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Process Systems

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Agenda

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- Flow Measurement Presentation :
  - Introduction
  - Differential pressure Flowmeters.
    - Venturi
    - Orifice Plates
    - Averaging Pitot
    - New Designs
  - Linear Flowmeters
    - Vortex Flowmeters.
    - Electromagnetic Flowmeters.
    - Coriolis Mass Flowmeters.
  - FlowExpertPro Flowmeter Sizing Tool

Flow Measurement

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Understanding the terminology

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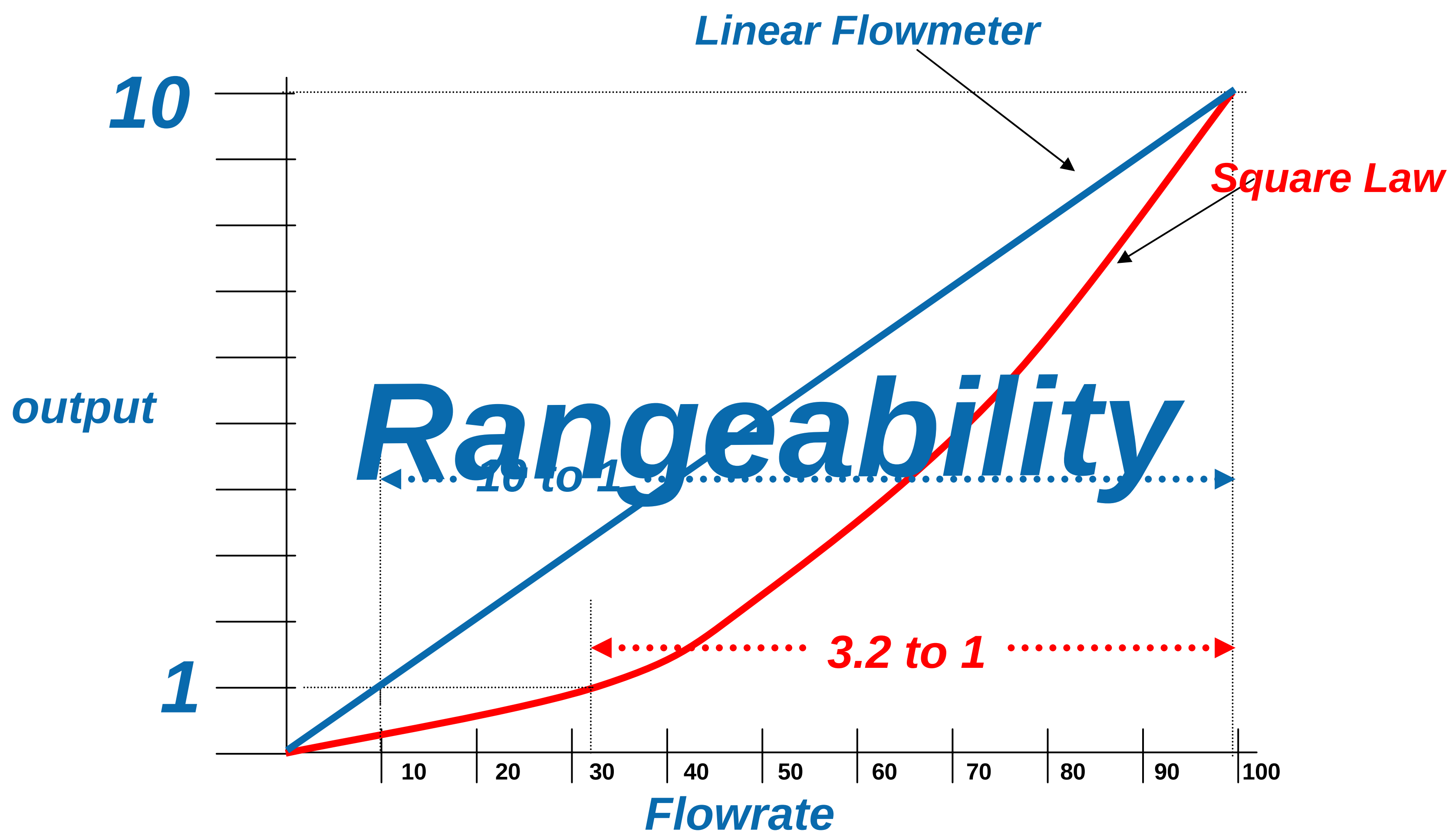
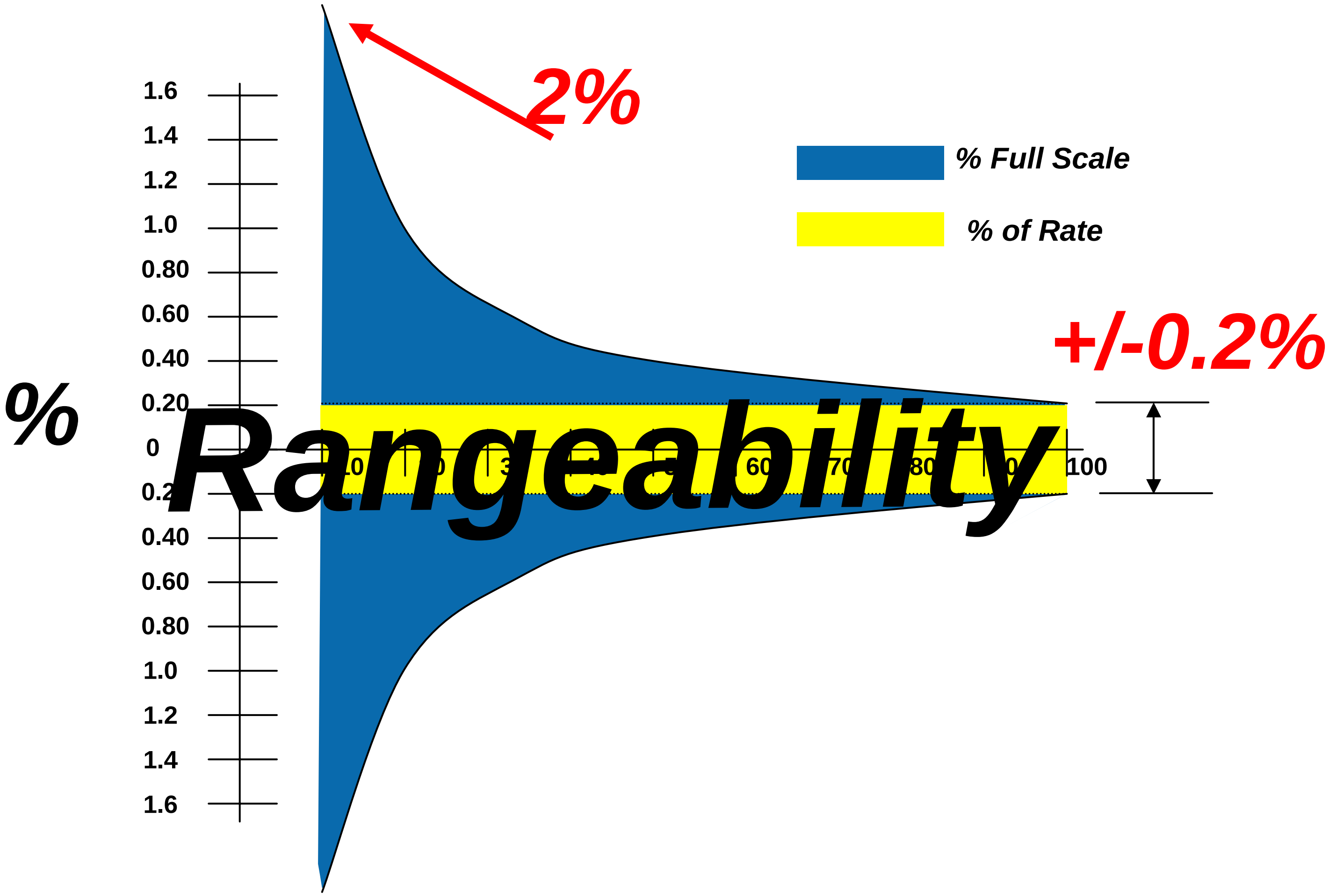
- Accuracy
- Repeatability
- Rangeability
- Density, Viscosity, Reynold’s number
- Equations of State, AGA 8
- Concentration, Brix, Baume, Proof etc.
- Mass flow, Volume flow, Standard volume

Advantages of linear flowmeters



Advantages of % of rate



What is Reynolds Number ?

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Flow Rate

Viscosity

$$\frac{\rho V D}{\mu}$$

Asking the right questions

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About the fluid…

- Liquid, gas or vapor
- Density, viscosity
- Single, 2-phase or multi-phase
- Single or multi-component mixture
- Conductive or non-conductive
- Is it extremely valuable
- Abrasive, corrosive, flashing, solidifying, condensing
- …

Asking the right questions

About the process…

- pressure, temperature
- pressure drop requirements
- flowrates required
- start up issues
- batching or continuous
- response time requirements
- installation requirements
- communication protocols
- safety requirements

Asking the right questions

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About the economic issues……

- Purchase Price
- Installation Costs
- Operating Costs
- Maintenance Costs
- Calibration Costs
- Instrument Life

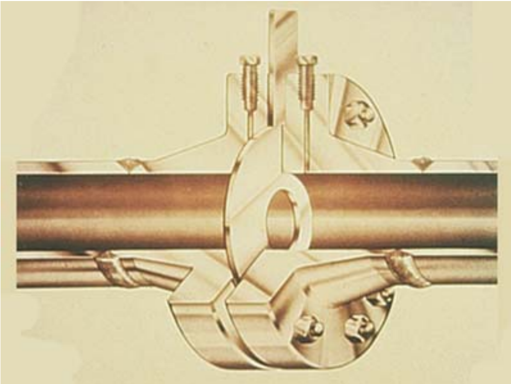
Which Flowmeter Do I Use ?

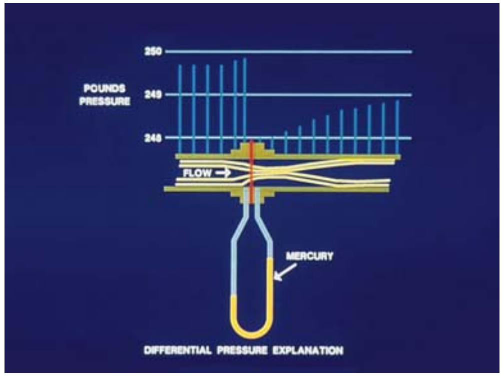
- Vortex?
- Magflow?
- Coriolis?
- Dp?
- None of the above?

Industrial Flowmeter Types

- Head Producing (DP)
  - Orifice
  - Nozzle
  - Venturi
  - Wedge
  - Annubar/Pitot Tube
  - Variable Area/Rotameter
- Positive Displacement
- Velocity
  - Turbine
  - Electromagnetic
  - Vortex
  - Ultrasonic
- Mass
  - Coriolis
    - Straight
    - Bent
  - Thermal

Flowmeter Types



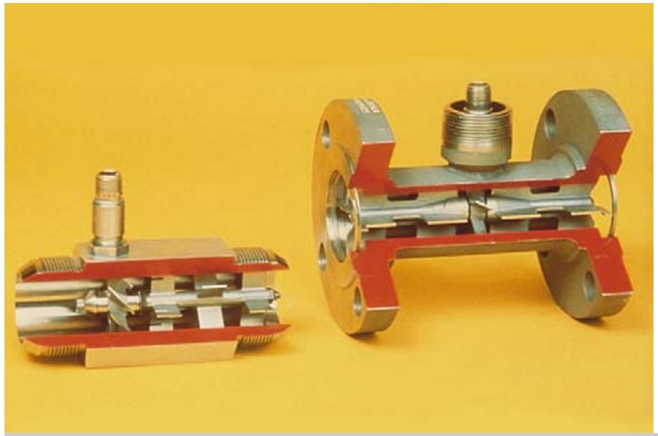


Head Class (orifice, nozzle,venturi)

- Pros
  - Tried and true
  - Low capital cost
  - Liquids, gases, vapors
  - Accepted by most industries
  - Supported by standards
- Cons
  - Low Accuracy
  - Poor Rangeability (square law)
  - Requires compensation always
  - High sensitivity to wear
  - High cost of ownership
  - Plugging/ damming

Flowmeter Types

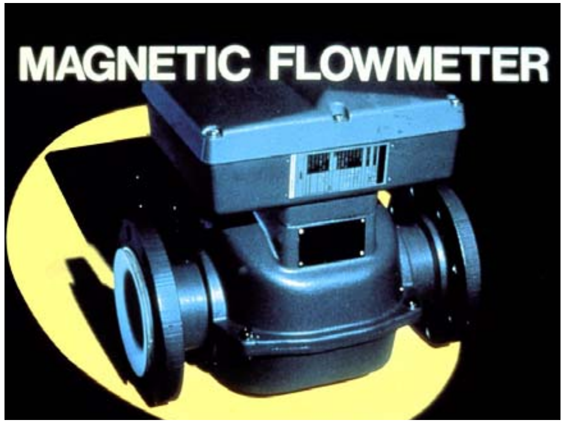
Turbine

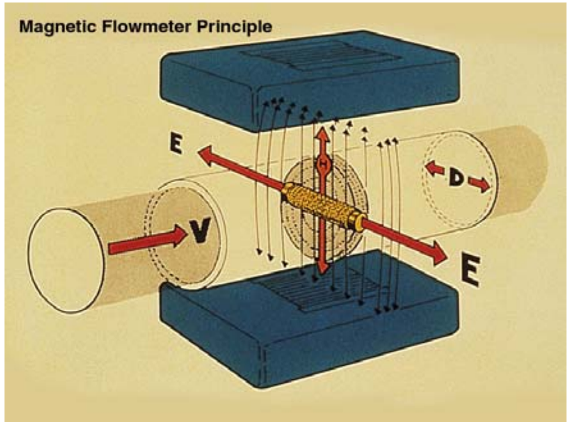


Frequency ∝ to flowrate

- Pros
  - Linear with flow
  - Easy to install
  - Principle readily accepted
  - High accuracy
  - Wide Rangeability
  - Liquids, gases, vapors
  - Approved by AGA
- Cons
  - Moving parts/ bearings
  - Not suited for dirty fluids
  - High maintenance costs

