

An Overview of the Current NO_x, O₂, SO₂ Analyzers and Sample Acquisition Technologies and Equipment Installed by the Electric Utility Industry

**Presented by
J. Ron Jernigan, P.E., DEE**

2nd U.S.-China NO_x and SO₂ Control Workshop

August 2-5, 2005

**Dalian Bangchui Island Hotel
Zhongshan District, Dalian, Liaoning Province
The People's Republic of China**

Overview of CEMS Technologies & Equipment

- **This Presentation Will Present The Air Emissions Monitoring Techniques Selected By The U.S. Electric Utility Industry For Complying With U.S. EPA's Part 75 Acid Rain Monitoring Program**
- **Since Early 1993 Over 3000 New CEM Systems Have Installed By The Electric Utility Industry**
- **This Presentation's CEMS Technologies' Data Are Compiled From EPA's 4th Quarter 2003 EDR Data**

Overview of CEMS Technologies & Equipment

Sample Acquisition Techniques

- **Dilution-Extractive Systems**
 - *In-Stack*
 - *Out-of-Stack*
- **Extractive Systems**
 - *Cold/Dry*
 - *Hot/Wet*
- **In-Situ Systems**
 - *Across-Stack*
 - *Point*

Overview of CEMS Technologies & Equipment

Part 75 CEMS Sample Acquisition Methods

| Sample Acquisition Method | Total SO ₂ CEMS (1,045 analyzers) | % SO ₂ CEMS | Total NO _x CEMS (3,193 analyzers) | % NO _x CEMS |
|---------------------------------|--|---------------------------|--|---------------------------|
| Dilution Extractive | 920 | 88.0 | 1,508 | 47.2 |
| Extractive (cool/dry & hot/wet) | 104 | 10.0 | 1,357 | 51.5 |
| In-Situ (Point & Across-Stack) | 21 | 2.0 | 46 | 1.3 |

Overview of CEMS Technologies & Equipment

Part 75 CEMS Sample Acquisition Methods

- All of the 1,045 SO₂ Analyzers are Installed on Coal-Fired boilers.
- 920 (88%) of the SO₂ and NO_x analyzers chose dilution-extractive over non-dilution extractive due to dilution-extractive providing wet-basis concentrations working more economically with flue gas flow rate monitor which also provides wet-basis stack flow rate values, therefore no moisture analyzers required for data correction to wet-basis and also lower maintenance cost (50% -100% less cost than non-dilution extractive CEMS.
- 588 oil and gas-fired boilers also chose to install the dilution-extractive technology over non-dilution extractive technology.
- Approximately 2,000 of the 3,193 NO_x analyzers are installed on gas-fired combustion turbines which only measure NO_x and O₂ with CEMS, these units chose non-dilution extractive systems.

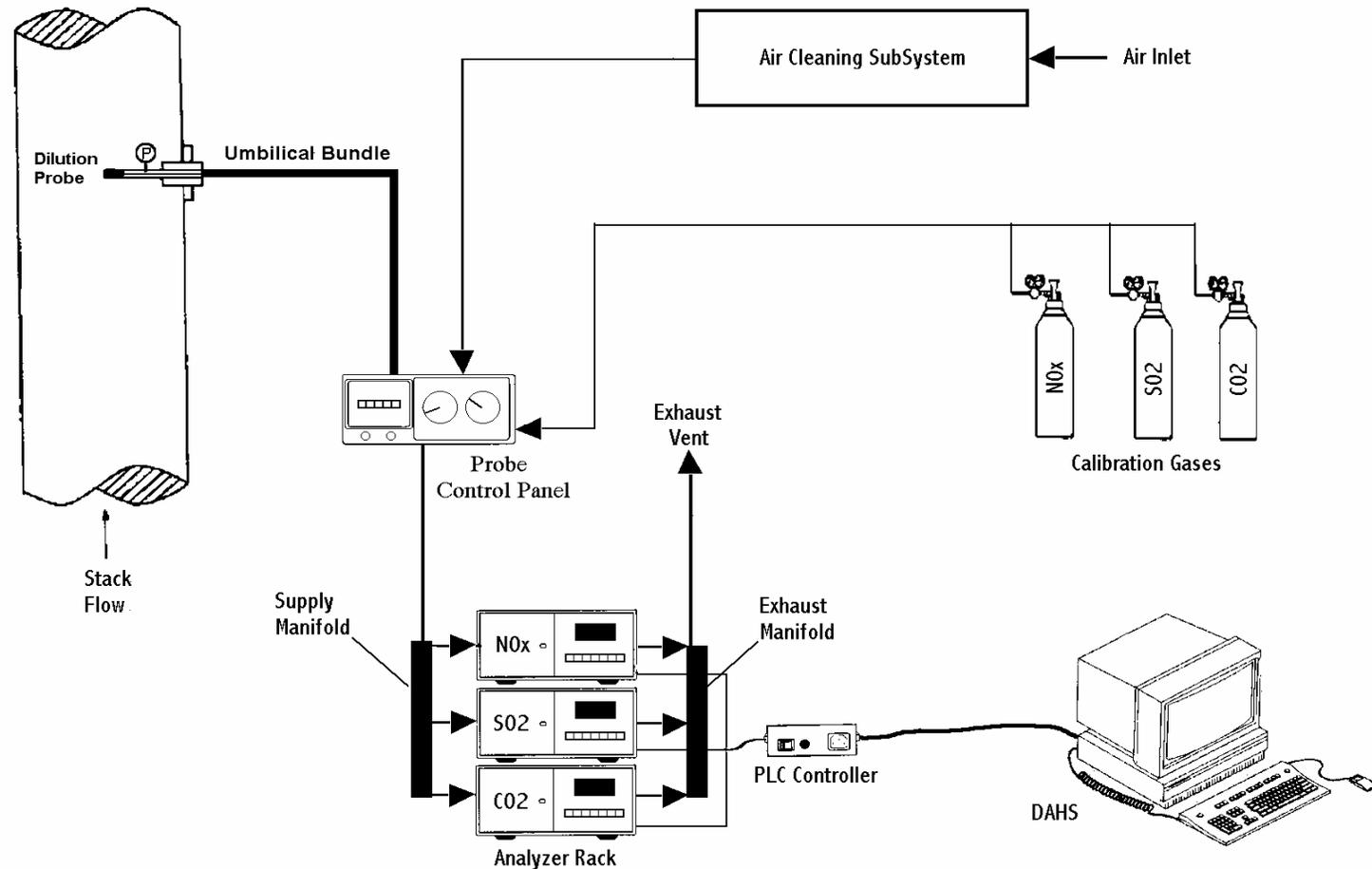
Overview of CEMS Technologies & Equipment

