Module 2: Overview of CMS and CMS Design and Components

Module 2 Outline

- Review of Types of CMS
- Opacity
- Gaseous CEMS Designs (pros/cons and comparisons)
- Continuous Emission Rate Monitoring Systems (CERMS)
- Location Considerations for CEMS

Module 2 Learning Objectives

At the end of Module 2, learners will be able to:

- Define opacity and describe how continuous opacity monitoring systems (COMS) are used
- Recognize the pollutant parameters measured by continuous monitoring systems (CMS)
- Distinguish between extractive and in-situ systems
- Describe how continuous emission rate monitoring systems (CERMS) function
- Give examples of CEMS location and siting considerations

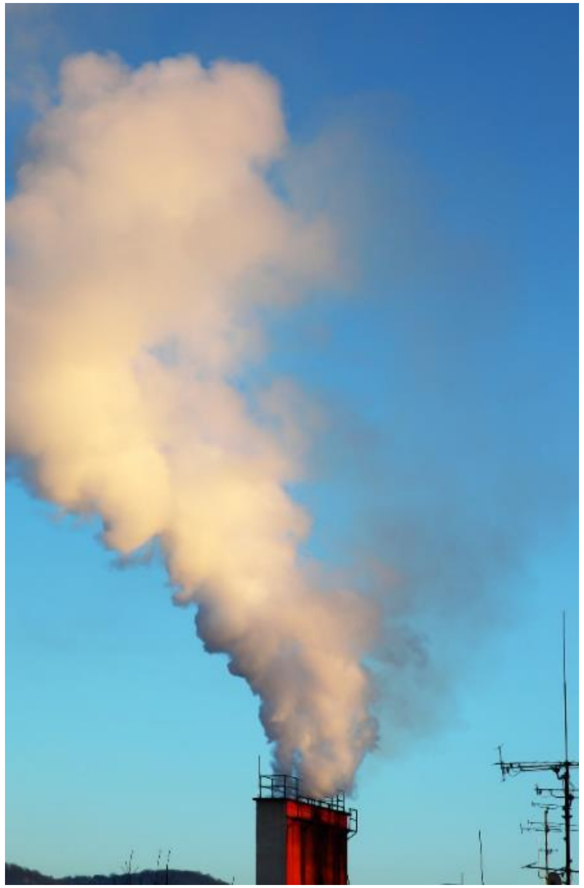
Types of CMS

Reminder: There are four main types of CMS. These are:

- Continuous Opacity Monitoring Systems (COMS)
- Continuous Emission Monitoring Systems (CEMS)
- Predictive Emission Monitoring Systems (PEMS)
- Continuous Emission Rate Monitoring Systems (CERMS)

This module will provide an overview of CEMS, COMS and CERMS. PEMS will be covered later in Module 3, when we discuss Performance Specification 16.

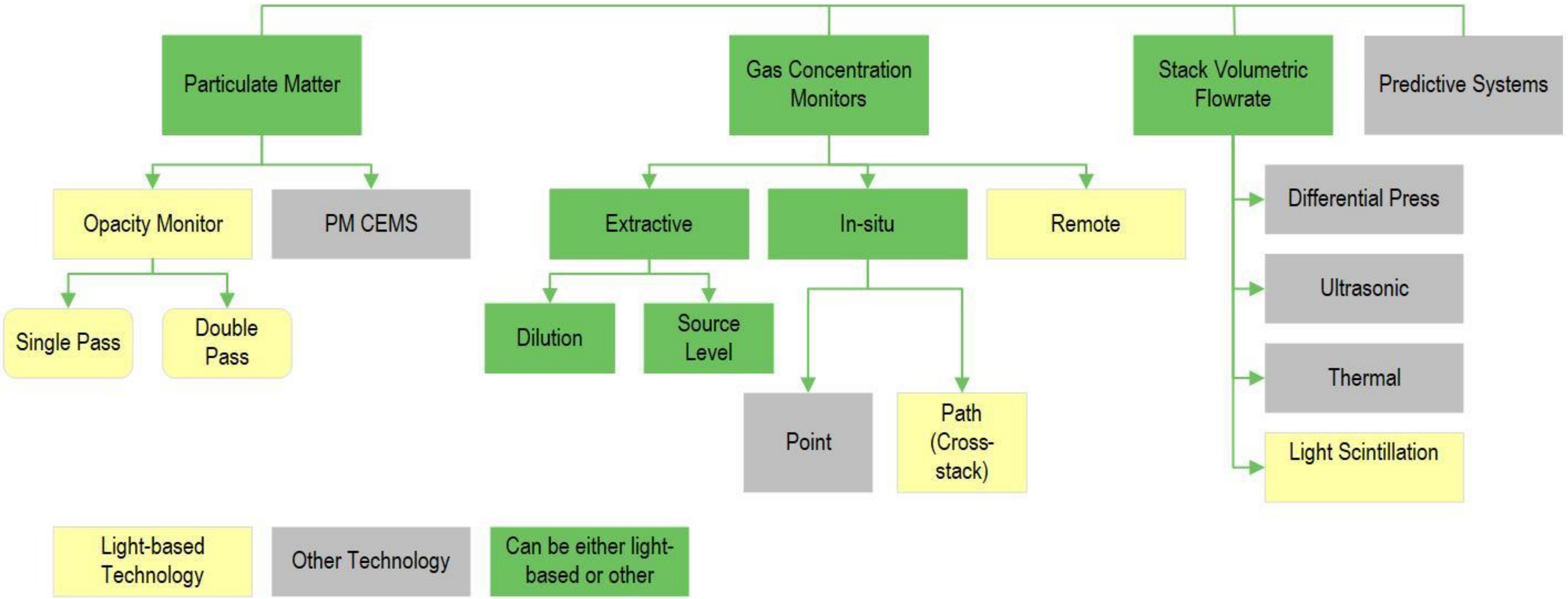
Pollutant Parameters



Continuous Monitoring Systems (CMS) may be used to measure the following:

- Opacity
- Sulfur Dioxide
- Nitrogen Oxides
- Carbon Dioxide
- Oxygen
- Carbon Monoxide
- Total Reduced Sulfur
- Stack Flow Rate
- Hydrogen Sulfide
- Volatile Organic Compounds
- Particulate matter
- Ammonia
- Mercury
- Hydrogen Chloride
- (And other pollutants)

