Multipath Ultrasonic Flow Monitoring Systems

- Ultrasonic Flow Monitoring Fundamentals
- Installation Considerations
- Multipath Configurations
- Advantages of Each Configuration
Ultrasonic Flow Monitor
• **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
Stack Geometry

- **Typical Installation:**
  - $\theta \geq 45^\circ$ 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.

- Max Diameter 45 Ft.
Time of Flight Principle

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

Velocity (With Gas Flow)

$$V_1 = Cs + Fv \cos \theta$$  (added velocity)

Velocity (Against Gas Flow)

$$V_2 = Cs - Fv \cos \theta$$  (subtracted velocity)

- Where
  - $Cs$ is the speed of sound
  - $Fv$ is Nominal flow velocity up stack
  - $\theta$ is the angle of installation
Velocity (Fv) Calculations

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

\[
F_v = \frac{L/t_1 - L/t_2}{2(\cos \theta)}
\]

- Rearrange

\[
F_v = \frac{L}{2(\cos \theta)} \left[ \frac{t_2 - t_1}{t_1 t_2} \right]
\]
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
  - $De = \frac{2LW}{L+W}$
General Criteria

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

\[ \text{Re} = \frac{\text{Dia.} \times \text{Vel}}{\mu} \]

• Where \( \mu \) is kinematic viscosity
  • \( \mu = 27.3 \times 10^{-5} \) ft\(^2\)/sec for air @ 250°F

• Rarely is flow laminar
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
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
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.
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
Lazy X-Pattern

- Multiple paths used to get a more representative measurement
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