Utility Flow Metering for Steam and Heated/Chilled Water: A Tutorial

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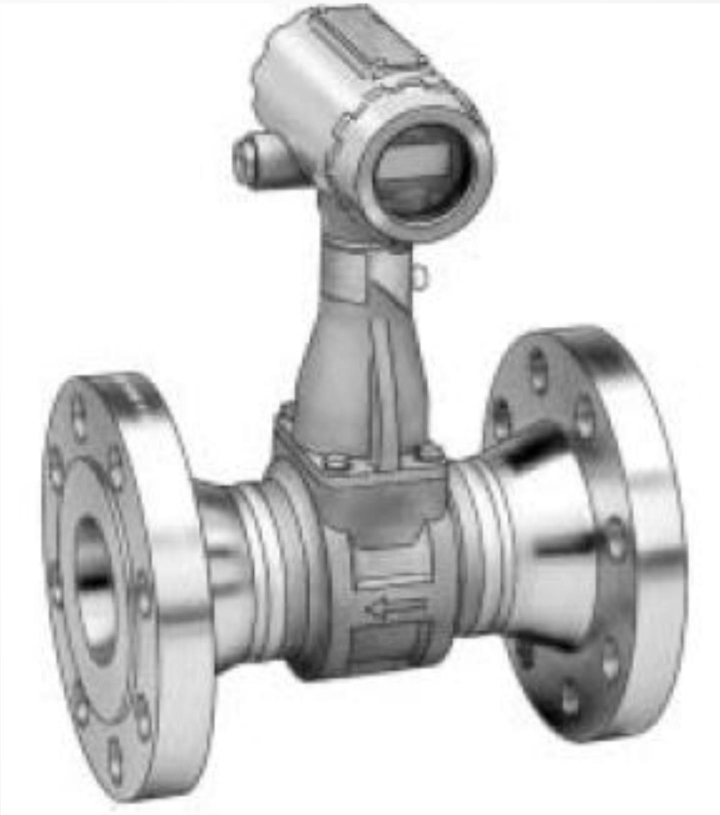
Review Flow Metering Principles: Flow Meters and Flow Computers



Utility Distribution & Customer Metering Concerns

- Service pressure, temperature, energy
- Expected customer load (flow rates)
- Service Reliability & Service Interruptions
- Billing Accuracy
- Scheduled Maintenance
- Information and Expertise Sharing
- Proposed installation location
- Steam Quality

Basic Input Measurements of Flowing Process Conditions

- Differential Pressure
- Static Pressure
- Temperature
- Volume Flow Rate
- Velocity
- Fluid properties are computed by temperature and/or pressure

Fluid Properties

- Density of Water or Saturated and Superheated Steam can be implied from measured (absolute) pressure and/or temperature and internally stored fluid properties
- Other properties: energy/unit mass, isentropic exponent, and viscosity are also computed
- Unfortunately steam quality is not implied and removing steam condensate prior to metering is a installation requirement

Attributes of Flow Meters

- Accurate Flow Rate Range at fluid density
- Mandatory Installation Piping Requirements
- Available output signal type(s)
- Uncertainty (or accuracy)
- Basis of Calibration (water or air)
- Application of required Correction Factors
- Maintenance required
- Flow profile and flow swirl effects
- Inline vs insertion vs clamp-on types

Attributes of Installation Site

- Fluid state and available inlet and outlet pipe runs
- Elevation above sea level (barometric pressure)
- Process noise in the differential pressure sensing lines at the steam/water interface
- Wet leg compensation of static pressure xmtrs
- Winter demand/Summer demand flow rates
- Vibration in piping systems
- Electrical Interference & Electrical Grounding alternatives
- Interconnections to Building Controls
- Condensate recovery from customer site

