

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



September 2023



Custom Instrumentation Services Corporation
12th Annual 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 of 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

**“Front-End”
Sample
Conditioning
Components**

- Gas Sample Probes
- Heated Sample Line
- Gas Coolers / Chillers
- Pumps, Flowmeters, Regulators, Gauges, Alarms...

B

Analyzers

- NO_x
- CO
- O₂
- SO_x
- CO₂
- HCl
- Hg
- THC
- . H₂S
- . CH₄

C

**Calibration
Gas**

- Span Gases
- Zero Gas

D

**Data
Acquisition
System**

- 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

UNIVERSAL ANALYZERS INC.
5200 Conair Drive
Carson City, NV 89706, USA
Telephone: +1 (775) 863-2500
Fax: +1 (775) 863-6388



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? ☐ Both

☐ Components ☐ Compliance ☐ Process

Stream or Process Data

Type of measurement: _____
Stream Components Concentration/Vol%
1. Water _____ ppm
2. _____ ppm
3. _____ ppm
4. _____ ppm
5. _____ ppm
6. _____ ppm
Required Gas Cooler/Chiller flow rate _____ l/min

Particulate Loading
Amount: _____ g/m³
Micron size: _____ Min _____ Max

Stream
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 Temperature (°C or °F) _____ Min _____ Max



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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 ☐ Not Applicable ☐ Downstream
Is there any excess stack/duct vibration? (e.g. Simple Cycle Gas Turbine) ☐ Yes ☐ No

At Mounting Point

Ambient Temperature (°C or °F) _____ Min _____ Max
Distance to Analyzer: _____ ft
Length of Sample Line: _____ ft
Return sample to process? ☐ Yes ☐ No
Diameter of stack at Sample Location: _____ in
Flange Size: _____ in
Flange Spool length from stack/duct wall: _____ in
Is there an Annulus? ☐ Yes ☐ No
I.D. of Sample Line: _____ in
Pressure at Return Point: _____ in
O.D. of Sample Line: _____ in

Miscellaneous

Are you interested in PLC services?
Ethernet, RS232, Internet? ☐ Yes ☐ No
Any special requests for material? ☐ Yes ☐ No
☐ SS ☐ PTFE ☐ Ceramic ☐ Other: _____
☐ Hastelloy ☐ PVDF

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) 863-6388.
You will be contacted shortly.



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, probe and sample line 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
 - If determined to be Hazardous, we need to take care to prevent the spark and arc that may 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 NH₃ 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?)
 - o Non Metallic
 - o Stainless Steel
- Interior Enclosure Heater with insulation
- Filter Temperature maintain...340°F ...375°F up to 550°F?
- Temperature control (integrated thermostatic 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”

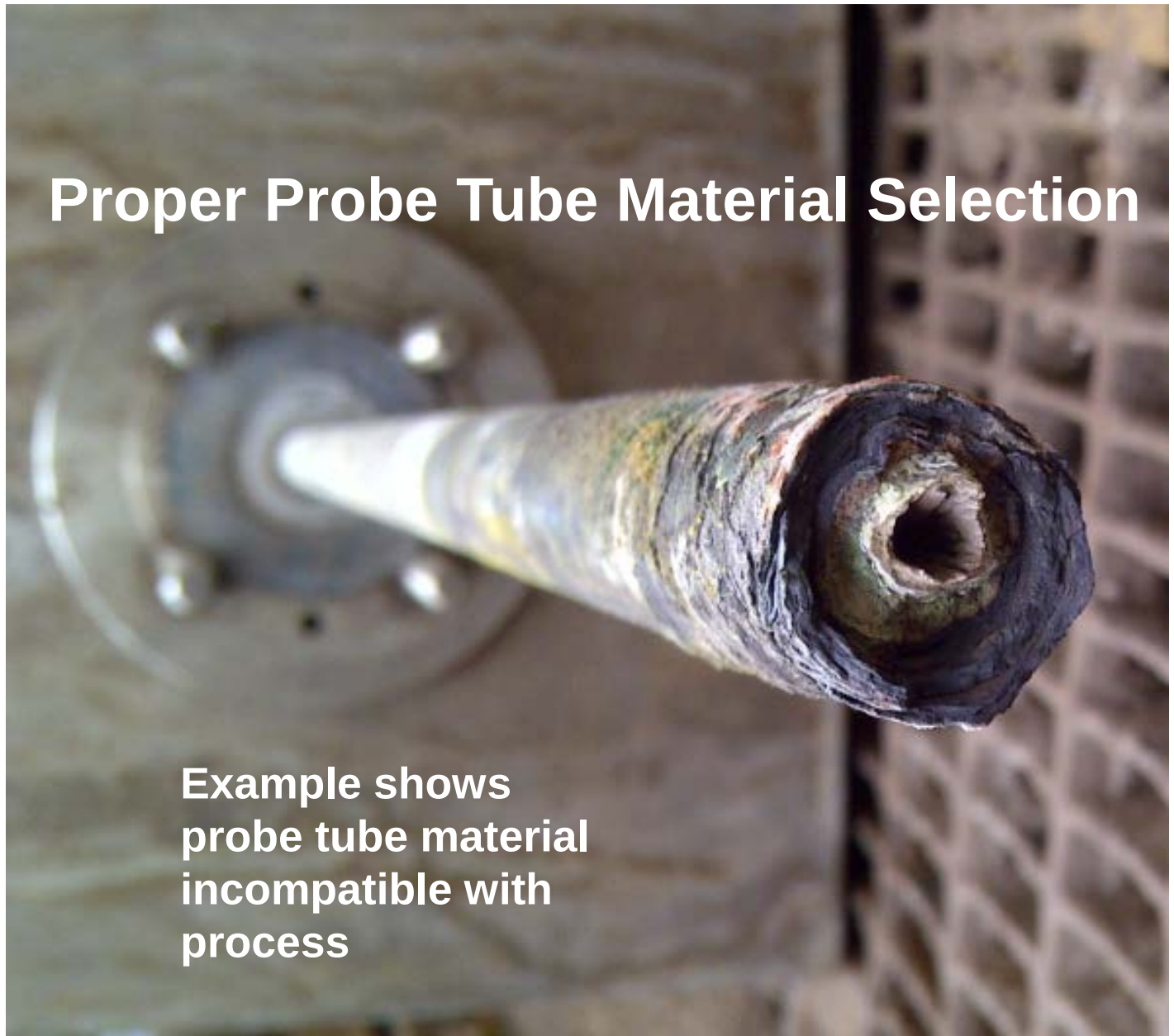
**What happens when you don't
specify the flange orientation
...50/50 shot at getting it right...**