Part 75 CEMS Sample Acquisition Methods

- For gas-fired combustion turbines NO_x & O_2 non-dilution extractives systems have a slightly lower initial cost, and annual cost of maintenance is only slightly higher than dilution extractive systems.
- In-Situ, both point and across-stack types, are not popular with the U.S. electric utility industry because they have proven to be less reliable and more costly to operate than dilution and non-dilution extractive systems.
- Only 21 of the 1,045 SO_2 CEMS were listed as In-Situ systems.
- Only 46 of the 3,193 NO_x CEMS were listed as In-Situ systems.

Overview of CEMS Technologies & Equipment

In-Stack Dilution Probe Sampling System



Overview of CEMS Technologies & Equipment

Dilution Probe Sampling System

- Dilution probe particulate matter filter – flow through the filter is typically 100 cubic centimeters per minute compared to a non-dilution probe system which is approximately 3,500 cubic centimeters per minute, accordingly, dilution probe systems have must less problem with filter plugging and lower annual maintenance cost.
- Dilution probe sampling systems do not require a heated sample line – Non-dilution sampling systems require a more expensive heated sample line which periodically fail or malfunction. Heated sample line failures can cause sample line plugging and result in high maintenance cost.
- Dilution probe sampling systems do not require moisture removal systems – therefore, no additional cost for a moisture analyzer, or high maintenance cost due to moisture removal systems malfunctions or failures that may result in analyzer failures due to contamination from moisture condensation and corrosion gases.