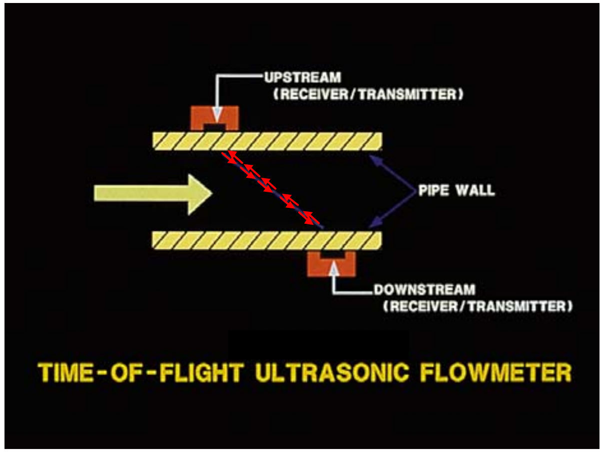
Flowmeter Types

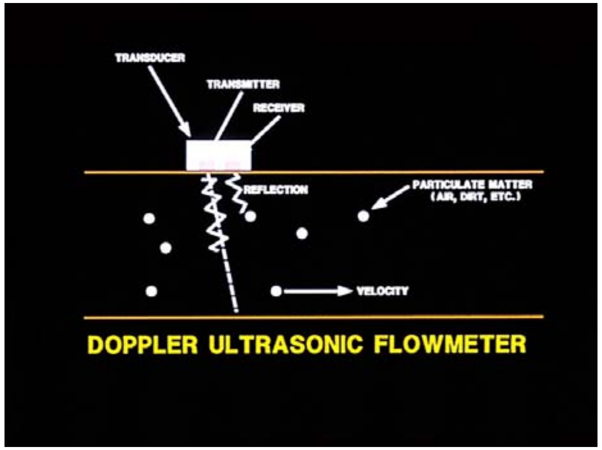




- Pros
  - Obstructionless
  - Easy to install
  - Linear with flow
  - High accuracy
  - Wide Rangeability
  - Bi-directional
  - Available in very large lines
- Cons
  - Requires conductive liquids
  - Higher cost

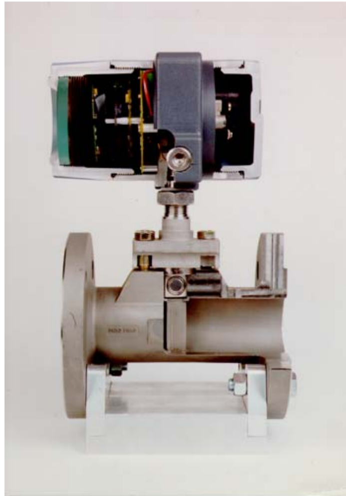
Flowmeter Types





- Time of Flight
  - Requires clean fluid
  - Available in-line and clamp on
  - Low accuracy with single beam
  - Higher accuracy but very expensive in multi-beam
  - Can handle very large lines
  - Gaining acceptance for natural gas
- Doppler
  - Generally clamp on device
  - Low accuracy
  - More flow indicator than meter

Flowmeter Types



- Pros
  - Linear device
  - Frequency output
  - No moving parts
  - High accuracy
  - Wide rangeability
  - Relatively low cost
  - Liquids, gases, vapors
- Cons
  - Not suited for high viscosity/slurries
  - Doesn't go to zero flow

Flowmeter Types

Coriolis Mass Flow

- Pros
  - True mass flow
  - Highest accuracy
  - Widest rangeability
  - Ideal for difficult liquids
  - Ideal for high viscosity
- Cons
  - Relatively expensive
  - Size limited

Flowmeter Evaluation Table

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FLOWMETER	PIPE SIZE, in. (mm)	STEAM	GASES (VAPORS): CLEAN	GASES (VAPORS): DIRTY	GASES (VAPORS): PRESS HIGH	GASES (VAPORS): PRESS LOW	LIQUIDS: CLEAN	LIQUIDS: VISCOUS HIGH	LIQUIDS: VISCOUS LOW	LIQUIDS: DIRTY	LIQUIDS: CORROSIVE	LIQUIDS: VERY CORROSIVE	LIQUIDS: SLURRIES FIBROUS	LIQUIDS: SLURRIES ABRASIVE	REVERSE FLOW	PULSATING FLOW	HIGH TEMPERATURE	CRYOGENIC	SEMI-FILLED PIPES	NON-NEWTONIANS	OPEN CHANNEL	TYPICAL Accuracy, uncalibrated (Including transmitter)	TYPICAL Reynolds number ‡ or viscosity	TEMPERATURE °F (°C)	PRESSURE psig (kPa)
SQUARE ROOT SCALE: MAXIMUM SINGLE RANGE 4:1 (Typical)**																									
Orifice																									
Square-Edged	>1.5 (40)	√	√	X	√	√	√	X	?	X	?	X	X	X	SD	?	√	√	X	?	X	±1-4% URV	R_D > 10,000	Process temperature to 1000°F (540°C) Transmitter limited to -30-250°F (-30-120°C)	To 4,000 psig (41,000 kPa)
Honed Meter Run	0.5-1.5 (12-40)	√	√	X	√	√	√	?	?	X	?	X	X	X	SD	?	√	√	X	?	X	±1% URV	R_D > 10,000		
Integrated	<0.5 (12)	?	√	X	√	√	√	X	?	X	?	?	X	X	SD	?	?	X	X	?	X	±2-5% URV	R_D > 10,000		
Segmental Wedge	<12 (300)	√	√	√	√	√	√	?	√	?	?	X	?	?	SD	?	√	√	X	?	X	±0.5% URV	R_D > 500		
Eccentric	>2 (50)	?	?	√	√	√	?	X	?	?	?	X	?	X	SD	?	√	√	X	?	X	±2-4% URV	R_D > 10,000		
Segmental	>4 (100)	?	?	√	√	√	?	X	?	?	?	X	?	X	SD	?	√	√	X	?	X	±2-4% URV	R_D > 10,000		
V-Cone	0.5-72 (12-1800)	√	√	?	√	√	√	?	√	?	?	X	?	?	X	?	?	?	X	?	X	±0.5-1% of rate	R_D : 8,000-5,000,000	700 (370)	≤600 (4,100)
Target***	<0.5 (12)	?	√	√	√	√	√	?	√	√	?	X	X	X	?	X	?	?	X	?	X	±0.5-5% URV	R_D > 100	Process temperature to 1000°F (540°C) Transmitter limited to -30-250°F (-30-120°C)	To 4,000 psig (41,000 kPa)
Venturi	>2 (50)	√	√	?	√	√	√	?	√	?	?	X	√	?	X	?	?	?	X	?	X	±0.5-2% URV	R_D > 75,000L		
Flow Nozzle	>2 (50)	?	√	?	√	√	√	X	?	?	?	X	X	X	X	?	?	?	X	?	X	±1-2% URV	R_D > 50,000L		
Low Loss Venturi	>3 (75)	√	√	X	√	√	√	X	?	X	√	X	X	X	X	?	?	?	X	?	X	±1.25% URV	R_D > 12,800L		
Pitot	>3 (75)	X	√	X	√	√	√	X	?	X	?	X	X	X	X	X	?	?	X	X	X	±3-5% URV	R_D > 100,000L		
Averaging Pitot	>1 (25)	√	√	SD	√	√	√	X	?	SD	?	X	X	X	SD	X	?	?	X	X	X	±1-2% URV	R_D > 40,000L		
Elbow	>2 (50)	X	√	?	√	√	√	X	?	?	?	X	X	X	√	X	?	?	X	?	X	±5-10% URV	R_D > 10,000L		
Laminar	0.25-16.6 (6-400)	?	√	X	√	√	√	√	?	X	?	X	X	X	X	√	X	X	X	X	X	±1% of rate	R_D < 500	150 (66)	≤30 (225)
LINEAR SCALE TYPICAL RANGE 10:1 (Or better)																									
Magnetic*	0.1-72 (2.5-1800)	X	X	X	X	X	√	?	√	√	√	√	√	√	√	√	?	X	?	?	?	±0.5% of rate	R_D > 4,500	360 (180)	≤1,500 (10,800)
Positive Displacement																									
Gas	<12 (300)	X	√	X	?	√	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	±1% of rate	-	250 (120)	≤1,400 (10,000)
Liquid	<12 (300)	X	X	X	X	X	√	√	?	X	?	X	X	X	X	X	?	X	X	X	X	±0.5% of rate	No R_D limit ≤ 8,000 cS	600 (315)	≤1,400 (10,000)
Turbine																									
Gas	0.25-24 (6-600)	SD	√	X	√	√	X	X	X	X	X	X	X	X	SD	SD	?	?	X	X	?	±0.5% of rate	-	-450-500 (268-260)	≤3,000 (21,000)
Liquid	0.25-24 (6-600)	X	X	X	X	X	√	X	?	X	?	X	X	SD	SD	SD	?	?	X	X	?	±0.5% of rate	R_D > 5,000, ≤15 cS	-450-500 (268-260)	≤3,000 (21,000)
Ultrasonic																									
Time of Flight	>0.5 (12)	X	SD	SD	SD	SD	√	?	?	X	√	√	?	?	√	√	X	?	X	X	?	±1% of rate to ff15% URV	R_D > 10,000	-300-500 (-180-260)	Pipe rating
Doppler	>0.5 (12)	X	X	X	X	X	X	?	?	√	√	√	√	√	√	√	X	X	X	?	X	±1% of rate to ff15% URV	R_D > 4,000	-300-500 (-180-260)	Pipe rating
Variable-Area (Rotameter)	≤3 (75)	?	√	X	X	√	√	X	?	X	?	?	X	X	X	?	?	?	X	X	X	±1% of rate to ff10% URV	No R_D limit, <100 cS	Glass: 400 (200) Metal: 1,000 (540)	Glass: 350 (2,400) Metal: 720 (5,000)
Vortex Shedding	1.5-16 (40-400)	√	√	?	√	√	√	X	?	?	?	X	X	X	X	X	?	?	X	X	X	±0.75-1.5% of rate	R_D > 10,000, <30 cP	400 (200)	≤1,500 (10,500)
Vortex Precession (Swirl)	<16 (400)	√	√	?	√	√	√	X	?	X	?	X	X	X	X	X	?	X	X	X	X	±0.5% of rate	R_D > 10,000, <5 cP	536 (280)	Pipe rating
Fluidic Oscillation (Coanda)	>1.5 (40)	X	X	X	X	X	√	X	X	?	?	X	X	X	X	?	?	?	X	X	X	±2% of rate	R_D > 2,000, <80 cS	350 (175)	≤720 (5,000)
Mass																									
Coriolis	0.25-6 (6-150)	?	?	?	√	√	√	√	√	√	?	?	?	√	?	?	?	?	X	√	X	±0.15-1.0% of rate	No R_D limit	-400-800 (-224-427)	≤5,700 (39,900)
Thermal Probe	<72 (1800)	X	√	?	√	√	√	?	√	√	?	?	?	?	X	?	?	X	X	?	X	±1-2% URV	No R_D limit	1,500 (816)	Pipe rating
Solids Flowmeter	<24 (600)	X	X	X	X	X	X	SD	X	?	X	X	SD	SD	X	SD	SD	X	√	X	X	±0.5% of rate to ff4% URV	-	750 (400)	≤580 (4,000)
Correlation																									
Capacitance	<8 (200)	X	X	X	X	X	X	√	√	√	√	√	√	√	X	?	?	X	?	?	X	No data available	No data available	300 (149)	≤580 (4,000)
Ultrasonic	>0.5 (12)	X	X	X	X	X	X	?	√	√	√	√	√	√	X	?	X	X	X	?	X	±6% of ??	No data available	-300-250 (-180-120)	Pipe rating

cP = centi Poise
cS = centi Stokes
SD = Some designs

? = Normally applicable (worth consideration)
√ = Designed for this application (generally suitable)

URV = Upper Range Value
X = Not applicable

‡ According to other sources, the minimum Reynolds number should be much higher

* Liquid must be electrically conductive
** Range 10:1 for laminar, and 15:1 for target
*** Newer designs linearize the signal

Differential Pressure Flowmeters

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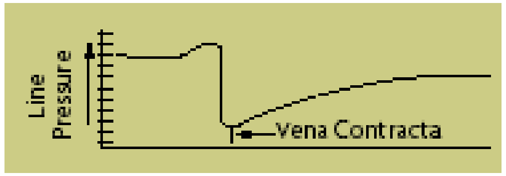
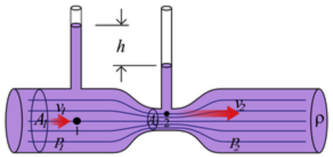
Bernoulli’s principle

Bernoulli's principle states that in fluid flow, an increase in velocity occurs simultaneously with decrease in pressure.

This principle is a simplification of Bernoulli's equation which states that the sum of all forms of energy in a fluid flowing along an enclosed path (a streamline) is the same at any two points in that path.





$$V = k\,(h/D)^{0.5}$$

or $$Q = kA\,(h/D)^{0.5}$$

or $$W = kA\,(hD)^{0.5}$$

Primary Elements

Venturi

Flow Nozzle

Orifice Plate

Averaging Pitot (Annubar)

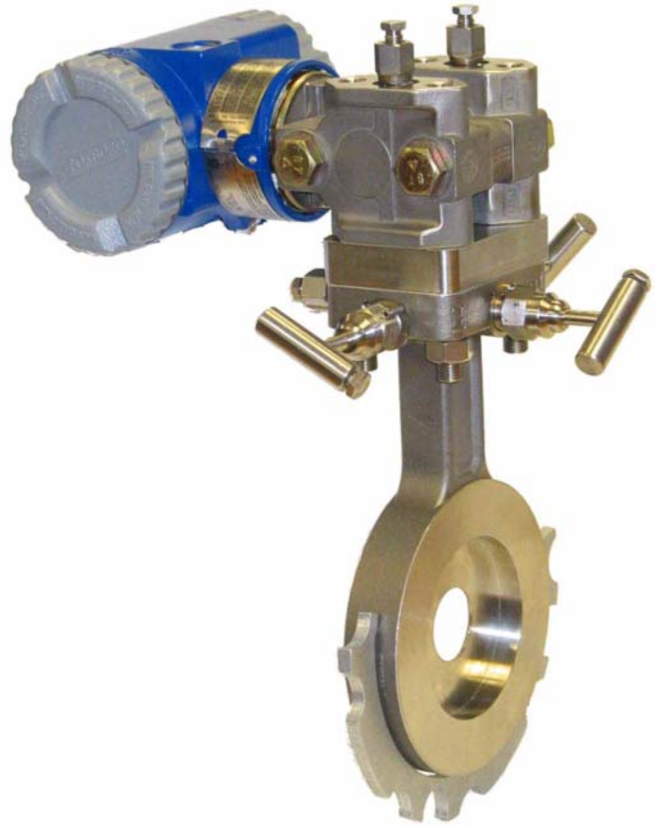
Accelabar

V – Cone

Wedge

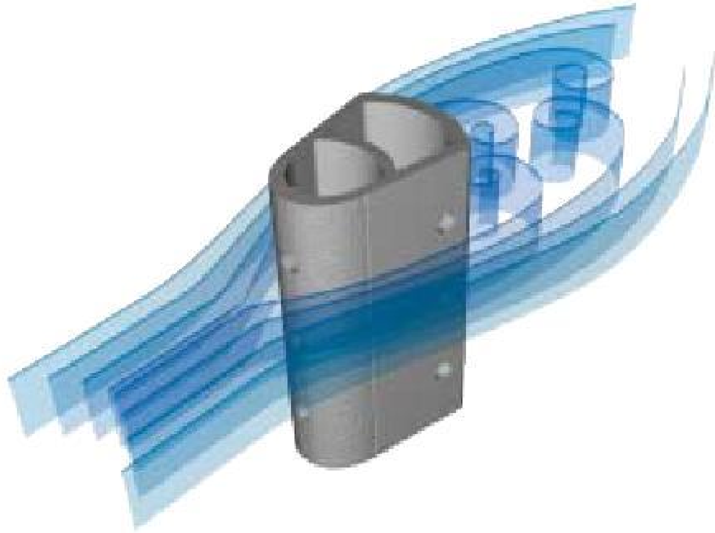
Compact Orifice

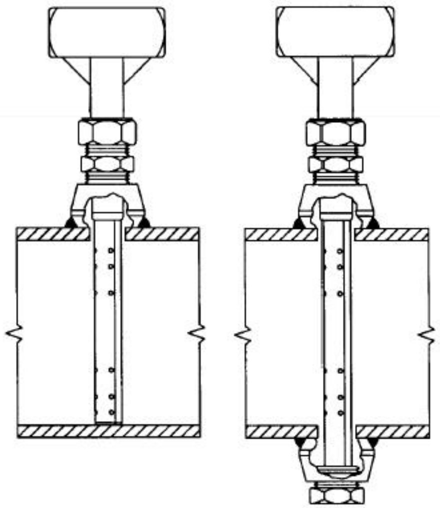
- Easy to use flowmeter
- Mass or volume flow
- 0.5” thru 4” pipe sizes
- Bi-planar body allows purging
- Integral isolation manifold
- Integral alignment ring
- Body, 1” Thickness
- Ideal for retrofits or upgrades



Veris Inc. Verabar ™

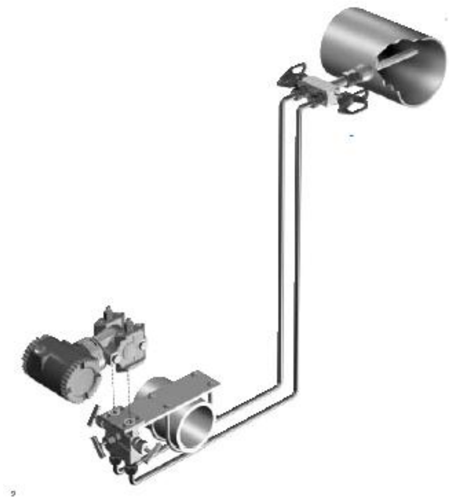
- Developed from aerospace technology, the *Verabar* averaging pitot flow sensor provides unsurpassed accuracy and reliability.
- With its solid one piece construction and bullet shape, the *Verabar* makes flow measurement clog-free and precise.