Proper Probe Tube Material Selection

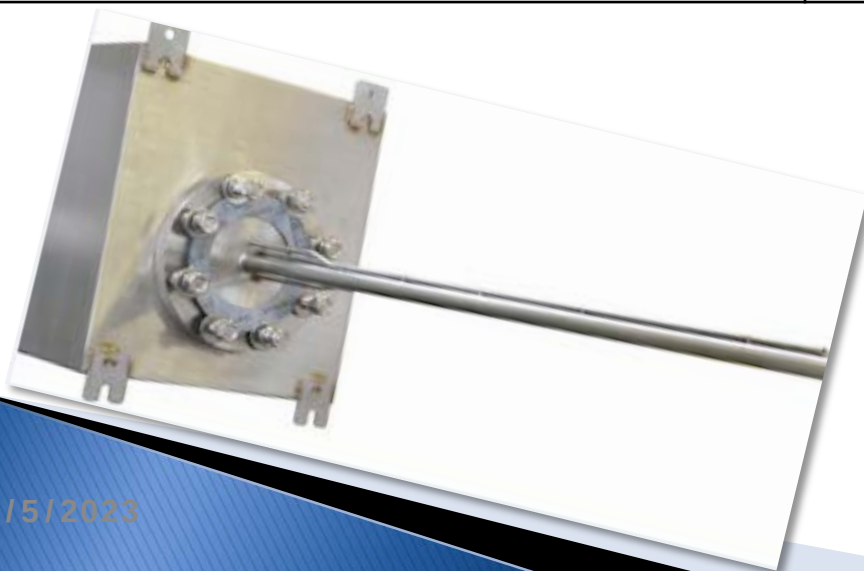


Example shows
probe tube material
incompatible with
process

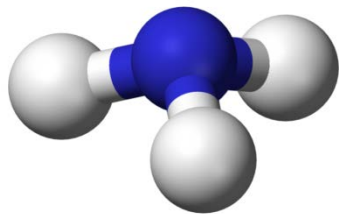


Probe Tube Material Selection

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



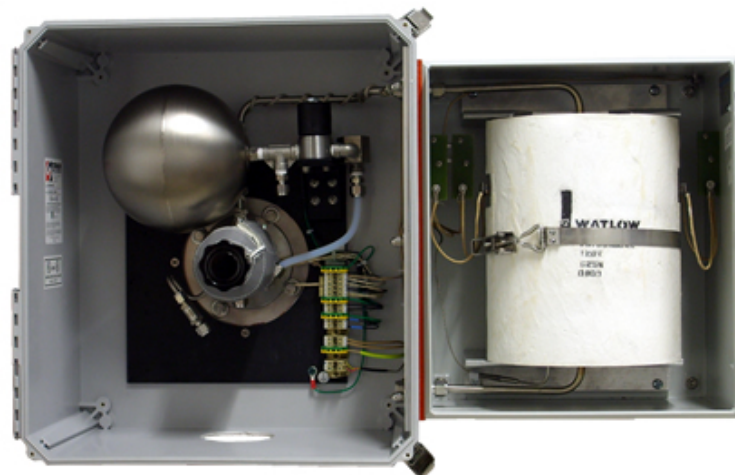
Considerations for Dealing with and / or Measuring Ammonia



