

# Aeration Air & Digester Gas Flow Metering Using Thermal Mass Technology

complex technology  
**MADE SIMPLE**



HWEA 2011 Conference

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# Presentation Overview



Control Solutions for Industry



- Introduction
- Aeration Air & Digester gas challenges
- Gas flow metering technologies
- Mass versus volumetric flow
- Thermal flow measurement techniques
- Flow conditioning
- Installation considerations



# Aeration Air & Digester Gas Challenges

# Aeration Air

- Aeration is the addition of oxygen to wastewater to provide an aerobic environment for the bacteria breaking down the organic matter.
- Introducing oxygen is expensive.
- Controlling the DO levels in each “zone” is critical and the ideal value changes based on conditions and objectives.



# Aeration Air – Metering Challenges

- Wide flow ranges
- Fast response needed
- Mass basis
- Measurement locations at inlet to each zone – limited straight pipe
- Low pressure drop
- Large pipes



# Digester Gas



- Gas produced by the biological breakdown of organic matter in the absence of O<sub>2</sub>
- Mostly Methane and Carbon Dioxide
  - Percentage varies
  - 50/50 to 70/30 typical for WWTP
- Biogas, LFG

# Digester Gas - Metering Challenges



- Low pressure & limited pressure drop allowance
- Low flows
- High moisture/water content
- H<sub>2</sub>S
- Large pipes
- Varying Methane/CO<sub>2</sub> percentages
- Mass basis

# **GAS FLOW METER TECHNOLOGIES**

# Gas Flow Meter Technologies



- **Thermal Mass**
  - Wind chill meter
- **Differential Pressure**
  - Orifice Plates, Pitot Tubes, Venturi, Air Foils, etc.
- **Turbine**
  - Rotating fan
- **Vortex**
  - Waving flag
- **Coriolis**
  - Vibrating tube
- **Ultrasonic**
  - Speed of pressure waves

# Gas Flow Meter Technologies

Type	Mass or Volume	Turndown Range	Low Flow	Dirt	Line Sizes	Pressure Drop (\$)
Thermal	Mass	1,000:1	Yes	OK	1/8" – Insertion	Low
DP	Volume	10:1	No	Bad	1/8"- Insertion	High
Turbine	Volume	50:1	No	Bad	1/4"- Insertion	High
Vortex	Volume	25:1	No	Bad	1"- Insertion	Low
Coriolis	Mass	100:1	No	OK	1/8"-10"	Medium
Ultrasonic	Volume	100:1	Yes	Bad	2" – 120"	Low

# Where does Thermal Mass fit in?



- Where direct mass flow is beneficial over volumetric flow measurement
- Low velocities
- Wide flow range needed
- Large duct size
- High temperatures
- Dirty applications
- Low pressure drop required
- High Vibration

# Major Industries Use Thermal Mass Flow Meters



- Municipal
- Power
- Refining & Chemical
- Biotech & Pharmaceutical
- Semiconductor
- Pulp & Paper
- Food & Beverage
- Nuclear
- Aerospace

# What is Thermal Mass?

# What is Thermal Mass?

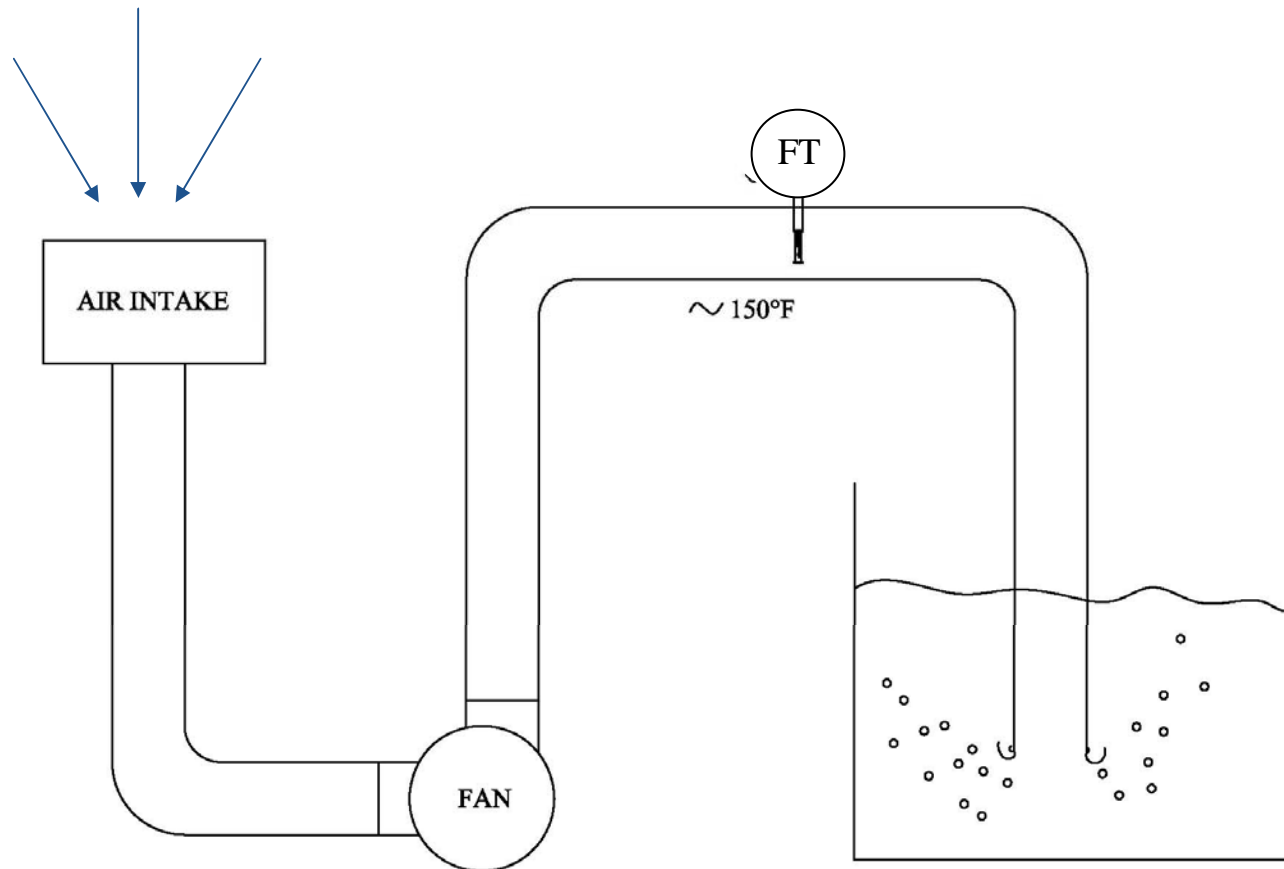
A complex technology simply stated is:

**Measuring the flow of  
molecules using heat transfer**

# WHY MEASURE FLOW BASED ON MASS?

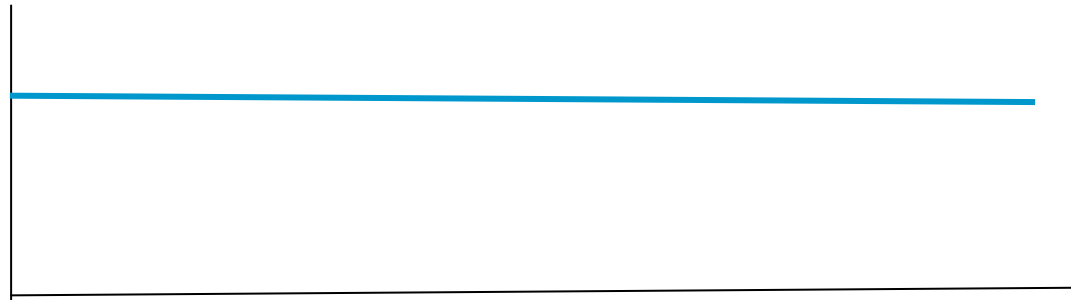
# Real Life Example

Aeration blower with constant speed fan



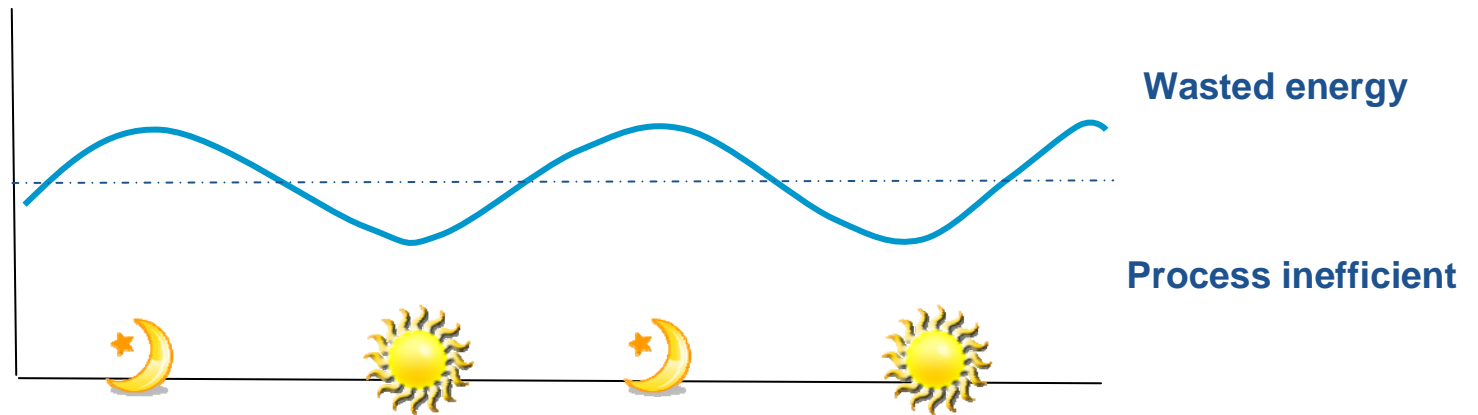
# Real Life Example

ACFM



Volumetric (DP) flow meter showed constant flow rate

SCFM



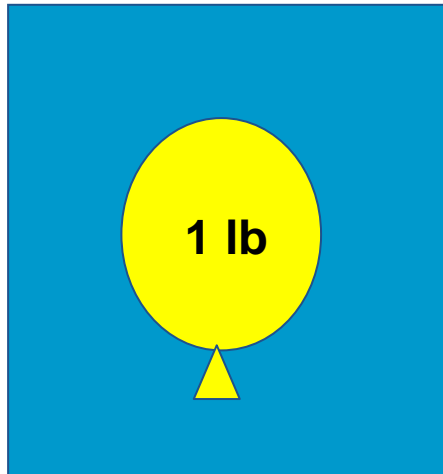
Mass flow meter showed changing flow rate due to ambient temperature and tank level changes

