

# Reinhold Environmental Ltd.



2008 APC Round Table  
& Expo Presentation

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# Flow and Emissions Testing

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# Outline

- ❖ Introduction
- ❖ Flow Testing Methodology
- ❖ Emissions Testing
- ❖ Field Test Case Studies
- ❖ Questions



# Introduction

## ❖ Why are Flow Characteristics Important to Power Plant Equipment?

- Performance
  - Flow uniformity
  - Chemical species or particulate injection
  - Combustion optimization
  - Ash capture / build-up
- Operating costs
  - Pressure drop
  - Injected chemical or solids cost
- Maintenance issues
  - Erosion
  - Corrosion
  - Pluggage
  - Vibration



# Introduction

## ❖ How Can Field Testing Help?

- Velocity/Temperature Traverses

- Determine flow uniformity
- Highlight problem flow areas
  - Temperature stratification
  - Low velocity regions
  - High velocity regions
  - Flow imbalance
  - Coal pipe balance

- Gas Sampling

- Boiler combustion optimization
- Inleakage assessment
- AIG performance evaluation/tuning

- Performance Testing



# Outline

- ❖ Introduction
- ❖ Flow Testing Methodology
  - Objectives
  - EPA Methods
  - Other Tests
- ❖ Emissions Testing
- ❖ Field Test Case Studies
- ❖ Questions