General Categories of CMS



Opacity and COMS

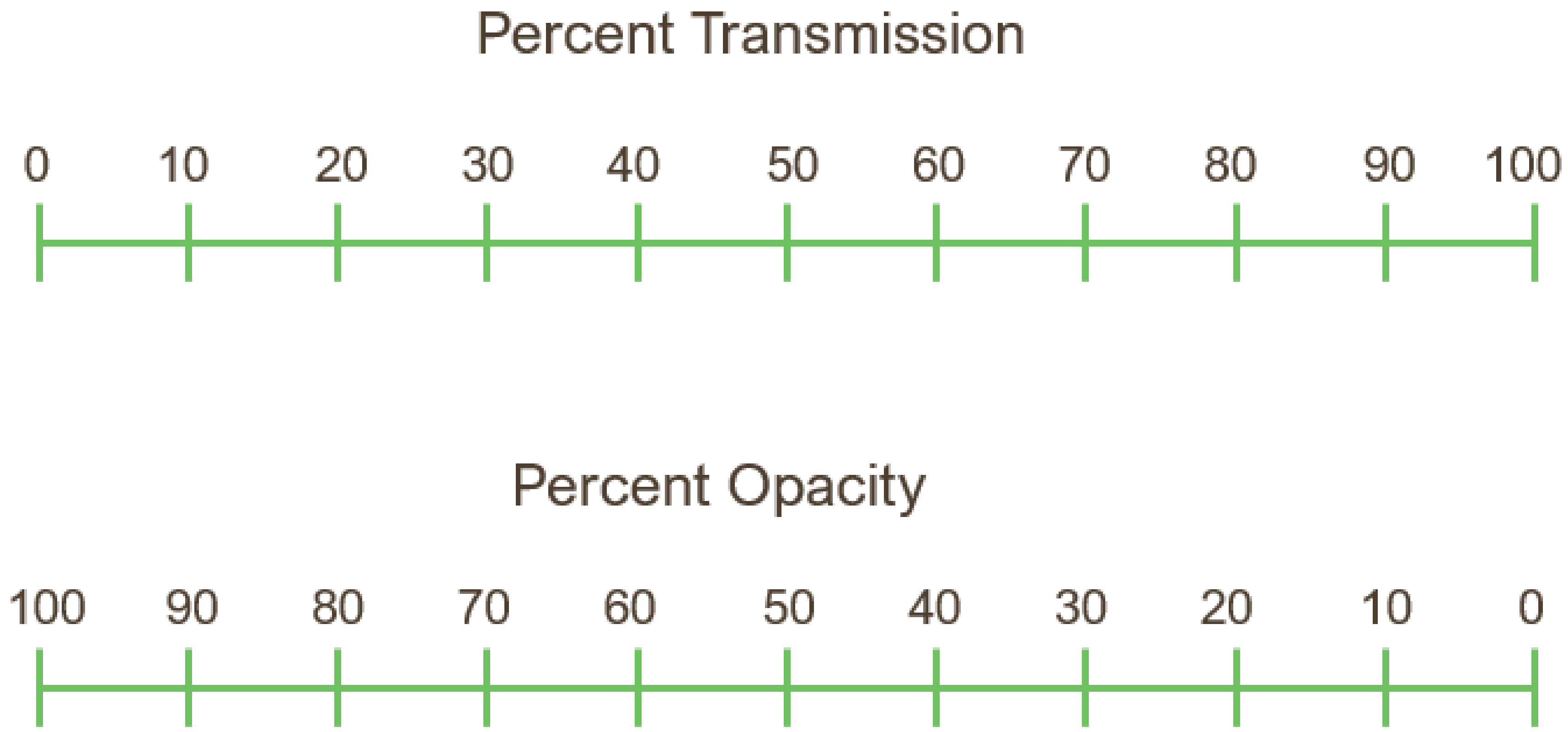
Opacity – Setting the Stage

- **OPACITY (Op)** → The percentage of light that is attenuated by an optical medium – in our case, the effluent gas stream.

- **TRANSMITTANCE (Tr)**→ The percentage of light that is transmitted through an optical medium.

  Therefore, Op = 100 - Tr

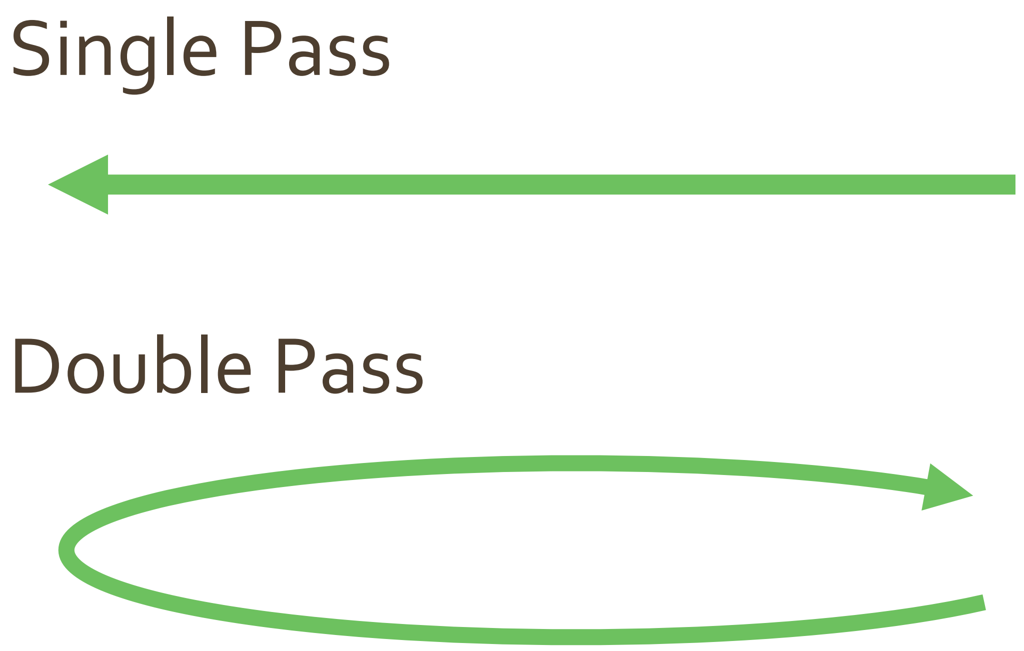
Transmittance vs. Opacity



Opacity

- Light is reduced by scattering and absorption by the particles in the stack gas exhaust stream.
- Amount of light reduction is dependent on type, size, and size distribution of particles.
- % opacity is a function of the amount of particulate in the gas stream.
- However, the % opacity cannot, in general, be easily correlated to a specific mass emission rate of PM.

COMS



- Can be single pass or double pass design (double pass transmissometer).
- Most COMS used for compliance determinations are double pass, which use a light path that is twice the stack diameter.
- Require a means to calibrate and periodically (usually quarterly) audit the COMS.
- Most have a remote display and control panel in the facility control room or CEMS shelter.
- Must have a means to capture, average, and store data measured by the COMS.
- Must have means (most use air blowers) to keep stack gas from impinging on and potentially damaging the lenses of the COMS.

CEMS Design

Basics of CEMS Design

CEMS can be divided into two general categories based on the means by which the sample gas is acquired (captured) and delivered to the analyzer:

1. Extractive systems

- Withdraw flue gas from the stack and transport the gas to analyzers.
- An extractive system may be either source-level or dilution.

