



Water Management in Gas Analysis

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Challenges for CEMS Sample Conditioning

- Difficult to sample a hot, wet, dirty and corrosive gas reliably & consistently

- High reliability required – systems must run for a long time without supervision
  - ✓ Must tolerate adverse and faulty operating conditions
  - ✓ Hot and Humid ambient conditions (up to 50 C) if installed outside
  - ✓ Systems require maintenance and sometimes costly repair to maintain compliance

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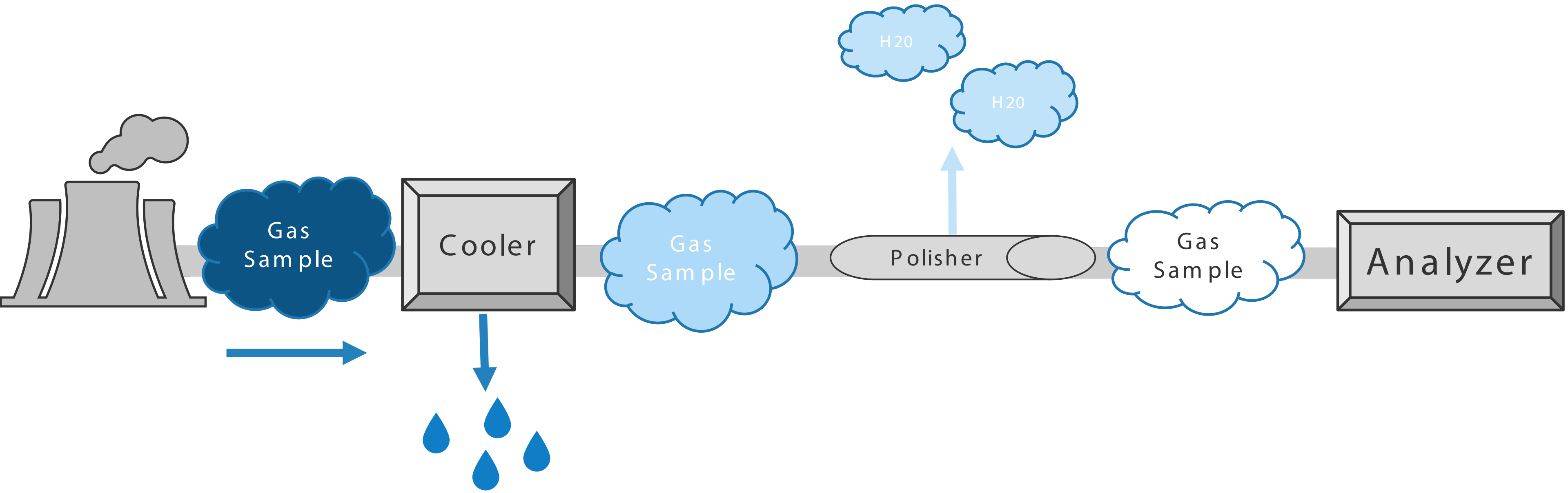
Sample Pathway



Sample Conditioning Prevents Unexpected Liquid Water!

Why do we care so much?

Costs of Unexpected Water

Corrosion

Unplanned Maintenance

Loss of Water-Soluble Components

Inaccurate Analysis

How Wet is Wet?

Relative Humidity (RH)

- The amount of moisture in the air as a percentage of the maximum amount that air can hold depending on the temperature of the air.
- RH changes as temperature changes
- Amount of actual moisture in air is not necessarily changed by temperature

Partial Pressure of Water Vapor (P_W)

- The part of the total pressure that is exerted by the water vapor alone.

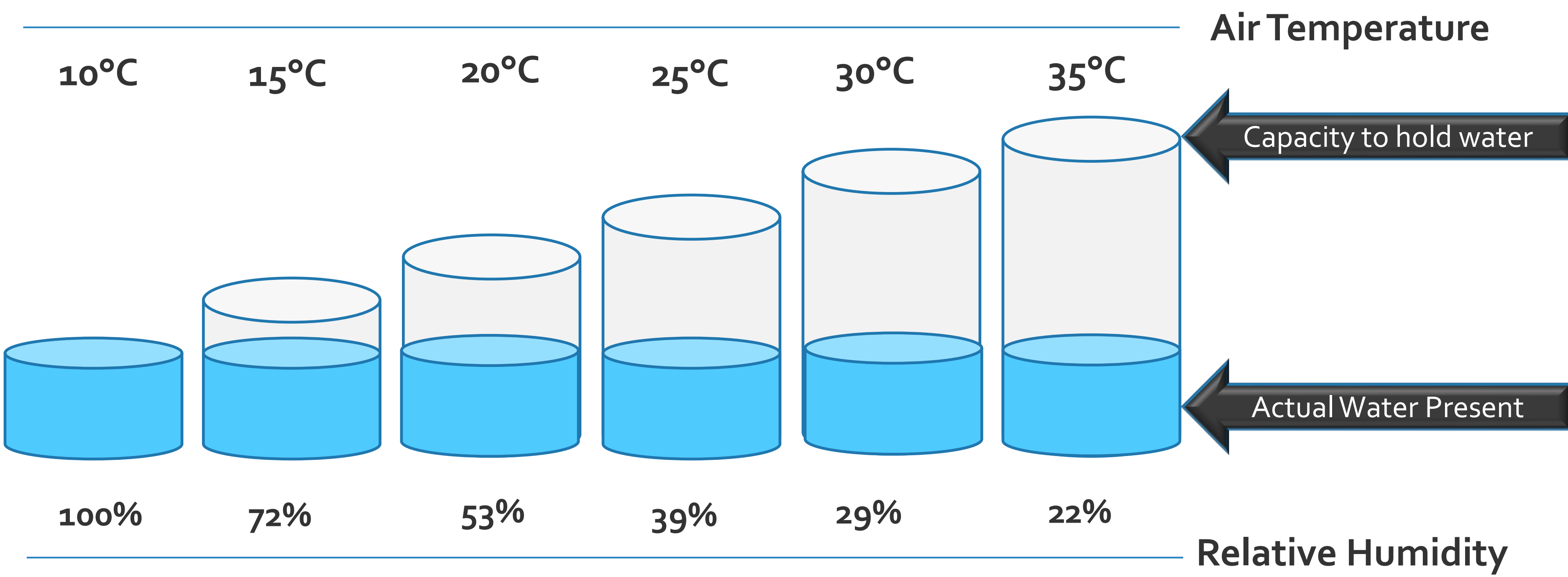
Dew Point

- The temperature at which RH reaches 100% and condensation forms
- Scale used by those people concerned about water condensation.