# Flow Testing Objectives

## ❖ Air and Gas Ductwork

- Velocity, temperature, pressure
- Particulate sampling, species concentration

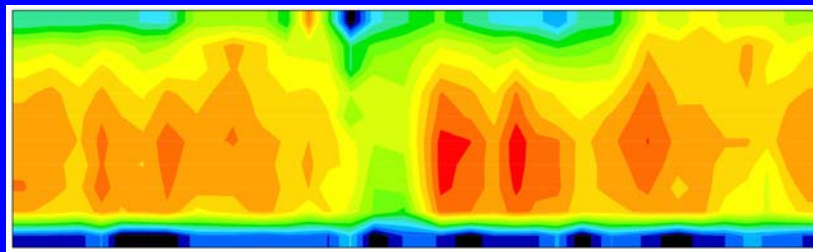


## ❖ ESP Collection Region

- Velocity distribution

## ❖ Fabric Filter Compartments

- Flow balance, peak velocities



# EPA Testing Methods (40 CFR Part 60)

## ❖ Method 1

- Test port installation advice

## ❖ Method 2, 2FGH

- Velocity, temperature, pressure, flow rate
- S-probe or 3D probe

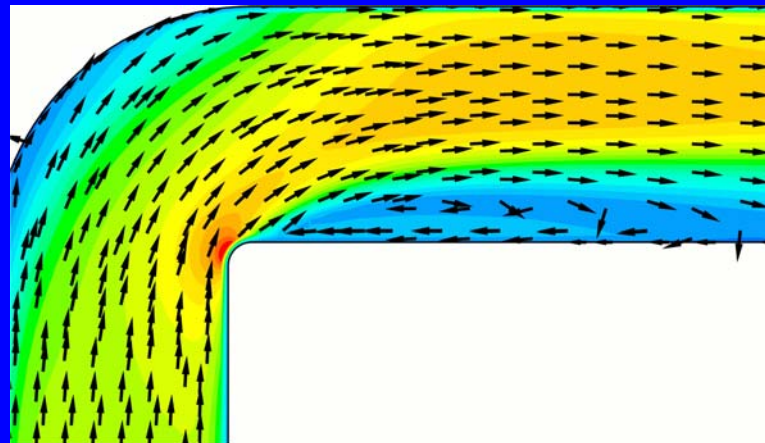


# EPA Testing Methods (40 CFR Part 60)

## Method 1: Sample and Velocity Traverses for Stationary Sources

### ❖ Test Port Location

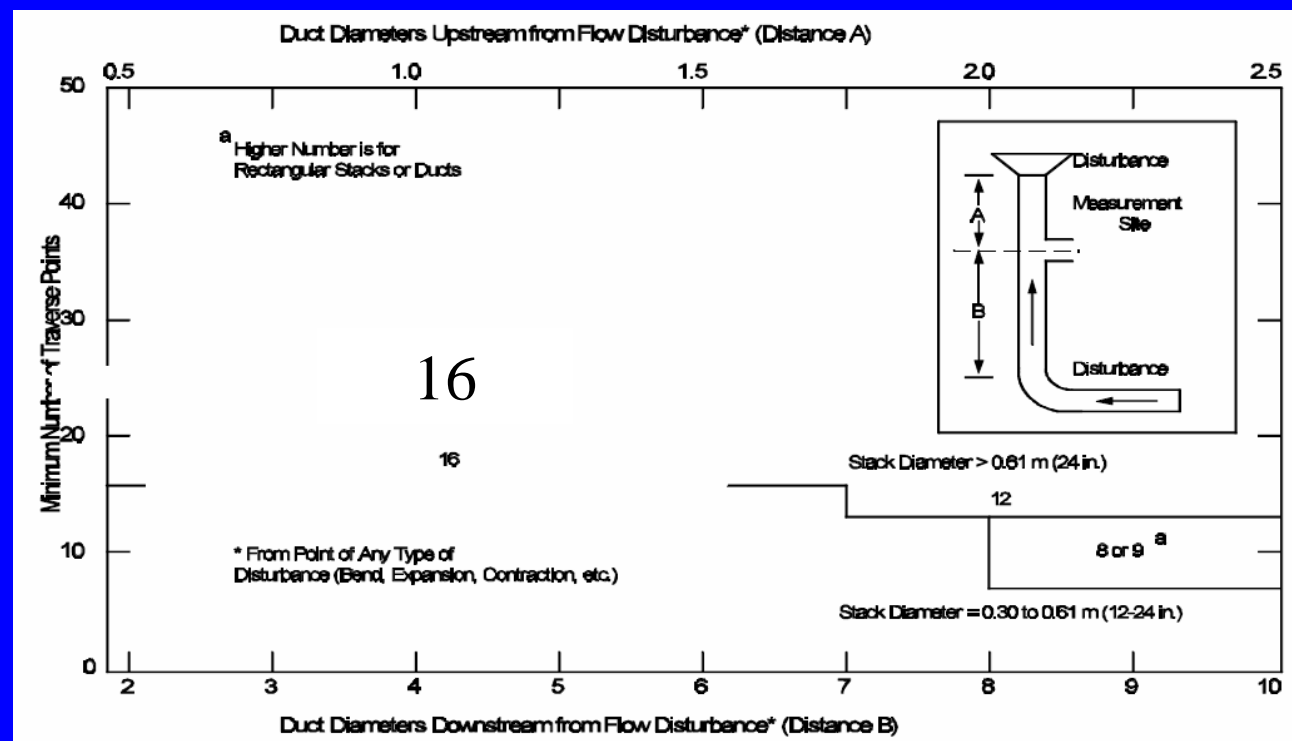
- Test ports located sufficiently far from a flow disturbance (bend, baffle, expansion, contraction, etc.)
- $> 8$  diameters downstream of disturbance
- $> 2$  diameters upstream of disturbance



# EPA Testing Methods (40 CFR Part 60)

## ❖ Method 1 – Traverse Point Determination

- Minimum number of traverse points specified via chart
- Number of points dependent on location relative to flow disturbances



# EPA Testing Methods (40 CFR Part 60)

## ❖ Method 1 – Traverse Point Determination

- The Method provides a recommendation of the **MINIMUM** number of traverse points to use
- Industry standard is to use a number of points according to:

$$1.5\sqrt{A}$$

where  $A$  is the duct cross-sectional area in  $\text{ft}^2$

Examples:

20 ft x 20 ft duct

Method 1: 16 points,      Formula: 30 points

40 ft x 60 ft duct

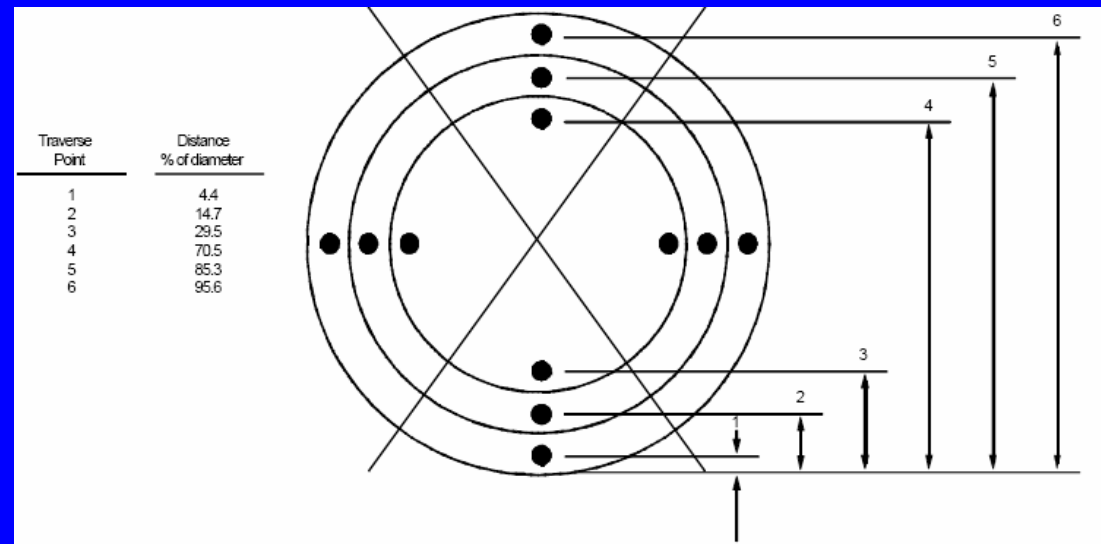
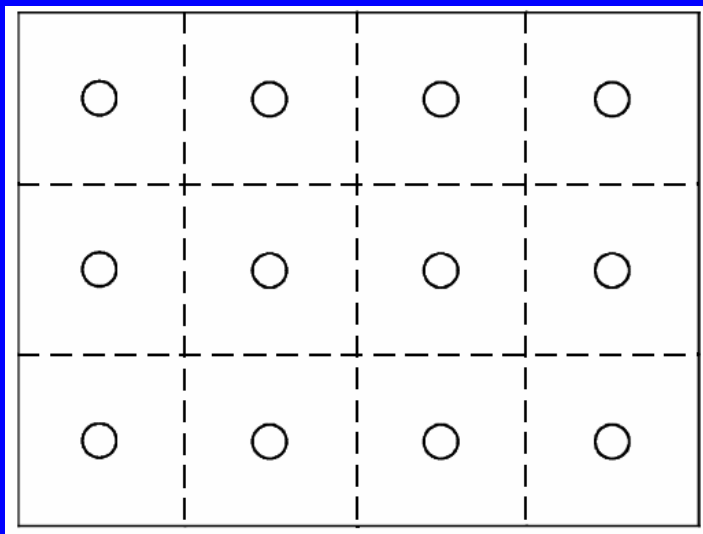
Method 1: 16 points,      Formula: 72 points



