Continuous Emissions Monitoring Systems
-CEMS-
…Sample Systems Considerations…

September 2022

CUSTOM INSTRUMENTATION SERVICES CORPORATION

ELEVENTH ANNUAL CISCO CEMS USER'S GROUP MEETING

Back-Ground for Bob Bertik…

- In the CEMS business for over 30 years
- Was a System Integrator in my early years, now concentrate on the "piece parts" that make up the sample conditioning system segment of most types of gas analysis systems
- Currently work for Universal Analyzers an Ametek company – 18 yr anniversary this month
- Universal Analyzers manufactures sample conditioning systems and components "pieces-parts" in the USA (Carson City, Nevada specifically) and sells / consults and supports globally

- CEMS have been in play for +- 50 years…some used for compliance purposes and others for process measurements.

- CEMS technology and practices for the most part have matured in the USA along with a few other areas in the world but there are still many areas globally that have requirements but little understanding of the importance of the “piece parts” that make up the system.

- Many of the godfathers of the industry have since retired or moved on leaving the new generation with little experience on the what can arguably be the most important part of any gas analysis system…that is the sample conditioning and handling components of a CEMS

- Many that have the responsibility to maintain and operate any CEMS most likely inherited what they have, didn’t have a say in what might have been appropriate for their application and don’t realize there may be a different and / or better way.

- Today’s brief discussion will touch on many but not all the various considerations that should go into the thought process when specifying and designing or after the fact upgrading a CEMS “Sample System”.

Major Components of a CEMS

A	B	C	D
"Front-End" Sample Conditioning Components	Analyzers	Calibration Gas	Data Acquisition System
-Gas Sample Probes -Heated Sample Line -Gas Coolers / Chillers -Pumps, Flowmeters, Regulators, Gauges, Alarms…	-NOx -CO -O2 -SOx -CO2 -HCl -Hg -THC . H2S . CH4 .	-Span Gases -Zero Gas	-Compliance Software Data Collection -Housekeeping functions such as calibrations, blow back, alarms, etc.

LOTS TO THINK ABOUT AND CONSIDER

…Too much to read but you get the idea…

Water %, Sample Line Maintain temperature, Process Temperature, Analyzer flow rates, Stack Pressure; Vortex induced vibrations, wall effects, upstream equipment, proximate pipeline bends, positioning in gas flow, center 1/3 sampling, aerosol formation at tip of probe tube, flow eddies at tip of probe tube, particulate accumulation at tip of probe tube, Dust Load, minimizing diameter of sample path, maintaining constant sample pathway diameter, surface finish, selection of surface treatment, appropriate material selection for media, beware use of dissimilar material, minimize length of sample path, minimize number of components in sample pathway, minimize wetted surface areas, minimize internal volumes, dead legs in sample pathway, dead legs in valves and fittings, threaded connections, flanged connections, seals, avoid contamination accumulation, ability to clean entire sample pathway, ability to remove & replace filtered contamination, ability to validate sample system, minimize flow rate, stratification!!

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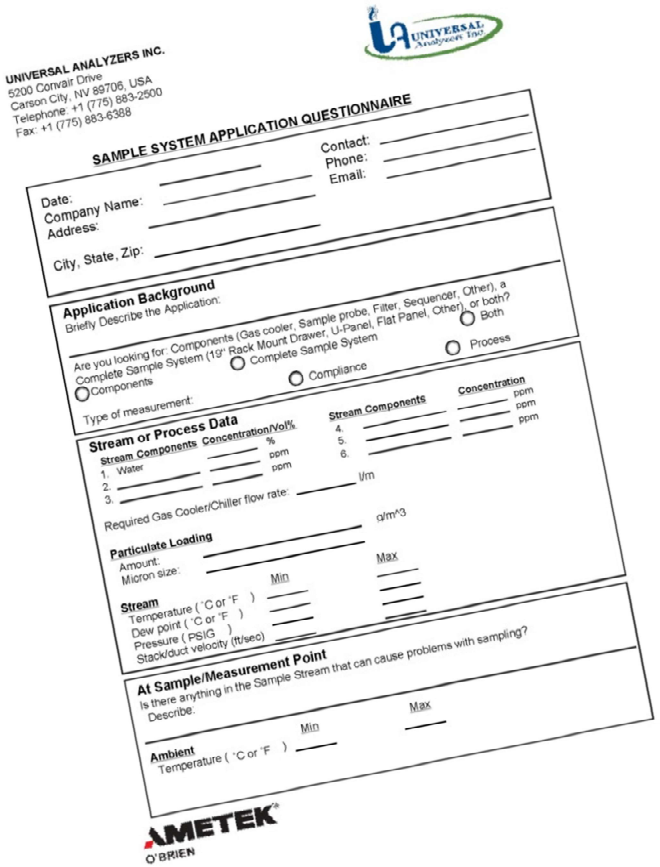
ONE SIZE DOES

NOT FIT ALL

Application Questionnaire



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5200 Convair Drive
Carson City, NV 89706, USA
Telephone: +1 (775) 883-2500
Fax: +1 (775) 883-6388

SAMPLE SYSTEM APPLICATION QUESTIONNAIRE

Date:
Company Name:
Address:
City, State, Zip:
Contact:
Phone:
Email:

