FLUID COMPONENTS INTERNATIONAL LLC

MEDIÇÃO DE VAZÃO MASSICA TERMAL
Technologia & Applications

Hirsa – Sistemas de Automação e Controle

Medição Termal tecnologia e aplicações

- **AGENDA**

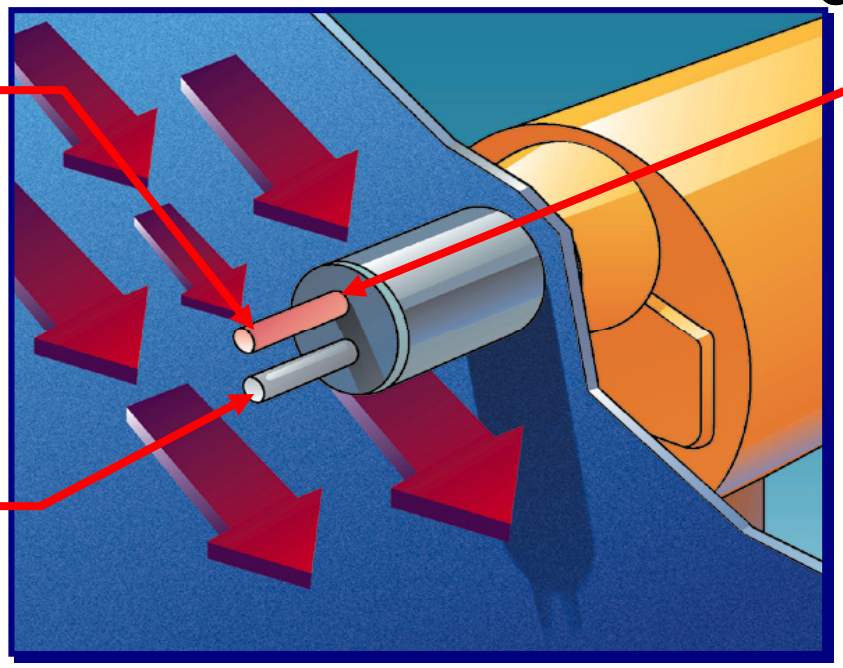
- **Teoria de Operação**
- **Principais Aplicações**
- **Medição em Grandes Dutos**
- **Criterios de Seleção**
- **Instalação**
- **Calibração**
- **Novos produtos e tendências**

Theory of Operation

Thermal Dispersion

Temperature Sensor (Pt1000) plus Heater Element as Active or Heated Sensor

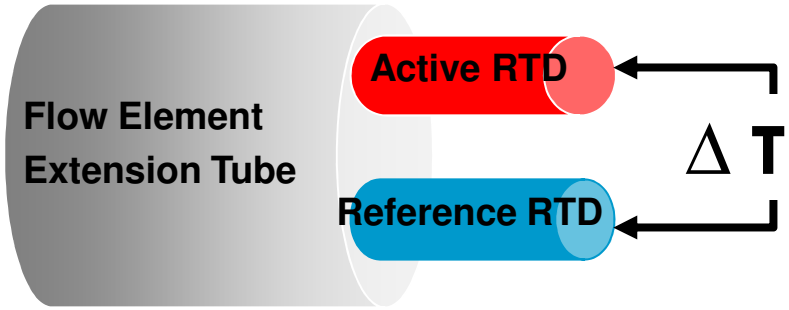
Constant Power Supply from Electronics to Heater Element



Temperature Sensor (Pt1000) as Reference Sensor or Unheated Sensor

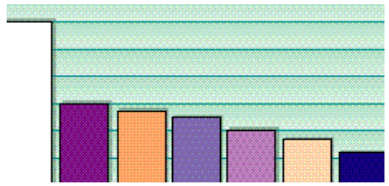
Theory of Operation

Thermal Dispersion



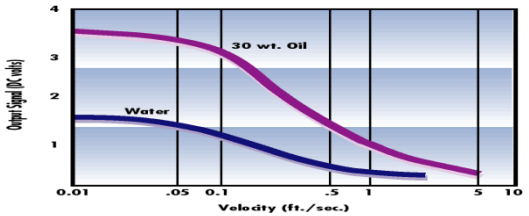
@ No Flow

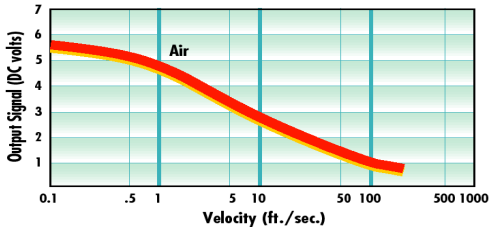
- Heat Conductivity
- Level Detection
- Interface Detection



@ Flow

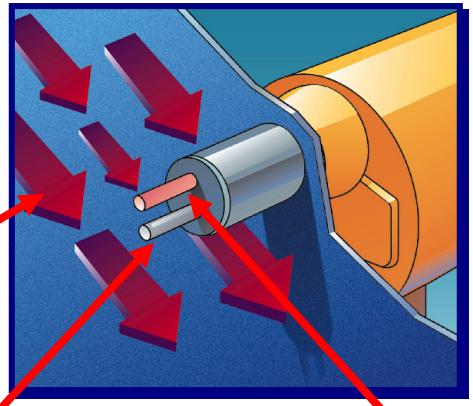
- Heat Conductivity + Cooling Effect
- Flow Detection
  - Liquids
  - Gas Mass
- Flow Metering
  - Gas Mass





Theory of Operation

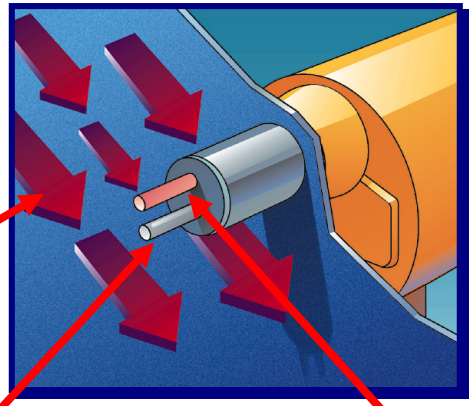
Temperature Difference at No Flow with FCI's constant Power Technology



Process Temp.	Reference RTD	Active RTD (.75 watts)	△T (△R)
70°F	70°F (1100Ω)	130°F (1200Ω)	+85°F (110Ω)
850°F	850°F (2700Ω)	900°F (2800Ω)	+85°F (110Ω)

Theory of Operation

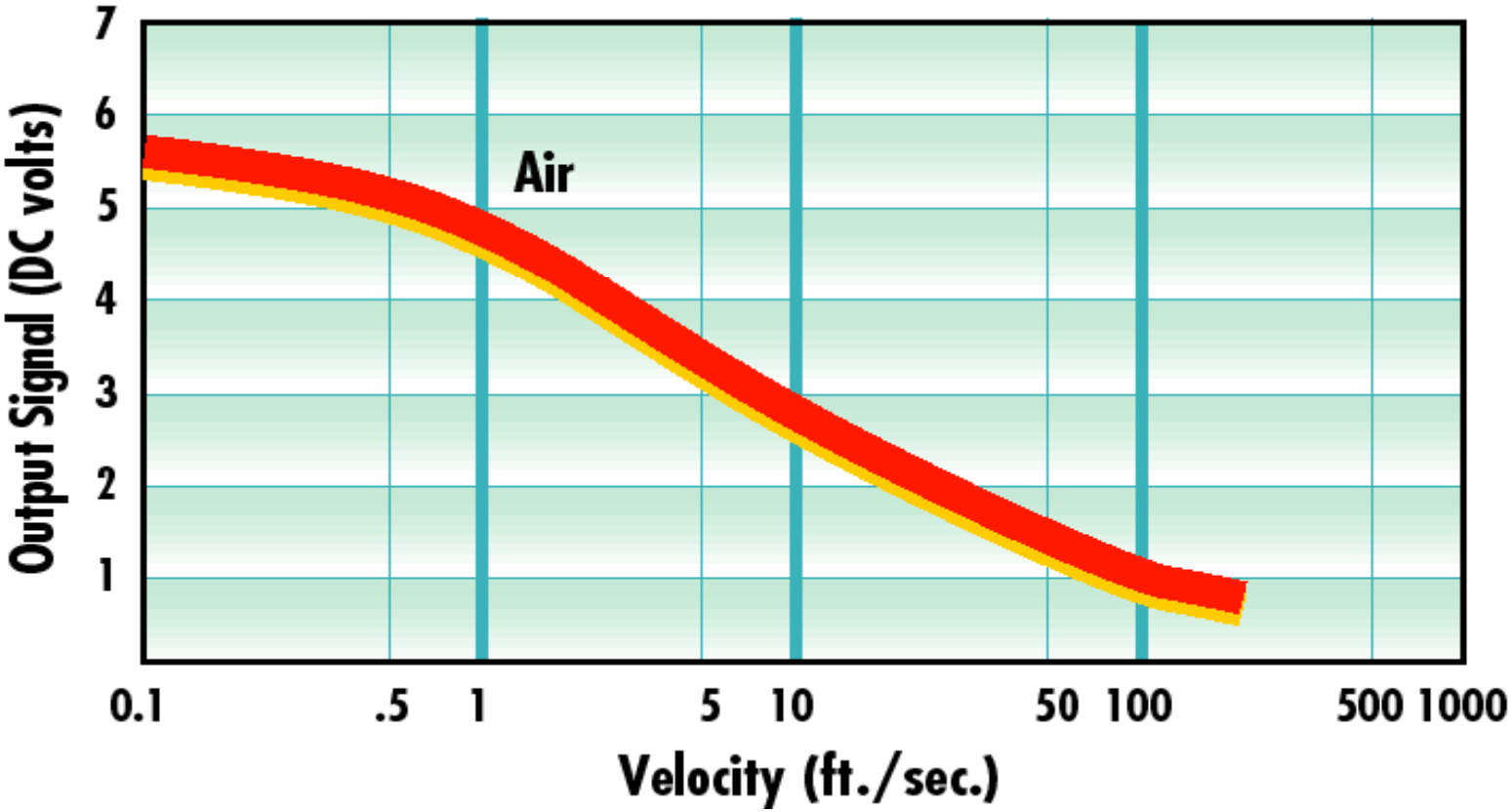
Temperature Difference at Flow with FCI's constant Power Technology



Process Temp.	Reference RTD	Active RTD (.75 watts)	△T (△R)
70°F	70°F (1100Ω)	80°F (1100 Ω)	+40°F (20Ω)
850°F	850°F (2700Ω)	850°F (2700Ω)	+40°F (20Ω)

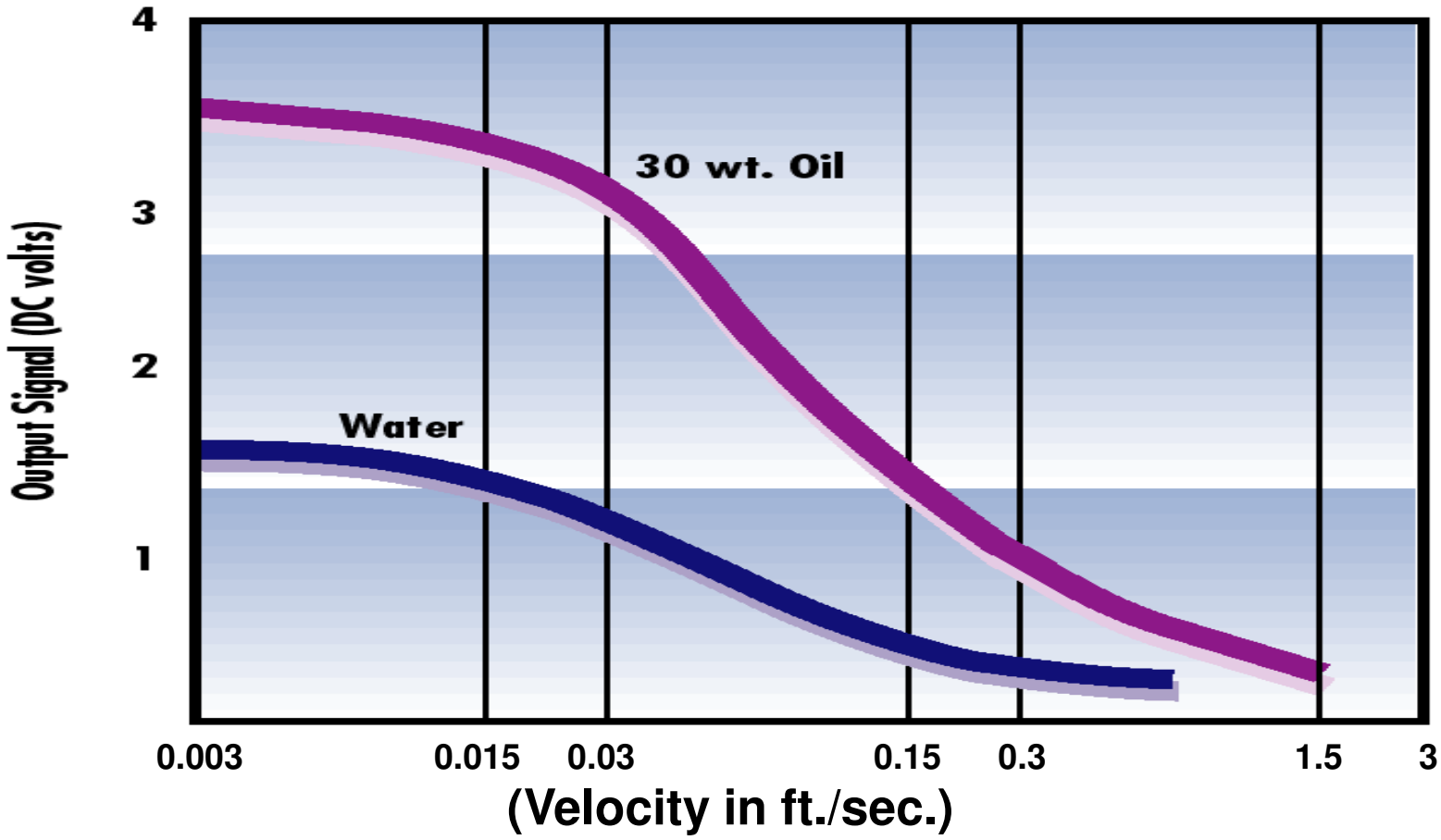
Theory of Operation

Typical Flow Signal Gasses



Theory of Operation

Typical Flowsignal Liquids



Theory of Operation

- **Thermal Dispersion**

Primairy Measuring Parameters

- **Velocity**
- **Viscosity**
- **Thermal Conductivity**
- **Density**
- **Specific Heat**

Theory of Operation

Heat Loss Equation

ρv = Mass Velocity
C, M, N = Constants
d = Diameter of Heated Element
a = Area of Heated Element
W = Heating Power
ΔT = Temperature Difference

Gas Properties

k = Thermal Conductivity of Gas
μ = Absolute Viscosity of Gas
c_P = Specific Heat of Gas (Constant Pressure)

$$\rho \times v = \frac{\mu}{d} \left(\frac{d \cdot W}{a \cdot \Delta T \cdot c \cdot k \left(\frac{c\rho \cdot \mu}{k} \right)} \right)^{1/M}$$

Mass Velocity = f (a, d, W, ΔT, μ, c_{ρ}, k)

Theory of Operation

Basic Heat Loss Equation:

$$\rho V = C \left(W/_{\Delta T}\right)^{X}$$

Where:

ρ **V** = Mass – Velocity

C, X = Calibration Constants

W = Heating Power

Δ **T** = Temperature Difference

- **The constant power heater design results in mass velocity measurement from ΔT**

Theory of Operation

Mass Flow

Mass Flow Equations

$$M = \rho \cdot A \cdot v \quad \text{or} \quad M = \rho \cdot Q$$

WHERE

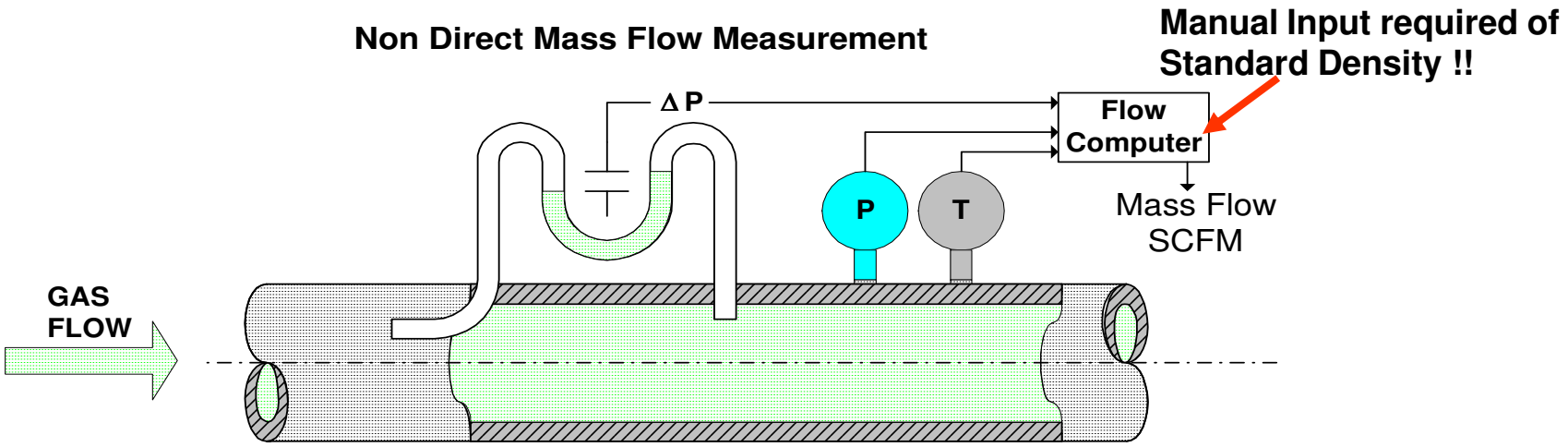
M = Mass Flow Rate	(mass/time)	**lb/sec**
ρ **=** Density of Gas	(mass/volume)	**lb/ft^3**
A = Area of Pipe	(area)	**ft^2**
v = Velocity of Gas	(length/time)	**SFPS**
Q = Volumetric Flow Rate	(volume/time)	SCFM

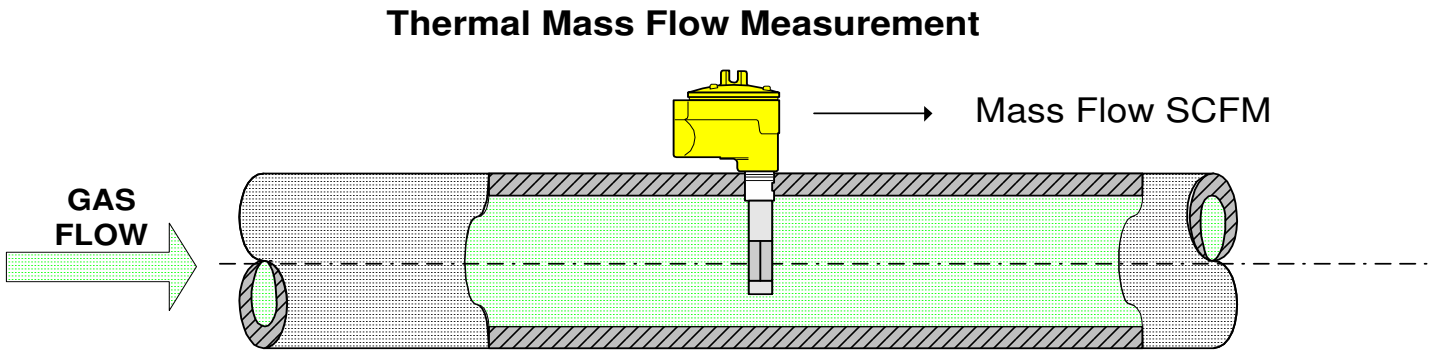
Non-Direct Method:

Volumetric Flow Rate **= Q = V · A**
with Additional Device to Measure Density
(temp & pressure&standard density)

Theory of Operation

Thermal Dispersion





Theory of Operation

Thermal Dispersion

Em outras palavras :

O medidor Termal mede a taxa de de resfriamento das moleculas do gas que passam pelos sensores .