Percent Moisture by Volume

- # of molecules of H_2O per unit volume / total # of molecules per unit volume
- P_W / P_T

Dew Point & Ambient Air Temperature



Dew Point = 10°C

How Dry is Dry?

Dryness targets are based on application requirements.

- Preventing condensation / damage to the sensor
  - Target dew point: + 8-10 C
- Removing moisture for most CEMS & particulate monitoring
  - Target dew point: +4 C
- Eliminating water interference for NIR and improved CEMS performance
  - Target dew point: -10 to -15 C
- Ultimate drying for IMS and other methods
  - Target dew point -40 to -60 C

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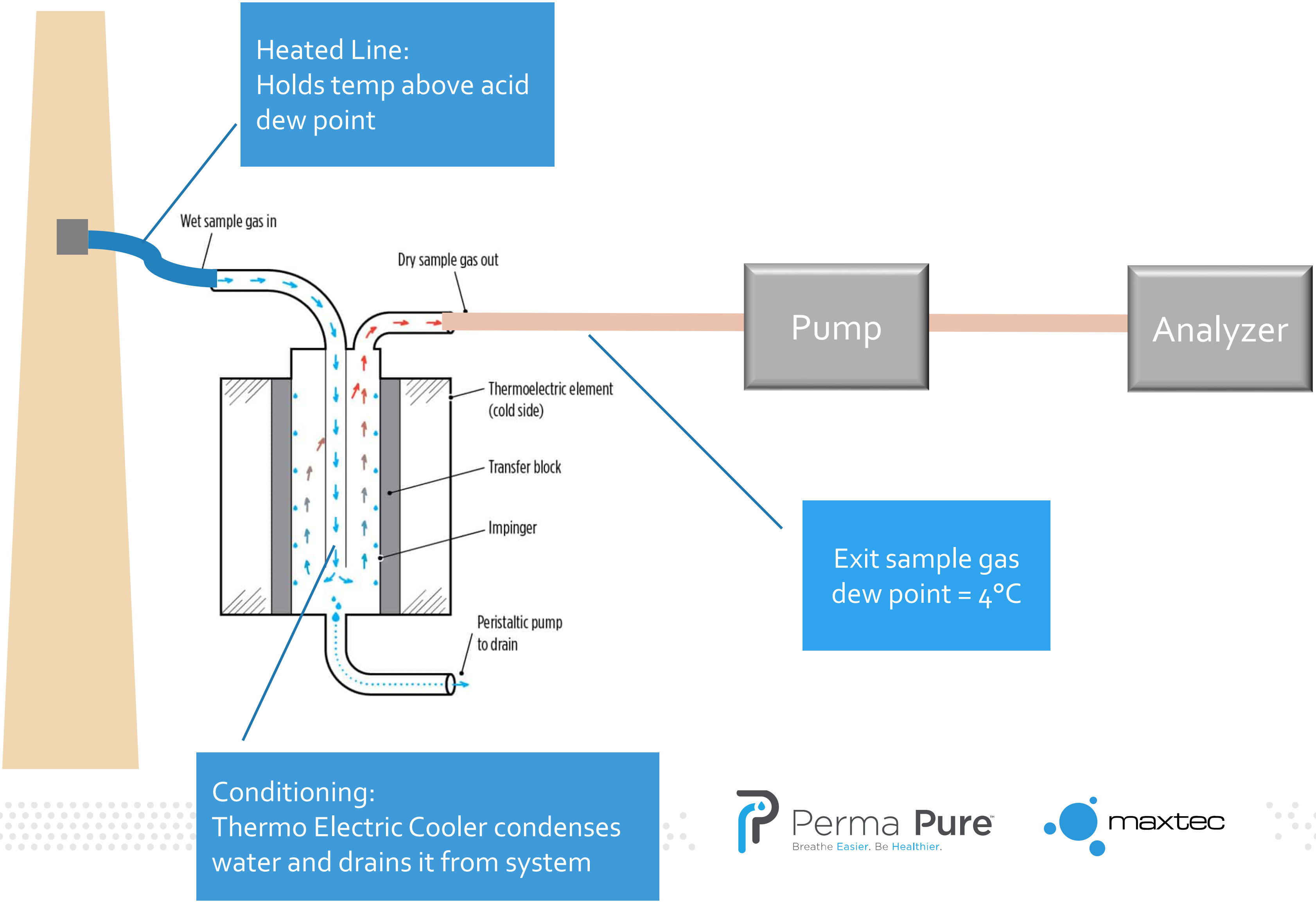
Changing Conditions Along CEMS Pathway



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Areas of Concern Along CEMS Pathway