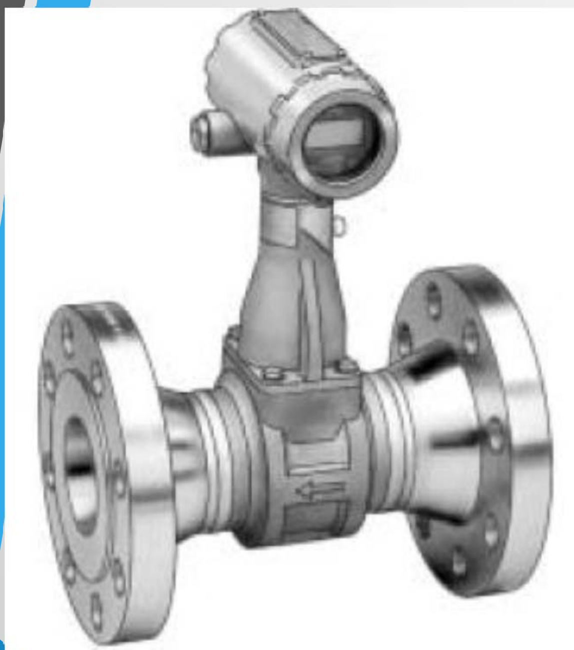
Estimating Overall Metering Uncertainty

- Define the intended operating region of flow rate, temperature, and pressure at the site
- Identify the uncertainty in the volume flow rate measurement
- Identify the uncertainty in the inferred steam density as a result of uncertainty in the steam temperature and/or pressure
- RMS the individual error components to arrive at the estimated uncertainty of steam mass flow
- Similar process is used in liquid BTU systems

Commercial Flow Meter Types

- Vortex Flow Meters
- Orifice Plate Square Law Meters
- Contoured Inlet Square Law Meters Nozzles, V-Cone, Accelabar)
- Averaging Pitot Square Law Flow Meters
- Gilflo and ILVA Type Meters
- Target Flow Meters
- Insertion Turbine/Vortex Flow Meters
- Shunt Flow Meters (Bypass or Compound Flow)
- Ultrasonic Flow Meters
- Condensate Flow Meters
- Electromagnetic Flowmeters

Survey of Steam and Condensate Flow Meter Techniques



Basic Techniques

Measure steam into facility

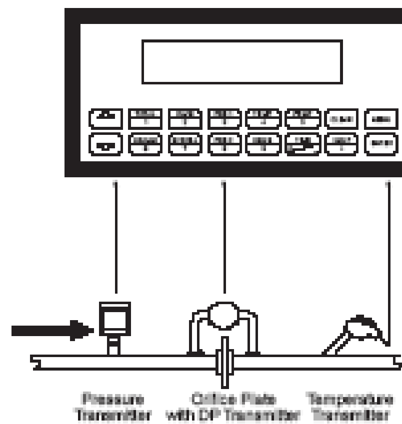
- Measure the volume flow rate in steam line
- Compute the fluid properties of steam from T & P
- Compute (and sum) mass flow rate as:
  - Mass flow = Density * Volume flow
  - Energy flow = Enthalpy * Mass flow

Measure only condensate out from facility

- Requires collection and metering of ALL condensate
- Assumes no unintentional entry of process water into condensate collection

Steam Metering

Steam Mass & Steam Heat Illustration



Calculations

Mass Flow

Mass Flow = volume flow • density (T, p)

Heat Flow

Heat Flow = Volume flow • density (T, p) • Sp. Enthalpy of steam (T, p)

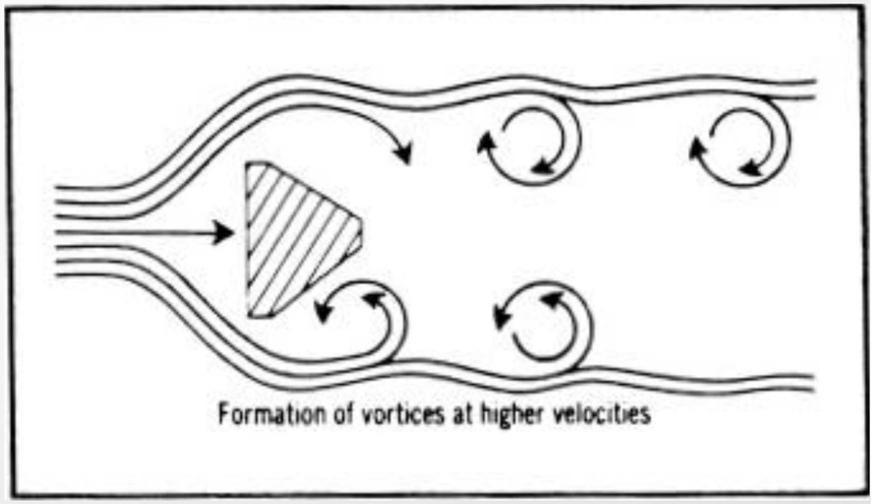
Vortex Flow Meter Principles

Flow around non-streamlined shape produces alternating vortices at higher velocities whose shedding frequency is essentially linear with volume flow through the meter run.