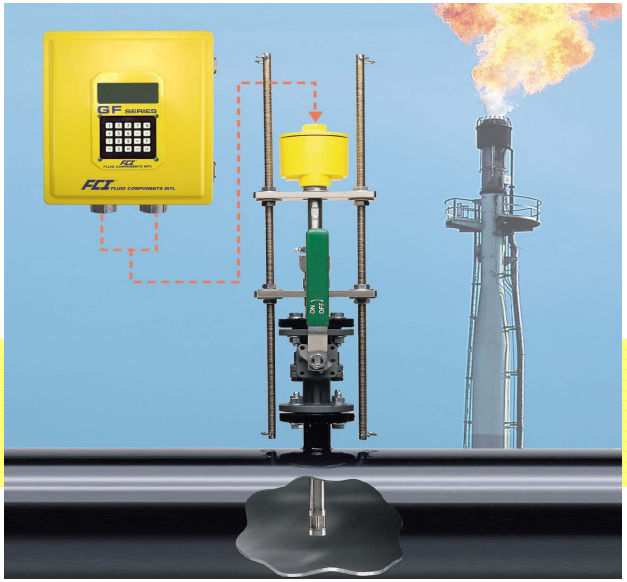
A quantidade de Resfriamento depende da

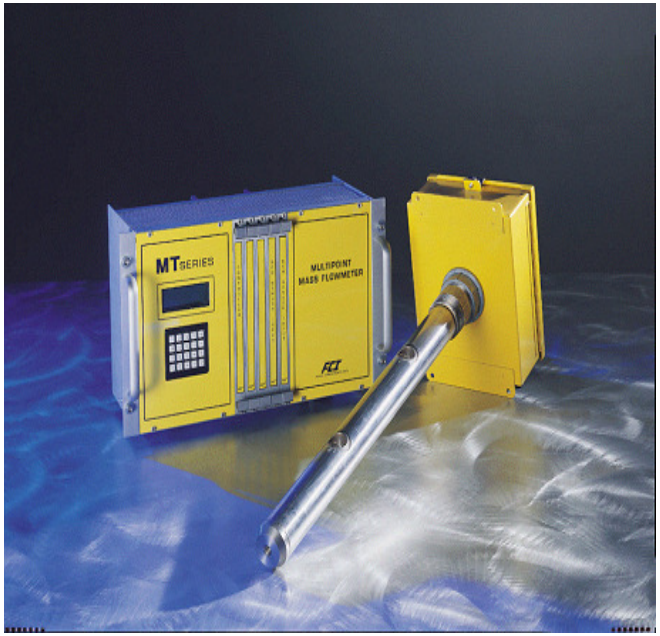
Densidade atual , vezes velocidade atual das moleculas do Gas .

Então se multiplicarmos pelo diametro interno do tubo /linha , teremos a medição direta em vazão massica

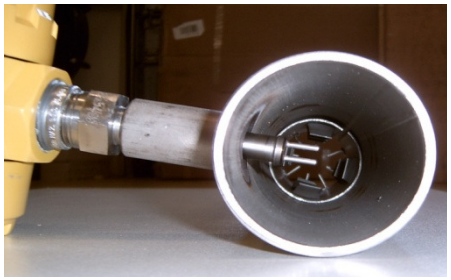
Products

Non Ex ST98





Ex ST98



Products FCI

- **Switches: Flow, Level and Interface**

Insertion Style FLT93S and FLT93F

Inline Style FLT93L

CARCTERISTICAS BASICAS

Transmitters: Generic Specifications

Functions	▪ Mass flowmetering of gasses with available flowranges from: ▪ 0.25 to 1500 SFPS ▪ Available for 1/8” tubing upto 5000 mm
Available versions	▪ Single point insertion style ▪ Multi point insertion style (16 points max) ▪ In-line optionally with integral flowconditioner
Temperature ratings	▪ Types available from -100 to to 850 ºF (454Cº)
Pressure ratings	▪ From full vacuum upto 1300 PSI
Wetted parts selection	▪ 316lss, Hastelloy C, Hastelloy B, Monel, Inconel, Tantalum, Titanium, Gold plated, Kynar coated, Chromium Carbide coated

Application Flowtransmitters

Aeration Air Control to Waste Water Basin

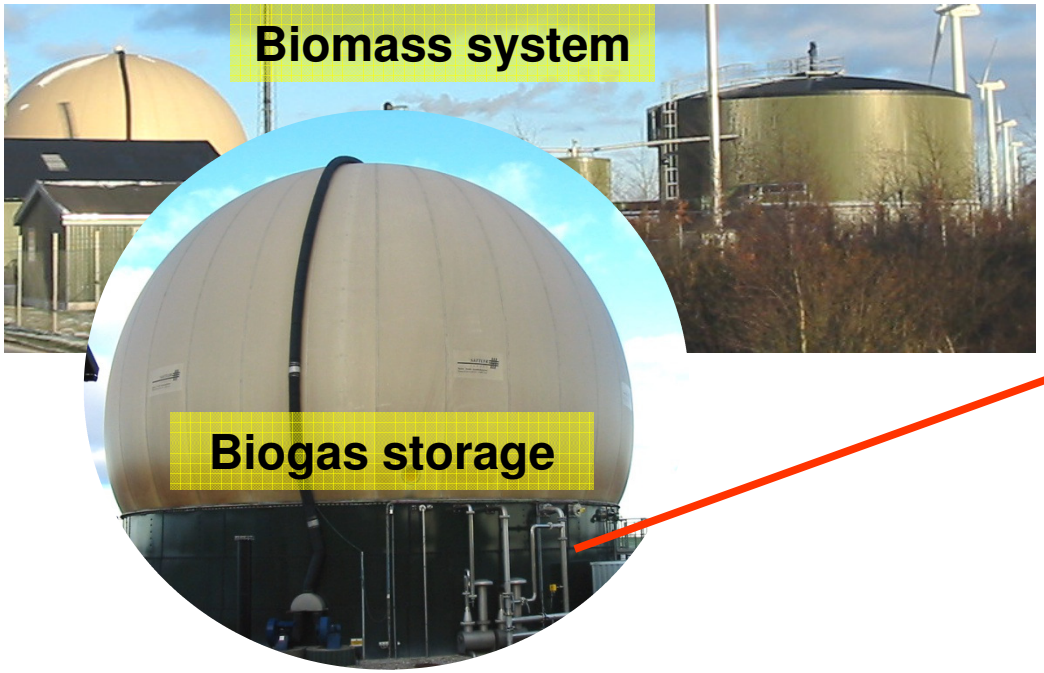
Flow Transmitter and Flow Controlling Valve both Profibus

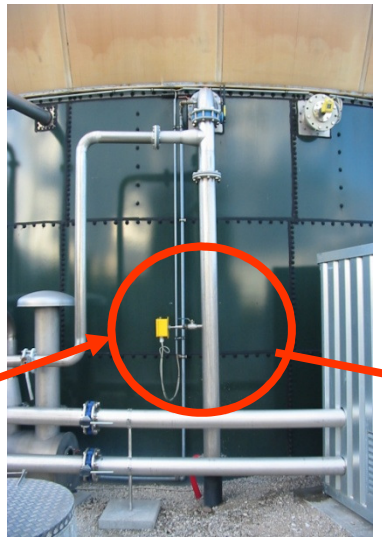
ST98 Profibus

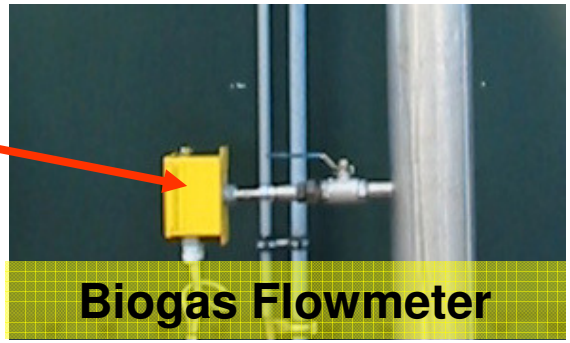
Function	■To air feeds to waste water basins
Specifics	■Also available with Profibus for direct Oxygen control with Profibus Actuated Air feed control valve ■Direct Mass flow ■Wide measuring range of standard 100:1

Application Flowtransmitters

Biogas or Digester Gas



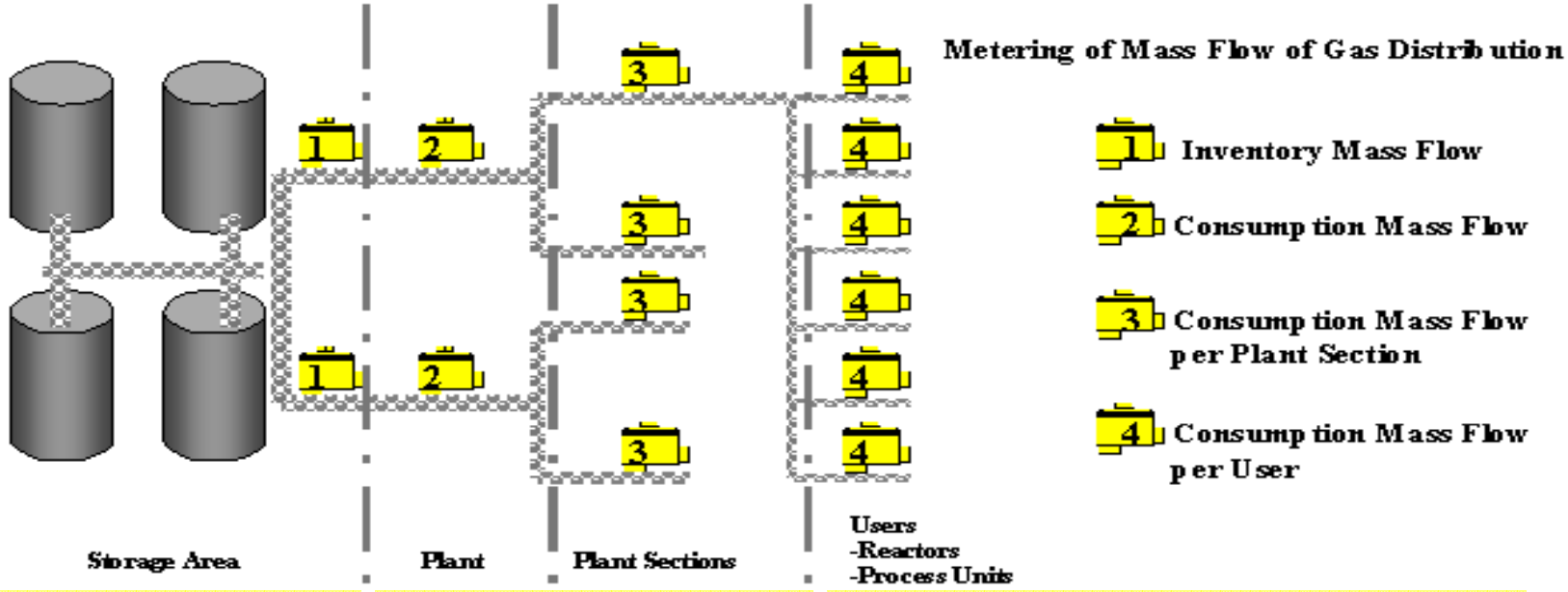




Function	■To monitor production of Biogas of digesting Waste Water or from fermenting Organic Waste
Specifics	■Virtually no pressure drop (< 0.015 PSI at 1800 SCFM in 4”line) ■Separate heater prevents Condensation ■Easy to install ■Available in integral IP66 or ATEX approved version

Application Flowtransmitters

- Gas Production, Storage, Distribution and Consumption

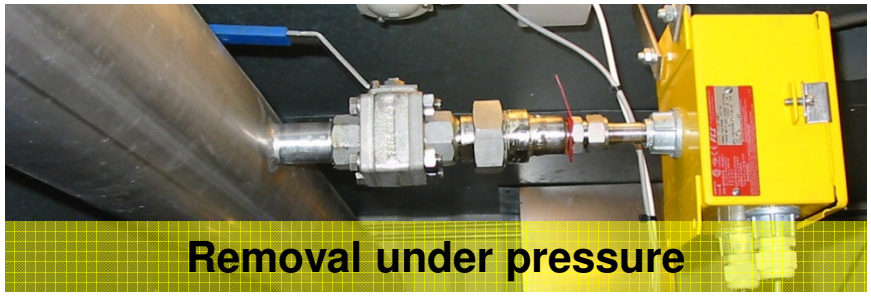


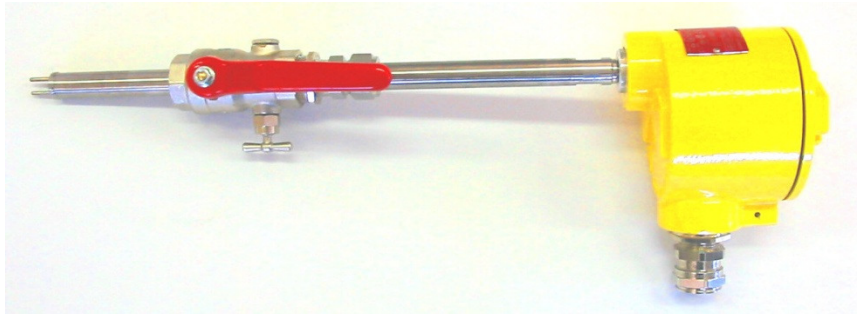
Function	■To quantity use-age of gasses by plant and various departments
Why	■Internal Billing and Mass balancing operations ■Optimize sizing of fans, compressor, dryers, filters and others ■Identify problems like blockages, leakages etc
Where	■All gasses, samples: Compressed air, Nitrogen, Methane, Argon, Propane, Hydrogen, Oxygen, Air, Natural Gas

Application Flowtransmitters

Compressed Air Production

Compressor Station

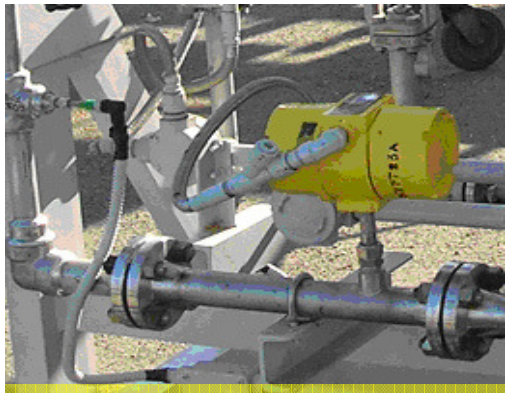

Removal under pressure



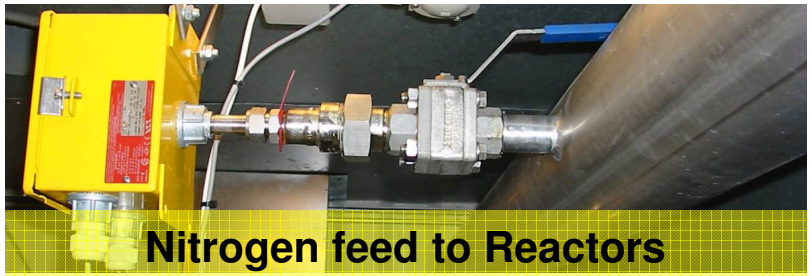
Function	■To measure total consumption of Compressed Air
Specifics	■Hot tap installation thru ball valve ■Direct Mass flow ■Wide measuring range from 0.65 to 650 SFPS ■Universal use in pipes from 1.4” upto 120” ■Wide temp range upto 500 Degr F