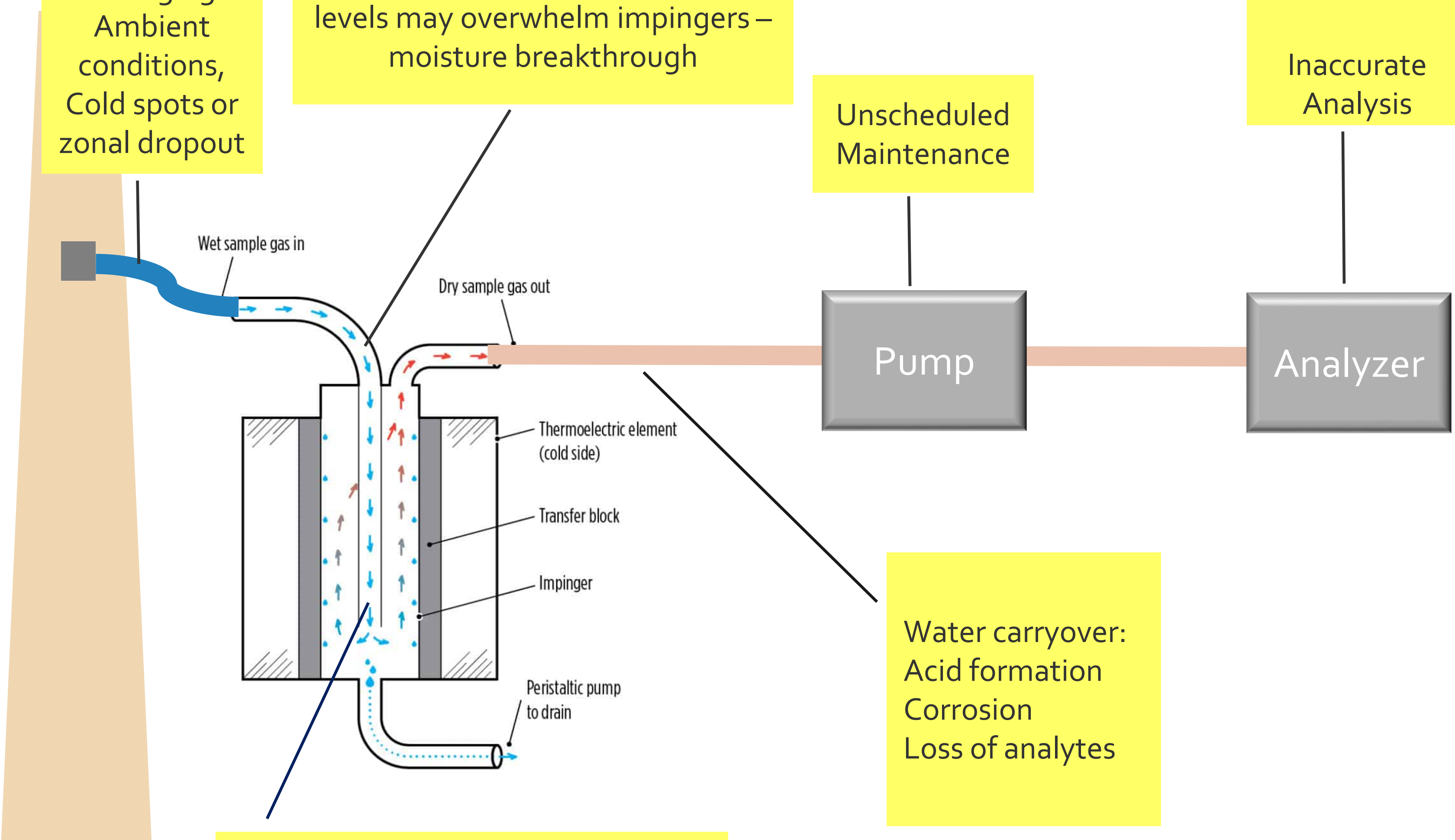
Changing Ambient conditions, Cold spots or zonal dropout

Higher than expected moisture levels may overwhelm impingers – moisture breakthrough

Unscheduled Maintenance

Unscheduled Maintenance

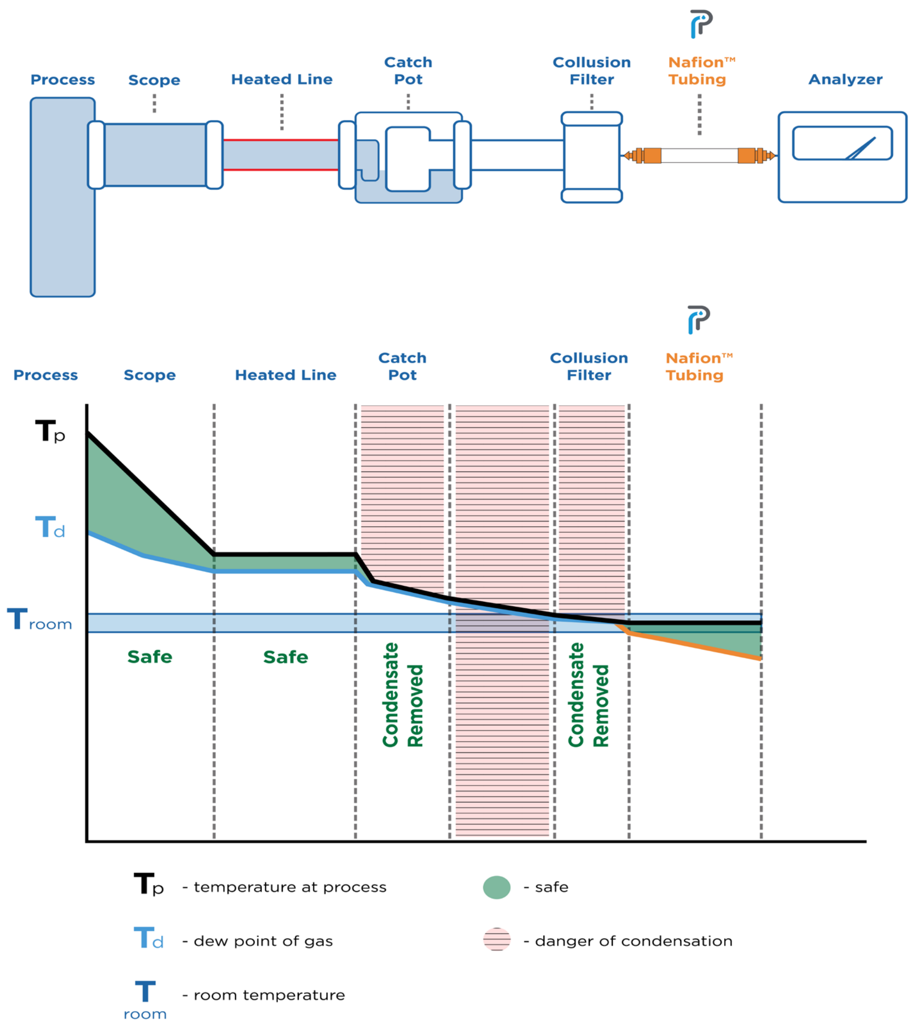
Inaccurate Analysis



Water carryover:
Acid formation
Corrosion
Loss of analytes

Not all condensed water may be trapped and drained

Changing Conditions Along Process Pathway



- Sample moisture volume may be dynamic
- Drying solution may remove only liquid water from line
- Dew point reduction may not reach below ambient
- Water vapor removal may not be low enough based on changing temperatures along pathway
- Not all processes are linear, drying may need to be added at multiple points
- Potential solutions:
  - Increase gas temperature
  - Remove more water in vapor form

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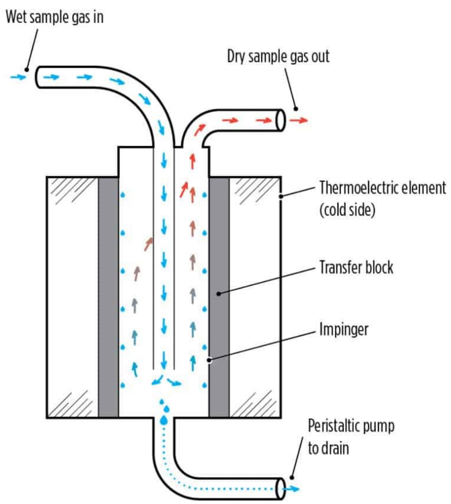
Moisture Management Solutions