2. In-situ systems

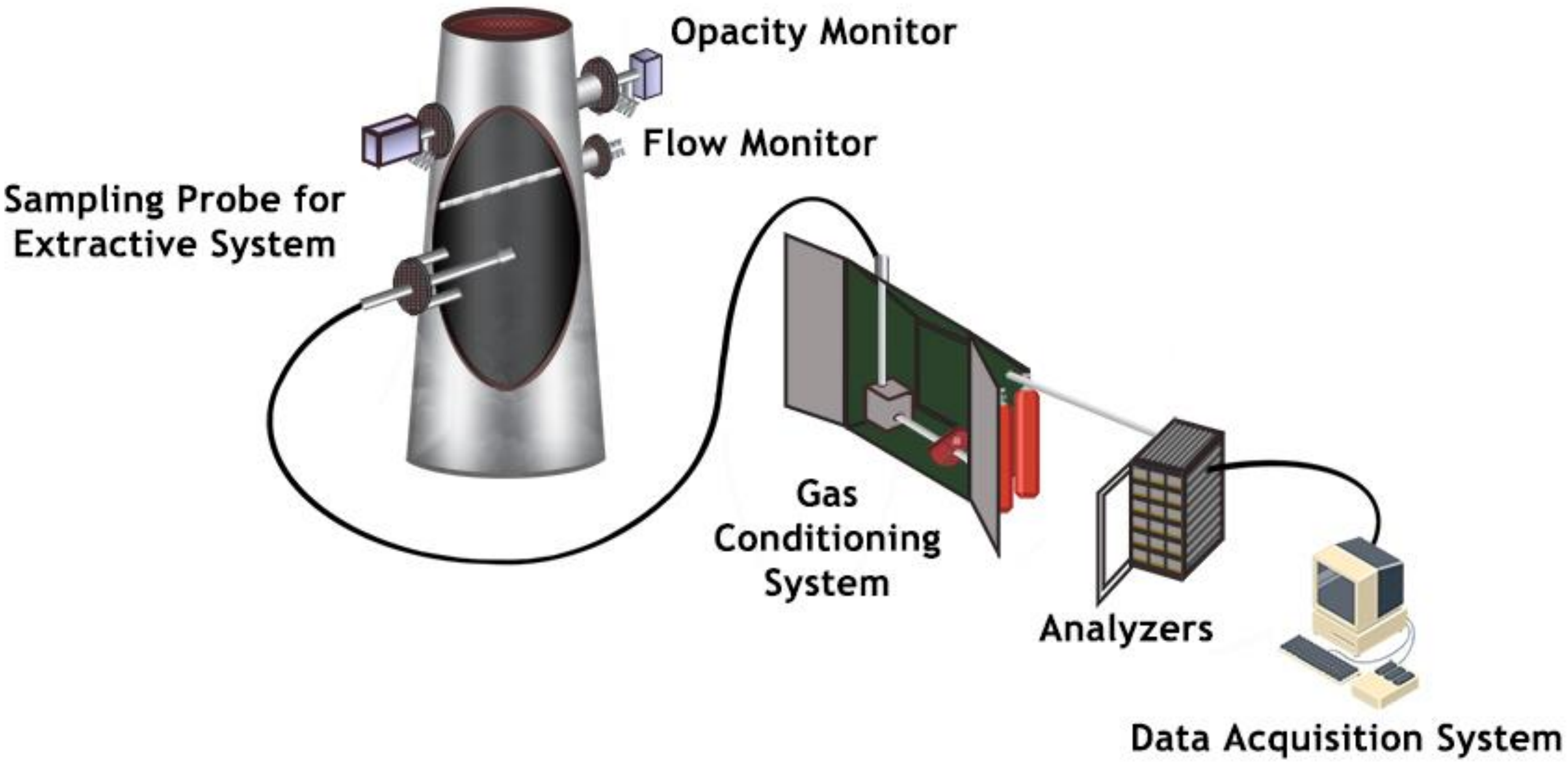
- Have at least some part of their analysis subsystem mounted in the stack in direct contact with the flue gas.

General Extractive System – Conditioning Cabinet

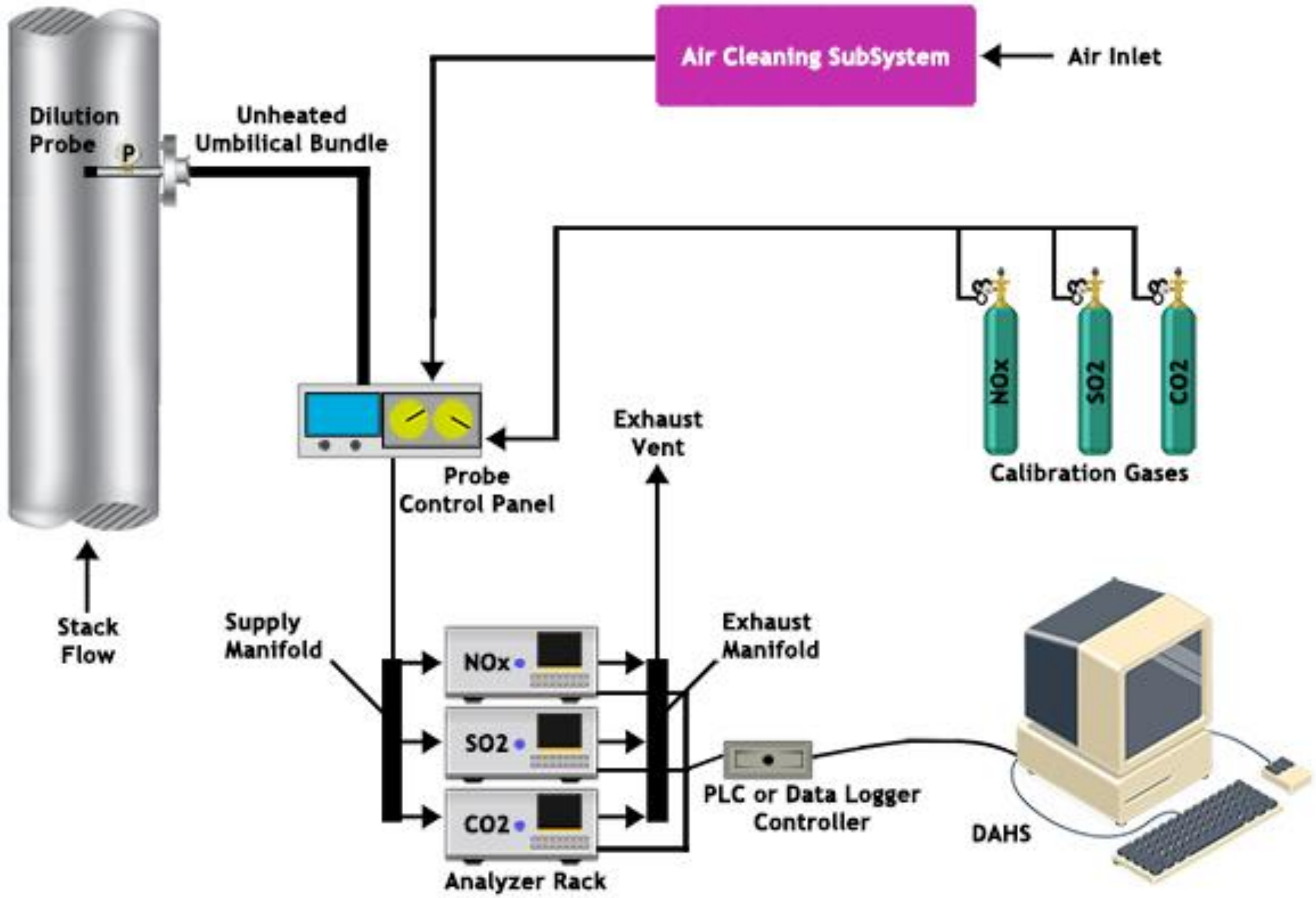
General Extractive System Components

- Probe
- Particulate Filter
- Sample Conditioning or Dilution
- Sample Line
- Pump
- Controller
- Analyzer
- Data Calculation and Storage

