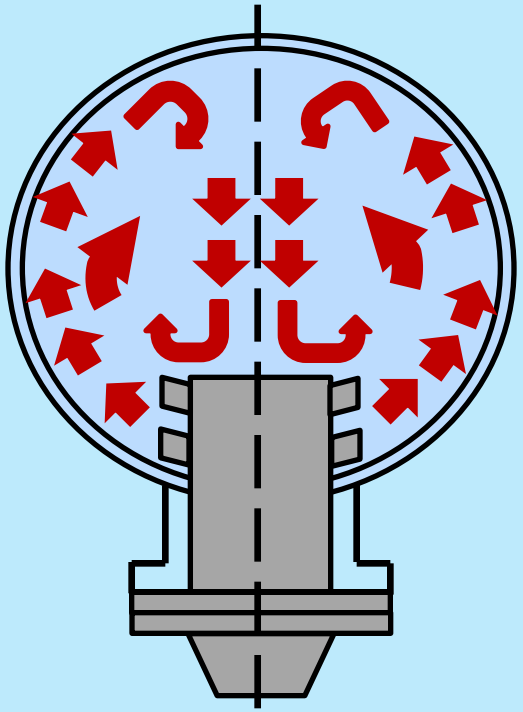


Static Mixer

Jet Mixer

- A jet mixer are jet pumps to mix and circulate models. Used in a bypass system
  - The mixer will not introduce a pressure drop into the pipeline





Jet Mixer

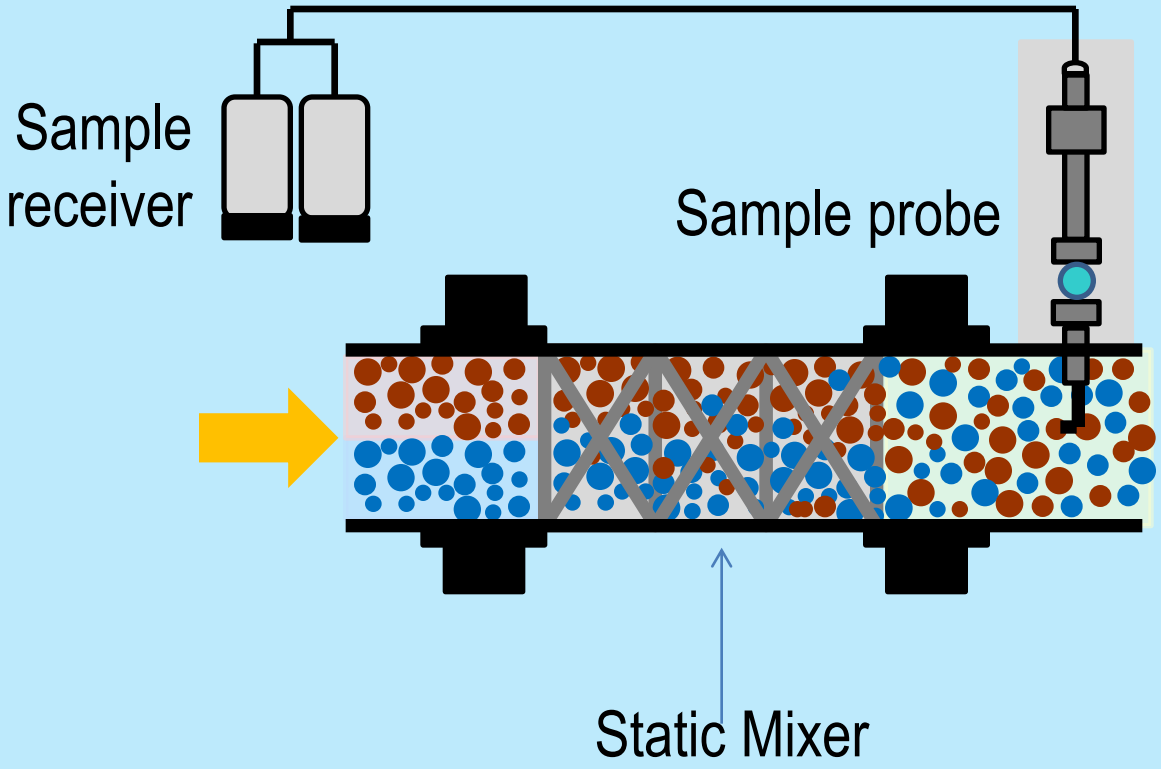
Types of Sampling Method

Composite Sampling

- Composed of a number of smaller samples taken over a number of time or flow intervals
- Flow Proportional Sampling
  - Samples collected at defined volume interval
- Time proportional Sampling
  - Samples collected at defined time interval

