Practical Experience with CEMS Measurement

Challenges Associated with making:

Reliable

Believable

CONTINUOUS

Flow Measurements in Large Utility Stacks

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Ultrasonic Flow Monitor

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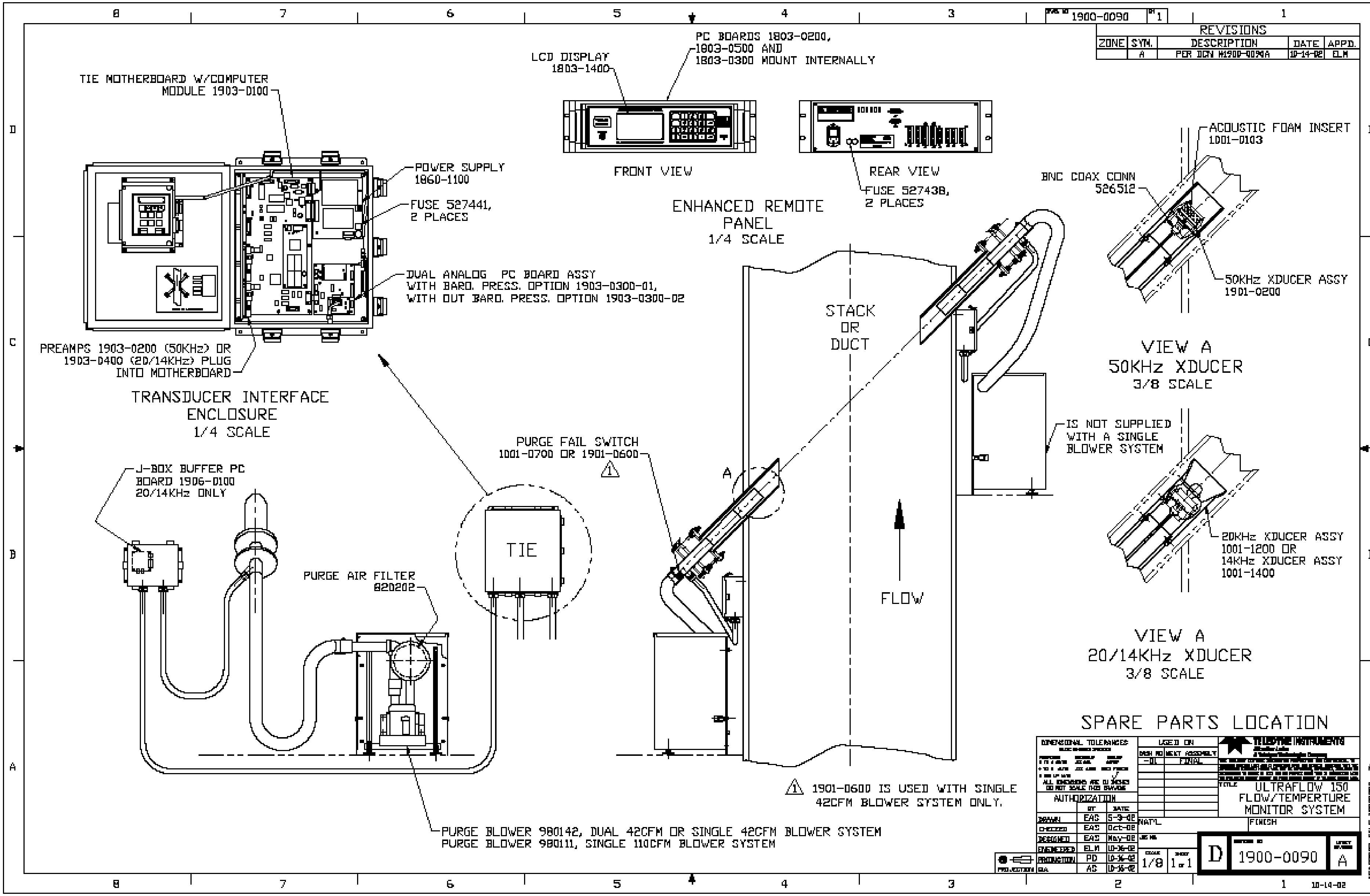