Veris Inc. Verabar TM

- **Specifications Mass**
- System Accuracy:
  - ±1.0% @ constant T&P
  - ±1.3% @ variable T&P
- Pressure ANSI 600# (max)
- Temperature:
  - **Remote Mount** 427 °C (max)
  - **Direct Mount** Limited by the DP transmitter 120 ºC



Veris Inc. Accelabar ™

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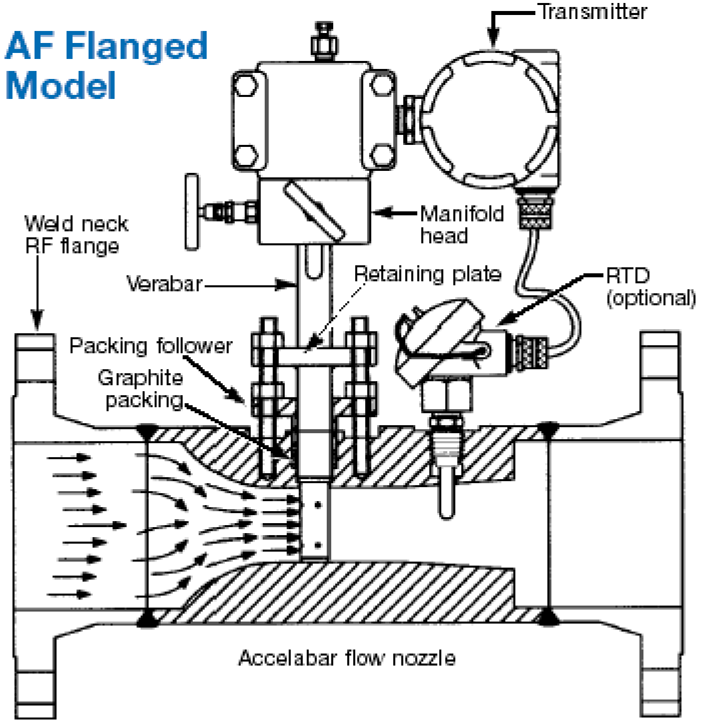
- *The Accelabar is a new and unique flowmeter that combines two differential pressure technologies to produce operating ranges never before attainable in a single flow meter.*

- *It is capable of generating high differential pressures for measuring gas, liquids and steam at turndowns up to 65:1 with no straight run requirements.*



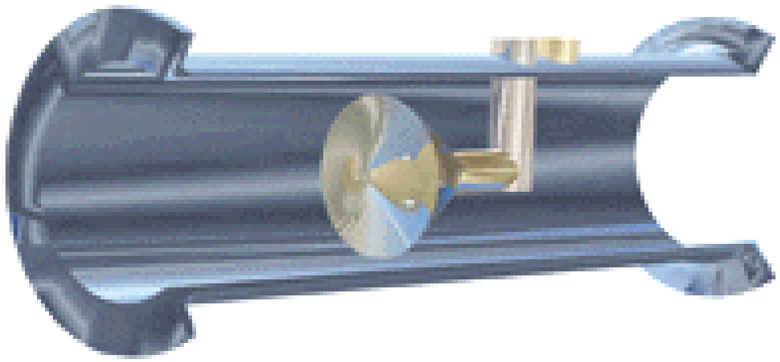
Veris Inc. Accelabar ™

- **Engineering Specifications**
- • Low velocity flow rates
- • High accuracy to ± 0.75%
- • Repeatability: ±0.075%
- • Verified flow coefficients
- • No calibration required
- • Extended turndown:up to 65:1
- • No straight run requirements
- • Low permanent pressure loss
- • Mass or volumetric flow

- **Actual Application**
- **Application:** 3” Sch 40 Natural Gas
- **Operating Pressure/**
- **Temperature:** 80 PSIG/70° F (5,4 bar g / 21 ºC)
- **Max/Min Flow Rate:** 60,000 SCFH / 1,000 SCFH
  1700 nm3h / 28,3 nm3h
- **Flow Turndown:** 60:1

McCrometer V-Cone ™

- The V-Cone is a differential pressure type flowmeter with a unique design that conditions the flow prior to measurement.
- Differential pressure is created by a cone placed in the center of the pipe.
- The cone is shaped so that it “flattens” the fluid velocity profile in the pipe, creating a more stable signal across wide flow downturns.
- Flow rate is calculated by measuring the difference between the pressure upstream of the cone at the meter wall and the pressure downstream of the cone through its center.



McCrometer V-Cone ™

- **Engineering Specifications**
- **Standard Accuracy:** From +/-0.5% of actual flow (certain fluids and Reynolds number applications require specific calibrations to achieve this value).
- **Repeatability:** +/-0.1% or better.
- **Flow Ranges:** 10:1 and greater.
- **Standard Beta Ratios:** 0.45 to 0.80, special betas available.
- **Head Loss:** Varies with beta ratio and DP.
- **Installation Piping Requirements:** Typically 0-3 diameters upstream and 0-1 diameters downstream of the cone are required, depending on fittings or valves in the adjacent pipeline.
- **Materials of Construction Include:** Duplex 2205, 304, or 316 stainless steel, Hastelloy C-276, 254, SMO, carbon steels. Special materials on request.
- **Line sizes:** 0.5" to 120" or larger.
- **End Fittings:** Flanged, threaded, hub or weld-end standard. Others on request.
- **Configurations:** Precision flow tube and wafer-type
- **Calibrated for customer application.**
- **ASME B31.3 construction available.**

Multivariable Transmitter for Flow

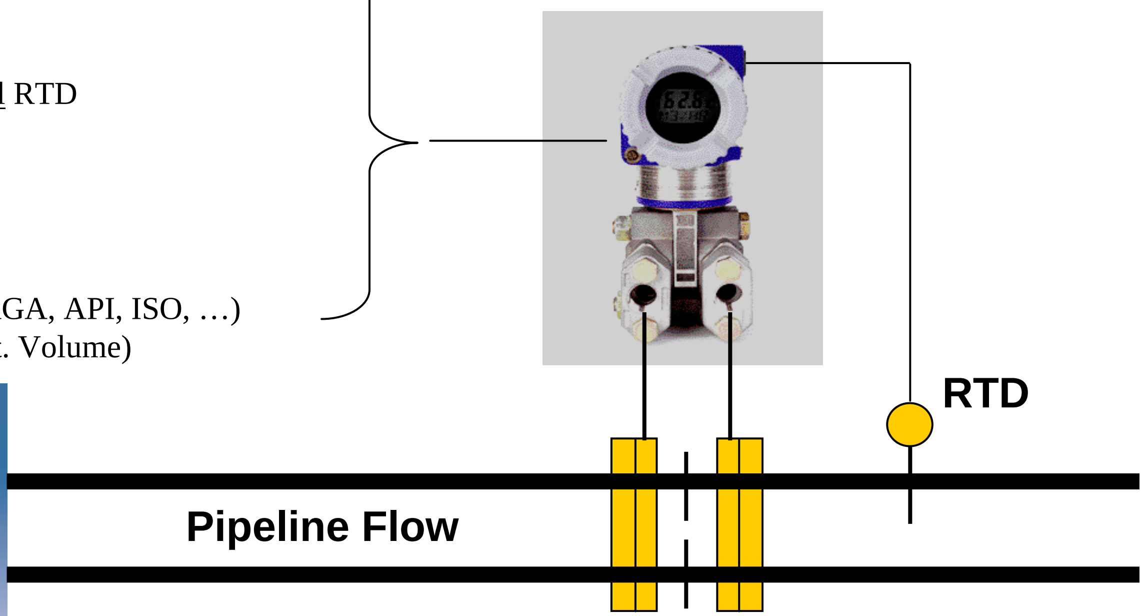
Multiple Measurements

- Differential Pressure
- Absolute Pressure
- Process Temperature from external RTD
- Sensor Temperature
- Electronics Temperature

Internal Computations

- Fluid Density
- Computation Standards (ASME, AGA, API, ISO, …)
- Flow rate (Mass, Std. Volume, Act. Volume)

Multivariable Transmitter



Orifice Plate & Flange Union

Variety of Primary Elements
Venturis, Flow Nozzles, Averaging Pitot, V-Cone, etc.

Integral Assembly
Small Flows

Linear Flowmeters

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Vortex Flowmeters

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Vortex Flowmeter

- ✓Volumetric Flow Measurement
- ✓Solid-state sensing, no moving parts
- ✓Wetted sensor provides wide range
- ✓Redundant sensing option
- ✓Sizes: ¾” to 12”; 15 to 300mm
- ✓Pressures to 3000 psi
- ✓Temperatures to 800F
- ✓Integral or Remote Electronics
- ✓Hart & FF-H1
- ✓Optional Isolation Valve

- **Typical Applications**
  - Steam, saturated or super-heated
  - Gases, dry & wet
  - Volatile liquids, prone to flashing
  - Non-conductive liquids,
    - Hydrocarbons
    - De-ionized water

WE'VE GOT HART ABILITY

Vortex Shedding

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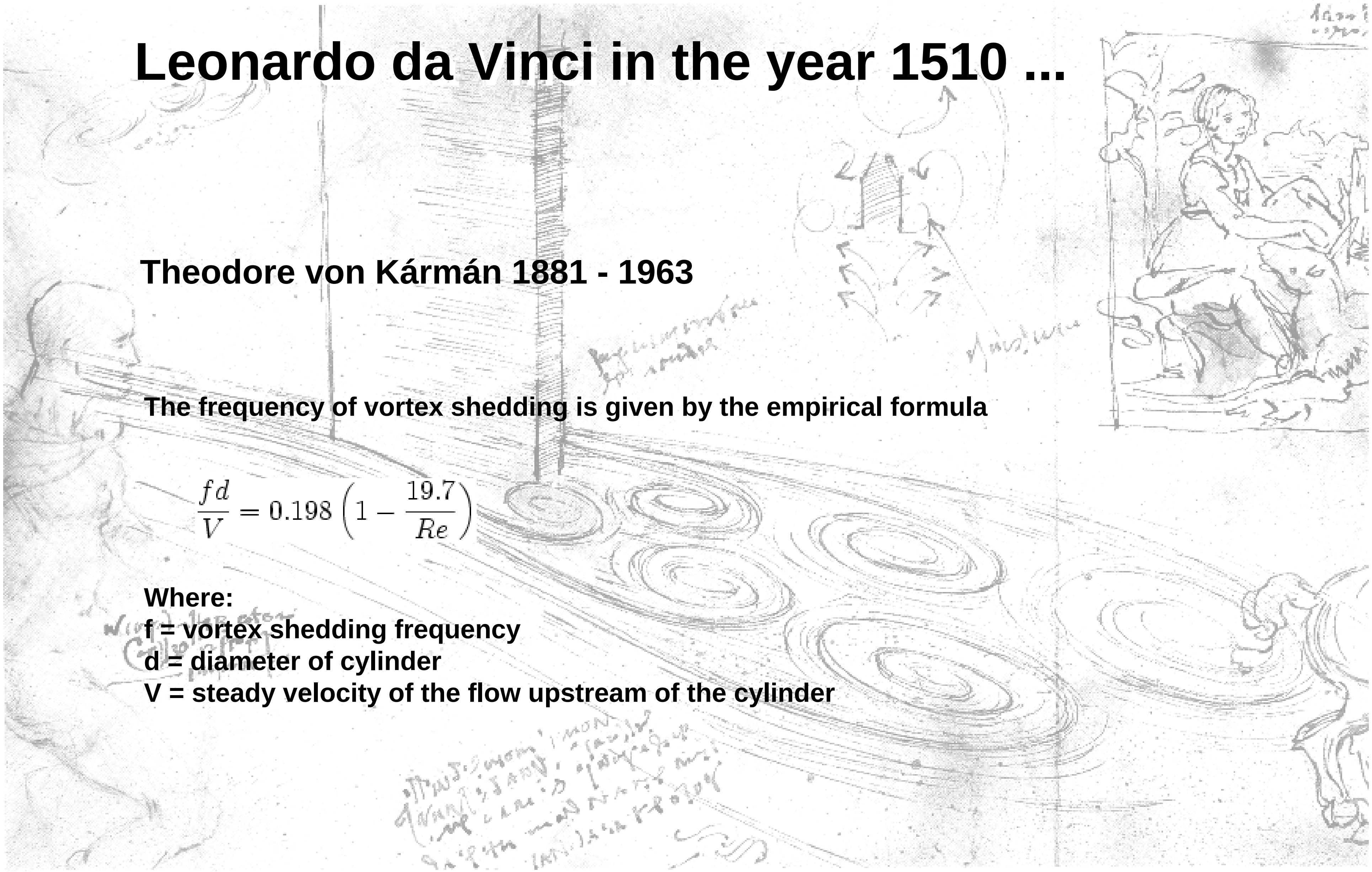


Leonardo da Vinci in the year 1510 ...