- 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

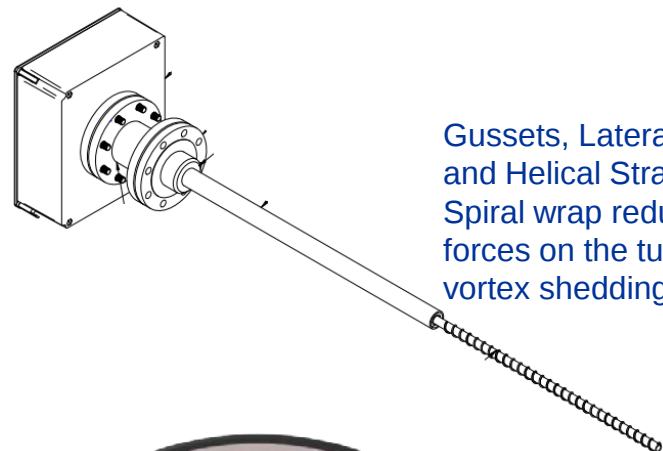
- Scrub them with a dry scrubber
- Phosphoric acid injection
- Temperature – salts dissociate when hot



Standard and High Velocity Applications



High Velocity Probe Tube
Duct / Exhaust Flows > 100 fps



Gussets, Lateral support
and Helical Strakes /
Spiral wrap reduce the
forces on the tube due to
vortex shedding

Point of Connection Support



Probe Tube Support Collar

Sample Probe – High Dust Load Option



- For Higher Dust Loading Applications - $>5 \text{ g/m}^3$
Typical used but not limited to: Cement, Coal, Steel, FCC, SRU...
- 9" Stainless Steel Filter Element – $2\mu\text{m}$
- 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 Option

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)

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

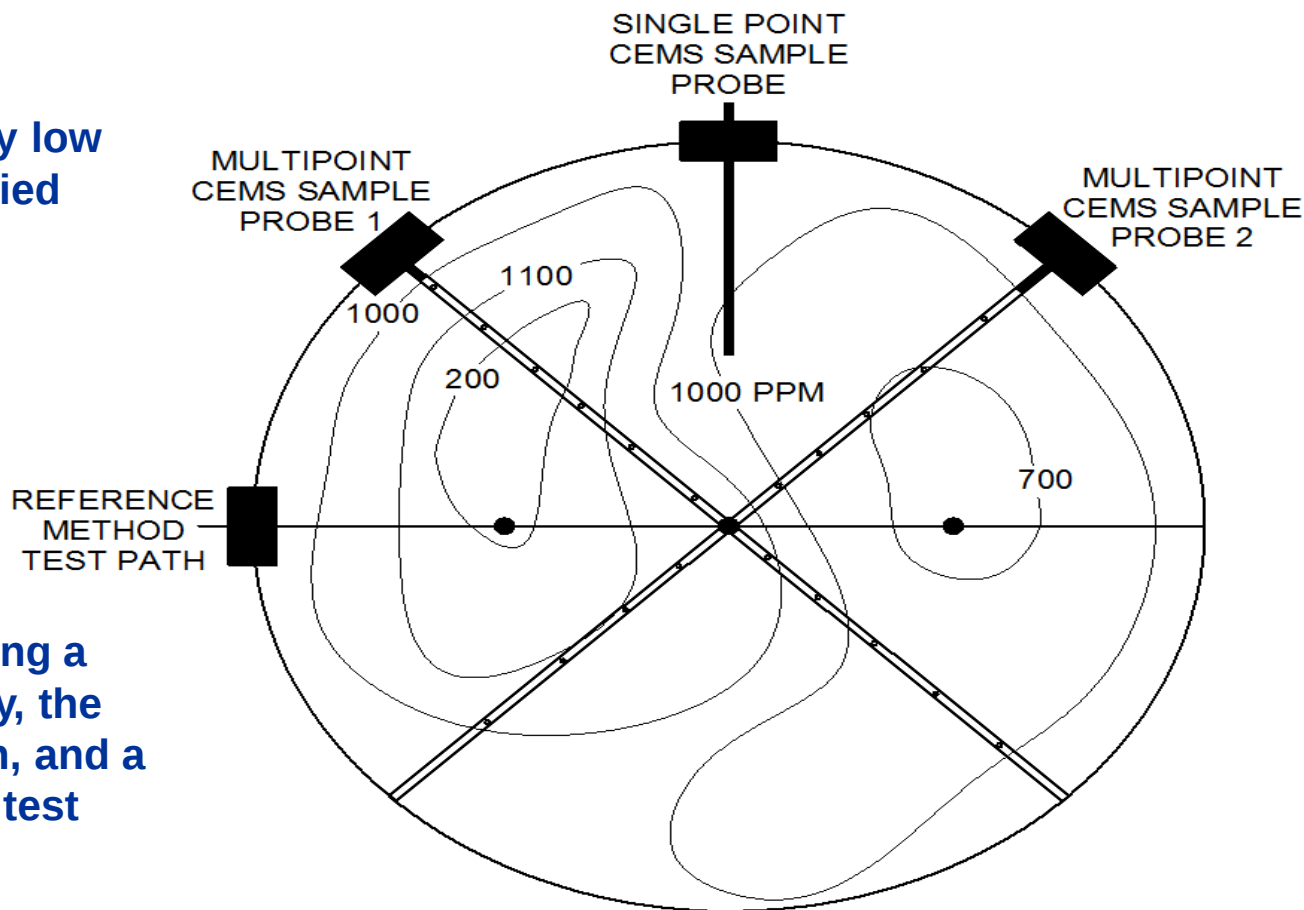
Multipoint Probe Tube and Sampling System are designed to obtain a representative sample when there is cross-stack stratification in a Continuous Emissions Monitoring System.