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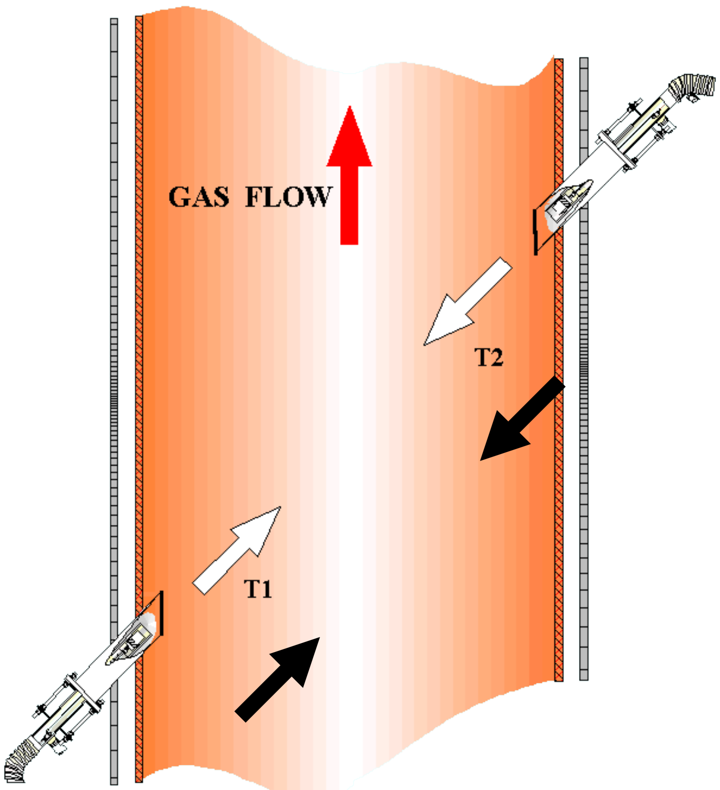
Overview

- What is an Ultrasonic Flow Monitor?
  - It is a device that measures velocity based on the time-of-flight of signals t_1, t_2
  - By determining t_1, t_2, the monitor calculates velocity, volumetric flow and temperature



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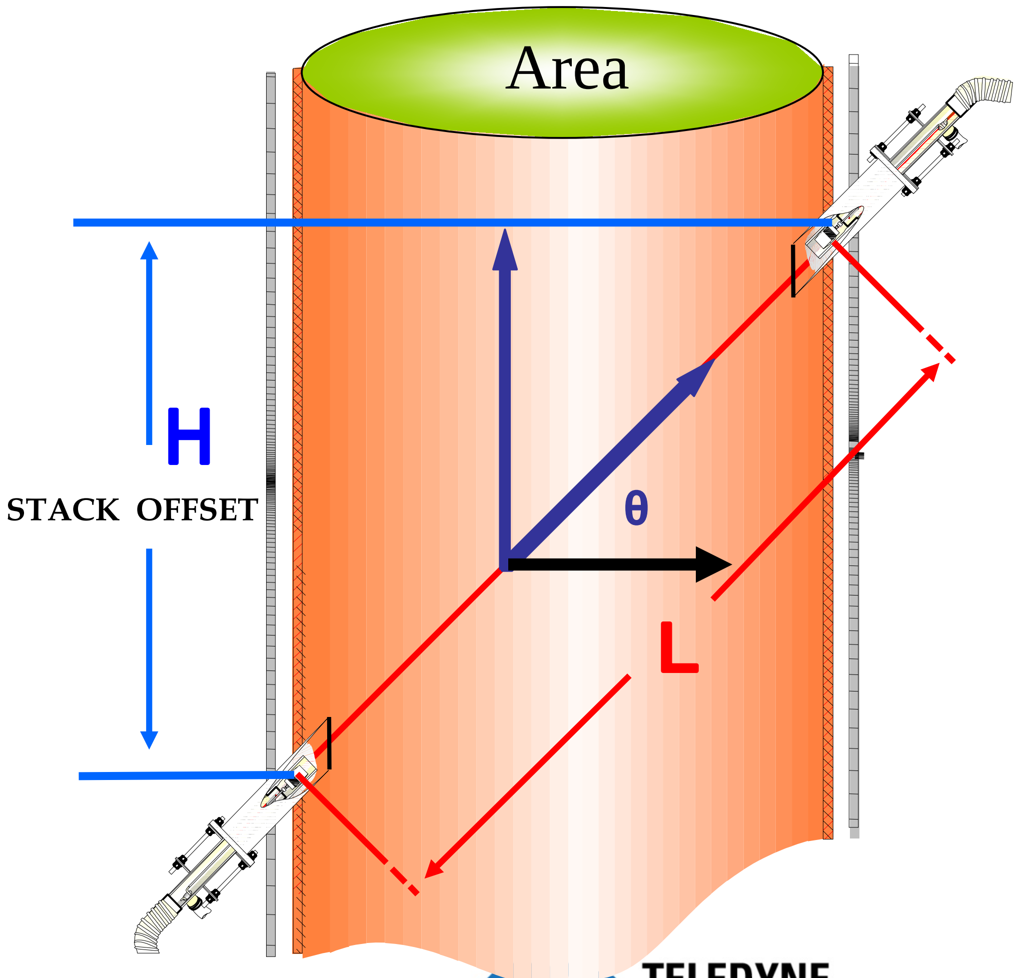
Stack Geometry