# EPA Testing Methods (40 CFR Part 60)

## ❖ Method 1 – Traverse Point Location

- Each traverse point located at the centroid of equal-area sectors
- Traverse point distances determined based on a table look-up, or an equivalent formula



- Method 1 based on equal area traverse points
- If you don't have equal areas, you must integrate properly or use area-weighted stats.

# EPA Testing Methods (40 CFR Part 60)

## ❖ Method 2: Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)

- S Probe used versus a standard pitot which is more prone to plugage where flyash or other particulate is present
- Traverses performed at location as specified in Method 1
- Gas velocity determined from the gas density, pressure measurement, and pitot calibration coefficient



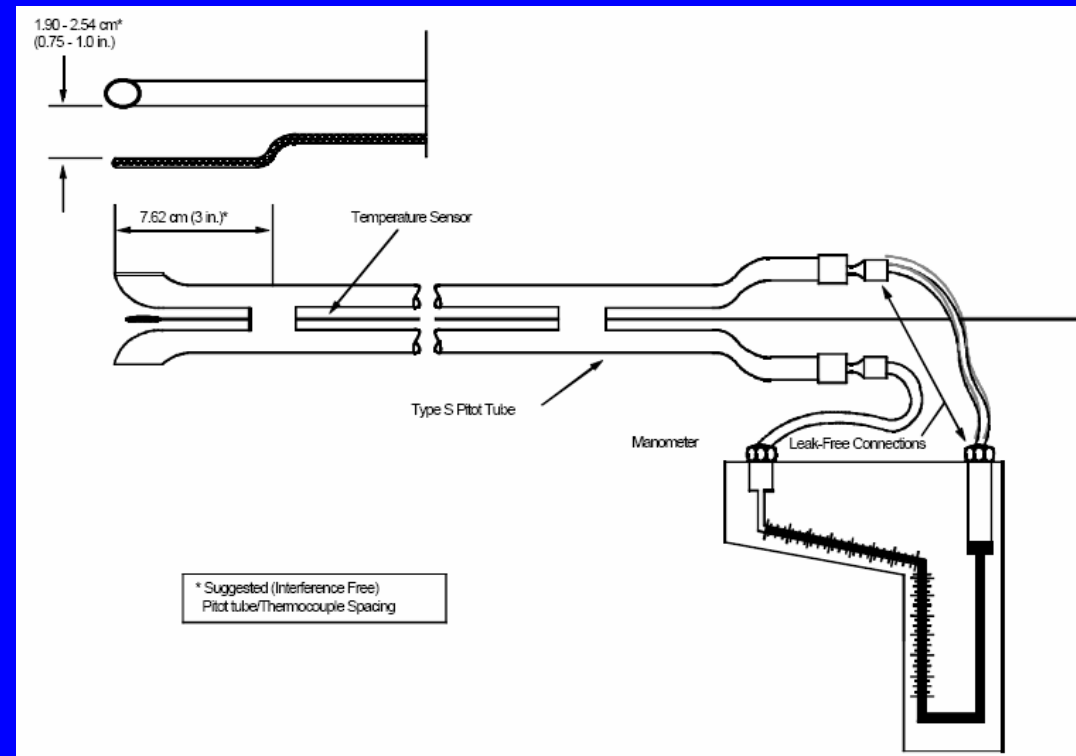
# EPA Testing Methods (40 CFR Part 60)