# Mass Portion of Thermal Mass

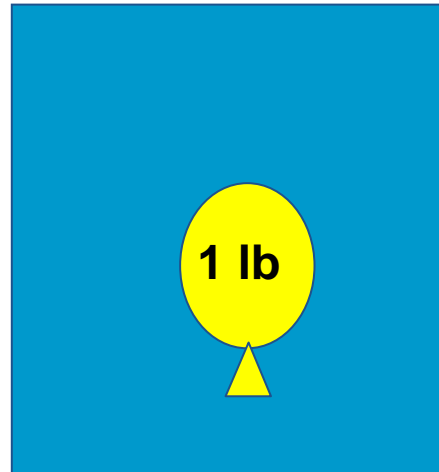
- Mass flow is independent of density  
Pounds/hour, kilograms/sec
- Volume based and referenced to standard conditions  
SCFM, SLPM
- Mass flow is needed to compare flows within a system

# Pictorial Example of Mass vs Volume

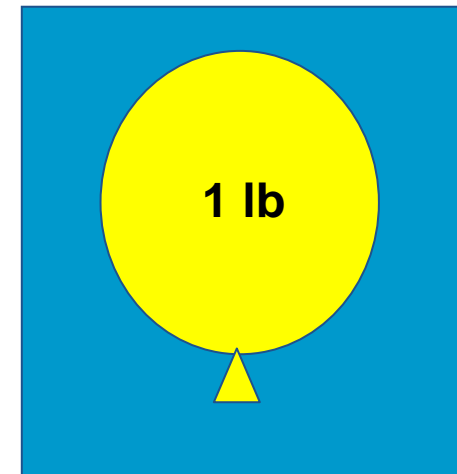
STP  
P = 14.7 psi  
T = 77°F



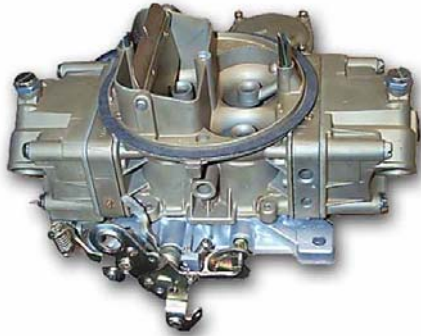
P = High  
T = Low



P = Low  
T = High

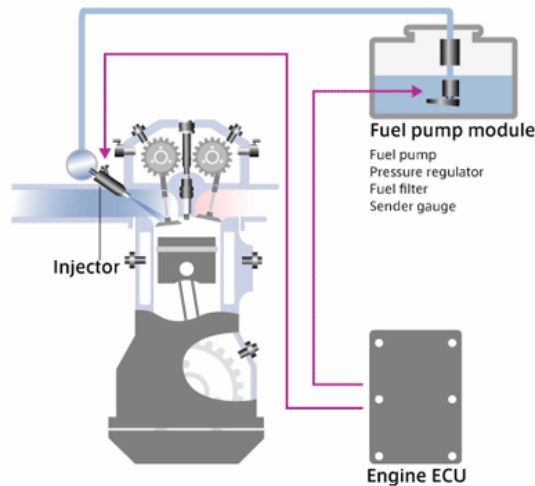


# Example of Mass vs Volume



## Carburetor vs Fuel Injection

- A carburetor creates a fixed ratio of air volume to fuel volume and works OK in normal conditions. Problems occur with altitude (pressure) or cold (temp) since density of air changes



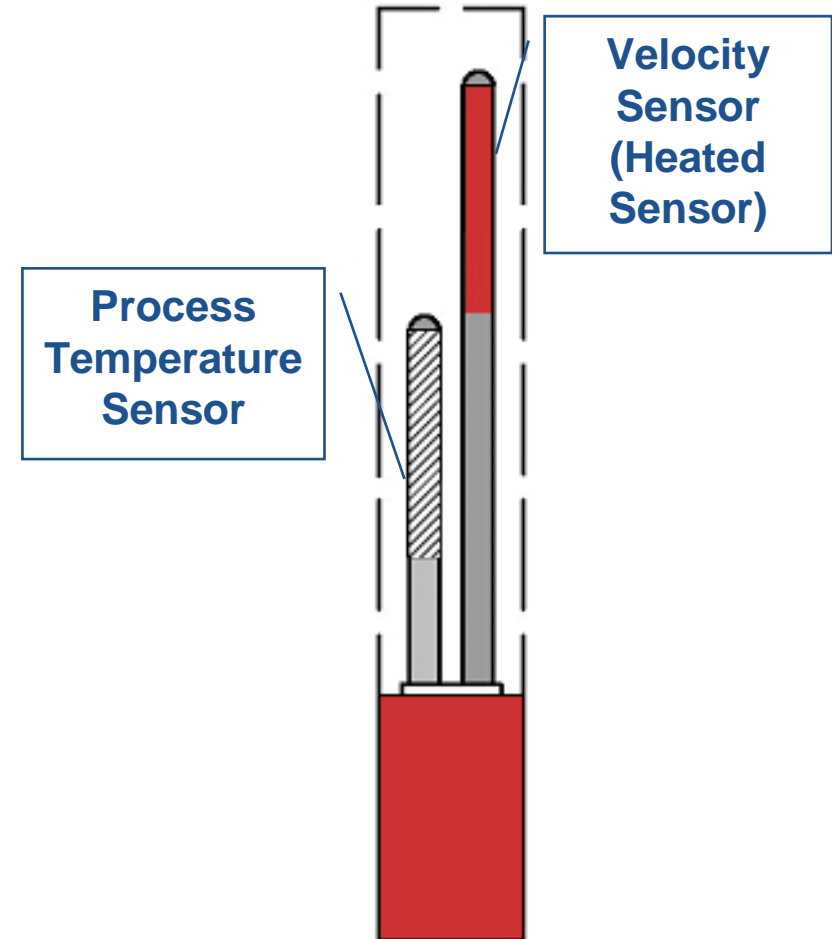
- Fuel Injection ratios the air to fuel mixture based on mass using a thermal mass air flow sensor