Application Background
Briefly Describe the Application:

Are you looking for: Components (Gas cooler, Sample probe, Filter, Sequencer, Other), a Complete Sample System (19" Rack Mount Drawer, U-Panel, Flat Panel, Other), or both?
Components ○ Complete Sample System ○ Both

Type of measurement: ○ Compliance ○ Process

Stream or Process Data

Stream Components	Concentration/Vol%	Stream Components	Concentration
1. Water	%	4.	ppm
2.	ppm	5.	ppm
3.	ppm	6.	ppm

Required Gas Cooler/Chiller flow rate: l/m

Particulate Loading
Amount: g/m^3
Micron size:

Stream

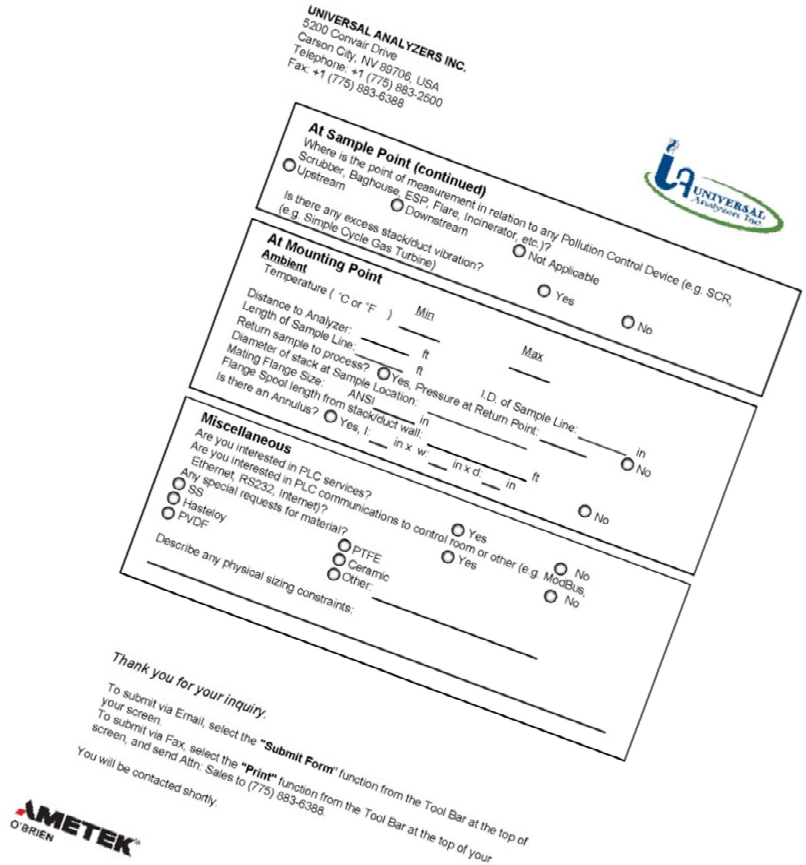
	Min	Max
Temperature (°C or °F)		
Dew point (°C or °F)		
Pressure (PSIG)		
Stack/duct velocity (ft/sec)		

At Sample/Measurement Point
Is there anything in the Sample Stream that can cause problems with sampling?
Describe:

Ambient

	Min	Max
Temperature (°C or °F)		

AMETEK O'BRIEN



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At Sample Point (continued)
Where is the point of measurement in relation to any Pollution Control Device (e.g. SCR, Scrubber, Baghouse, ESP, Flare, Incinerator, etc.)?
○ Upstream ○ Downstream ○ Not Applicable

Is there any excess stack/duct vibration? ○ Yes ○ No
(e.g. Simple Cycle Gas Turbine)

At Mounting Point

Ambient

	Min	Max
Temperature (°C or °F)		

Distance to Analyzer: ft
Length of Sample Line: ft
Return sample to process? ○ Yes, Pressure at Return Point: ○ No
Diameter of stack at Sample Location: I.D. of Sample Line: in
Mating Flange Size: ANSI in
Flange Spool length from stack/duct wall: ft
Is there an Annulus? ○ Yes, I: in x w: in x d: in ○ No

Miscellaneous
Are you interested in PLC services? ○ Yes ○ No
Are you interested in PLC communications to control room or other (e.g. ModBus, Ethernet, RS232, Internet)? ○ Yes ○ No
Any special requests for material?
○ SS ○ PTFE ○ Ceramic
○ Hasteloy ○ Other:
○ PVDF

Describe any physical sizing constraints:

Thank you for your inquiry.

To submit via Email, select the **"Submit Form"** function from the Tool Bar at the top of your screen.
To submit via Fax, select the **"Print"** function from the Tool Bar at the top of your screen, and send Attn: Sales to (775) 883-6388.
You will be contacted shortly.