## ❖ Method 2 – Test rig consists of;

- Manometer (oil or digital) with proper scale and accuracy
- Thermocouple
- Thermocouple reader
- S Probe

## ❖ Procedure

- Position probe tip at proper traverse point
- Pressure differential measured between P1 and P2



# EPA Testing Methods (40 CFR Part 60)

- ❖ Method 2FGH: Three Methods for Velocity and Volumetric Flow Rate Determination in Stacks or Ducts
  - 2F – 3D probes
  - 2G – 2D probes with angularity
  - 2H – Near wall velocity decay (Round ducts)



# EPA Testing Methods (40 CFR Part 60)

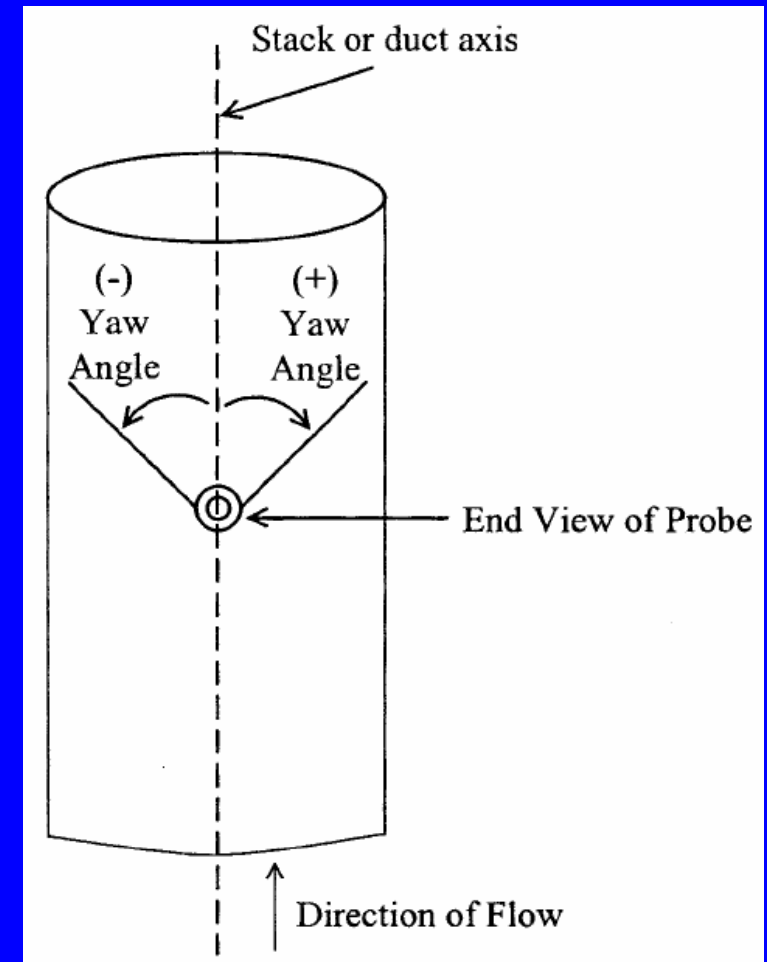
## ❖ Method 2G: Determination of Stack Gas Velocity and Volumetric Flow Rate With Two-Dimensional Probes

- 2D probes with angularity
- S Probe is “nulled” in order to determine the yaw angle of the flow
- Often used in RATA testing
- Correctly defining the velocity components results in more accurate axial velocity readings in stacks with high flow angularity



# EPA Testing Methods (40 CFR Part 60)

- ❖ Method 2G – Test rig consists of;
  - All equipment required for Method 2
  - Inclinator to measure angle of probe