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.

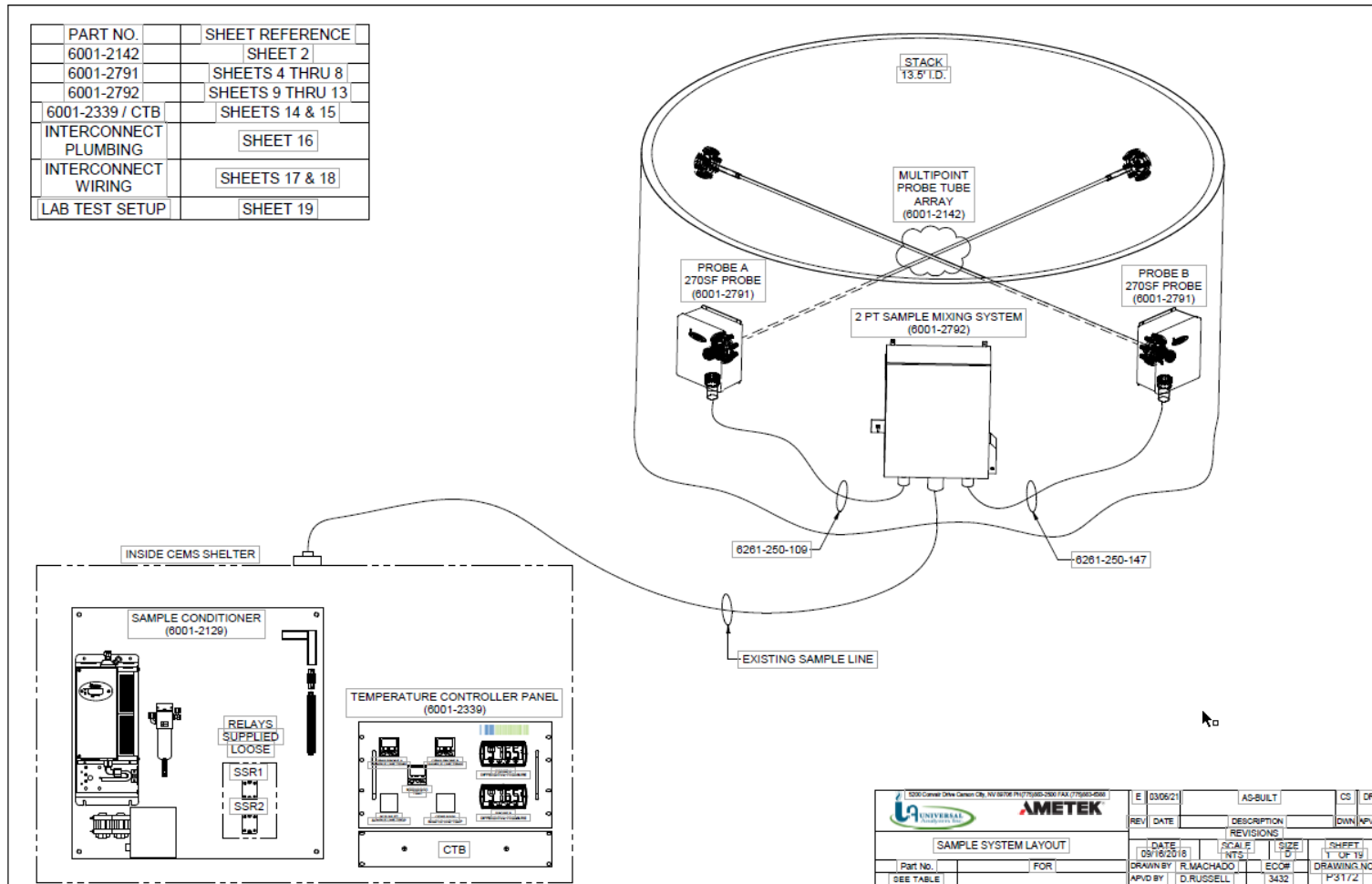
Stratification profile showing a multipoint probe tube array, the reference method test path, and a single point sample probe test point