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Examples of considerations for an Extractive Sampling System

- Straight Extractive or Dilution Extractive?
- Cold Dry or Hot Wet
  - **Determines the style of probe and analyzers**

- What are we measuring & how many analyzers will be used?
  - **Used to determine flow rate requirement & pump / gas cooler sizing**

- How much dust should we expect at the point of measurement?
  - **Used to determine filter sizing, filter staging and blow back / back purge requirement**

Examples of considerations for an Extractive Sampling System

- Particle size if it can be determined?
  - **Used to determine what the porosity size of the filters should be**

- How much water is present in vol %?
  - **Used to determine proper gas cooler sizing**

Examples of considerations for an Extractive Sampling System

- Temperature, Pressure, Velocity & other compounds in the measured gas stream
  - **Used to determine material types, maintain temperatures & any extra probe tube support issues**

- How long should sample line be?
  - **Because we need to know**
  - **Buy exact or Buy long and trim in the field**

Examples of considerations for an Extractive Sampling System

- Voltage, Maintain & Ambient temperature for the heated sample line bundle
  - **Used for design of heater and insulation requirement**

- Hazardous Area Classification or General Purpose
  - **Used to determine heat trace type for sample lines**
  - **Used to determine sample probe heater and gas cooler electronics**
  - **All with the purpose of preventing the spark and arc that would cause an explosion…not a good thing!**

Sample Probes

Gas Coolers

Heated Sample Line

Sample Conditioning Systems

Accessories

Types of gas sample probes …

- Extractive - Non-Dilution
- Extractive - Dilution
- Extractive - Low Dust Loading
- Extractive - High Dust Loading
- Extractive – Hazardous Area Classifications
- With NH_3 Converter for Ammonia slip measurement
- Multi-Point Probe Arrays
- Retractable

Heated Sample Probes
The real purpose …

- Heated Junction Between the Point of Measurement and the Heated Sample Line
- Keeps Gas Sample Heated and in a Gas Phase to prevent Cold Spots Avoiding Pre-Mature Condensate Drop Out
- Initial Point of Filtration
- Calibration gas inlet – EPA compliance
- Provides proper representation of sample with properly engineered and placed probe tube

SAMPLE PROBE CONSIDERATIONS AGAIN…LOTS TO THINK ABOUT

- Weather Protection Enclosure (NEMA or IP?)
  - Non Metallic
  - Stainless Steel
- Interior Enclosure Heater with insulation
- Filter Temperature maintain…340°F …375°F up to 550°F?
- Temperature control (integrated thermoswitch or remote electronic control)
- Flange Sizing / Flange Orientation
- Heat Shrink Entry Seal for Heated Sample Line – SIZE?
- Probe tube length and material and reinforcement
- Filter Size / Filter Material
- Probe tip / Pre Filter
- Blow Back … from shelter or directly at the probe housing
- Hazardous or General Purpose

SAMPLE PROBE MATING FLANGE

Need to specify size to properly mate to stack or duct flange

PLUS

Need to specify orientation

“TOP DEAD CENTER”

OR

“STRADDLED”

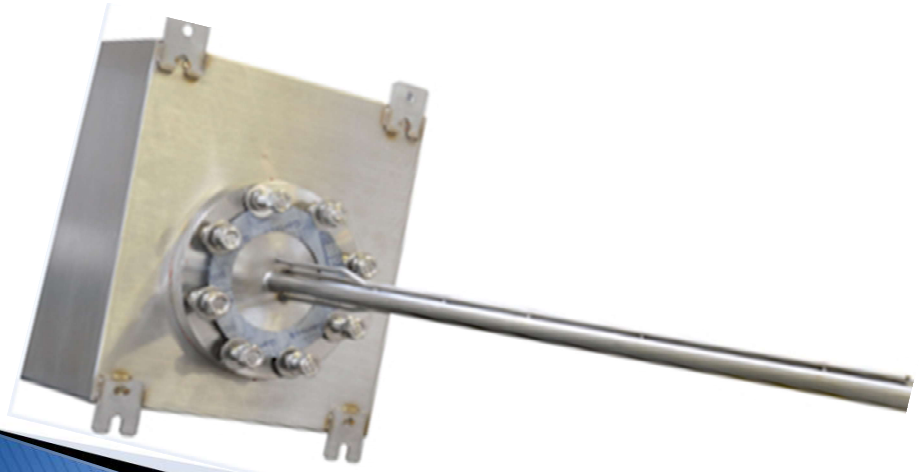
What happens when you don't specify the flange orientation …50/50 shot at getting it right…

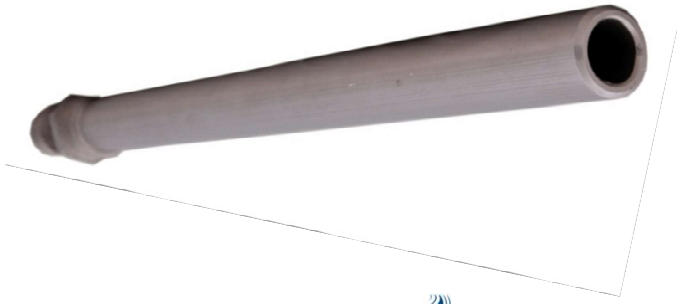
Proper Probe Tube Material Selection

Example shows probe tube material incompatible with process

Probe Tube Material Selection

Probe Tube Material	Max Temperature
316 SS	1100ºF / 593ºC
Inconel®	1600ºF / 871ºC
Hastelloy® C276	1900ºF / 1037ºC
310 SS	2000ºF / 1093ºC
Hastelloy ® X	2150ºF / 1177ºC
Ceramic	2600ºF / 1427ºC





