Multipath Ultrasonic Flow Monitoring Systems

- Ultrasonic Flow Monitoring Fundamentals
- Installation Considerations
- Multipath Configurations
- Advantages of Each Configuration

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Ultrasonic Flow Monitor

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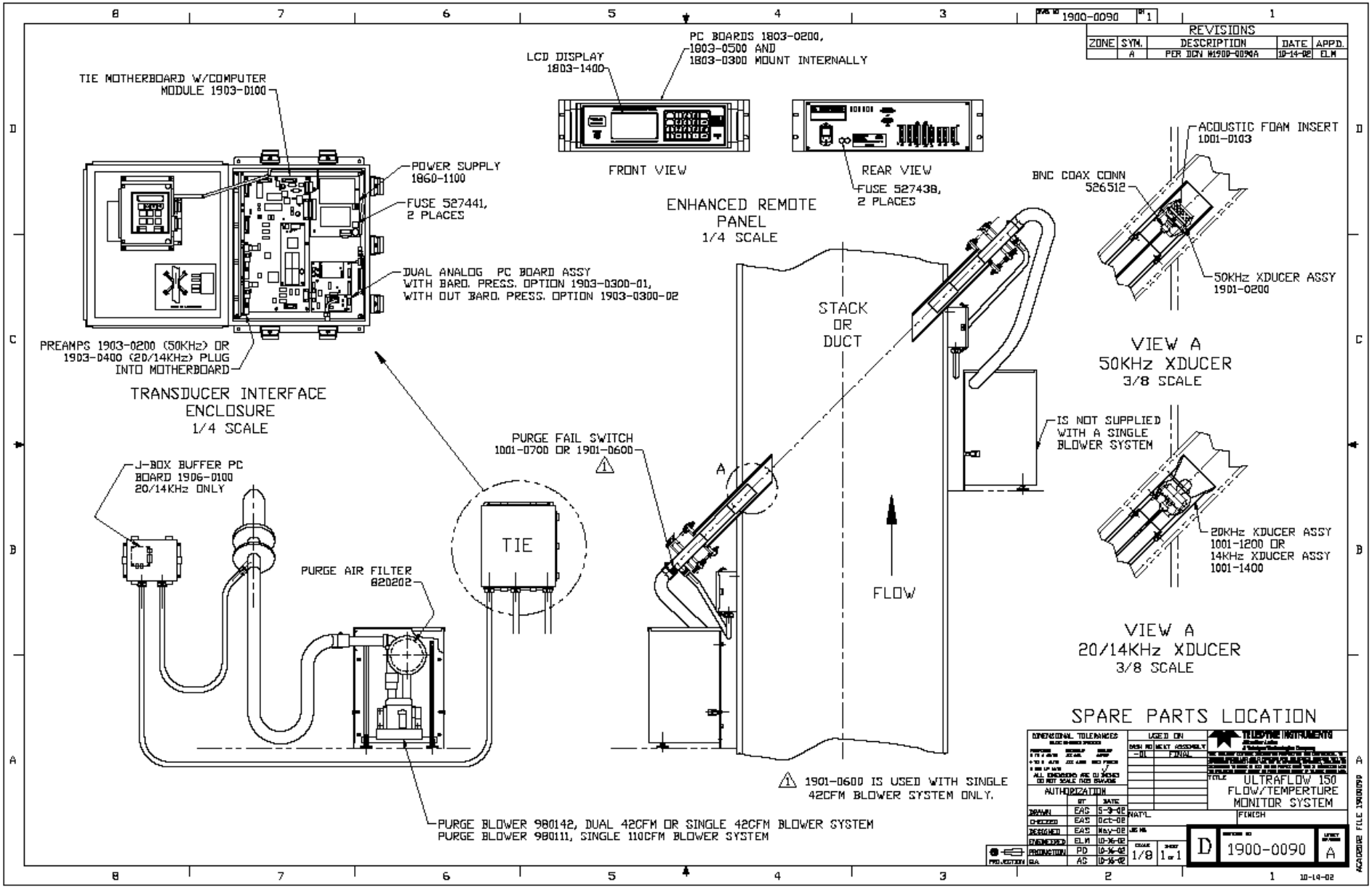