# **Thermal Mass Measurement Techniques**

**Constant Temperature  
Constant Power**

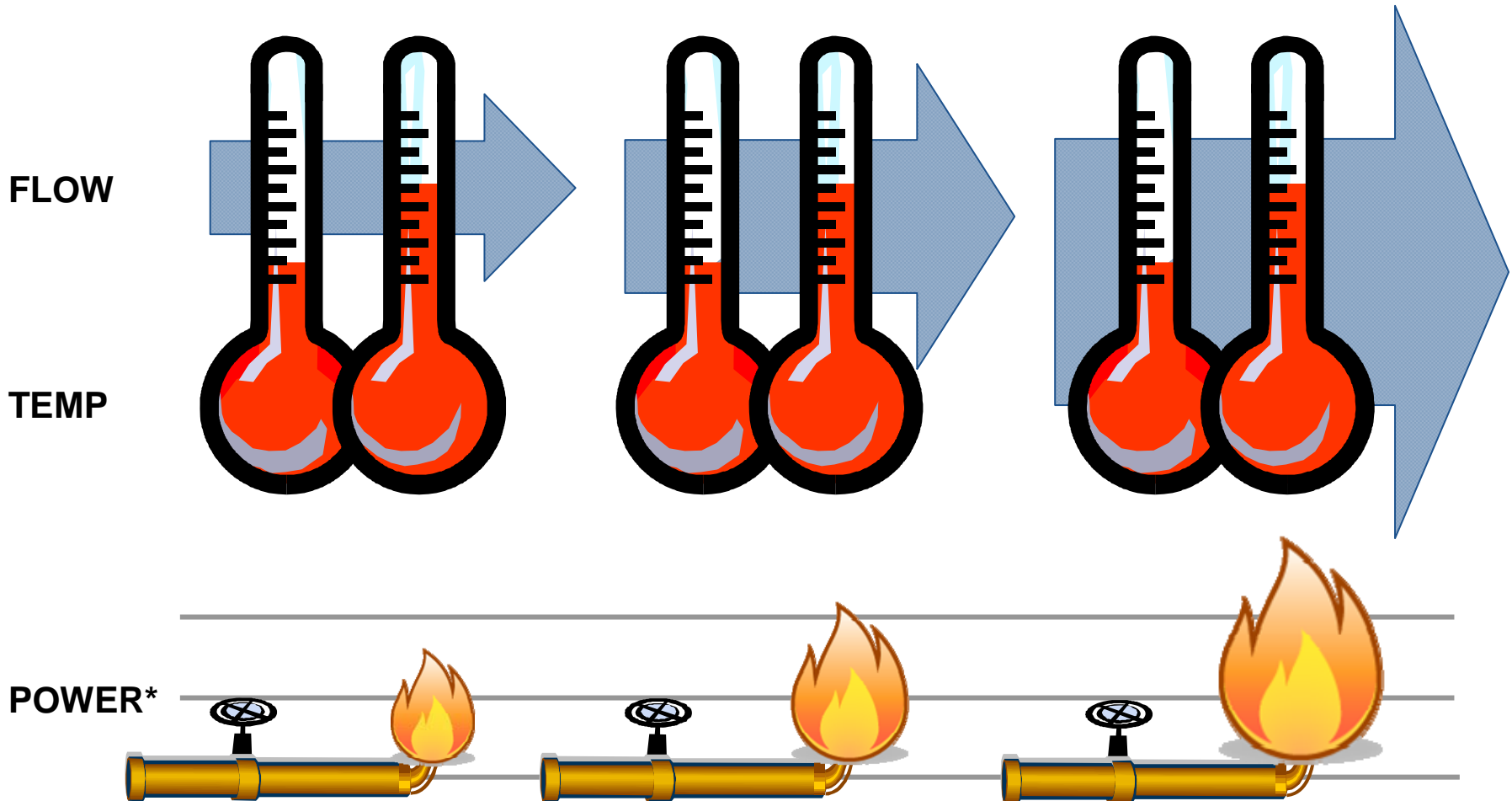
# Constant Temperature

- One RTD measures the process temperature and a second RTD is heated to 100 °F higher
- As gas flows by it pulls heat away from the heated sensor skin, the electronics increase current flow to maintain a constant 100 °F
- The current flow (power delivered to the heated sensor) directly relates to the fluid mass flow rate