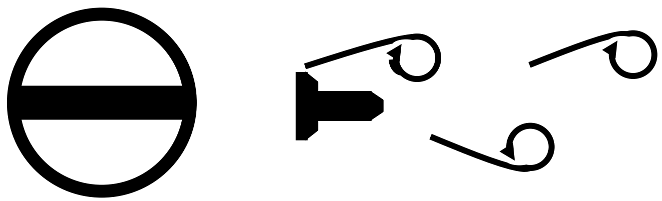
Theodore von Kármán 1881 - 1963

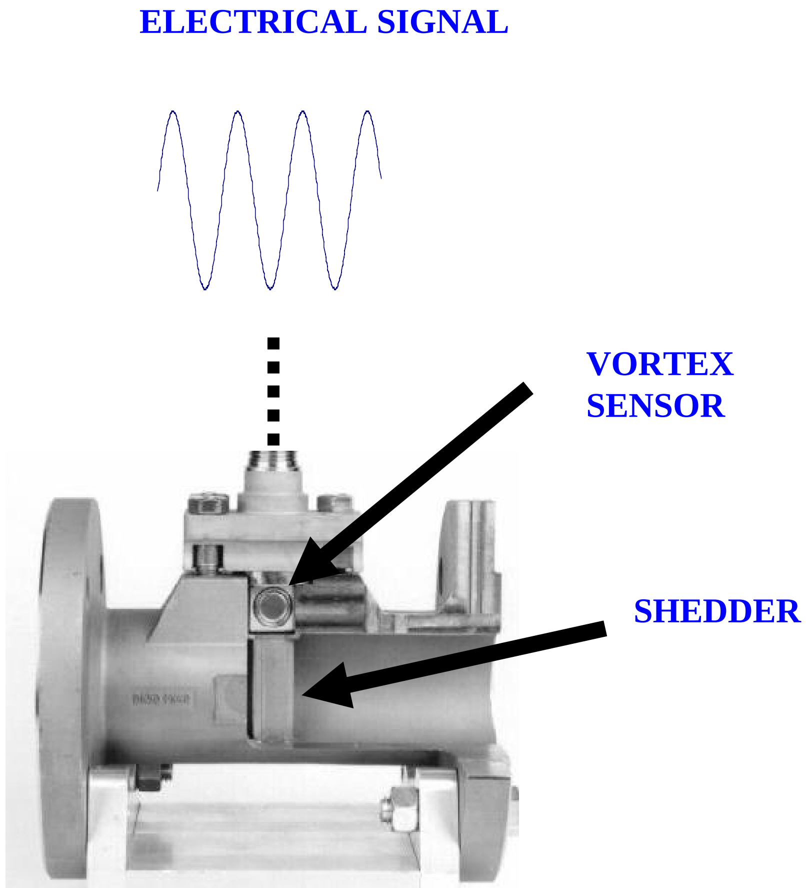
The frequency of vortex shedding is given by the empirical formula

$$\frac{fd}{V} = 0.198\left(1 - \frac{19.7}{Re}\right)$$

Where:
f = vortex shedding frequency
d = diameter of cylinder
V = steady velocity of the flow upstream of the cylinder

Vortex Shedding

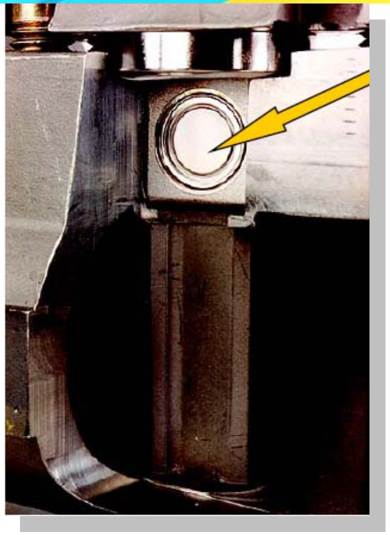


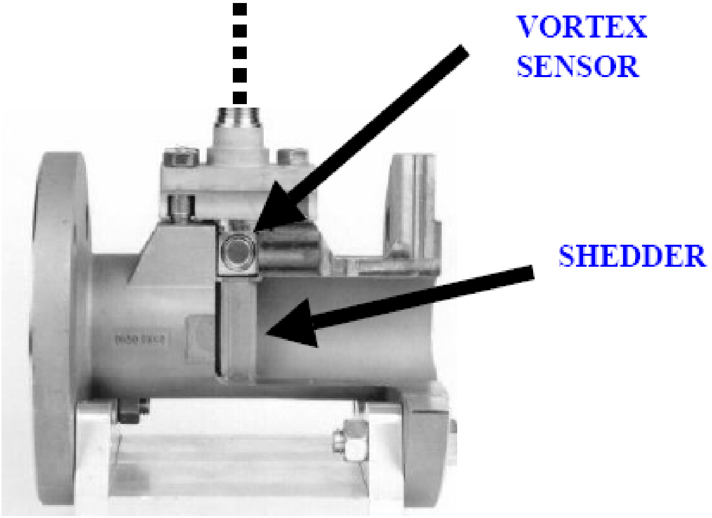


DirectSense™ Technology – Higher Performance, Better Reliability

invensys Process Systems

- **No unreliable mechanical linkage** between process and sensor, no vibrating shedder bars
  - Greater sensitivity for **higher accuracy** and **wider flow rate** measurement capability
  - **Less noise** from pipe vibration
  - Large ports, **no clogging**
  - Simpler design for **better reliability**
- **Lifetime sensor warranty**





83 Series Vortex: advantages direct (wetted) sensing

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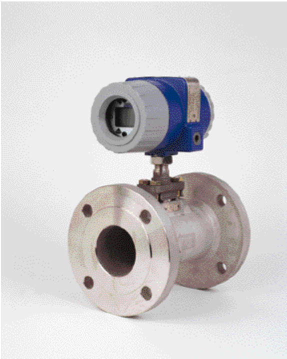
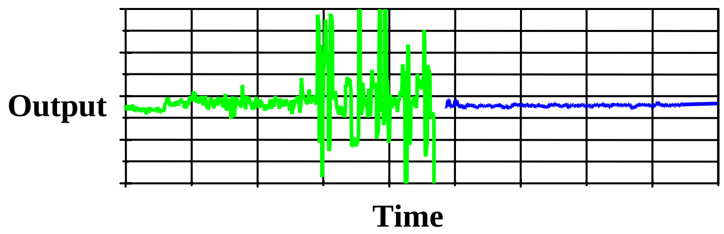


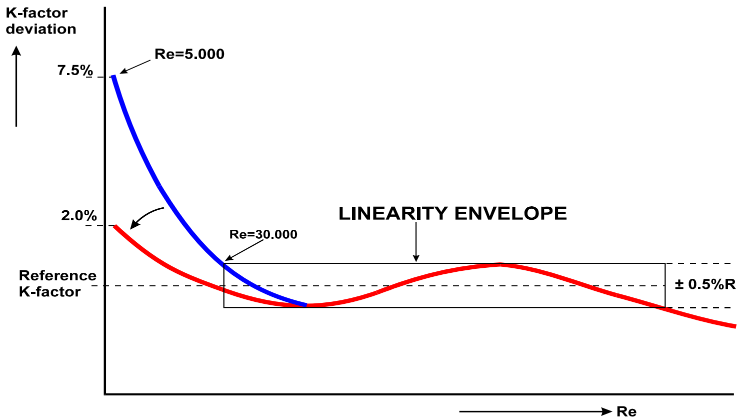
83F

- Maximum possible signal to noise
- Maximum reliability (no need for linkages)
- Simplicity of design
- maximum rangeability
  - And foxboro's direct sensing
- low mass
- High reliability
- Lifetime warranty
- Replaceable without need to re-cal

- Automatic "low flow cut-in" selection
- Automatic "K-factor" correction
    - Upstream disturbances
    - Flowing temperature



- Adaptive filtering for noise rejection
- Low flow signal conditioning
- Curve linearisation for low Reynolds number
- On-line diagnostics



Vortex Flowmeter Calibration

invensys
Process Systems

De: Merrett,John
Enviado: Thursday, February 11, 1999 9:30 AM
Para: Pedro Correia
Asunto: RE: flowmeter certification

Pedro,
We regularly face this question of ISO9001 Vortex & Magflow calibration from various users both at enquiry stage & when they realise the problem later on.

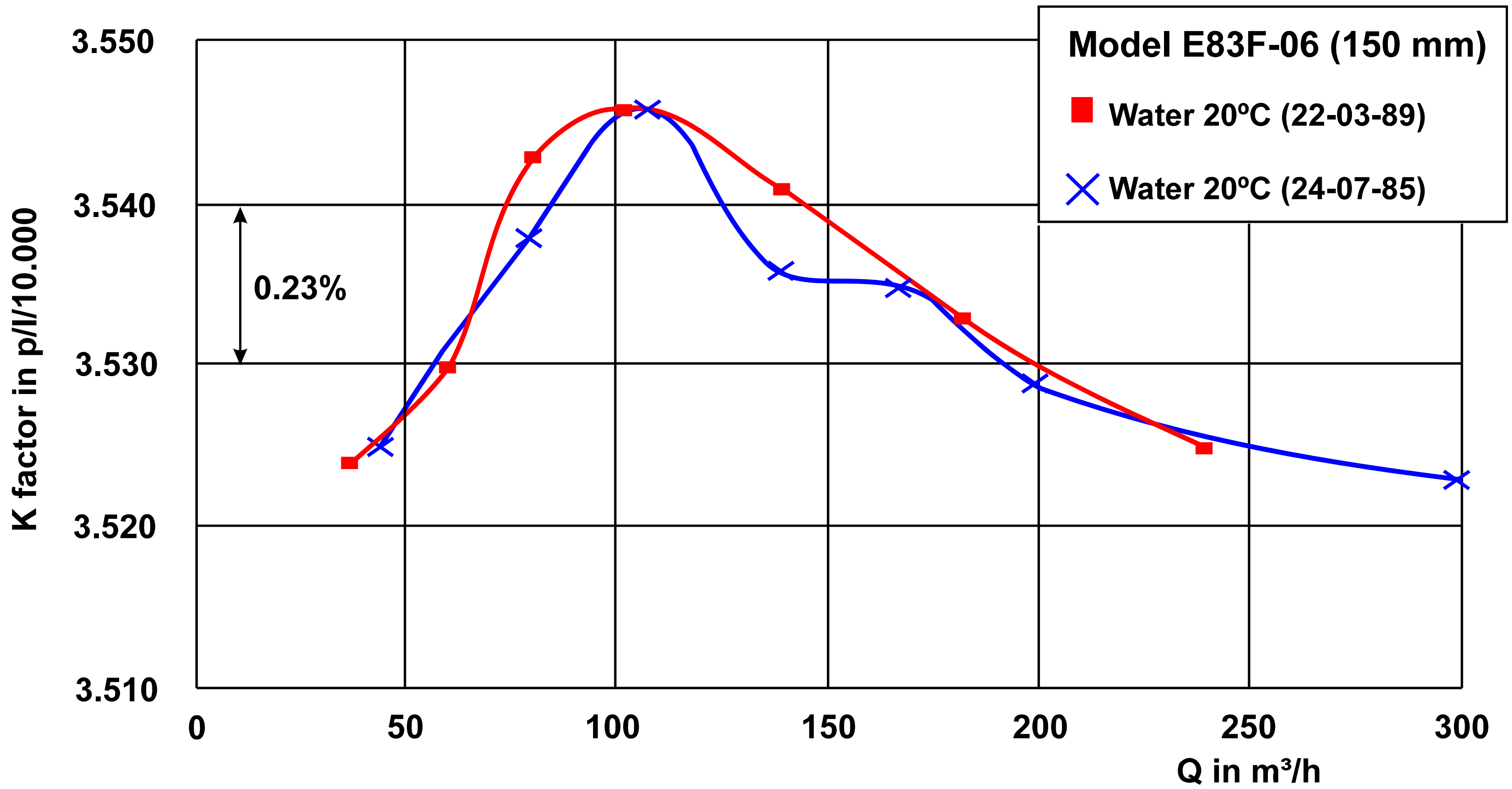
The real answer is that the user does not have to take his meter out of the line & have it check calibrated providing he writes into his Proceedure the statement:

" This device has a fixed Meter K Factor established on a traceable Flow Rig at the Manufacturers which will remain Constant for the life of the Meter/Plant!"

It may be necessary to prove the Transmitter Electronics but with the Digital operation, Intelligent Ranging & Diagnostics it is questionable whether this is necessary either.
If it is ever required to verify a Meter K Factor it can prove to be a Tedious, Expensive & sometimes a Confusing exersise!

Regards
JOHN MERRETT

Vortex Flowmeter



Excellent long term stability

Magnetic Flowmeters

invensys®

Process Systems

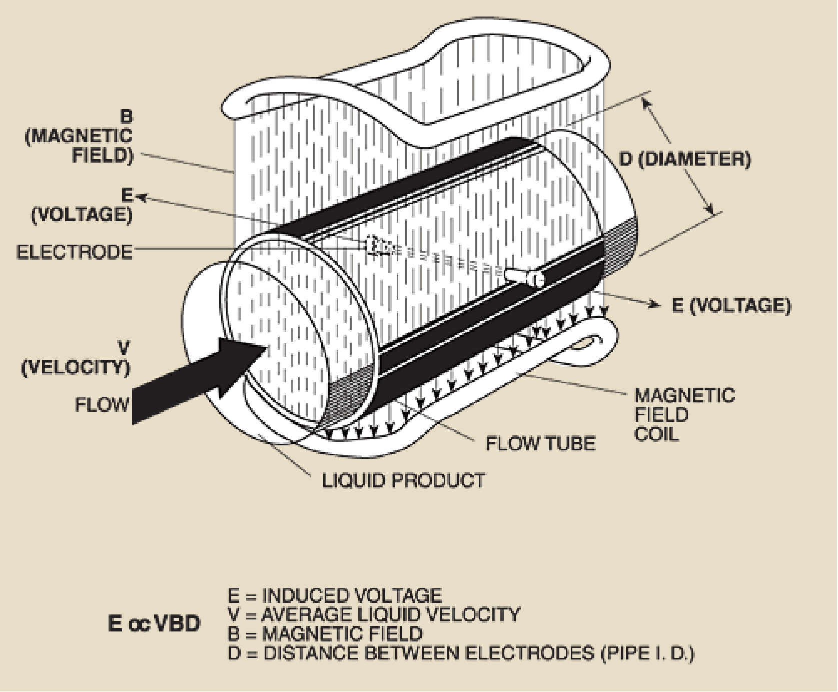
Get More from One

Avantis • Foxboro • SimSci-Esscor • Triconex

Magnetic Flowmeter

A magnetic field is applied to the metering tube, which results in a potential difference proportional to the flow velocity perpendicular to the flux lines. The physical principle at work is electromagnetic induction.

Faraday found that the electromotive force (EMF) produced around a closed path is proportional to the rate of change of the magnetic flux through any surface bounded by that path.