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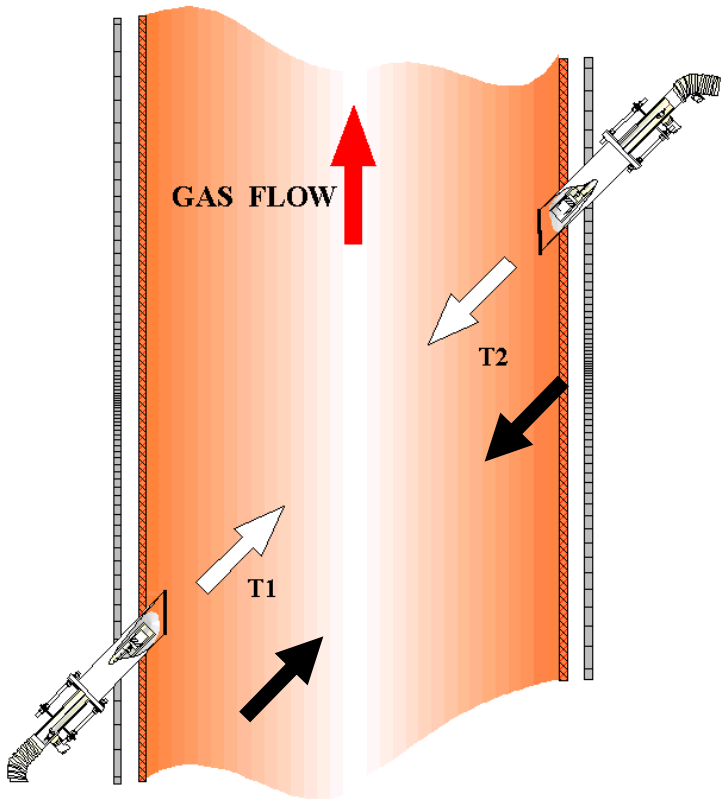
Overview

- 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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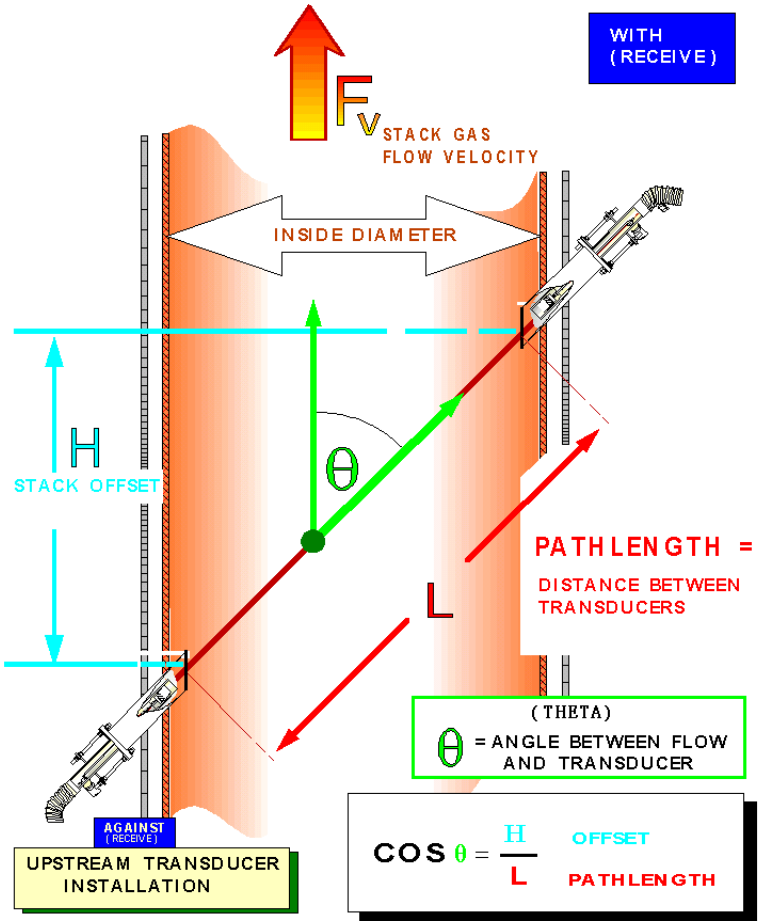
Stack Geometery

- **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 650°F
  - Min. Diameter 3 Ft.
  - Max Diameter 45 Ft.