# Constant Temperature

## Same Process Temp, Increasing Flow

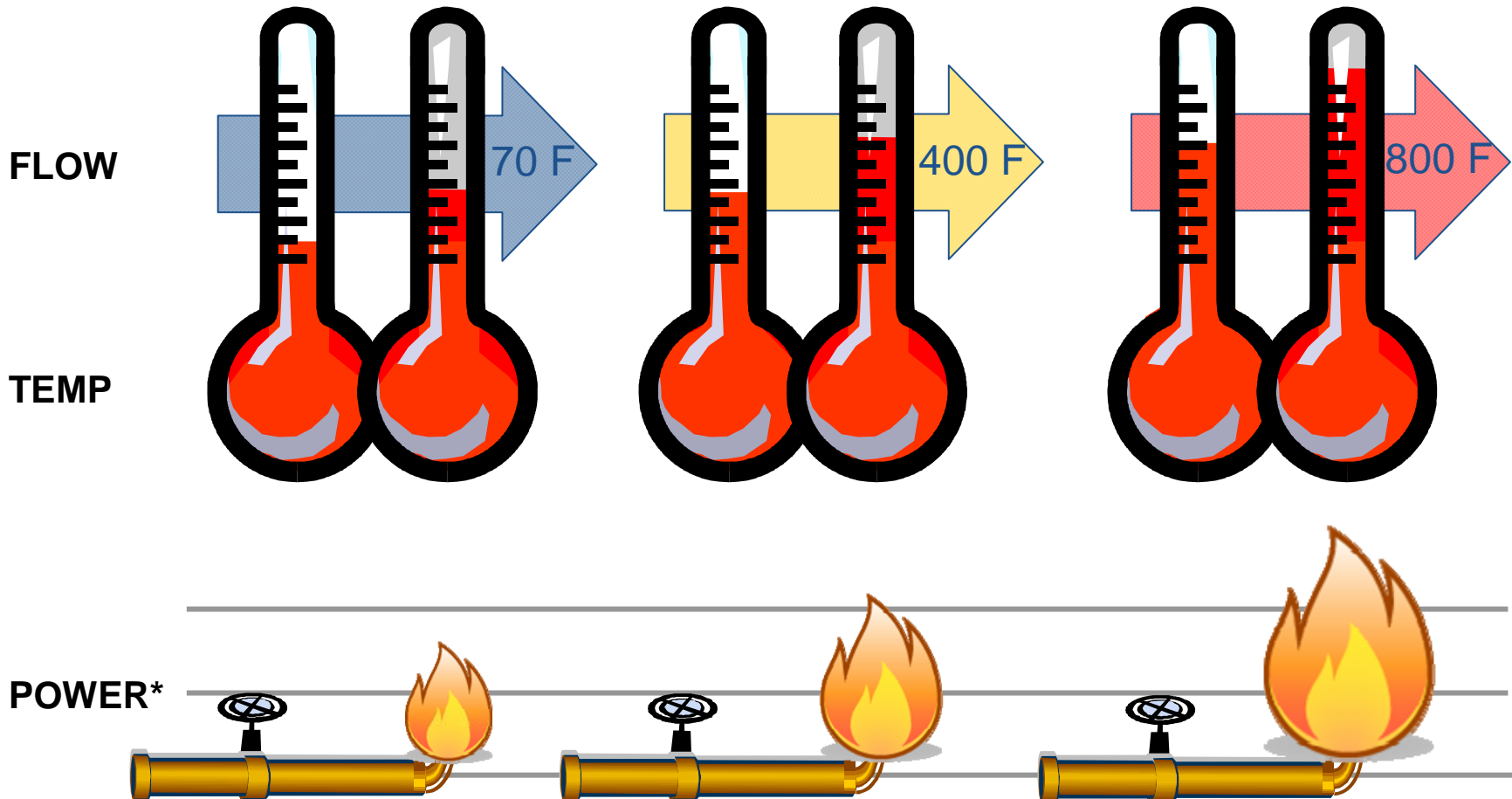


\*Power required to keep 100° TEMP DELTA is SIGNAL



# Constant Temperature

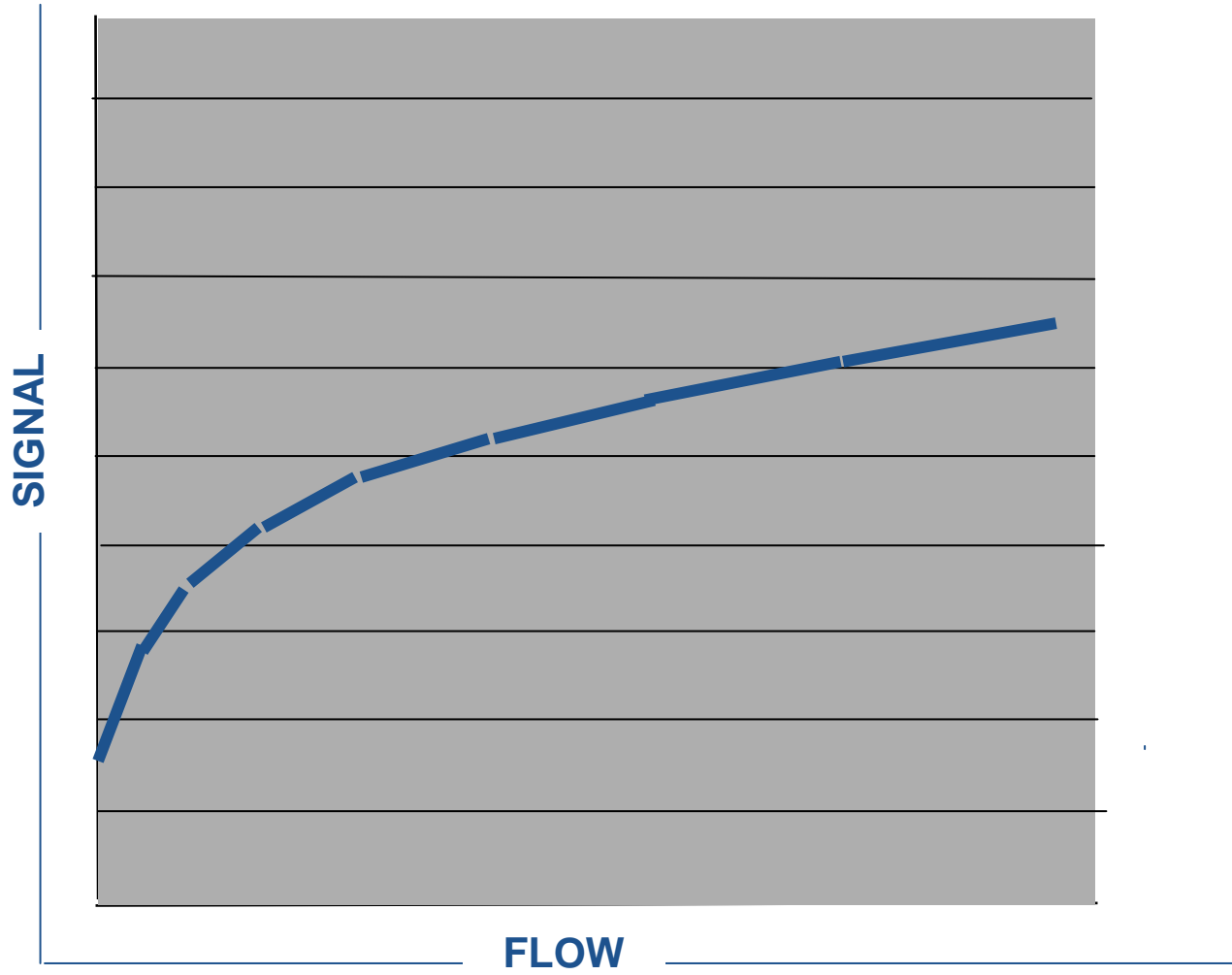
## Same Flow, Increasing Process Temp



\*Power required to keep 100° TEMP DELTA is SIGNAL

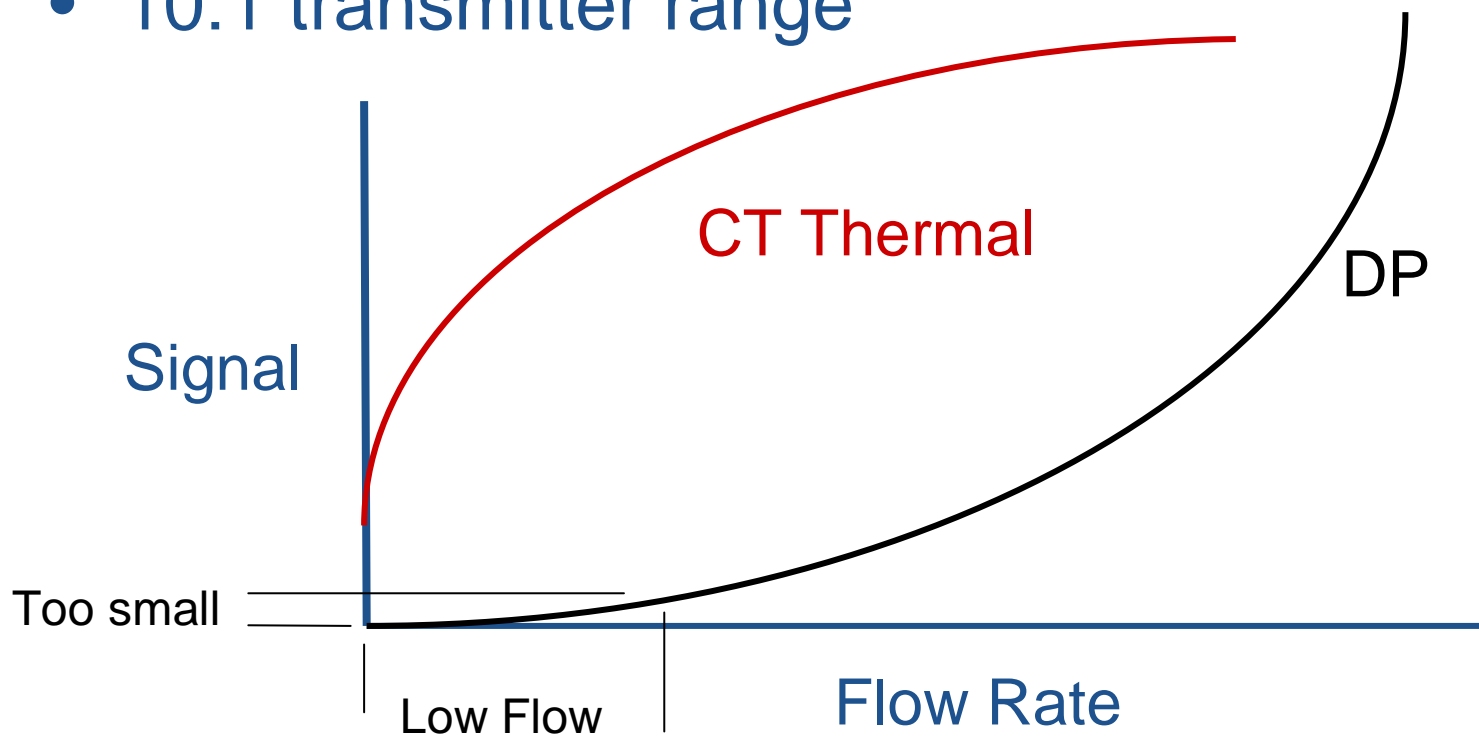


# Constant Temperature Signal vs Flow Curve



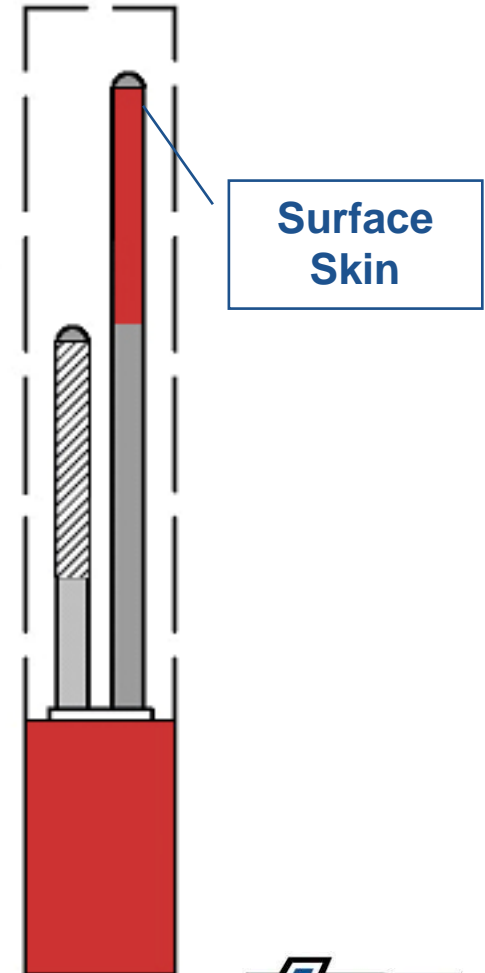
# Pressure Differential Problem

- Square Root relationship
- 10:1 transmitter range

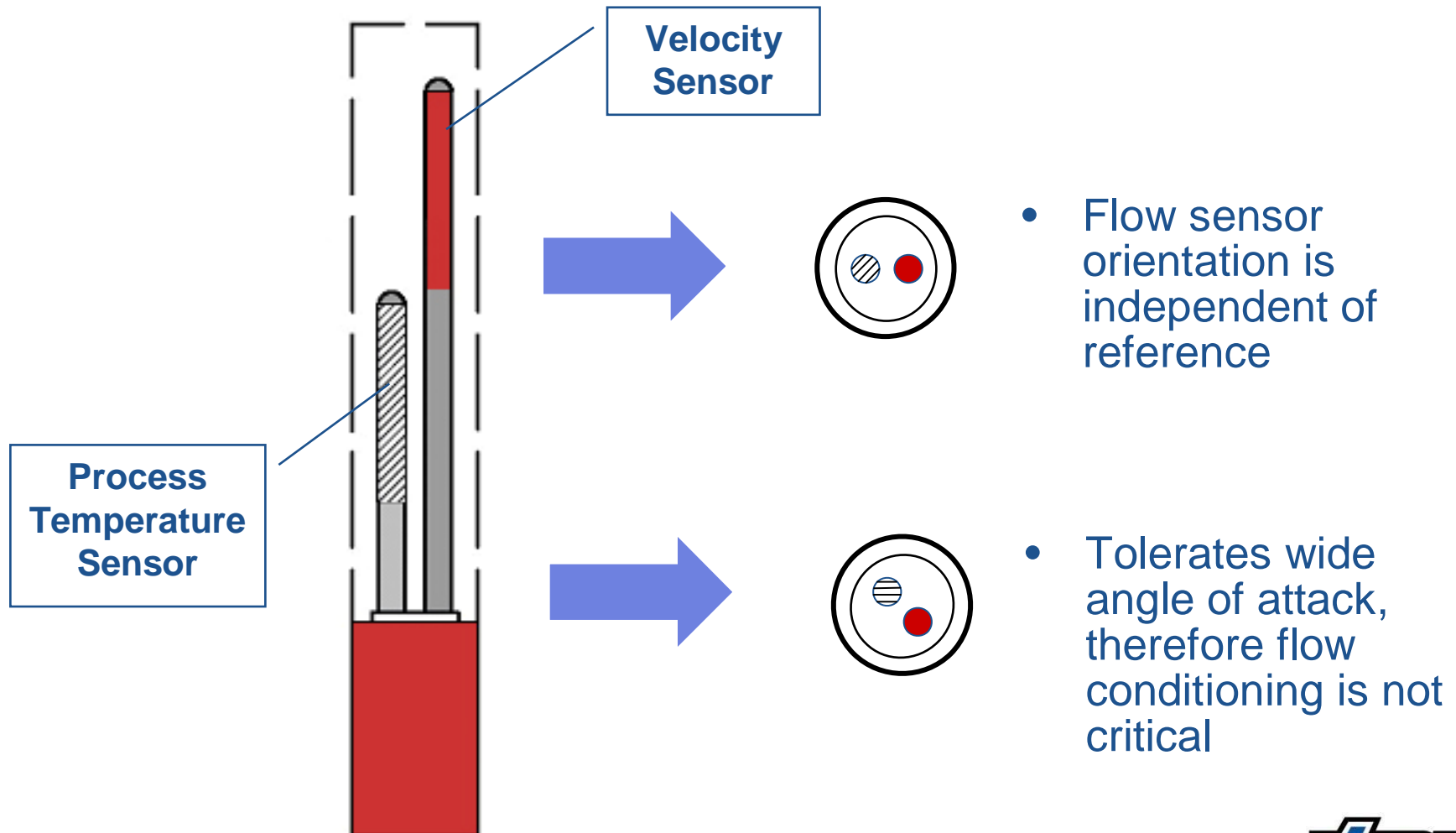


# Constant Temperature Response Time

- Sensor “core” temperature remains constant
- Heat transfer occurs on “skin” of sensor
- Fast response time measured in seconds
  - Good for control loops