Thermoeletric Cooler



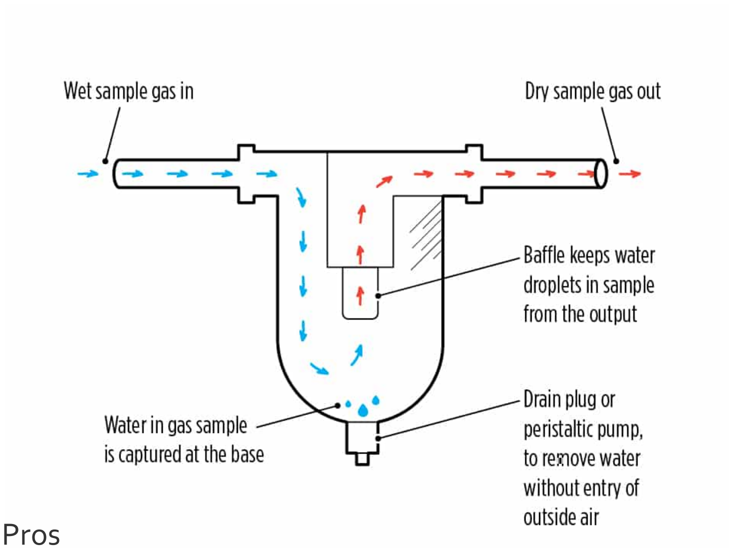
Pros

- Provide a consistent moisture content within specifications(+4 C dew point)
- In CEMS applications, this is the industry standard for gas sample conditioning.

Cons

- Moisture content levels limited to +4 °C dew point
- Unexpected moisture increases can lead to moisture breakthrough
- In presence of acidic gases (e.g. SOx, NOx, and HCL) , water carryover leads to acid formation
- Highly water-soluble components in sample may be lost

Water Trap



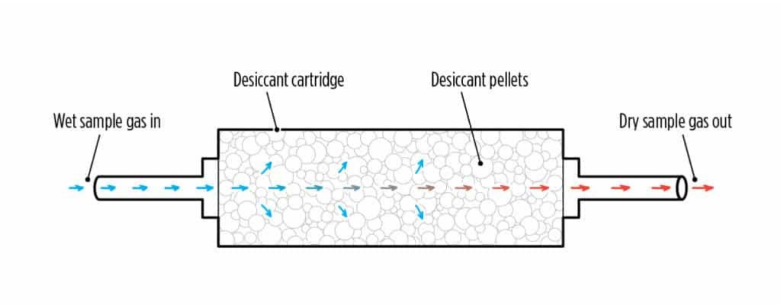
Pros

- Cost effective
- No moving parts and no power required

Cons

- Only removes liquid water
- Water-soluble analytes may be lost
- Manually drained water may increase maintenance

Desiccant Dryer



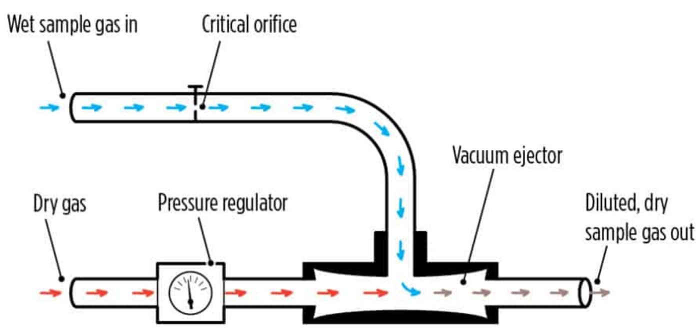
Pros

- Cost effective
- Achieves sub-ambient moisture levels
- No moving parts and no power required

Cons

- Desiccants non-selectively remove water and other analytes from the gas stream
- Requires regular replacement
- Performance of desiccant degrades over time leading to inconsistent output

Gas Dilution



Pros

- Low maintenance
- Can achieve very low, sub-ambient, moisture levels
- No moving parts

Cons

- Analytes becomes diluted in the gas sample, requiring increased analyzer sensitivity.
- Critical stability of the dilution ratio can difficult to maintain due to variations in pressure and temperature
- Requires access to a dry gas, such as instrument quality air

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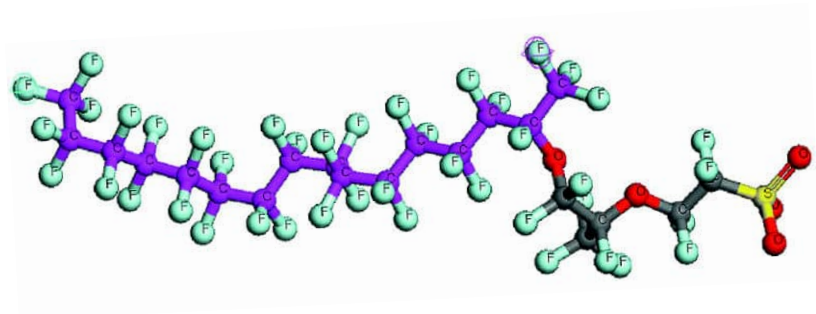
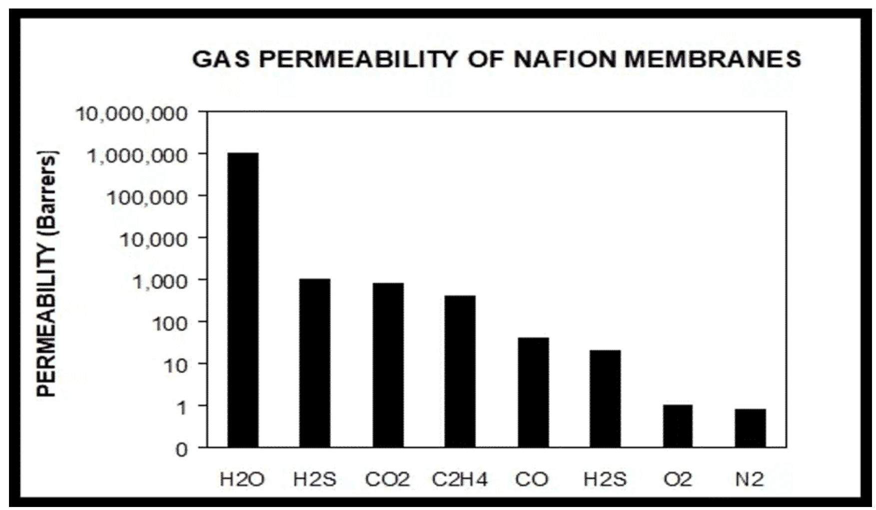
Nafion™ Technology