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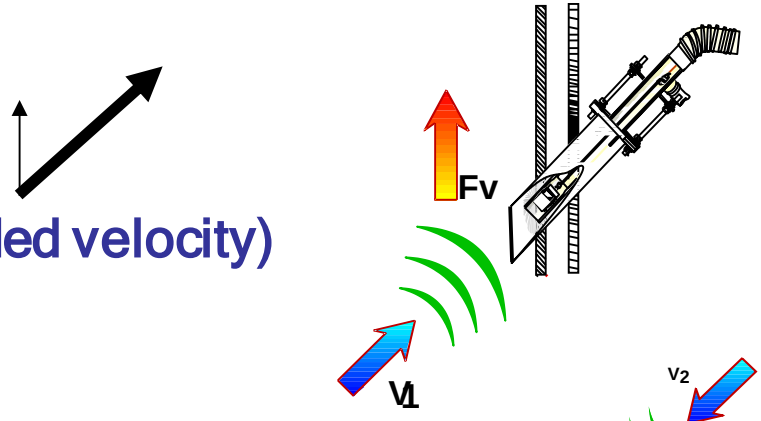
Time of Flight Principle

- 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

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

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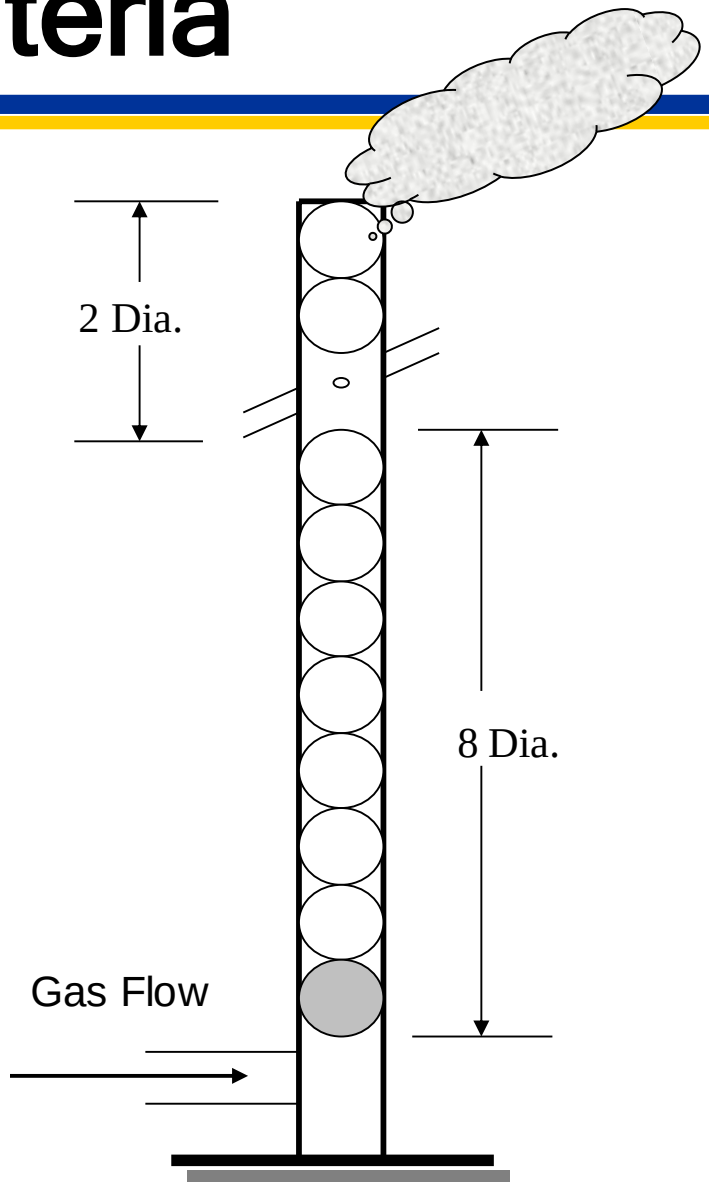
General Criteria

- **Measurement Location**
  - **In general**
    - 8 Duct Diameters downstream and 2 duct diameters upstream from flow disturbance
    - Usually pass the resultant Angle test of <20°
- **For Rectangular Ducts**
    - De = 2LW/(L+W)