# Constant Temperature Sensor Orientation is not Critical

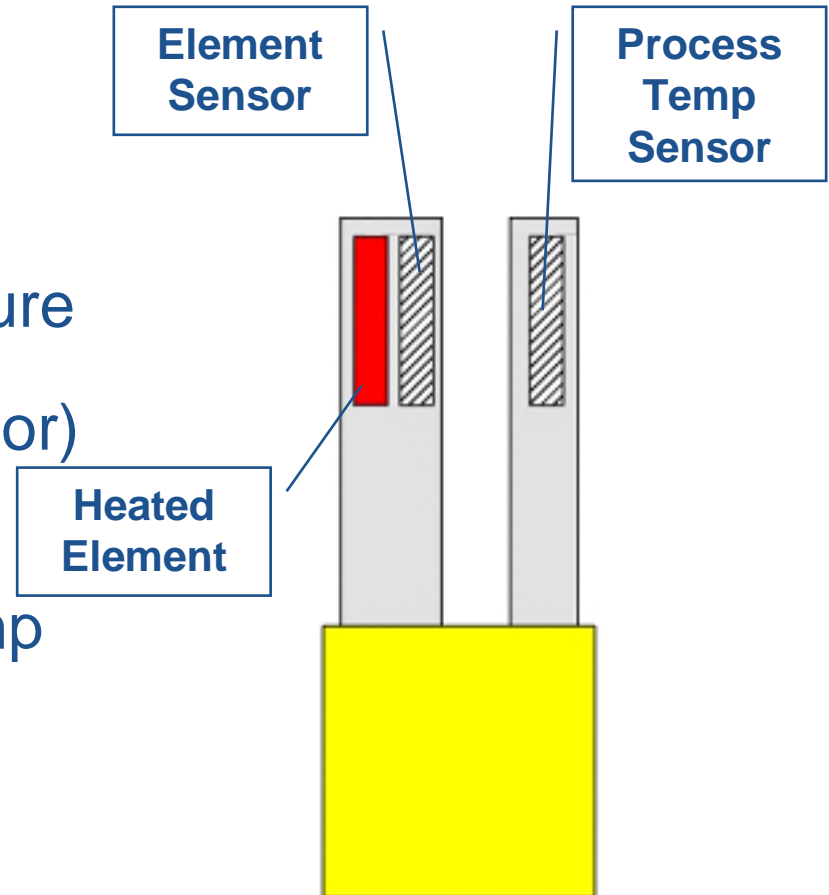


# Constant Temperature Summary

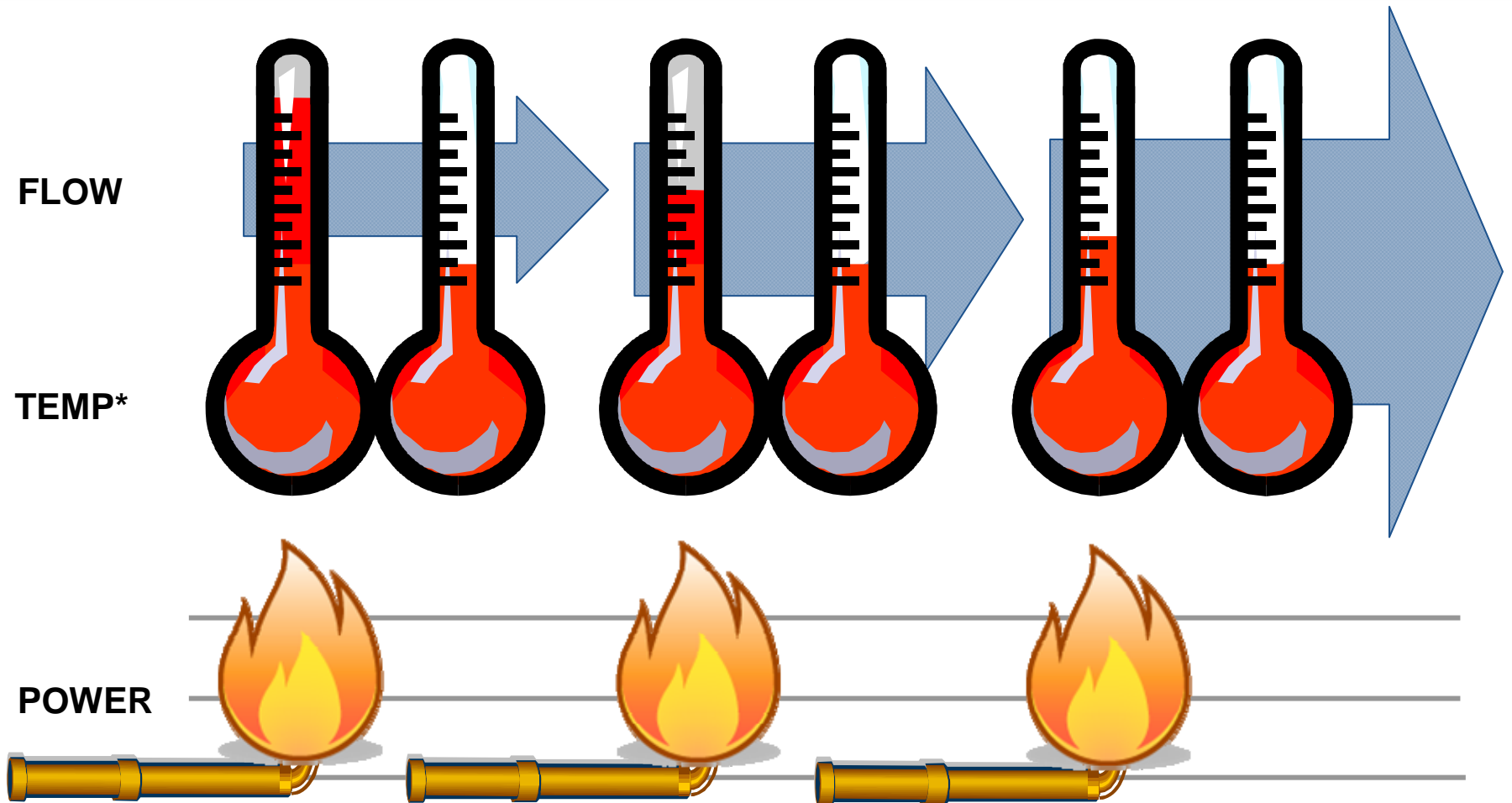
- + Fast response to flow changes
- + Less sensitive to sensor orientation
- + Good for gas flow metering applications

# Constant Power

- An element is heated with a constant current (~2 watts)
- As fluid flows it pulls heat away from this element. Its temperature drops and is measured with a connected RTD (Element Sensor)
- A second RTD (Process Temp Sensor) measures the fluid temp and is compared to the heated element temp
- The difference in temperature readings correlates to mass flow



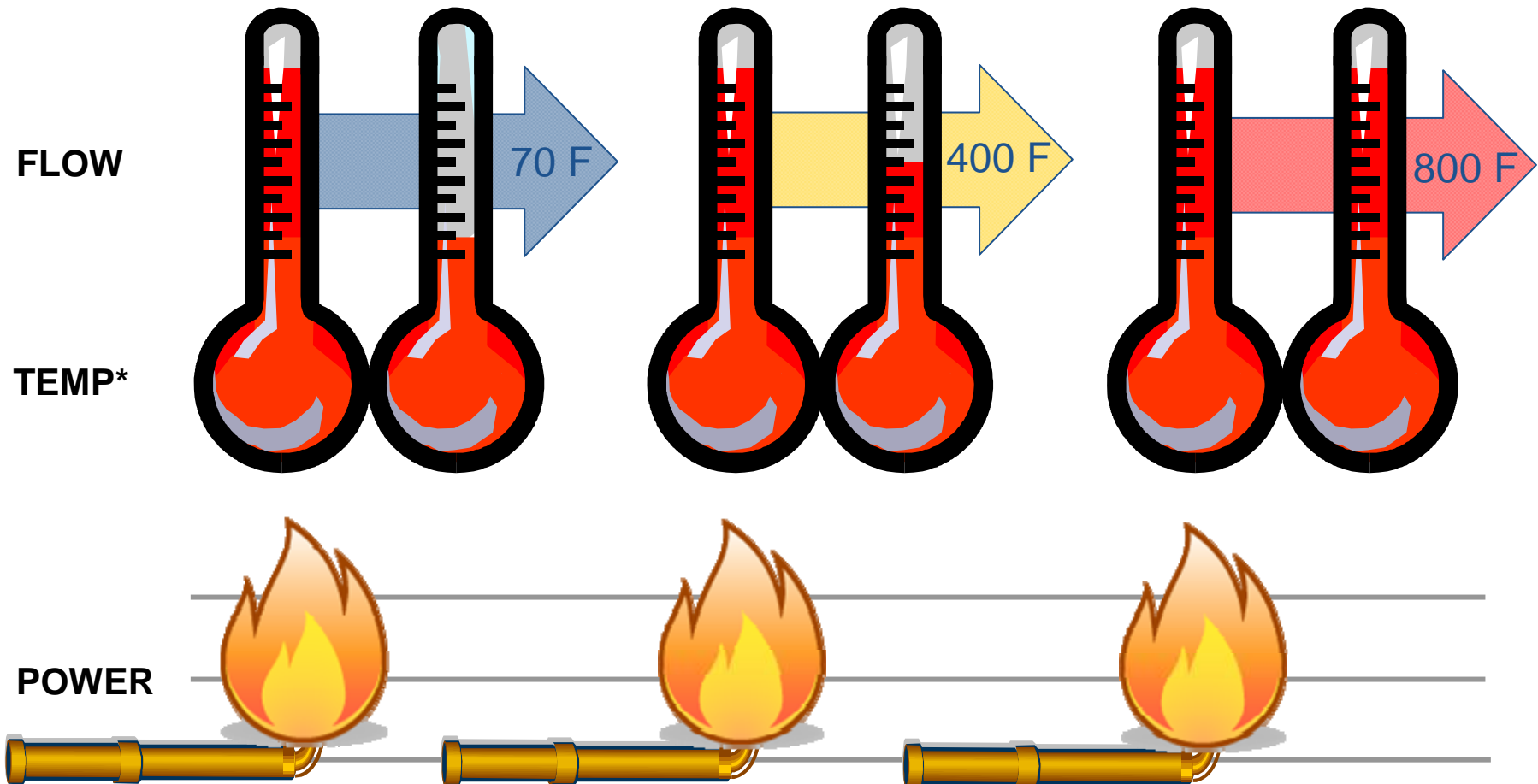
# Constant Power Same Process Temp, Increasing Flow