# EPA Testing Methods (40 CFR Part 60)

## ❖ Method 2G– Test Procedure

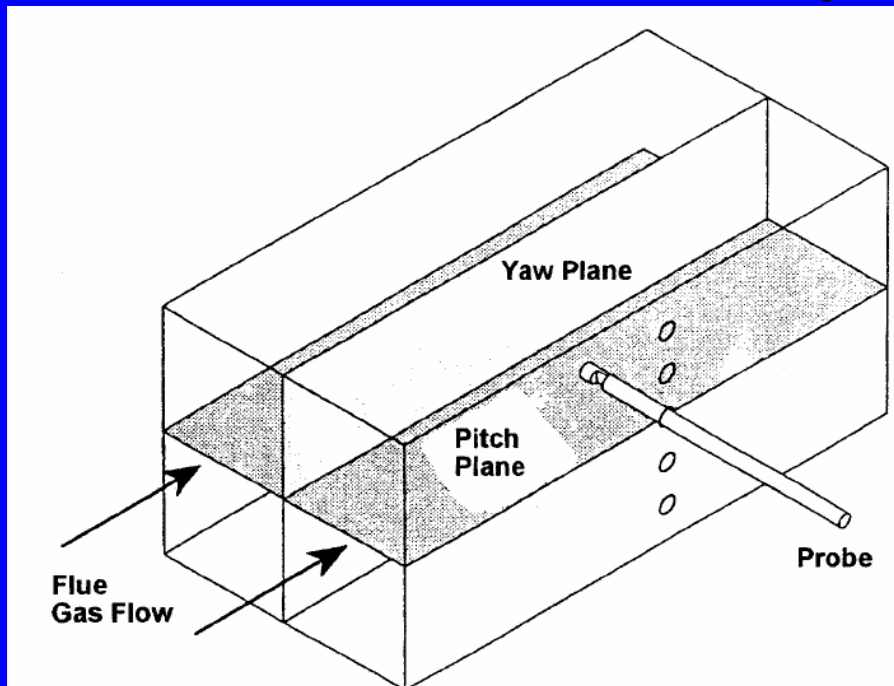
- Probe head is positioned at the proper traverse point
- Pressure differential measured between P1 and P2
- Probe is rotated until  $P1=P2$  (“nulled”), this is the flow yaw null angle
- The probe is then rotated 90 degrees to the true flow aligned angle and the P1-P2, velocity pressure, is recorded at this angle



# EPA Testing Methods (40 CFR Part 60)

## ❖ Method 2F: Determination of Stack Gas Velocity and Volumetric Flow Rate With Three-Dimensional Probes

- 5-hole prism or spherical head probe
- Can determine axial, yaw, and pitch velocity components



# EPA Testing Methods (40 CFR Part 60)

## ❖ Method 2F– Test rig consists of;

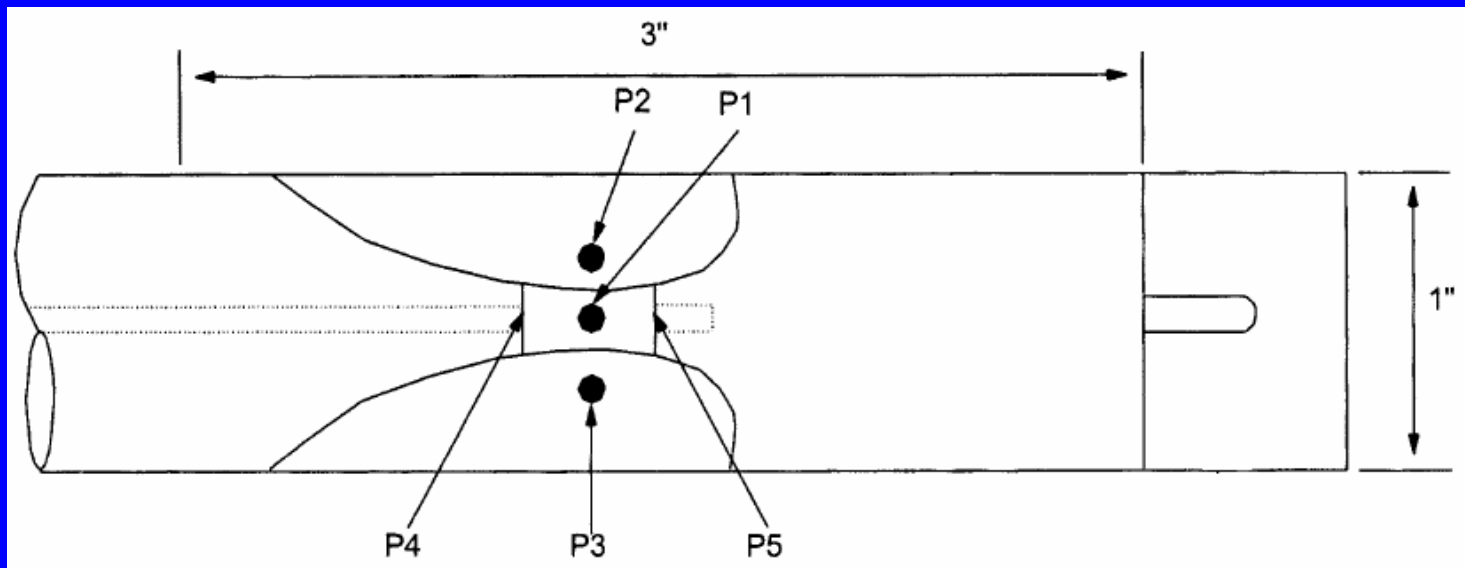
- Manometer(s) (oil or digital) with proper scale and accuracy
- Inclinator to measure probe angle
- Thermocouple
- Thermocouple reader
- 3D probe