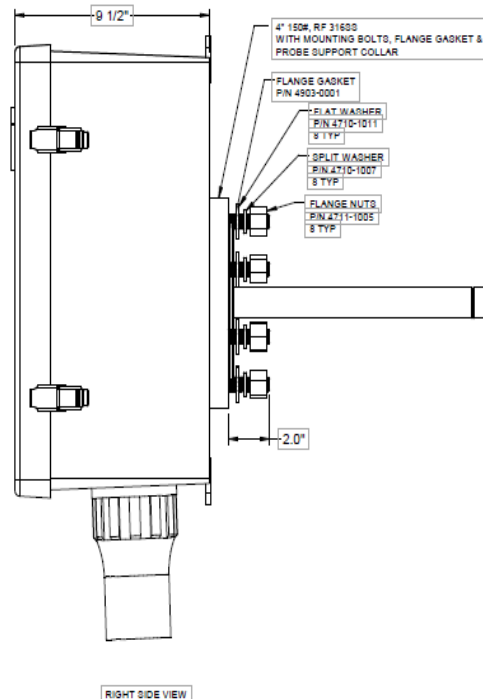
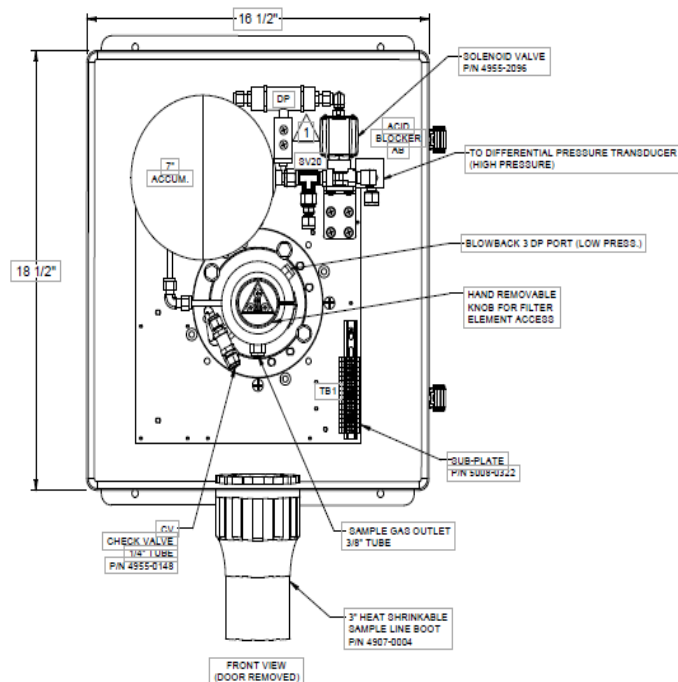


Example
Stack i.d. 13.5ft.

2ea. Cross stack
“criss-cross probe
tubes

1ea. Heated / nested
mixing/averaging
enclosure with
heated flow meters
and manifold





Gas Sample probe with...

-Heated filter

-Blow back

-Mating flange

-Extra support welded to flange for long probe tube

-Heat shrink boot/entry seal for heated sample line

-Differential pressure connections and transducer to monitor health of the multi-point array

REQD	DESCRIPTION	U.A.I. P/N
1	KNOB O-RING VITON	4904-0016
1	FILTER O-RING VITON	4904-0016
1	SPLIT PINCH VALVE (24V)	4845-2086
1	ACID BLOCKER	4710-1011
1	FLAT WASHER	4710-1011
1	SPLIT WASHER	4710-1007
1	FLANGE NUTS	4711-1005
1	FILTER / KNOB O-RING	4904-0004

ENCLOSURE 18" X 16" X 8"
FIBERGLASS
P/N 5023-1008

NOTE:

1. PRESSURE XMTR ADJUSTMENT SCREWS
SHOULD FACE THE DOOR.

BOTTOM VIEW

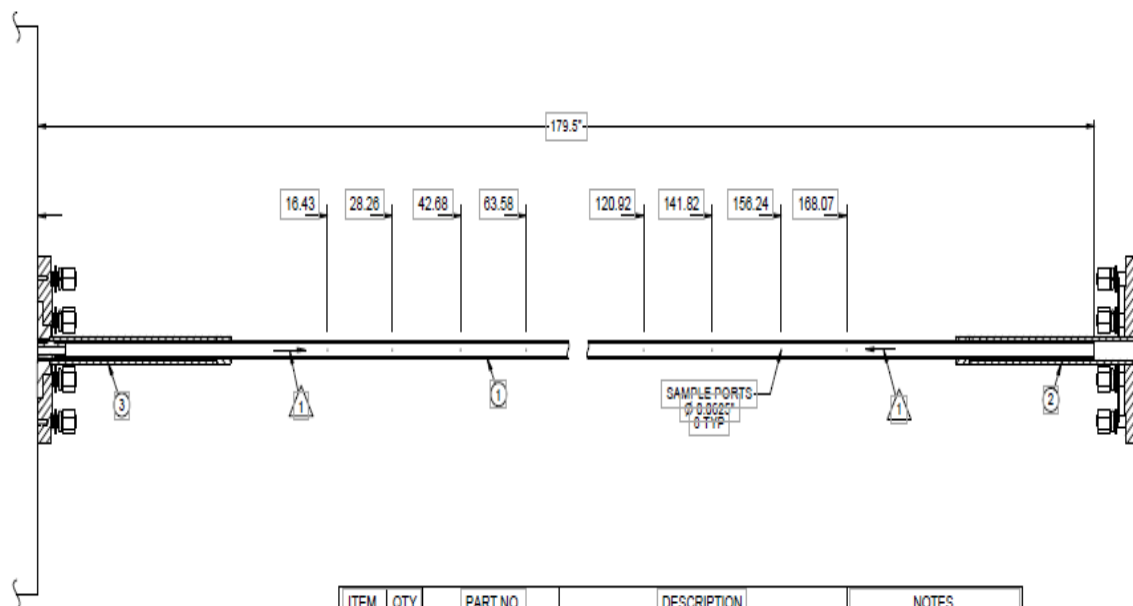
		E 03/05/21		AS-BUILT	CS	DR
5000 Central Express Canyon City, NV 86706 PH: (775) 690-2300 FAX: (775) 690-4566		REV		DATE	DESCRIPTION	OWN/APVD
6001-2791 LAYOUT & DIMENSIONS		REV		DATE	DESCRIPTION	OWN/APVD
Part No.	FOR	DATE	SCALE	SIZE	SHEET	
SEE TABLE		09/18/2018	1/8"	10"	1 OF 19	
		DRAWN BY	R. MACHADO	ECN#	DRAWING NO.	
		APVD BY	D. RUSSELL	3432	P31/2	