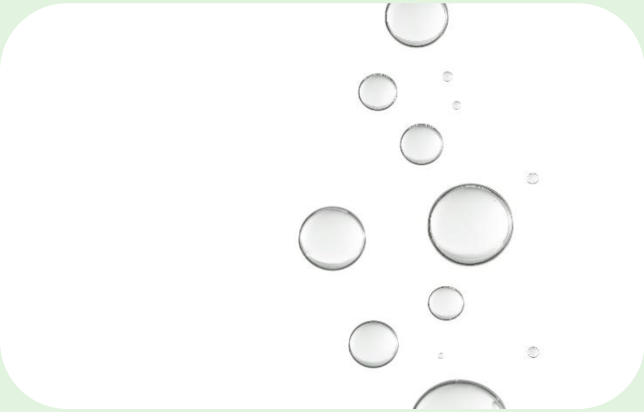
Source-Level Extractive System



Dilution Extractive Systems



Dilution Extractive Systems (Cont'd)



The sample gas is diluted with dry, contamination-free air to a level below the dew point of the diluted sample gas to eliminate condensation in the sample line.

- The diluted sample is measured by pollutant and CO_2 monitors operating at or near ambient concentration ranges to provide concentration measurements on a wet basis.

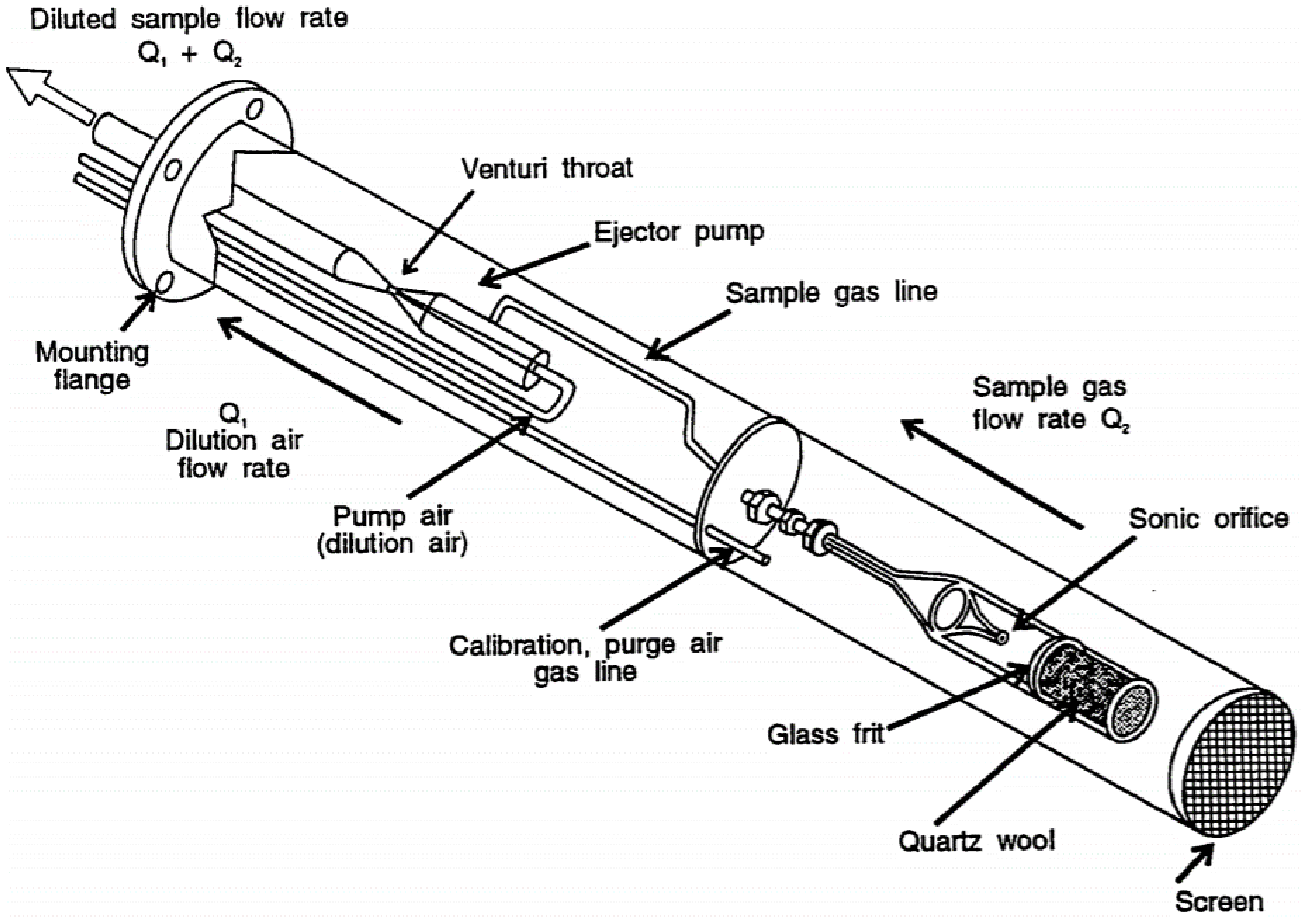
The concentrations are measured on a wet-basis. With a wet stack volume flowrate measurement, the pollutant mass emission rate can be calculated without a separate stack gas moisture measurement or assumption needed.

The most unique component of a dilution-extractive system is the dilution sampling probe.

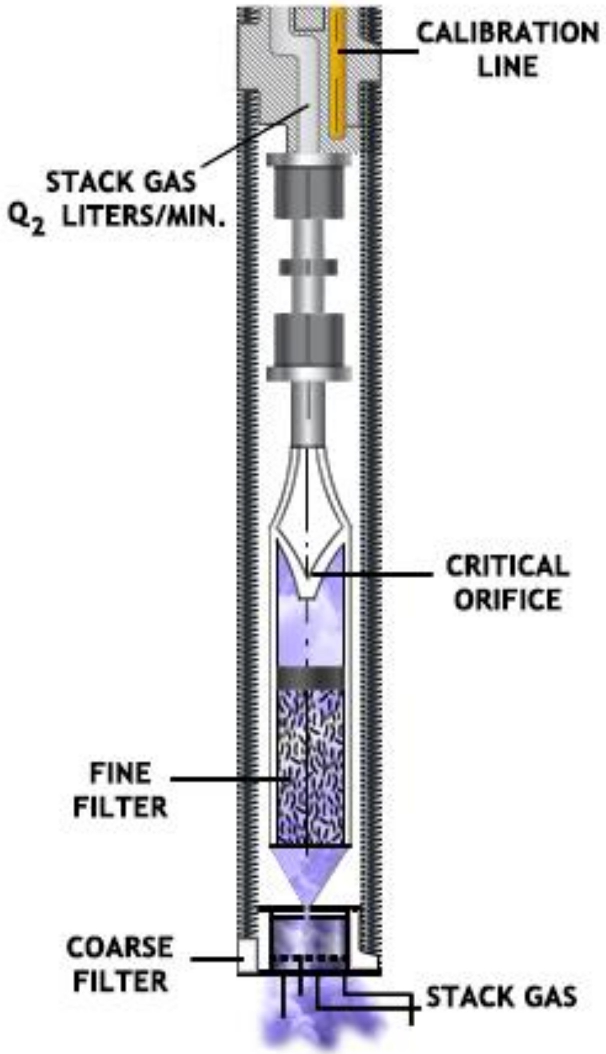
There are two types, depending on where the dilution occurs:

- In-stack
- Out of stack

Dilution Probe



Dilution Probe Orifice



Reasons to Consider Using Dilution Probes

Allows the emissions to be measured on a “wet” basis

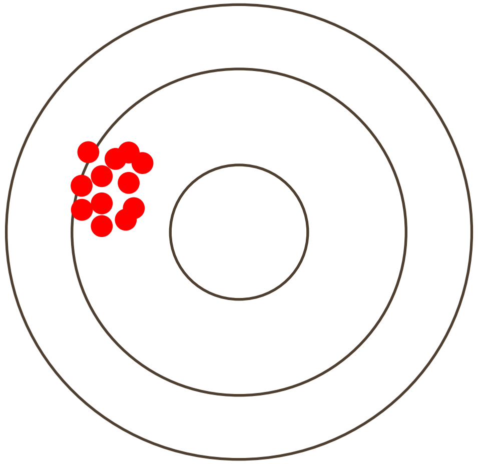
Sampling rate of stack gas (~20-50 mL/min) much lower than conventional extractive systems (~2-5 L/min.) resulting in less PM being pulled in with sample

Reduces moisture of the sample gas, thus not requiring gas conditioning system or “heated” sample lines to prevent condensation to analyzer, which results in lower maintenance

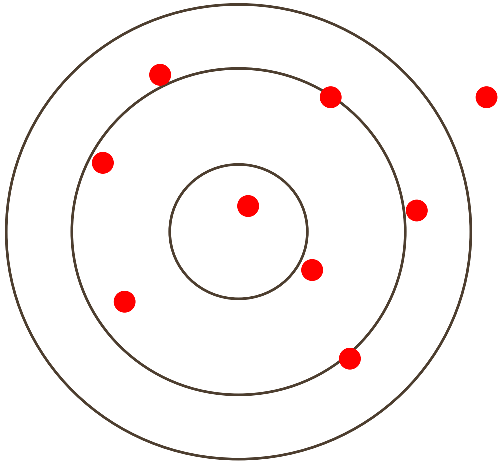
Allows the use of ambient monitors which meet design and performance criteria set by EPA

Overview of Measurement Bias

- Bias is the amount of systematic error of a measurement system
  - Consistent in direction (positive or negative) and magnitude
  - Different than a random error

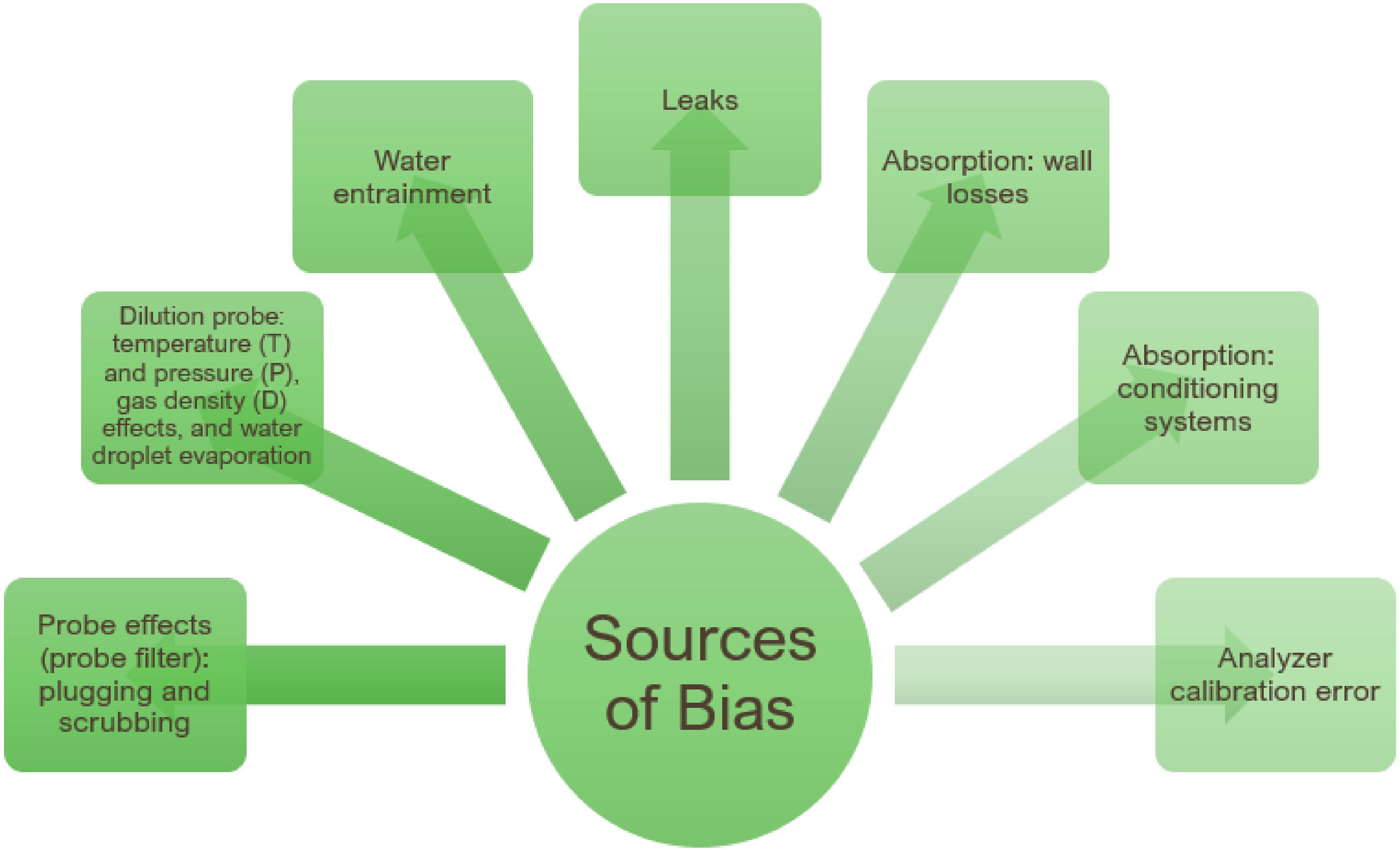


Systematic Error



Random Error

General Sources of Bias for Extractive Systems



Sources of Biases in Dilution Probes

If installed after wet scrubbers, moisture or aerosols can enter the probe and change the dynamics of dilution, unless the stack gas is adequately filtered, or the probe is sufficiently sloped (one or two degrees downward) to prevent their entrance.

Dilution probes are affected by changes in stack gas temperature (T_s), pressure (P_s), and molecular weight (MW), which changes dilution ratio.

Dilution ratio of a stack gas can change if the MW of the analyzer calibration gas (i.e., “gas blends” vs. “single” gases, and the effect of heavier in a blended gas) is different from the MW of the stack gas.

