Practical Experience with CEMS Measurement

Challenges Associated with making:

Reliable
Believable
CONTINUOUS

Flow Measurements in Large Utility Stacks
Ultrasonic Flow Monitor
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
Stack Geometry

- $L =$ Pathlength Transducer to Transducer
- $H =$ Offset
- Area = Cross Sectional Area
- $\theta =$ Angle; $< 45^\circ$
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:**
  - $\theta \geq 45^\circ$ 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 850°F
  - Min. Diameter 3 Ft.
  - Max Diameter 45 Ft.
Typical Transducer Installation

Y = 3” on Stacks <10’ dia.
Y = 6” on Stacks >10’ dia.

MOUNTING TUBE
3 1/2” SCH 40 PIPE. 4” O.D.
SUPPLIED BY CUSTOMER

FLEXIBLE HOSE
COAX DATA CABLE
PURGE FAIL CABLE
FLEXIBLE CONDUIT

TOP OF CATWALK
FULL STRENGTH CONTINUOUS FILLET WELDS

OTES

TYPICAL_UPSTREAM_SIDE
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
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

- Stack or Duct
- Upstream Transducer
- Mounting Tube
- Downstream Transducer
- Mounting Tube
- Purge Hose
- Stack Electronics Assembly
- Power
- To Microprocessor
- Remote Panel
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
  • \( \theta \) 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

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

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