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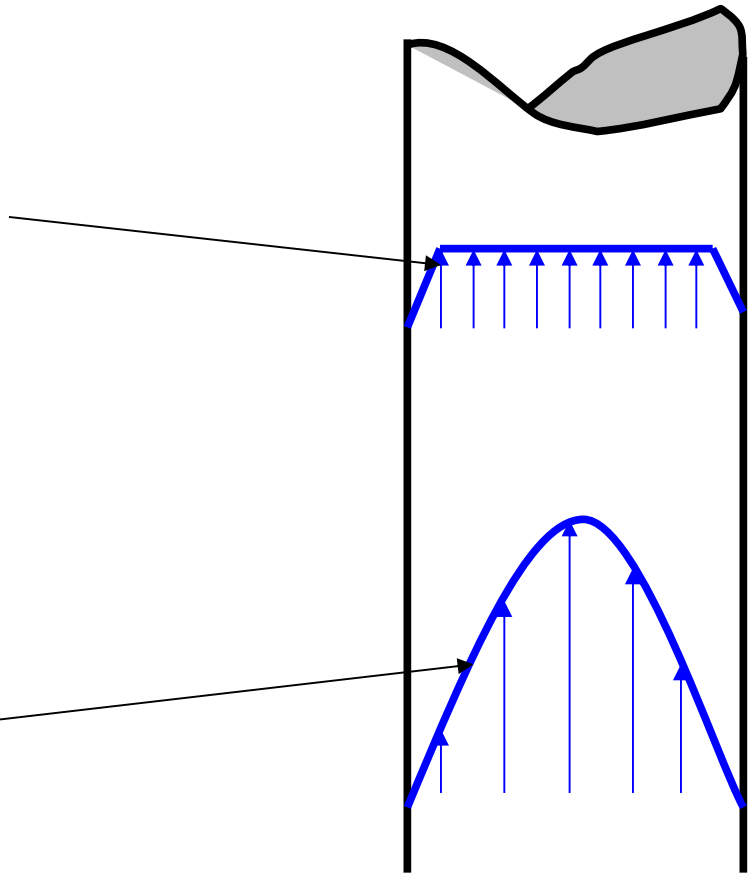
General Criteria

- Flow monitor is installed where **fully developed turbulent flow** is present;
  - Reynolds # > 4000

    Re = Dia.x Vel / μ
    - Where μ is kinematic viscosity
    - $\mu = 27.3 \times 10^{-5}$ ft^2/sec for air @ 250°F
- Rarely is flow laminar



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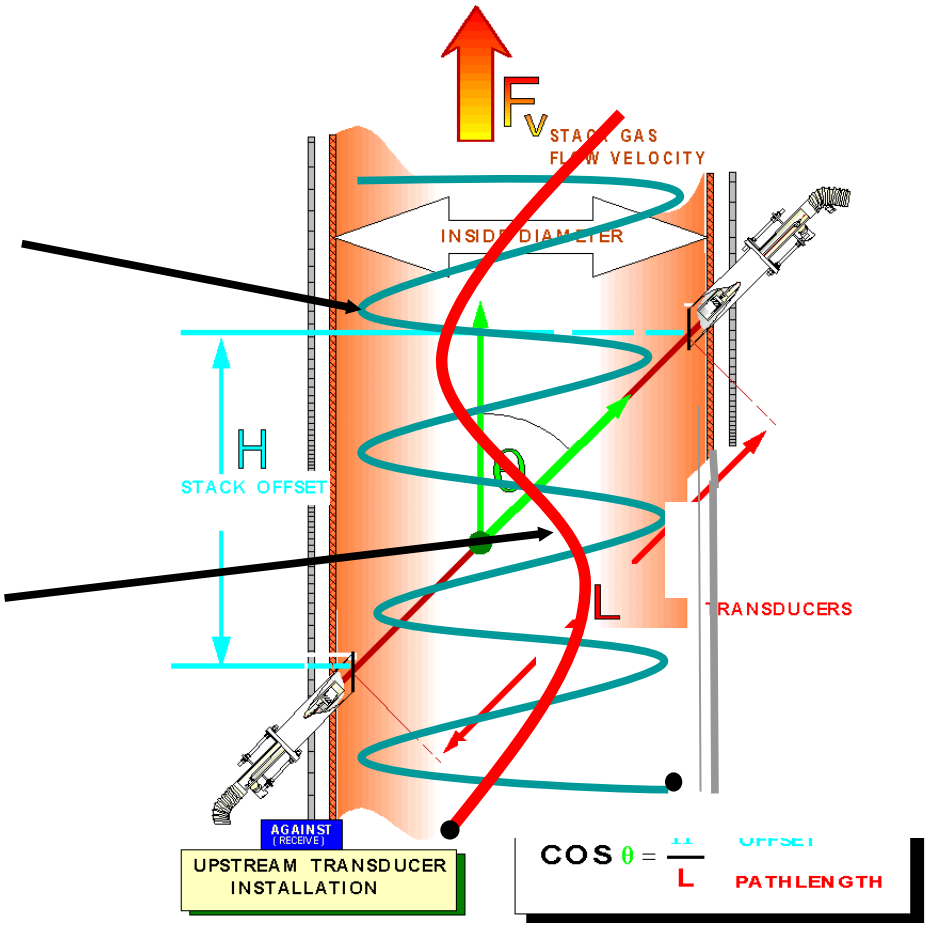
Non-axial Flow Patterns