Application Flowtransmitters

Process Control



Hydrogen feed to Fuel cells flowmeter with integral flowconditioner



Nitrogen feed to Reactors

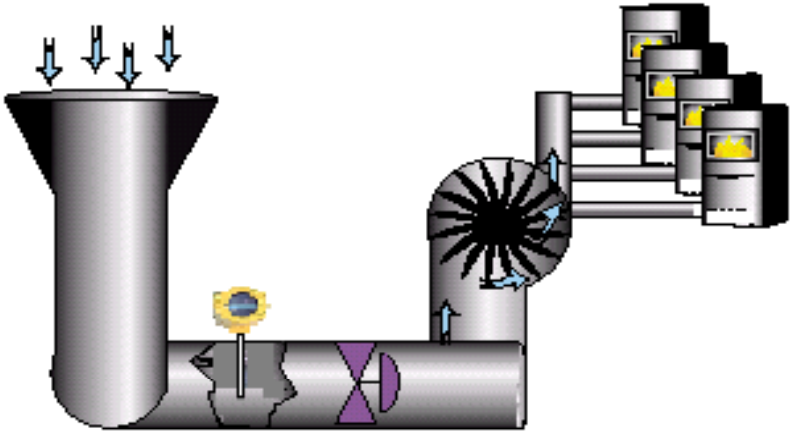
- No Pipe reductions
- Direct Mass flow
- Retractable assembly
- No pressure loss

Hydrogen feed to Reactors

Function	■ To measure gas flows for Process Control
Specifics	■ Insertion and In-line versions available ■ Direct Mass flow ■ No pipe reduction needed to measure flow as low as 0.3 SFPS ■ Wide measuring range over standard 100:1 ■ Virtually no pressure drop

Application Flowtransmitters

Burner Control



Air feed to burner in oversized pipe replacing too large Venturi's

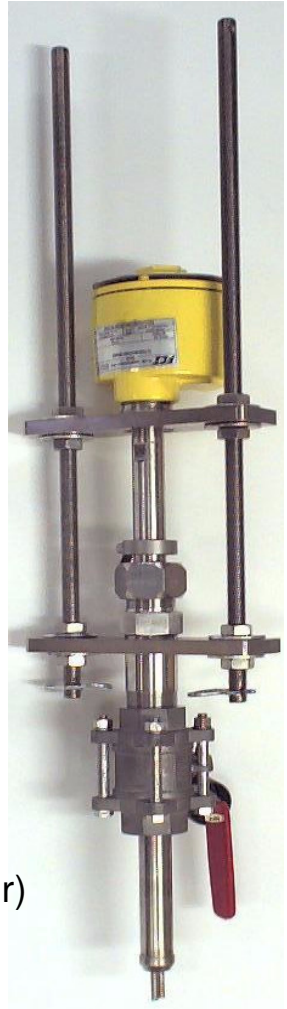
ST98 Integral Eexd version

Function	■To measure air flow to Furnaces
Specifics	■Direct Mass flow ■Easy installation also in existing piping ■Measure flow from 0.3 SFPS! ■Virtually no pressure drop ■Universal use in pipes from 1.4" upto 120" ■Wide temp range upto 850 Degr F

Flare Flow meter

Flowelement

- No Moving Parts
- Single Processconnection
- Hot Tap Retractable Mounting
- Hi-Temp rated upto 850 ºF
- All Metal Construction
  - in 316l ss
  - in Hastelloy C
  - other exotic metals
- Pressure drop < 1mBar in Pipe >4”
- “Tolerant to Dirt” Design
- Extreme Large Rangeability of 1600: 1
- Extreme Low Flow Sensitivity from 0.25 SFPS (on air)
- Eexd Approved Design
- No Local Electronic Parts
- Optional with veriCal or internal purge



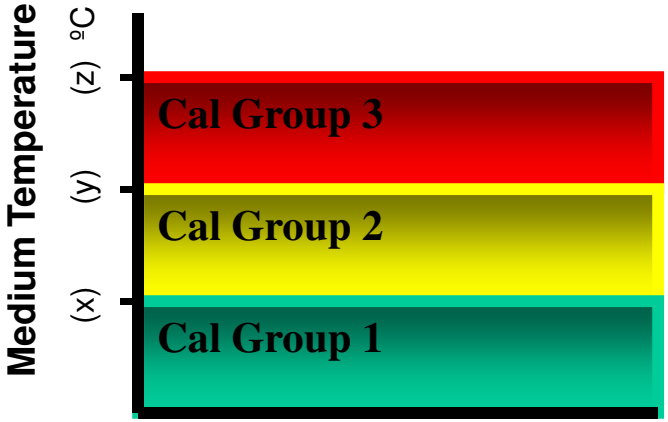
Flare Flow meter

Flare Function: 3 calibration groups

The GF90 has three Calibration Groups to store calibration data from three different Gascompositions.

Selection can be done by:

- **External Command using the Digital or Analogue Input**
- **External Command using the Keypath**
- **If Gascomposition is related to Medium Temp the GF90 Transmitter can automatically select the best possible Calibration Group**



Medição Termal tecnologia e aplicações

Principais Usuários

> Petrobras Refino : Flare , Tail gas , Ar de combustão , Gas de processo .

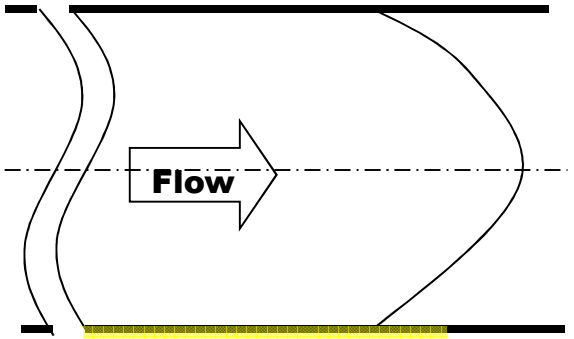
- Petrobras Off-Shore : Gas de Flare , separadores de teste e produção
- Transpetro : Chaves de Fluxo
- Saneamento : Aeração ,Filtração .
- Ambiental : Biogás (combustão e Cred. de Carbono)
- Mineração Metal. : Ar & gases de Combustão . Gases exaustão , Ar de Flotação
- CIMENTO : Eficiência de Filtros de Manga , Gas de Combustão
- ALIMENTICIA : CO2 , N2 , Gas & Ar de combustão
- Celulose & Papel : Ar Caldeira de Recuperação

MEDIÇÃO EM GRANDES DUTOS

Justification Dual Sensing System

Profile 1 at 20D up and 10D down at flow above 1 m/sec

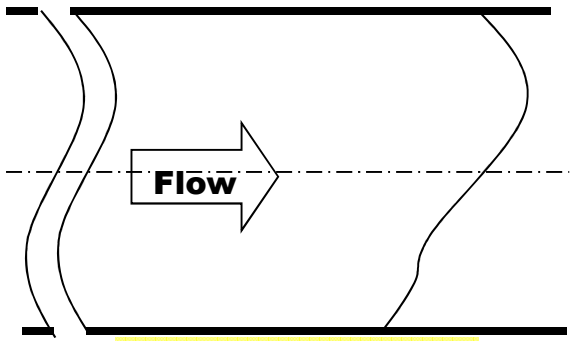
- **Fully developed**
- **Symmetrical**
- **One singe point sufficient**



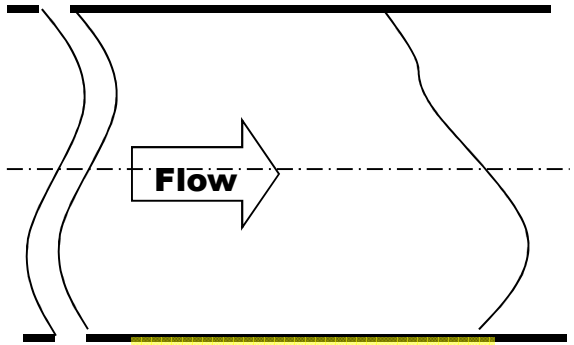
Profile 1

Profile 2 and 3 at 20D up and 10 D down at flow below 3 ft/sec in pipes >20 Inch

- **External factors like per example sun disturbs flowprofile**
- **Non Symmetrical profile**
- **Dual sensing recommended to improve accuracy under low flow conditions in pipes > 24".**



Profile 2



Profile 3

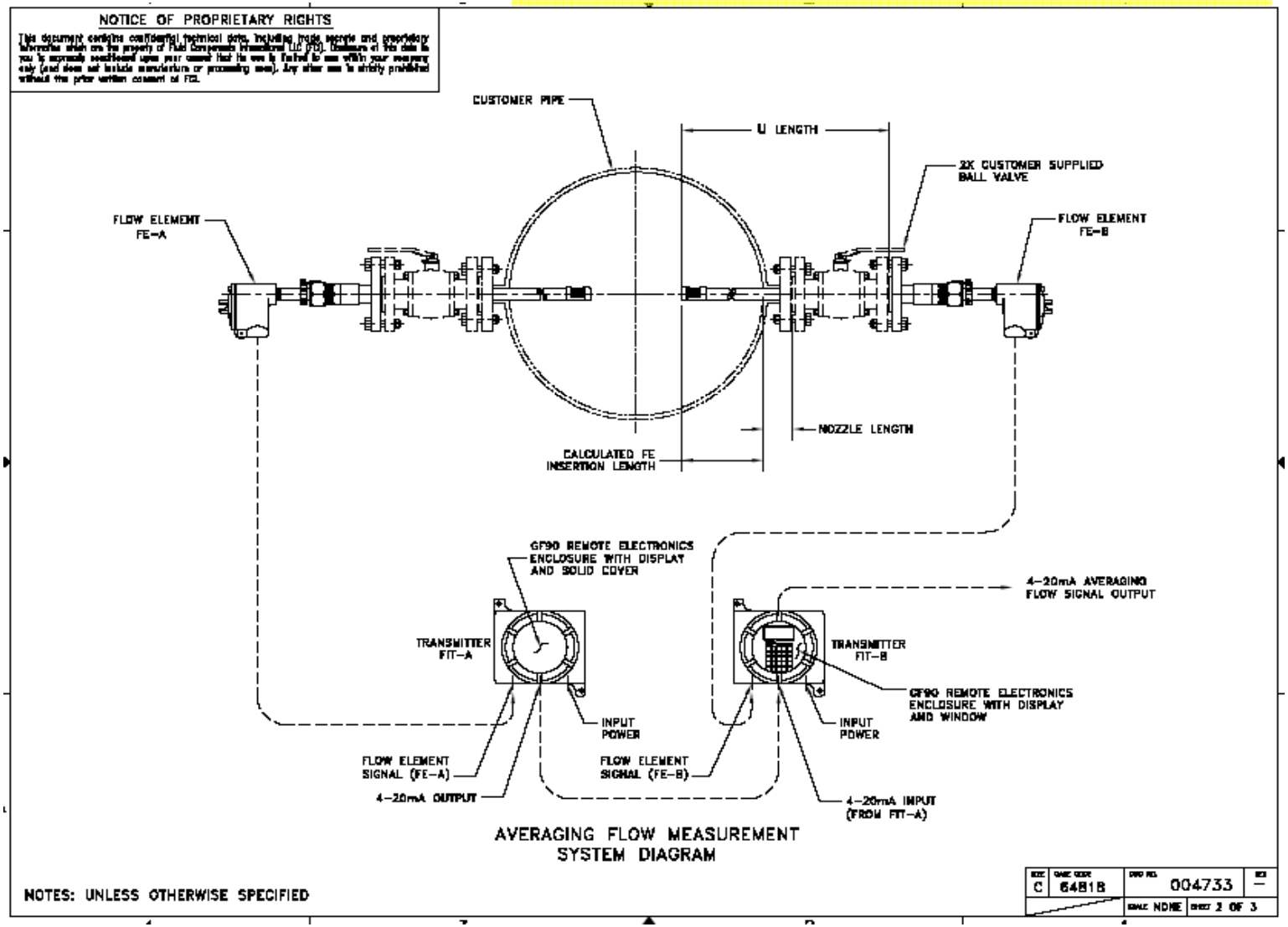
Dual Sensing System

FCI offers a Multi Point Sensing system specifically designed for larger pipe lines (>24" and up):

- **Two flowelements mounted at 90 or 180 Degrees from each other**
- **Two flowtransmitters (available also as Eexd approved):**
  - **First transmitter connects to one flowelement and generate input to second flowtransmitter**
  - **Second flowtransmitter connects to other flowelement, accepts input from first transmitter and computes the average flow and converts to one 4-20 mAmp signal equaling the Average flow measured by the two flowelements.**
- **Provides significant improvement of measuring accuracy when measuring Flare gas flow in pipes larger as 24 Inch**

Dual Sensing System

Typical lay-out Averaging System

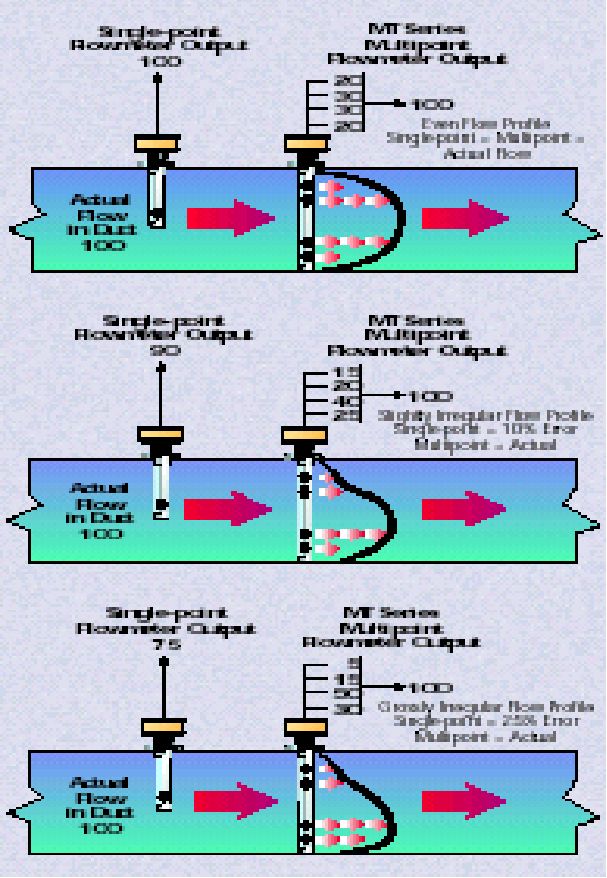


Dual Sensing System

Multi Sensing System because of:

- significant improvement of measuring accuracy when measuring gas flow in larger pipes sizes (24” and up)
- Averaging solution to stratified gas layers
- If not in Averaging mode, provides redundant Solution

Multi Point Flowsystem

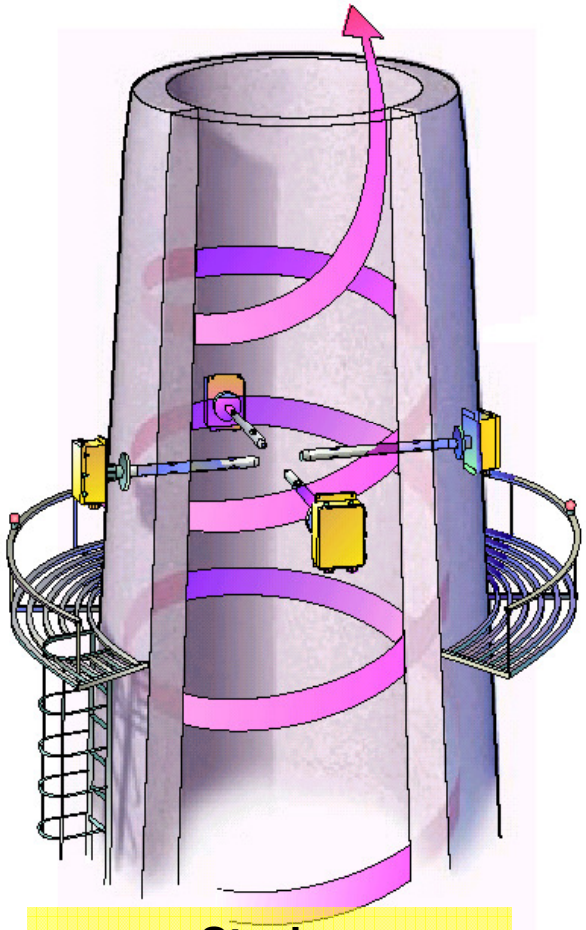


Multiple Flow sensors are connected to One Flowtransmitter to measure True Average Mass flow in ducts and stacks:

- 1 to 8 Flowsensors can be integrated in one Flowelement
- Each Flowsensor measures:
  - The Gas Mass Flow at its Location
  - The Gas Temperature at its Location
- 1 Flowtransmitter averages 1-16 Flowsensor signals into:
  - Average Mass Flow Output Signal
  - Average Temperature Output Signal (MT91)
  - Flow Profiling Diagnostics
  - Temperature Profiling Diagnostics (MT91)