Complete Range of Magnetic Flowmeters

invensys
Process Systems

Foxboro family of DC magnetic flowmeters

IMT96 Mag EXPERT and 2800 Series Flowtube

- Invented by Foxboro 1954
- Sizes from 0.1” to 80”
- Wafer, flanged and sanitary models
- The versatile IMT25 Transmitter for your general purpose applications provides the ease of use and flexibility you want in a general purpose magnetic flowmeter
- For those tough applications like pulp stock, high consistency or mixing flows the patented IMT96 MagExpert with the industry proven 2800 series of flowtubes is the best solution

Magnetic Flowmeters

- Specific flowtube designs for different applications
  - Low cost units for water & waste streams
  - High durability units for slurries or corrosives
  - Ceramic for corrosive/abrasive combinations
- Liners for specific applications
  - Polymers for corrosion, ptfe, pfa, Kynar
  - Rubbers for abrasion; Neoprene, Linatex, poly
- Raised, large surface electrodes
  - Two measurement, opt grounding
  - Wide variety of materials
- On-line diagnostics
  - Monitor the electrodes
  - Monitor the system wiring
- Forward, reverse, or bi-directional flow
- Auto, empty flowtube detection & zeroing

IMT25 – Magnetic Transmitter

Magflow Pulsed DC

IMT25 – Magnetic Transmitter

IMT25 pulsed DC
Transmitter
Hart or FF- H1

9100A (1"-78")
Water and Waste

9200A (8'-48")
General Process

9300A series flanged
1/2" to 16"

8000A series wafer
1/16" to 6"

IMTSIM, ISO9000
Simulator

Pulsed DC Mag Flow Systems

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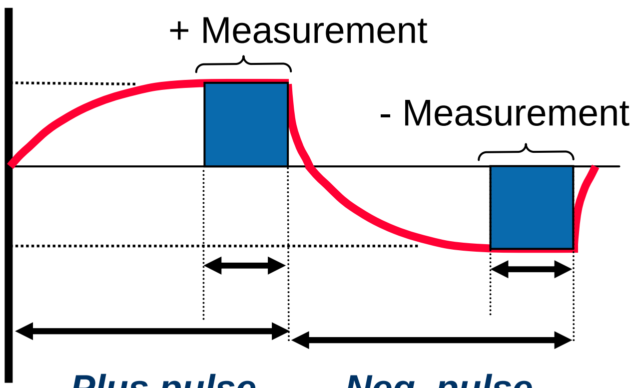
- *Coils of flowtube powered by Pulsed DC*
- *Microprocessor based transmitter powered by AC line or 24 VDC*



Plus pulse ***Neg. pulse***

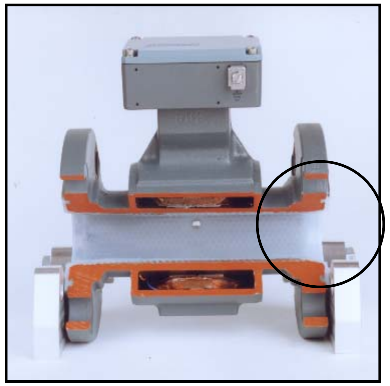
6 measurements per second

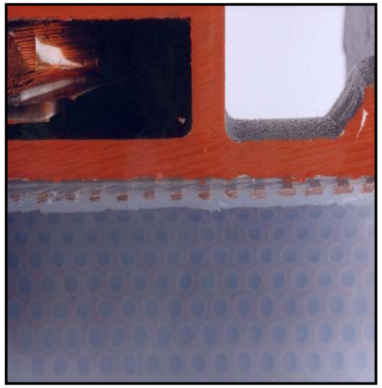
Advantages

- High Performance system at lowest cost
- Highest Accuracy (0.25% or 0.50% of rate)
- Excellent Zero Stability (Auto Zeroing)
- Low power consumption (24 Watts)

8000A / 9300A - ½ through 6 inch size

- Retained PFA Liner
  - Higher Combined Temperature & Pressure Service than PTFE
  - Better Abrasion Resistance than PTFE
  - PFA Molded into Perforated Grid Welded to Flowtube; Maximum Durability to Temperature Cycling and Vacuum





Cut-Away View of 9300A Flowtube

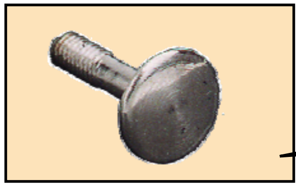
Close-Up View of PFA Molded Into Grid

Stainless Steel Perforated Grid

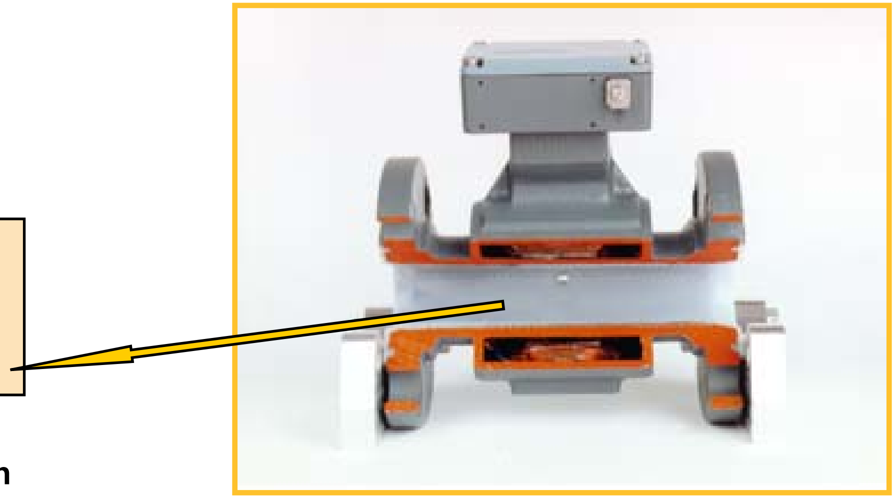
Superior electrode system

- *Less sensitivity to effects of entrained air*
- *Better performance in low conductivity*
- *Inside inserted electrodes for positive sealing*

Other Designs



Foxboro Design



Superior electrode system

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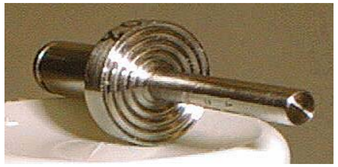
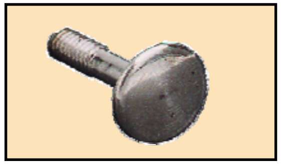
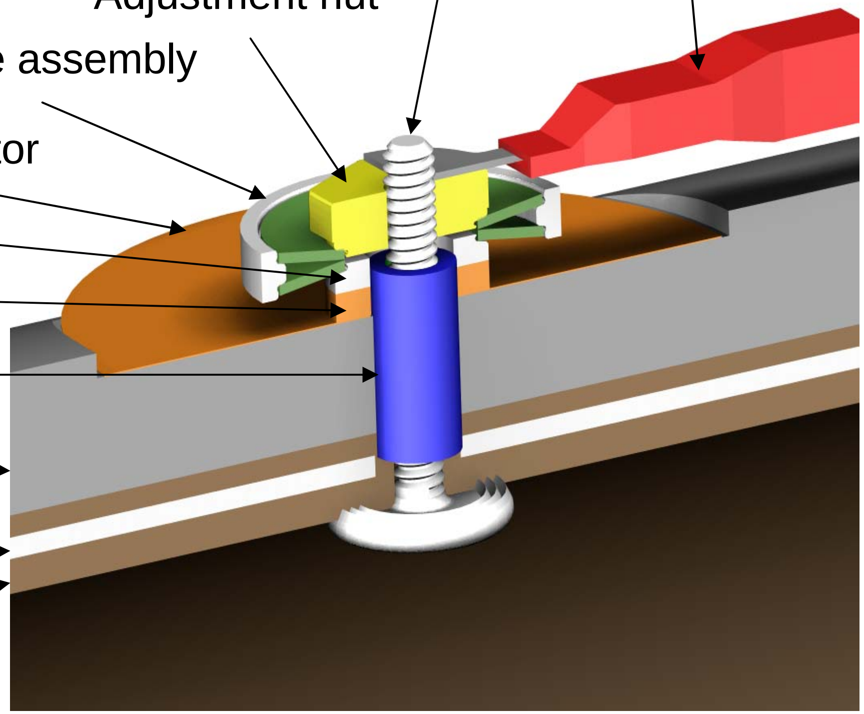


Other Designs (Outside Inserted)



Foxboro Design (Inside Inserted)



- Compatible with old flowtubes (Backward)
- Standard Cable
- Unique Noise Reduction Algorithm
  - Fast Speed Of Response For Control
  - Excellent Zero Stability
- Auto-Signal Lock (empty tube)

IMT Flowtube Simulator

Verifies IMT25 Transmitter performance

Portable Unit, Transmitter Powered

Dust and Rail Tight

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- **Patented eX-Pulse Technology**
- **High excitation & measurement frequency**
- **Near ac power levels**
- **Flow signal integration over entire pulse cycle**
- **Best of AC & DC features**

IMT96 Transmister

Flowtube 2800 high power CA
De 1” a 36”

Ideal solution for critical applications

eX-Pulse Mag Flow system, IMT96/ 2800 tube

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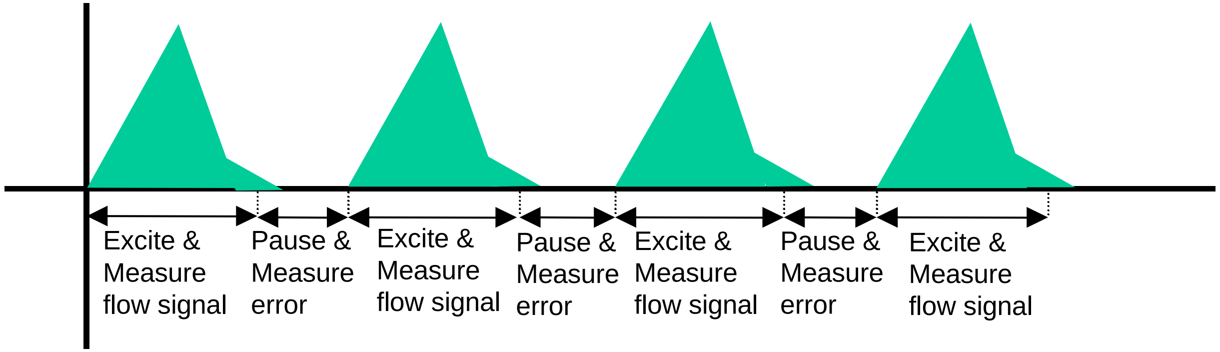

eX-Pulse signal is integrated over the entire coil excitation, followed by a pause interval

- eX-Pulse Coil excitation 2/3 that of continuous AC systems (40 Hz)
- eX-Pulse Coil excitation strength is 10 times the power of typical DC systems
- Fast speed of response
- High Accuracy (0.50%)
- Microprocessor-based electronics, analog and digital outputs, no calibrator required for setup or calibration.

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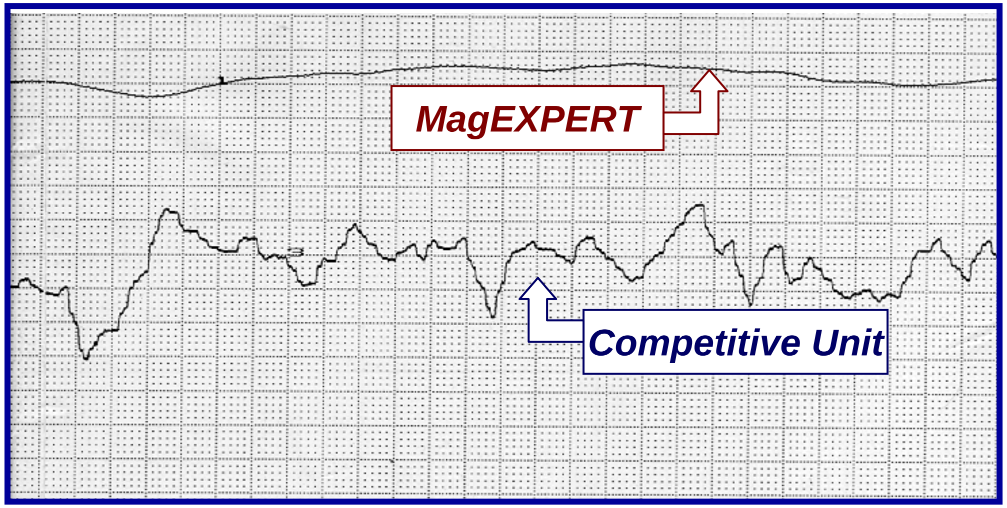


Output Signal under "constant" process conditions
(Signals off-set to show comparison)

- **Process: 15.8% Consistency Pulp Stock**
- **Line Size: 6 in.**
- **Velocity: 12 FPS**
- **Flow Rate: 1100 GPM**

Coriolis Flowmeters

invensys®

Process Systems

Get More from One

Avantis • Foxboro • SimSci-Esscor • Triconex

Coriolis Mass Flowmeters

Process Systems

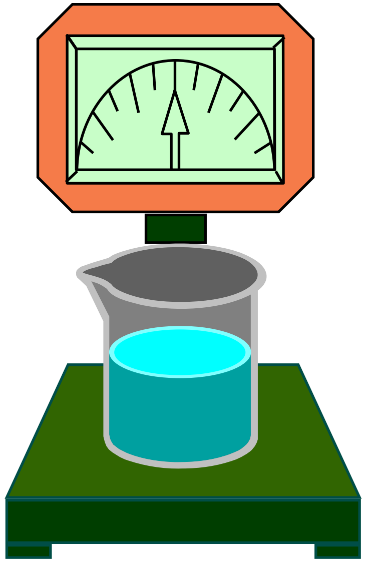
Features/Benefits

- Precise mass, density, and temperature measurement
- Accurate two-phase flow measurement with no interruption or stalls.
- Gas measurements
- Empty-tube startup capability

Why Mass Flow?

Measurement by weight
is the most accurate
method of
Flow Measurement ....

... is independent of
- pressure
- temperature
- viscosity
- electrical conductivity



.... however,
scale calibration and
loadcell replacement are
costly, difficult and
sometimes hazardous.

What are the alternatives?

Coriolis Mass Flowmeters

G.G. Coriolis, a French engineer,noticed that all bodies moving on the surface of the Earth tend to drift sideways because of the eastward rotation of the planet.

In the Northern Hemisphere the deflection is to the right of the motion; in the Southern, it is to the left.

This drift plays a principal role in both the tidal activity of the oceans and the weather of the planet.

The first industrial Coriolis patents date back to the 1950s, and the first Coriolis mass flowmeters were built in the 1970s.

These flowmeters artificially introduce a Coriolis acceleration into the flowing stream and measure mass flow by detecting the resulting angular momentum.