- There Are Two Types:
  - Cyclonic Flow is the whirlwind pattern
  - Pitch Flow is the fishtail pattern

(*) Note: Cyclonic Flow Has No Impact on Flow Calculations In Most Cases



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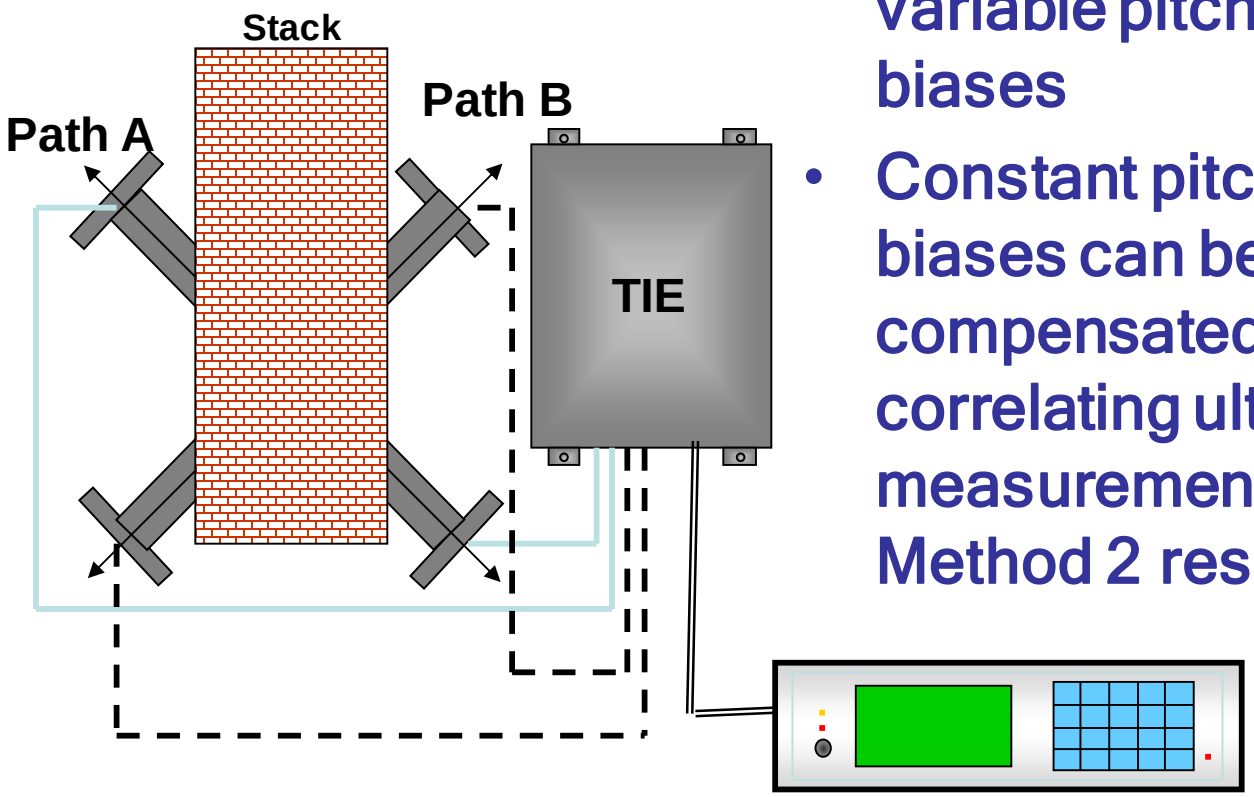
True X-Pattern



- Used to cancel out variable pitched flow biases
- Constant pitched flow biases can be compensated for by correlating ultrasonic measurement to EPA Method 2 results