# EPA Testing Methods (40 CFR Part 60)

## ❖ Method 2F– Test Procedure

- Probe head is positioned at the proper traverse point
- Pressure differential measured between P2 and P3
- Probe is rotated until  $P2=P3$  (“nulled”)
- This is the true flow aligned angle and the P1-P2, velocity pressure, and P4-P5, pitch pressure, are recorded at this angle



# EPA Testing Methods (40 CFR Part 60)

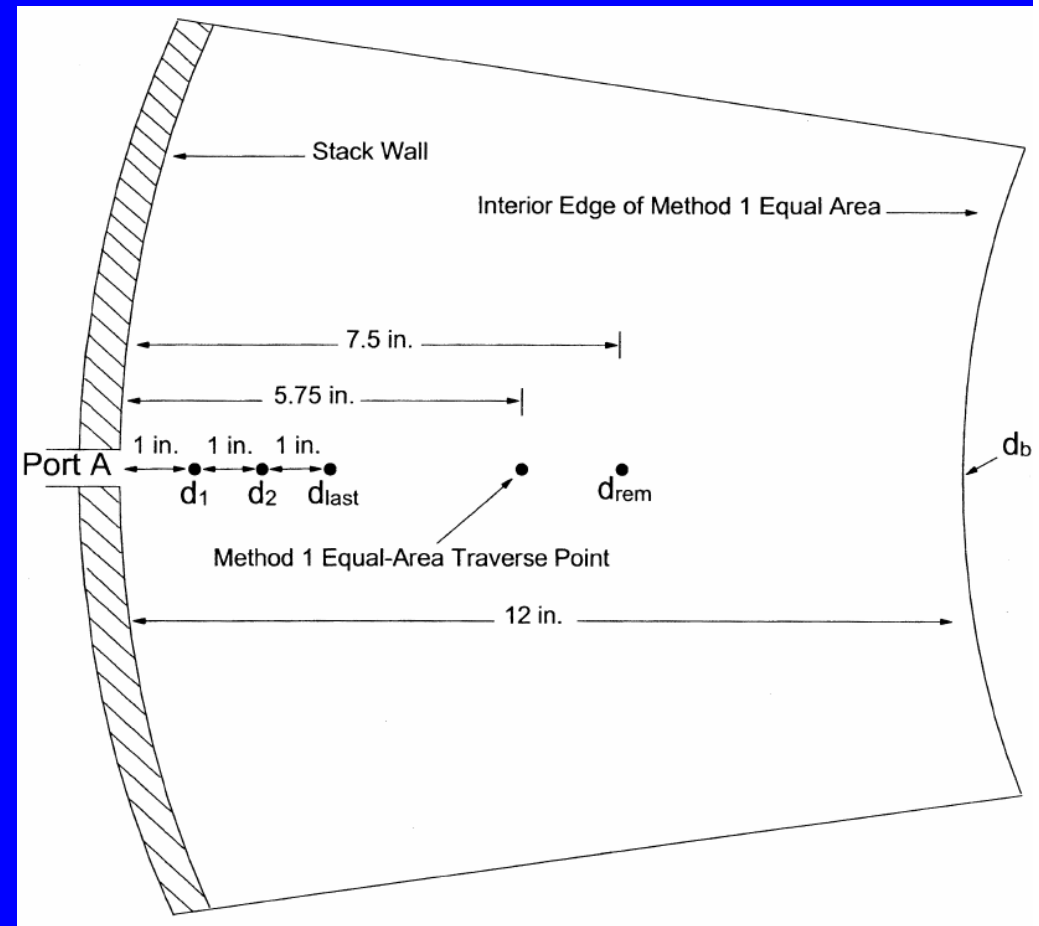
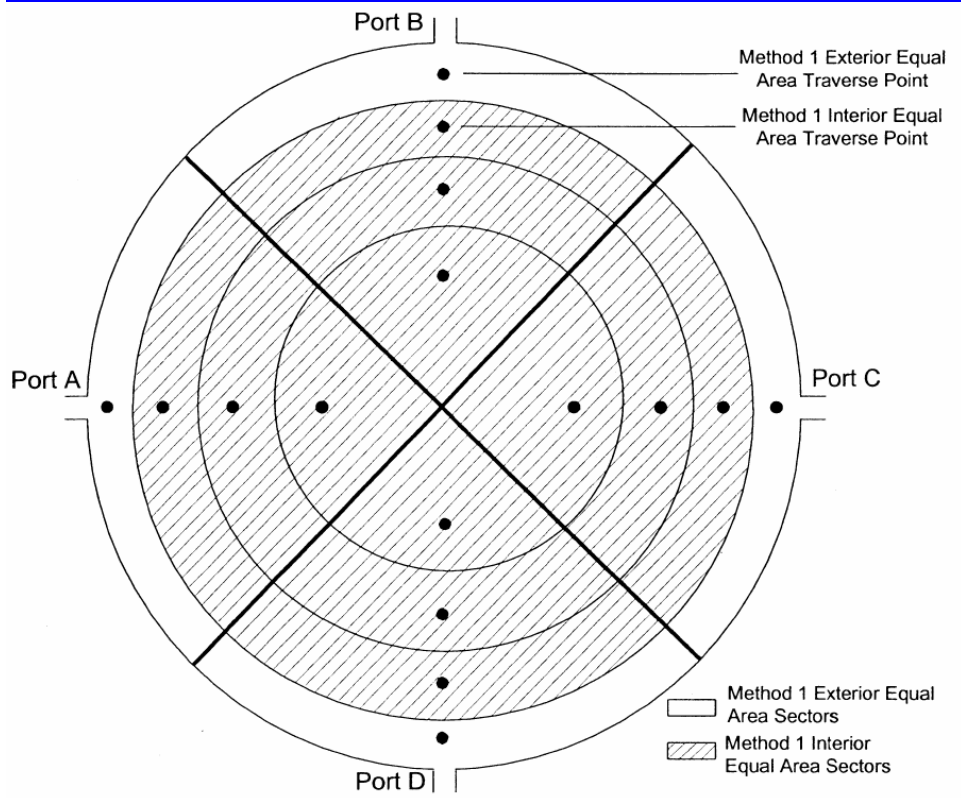
## ❖ Method 2H: Determination of Stack Gas Velocity Taking Into Account Velocity Decay Near the Stack Wall