- L = Pathlength

Transducer to Transducer

- H = Offset
- Area = Cross Sectional Area
- θ= Angle; <45°



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RELIABILITY CONCERNS

Utility smokestacks are harsh environments:

-Hot /Dry scrubbed or unscrubbed stacks

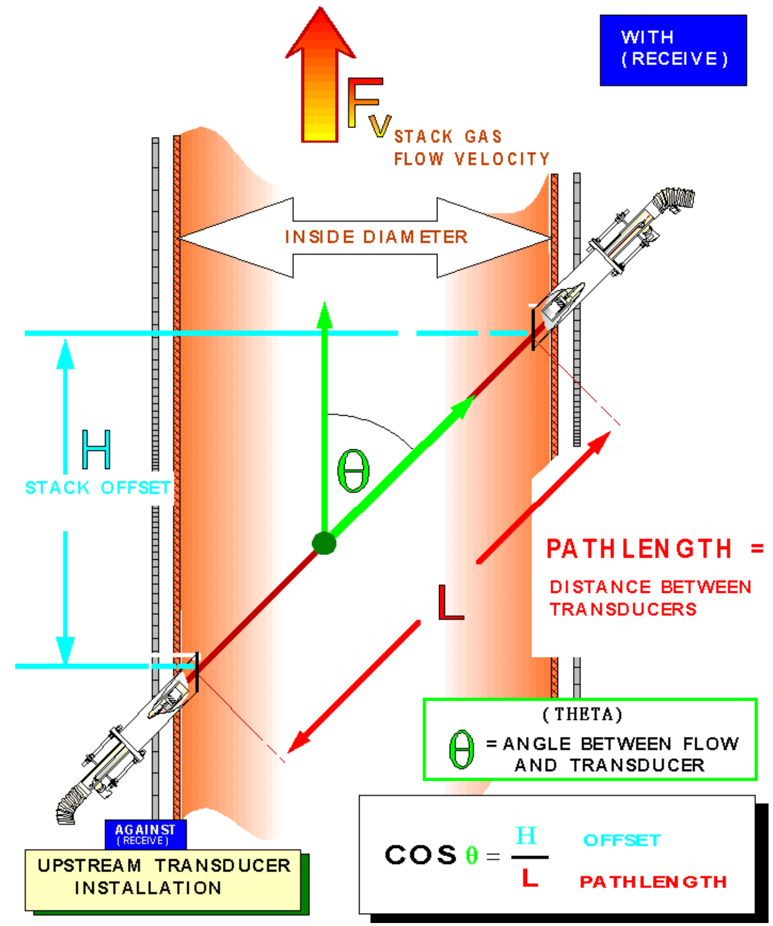
-Cool/Wet scrubbed stacks

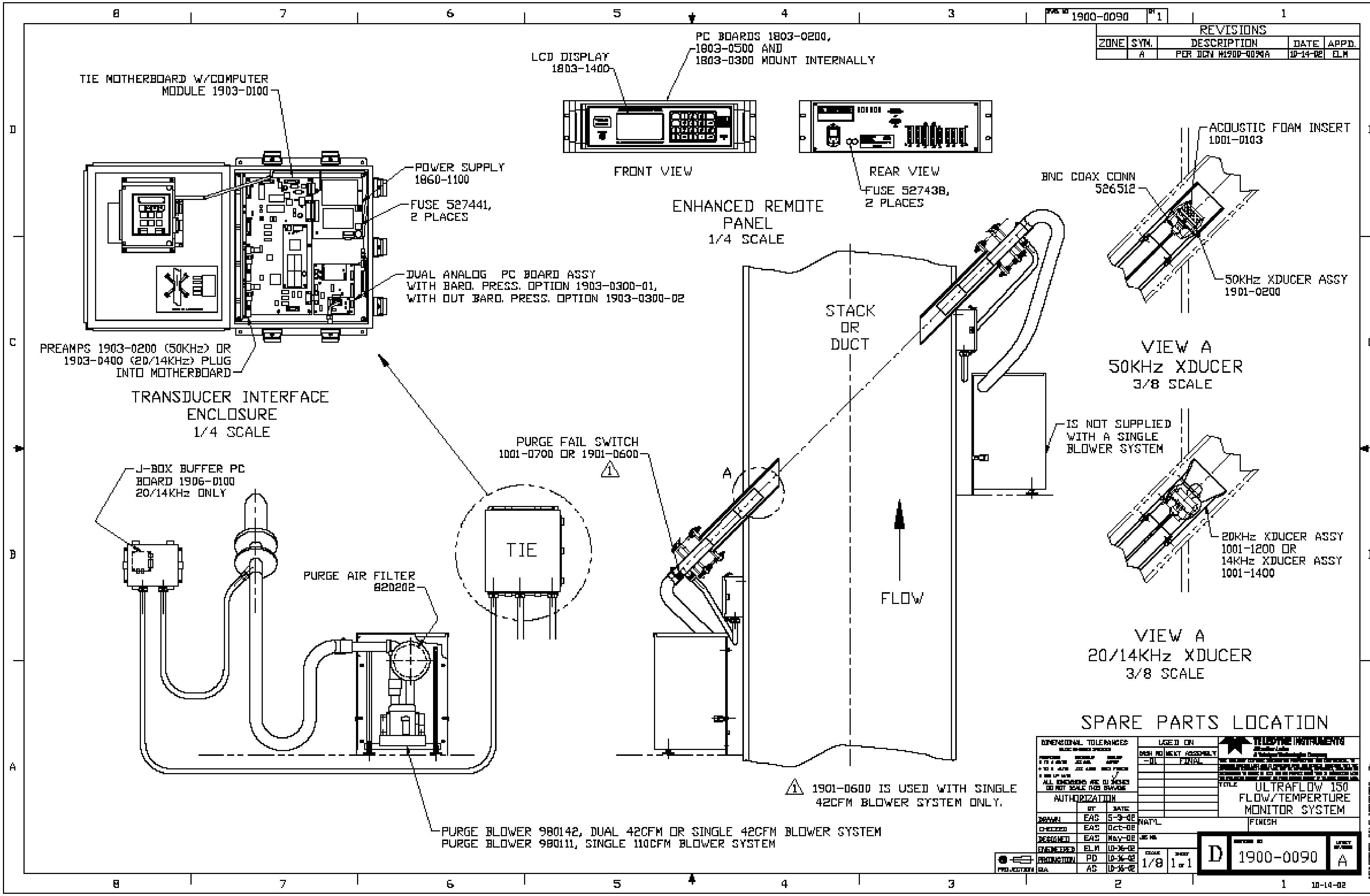
-Corrosive gases present (SO2)

-THEY ARE BIG……..diameter & height

Limitations of Ultrasonic Flow

- Typical Installation:
  - θ ≥45° angle but depends on:
    - pitch angle
    - # diameters down
    - # flues feeding the stack
    - Gas temperature
    - Gas velocity
  - **Need** Vertical Offset (H) to be No Less Than 4-5 Ft.
  - Max. Temp 850°F
  - Min. Diameter 3 Ft.
  - Max Diameter 45 Ft.