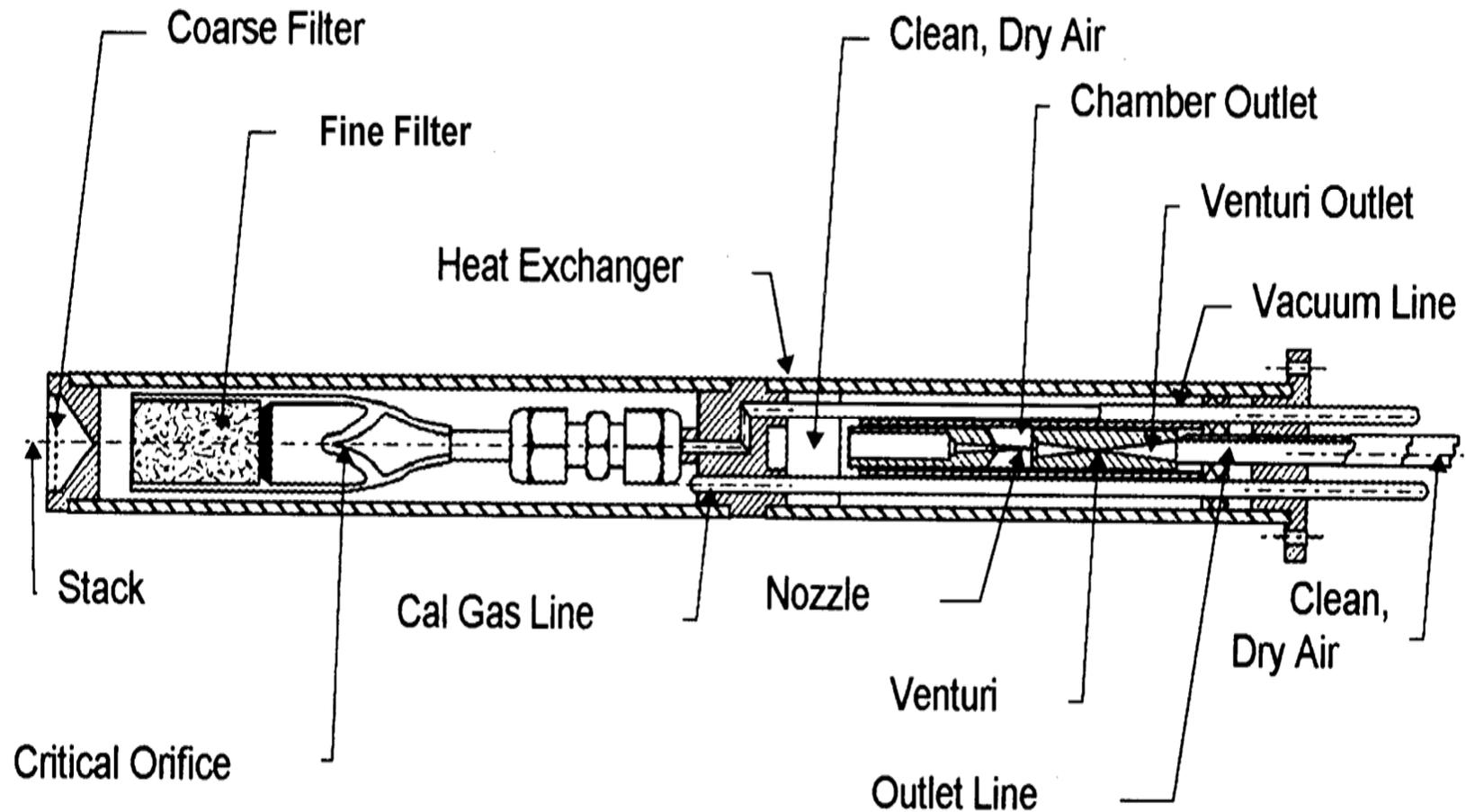
Overview of CEMS Technologies & Equipment

In-Stack Dilution Probe Sampling System

- Dilution probe sampling systems do not require sample pumps or numerous flow control valves as required by non-dilution sampling systems – therefore, this is another area of lower maintenance cost.
- Industry can use very reliable ambient level analyzers, which are very robust and generally require less routine maintenance than source level analyzers.
- Using very clean dilution air virtually eliminates analyzer internal corrosion.

Overview of CEMS Technologies & Equipment

Dilution Probe



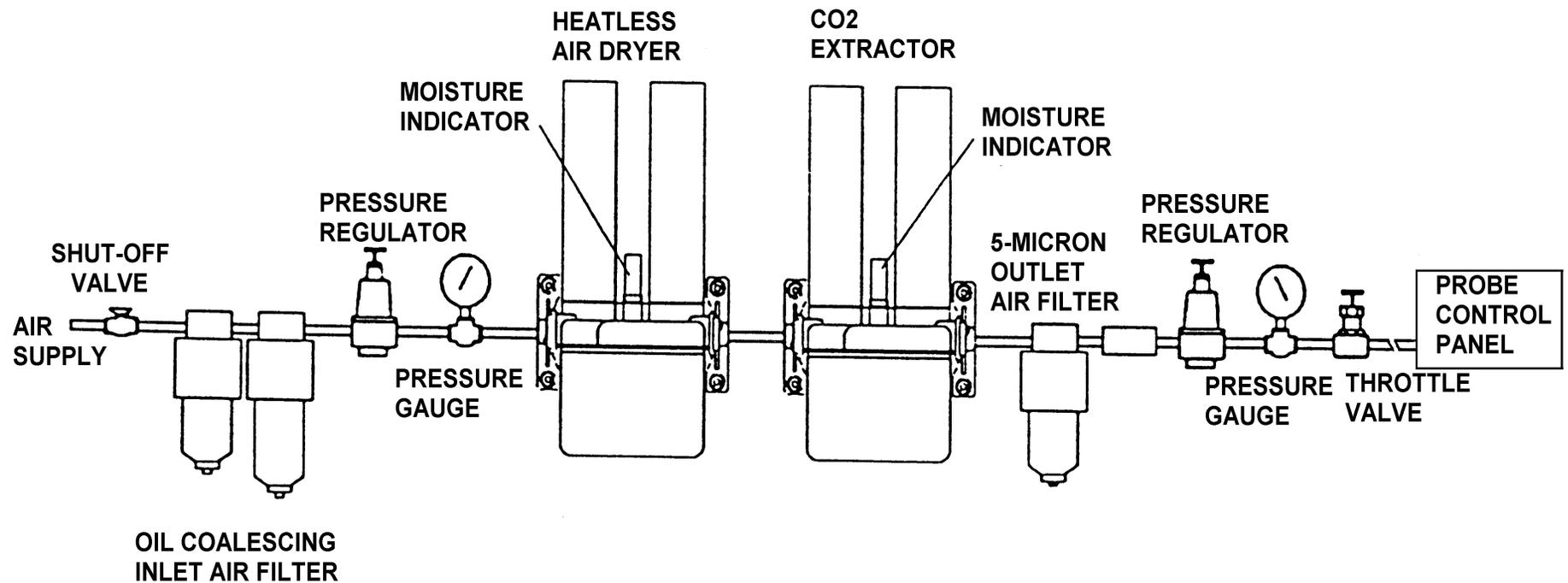
Overview of CEMS Technologies & Equipment