- Copolymer of a Teflon™ backbone with periodic fluorocarbon sidechains which terminate in a sulfonic acid
- Sulfonic acid groups participate in chemical reactions, therefore Nafion™ polymer:
  - Functions as an acid catalyst
  - Functions as an ion exchange resin with exposed to solutions
  - <u>Readily absorbs water in vapor or liquid phase</u>



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Nafion™ Selectivity

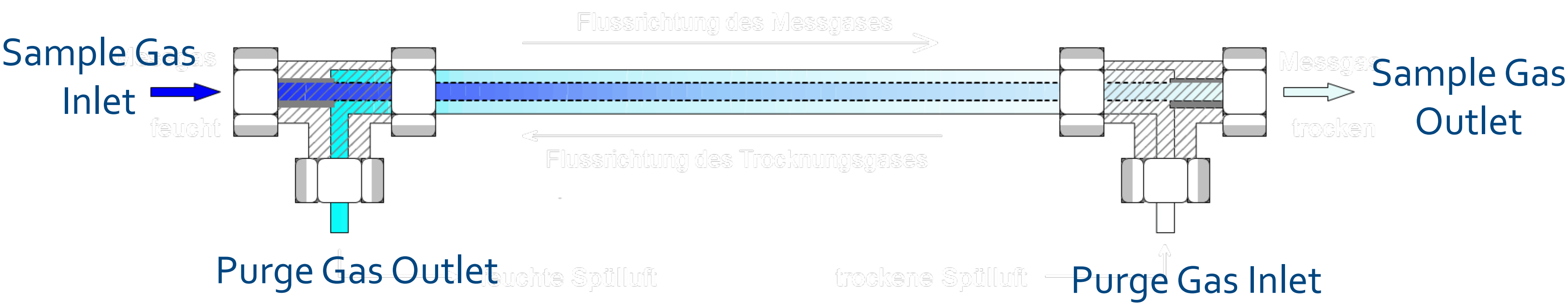
- Nafion permeation selectivity is based on chemical reactivity, not the size of the molecule – not traditional permeation
- Only compounds that chemically associate with sulfonic acid permeate through Nafion
- Bases associate with sulfonic acid and permeate through Nafion
- Few bases are gases at typical operating temperatures, so very few compounds permeate

Retained by Nafion

Atmospheric Gases	Ar He H_2 N_2 O_2 O_3
Halogens	Br_2 Cl_2 F_2 I_2
Hydrocarbons	Simple forms (alkanes)
Inorganic Acids	HCl HF HNO_3 H_2SO_4
Other Organics	Aromatics Esters Ethers
Oxides	CO CO_2 SO_X NO_X
Sulfur	COS H_2S Mercaptans
Toxic Gases	$COCl_2$ HCN NOCl

Perma Pure Dryers

- Reach dew points of -40°C
- Flow rates up to 40 lpm
- Temperatures up to 100°C
- Tube in shell design: inner Nafion™ element with outer polymer or SS shell.
- Removes water vapor based on partial pressure of water vapor differential
- The sample gas flows through the tube, and the dry purge gas flows outside of the tube in the opposite direction
- The flows are sealed off from each other
- Available in a wide range of dryer lengths and tubing diameters



Perma Pure Dryers

Pro

- Achieves sub-ambient humidity levels (as low as –40 °C dew point) depending on configuration
- Keeps analytes, including those that are water-soluble, in the gas sample
- Provides a consistent humidity level of the output gas
- No moving parts to wear out and no power required

Con

- Requires access to a dry purge gas, such as instrument quality air, compressed air or use of another purge gas configuration
- Damaged by Ammonia

Water Vapor Saturation Temperatures

°F	°C	% Water	
212	100	100	
158	70	30.7	Wet Scrubber
149	65	25.2	
141	61	20.0	
131	55	15.5	
114	46	10.0	Natural Gas Combustion
95	35	5.55	
68	20	3.31	
50	10	1.21	
41	4	0.80	TE Cooler output
32	0	0.61	
12	-10	0.26	
0	-18	0.12	Nafion Dryers remove 80% of Water Vapor left by Cooler

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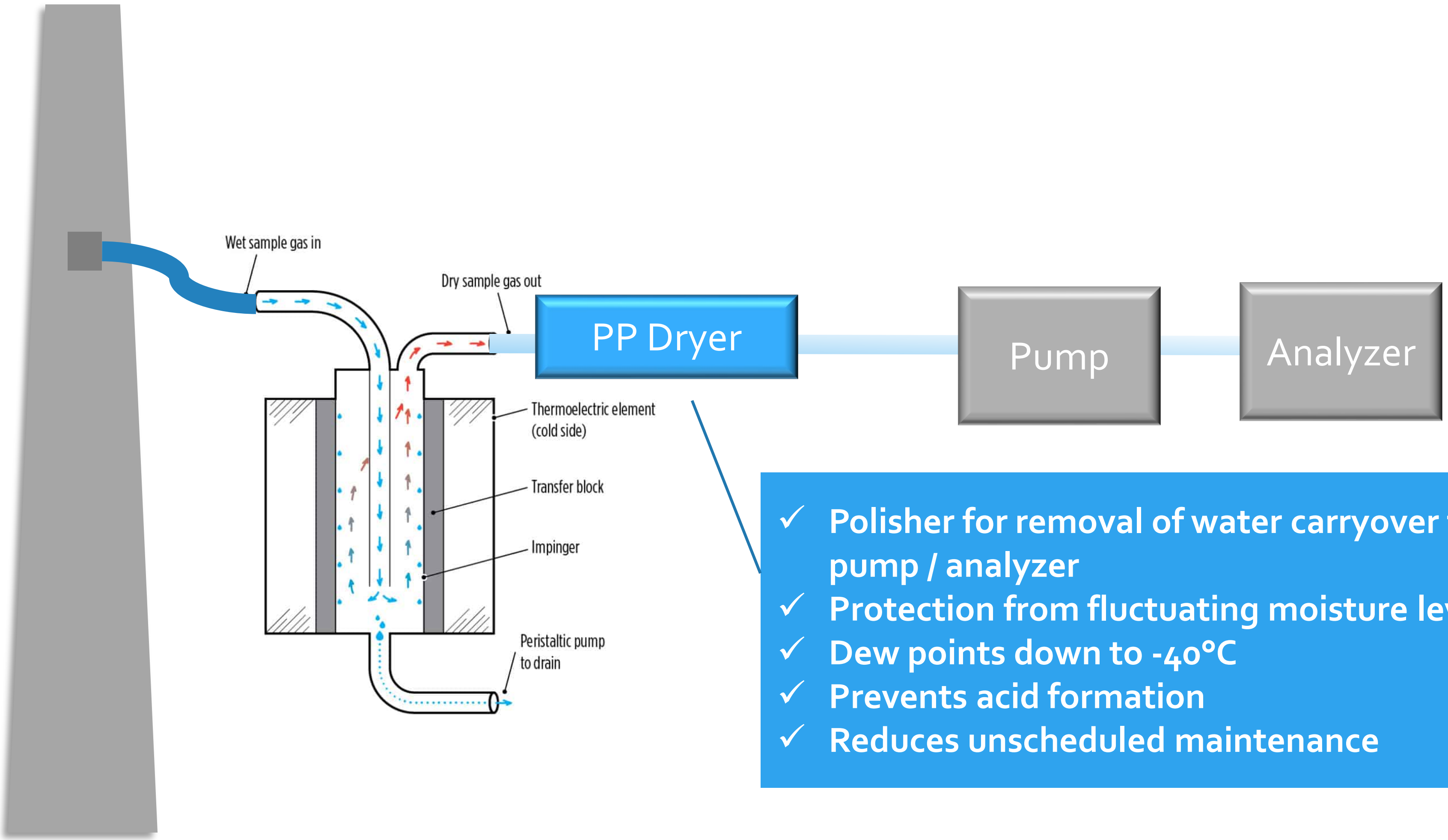
Emissions Monitoring