Another Probe Tube Option ----- Multi-Point

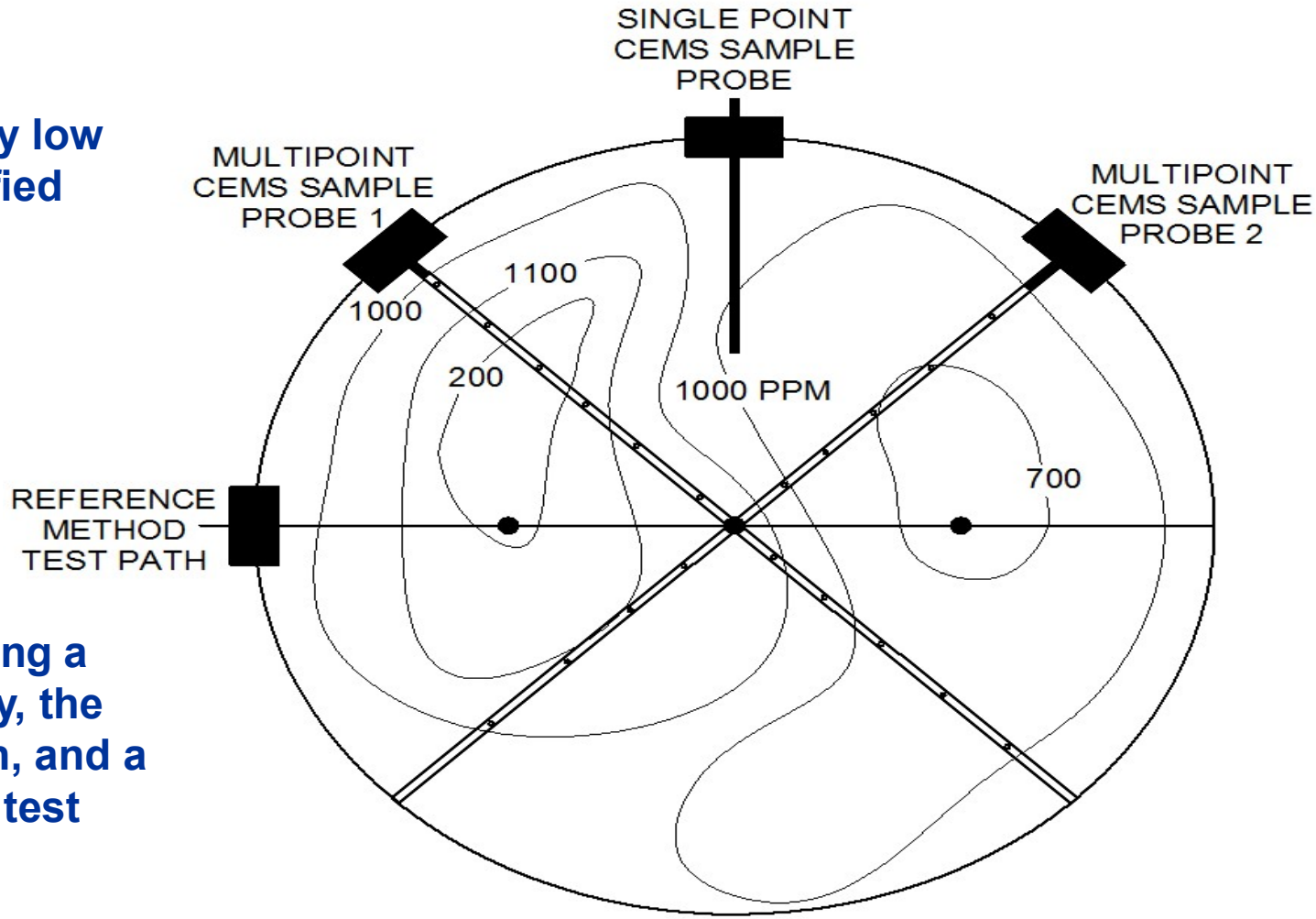
Multi-point probe array's are used and excel as a useful solution for a cross-stratified stack in scenarios where the user is attempting to measure relatively low pollutant/concentration levels

Multipoint Probe Tube and Sampling System are designed to obtain a representative sample when there is cross-stack stratification in a Continuous Emissions Monitoring System.

A typical system will include two multipoint probe tubes (each with a dedicated heated probe filter), two short heated sample bundles, and a two-point mixing/averaging module.

Another Probe Tube Option ----- Multi-Point

Used to measure relatively low concentrations in a stratified gas stream.