Enhanced Remote Panel

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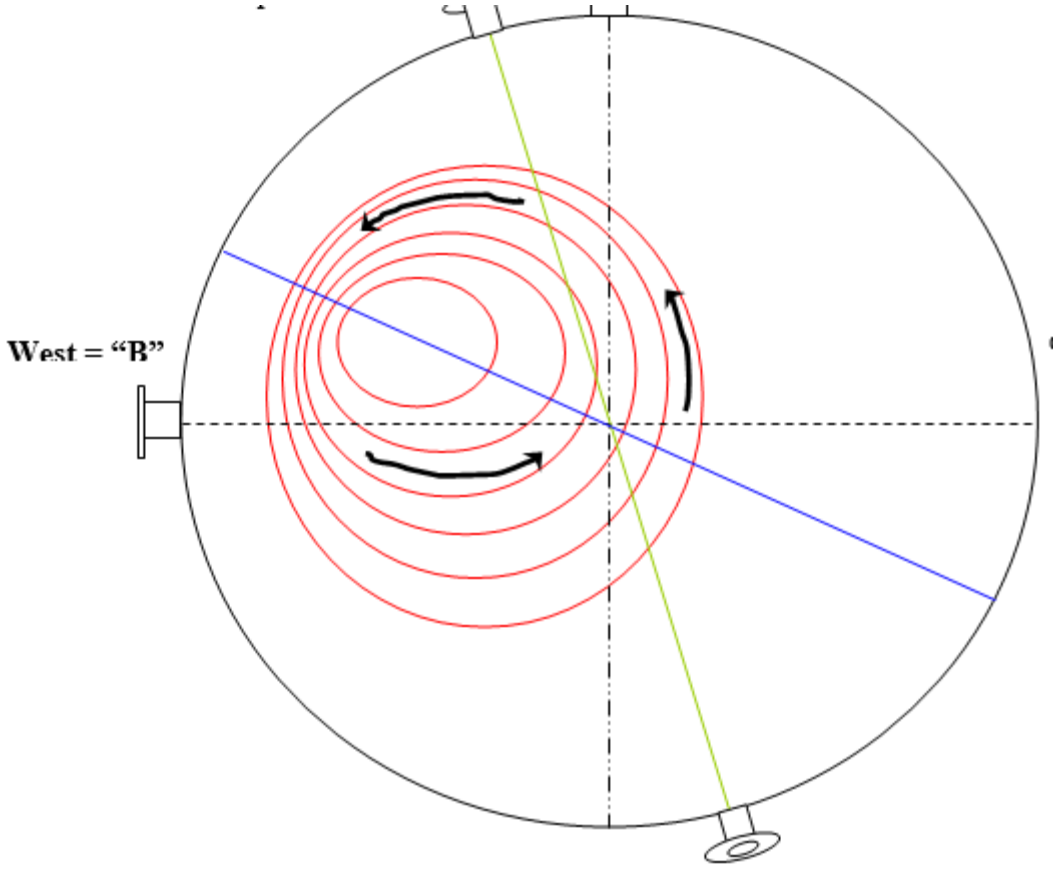
Case Where Ultrasonic Measurement is Not Immune to Cyclonic Flow

- Cyclonic flow does become a problem when the axis of the cyclone is not concentric with the stack centerline.
- Remedied by installing the measurement path directly through the cyclone or installing a true X-pattern



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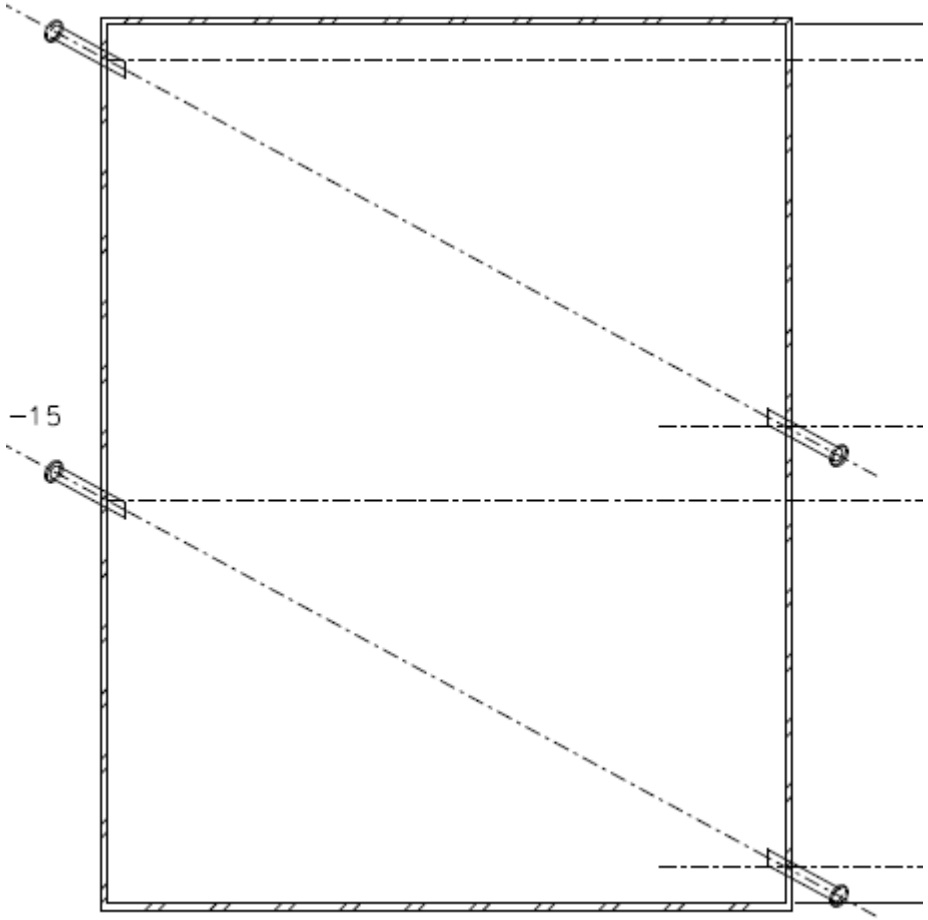
Two Independent Compound Angle Measurement Paths