\*Delta TEMP is SIGNAL

# Constant Power

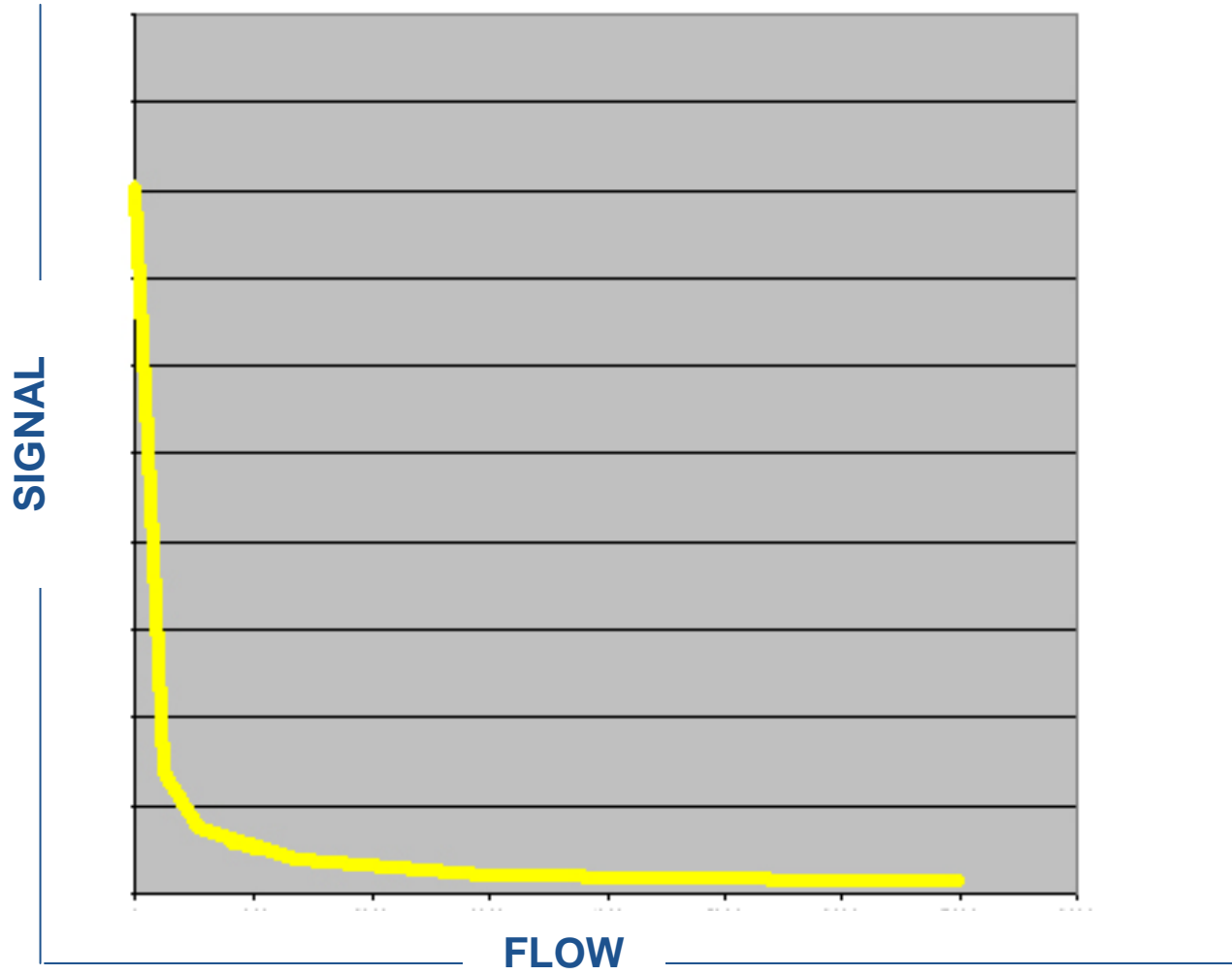
## Same Flow, Increasing Process Temp



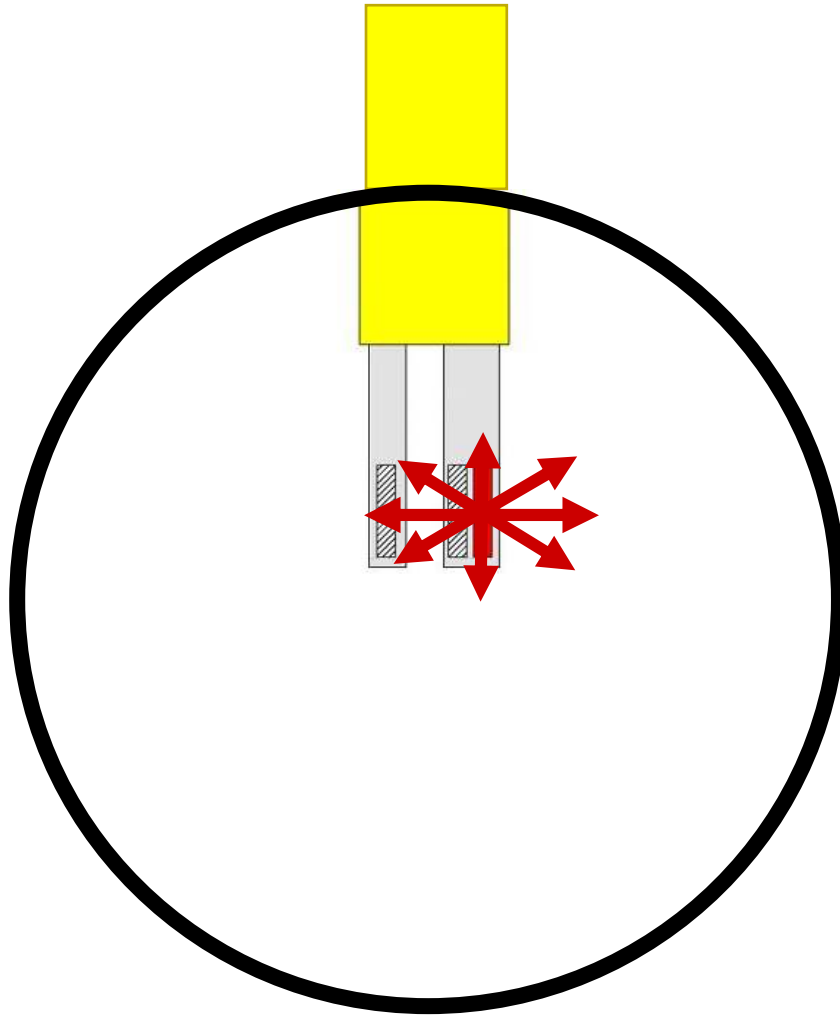
\*Delta TEMP is SIGNAL



# Constant Power Signal vs Flow Curve



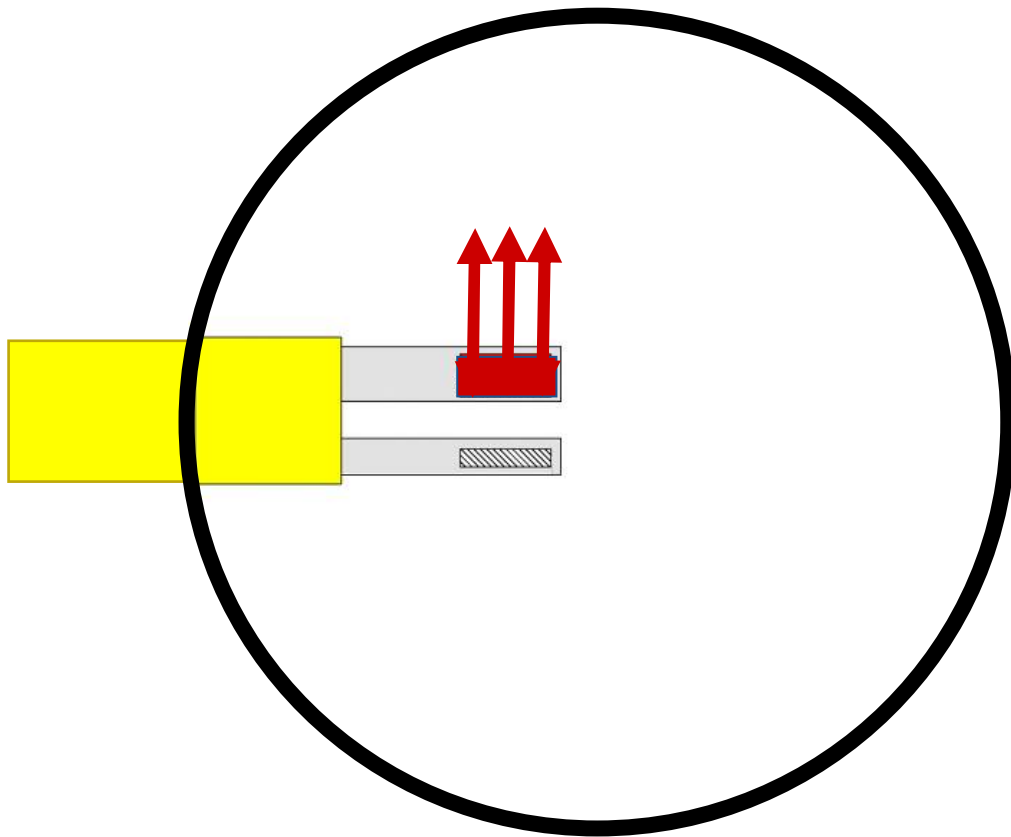
# Constant Power Self Heating Effect at low flows