- Calibrated by manufacturer on water.
- Corrections can be applied for effects of flowing temperature on the meter run (K drops with Tf).
- Mass flow can be computed from volume flow and flowing density.
- Full bore and reduced bore models available as well as insertion styles

Some Important Observations

- Grounding of piping and signal common to earth.
- Mounting shedder bar horizontal reduces adverse impact of condensate hitting bar.
- Use adjustable trigger sensitivity if false output @ no flow (this reduces range of the meter).
- Avoid accidental, duplicate corrections.



Vortex Advantages

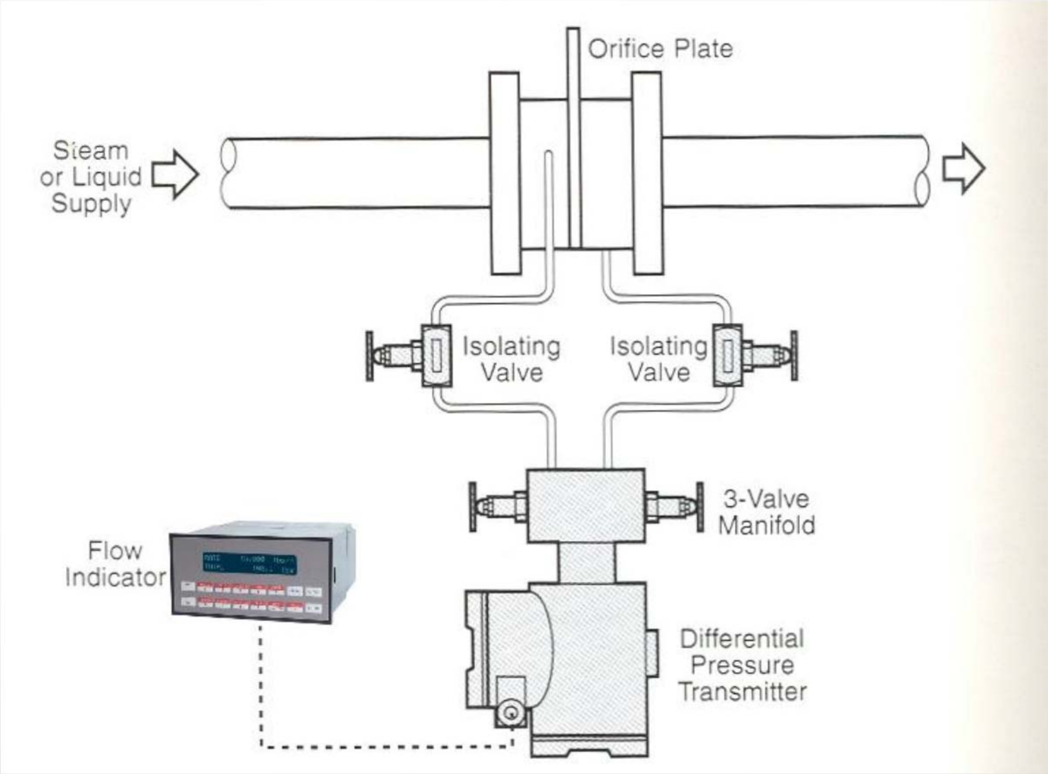
- Most popular steam flow meter.
- Accuracy of +/- 1% of volume flow rate.
- Wide flow turn-down range 15:1 type.
- Pulse and analog output signals available.
- Swirlmeter for short runs.
- Reduced bore meters for existing meter runs and resizing.

Orifice Flow Meter Principles

- Orifice Meters are the historic bench mark “Square-law” flow meter others are compared against.
- Includes various orifice styles and pressure tap locations.
- Intended for limited accurate flow range of 4:1 but can be increased to a usable 20:1 range if stacked (high and low range). DP transmitters are used on primary element.
- Generally not calibrated but rather “sized” with standardized methods and so fabricated and installed.
- Corrections required include: correction for density, dimensional changes with temperature Fa, Y1 correction for velocity of approach, and sometimes Cd verses Rn.