Contaminated source “dilution air” can affect dilution ratio or change the measured concentration of the pollutant in the stack gas, either high or low ratio.

Considerations for Extractive System Components

Filters	Pumps	Cabinets or Shelters	System Controller	Electrical Support	Calibration Gases
• Coarse/Fine • Quality	• Capacity • Type • Quality	• Location • Temperature Stability	• Microprocessor To Sequence/Control Automatic Functions	• Fuses • Circuit Breakers	• Location • Injection Point • Gas Certification

In-Situ Systems

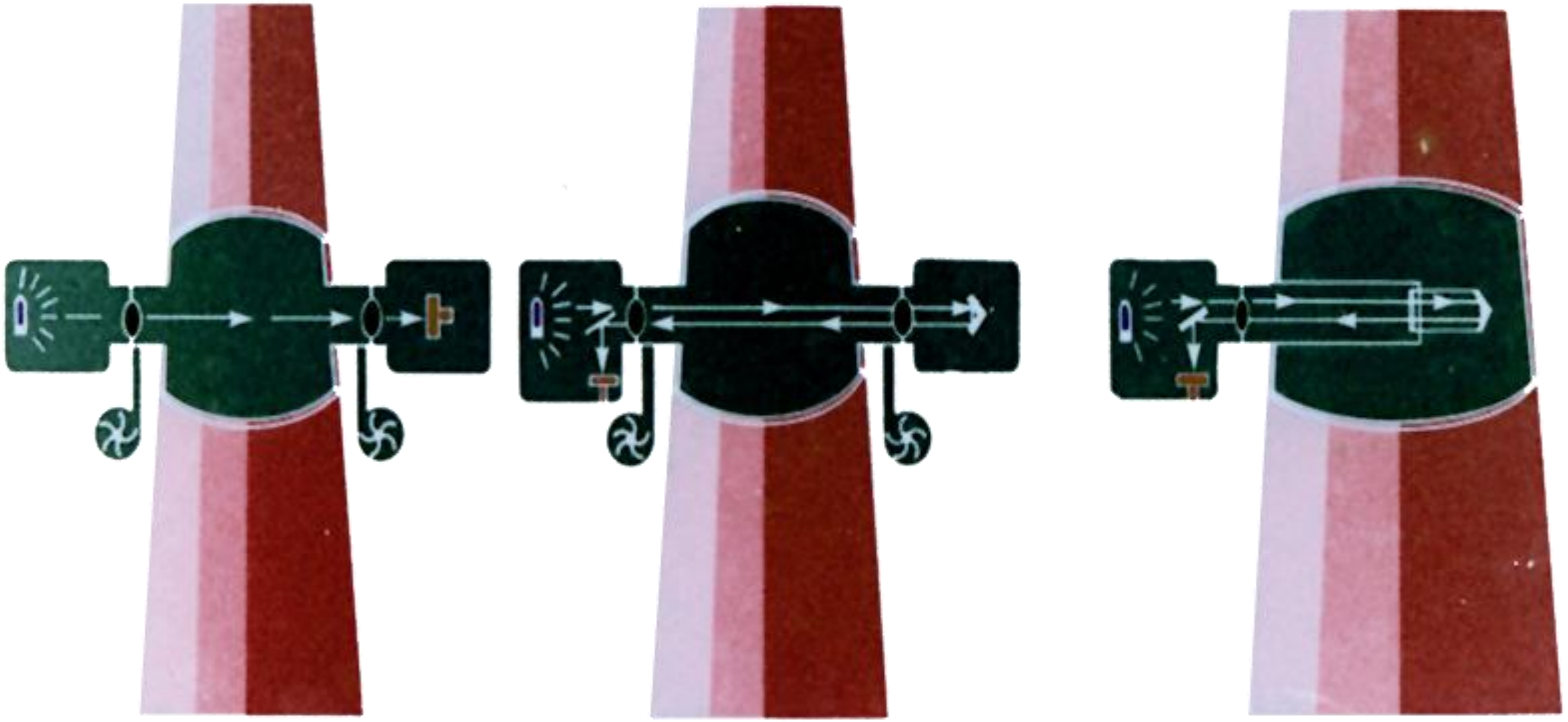
- Perform analysis at the stack
  - Lack of conditioning and transport sub-systems, hence, generally less equipment required than extractive systems
- EPA distinguishes between point and path monitors by the amount of gas stream that the probe is blocking.
  - Usually "very small" segment (point), or 1 or 2 diameters (path).

There are two types of in-situ systems:

- **Point systems** – monitor at a single point or along a very short path within the stack.
- **Path systems** (also called "cross stack") – monitor across a certain path of stack gas.

In-Situ Monitors

Cross-Stack (path)   In-Stack (point)



Single Pass   Double Pass

Advantages of Extractive Systems

- ✓ Analyzers can be installed in an accessible, clean environment
- ✓ Ease of maintenance
- ✓ Time sharing capability
- ✓ Allows widest selection of analyzer technologies
- ✓ Can combine more than one analyzer
- ✓ Can remove interfering substances before measurement
- ✓ Gas is measured on a dry or wet basis depending on design

Disadvantages of Extractive Systems

Sample transport and conditioning system is expensive to install and operate and has high power requirements, and has potential for pluggage, leaks and condensation problems (both water and acid)

Sample gas conditioning or dilution is required

May alter sample, may inadvertently remove substances of interest from sample gas

Response time of the sampling system may be slow

Has lots of components and a complicated design

Analyzer may have time-lag with high concentrations

Advantages of In-Situ Systems

Advantages

Fast response time
No sample transport or conditioning
Simple, less expensive installation
Less equipment to buy and maintain
Has few components

Disadvantages

Vibration sensitive
Access for service and maintenance can be difficult
Limits choice of analyzer
Does not allow for expansion
Operates in a potentially harsh environment
Path type may not be able to be located downstream of sorbent injection or spray dryer systems