Stratification profile showing a multipoint probe tube array, the reference method test path, and a single point sample probe test point

Gas Sample Probe – High Dust Load

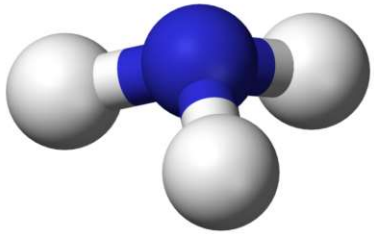
- For Higher Dust Loading Applications - >5 g/m3
  Typical used but not limited to: Cement, Coal, Steel, FCC, SRU…
- 9” Stainless Steel Filter Element – 2µm
- Dual Accumulator Tanks For High-Efficiency Blow-Back
- Incorporates a Pneumatically Controlled Sample Line “Isolation Valve”
- Blow-Back - Inside Out
- Standard Stainless Steel NEMA Type Enclosure
- Easy To Remove Filter Element –No Tools Required

Dilution Probe

Typical but not exclusive for Coal Fired Power Plants

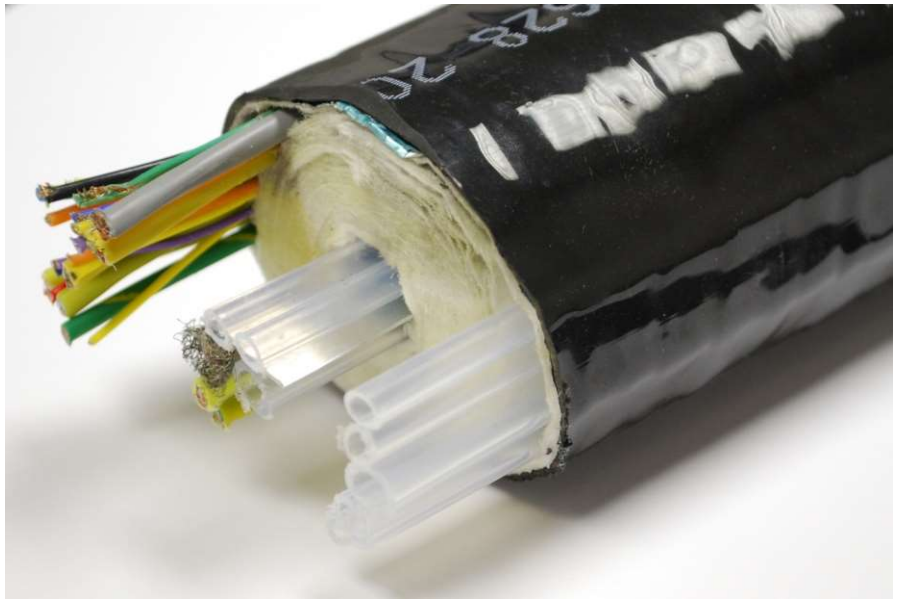
- Application usually dirtier than clean burning natural gas fired turbines
- Uses air and a critical orifice to dilute the sample
- Sample System reduced to cleaning up instrument air and pressure and flow regulation to the analyzer(s)

Considerations for Dealing with and / or Measuring Ammonia



- Ammonia Converter
  - When to use?
    - •Ammonia Slip (NOx differential)
    - •SCR to convert NH3 to NO
    - • +- 1250 - 1300°F for conversion

- Ammonia Scrubber
  - When to use?
    - Ammonia reacts with acid gases to form salts (ammonium sulfate, ammonium nitrate)
    - Salts plug off filters, sample lines and act as powerful adsorption sites
  - Three solutions
    - Scrub them with a dry scrubber
    - Phosphoric acid injection
    - Temperature – salts dissociate when hot



Sample Probes

Heated Sample Line

Gas Coolers

Sample Conditioning Systems

- Heated Sample Lines are an equally important segment of the sample transport system.
- They are not typically an off the shelf item
- They are specifically an engineered product with many considerations
- And it’s not enough to spec and buy the bundle, proper installation is of utmost importance

Important Heated Sample line Design Considerations …and again, lots to think about…

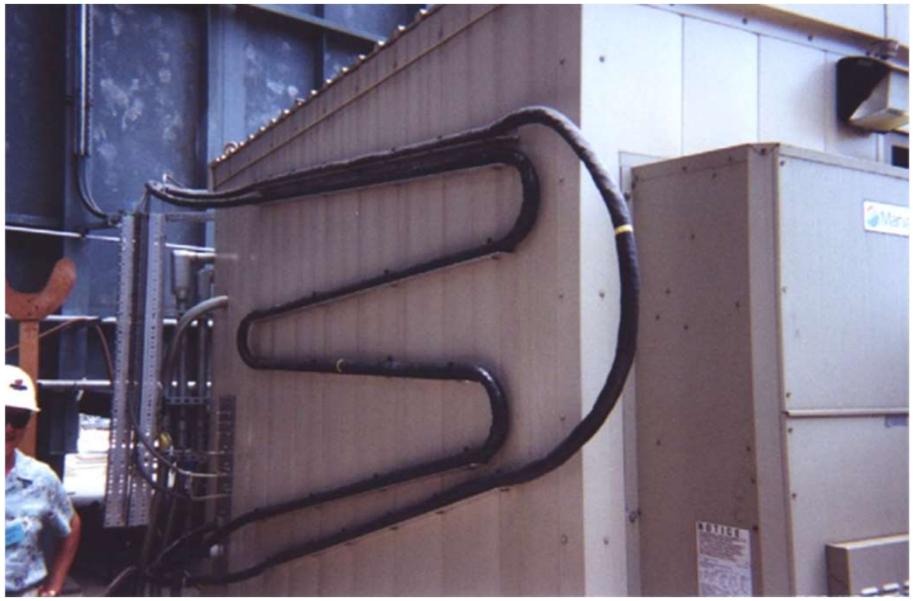
- Run Length
- Power Supply
- Dew point / Maintain Temperature/ Control
- Direct control or self-control
- Types of Tube Material
- Ambient Conditions … coldest day of the year
- Circuit Breaker Sizing
- Installation
- Hazardous Area Electrical Classification
- Insulation Thickness