Typical Installation

- Orifice Beta Ratio typically chosen to provide 100“ H2O at Maximum Flow and nominal line pressure.
- Normal Flow is typically 70% of Maximum Flow.



Considerations for Installation

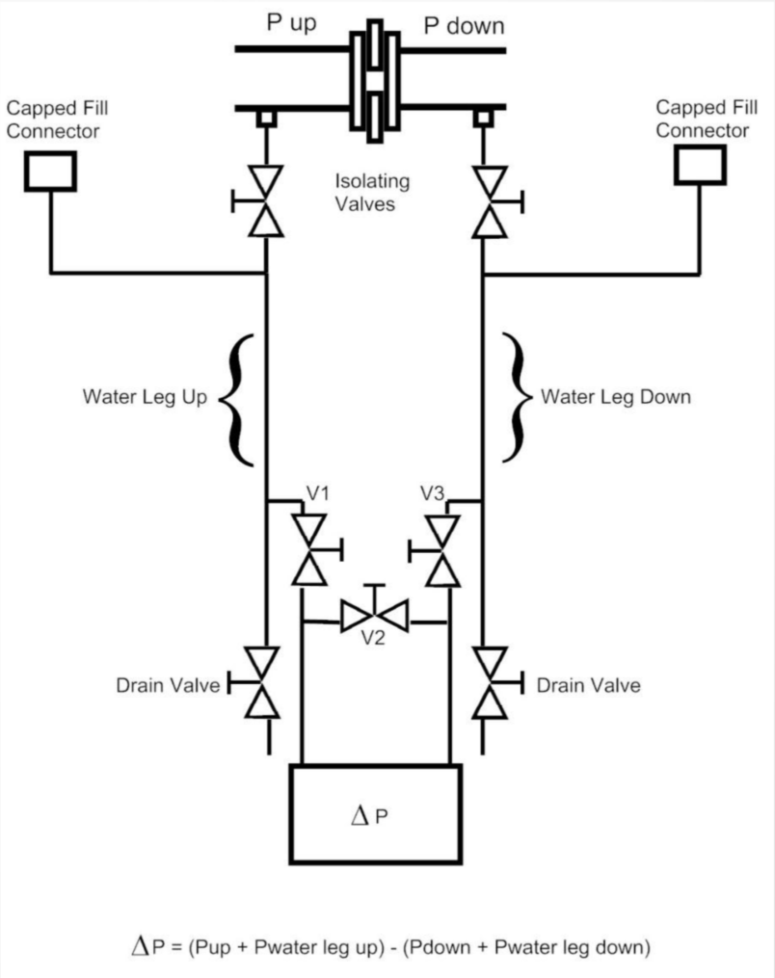
- The Uncertainty of an orifice meter run is approximately +/- 0.5% to +/- 1%.
- The metering code for orifice plates dictate the straight inlet and outlet pipe run requirements for the installation (40 pipe diameters are now called out).
- Also restrictions on weld and gasket protrusion and positioning of the orifice plate.

Using 3-Valve Manifold for Differential Pressure Transmitters in Steam

- Differential pressure transmitters are not intended to see high steam temperatures.
- The differential pressure transmitter is located below the orifice plate and connected to orifice taps by inclined sense lines that should be filled equally with water.
- Sense lines should initially be equally filled to keep equal water legs to leveled delta P transmitter ports.
- To check for proper transmitter output at no flow: Close inlet valve, open bypass valve to produce 0.0" delta P. Close bypass and open inlet to return to normal service.
- Valve sequencing is important to avoid imbalance in legs.

Draining Sense Lines

- If legs are drained to purge contaminates then water legs take time to refill and stabilize. Meter errors can occur in the interim. Manually refill at fill points with V2 closed.
- Do not simultaneously open all 3 valves in manifold. Water legs can be imbalanced and water flushed downstream.