Dilution Probe

- Dilution probe systems use dry contamination-free air (“dilution air”) and an eductor (also referred to as a venturi pump) to extract a diluted flue gas sample from the exhaust stack or duct.
- It is not necessary to remove the moisture from the flue gas sample prior to analysis by the analyzers, because the sample is diluted sufficiently (typical dilution ratios range from 100:1 to 250:1) to avoid condensation problems during analysis at normal ambient temperatures, however, the concentration is still a wet-basis concentration.
- Dilution probe systems provide wet-basis concentrations that works very well with flue gas flow rate monitor which also provides wet-basis stack flow rate values, therefore no moisture analyzers are required for data correction.

Overview of CEMS Technologies & Equipment

Dilution Air Clean-Up System



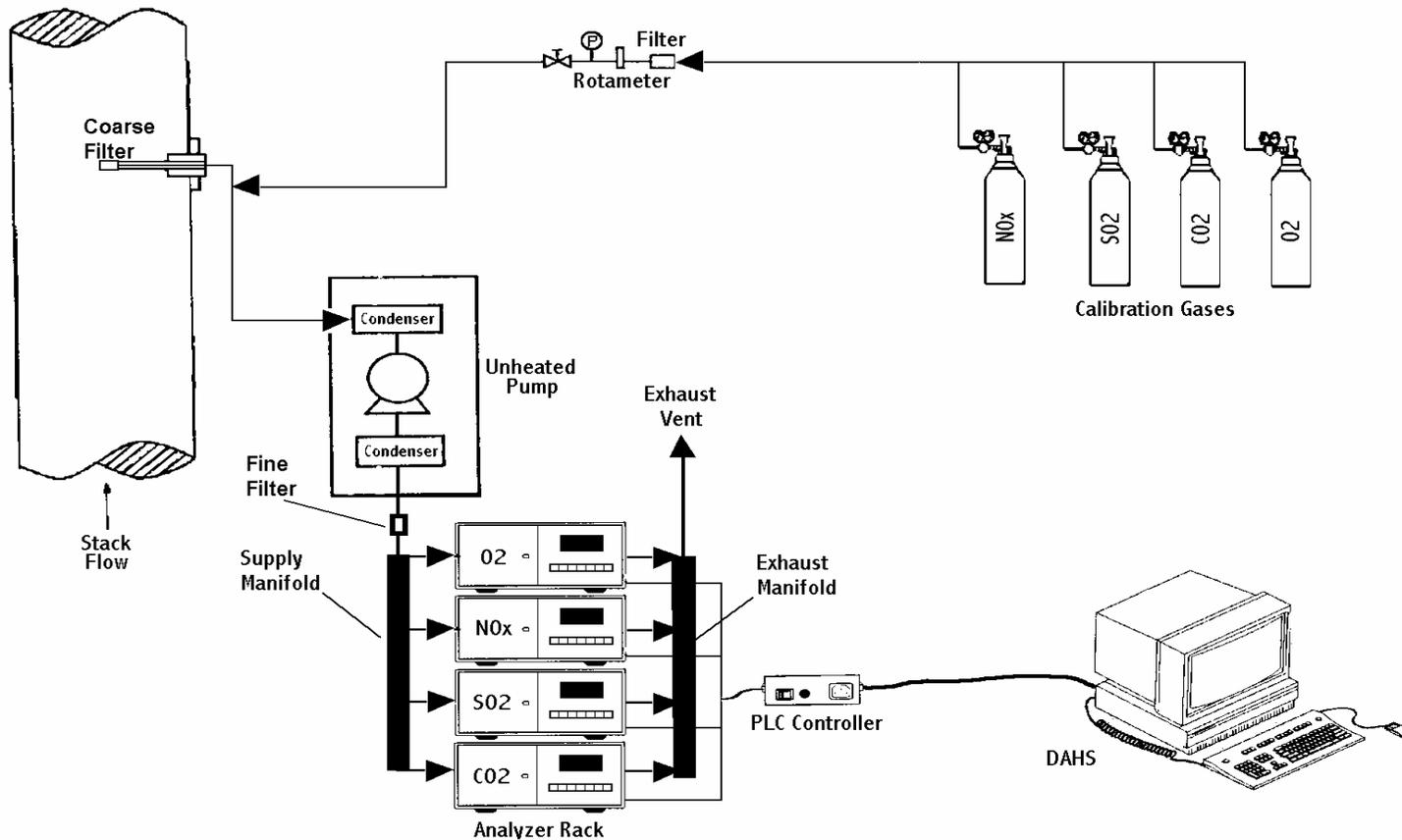
Overview of CEMS Technologies & Equipment