Tubing Selection for Process Applications

- Teflon: Inert but temperature limitations on temperature permeation issue, bend radius concern
- Stainless Steel: welded or seamless cleanliness and adsorption issue with some applications
- Electro Polished: Provides surface finish for improved adsorption resistance
- Electro Polished/Coated: Provides Superior surface finish for maximum adsorption resistance; surface finish is inert like Teflon and strong as steel

Improper Installations

- Measure Twice: EPA recommends a 5% slope
- Poor Routing
- Improper Supports



Temperature Sensor Location needs to be outside analyzer shelter

Indication of Probe End, Power End, Temperature Sensor

Sample Probes

Gas Coolers

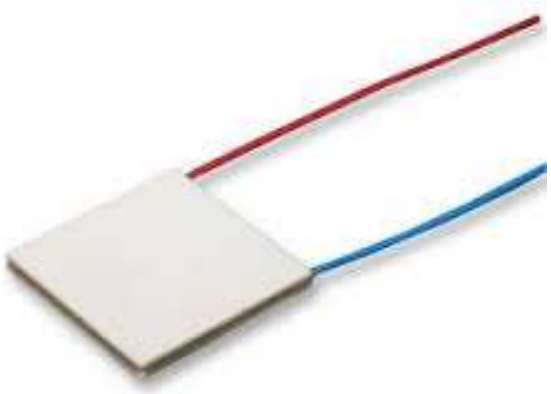
Sample Conditioning Systems

Function of a Gas Cooler

- Remove the water vapor to a certain dew-point, typically 4-5°C without removing the water-soluble compounds from the gas stream.
- Water vapor can interfere with the measurement of your gas analyzer(s).
- Water vapor will can harm the analyzer
- Water will react with certain compounds
- Water can mix with particulates to form a “muck” and plug things
- Cold-Dry Systems are reported on a Dry basis
- Most analyzers DO NOT like water

Types of CEMS style Gas Coolers

- **Thermoelectric**
  - Solid state Peltier effect cooler
  - No moving parts



- **Compressor**
  - Refrigeration type gas cooler
  - More cooling Power at high ambient conditions…> 90°F

- **Vortex**
  - Compressed Air cooler
  - No electricity required
  - Perfect for Hazardous Areas

Gas Coolers…How do they do what they do…

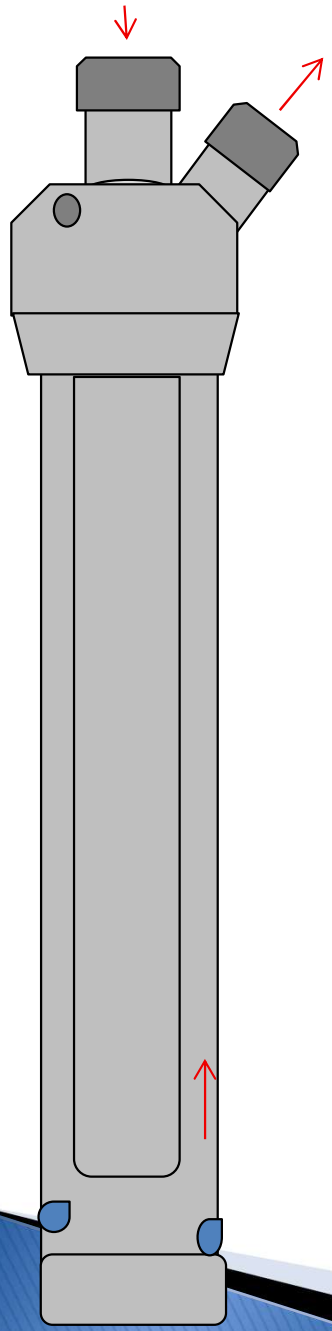
- They all do the same thing which is to chill the gas sample stream, lowering the dew-point and condensing out water and other condensable compounds down to a safe level for the analyzer(s)
- Standard outlet dew-points are typically 4-5 deg C
- Oddly, Southern California requires 37.5 deg C
- Whether thermoelectric, refrigeration or compressed air, they all chill a medium that chills a heat exchanger that chills the sample resulting in condensation and a dry sample, according to EPA protocols.

Gas Coolers…How do they do what they do…

- Some heat exchangers consist of a coil of tubing
  - Submersed in a water bath or wrapped around an aluminum block

- Others are tube within a tube design offering options for materials such as …
- Glass
- Kynar
- Hastelloy
- Silconert Coated
- Teflon Coated

Example of a Tube in Tube Design



Gas Cooler Flow Path

- Tube within a tube design
- Inner tube isolated from outside chilled walls of heat exchanger
- Gas stays hot until it exits bottom of inner tube and flash dries
- Condensate forms and is continuously drained
- Dry gas travels up annular space to sample output of heat exchanger
- By design we try to minimize contact of the condensate and the gases being measured (to prevent re-equalization of the liquid into the dry gas)
- Electro-polished exchangers minimize loss of water-soluble gasses such as NO_2 and SO_2

UNIVERSAL Analyzers Inc.