Sizing differential pressure meters for steam service

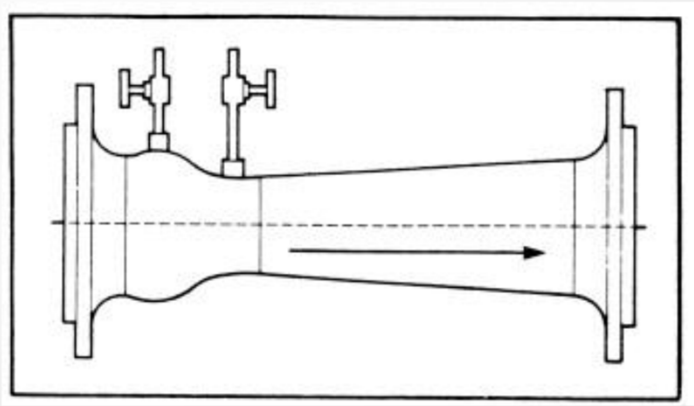
- Steam process noise may limit useful differential pressure to above 0.25” (Is 1” more practical?)
- Note that orifice sizing sheets only compute many key values at the “Normal” flow rate.
- Sizing sheets often compute inaccurate values for saturated steam density and isentropic exponent. ASME Steam Tables should be selected.
- Expected test results should include Y1 at each flow rate. (Need to re-run at other flow rates.)

Contoured Inlet, Square Law Flow Meter Principles

- Class includes Nozzle, Venturi, Wedge
- Industry-standard sizing equations.
- That standard also means long installation straight pipe run requirements.
- Low maintenance .
- Better accuracy than orifice type.
- V-Cone and Accelabar are proprietary types intended for improved performance .

Venturi and Nozzle and Wedge

- Shape of nozzle or venturi is intended to create a predictable flow pattern
- Follows many other characteristics of orifice flow meters
- Unique equation for Y1



Special case of a V-Cone

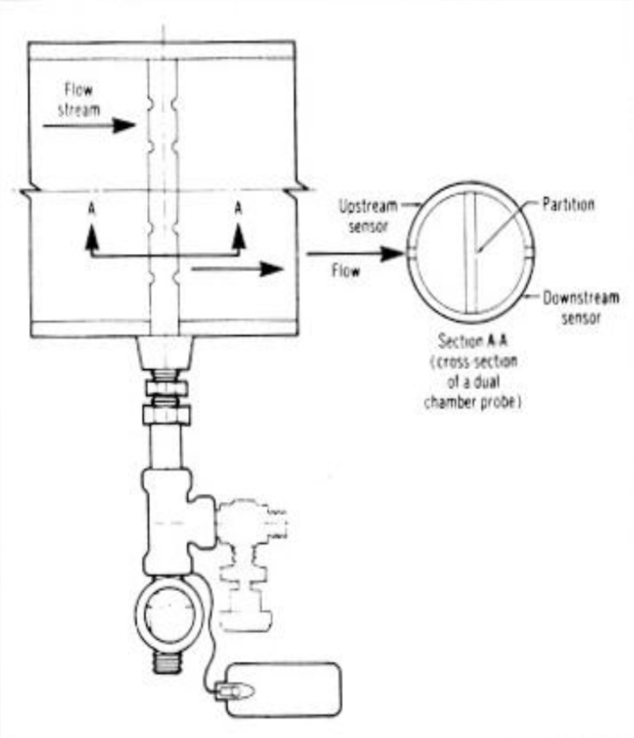
- Calibrated on water
- Condensate can pass easily through meter Shorter inlet/outlet pipe runs required
- Performance is very independent of Rn
- Unique, proprietary equation for Y1

Averaging Pitot Tube Flow Meter Principles

- Class includes averaging pitot tube, annubar, verabar insertion type flow meter types.
- Computation of implied fluid density and diff. pressure are used to compute velocity.
- Velocity and pipe area to compute volume flow.
- Density and volume flow to compute mass flow.
- Low cost in large lines (can be hot tapped).
- Lower differential pressure produced by device.
- Lower pressure loss through meter run.