- ✓ **Polisher for removal of water carryover to pump / analyzer**
- ✓ **Protection from fluctuating moisture levels**
- ✓ **Dew points down to -40°C**
- ✓ **Prevents acid formation**
- ✓ **Reduces unscheduled maintenance**

Considerations In Moisture Removal

- Is the actual dew point of the gas known at all points in process?
- Can the environment along the pathway be controlled?
- Does any part of the process affect the moisture content of the gas?
    - Unexpected increase in moisture content from source
    - Addition of other gases including ambient air
- Do current drying solutions remove enough water
    - Liquid
    - Vapor

New Products

Hybrid Sample Gas Cooler

Feature	Benefits
Passive system requires no electric current	Ideal for sites that have limited/no access to power or other areas where a non-electric product may be desirable
	Eliminates the cost associated with installation and permits
Simple mechanical design (No Moving Parts)	Lower Maintenance Cost
	Increased Reliability
Ability to be stack mounted	Eliminates the cost of heated lines Saves room in crowded CEMS shed
Utilizes Nafion technology	Better performance, ability to reach lower dew point than traditional coolers

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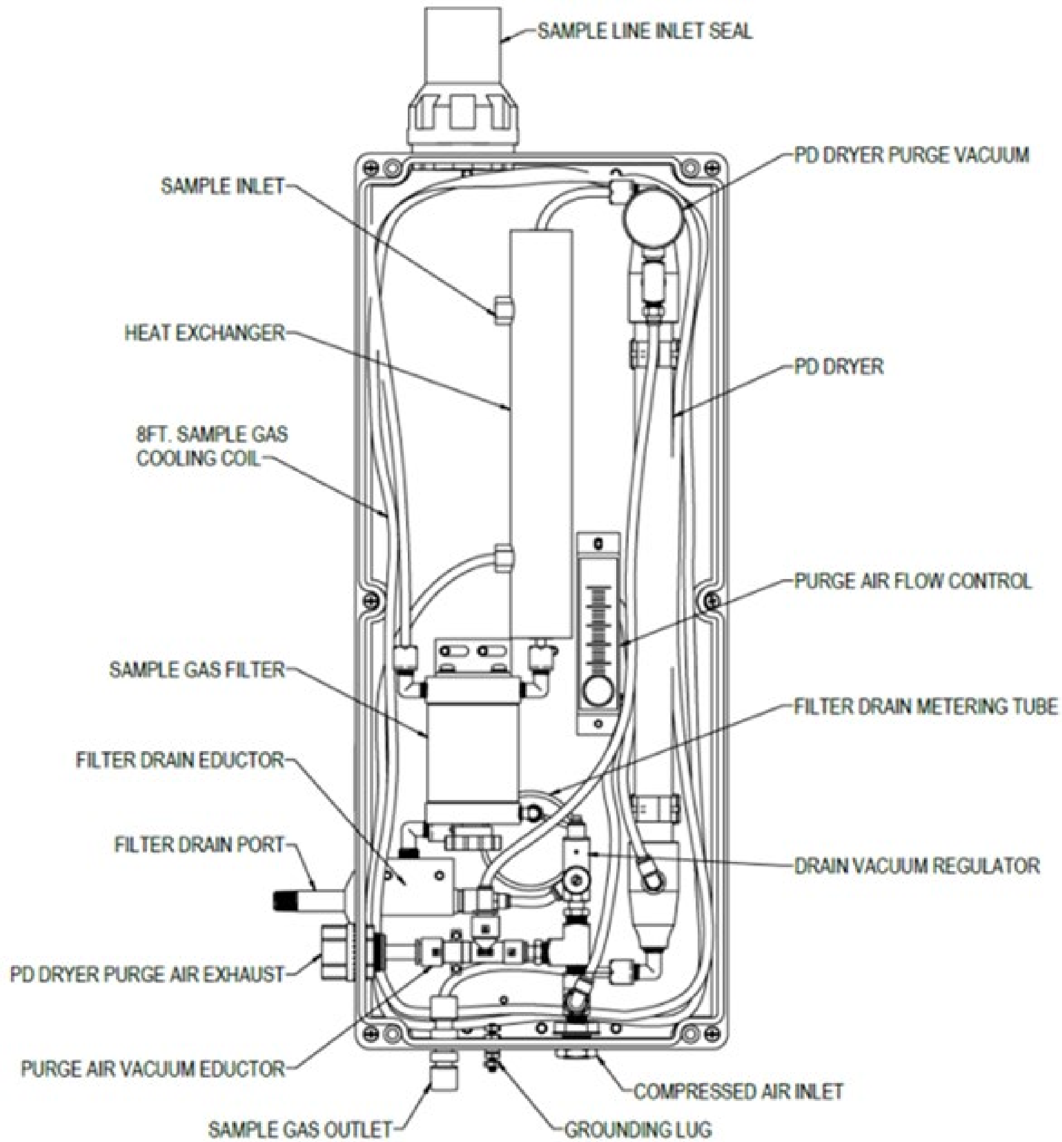
Hybrid Sample Gas Cooler



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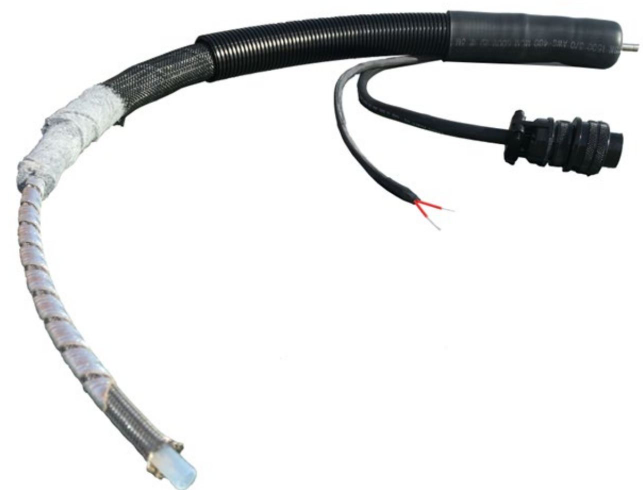
OUR ENVIRONMENTAL BUSINESS IS **HEATING UP!**

Heated Lines

Where are they used?