- Multiple paths used to get a more representative sample of the duct.
- Certified flow measurement is an average of the two paths

[Attachment_2_CEMS_Ports_Revised_Layout_3D_R4_No_Platform.pdf]



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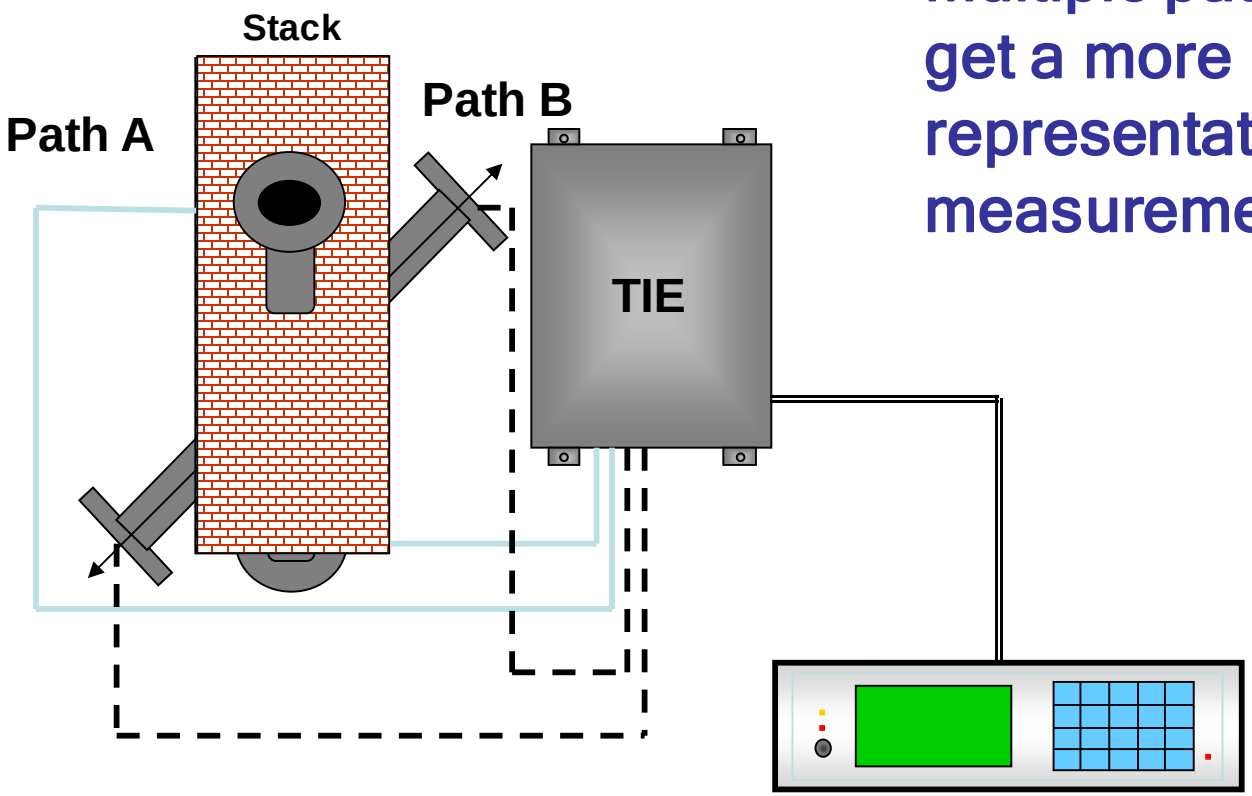
Lazy X-Pattern