Dilution Air Clean-Up System

- Dilution probe systems require a constant source of contamination free dilution air.
 - *The air supply should be dry (-30° C to - 40° C) and delivered at 620 ± 68 kilopascals.*
 - *The dilution air should be free of oils, particulates, CO₂, NO_x, and SO₂.*

Overview of CEMS Technologies & Equipment

Non-Dilution Extractive System



Overview of CEMS Technologies & Equipment

Non-Dilution Extractive System

- Typically non-dilution extractive systems are “cold/dry” systems
- The hot flue (sample) gases are transported by means of a heated sample line (120° C to 175° C) to a sample gas conditioning system
- Typical gas conditioning systems are condensation type systems
- Sample gas conditioning systems are generally either refrigeration condensers or thermoelectric chillers. Thermoelectric chillers are becoming more common now.

Overview of CEMS Technologies & Equipment

Gaseous Continuous Emission Monitors

- **SO₂ Monitoring Technologies**
 - *Ultraviolet(UV) Fluorescence - 85%*
 - *UV Spectrophotometric - 14%*
 - *Other Technologies – 1%*
- **NO_x Monitoring Technologies**
 - *Chemiluminescence – 96.4%*
 - *UV Spectrophotometric – 2.3%*
 - *Non-dispersive Infrared – 1.3%*

Overview of CEMS Technologies & Equipment

Gaseous Continuous Emission Monitors

- After more than 10 years of CEMS operational experience, the most popular **SO₂ Monitoring & NO_x Monitoring Technologies** are:
 - **SO₂ – Ultraviolet(UV) Fluorescence - 85%**
 - **NO_x- Chemiluminescence – 96.4%**

Overview of CEMS Technologies & Equipment

Gaseous CEM Technologies

- After more than 10 years of CEMS operational experience in the U.S. EPA's Acid Rain Monitoring program, the electric utility industry have chosen Ultraviolet (UV) Fluorescence (85%) as the most popular SO₂ monitoring technology used and Chemiluminescence (96.4%) as the most popular NO_x monitoring technology used.
- These monitoring technologies have become the most widely used because they offer excellent monitoring accuracy, are very reliable with a very high data capture (>98%), and they have low annual maintenance costs.

Overview of CEMS Technologies & Equipment

SO₂ Analyzers Chosen For The Part 75 Acid Rain Program

Top Five SO₂ Manufacturers (Source of Data, EPA's 4th Quarter 2003 EDR Database – "Total 1,045 SO₂ Analyzers")

| | | |
|--------------------------------------|----------------------|--------------------|
| • Thermo Electron Corporation | <i>747 analyzers</i> | <i>71.5%</i> |
| • Teledyne/Monitor Labs/API | <i>177 analyzers</i> | <i>16.9%</i> |
| • Forney/Anarad/CSI | <i>51 analyzers</i> | <i>4.9%</i> |
| • Ametek/Western Research | <i>28 analyzers</i> | <i>2.7%</i> |
| • Siemens | <i>16 analyzers</i> | <i>1.5%</i> |
| | <i>Total</i> | <hr/> <i>97.5%</i> |

Overview of CEMS Technologies & Equipment

NO_x Analyzers Chosen For The Part 75 Acid Rain Program

Top Five NO_x Manufacturers (Source of Data, EPA's 4th Quarter 2003 EDR Database – "Total 3,193 NO_x Analyzers")

| | | |
|--------------------------------------|------------------------|--------------------|
| • Thermo Electron Corporation | <i>2,003 analyzers</i> | 62.7% |
| • Teledyne/ <i>Monitor Labs/API</i> | <i>411 analyzers</i> | 12.9% |
| • Rosemount | <i>384 analyzers</i> | 12.0% |
| • Forney/ <i>Anarad/CSI</i> | <i>156 analyzers</i> | 4.9% |
| • Horiba | <i>98 analyzers</i> | 3.1% |
| | Total | <hr/> 95.6% |