ONE SIZE DOESN'T FIT ALL

500 series

1000 series

3000 series

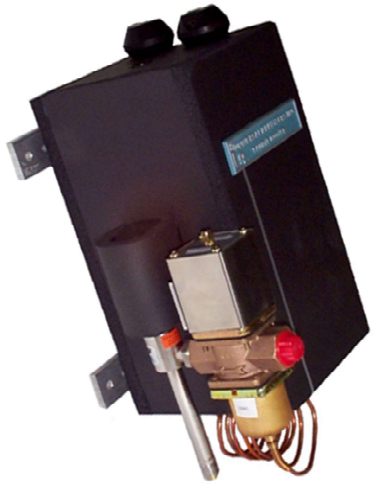
One to four heat exchangers – One, two or more gas streams

Flow rates from 4 – 16 l/m STP

General Purpose or Hazardous Area

4°C or Sub-Zero temperature set point

1095E "Freezer Chiller"



1100 Vortex series

600 series

Water Bath Using Coils & Refrigeration

Freezer Chiller - Why?

- Standard gas cooler @ 4°C dew point still has ≈ 0.8% H_2O by volume
- Freezer chiller @ -25°C dew point removes H_20 down to ≈ 0.03% H_2O by volume
- SO_3 & H_2O react to form H_2SO_4
- Do not know of an SO_3 only scrubber
- Must remove as much H_2O as possible to minimize formation of H_2SO_4 which forms in gas cooler as an acidic aerosol.

Eliminate the Green Slime

Visual of the results of not applying the proper sample system to a High Sulphur Application …could you imagine what the inside of the analyzer(s) looks like?

Sample Conditioning Systems
What is the real purpose …

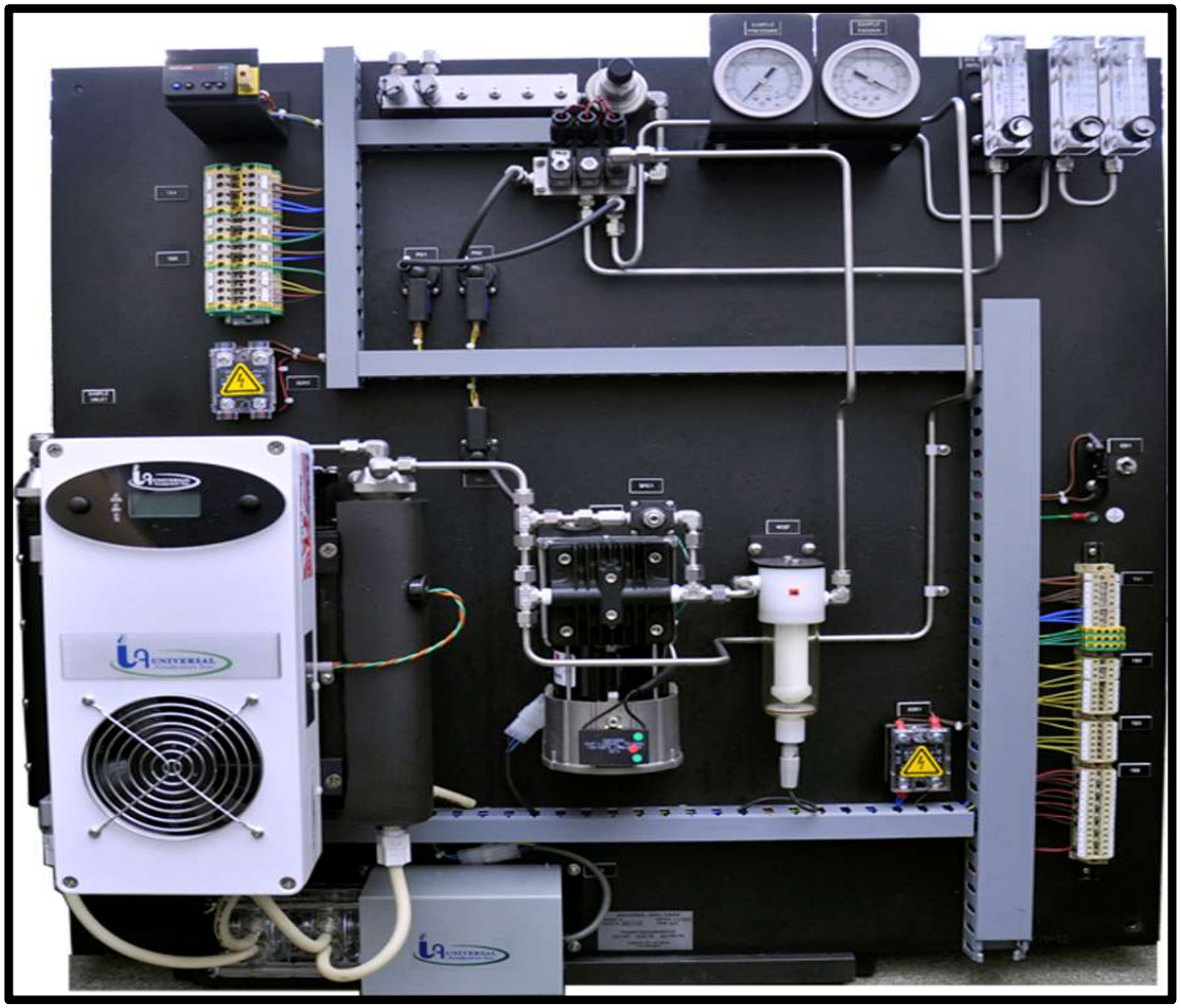
- Analyzer may not be compatible with pressure, temperature or moisture content of extracted sample.
- Prepare the sample for analysis without affecting relative concentration of components.
- Typically include some of the following:
  - Gas Cooler
  - Pumps (sample and peristaltic)
  - Flow meter(s)
  - Pressure & Vacuum gauges
  - Pressure regulator
  - Solenoid valves
  - Alarms
  - Temperature Controller