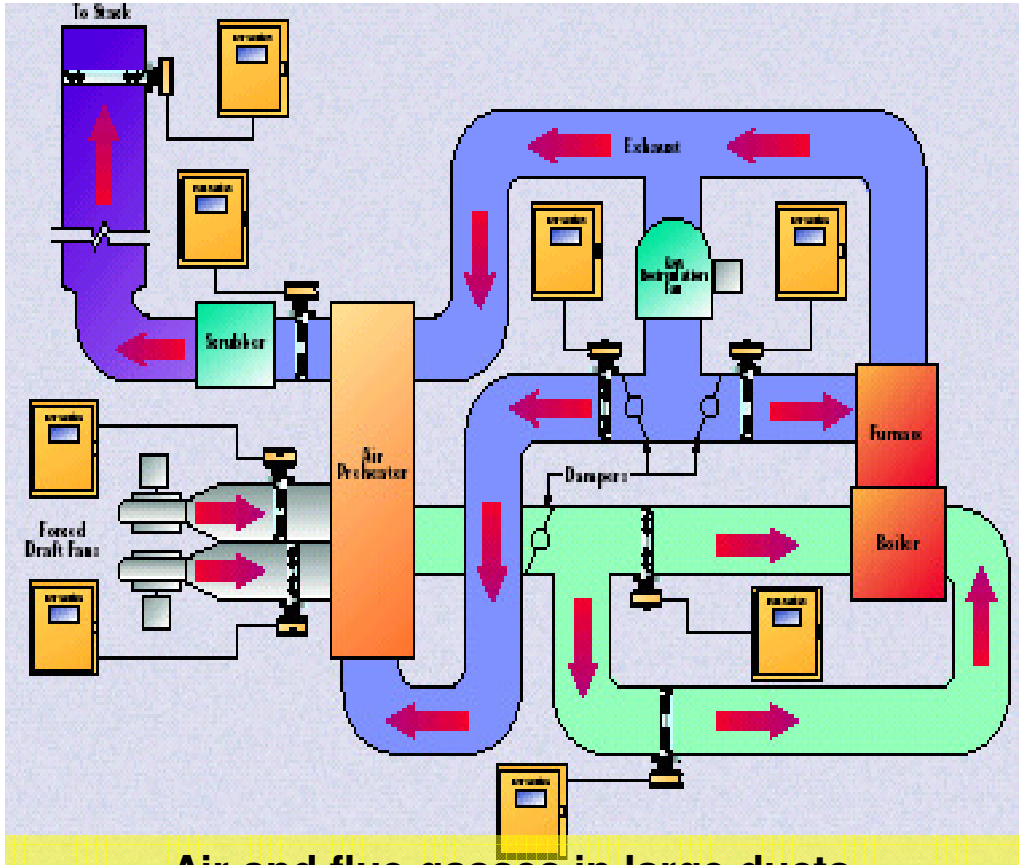
Application Multi Point Flowsystem

- Multi Point systems Applied in large Ducts or Stacks



Stacks

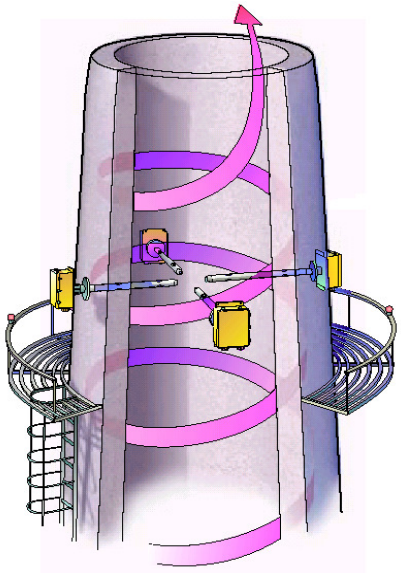
2 Pt MT sensor

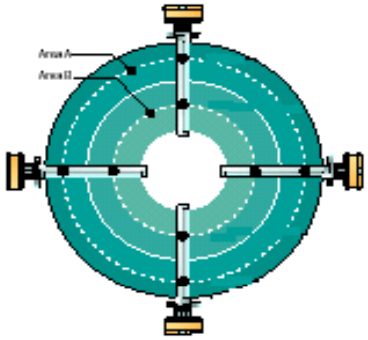


Air and flue gasses in large ducts

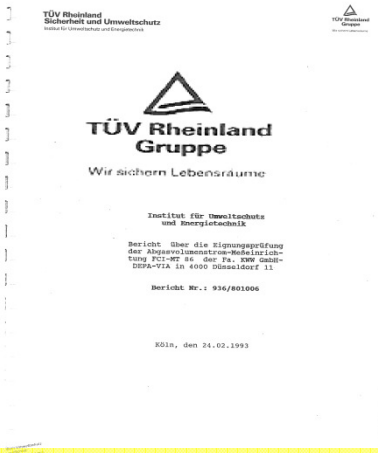
Application Multi Point Flowsystem

Continous Flow metering Stacks





Equal-Area Sensing Point Placement



TÜV Rheinland Sicherheit und Umweltschutz

TÜV Rheinland Gruppe

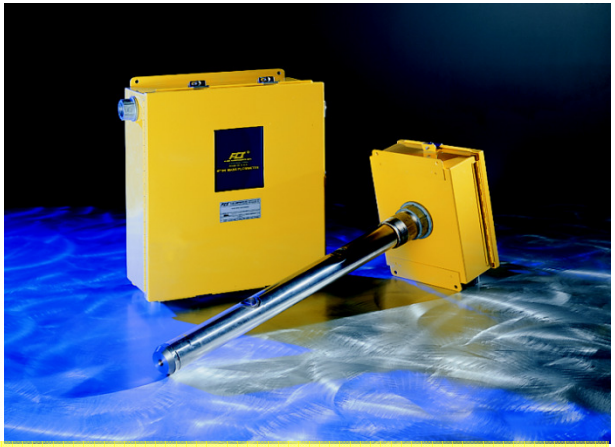
Wir sichern Lebensräume

Institut für Umweltschutz und Energietechnik

Bericht über die Eignungsprüfung der Abgasvolumenstrom-Meßeinrichtung FCI-MT 86 der Fa. KNW GmbH- DEPA-VIA in 4000 Düsseldorf 11

Bericht Nr.: 936/801006

Köln, den 24.02.1993



FCI MT systems in accordance to ISO 14164 standards

Function	■Continous Monitoring of flow in Stacks in accordance with ISO14164
Specifics	■Direct Massflowmetering ■Averaging Multi-point system ■Very tolerant to dirt and moisture ■Proven technology tested by TUV Germany ■Hi Temp version upto 850 Degr F available

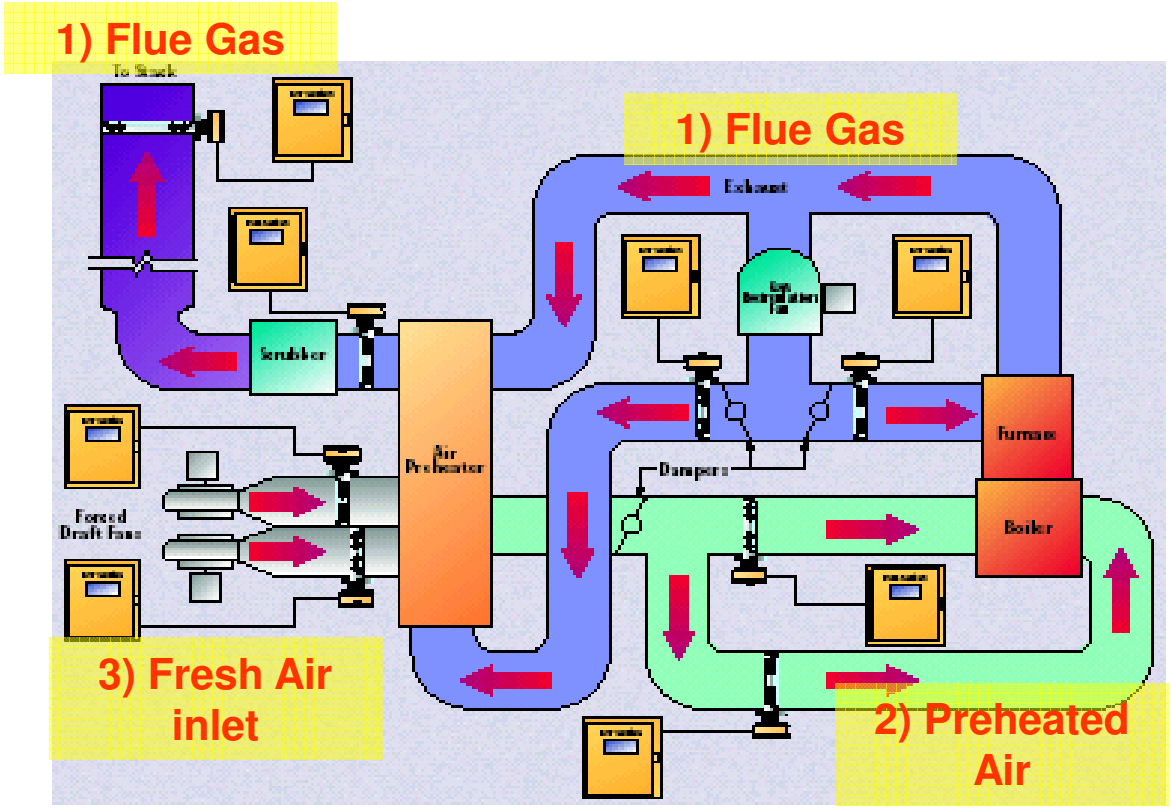
Application Multi Point Flowsystem

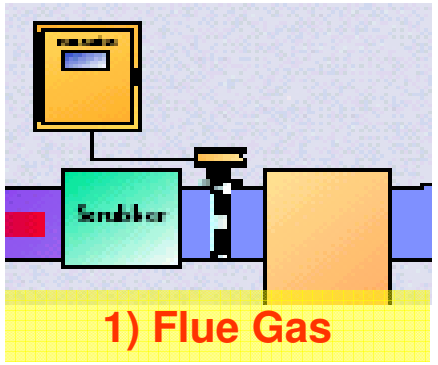
- Continous Flow metering Stacks

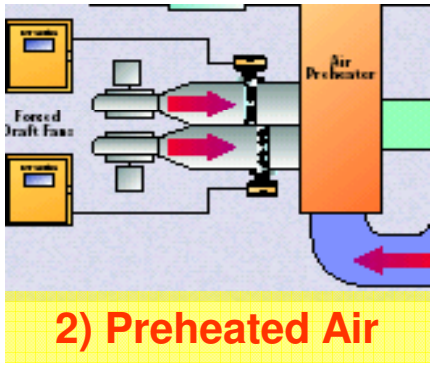
FCI MT systems in accordance to ISO 14164 standards

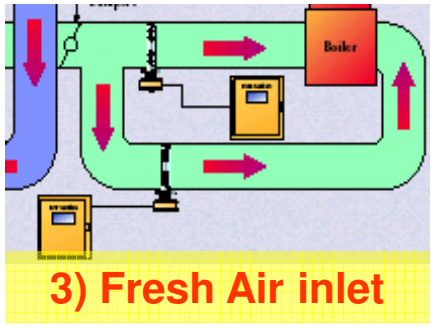
Application Multi Point Flowsystem

- **Air Feed to Boilers**



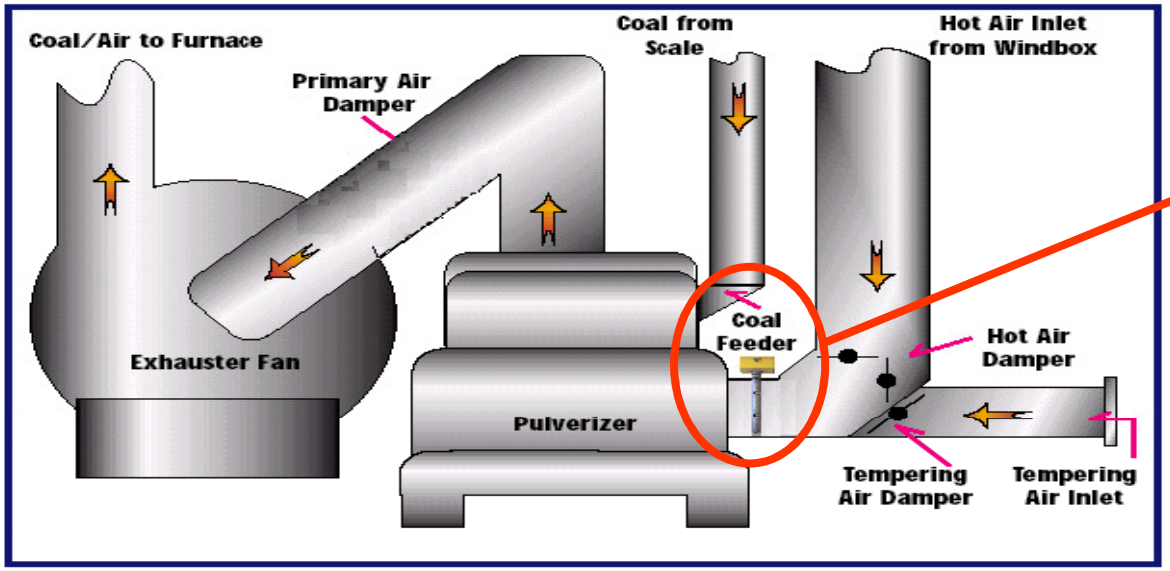






Application Multi Point Flowsystem

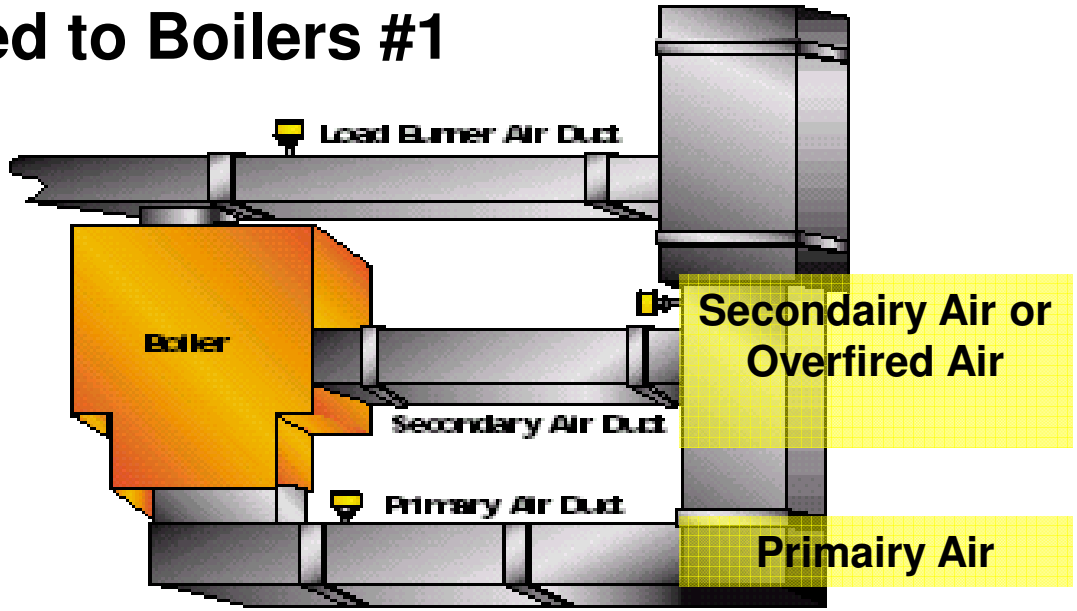
- **Air feed to Coal Mills #1**



Function	■To reduce NOx emission by better control of Coal Fired Boiler
Specifics	■Direct Air Mass Flowmetering ■Easy to install also in existing ducts with limited straight run ■Tolerant to Dirt ■Extremely rugged Design with All Metal Construction ■Using Mineral Insulated cable rated upto 850 ºF ■Averaging Mass Flow and Temperature system

Application Multi Point Flowsystem

- **Air feed to Boilers #1**



Function	■To increase the Efficient Operation of Boilers
Specifics	■Direct Air Mass Flowmetering ■Easy to install also in existing ducts with limited straight run ■Tolerant to Dirt ■Extremely rugged Design with All Metal Construction ■Using Mineral Insulated cable rated upto 850 Degr F ■Averaging Mass Flow and Temperature system