Overview of CEMS Technologies & Equipment

NO_x & SO₂ Analyzers Chosen For The Part 75 Acid Rain Program

- After more than 10 years of CEMS operational experience in the U.S. EPA's Acid Rain Monitoring program, the electric utility industry have continued to use, or replaced, their previous CEM analyzers with analyzers supplied primarily by two manufacturers, Thermo Electron Corporation and Teledyne Instruments. These two manufacturers supply over 88% of all the SO₂ analyzers and over 75% of all the NO_x analyzers.
- These two analyzer manufacturers have become the most widely used SO₂ and NO_x analyzer supplies because they offer robust, very accurate, very reliable analyzers with low annual cost of operation.

Overview of CEMS Technologies & Equipment

Gaseous Continuous Emission Monitors

- ***CO₂ Monitoring Technologies***
 - ***Non-Dispersive Infrared(NDIR) - 100%***
- ***O₂ Monitoring Technologies***
 - ***Paramagnetic - 73%***
 - ***Electrocatalytic - 27%***

Overview of CEMS Technologies & Equipment

CO₂ Analyzers Chosen For The Part 75 Acid Rain Program

Top Five CO₂ Manufacturers (Source of Data, EPA's 4th Quarter 2003 EDR Database – "Total 1,586 CO₂ Analyzers")

| | | |
|--------------------------------------|----------------------|--------------|
| • California Analytical Inc. | <i>617 analyzers</i> | 38.9% |
| • Thermo Electron Corporation | <i>554 analyzers</i> | 34.9% |
| • Siemens | <i>190 analyzers</i> | 12.0% |
| • Teledyne/ <i>Monitor Labs/API</i> | <i>116 analyzers</i> | 7.3% |
| • Forney/ <i>Anarad</i> | <i>34 analyzers</i> | 2.1% |
| | Total | 95.2% |

Overview of CEMS Technologies & Equipment

O₂ Analyzers Chosen For The Part 75 Acid Rain Program

Top Five O₂ Manufacturers (Source of Data, EPA's 4th Quarter 2003 EDR Database – "Total 1,588 O₂ Analyzers")

| | | |
|--------------------------------|----------------------|--------------|
| • Servomex | 599 analyzers | 37.7% |
| • Siemens | 259 analyzers | 16.3% |
| • Ametek/Thermox | 174 analyzers | 11.0% |
| • Teledyne/Monitor Labs | 143 analyzers | 9.0% |
| • Rosemount | 122 analyzers | 7.7% |
| | Total | 81.7% |

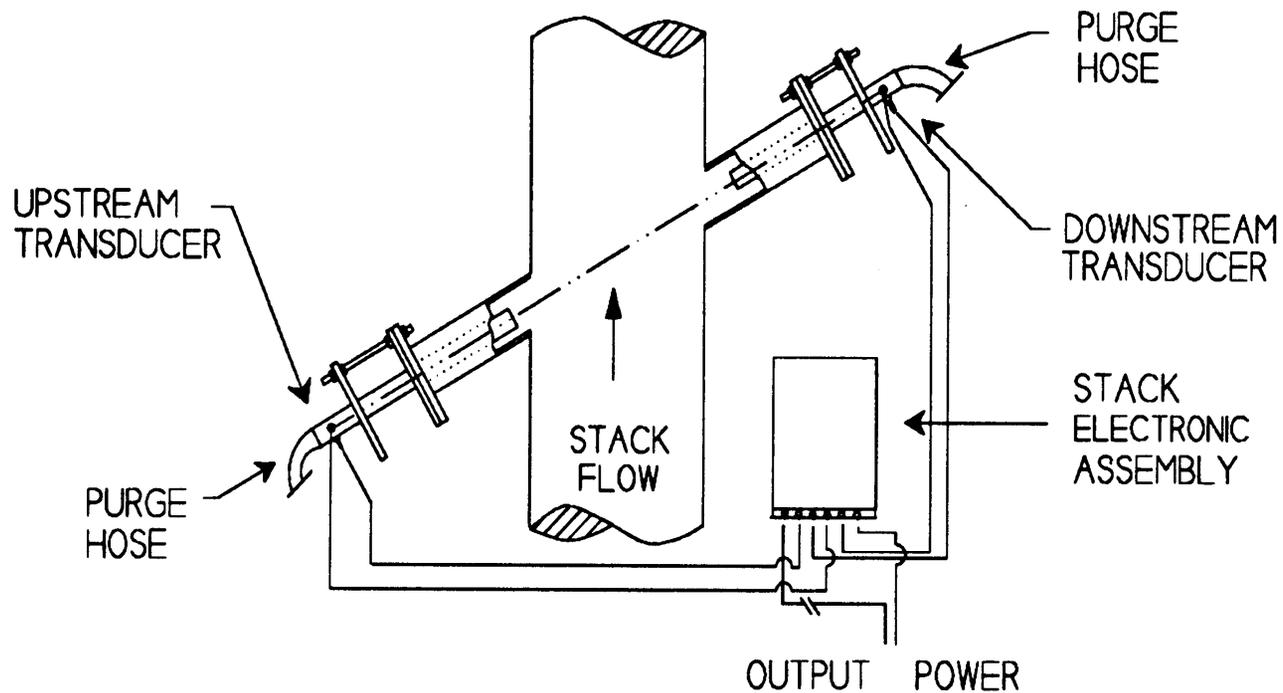
Overview of CEMS Technologies & Equipment