Coriolis Mass Flowmeters

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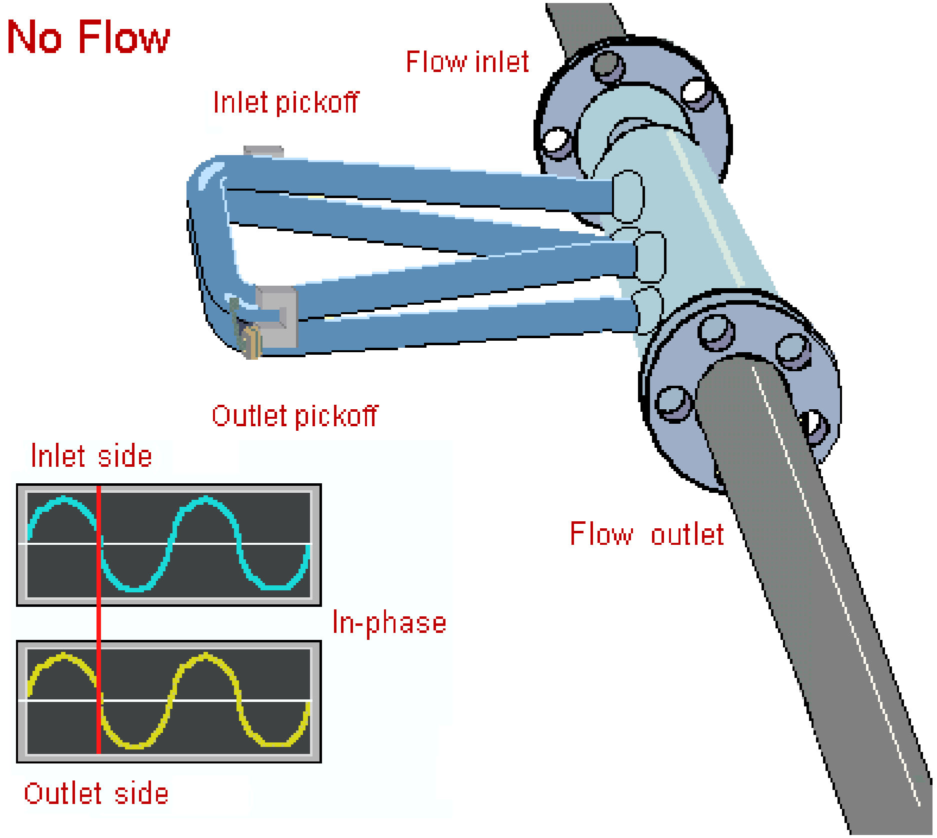
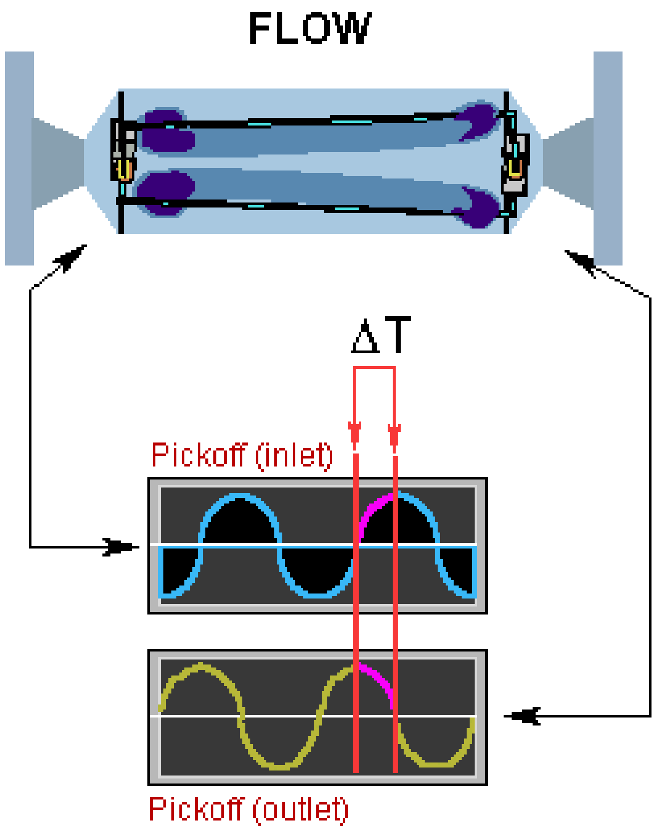
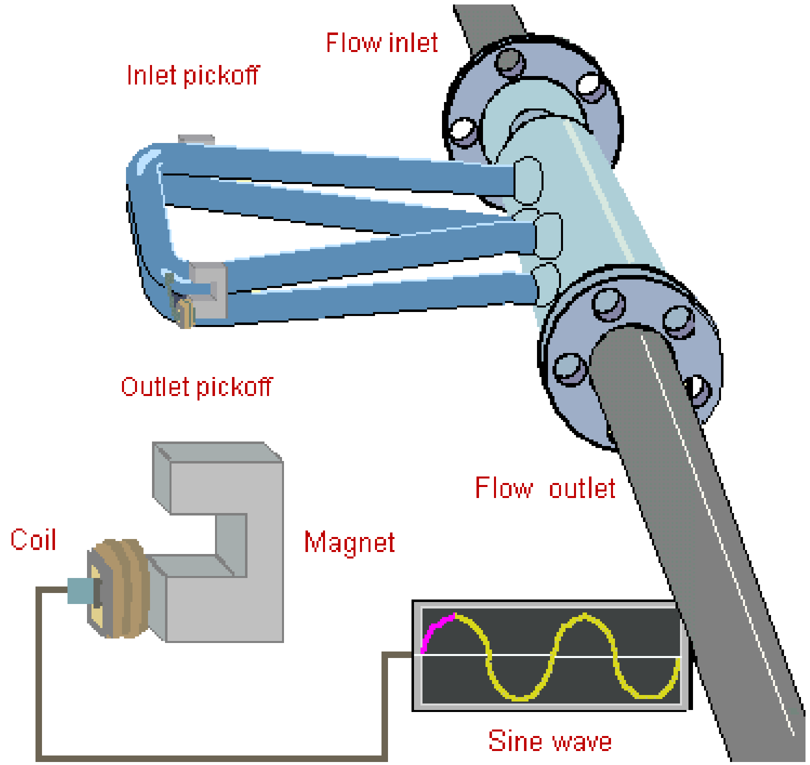
Working principle

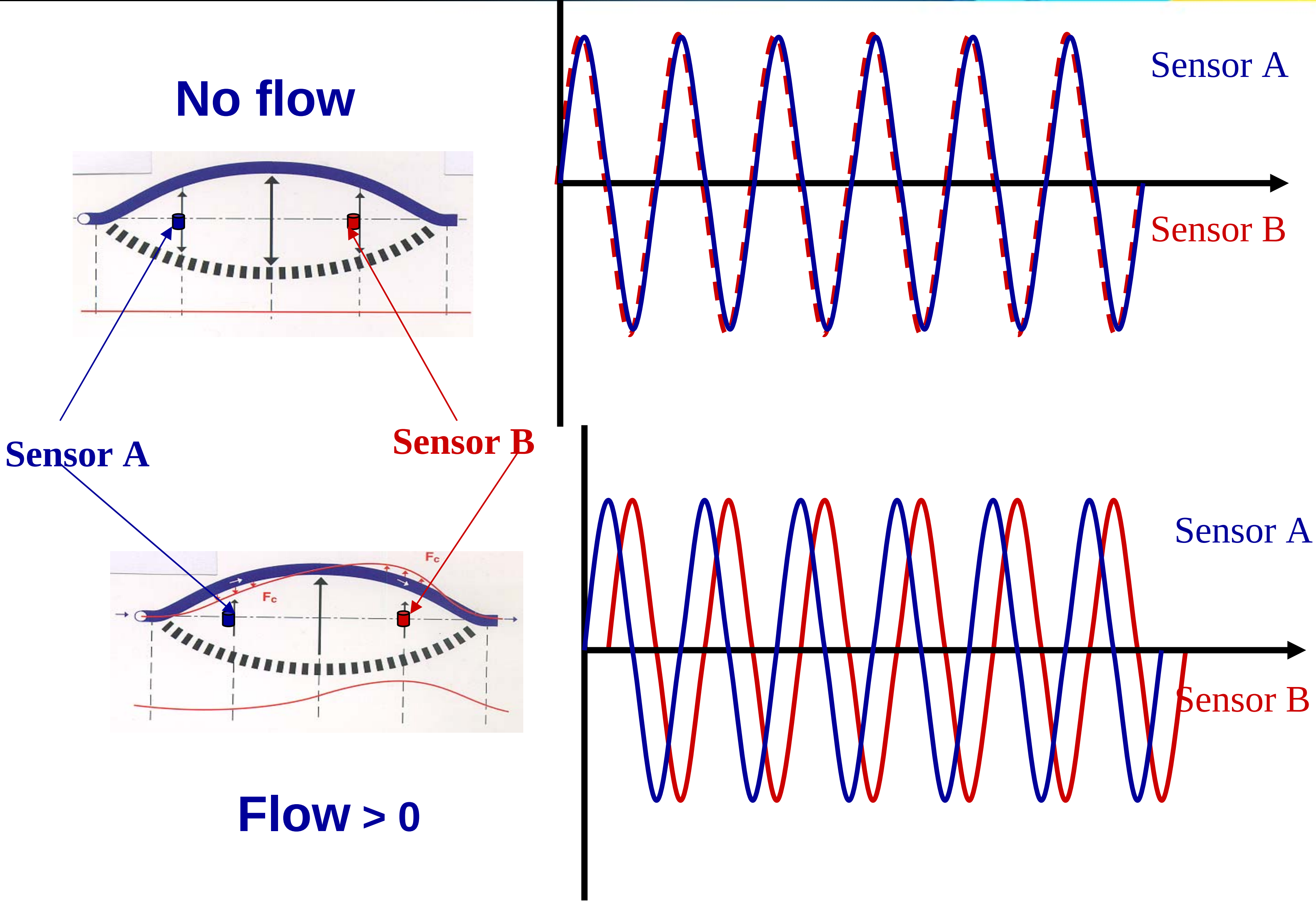


Coriolis Mass Flowmeters





Coriolis Mass Flowmeters

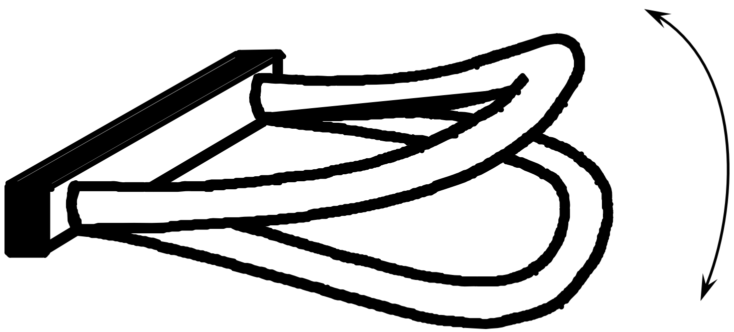


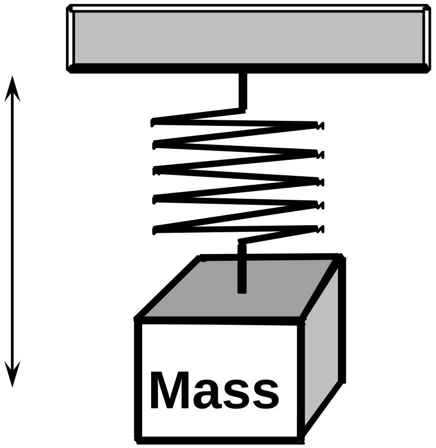
Coriolis Mass Flowmeters

Drivers cause flow tube to oscillate at natural frequency

Sensors measure the oscillation:

Frequency gives density





Spring and Mass Assembly

$$\rho = \frac{k}{4\pi^2 f^2 V} - \frac{m(tube)}{V}$$

$$\rho \alpha \frac{1}{f^2}$$

Coriolis Mass Flowmeters

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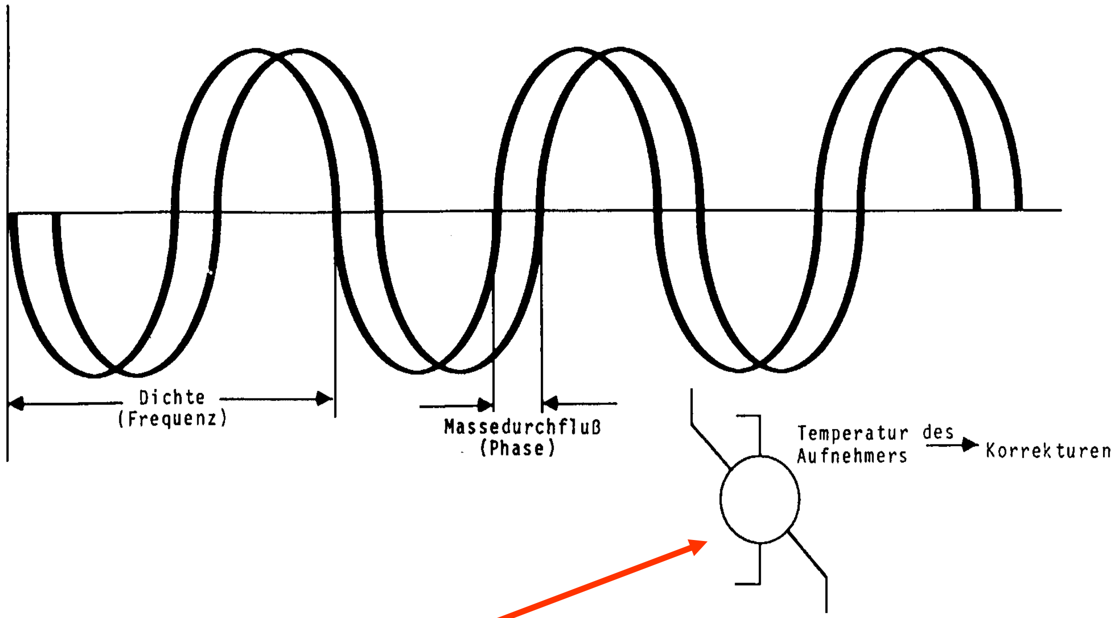
Drivers cause flow tube to oscillate at natural frequency

•**Density**

Oscillating Frequency



•**Mass Flow**

Phase offset

•**Temperature**

(Pt 100)

Coriolis Mass Flowmeters

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Mass Flow - Gas

Specific Gravity

Interface Detection

Temperature

Viscosity

%HFCS

Custody Transfer - Mass

Density - Gas

ºAPI

Net Solids

Mass Flow - Liquids

ºBaume

Blending

ºBrix

% Solids

Leak Detection

Net Volume

Batching

Custody Transfer - Volume

% Concentration

Density - Liquid

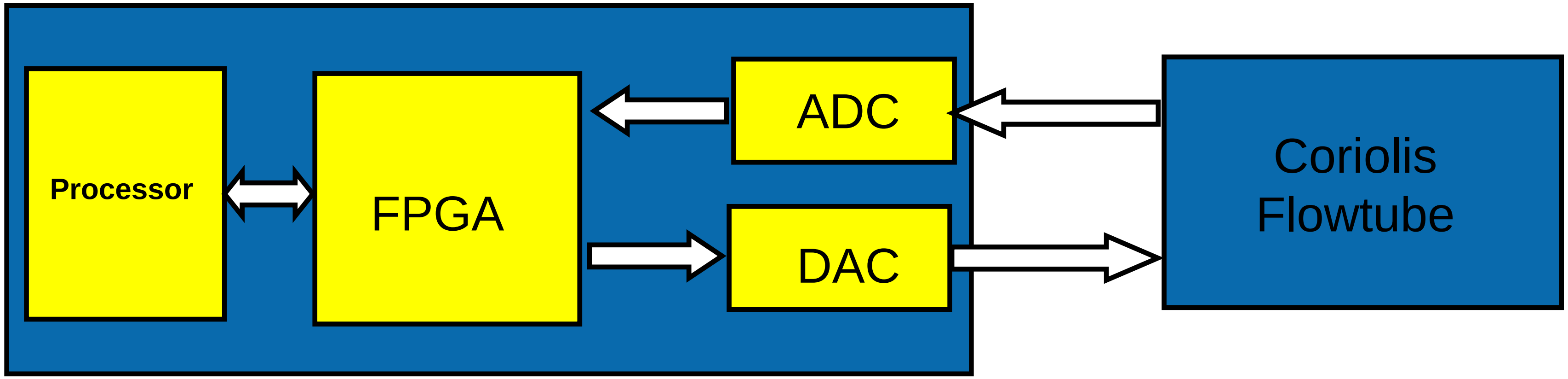
Benefits of Coriolis mass meters

- Mass meters yield high accuracy's
- Mass meters can be used on a variety of different fluids w/o re-calibrated
- Very Wide Rangeability
- BI-Directional Flows
- No piping constraints
- Impervious to changing process conditions
- Insensitive to flow profiles
- Unaffected by viscosity shifts