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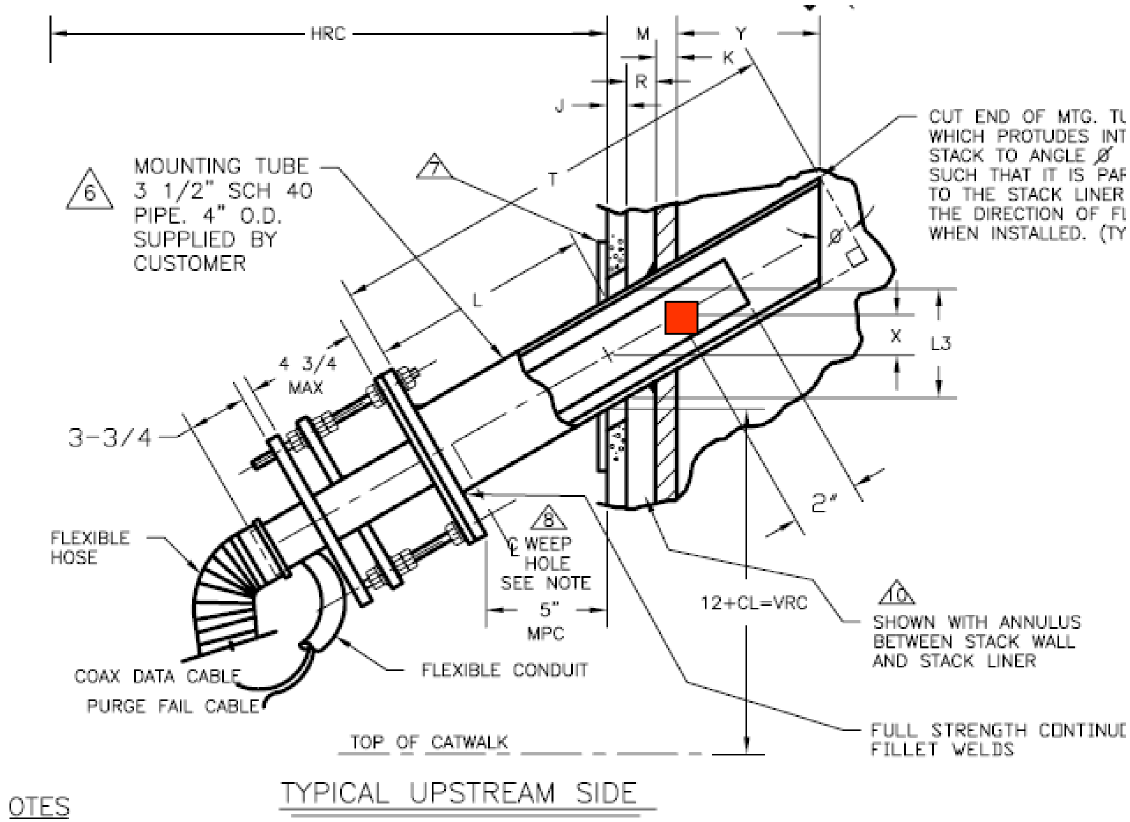
Typical Transducer Installation



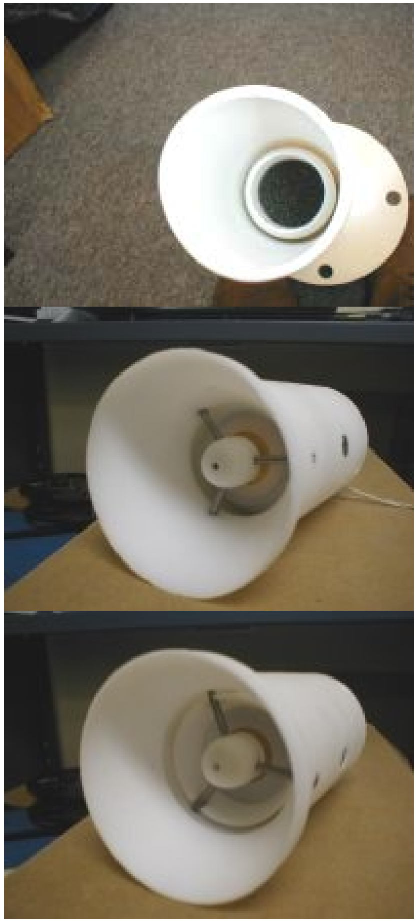
Y = 3" on Stacks <10' dia.