Multipoint Probe tube

-Can be Stainless Steel or Inconel or coated with Silconert Coating

-8 holes per tube usually to mimic traverse points from the stack test team

Flanges with extra in-stack support for the tube



ITEM	QTY	PART NO.	DESCRIPTION	NOTES
1	2	5155-1501	Multipoint Probe Tube, 316SS	(2) 5155-1501 + (2) 5155-1502 Make Up (1) 8001-2142.
2	2	5155-1502	1Ft. 316SS Probe Tube Support w/ 4" 150# Flange For Installation on Opposing Nozzle Flange	
3	2	8001-2238	270-SF w/ 1 Ft. Support & 4" 150# Flange, 316SS w/ Static Pressure Tube	

NOTES:

1. ALIGNMENT ARROW PROVIDED ON TOP AND BOTTOM OF PROBE TO HELP FACILITATE ALIGNMENT DURING INSTALLATION. FOR BEST RESULTS, INSTALL SUCH THAT THE SAMPLE PORTS ARE SIDEWAYS TO THE SAMPLE FLOW.

2. TWO PROBE TUBES AND TWO PROBE TUBE SUPPORTS FOR THE OPPOSING NOZZLE FLANGE WILL BE PROVIDED FOR INSTALLATION AT 90° FROM EACH OTHER.

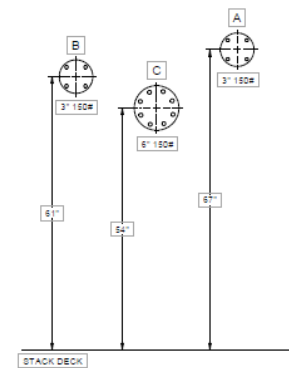
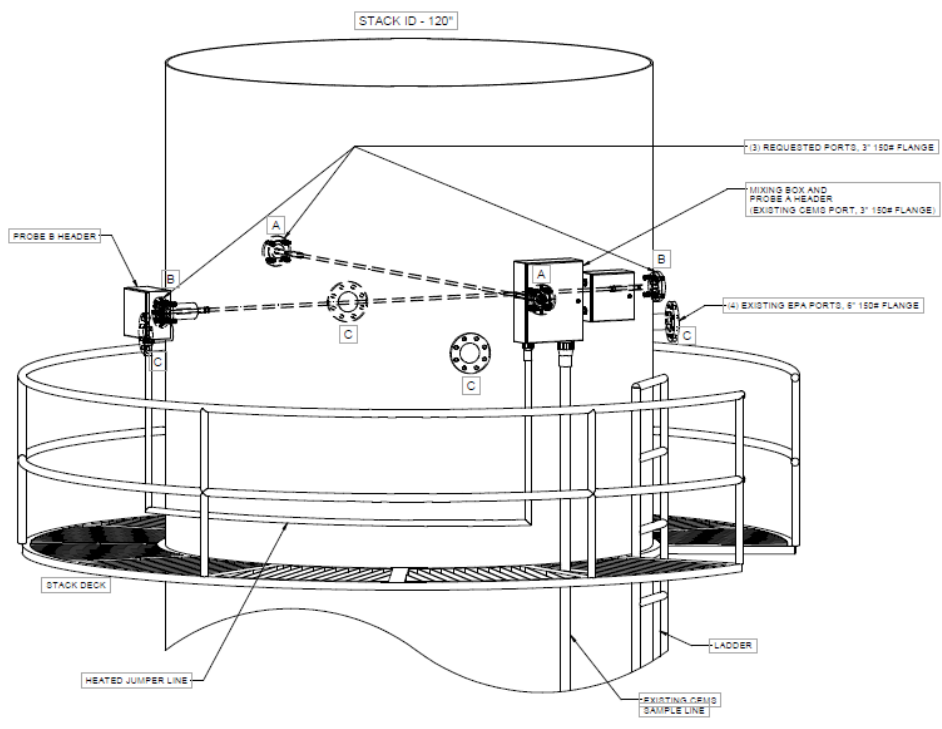
3. SEE DWG P2279 FOR CONTROL PRINT FOR 8001-2142.