Transport the sample gas from the sample source to the gas conditioning system or analyzer

- Moisture can distort the analytical measurement and damage the equipment
- Ensure the temperature of the sample gas stays above the dew point to prevent condensation from occurring in the samples



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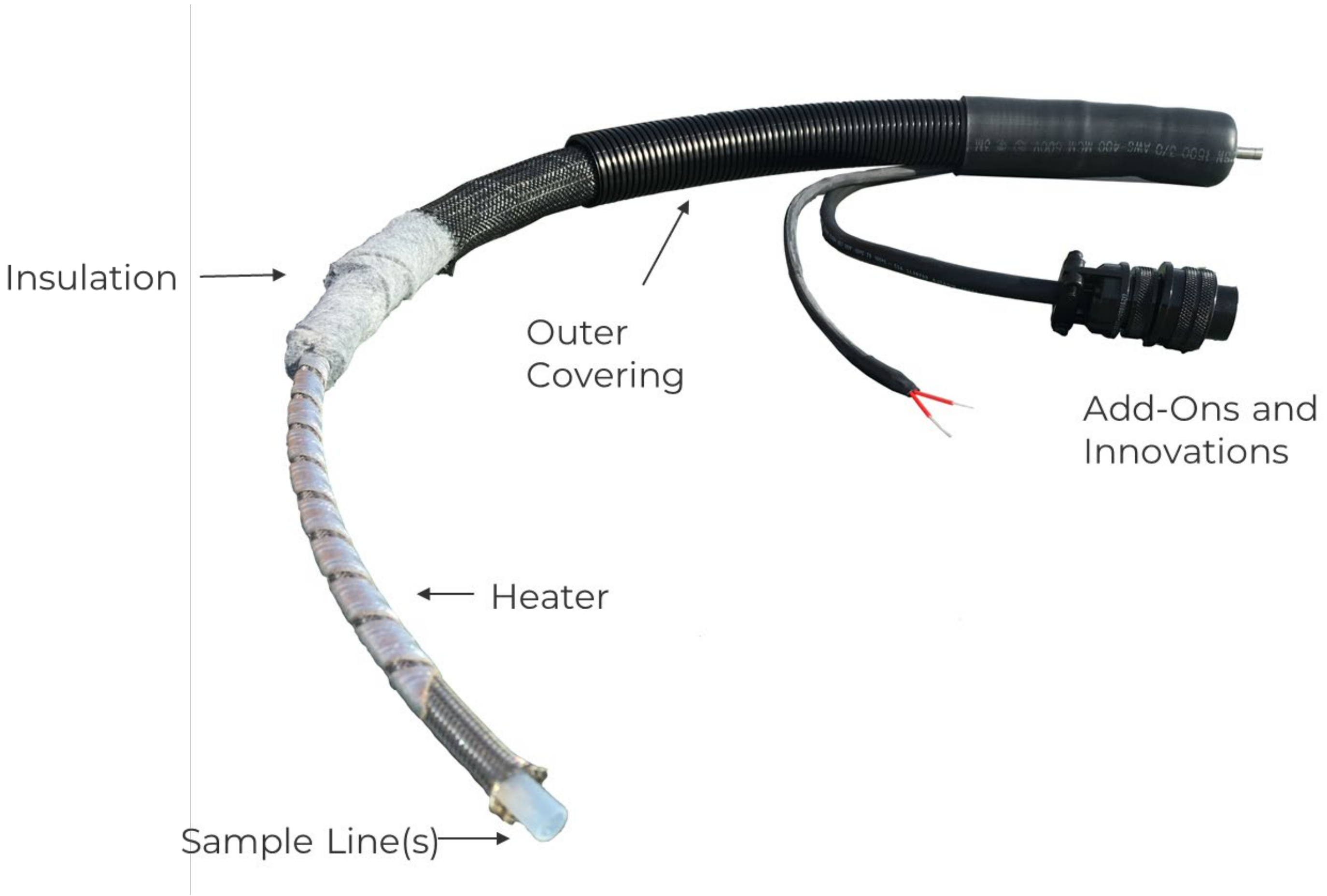
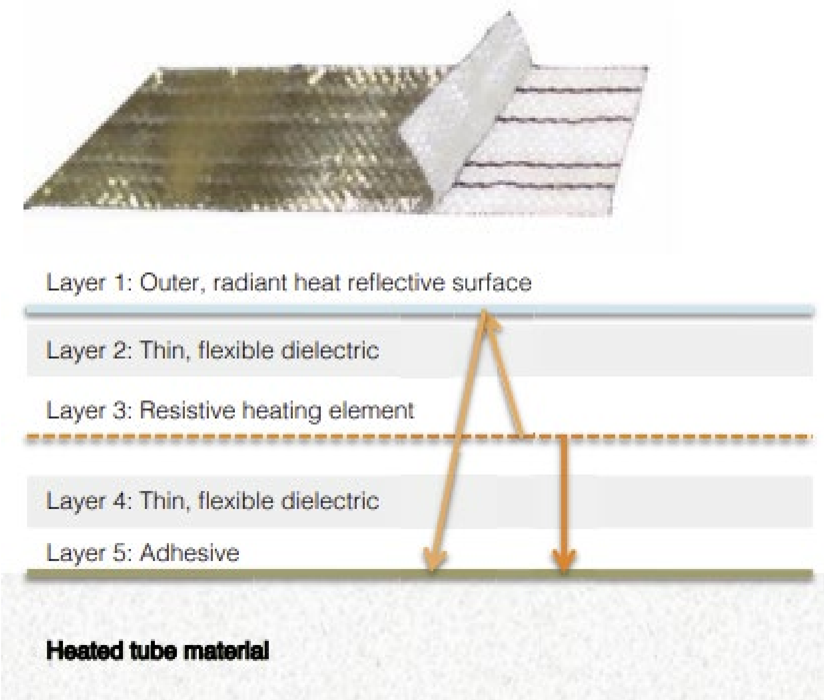
Anatomy