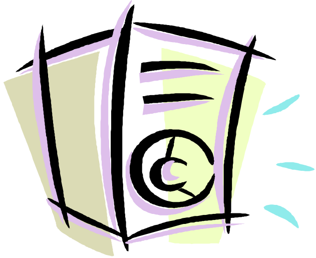
Y = 6" on Stacks >10' dia.

Transducer Types

- Short Range
  - 50Khz Electrostatic
- Long Range
  - 20Khz Piezo Electric
- Extended Long Range
  - 14Khz Piezo Electric
- Select based on stack dia., max temp, and max velocity

- Lower Frequency Provides MORE Power





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Ultrasonic Flow Monitor

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Believable Concerns

Inherent accuracy of time-of-flight technology

Wall effects, Pitch, Swirl, Multiple Units feeding a common stack

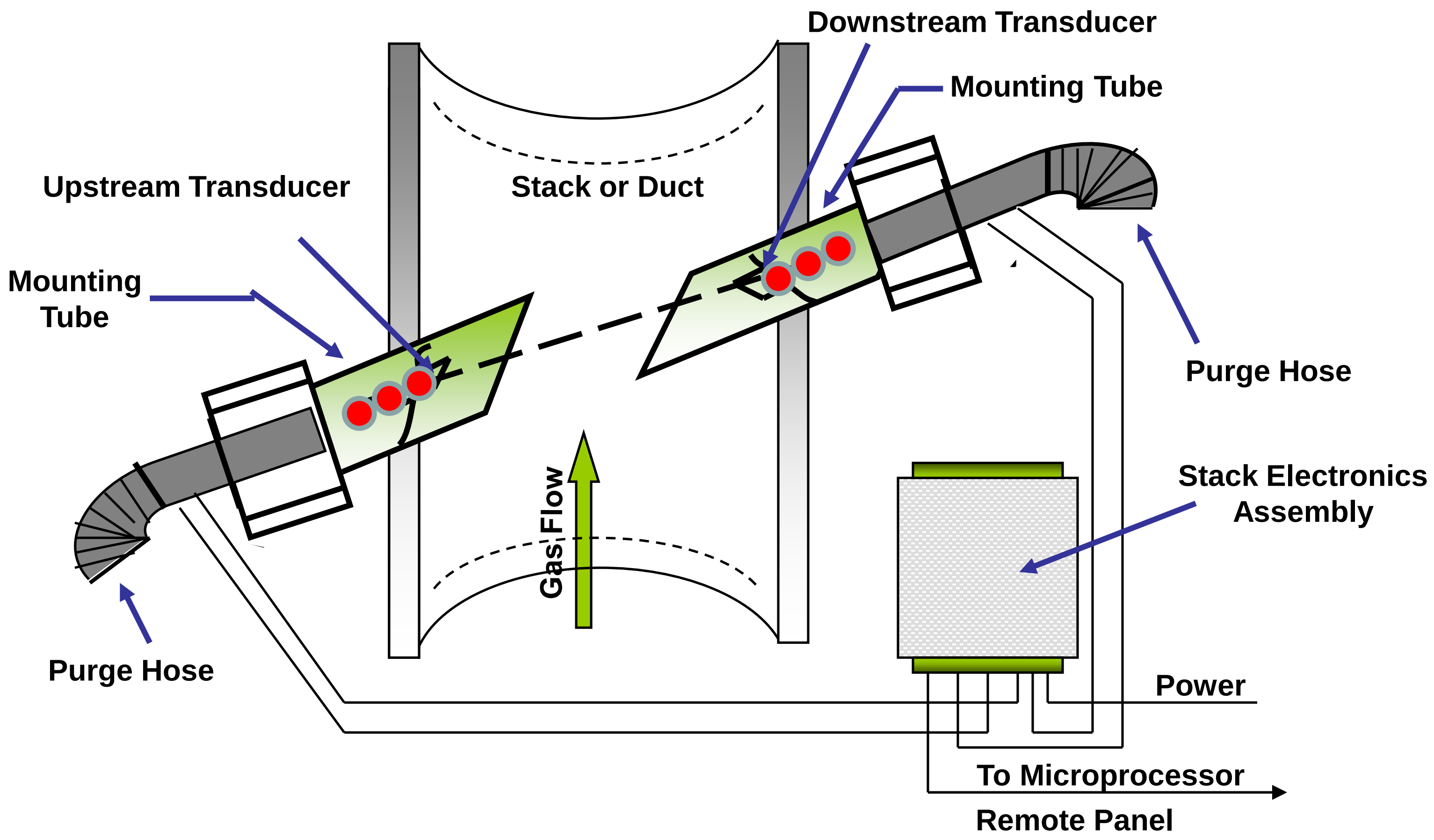
RELATIVE Accuracy……….