Disadvantages of In-Situ Systems

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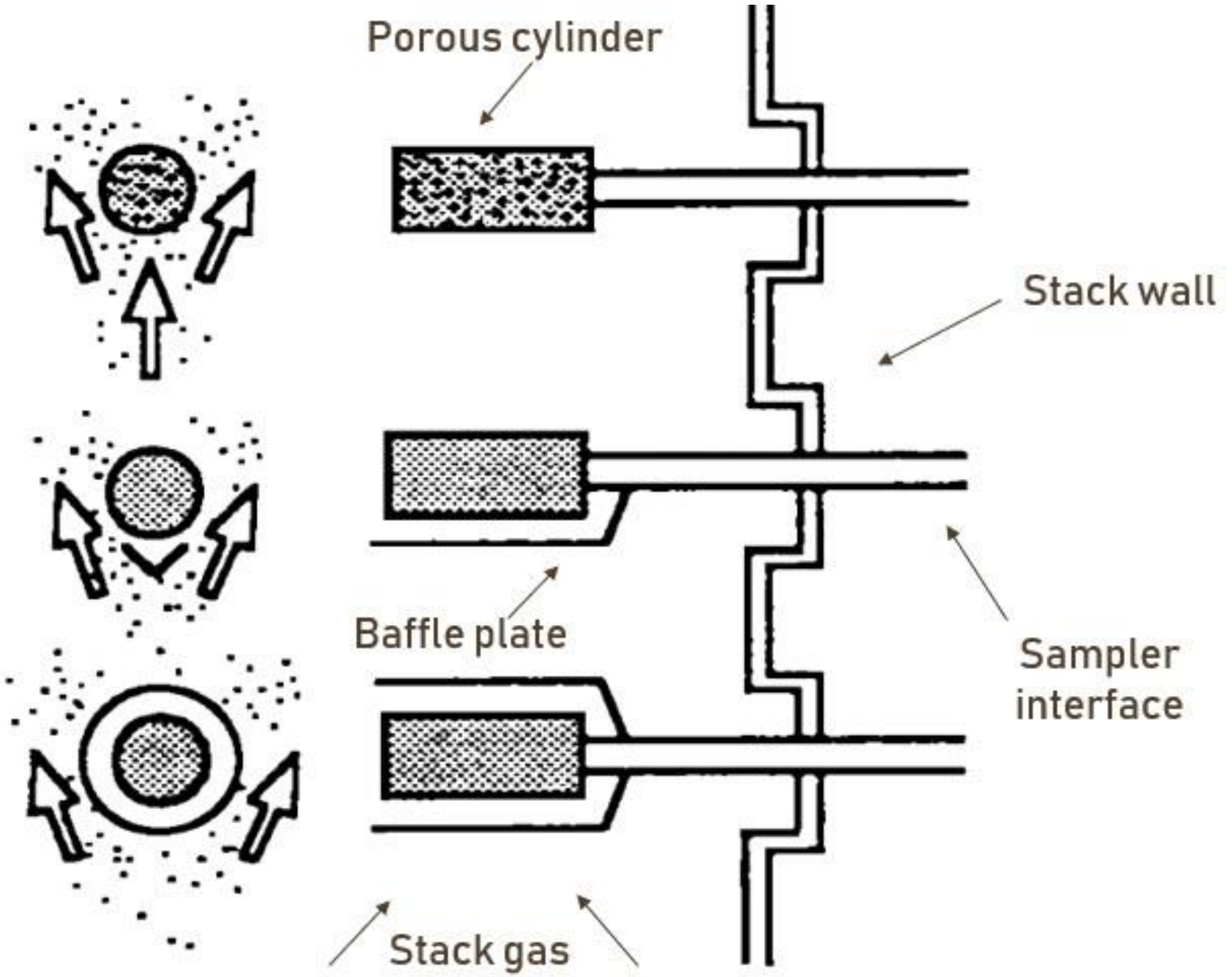
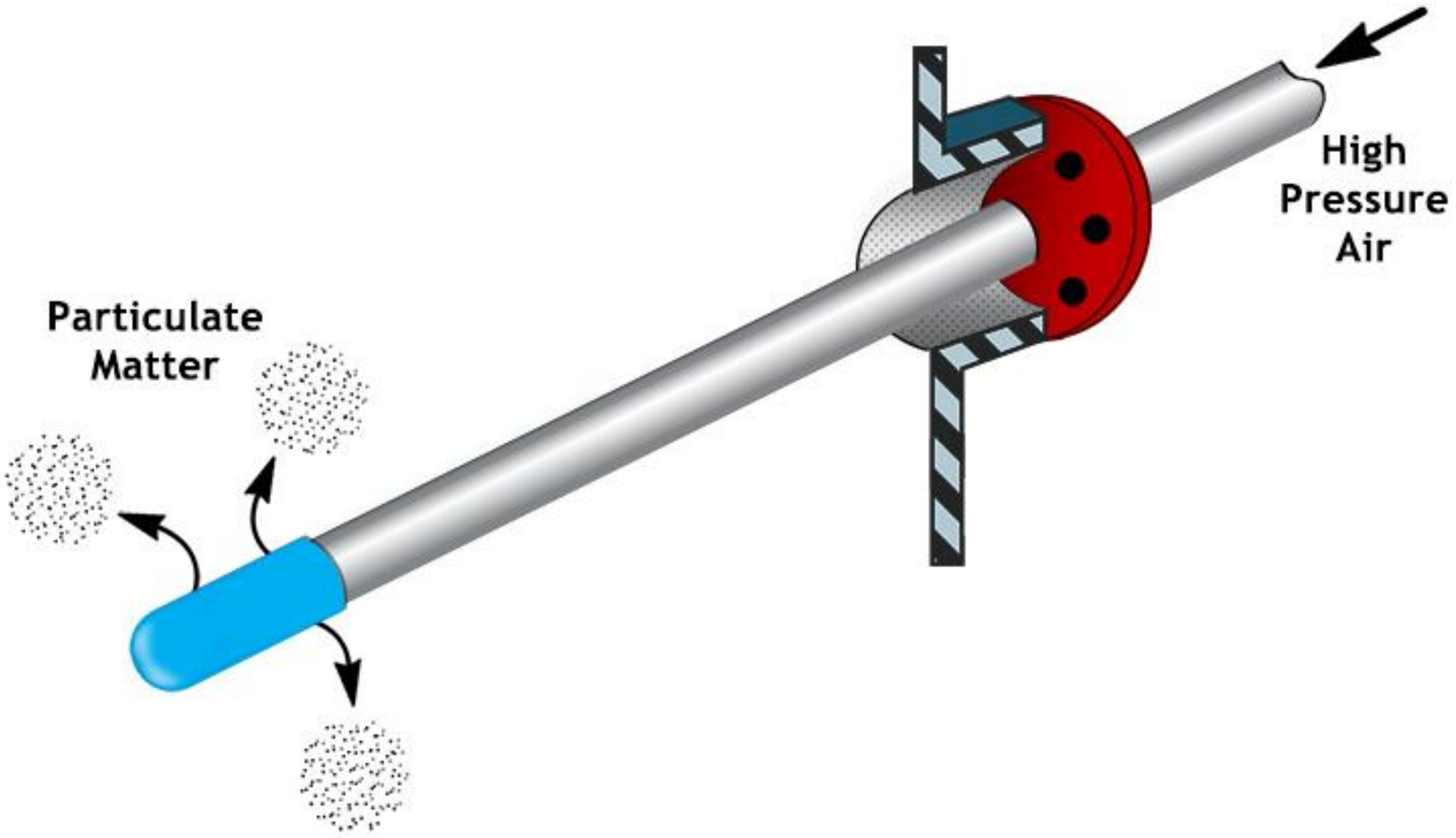
CEMS Components