Shortcomings of Coriolis Mass Flow Meters

- Though Coriolis meters offer many capabilities, they do have some disadvantages:
  - Entrained air
  - Empty tube issues
  - Sympathetic vibrations
  - Zero Shifts

Coriolis Mass Flowmeters



- **Simple design based on consumer (audio) technology.**
- **Replace complex analogue control system with all-digital design.**
- **Processor performs control, measurement and diagnostic functionality**
- **FPGA carries out all I/O and drive waveform synthesis**

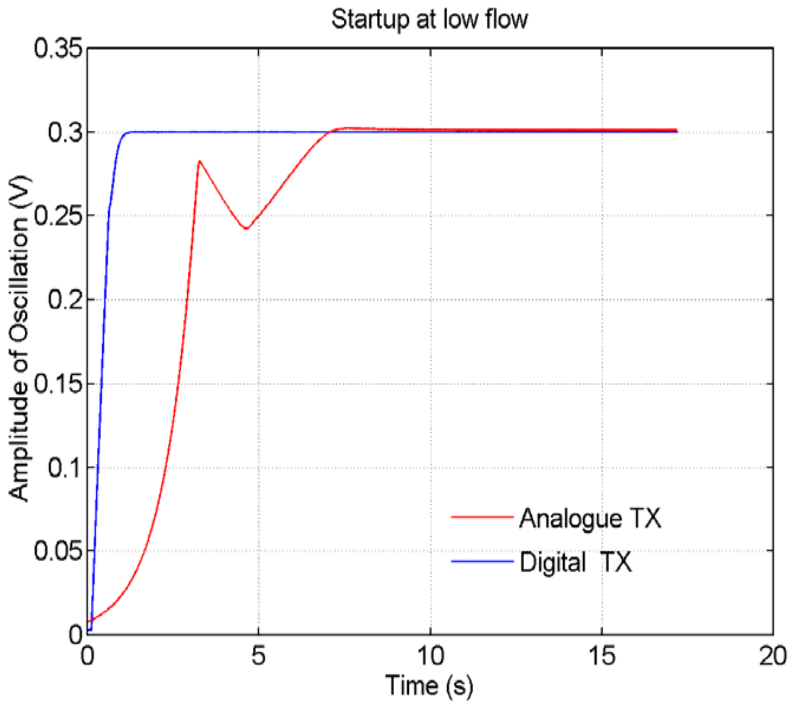
Developed by Invensys and Oxford University

Coriolis Mass Flowmeters

Capabilities of CFT50

- Volume, concentration, solids, % solids, Brixs and Baume measurements
- Capability to start measurements from empty flow tube
- Ability to measure liquid switch to gas and then back to liquid again without interruption
- 25 mS response time
- Direct measurements of mass, density and temperature

Flowtube control – Start up



- **Analogue TX has a slow start.**
- **CFT50 uses a sophisticated non-linear control algorithm.**
- **CF50 avoids flowtube stalling, even with entrained air.**
- **Start-up time reduced from 10-30s (analogue) to 2s (digital) for 1" flowtube.**

Measurement algorithms provide data within 0.1s.

Control and measurement algorithms can work at lower amplitudes of oscillation (down to 0.1% of normal) for low power operation.

Coriolis Mass Flowmeters

- **Benefits of using CFT50**

  - Accurate measurements for process control
  - Repeatable measurements
  - Ability to account for liquids during unloading of rail or truck
  - Accurate control of recipe batching during two phase flow
  - No false flow signals from zero shift due to empty flow tube
  - Increases meters rangability
  - Full measurement features
  - Meter response times

Coriolis Mass Flowmeters

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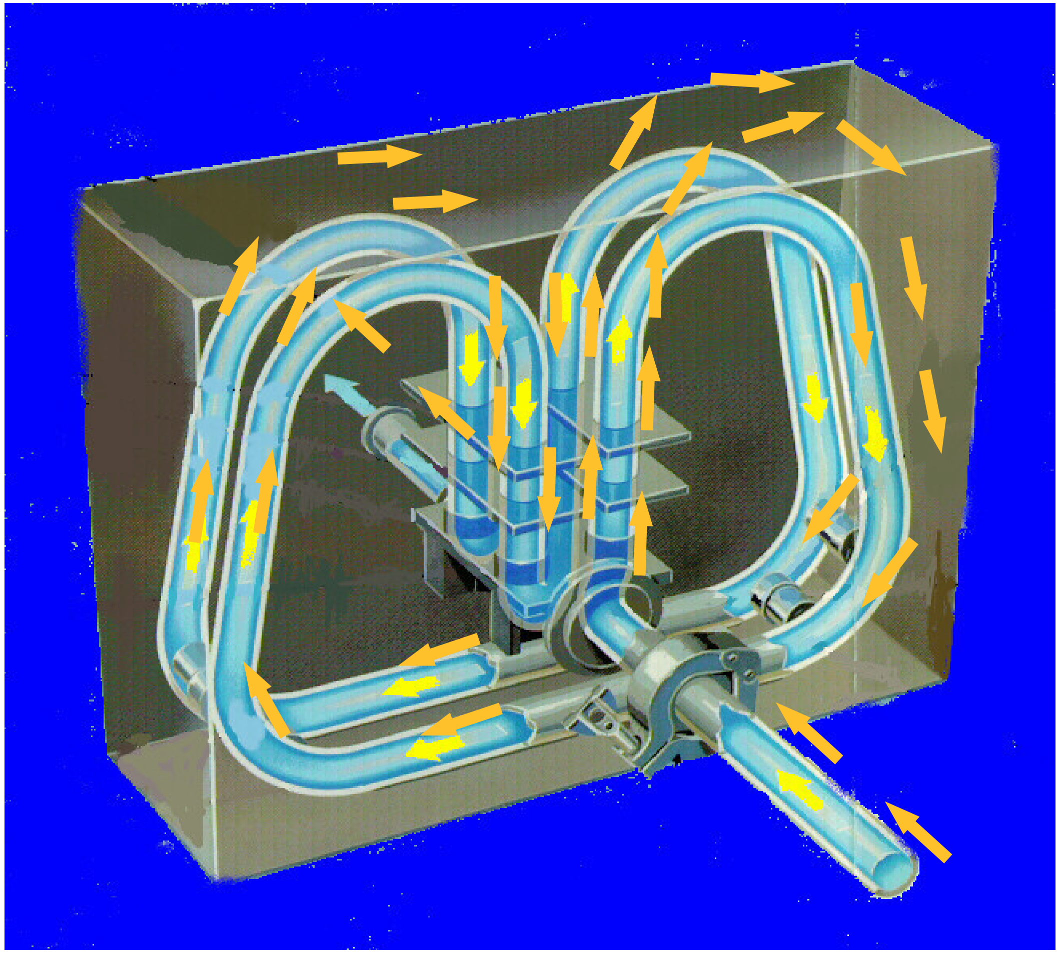
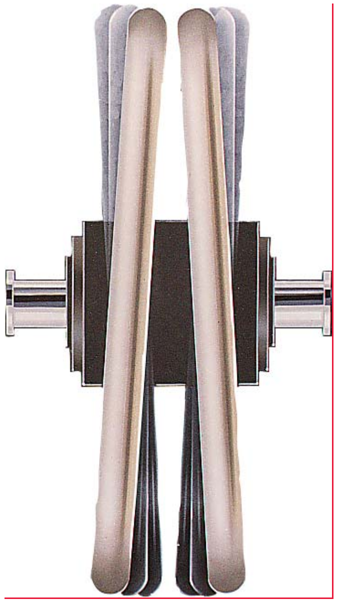


CFS10 single path
Available in:
3 to 50 mm
1/8 to 2 in

CFS20 dual path design
Available in:
40 and 80 mm
1 1/2 and 3 in

Anti-Phase Control :

- **Patented anti-phase double driver system allows close sensor proximity to inhibit signal distortion, and provides low power consumption per driver**
- **Tubes in torsion (not bending) with low stress throughout, particularly at welds and brazed joints**



Benefits:

•Zero stability

•Long term stability

•High stress resistance factor

•Less energy required

Tanker Truck Loading and Unloading

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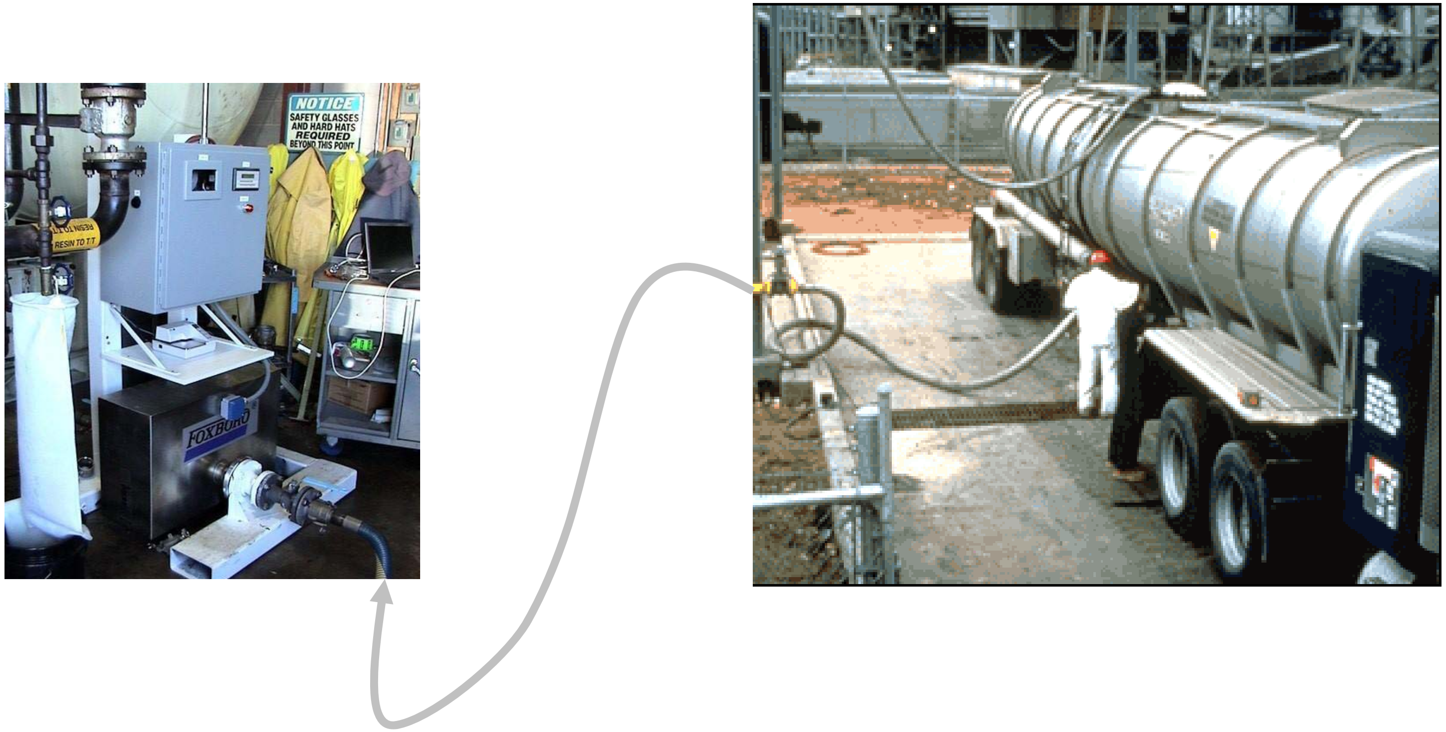

- Foxboro Digital Coriolis for product offloading from tanker trucks
- Density
- Mass
- Volume

OIML Certificate of Approval

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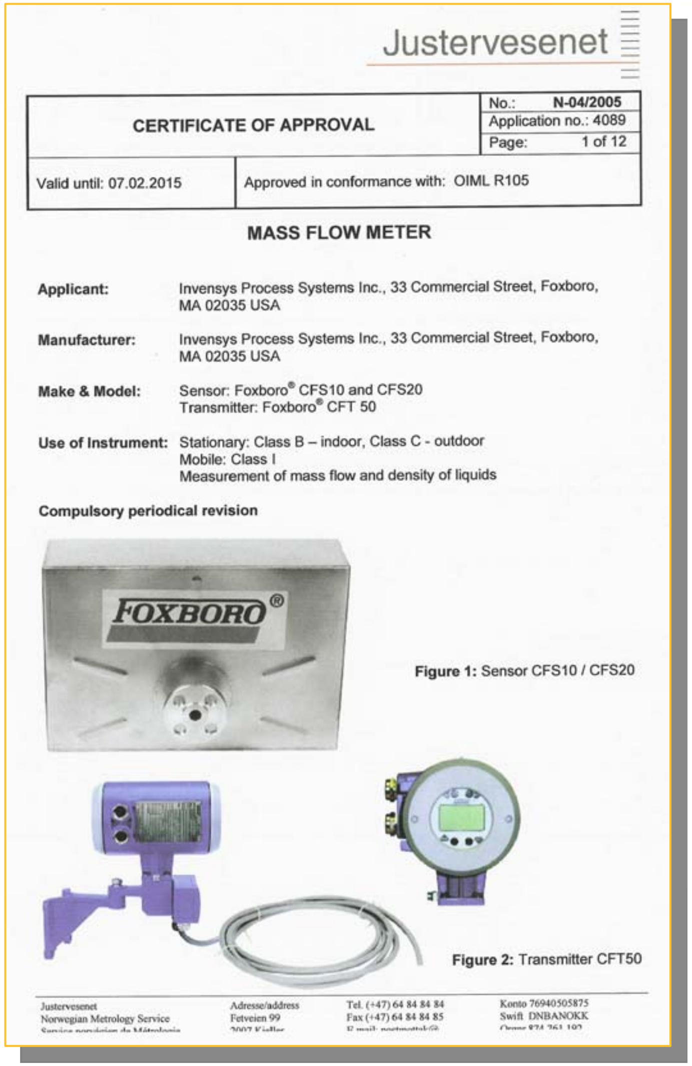


Justervesenet

CERTIFICATE OF APPROVAL	No.: N-04/2005 Application no.: 4089 Page: 1 of 12
Valid until: 07.02.2015	Approved in conformance with: OIML R105

MASS FLOW METER

Applicant: Invensys Process Systems Inc., 33 Commercial Street, Foxboro, MA 02035 USA

Manufacturer: Invensys Process Systems Inc., 33 Commercial Street, Foxboro, MA 02035 USA