- Intended to capture the effect of lower velocities near a stack or duct wall (For use with round ducts only)
- The data at the Method 1 traverse point #1 is used in conjunction with data at several “near-wall” points in order to determine a replacement velocity for point #1
- A wall effects factor (WAF) is determined which is used in RATA tests to determine the proper flow rate.
  - Default WAF is 0.9900 for brick and mortar stacks, 0.9950 for all other stacks



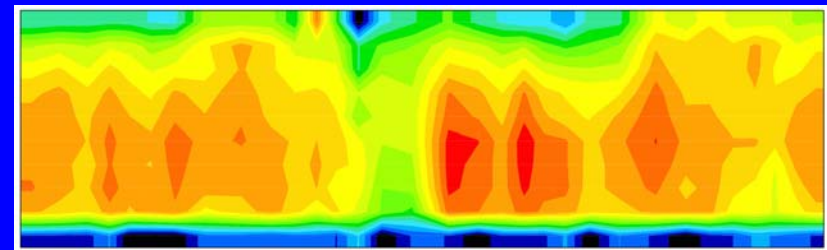
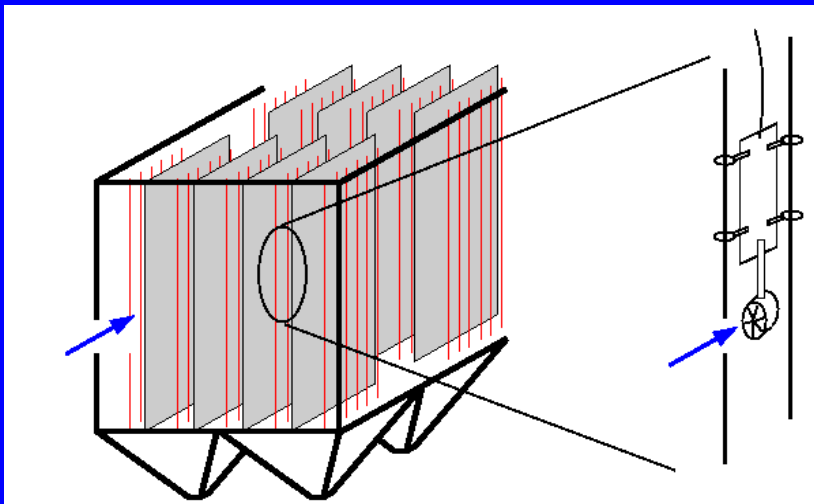
# EPA Testing Methods (40 CFR Part 60)

## ❖ Method 2H



# ESP Collection Region Testing

- ❖ Measure velocity distribution at ESP inlet & outlet planes
- ❖ Compare to industry standards (ICAC EP-7)
- ❖ Cold flow conditions
- ❖ Vane anemometer or hot wire
- ❖ Careful test planning a necessity
- ❖ Detailed data analysis required



# Outline

- ❖ Introduction
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  - Particulate
  - Gaseous species testing
- ❖ Field Test Case Studies
- ❖ Questions



# Outline

- ❖ Introduction
- ❖ Flow Testing Methodology
- ❖ Emissions Testing
- ❖ Field Test Case Studies
  - Combustion Optimization of a 400 MW PC Boiler
  - AIG Tuning on a 500 MW PC Boiler
  - Fabric Filter Balance, Air Heater Leakage
  - ESP Flow Testing
- ❖ Questions



# Case Studies – FF Balance, AH Leakage

Otter Tail Power Co. – Big Stone Plant

## Issues:

Worked with Otter Tail Power Company (OTPC) as they converted their Advanced Hybrid Particulate Collector to a conventional pulse jet fabric filter. In addition to baghouse flow distribution, the client was also concerned with their air heater leakage.