Insulation
Outer Covering
Add-Ons and Innovations
Heater
Sample Line(s)

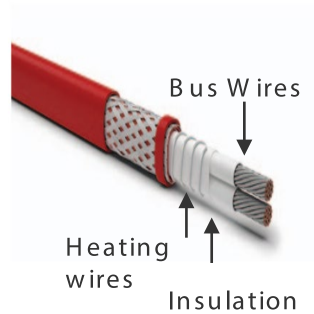
Anatomy of Different Heated Lines

Electrical Resistance Heat Tape



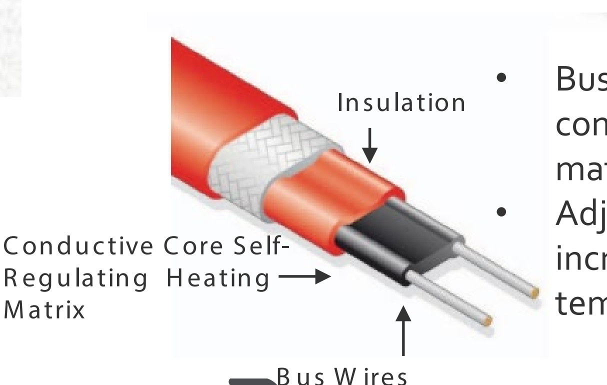
Thermal Energy is transferred to the tube through both conductive and radiant modes of heat. Radiant energy emitted away from the tube is reflected back on to the tube.

Constant Power Density (CPD)



- Alternating bus contacts at fixed intervals
- Produces constant foot to foot power output

Self-Regulating (SR)



- Bus contacts surrounded by a conductive self-regulating heating matrix
- Adjusts output heat in respect to increase and decreases in sample temperature

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Anatomy of Consistent Heating

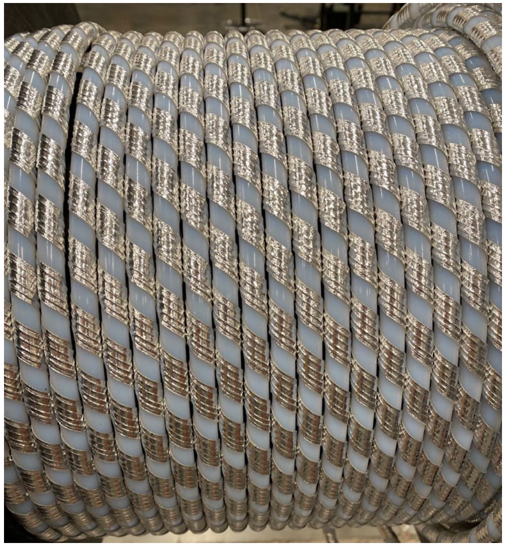
Electrical Resistance Heat Tape

- Heat Tape is precisely wound around the sample tube to provide consistent sample temperature along the entire circumference and length of the line
- Flexible even when energized
- Frequent movement does not damage the heating element
- Ideal for rugged applications

Clayborn Electrical Resistive Heat Tape

Heating Element

- Electrical resistance heating tape
  - Highly efficient architecture
  - Rapid heat-up time
  - Precise wrapping for consistent heating
  - Customizable to achieve specific temperature / length / input voltage combinations
    - AC or DC operation
    - 12v, 24v, 120v, 208v, 240, 277v, and 480v input
    - 3-phase operation



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Customizable Designs

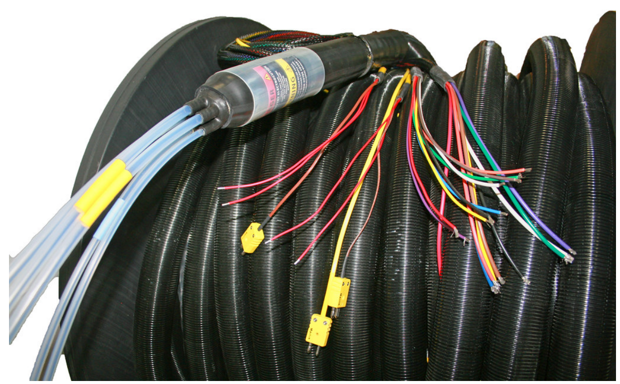
Sample Line Materials:

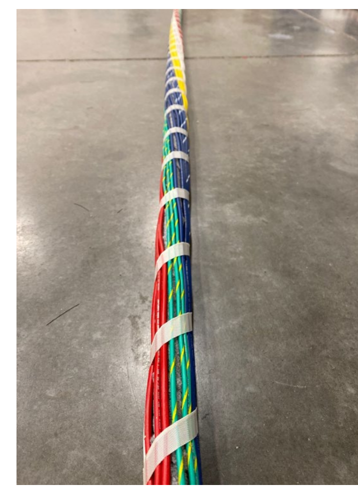
- Teflon
  - Various Grades
  - Smooth bore of convoluted
- Stainless Steel
  - Welded or Seamless
  - Electropolished
  - Large ID convoluted
- Polyethylene
- Nylon

Insulation Materials::

- Standard Nomex
- High performance Aerogel
- Closed/Open cell foam

Up to 6 Heated Sample Lines
Up to 6 Unheated Sample Lines
24 pass through wires



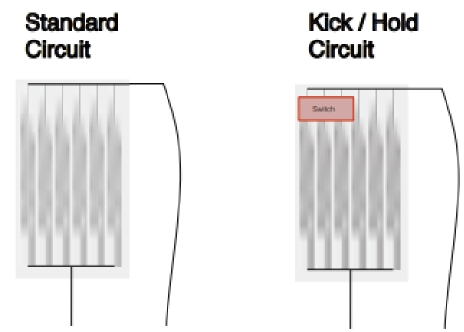


Customizable Design

Cover Options
- Tuffguard
- Nylon Braid
- Silicone
- Heat Shrink

Innovative Design
- Integrated strain relief loops at customizable locations
- Finished ends standard from factory
- Armored Ends
- Embedded Thermostats
- Thermocouples
- On/OFF indicator lights
- "Run Wild" Temperature of sample line will fluctuate with ambient
- Color Coding
- Labeling

Sample / Calibration 'Tee' fitting (far left)
Early calibration line breakout (middle)
Strain relief (far right)



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Thank you