Designing Sample Systems / Common Concerns

1. How Many Sample Locations/Streams?
2. Will the Sample System be in a hazardous location?
3. What are the stream components?
    a. Moisture Content
4. How many analyzers and what is the desired response time?
5. Size Cooler
6. Plate, U-bracket, Drawer?
7. Will there be system and direct calibration?
8. What are the maximum possibilities of calibration gas?
9. What visual indicators are necessary?
10. What alarms need to be passed along?
11. Heated Sample Line control?

Sample Conditioning System on a wall mount panel

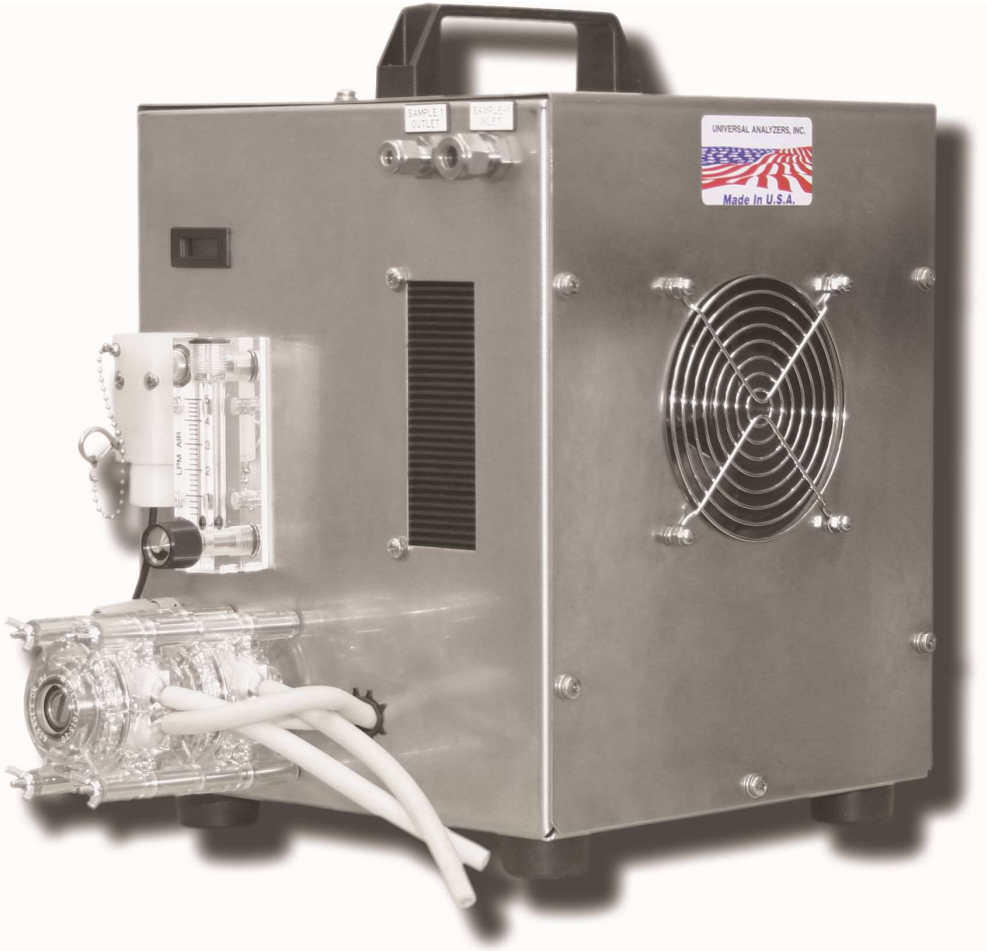
Sample System on a Wall Mount Panel



Sample Conditioning System In a 19” Rack Mount Drawer

Sample Conditioning System
19” U-Bracket

Portable Sample Systems



- One or two 5” heat exchangers
- One gas stream
- Flow rate options of 2.5 or 5 l/m STP
- Includes:
  - Gas cooler
  - Sample pump
  - Peristaltic pump
  - Flow meter
  - Water carry-over sensor
  - Digital temperature display
  - Stainless steel case
  - Carrying handle and feet
  - Approx: 16 kg

Again, lots to think about for arguably the most important segment of any gas analysis system. This applies to process gas analysis, measurements for safety and of course, compliance driven Continuous Emissions Monitoring Systems!

While this was brief, I hope I shared some food for thought. I will be here all day if you have any specific questions that I didn't' cover or if you have a nagging CEMS Sample System issue and often think to your self…

…there's got to be a better way!

THANK YOU FOR YOUR TIME!!!

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