Types of Sampling System

- In-line installations
- By-pass installations or fast-loop systems



National Measurement System

Secondary Instrumentation

nel technology for life

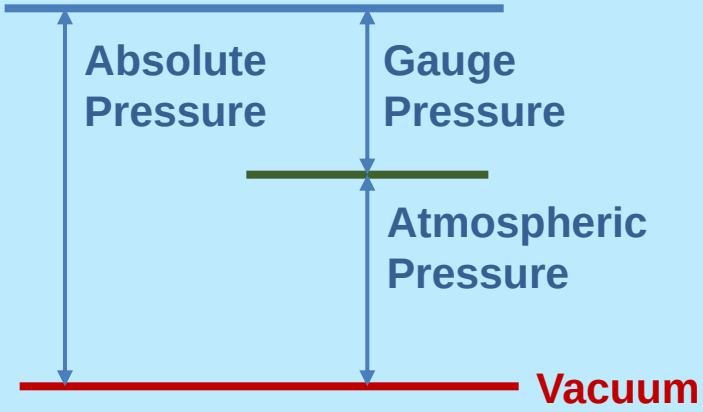
- Pressure and pressure measurement
  - Capacitance Diaphragm Transmitters
- Differential pressure transmitters
  - Pressure sensing elements
- Temperature measurement
  - Resistance temperature detectors
  - Temperature transmitters

National Measurement System

Pressure Measurement

nel technology for life

- Static ‘Absolute’:
  - Pressure relative to vacuum
- Static ‘Gauge’:
  - Pressure relative to atmosphere
- Differential:
  - Pressure relative to another pressure
- “Standard pressure” (101,325 Pa)



National Measurement System

Differential Pressure Measurement

nel technology for life

- Very often used for the measurement of flow rate in Orifice and Venturi Meters
- These flowmeters have a primary and secondary element
  - The **primary element** is designed to produce a difference in pressure as the flow increases (e.g. Orifice Plate)
  - The **secondary element** of the flowmeter is the differential pressure transmitter
  - It is designed to measure the differential pressure produced by the primary element as accurately as possible

National Measurement System

Differential Pressure Transmitter

nel technology for life

- Senses the difference in pressure between two ports
  - Produces an output signal with reference to a calibrated pressure range
- Industrial differential pressure transmitters are made of two housings
  - Pressure sensing element is housed in the bottom half
  - Electronics are housed at the top half
  - It has two pressure ports marked as high and low

National Measurement System

Resistance Temperature Detectors

nel technology for life

- A sensor used to measure **temperature** by correlating the **resistance** of the RTD element with temperature.
- Most RTD elements consist of a length of fine coiled wire wrapped around a ceramic or glass core.
- The RTD element is made from a pure material, typically platinum, nickel or copper

National Measurement System

Temperature Transmitters

nel technology for life

- Works by connecting to some form of temperature sensor
  - For example an RTD (Resistance Temperature Detector)
  - Typically, temperature transmitters isolate, amplify, filter noise, linearise, and convert the input signal from the sensor
  - Then send (transmit) a standardized output signal to the control device.

National Measurement System

What is a Flow Computer?