UNIVERSAL ANALYZERS INC.		AMETEK		A. 12/16	Initial Release	MM	DR
REV	DATE	DESCRIPTION		REVISED		OWN/APVD	
MULTIPOINT PROBE TUBE DETAIL							
DATE	SCALE	SIZE	SHEET				
12/01/15	1:1	11	1				
DRAWN BY: M. Waser		ECCS		DRAWING NO. P2586			
APVD BY: D. Russell							

Another view showing staggered flange pattern

-RATA Ports

-Multi-Point ports



10000 Greenway Drive, Greenway City, MO 64786-9400 (913) 778-0000 FAX (913) 778-0001		A	12/1/17	AS-BUILT	CS	DR
 AMETEK		REV	DATE	DESCRIPTION	DWN	APVD
MULTIPOINT SYSTEM ELEVATION VIEW		DATE	SCALE	DESIGN	DATE	SHEET
PART NO. 8001-2659		10/20/2017	1" = 1'	10/20/2017	10/20/2017	2 OF 2
FOR		DRAWN BY C. SHIELDS	INTS	10/20/2017	10/20/2017	DRAWING NO.
		APVD BY D. RUSSELL	10/20/2017	10/20/2017	10/20/2017	10/20/2017

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

- Multi-point probe array's rarely considered up-front with a new CEMS
- Usually a requirement consideration as RATA numbers trend towards failure
- Short stacks and not having proper mixing is one cause
- Changing disturbances up stream contribute to deteriorating values (e.g. Catalyst getting old, ducting out of alignment)
- Ever changing measured values going lower and lower...fewer molecules to measure
- Multi-Point Probe tube array is a special, more costly consideration but can be the difference between passing and not...

Sample Probes

Gas Coolers

Sample Conditioning Systems

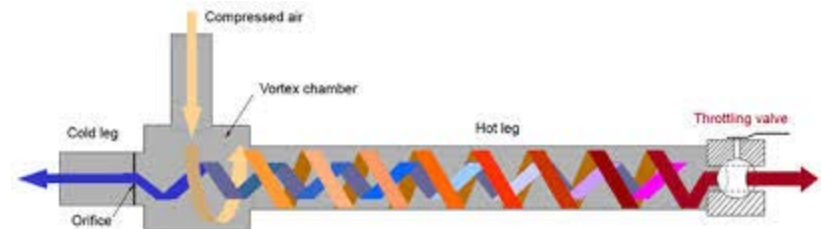
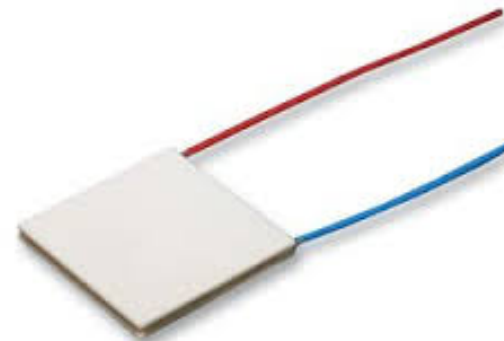


Function of a Gas Cooler and why!

- 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



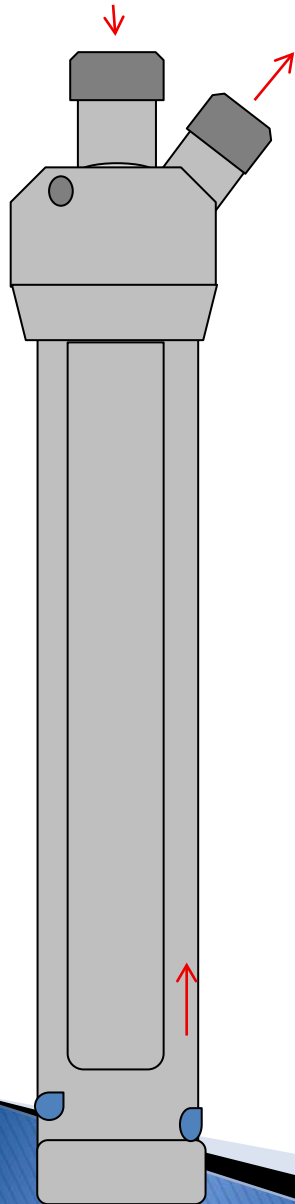
Gas Coolers...How do they do what they do...

- 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 3.75 deg C
- Oddly So Cal and the state of New Jersey both require that the gas stream sample temperature is measured...aka “NJ Option”!
- 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 via a peristaltic drain pump or other
- Dry gas travels up annular space to sample output of heat exchanger
- Design is to minimize the 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

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 $\approx 0.8\%$ H₂O by volume
- Freezer chiller @ -25°C dew point removes H₂O down to $\approx 0.03\%$ H₂O by volume
- SO₃ & H₂O react to form H₂SO₄
- Do not know of an SO₃ only scrubber
- Must remove as much H₂O as possible to minimize formation of H₂SO₄ 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