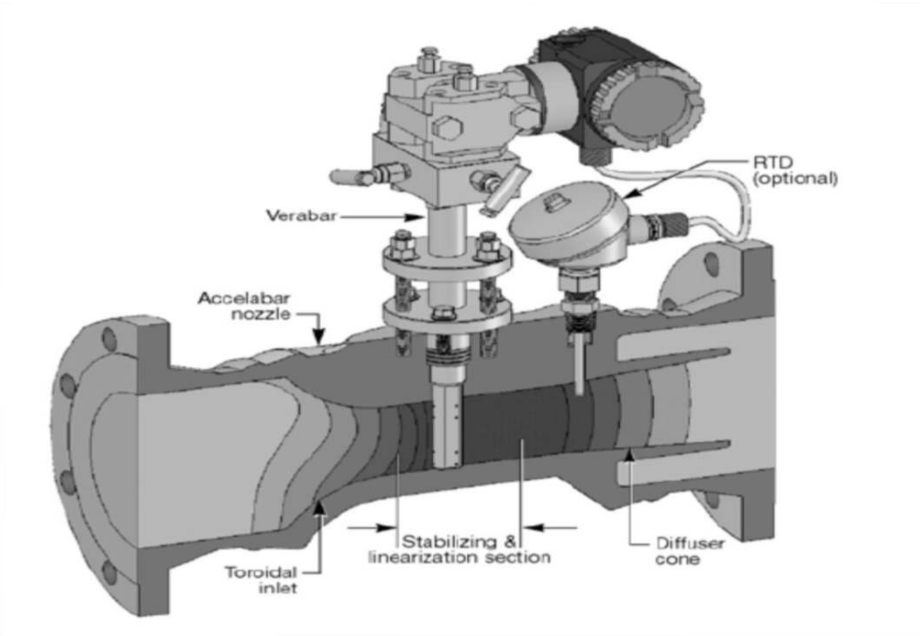
Averaging Pitot Tube Class

- Summary
  - square law
- Advantages
  - inexpensive to install on larger lines
- Disadvantages
  - lower delta P developed
- Remember 0.25" useful limit?

Accelabar-A Novel Configuration

- Toroidal inlet increases velocity at point of measurement.
- Averaging pitot tube provides flow measurement.
- Performance improved - similar to other contoured input devices.

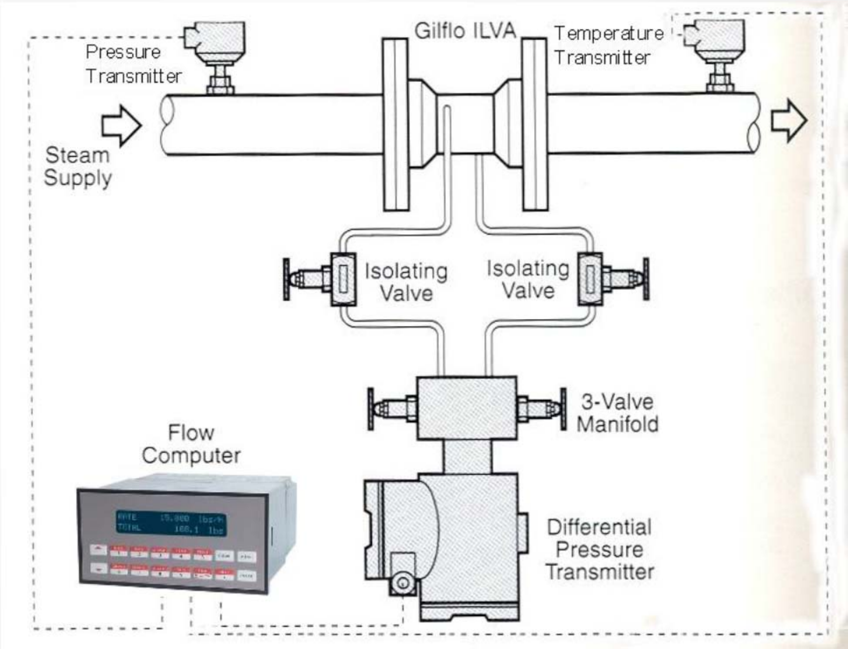


Gilflo and ILVA Flow Meter Principles

- Produces a differential pressure approximately linear with flow rate - movable cone pushes against spring with larger area at higher flows.
- Much wider turn down range than other differential producers .
- Linearization by table (or equation) and with temperature corrections for spring constant .
- Factory calibrated on water with results extrapolated for flowing density and temp.