- Constant Power sensors have MAX heat at low flow
- Reference sensor is affected by Heated Element at low flows
- <10% of flow range is not recommended for use

# Constant Power Sensor Orientation is Critical for Meters

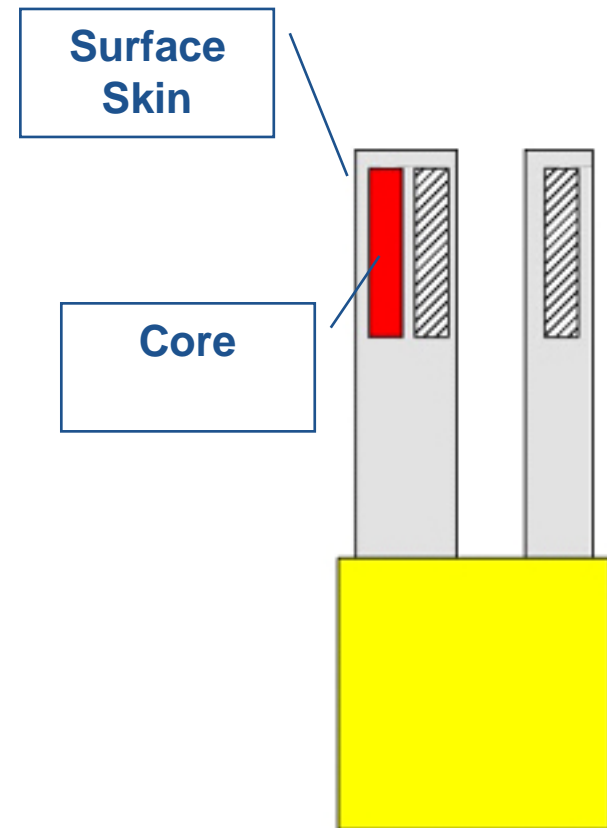
## Horizontal installations



- Heater must be on top otherwise reference sensor will be more affected
- Must be ordered and built for specific orientation to flow

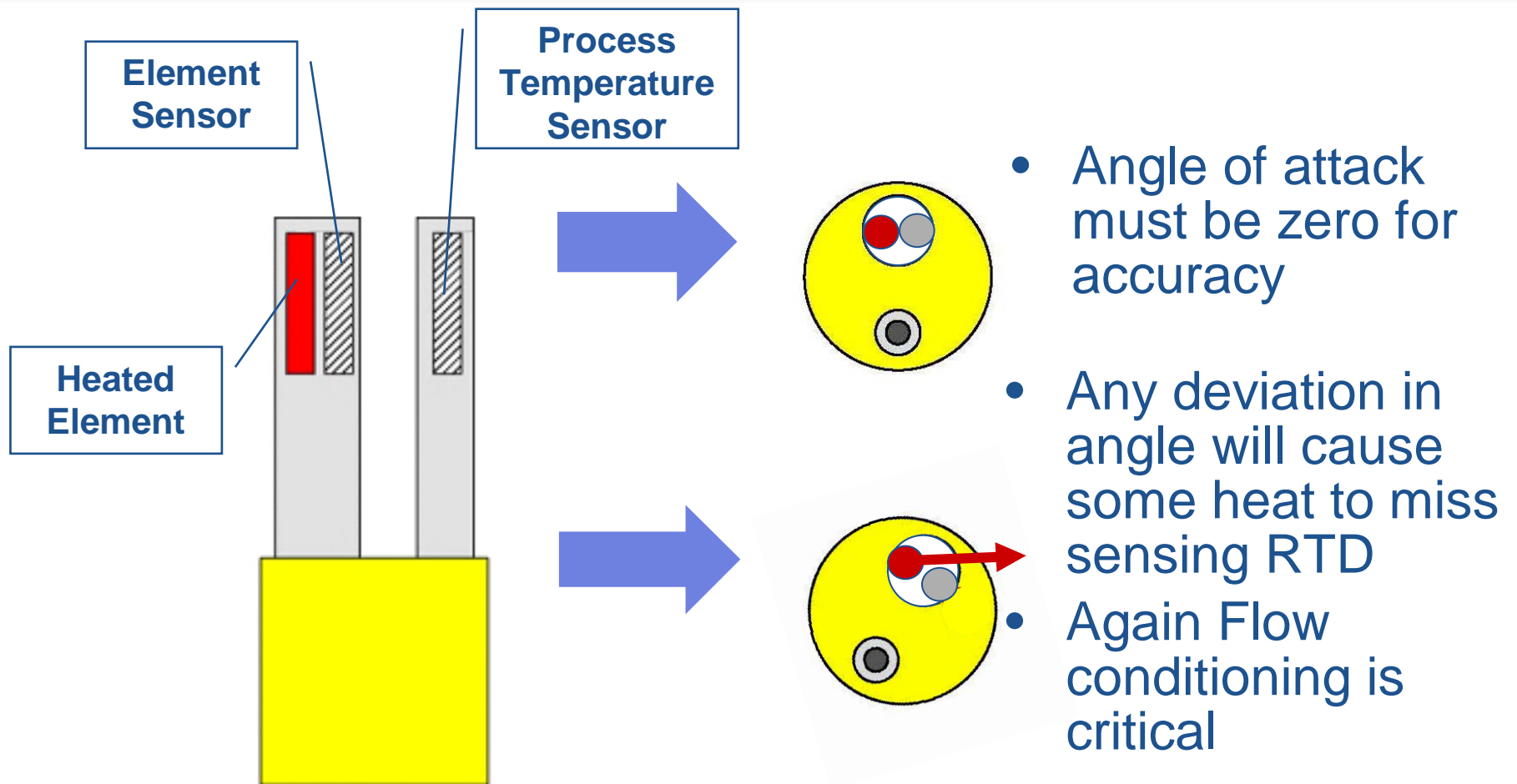
# Constant Power Response Time

- Heat transfer causes “skin & core” of sensor to change temperature
- Response time is measured in many minutes
- Not fast enough for most control loops



# Constant Power

## Sensor Orientation is Critical for Meters



# Constant Power Summary

- Slow response to flow changes
- Sensitive to orientation of flow
- Flow Conditioning Critical
- Limited at Low Flow
- Limited at high temperature
- + Great for Switch applications

# International Standard ISO-14164 Flow Metering

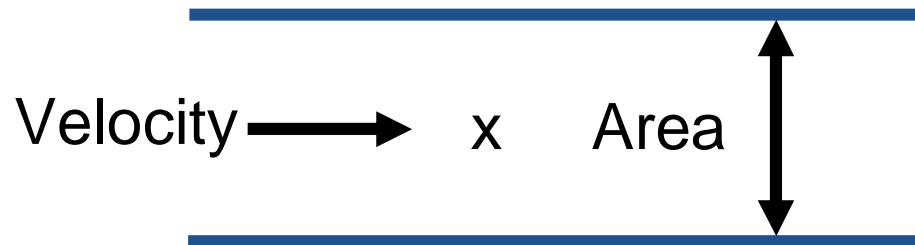


1. Explains the advantages of Constant Temperature technique
2. Specifically does not recommend Constant Power **"because they:**
  - a) are slow to respond to changes in velocity and temperature;
  - b) do not have a stable "zero"; and
  - c) have a limited range of temperature compensation”

# FLOW CONDITIONING

# Flow Profile

- Thermal mass sensors measures velocity (SFPM) multiplied by the cross sectional area of duct (FT<sup>2</sup>) = SCFM



- Velocity measured is assumed to be the average velocity
- If it is not, it needs to be corrected either mechanically or electronically