Application Multi Point Flowsystem

- Air feed to Boilers #4

Cogeneration power plant fueled by Biomass and Woodchips

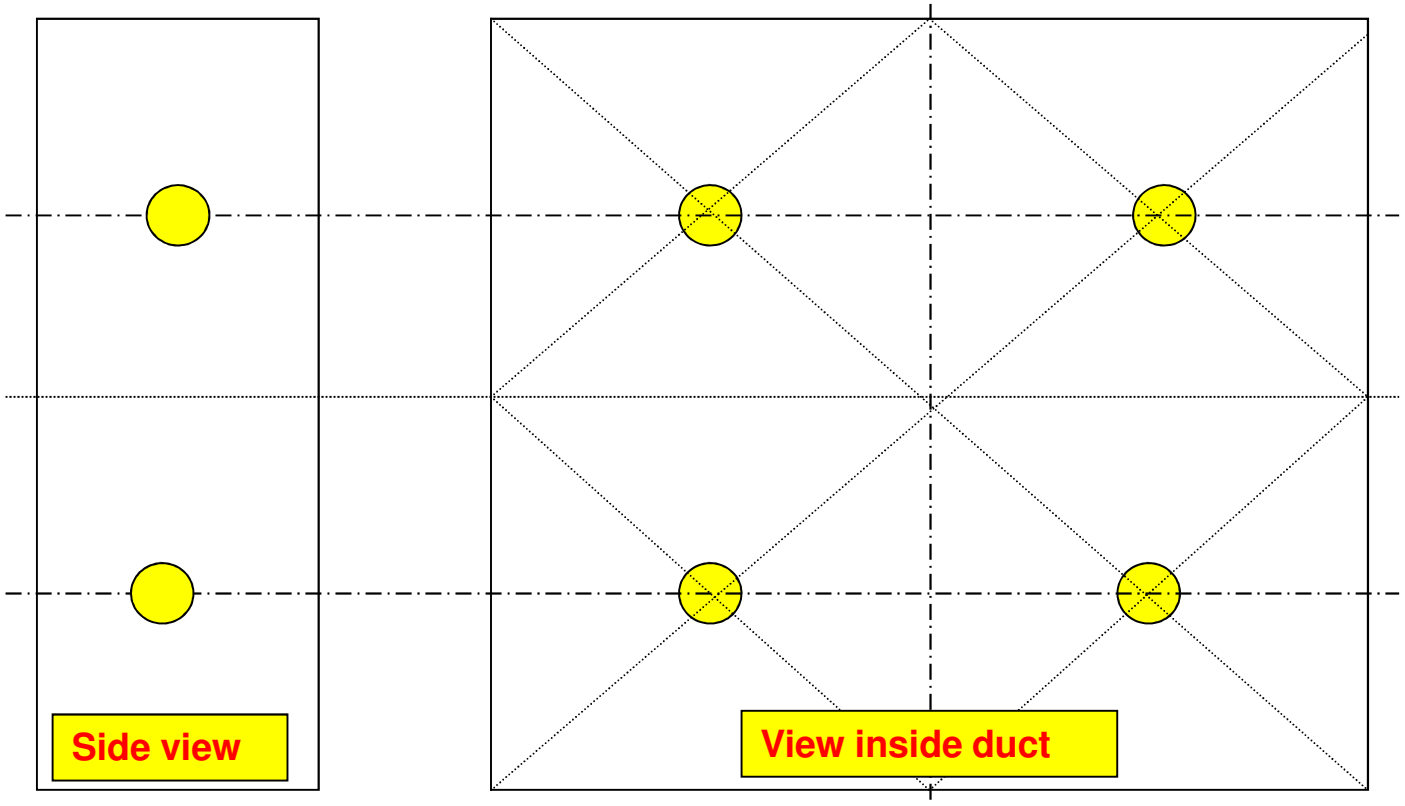
Secondary airfeed to boiler

Primary airfeed to boiler

Considerations Multi Point Flowsystem

Installation Recommendation #1

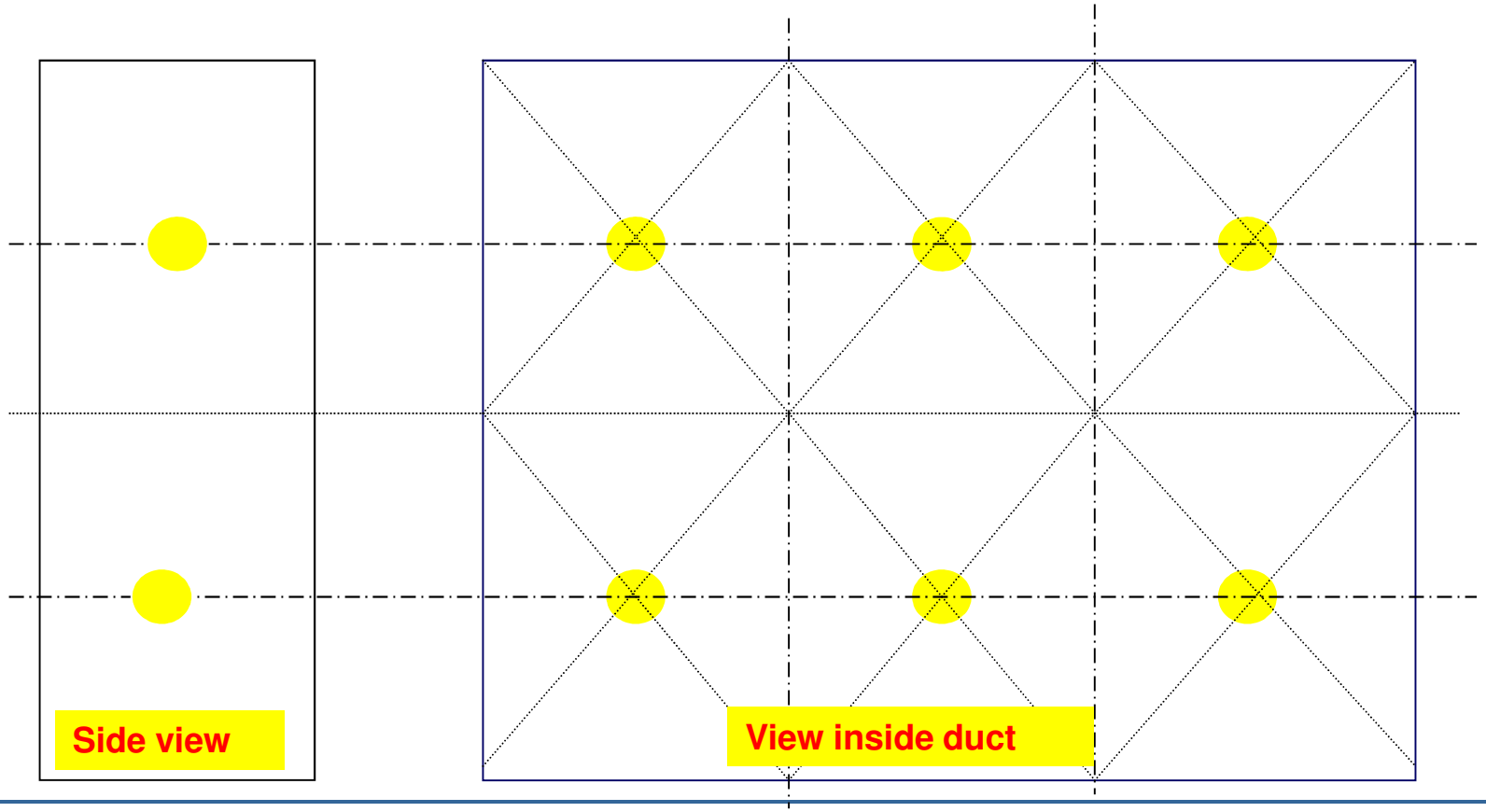
Rectangular ducts	**Divide total area by number of sensing points into equal areas and locate each point in center of its assigned area**
Sample	**4 Point System**



Considerations Multi Point Flowsystem

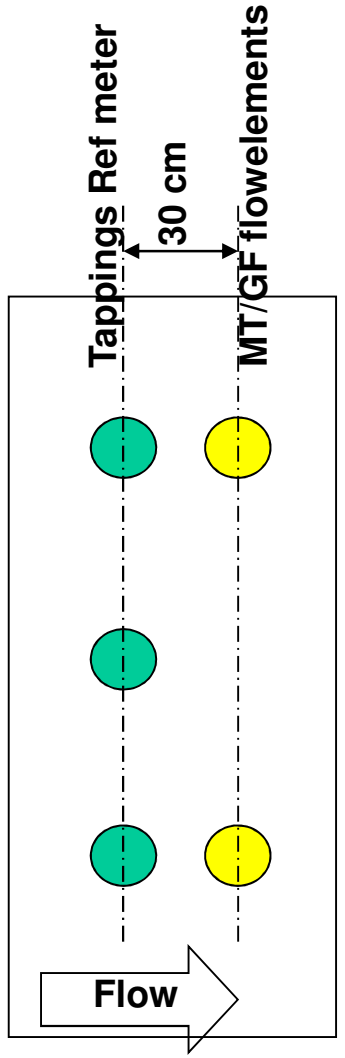
Installation Recommendation #2

Rectangular ducts	Divide total area by number of sensing points into equal areas and locate each point in center of its assigned area
Sample	6 Point System



Considerations Multi Point Flowsystem

Function	■To optimize installed accuracy of Multi-Point Thermal Mass-flowmeter
Requirements	**Mechanical:** Additional port to insert in-situ reference flowelement: ■Minimum size port: 1 ¼” ■Location: 1 ft upstream MT/GF flowelement at same location and if possible at additional locations ■Clearance to insert in-situ reference meter **Electrical:** MT system wired and powered, no additional power supply required if in-situ is pitot type of instrument **Operational:** Optimum is to run in-situ calibration at minimum three different loads, flow should be fairly constant during in-situ calibration



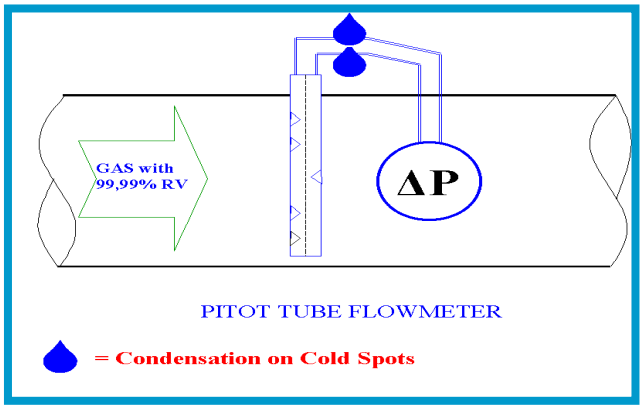
Considerations

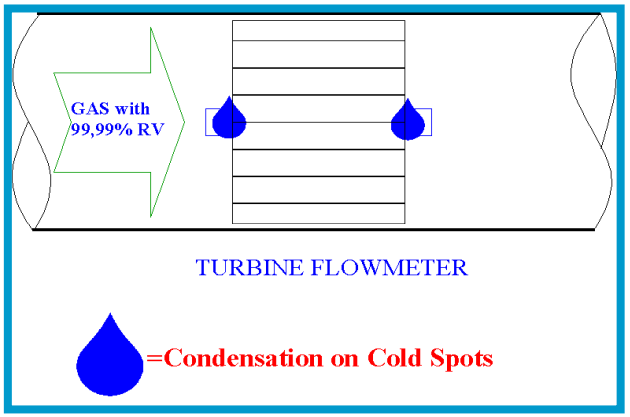
Considerações tecnicas para aplicações

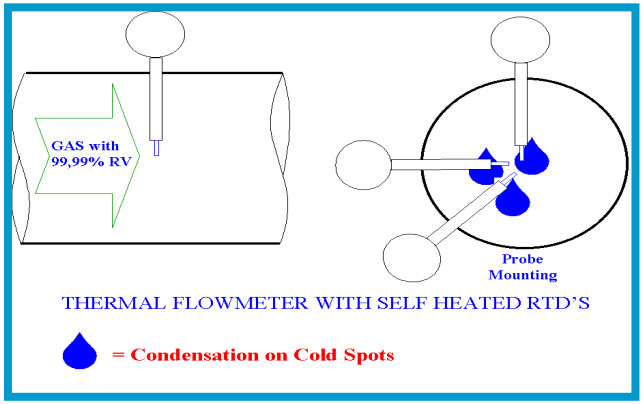
- Ausência de Trecho reto
- Humidade no Gas
- Efeito da Variação da composição do Gas
- Instalação do Sensor

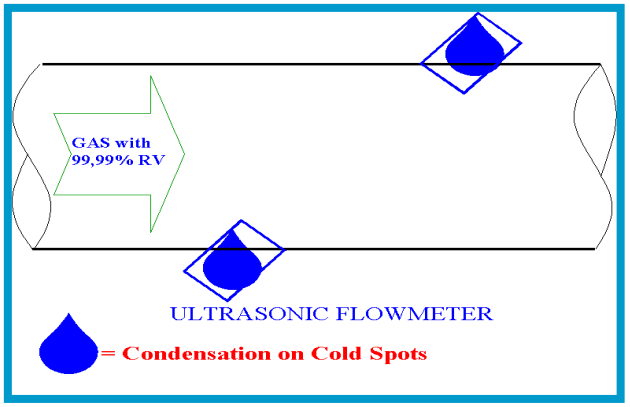
Application Flowtransmitters

- **Wet Gas Problems:**
  - **Condensation** on all **Cold Spots**
  - **Corrosion** caused by Condensation
  - **Deposits** of dirt certainly if wet



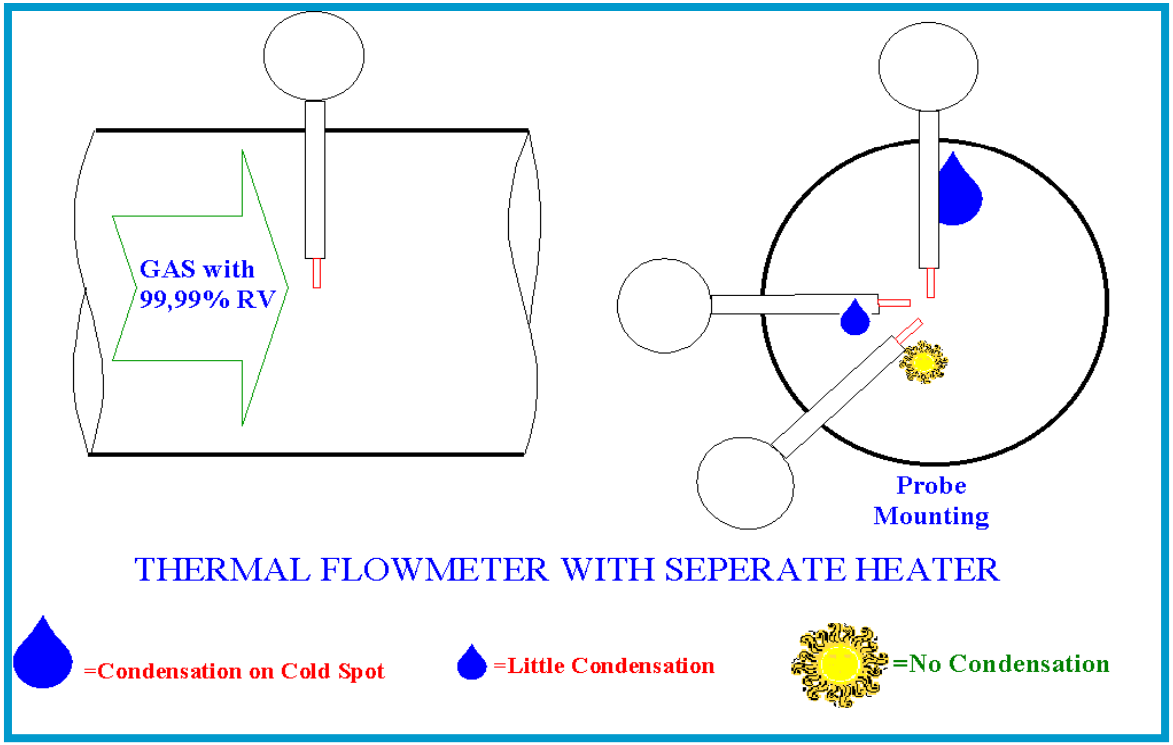






Application Flowtransmitters

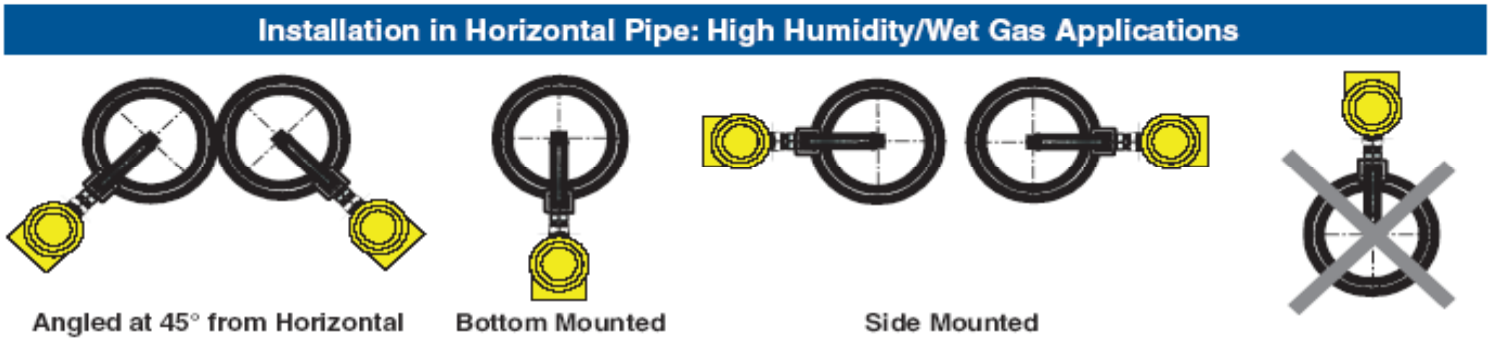
- **Wet Gas Solution; FCI because:**
  - **FCI avoids Cold Spots by Constant Powered Heated flowelements *(=all FCI Thermal Mass Flowmeters!)***
  - **FCI avoids deposits by open design flowelement**
  - **FCI avoids maintenance by using no-moving part design**



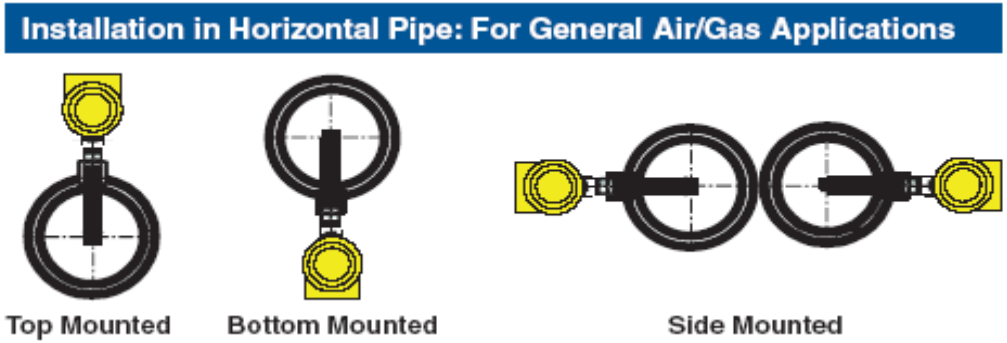
Application Flowtransmitters

- **Wet Gas Solution:**
  - **Avoid Top entry flowelement** ***(see FCI Best Practice Guide for more details)***