Gilflo and ILVA

- Wide flow turn-down range w/differential pressure output
- Output DP nearly linear with flow
- Calibrated on water



Target (or Obstruction) Style Flow Meter Principles

- Essentially a square law flow meter with integral, direct strain gauge electrical output.
  (No differential pressure to deal with).
- Insertion and In-Line type available.
- Size of target can be selected to create desired measurement range.
- 15:1 flow range.

Target Meter Equation

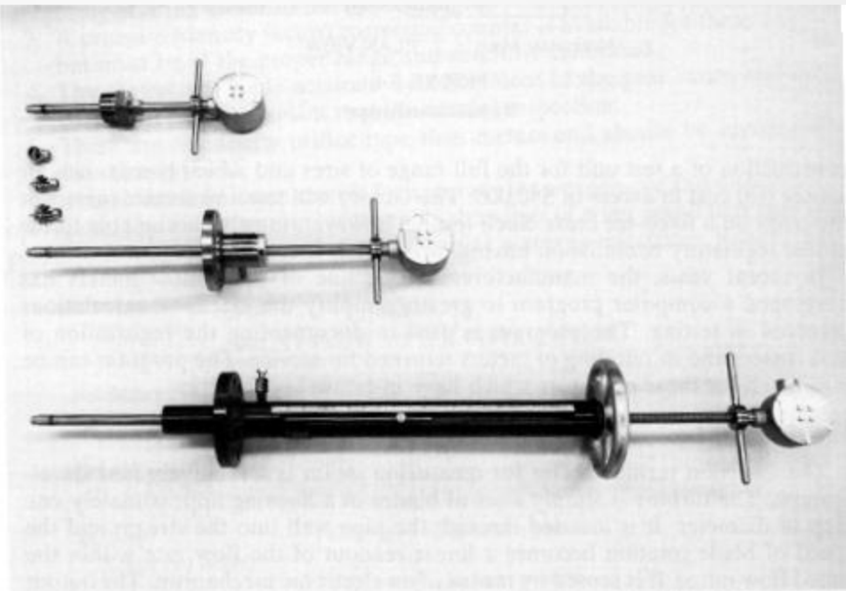
Analog Output = Cd * Density * V^2 * AT/2
where:

- Cd is empirical
- Density is at flowing
- V^2 is velocity squared
- AT is area of target

Linear Insertion-type Flow Meter Principles and Techniques

- Types included - Insertion Turbine and Insertion Vortex devices with pulse output linear with point velocity at the insertion depth and/or over its sensitive area.
- Seeks to apply a mathematical corrections arrive at the average velocity in the line from that measured a known insertion depth from assumed flow profile.
- Also applies mathematical corrections for its blockage effects and operating temperature on the meter run.
- Pressure and/or temperature are used to imply steam density.

Representative Insertion Turbine Flow Meters



Intended for mounting on full port isolation valve

- Can be fully retracted into housing
- Close isolation valve
- Service meter head

Pro's and Con's of Insertion Types

Pro's

- 10:1 - 20:1 Turndown.
- Measures velocity to +/- 1%.
- Can be hot tapped into existing lines.
- Access for maintenance.
- Low pressure drop.
- Inexpensive initial cost in large line sizes.

Con's

- Not as accurate as in-line techniques.
- Dependent on flow profile & swirl & empirical data fit.
- Turbine type needs regular, seasonal maintenance.
- External leakage around seals is potential area of concern.

Additional Steam Metering Techniques

- Shunt Flow Meter
- Flow Meter Manifold -applications where two or more flow meters are used to achieve the required turndown range.
  - Series connection involves 2 meters plus one control valve and manifold controller unit.
  - Parallel connection involves base meter system that brings one or more larger meter on line as the flow rate increases.

Condensate Flow Meter Principles and Techniques

- Suitable for totalization of condensate (which is assumed to follow inlet steam usage).
- The condensate flow pattern may be irregular, particularly in pumped condensate systems.
- Output linear with volume flow.
- May include an electronic pulser on shaft
- Calibrated on water for equivalent. pounds of water at 140 F reference temperature.
- Mathematical corrections can be applied for other condensate temperatures.
- Steam line can be sensed for energy calculations .

Condensate Meter

- Pro's
  - Wide measurement range.
- Con's
  - 2-3 year maintenance.
  - Requires all but only condensate be metered.