# Straight Run Recommendations



## Diameters

### Upstream

Expander

15

Elbow/Tee

20

Control Valve

40

### Downstream

5

# Flow Conditioners



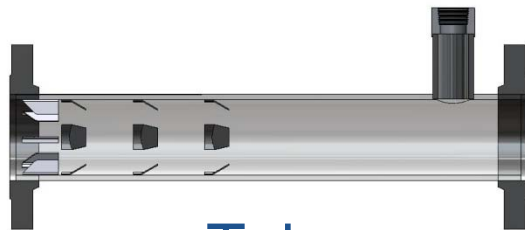
Long straight pipe



Perforated screens



Venturi

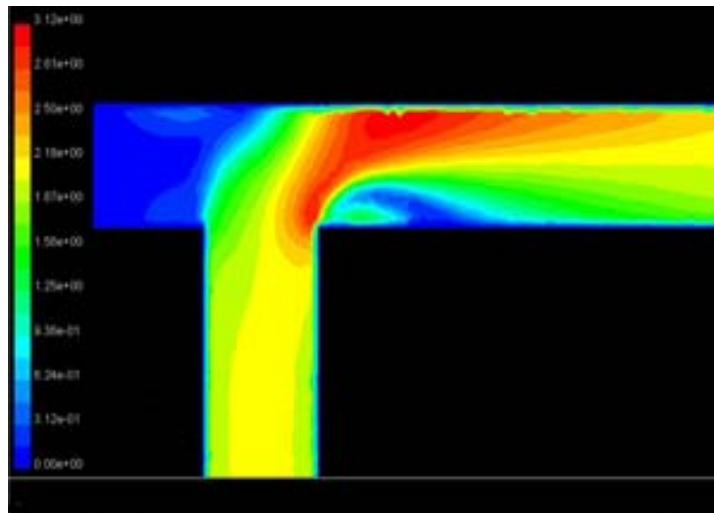
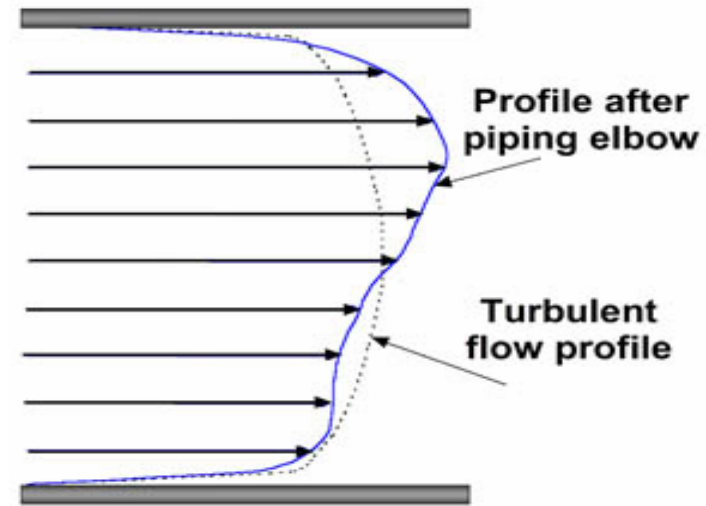
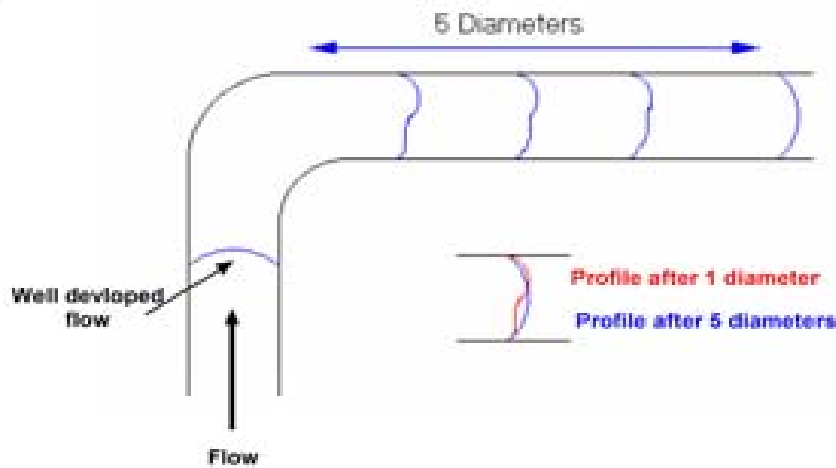


Tabs



Digital profile correction

# FlowCorrect™ Digital Profile Correction



## FlowCorrect™

- Digital Software Correction
- Variable Correction Factor compensates for changing profile over entire flow range based on up to 7 calibration profiles



# Flow Conditioners

Type	Perforated Plate	Tab	Venturi Style	Digital Profile Correction
Initial \$	Low	High	Medium	Free
Added Pressure Drop	High (47.4" H20)	Medium (28.6" H20)	Low (7.5" H20)	None
Operating \$	High	Medium	Low	Free

# Types of Thermal Meters

# Thermal Mass Flow Meter Types

In-Line



Single point insertion



Flow Computers



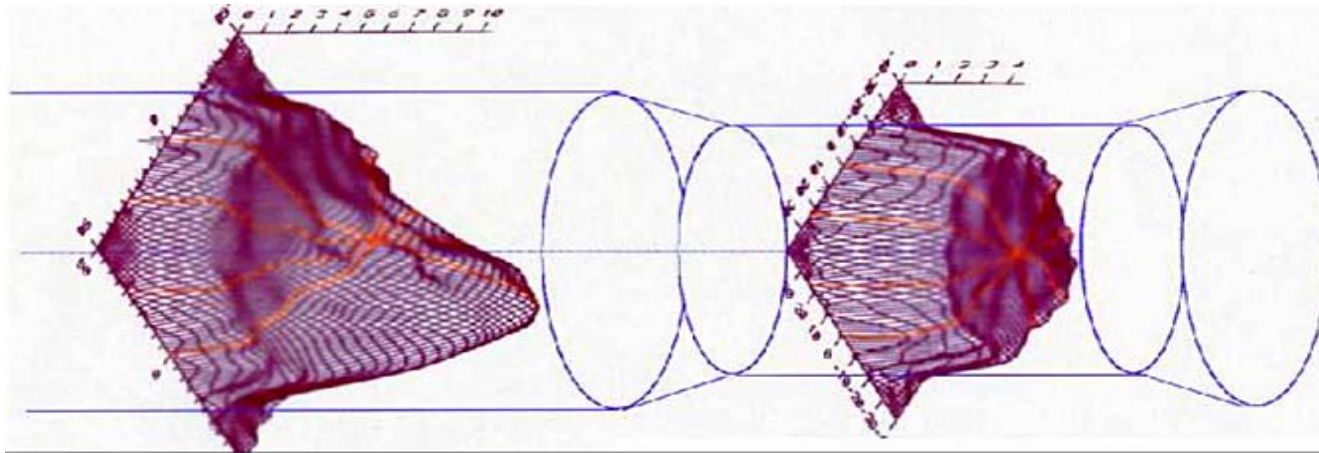
Multi-Point



Portable



# Venturi Style In-Line



- Excellent flow conditioning
- No extra straight pipe requirements
- Recovers majority of pressure loss

# Installation Considerations

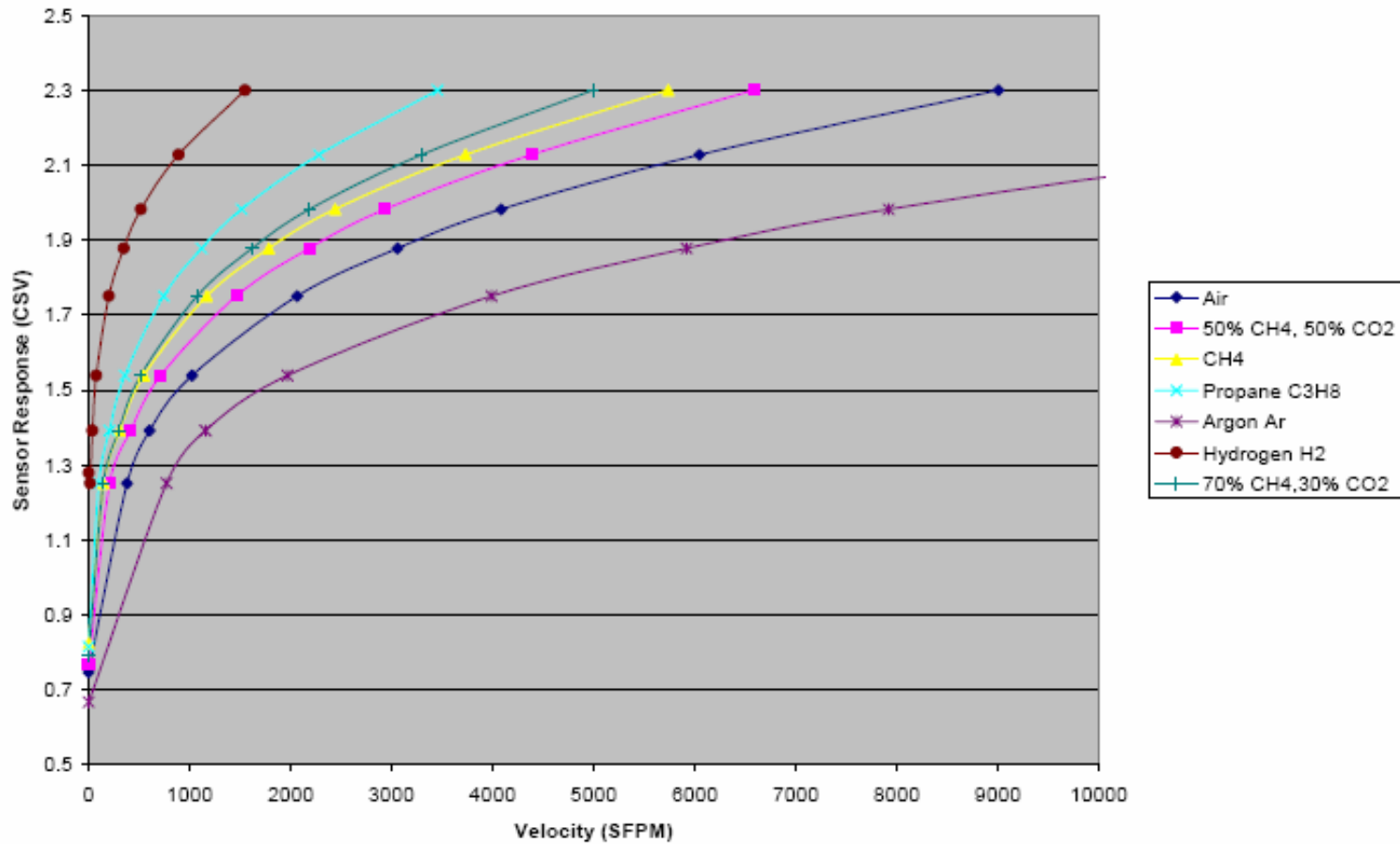
# Digester gas – Installation

- 4 o'clock sensor
- Eccentric Venturi
- Flat bottom to drain liquids



# Gas Composition

Calibration data in Different Gases



# ***VariCorrect™* Varying Gas Composition Correction**

- ***VariCorrect™*** auto-corrects for variable gas composition
- Ideal for landfill and digester gas applications
- Can take input from gas analyzer which allows real time gas composition tracking, and will then automatically correct for the varying constituents

# Presentation Summary

- Reviewed flow metering technologies
- Reasons to measure mass vs volume
- Flow conditioning & calibration options
- Analyzed thermal measurement techniques
- Installation considerations

**Mahalo**