nel technology for life

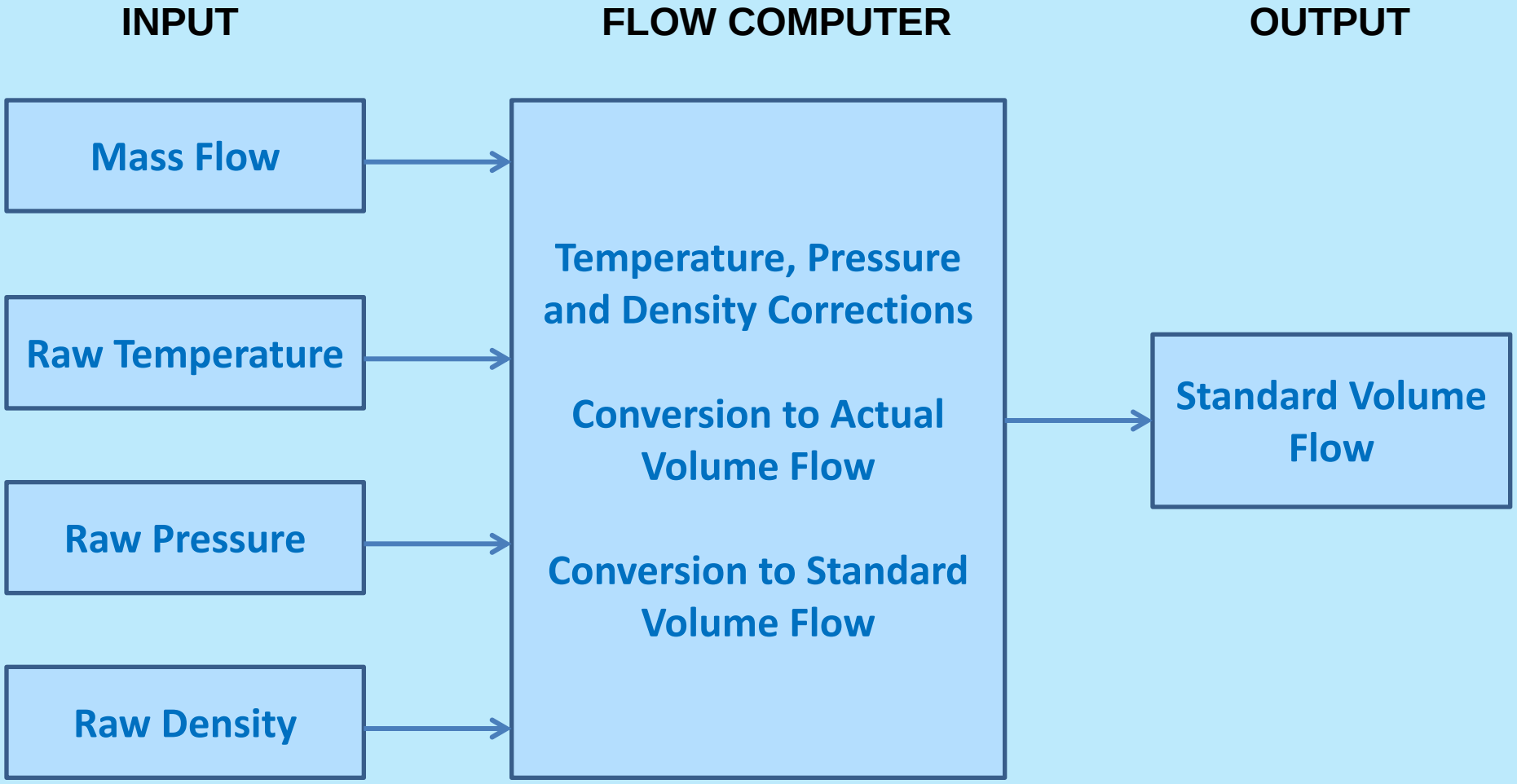
A flow computer is

- An electronic computational device
- Implements the required algorithms using the analogue and digital signals received from
- flow meters
- Temperature
- Pressure
- density transmitters
- Converts into volumes at base conditions.

National Measurement System

Flow Computer Functions

nel technology for life



National Measurement System

Summary

nel technology for life

- Custody transfer measurement is defined as a metering point (location) where the fluid is being measured for sale from one party to another.
- Requires low uncertainty (1% on standard volume with gas and 0.25% on standard volume for liquid)
- Metering to this standard requires a full system with
  - Flow meter
  - A prover (depending on metering technology)
  - Density determination
  - Temperature, static and differential pressure measurement
  - Mixing and sampling devices
  - Flow computers

Thank you for listening

Any questions?

Email: alick.macgillivray@tuv-sud.co.uk

Website: www.tuvnel.com

National Measurement System

NEL Contact Tel: + 44 (0) 1355 220222

nel technology for life

NEL Contacts

Audit & Allocation	Alick MacGillivray	alick.macgillivray@tuv-sud.co.uk
CFD	Neil Bowman	neil.bowman@tuv-sud.co.uk
Densitometers	Norman Glen	norman.glen@tuv-sud.co.uk
Erosion	John Peters	john.peters@tuv-sud.co.uk
Flow Consortium	Phil Mark	phil.mark@tuv-sud.co.uk
Heavy Oil	Chris Mills	chris.mills@tuv-sud.co.uk
Measurement Consultancy	Craig Marshall Chris Mills Alick MacGillivray	craig.marshall@tuv-sud.co.uk chris.mills@tuv-sud.co.uk alick.macgillivray@tuv-sud.co.uk
Measurement Uncertainty	Alick MacGillivray	alick.macgillivray@tuv-sud.co.uk
Meter Diagnostics	Craig Marshall	craig.marshall@tuv-sud.co.uk
MeterVue	Phil Mark	phil.mark@tuv-sud.co.uk
Multiphase	Terri Leonard	terri.leonard@tuv-sud.co.uk
PPDS	Norman Glen	norman.glen@tuv-sud.co.uk
Single Phase Metering	Sarah Pedley	sarah.pedley@tuv-sud.co.uk
Training	Hazel Hampson Susan Tough	events@tuvnel.com
Umbilicals	John Dods	john.dods@tuv-sud.co.uk
Valve Testing	John Dods	john.dods@tuv-sud.co.uk
Wet Gas	Emmelyn Graham	emmelyn.graham@tuv-sud.co.uk

For general queries contact the sales team on sales@tuvnel.com