- Multiple paths used to get a more representative measurement

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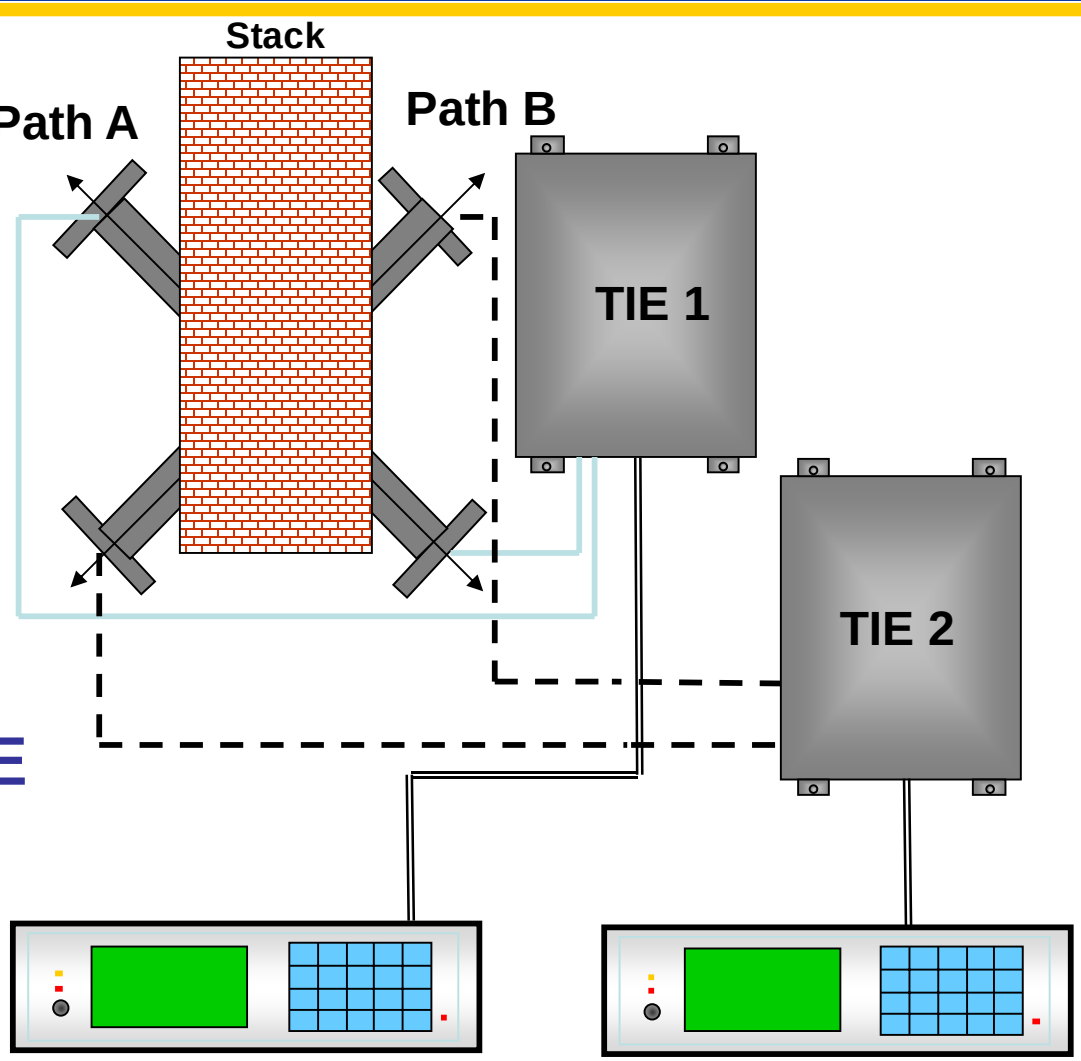
Redundancy

- Usually uses a true X-pattern
- Each measurement path is certified independently
- The degree of redundant assets is flexible
- Can use one or two TIE boxes
- Can use one or two ERPs



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