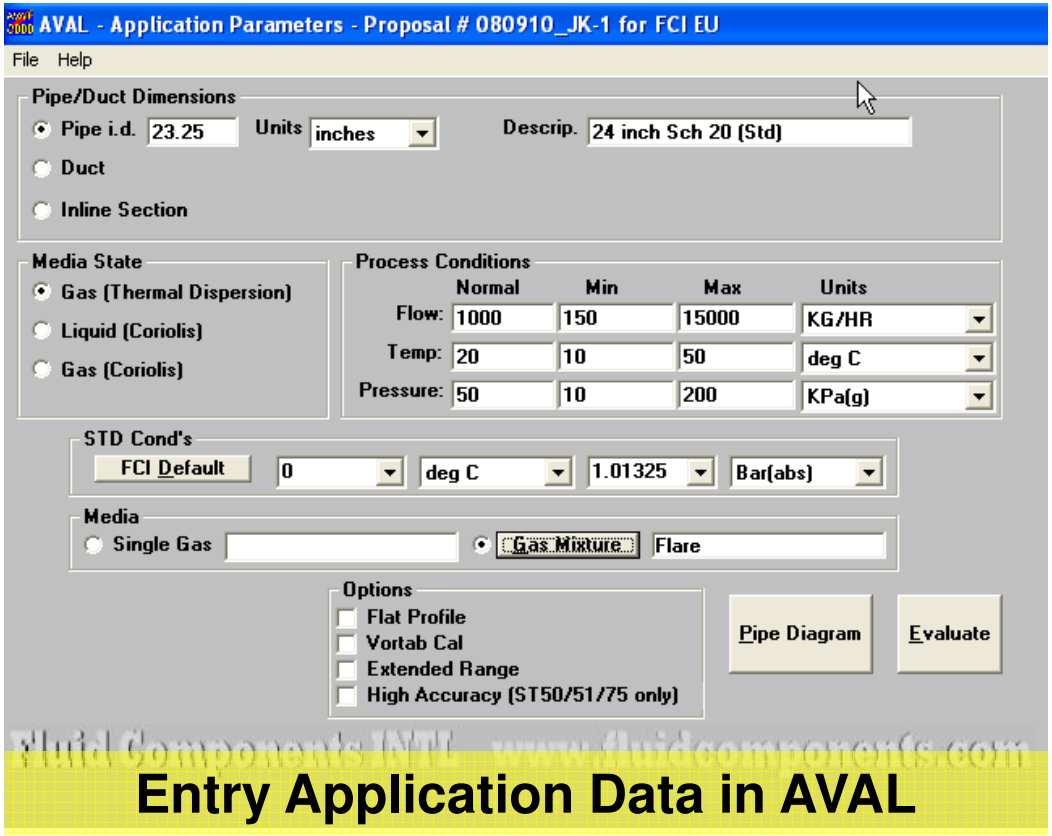
Installation recommendation for Wet Gas applications:



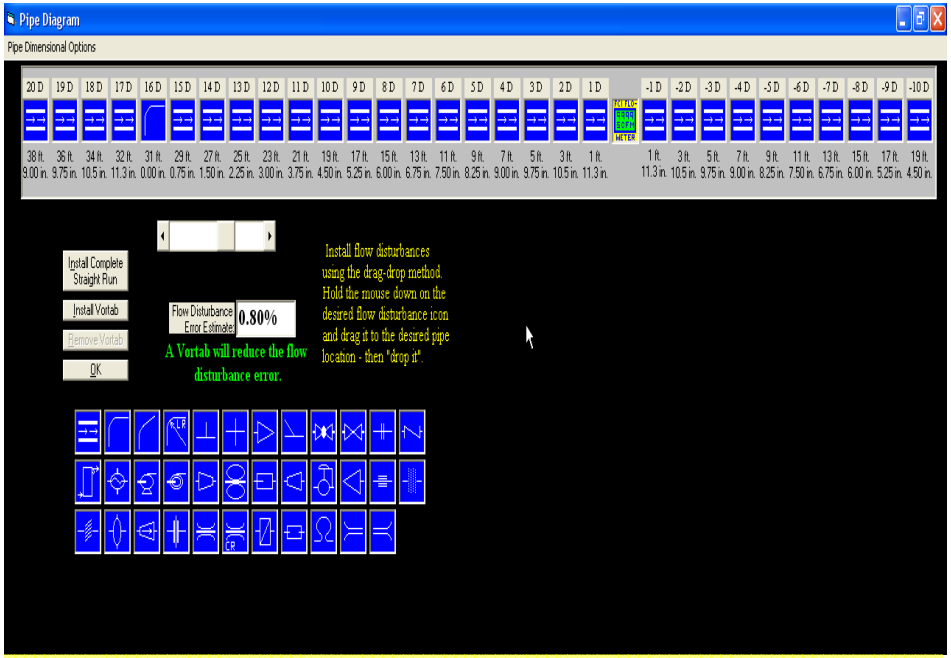
Installation recommendation for Normal Gas applications:



Application Evaluation



Entry Application Data in AVAL



Entry Available Straight Run

Application Evaluation

FCI FLUID COMPONENTS INTL
A limited liability company
1755 La Costa Meadows Drive, San Marcos, CA 92078
(760)744-6950 (800) 854-1993 FAX:(760) 736-6250
www.fluidcomponents.com

Application Data Sheet September 10, 2008
Customer: FCI EU
Representative:
Representative:
Rep Phone #:
Rep FAX #:

Application Parameters

Media: Flare - 7 components. Mole (Volume) percentage.

Methane	60.000%	Hydrogen	1.100%
N-butane	8.700%		
N-pentane	12.000%		
Ethane	11.000%		
Propane	5.200%		
Isobutane	2.000%		

Line Description: 23.25 inches I.D. pipe. (24 inch Sch 20 (Std)).
Pipe Diagram: ⟵4d⟶90⟵15d⟶×⟵10d⟶
×=Install location; 90=90-180 Deg. Bend

	Normal	Min	Max	Units
Flow	1000	150	15000	KG/HR
Temperature	20	10	50	deg C
Pressure	50	10	200	KPa(g)
Standard Conditions: 1.01325 Bar(abs) and 0 deg C				
Calibration Options: None				
Actual Velocity	1.757	0.2635	26.35	ft/sec
FCI Std. Velocity	2.639	0.3959	39.59	SFPS

Selected Instrument

GF90 - Base Accuracy: 1.00% rdg. + 0.50% of full scale. Repeatability: 0.50% rdg.
- Accuracy issues: 3. Overall uncertainty estimate: 4.25% rdg. + 0.50% of full scale.
- Repeatability issues: 1. Overall repeatability estimate: 1.40% of rdg.
- Standard Sensor Head • Temperature Compensation Required
- Calibration Code: GF90 Table A Process Media Code: D; GF90 Block 7: B; GF90 Block 8: A

Calibration Details

Pipe Orientation: Horizontal
Mounting: Side
Flow Direction: Right to Left
Analog Output 1: (Set for Flow) 4-20 mA= 0 to 15000 KG/HR (Zero-Based)
Analog Output 2: (Set for Temperature) 4-20 mA= 0 to 150 deg C
Switch Pt. #1: N/A
Switch Pt. #2: N/A
Name on Calibration Documentation: FCI EU
Quantity: 1 **Tags:** FT-1093

Special Instructions:
N/A

Application Evaluation report

Proposal #: 080910_JK-1 AVAL98 Version 3.600 Application Data Sheet

Considerations

- **Effects of variable Gas Compositions**

Facts at changing Gas Compositions:

If the gas composition does change FCI can evaluate the effects using their Application Evaluation Program AVAL.

A Data base of 200 different gasses are available in this program and various compositions can be entered for a full evaluation of the application by AVAL.

Typically Hydrocarbons have similar thermal characteristics and does not create large measuring errors, variations of the Hydrogen content is known to have a large effect, further evaluation is required.

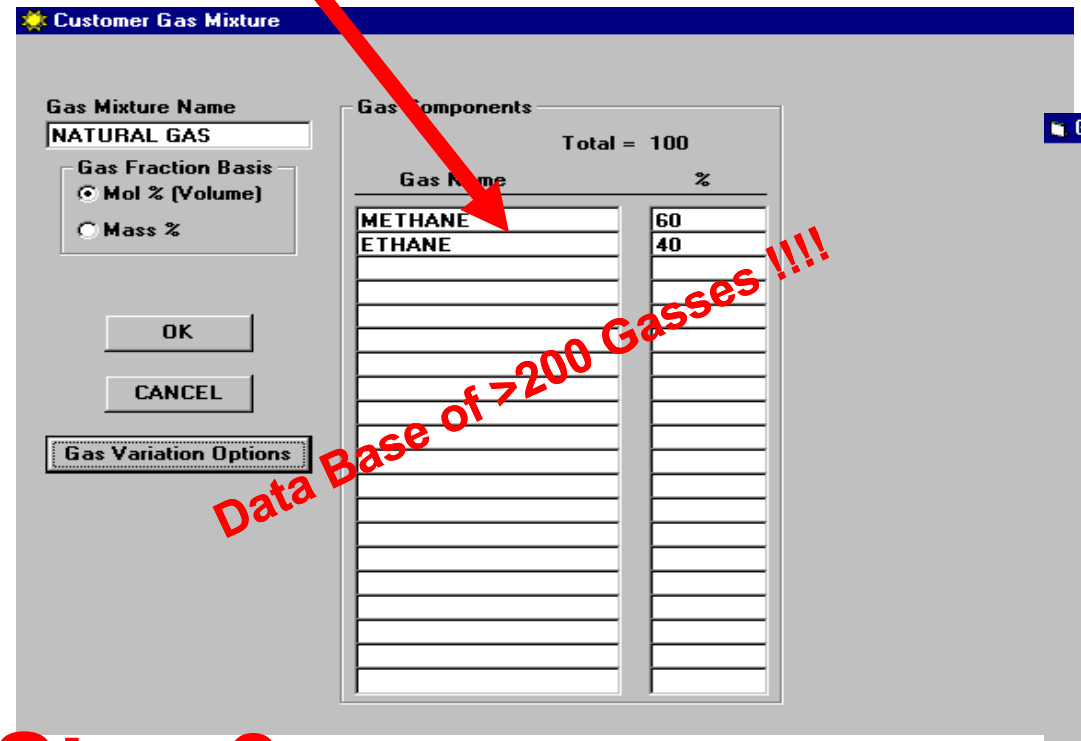
Only 3 steps away from being an expert in thermal flowmetering:

➢ **RUN AVAL!!!!**

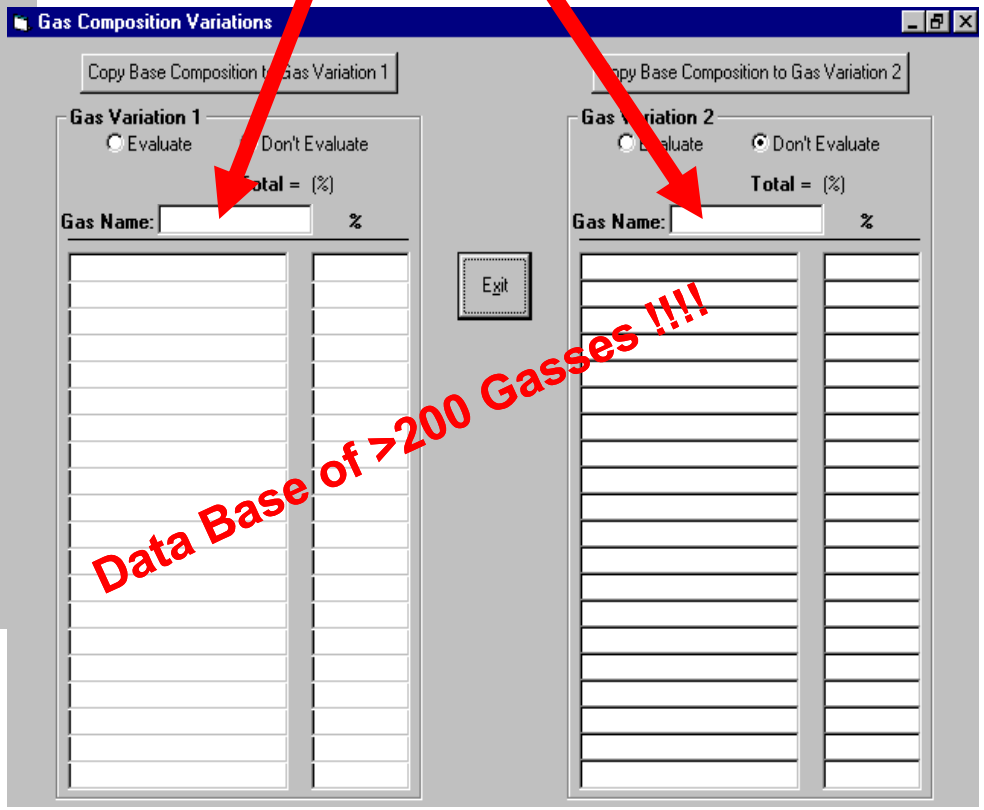
Considerations

- **Effects of variable Gas Compositions**

Step 1:
Enter Base Gas Composition



Step 2:
Enter Gas Variations

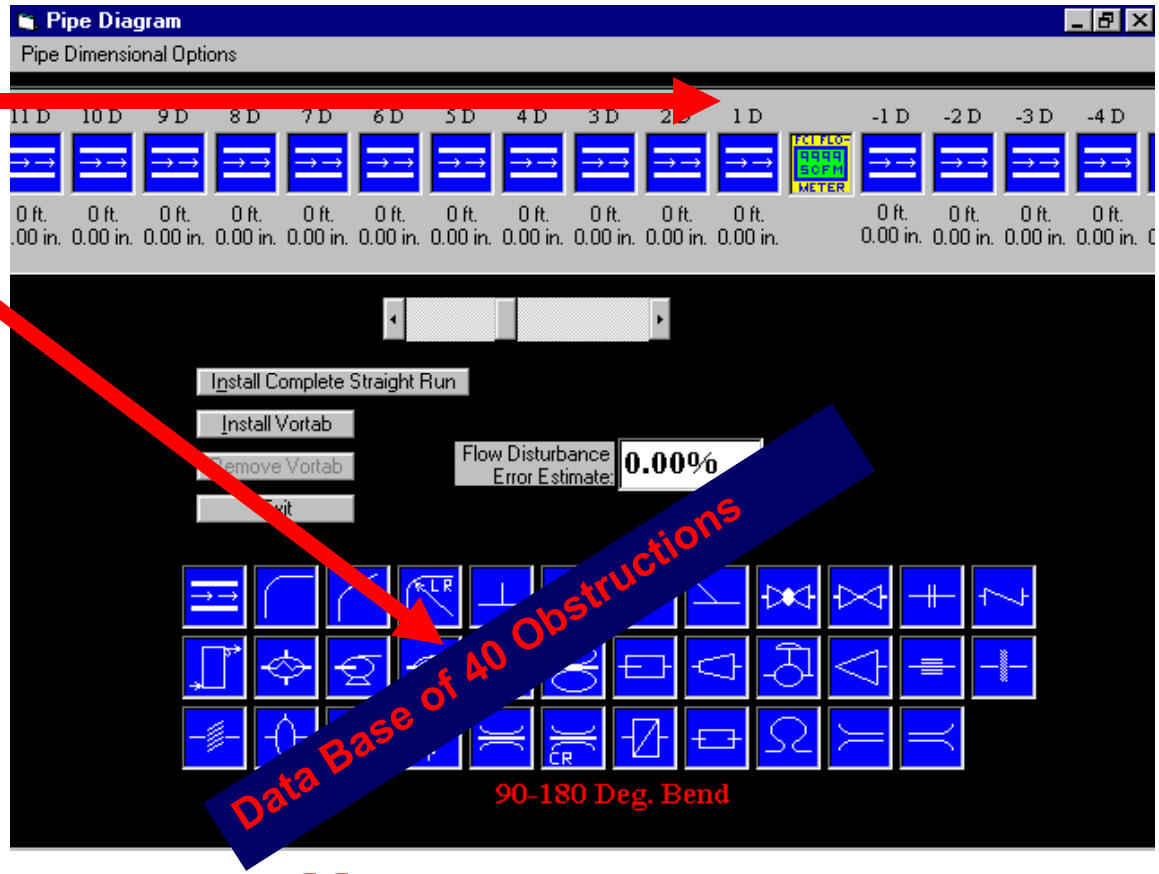


Step 3
AVAL shows offset

Considerations

- **Effects of straight run**

Step 1:
Enter Piping Info listing
Obstructions within 20 D up
And 10 D down of Flowmeter