Overview

- **How Does the Ultrasonic flow monitor Work to Calculate Velocity ?**
  - Tone bursts (Sound) are transmitted from the upstream transducer to the downstream transducer and then visa versa
  - Tone bursts are transmitted approximately every 30 milliseconds in this alternating fashion (33/sec)
  - The number of tone bursts sent in each direction is programmable (response time <5.0 seconds)
  - The large # of tone bursts enhances accuracy, i.e., a larger statistical sample

Ultrasonic Flow Installation

Typical Installation



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Time of Flight Principle

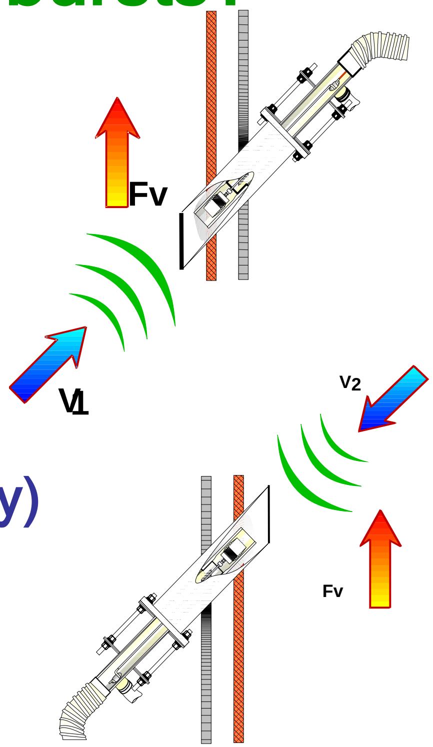
- What are the governing equations that model the time-of-flight of the tone bursts?

Velocity (With Gas Flow)

$$V1 = Cs + Fv \cos\theta$$ (added velocity)

Velocity (Against Gas Flow)

$$V2 = Cs - Fv \cos\theta$$ (subtracted velocity)



- Where
  - Cs is the speed of sound
  - Fv is Nominal flow velocity up stack
  - Ø is the angle of installation

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Velocity (Fv) Calculations

- Cs falls out of the subtracted equations
- Substitute Pathlength/Time for V_1 & V_2

$$Fv = \frac{L/t_1 - L/t_2}{2(\cos\theta)}$$

- Rearrange

$$Fv = \boxed{\frac{L}{2(\cos\theta)}}\left[\frac{t_2 - t_1}{t_1 t_2}\right]$$

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Believable Concerns

Statistical average over time (adjustable response time) leads to accurate flow measurement. Typically 1-5 minutes

Multiple transducers used for mitigation of flow anomalies in stacks (X-Pattern Config.)

Continuous Concerns

Non-Intrusive nature leads to long mean time before failure.

Mitigate the effects of condensing moisture in wet scrubbed stacks. "Weep Holes"

Blower Maintenance to maintain system performance

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Field Experience with Ultrasonic

Port Alignment within 1-2 degrees

Consider a “Link-Rod” assembly for large annulus spaces.

Error on the side of a “larger than needed” flow port. Inserts are available!

Field Experience with Ultrasonic

Temperature and pressure will be needed for SCFM calculation. From the monitor or from external devices/inputs.

Safe and accessible mounting locations with "decent" air available for blower intakes.

Questions?

Thank you!

Don Giel

Teledyne Monitor Labs, Inc.