Flue Gas Flow Rate Monitors

- **Ultrasonic – 61.9%**
- **Differential Pressure – 29.6%**
- **Thermal – 5.0%**
- **Optical Scintillation – 1.8**
- **Audible Acoustic – 1.6%**

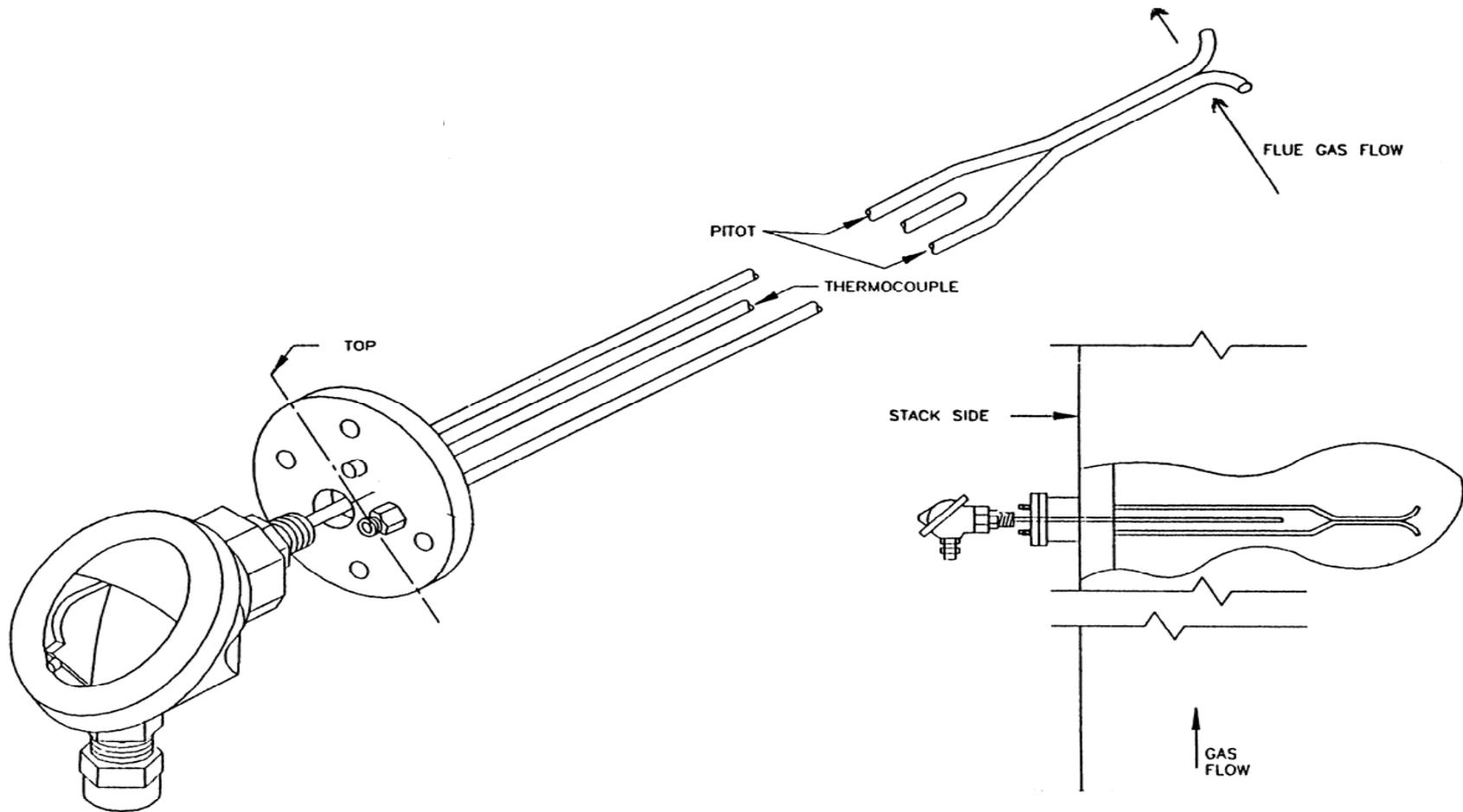
Overview of CEMS Technologies & Equipment