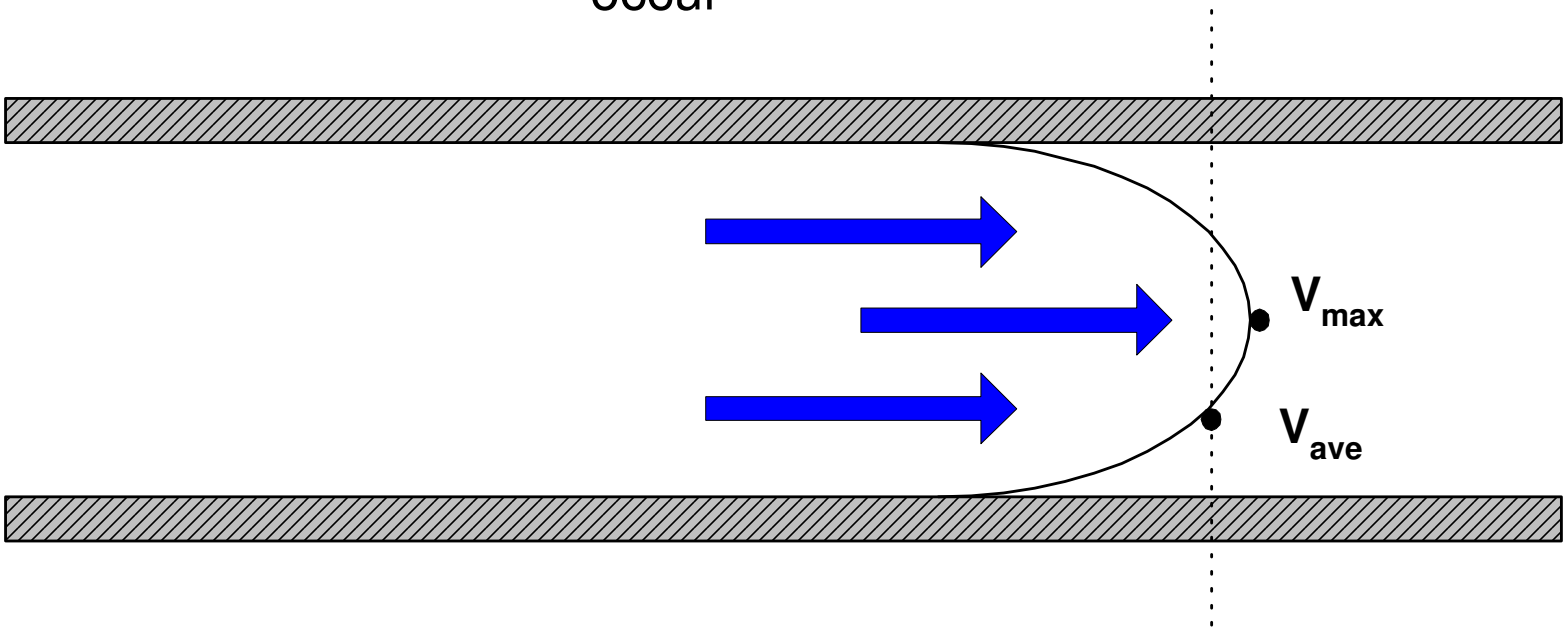
Step 2
AVAL shows offset

Considerations: Instalação da sonda

- **Perfil de Vazão**

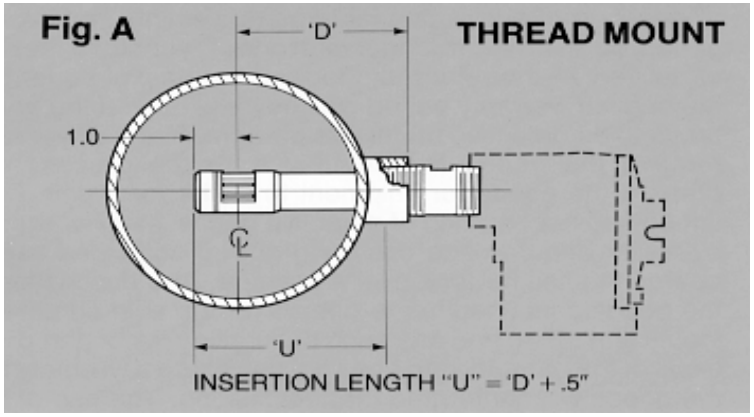
@Flowstand: FCI Flowmeters are calibrated at Centre of Pipeline so at Vmax. with developed FlowProfile

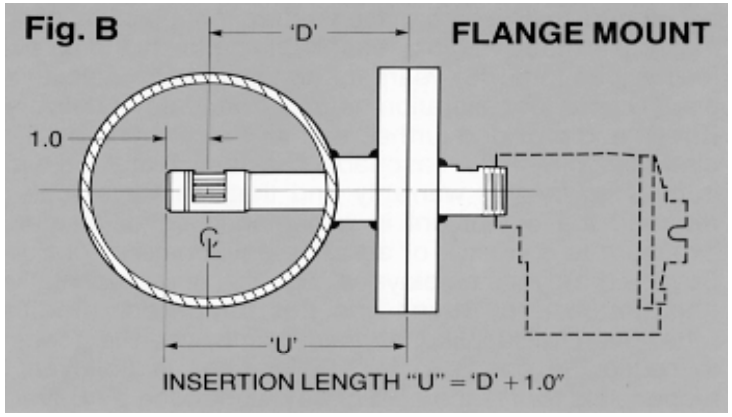
@Application: FCI to be mounted in Centre of Pipeline so at Vmax. If Flowprofile not developed, application error may occur

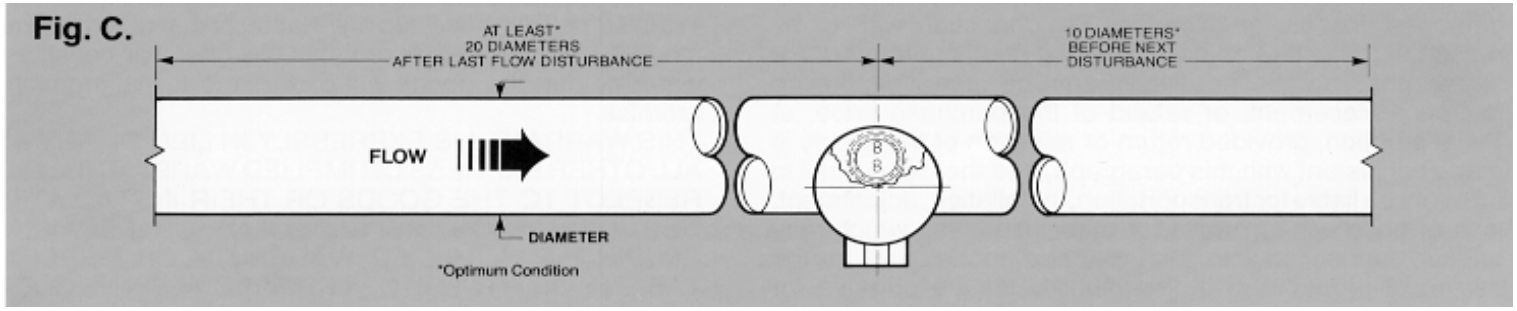


Considerations

- **Flowprofile**



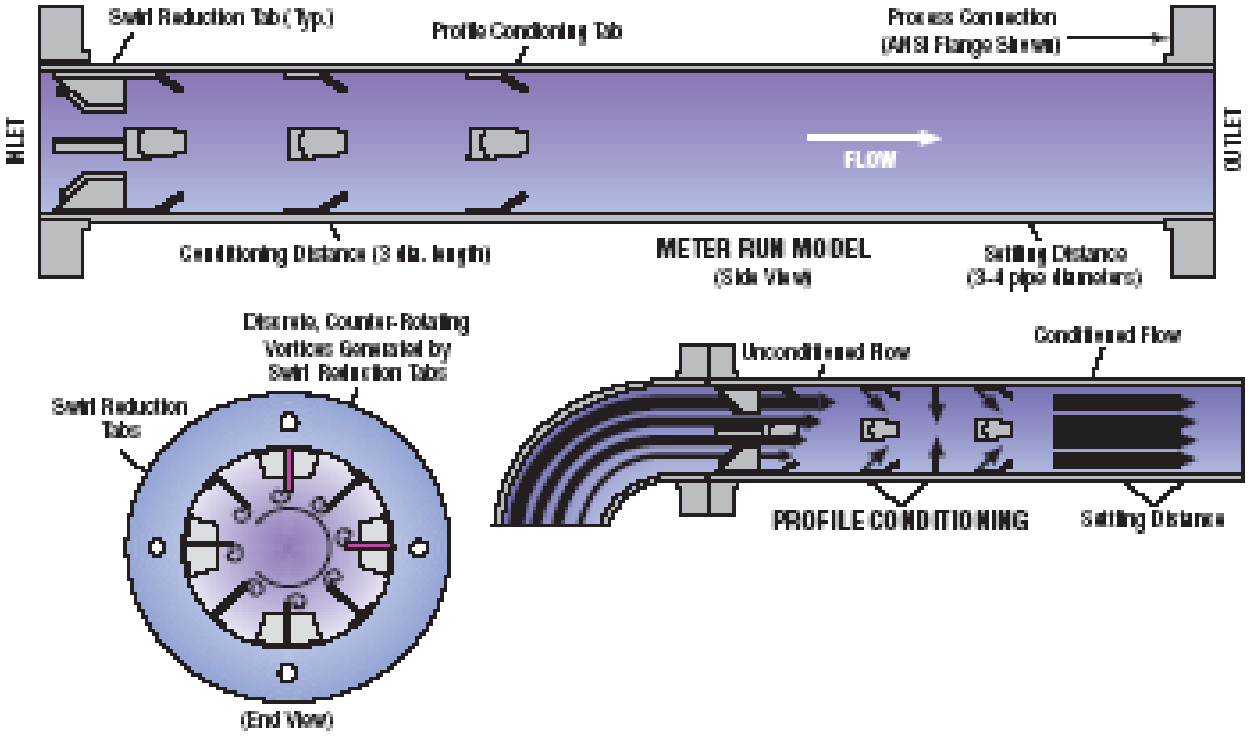




20 x Diameter Upstream and 10 x Diameter Downstream

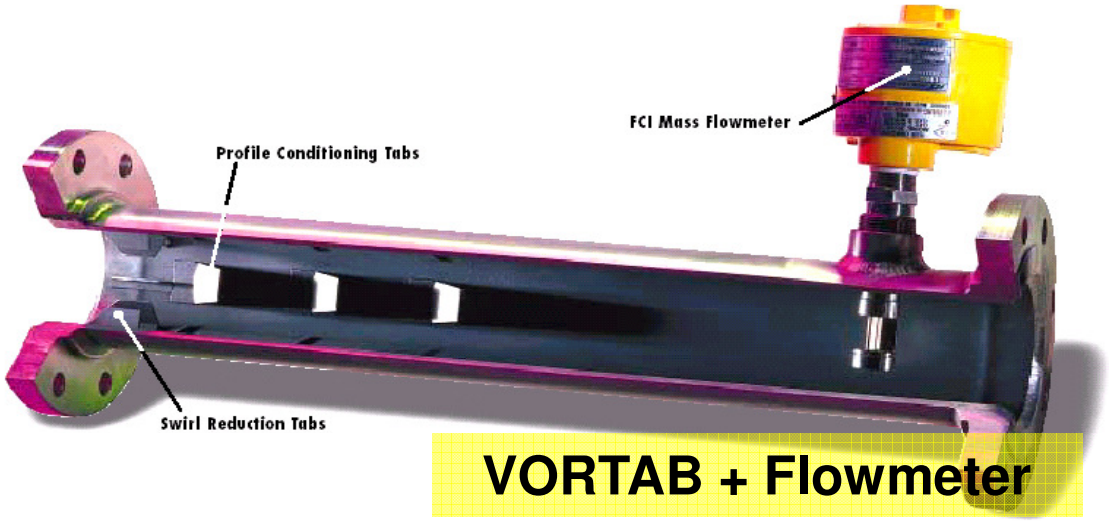
Considerations

- **Effects of straight run**

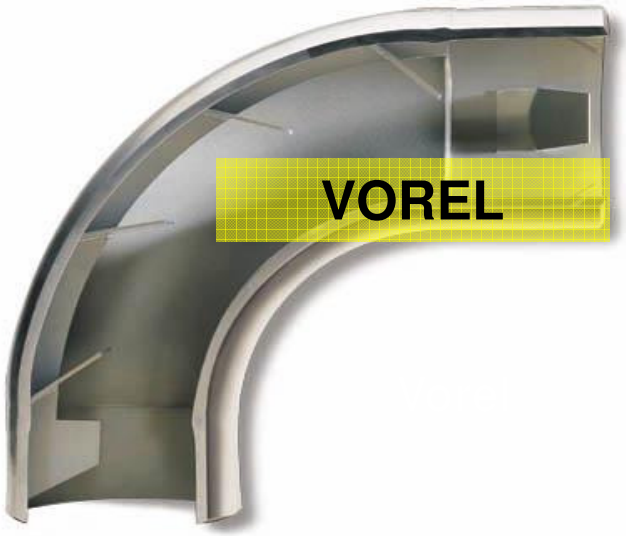


Products FCI

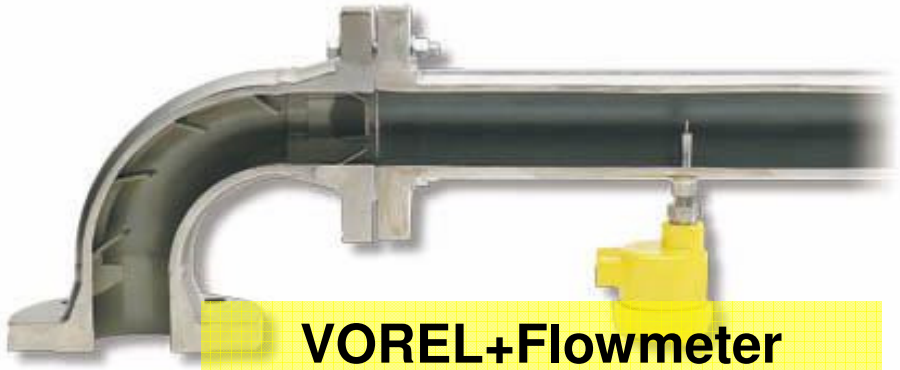
Flow Conditioners: Vortab and Vorel



VORTAB + Flowmeter

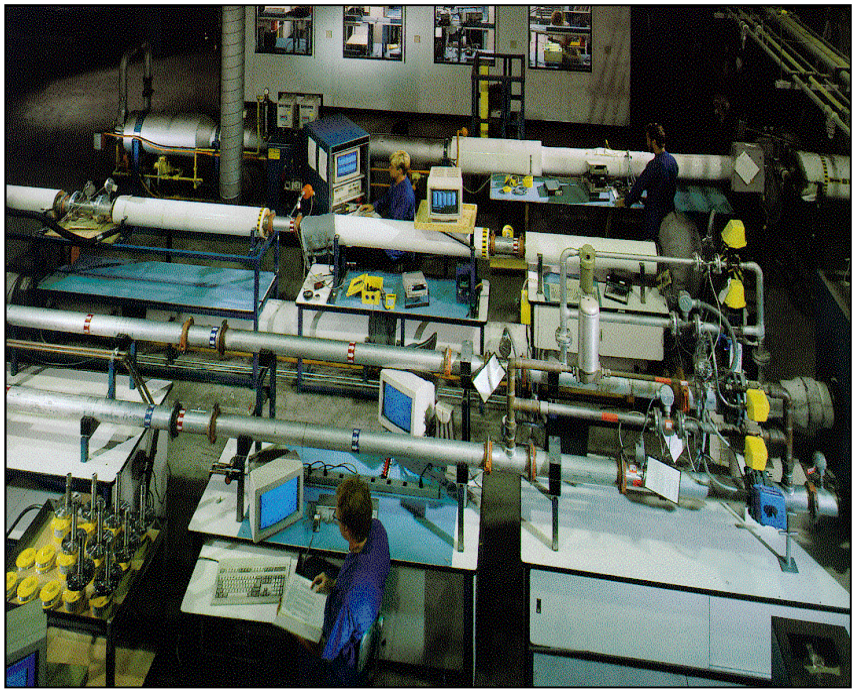


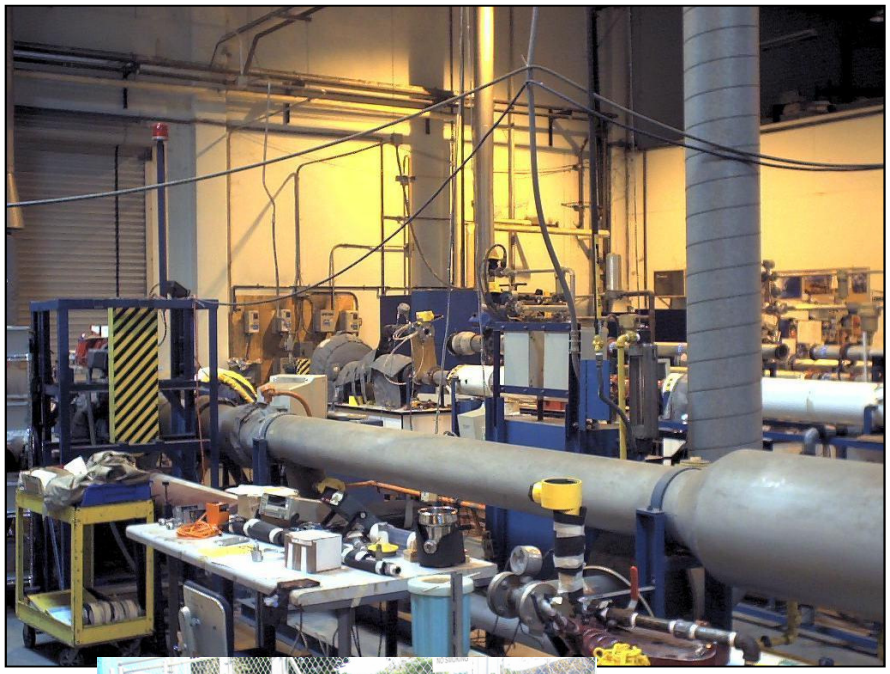
VOREL



VOREL+Flowmeter

Calibration Facilities





Primeiro Sistema On – Site , ou ferramenta de verificação de4 desempenho para

Medidores de Dispersão térmica .