Make & Model: Sensor: Foxboro® CFS10 and CFS20
Transmitter: Foxboro® CFT 50

Use of Instrument: Stationary: Class B – indoor, Class C - outdoor
Mobile: Class I
Measurement of mass flow and density of liquids

Compulsory periodical revision

Figure 1: Sensor CFS10 / CFS20

Figure 2: Transmitter CFT50

Justervesenet
Norwegian Metrology Service

Adresse/address
Fetveien 99

Tel. (+47) 64 84 84 84
Fax (+47) 64 84 84 85

Konto 76940505875
Swift DNBANOKK

- OIML Approval R105 is good for mass flow and density
- Must use CFS10 or CFS20 and CFT50 <u>with display</u>
- Conforms to Accuracy Class:
  - 0.3%
  - 0.5%

Meter Proving

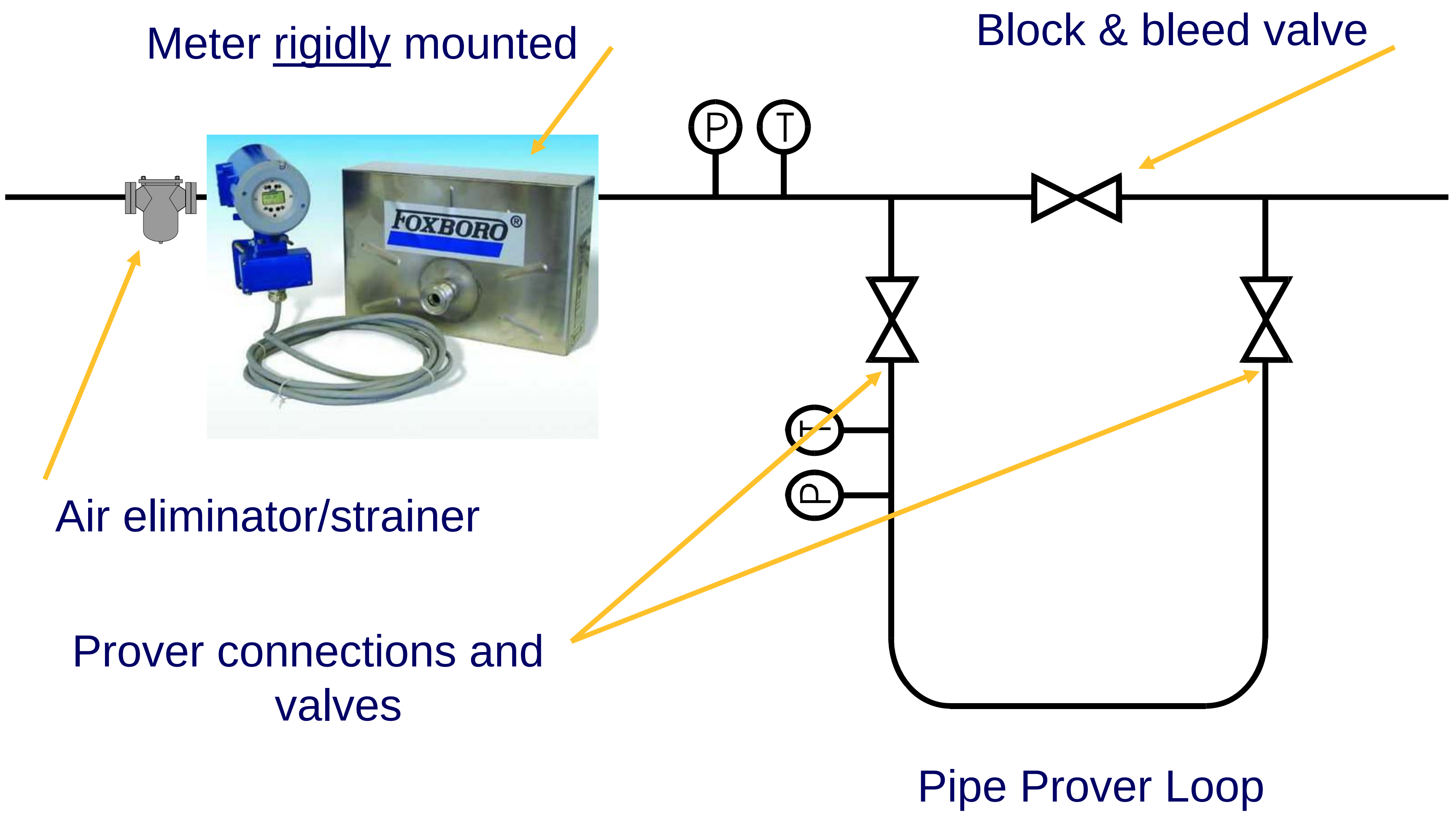
- **Meter proving is the in-situ comparison of the volume that goes through the CT meter with the volume that goes through a traceable standard (volumetric prover or master meter)**

- **Meter proving is usually performed monthly to account for the wear on PD and turbine meters—the drift of the Meter Factor**

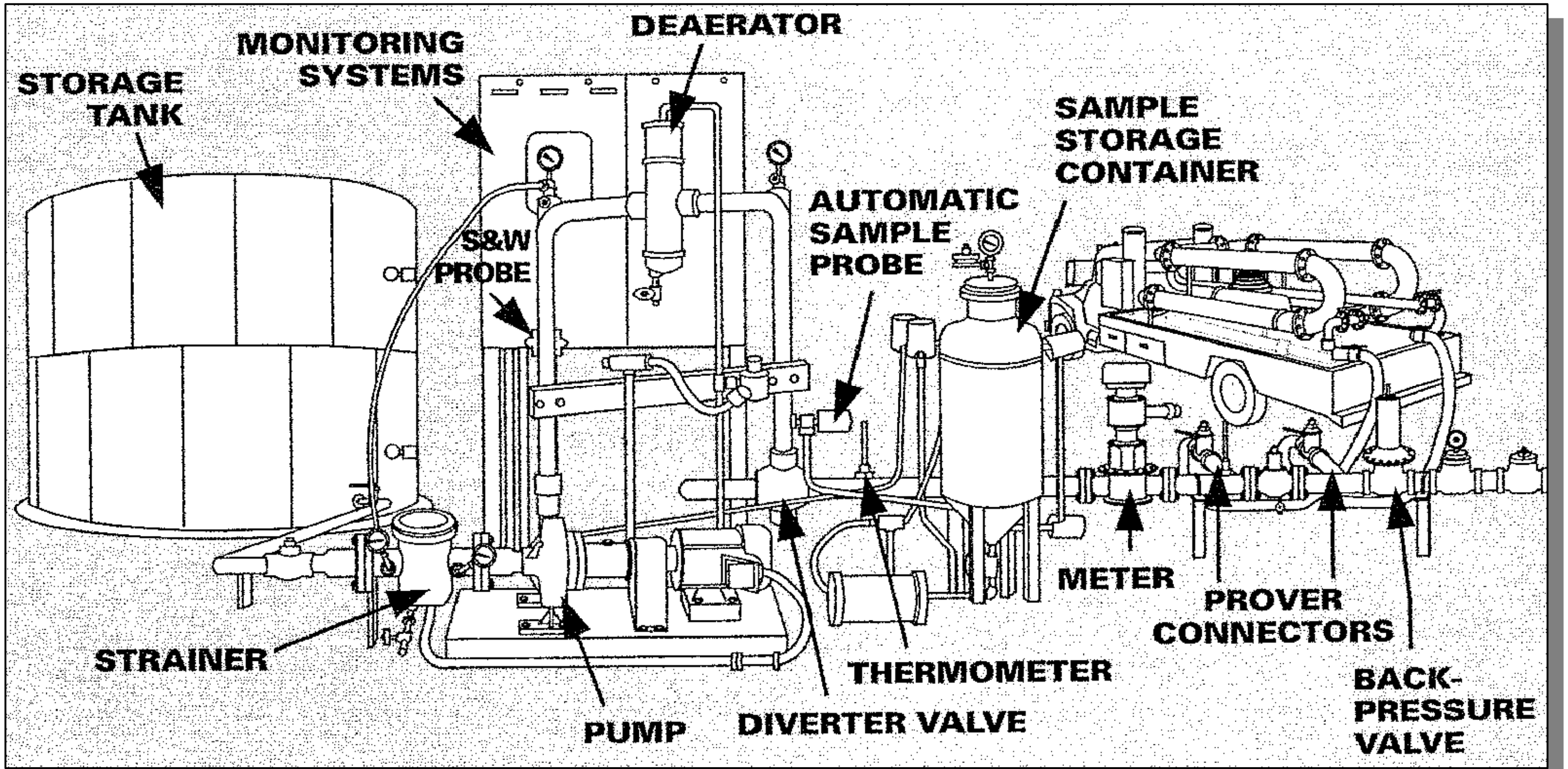
- **Volumetric provers are either ball-type (pipe provers) or piston-type (compact provers)**

- **Master meter method simply involves another meter that is on standby (or brought to site) and has been recently calibrated**

Meter and Prover Schematic

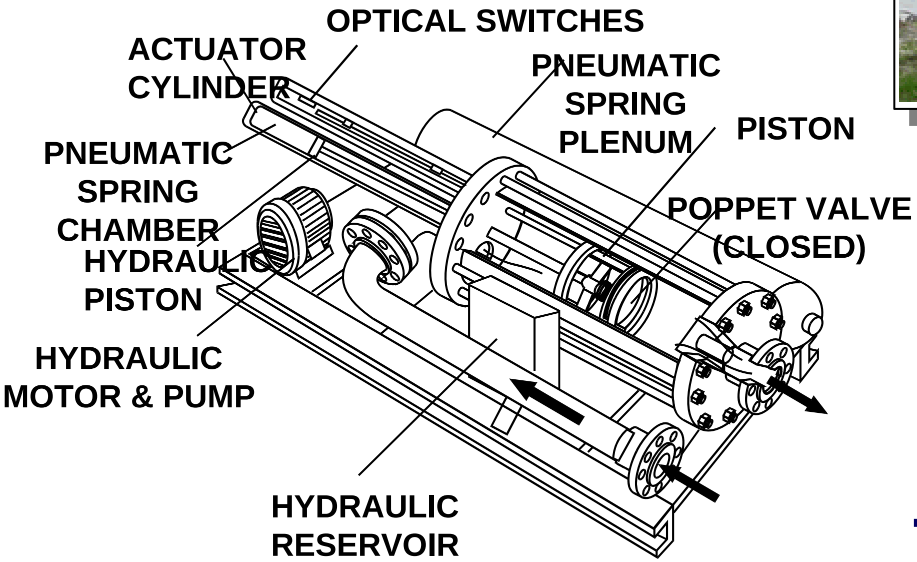


Unit with Portable Pipe Prover



Compact (or Piston) Provers…

Brooks/Daniel Compact Prover



Calibron Piston Prover

…also Called Small Volume Provers

Pipe (or Ball) Provers

Meter Factor

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$$\text{Meter Factor} = \frac{\text{Known Volume (Mass)}}{\text{Meter Volume (Mass)}}$$

- If the meter factor is greater then 1.0000 the meter is under-registering (reading low).

- If the meter factor is less then 1.0000 the meter is over-registering (reading high).

Custody Parties Plot Meter Factors Over Time

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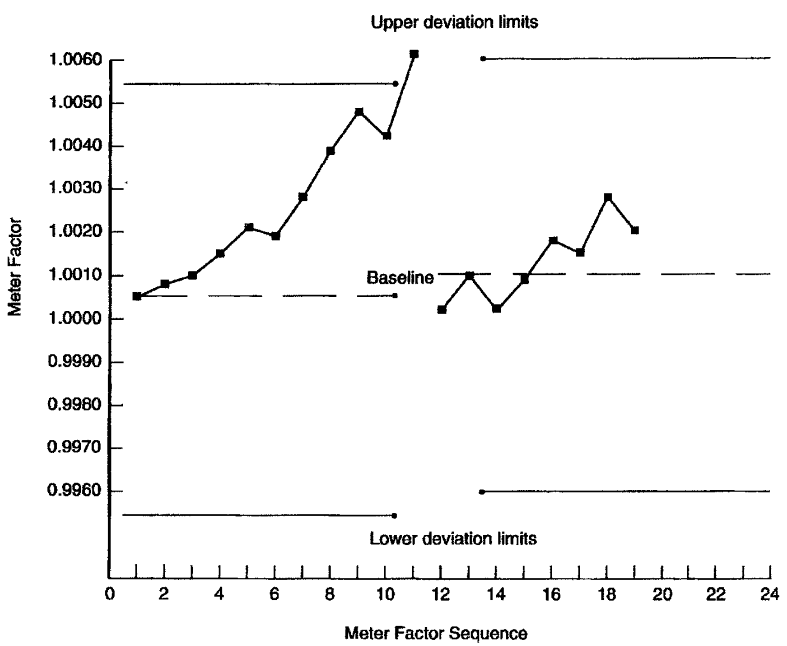

Figure 2—Example of a Meter Factor Graph

XYZ Company

METER FACTOR LOGGING SHEET

Location: Anywhere | Meter Make/Style: Generic PD | Flow Range: Min: 85 Max: 850 BPH

Serial #: G123456 | Temp Comp: Yes / No ATG | Action Limit: ±0.50%

Product: Crude | ProverType: Bi-Dir Ball | Prover Serial #: C12345

Sequence No.	Date	Meter Factor	Proving Report #	Meter Temp.	Meter Press.	Gravity API @ 60°F	Flow Rate	% Deviation Last Proving	% Deviation Baseline	Remarks
1	1-2-87	1.0005	101	78.0	60	35.5	180	Initial	Initial	Baseline factor
2	2-3-87	1.0008	102	76.5	58	35.4	178	+0.03	+0.03	
3	3-5-87	1.0010	103	80.5	61	35.8	181	+0.02	+0.05	
4	4-3-87	1.0015	104	81.2	60	36.0	180	+0.05	+0.10	
5	5-5-87	1.0021	105	84.0	61	35.8	179	+0.06	+0.16	
6	6-4-87	1.0019	106	83.5	60	35.5	182	−0.02	+0.14	
7	7-7-87	1.0028	107	87.0	62	35.8	180	+0.09	+0.23	
8	8-4-87	1.0037	108	88.0	60	35.4	180	+0.09	+0.32	
9	9-6-87	1.0048	109	89.0	60	35.8	181	+0.11	+0.43	
10	10-3-87	1.0042	110	85.0	60	35.2	185	+0.06	+0.37	
11	11-4-87	1.0061	111	81.0	60	35.4	180	+0.19	+0.55	Repaired meter
12	11-5-87	1.0002	112	81.5	59	35.6	176	–	–	First factor
13	11-6-87	1.0010	113	83.5	61	36.1	181	–	–	Baseline factor
14	12-8-87	1.0002	114	78.5	62	35.7	175	−0.08	−0.08	
15	1-4-88	1.0009	115	77.0	61	36.1	172	+0.07	−0.01	
16	2-6-88	1.0018	116	74.5	63	36.6	170	+0.09	+0.08	
17	3-4-88	1.0015	117	76.0	61	36.1	175	−0.03	+0.05	
18	4-6-88	1.0028	118	81.5	60	36.0	180	+0.13	+0.18	
19	5-4-88	1.0020	119	82.5	59	35.9	181	−0.08	+0.10	

Figure 1—Example of a Meter Factor Log