Ultrasonic Flow Rate Monitor



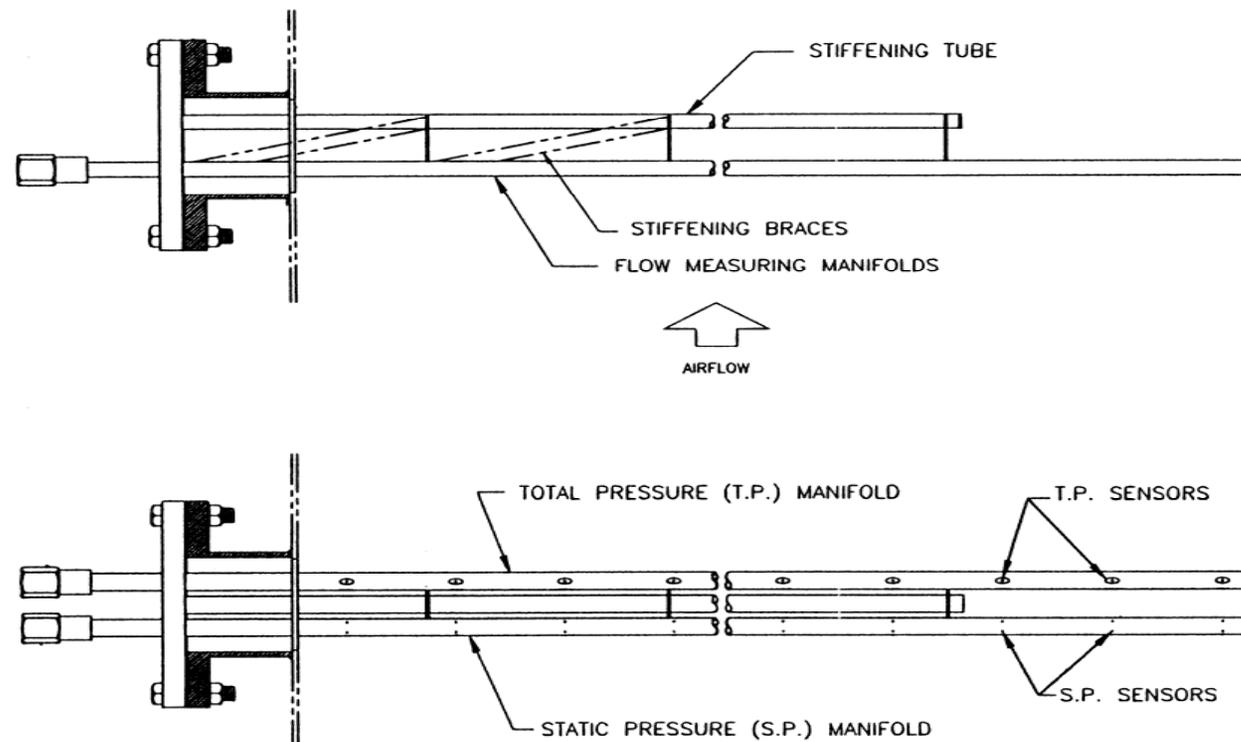
Overview of CEMS Technologies & Equipment

EMRC S-Type Pitot Pressure Differential



Overview of CEMS Technologies & Equipment

Schematic of An Air Monitor Corp. Pitot Probe



Overview of CEMS Technologies & Equipment

Flow Rate Monitors Chosen For The Part 75 Acid Rain Program

Top Five Flow Rate Monitor Manufacturers (Source of Data, EPA's 4th Quarter 2003 EDR Database – “Total 1,219 Flow Rate Monitors”)

| | | |
|--------------------------------------|---------------|--------------|
| • Teledyne/Monitor Labs [Ultrasonic] | 652 analyzers | 53.5% |
| • EMRC [DP] | 245 analyzers | 20.1% |
| • Air Monitor Corp. [DP] | 67 analyzers | 5.5% |
| • Sick [Ultrasonic] | 46 analyzers | 3.8% |
| • Kurz [Thermal] | 41 analyzers | 3.4% |
| | Total | 86.3% |

Overview of CEMS Technologies & Equipment Summary

- **The Major CEMS Technologies & Equipment Currently Used by U.S. Electric Utility Part 75 Sources Have Been Proven To Be Reliable, Accurate and have the Lowest Annual Cost of Operation**
 - *EPA Reports Average CEMS Data Availability >98%*
 - *EPA Reports Indicate That The Median Relative Accuracy for NO_x, and SO₂ and Flow Rate Monitors Were Approximately 3% Relative Accuracy.*