The VeriCal System

VeriCal System

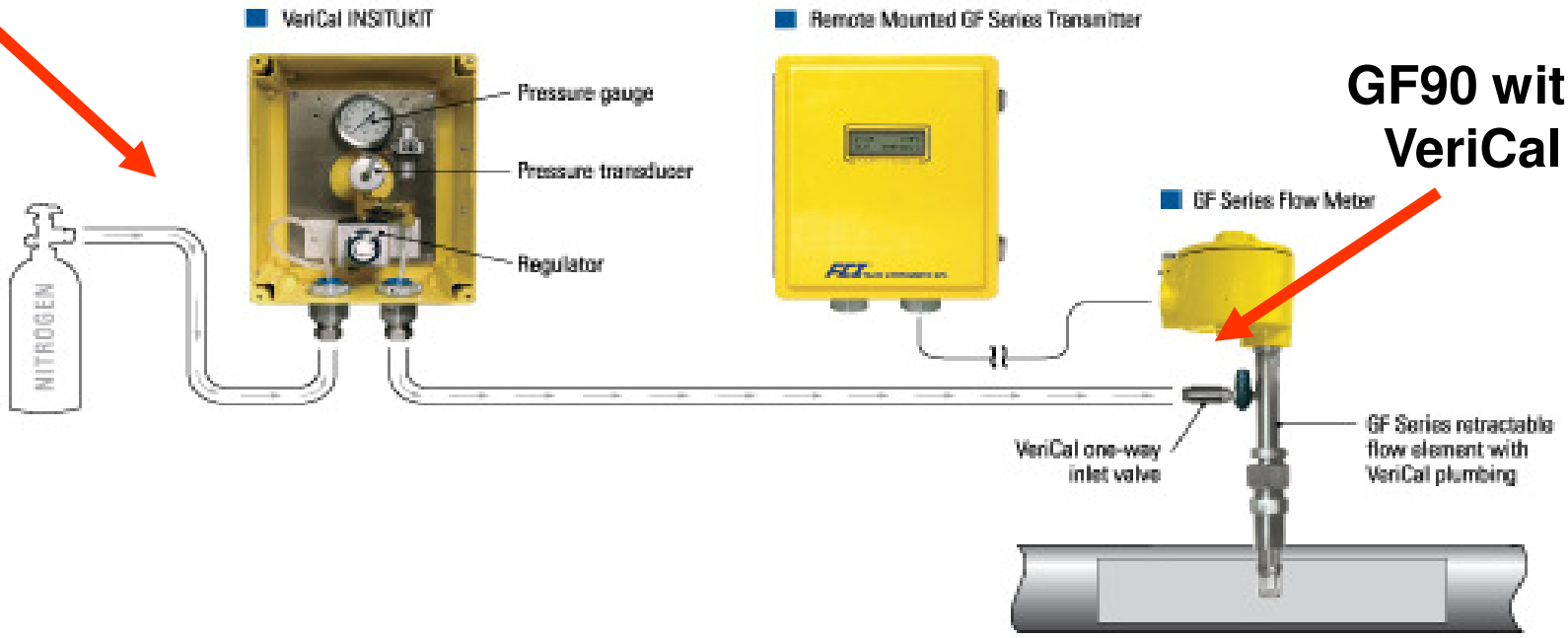
VeriCal provides:

- Verification da performance do Instrumento :
  - apos o Start Up
  - Após periodos de utilização (ISO 9000)
- Validação da montagem :
  - Instalação incorreta
  - Configuração Incorreta
- Trouble shooting of:
  - Incrustrações excessivas no sensor
  - Danos mecânicos no sensor

VeriCal System

- **VeriCal System consist of:**
  1. **GF90 Flowelement with VeriCal provision**
  2. **VeriCal portable Flow control kit**

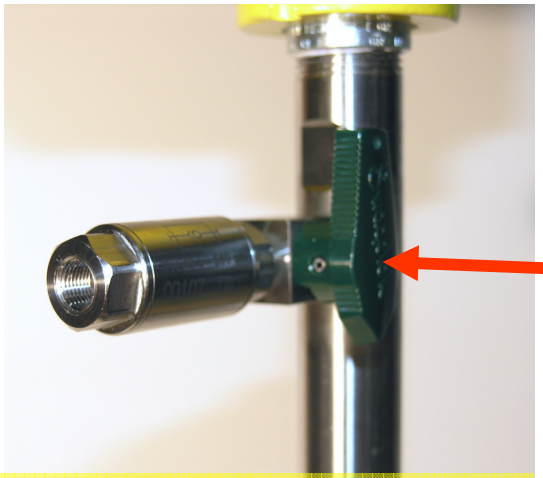
VeriCal Portable Flowcontrol Kit



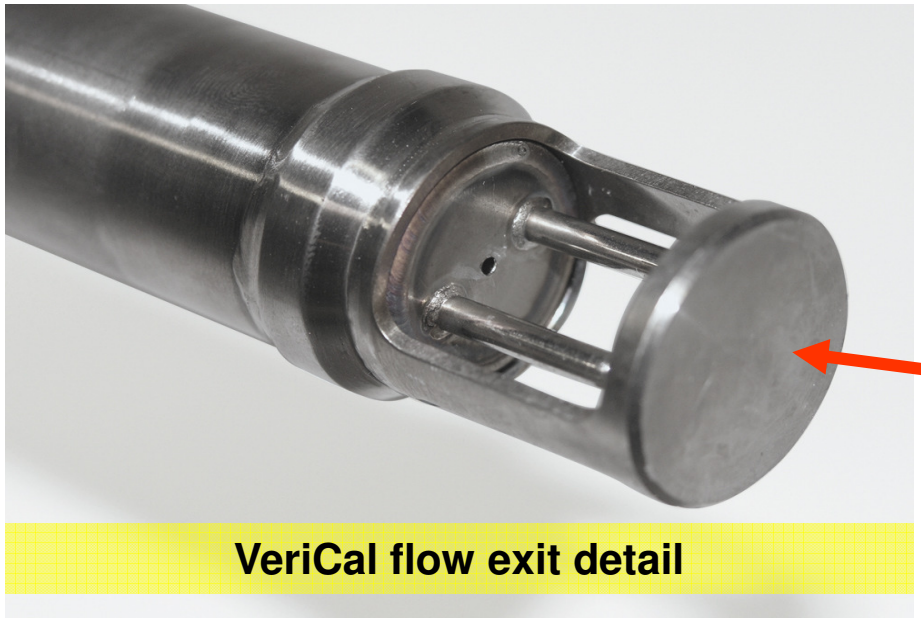
GF90 with VeriCal

VeriCal System

- GF90 Flowelement with VeriCal



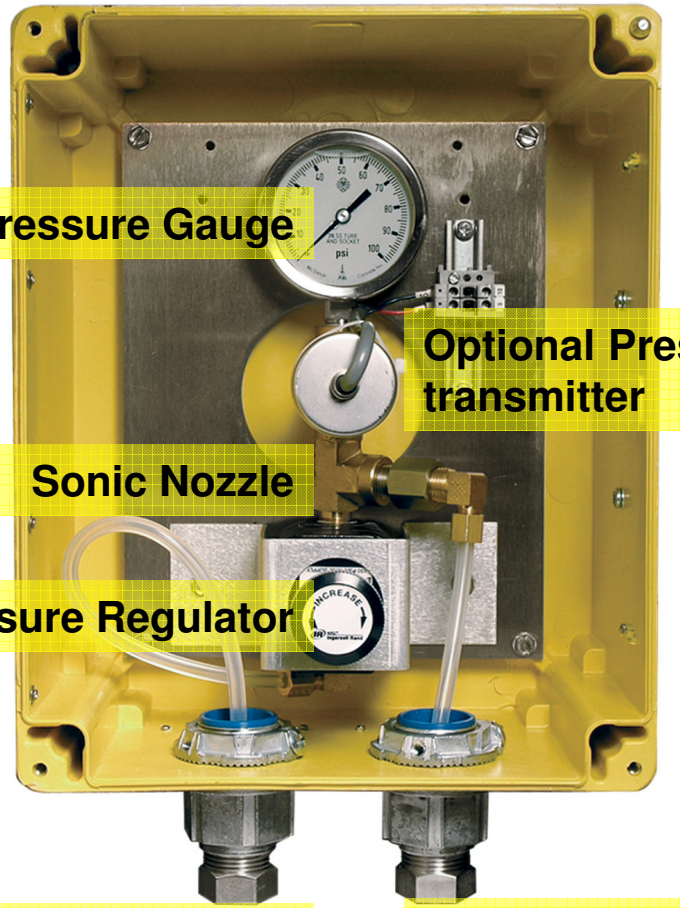
VeriCal connection with One-Way check valve



VeriCal flow exit detail

VeriCal System

- **VeriCal Portable Flowcontrol kit**



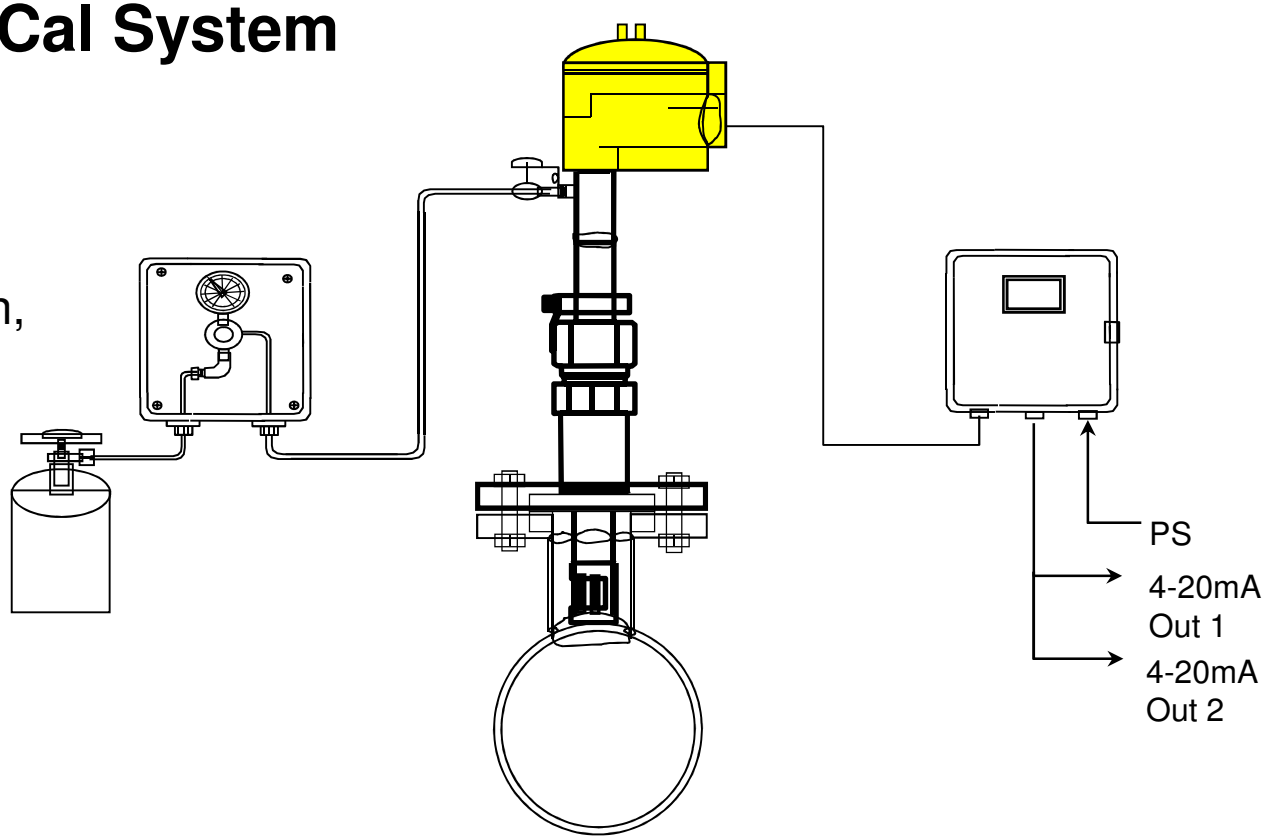
VeriCal System

VeriCal System

Operation VeriCal:

- Calibration Gas, typically Nitrogen, is flowcontrolled by VeriCal's pressure regulator and sonic nozzle and flows to cool off the thermal sensors with Flowelement retracted inside nozzle away from process flow.

- Flow readings at transmitter are noted and compared to earlier as found data for performance evaluation



Date	P1	Reading	Variation	P2	Readir	Variation

VeriCal System

VeriCal representa Economia $ / € / ♥

- Elimina a retirada do transmissor do processo (Speare / By Pass)
  - Elimina Custos e tempo Tranporte e Verificação externa
- Isolate only those instruments which show offset at VeriCal
- Aumenta a segurança de operação e disponibilidade .
  - Off-line time of flowmeter is limited to 30 minutes versus weeks of turn-around time from flowlab
  - Flowelement does not need to be removed from pipe so no risk for hazardous waste

Caracteristicas Basicas da Medição Termal

- Medição Direta de Vazão Massica
- No additional equipment required so:
  - No Pressure Transmitter
  - No Density Transmitter
  - No Temperature Transmitter
  - No Flowcomputer
- Rangeabilidade Excepcional
  - Standard 100:1
  - Optional 1000:1
- Extreme Capacidade para baixas vazões
- Example: apartir de 0.08SMPS,
- Tecnologia Comprovada com aplicações e desemoenho garantidos por Software.
- Repeatability of +/- 0,5% on Reading
- Precisão : of +/- 1 % on Reading + 0,5% Full Scale
- Perda de Carga desprezível
- Sem Partes Moveis

NOVOS PRODUTOS TENDENCIAS

Multiple Gas Calibrations

Dual-Element – Averaged or Discrete Measurements

VeriCalTM In-Situ Calibration Verification

Fieldbus Capabilities and Enhanced Outputs

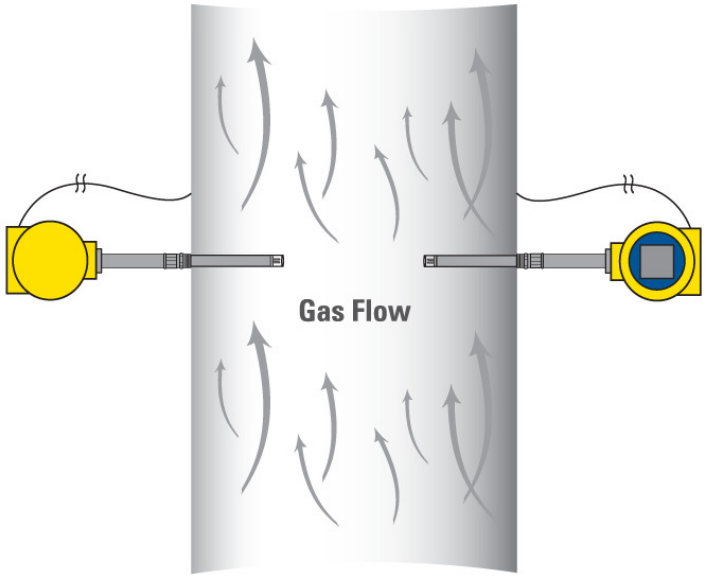
STP100 w/ Flow, Temperature & Pressure Multivariable Outputs

Graphic Display and Integral Keypad Configuration

Entrada para cromatógrafos

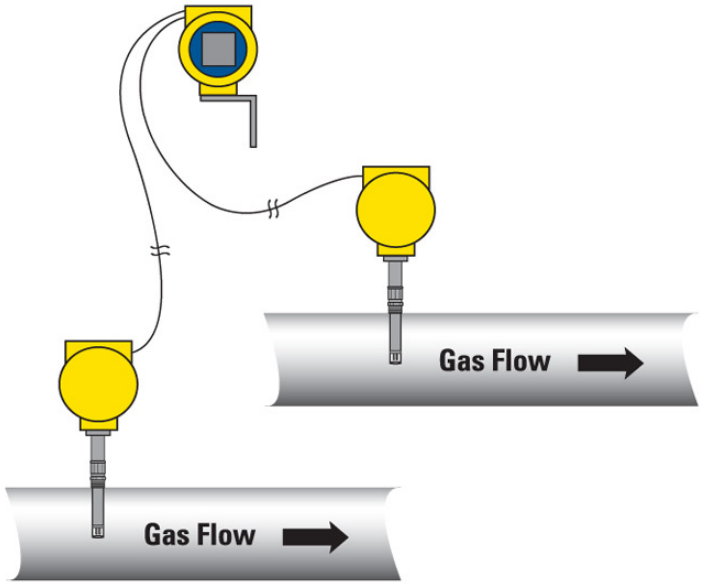
Dual-Element

- **Averaged Measurements**
  - **Improved Accuracy & Repeatability for Lines 12” or Larger**
    - **Addresses Inaccuracies Associated with Inadequate Straight-run Conditions or Flat Flow Profiles.**



Dual-Element

- **Discrete Measurements**
  - **Reduce Instrument Costs by 25% or more**
  - **Independent Flow Element Calibrations**
  - **Configure Display for Specific Flow Element or to Alternate**

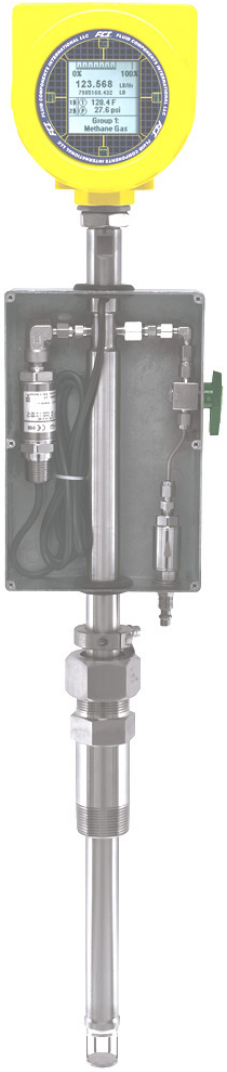


ST100 -VeriCal™

- VeriCal™ In-Situ Calibration Verification
  - Modified Flow Element
    - Sonic Nozzle, Inlet Valve, Internal Flow Tube, Pressure Transducer (Optional) and Packing Gland Assembly
  - VeriCal™ Kit
    - Portable Enclosure with Fittings, Pressure Regulator & Gauge
  - User-supplied Gas Source
    - Nitrogen, Compressed Air or Process Gas

MEDIÇÃO DE PRESSÃO

Insertion with Pressure and VeriCal



ST100 Series Mass Flow Meter

MEDIDORES MASSICOS TERMAIS

> ***OBRIGADO !***

➢ ***??? DUVIDAS ?????***

➢ ***Roberto Wendhausen Magalhaes***