Testing was proposed in order to meet the following goals:

1. Quantify gas flow balance between each of the four (4) fabric filter modules
2. Measure the gas velocity, temperature, pressure distribution, and O<sub>2</sub> concentration both upstream and downstream of the air heaters prior to fabric filter installation.
3. Repeat air heater testing after the unit was down and the client was able to make some repairs to try and eliminate leakage.



# Case Studies – FF Balance, AH Leakage

Otter Tail Power Co. – Big Stone Plant

## Test Methodology

To determine the gas flow distribution and O<sub>2</sub> concentration within the air heater inlet and outlet ductwork;

- ❖ Full duct traverses were conducted at select test ports to measure velocity, temperature, and pressure distributions
- ❖ Duct traverses were conducted with 5-hole prism head probe per EPA Method 2F guidelines
- ❖ O<sub>2</sub> concentration measured at the same traverse points using a gas monitor and sampling probe



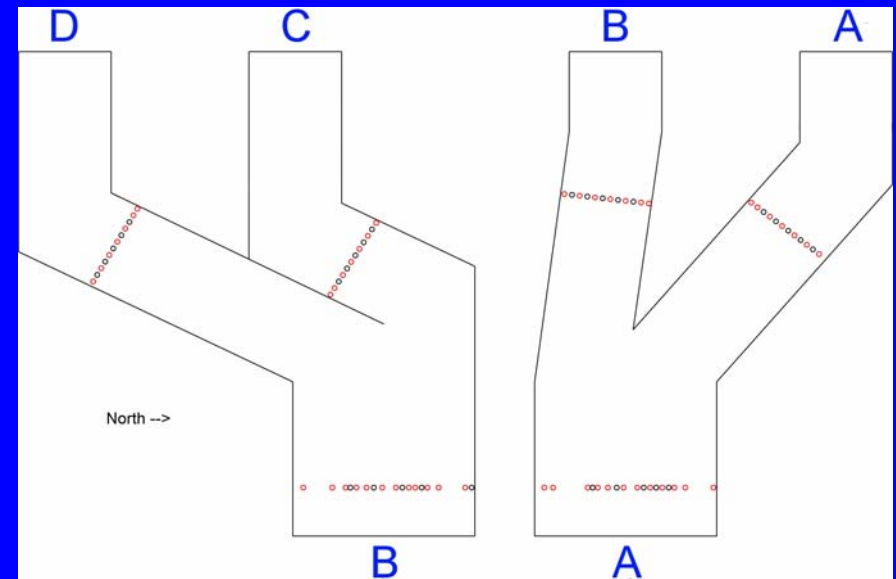
# Case Studies – Fabric Filter Balance

Otter Tail Power Co. – Big Stone Plant

## Results

Big Stone Plant has two airheaters labeled “A” and “B” from North to South. Each airheater outlet duct splits into two ducts to feed the fabric filter system. Flow was found to be fairly balanced between the FF compartments, with B the most skewed, at 12% high.

	Average Total Velocity	Velocity RMS	Measured Flow Rate	Deviation from Average
	[ft/s]	[%]	[ACFM]	
<b>A</b>	49.5	22.0	494,447	-4.83%
<b>B</b>	58.2	14.4	584,557	12.51%
<b>C</b>	51.8	21.6	474,122	-8.74%
<b>D</b>	55.7	17.3	525,050	1.06%
<b>Total</b>			<b>2,078,176</b>	<b>519,544</b>



# Case Studies – Air Heater Leakage

Otter Tail Power Co. – Big Stone Plant

## Results

Big Stone Plant has two air heaters labeled “A” and “B” from North to South. Air heater leakage was shown to have been reduced on both air heaters due to the client’s efforts to reduce leaks.

	<b>Baseline (06/2007)</b>	<b>Current (01/2008)</b>
	[%]	[%]
<b>Airheater A</b>	16.5	14.0
<b>Airheater B</b>	18.7	14.5

%-Leakage



# Conclusions

- ❖ Fluid dynamics and chemical reactions play major roles in plant operation
- ❖ Flow and emissions testing are widely used to diagnose problems and confirm design performance
- ❖ Field testing has been applied to nearly every component of a power plant from fan to stack

## Performance

- Heat Rate
- Capacity
- Pressure Loss
- Combustion
- Instrumentation

## Environmental

- Particulate Capture
- NO<sub>x</sub>
- SO<sub>2</sub>
- SO<sub>3</sub>
- Hg

## Maintenance

- Fouling
- Pluggage
- Erosion
- Corrosion
- Vibration

# Questions?