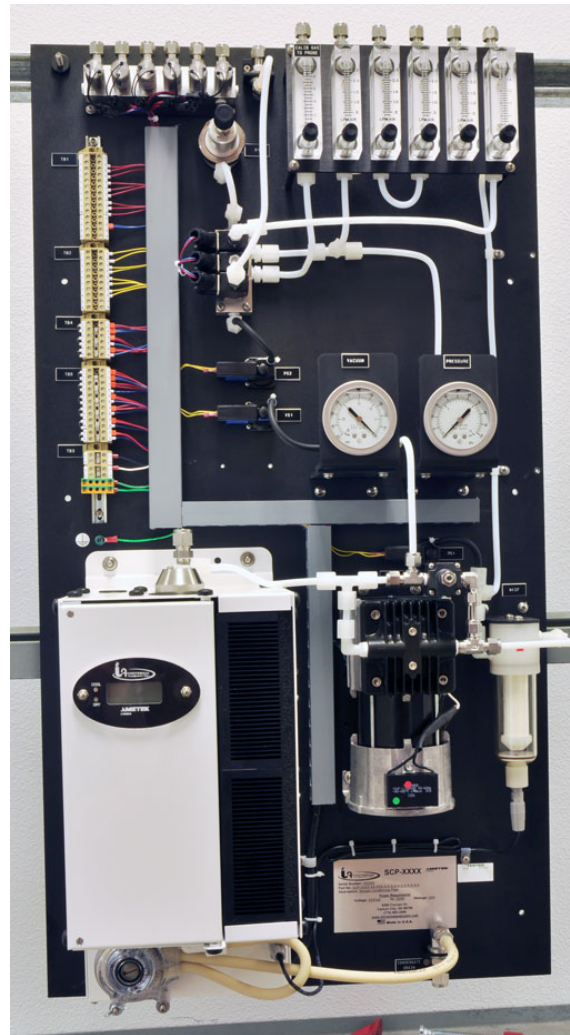
What is the real purpose ...

- 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

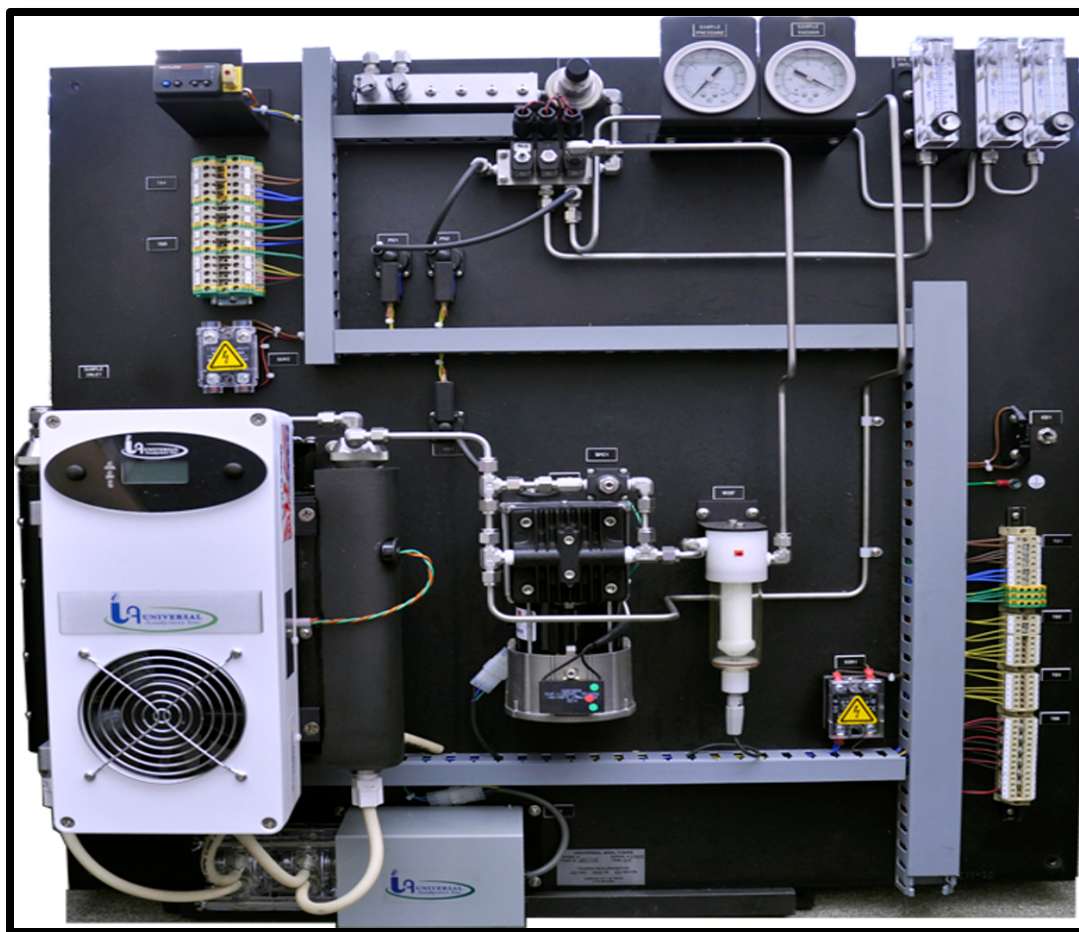
Designing Sample Systems / Common Concerns

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

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!!!

...AND A BIG THANKS FOR CISCO FOR ALLOWING ME THE OPPORTUNITY TO ADDRESS THIS WEEKS MEETING...

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