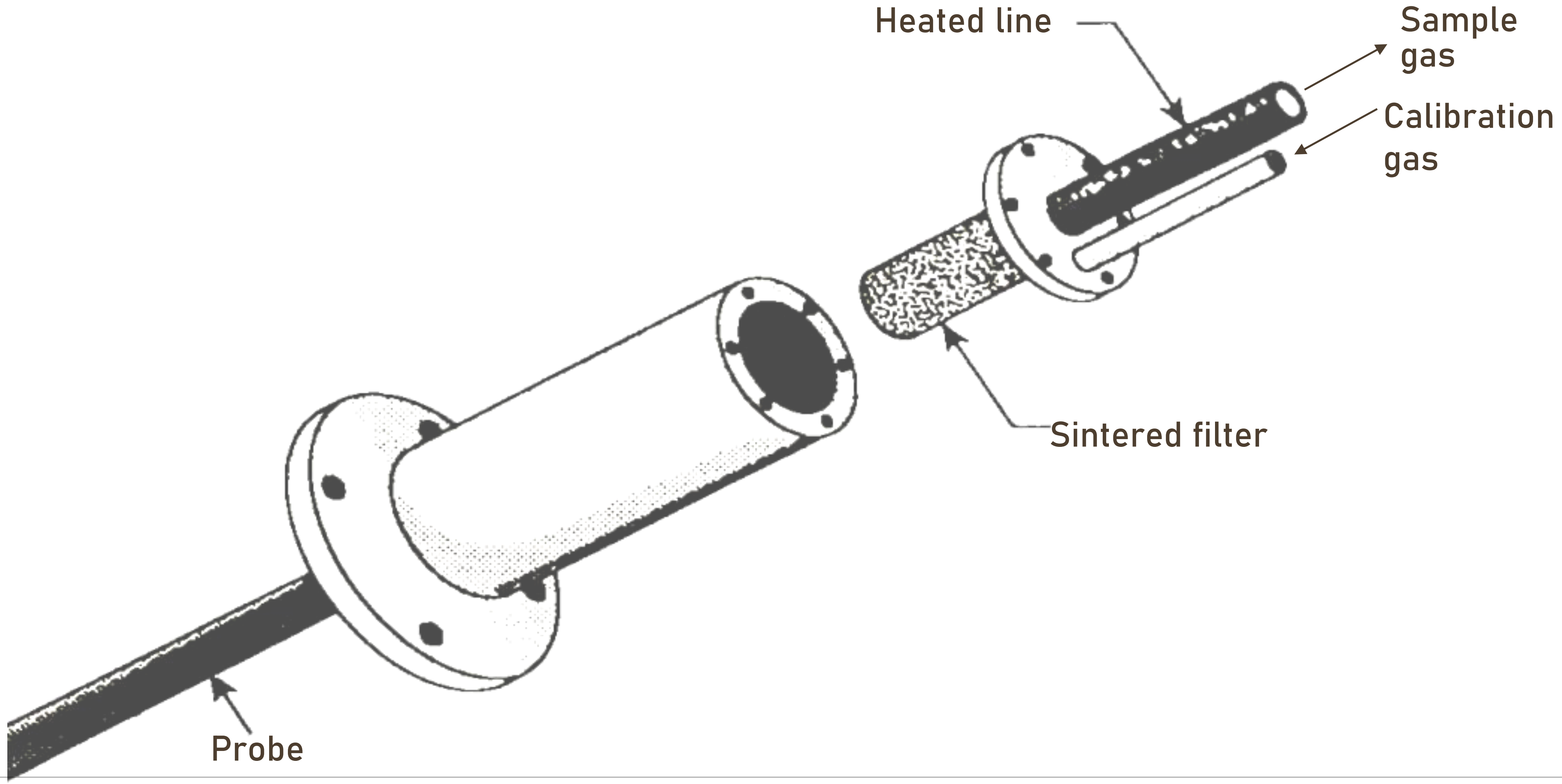
External Probe Filters



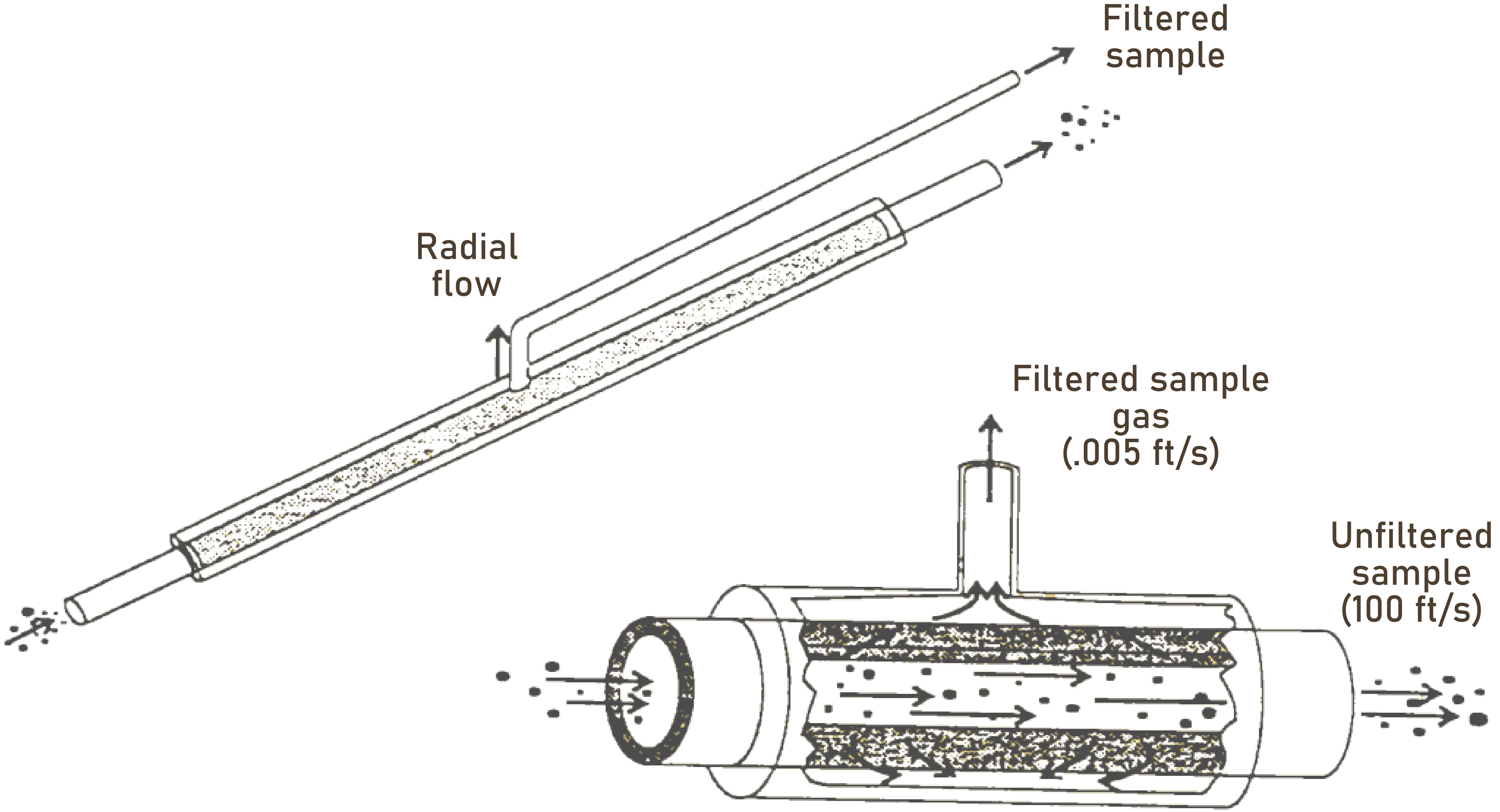
Filter Blow Back



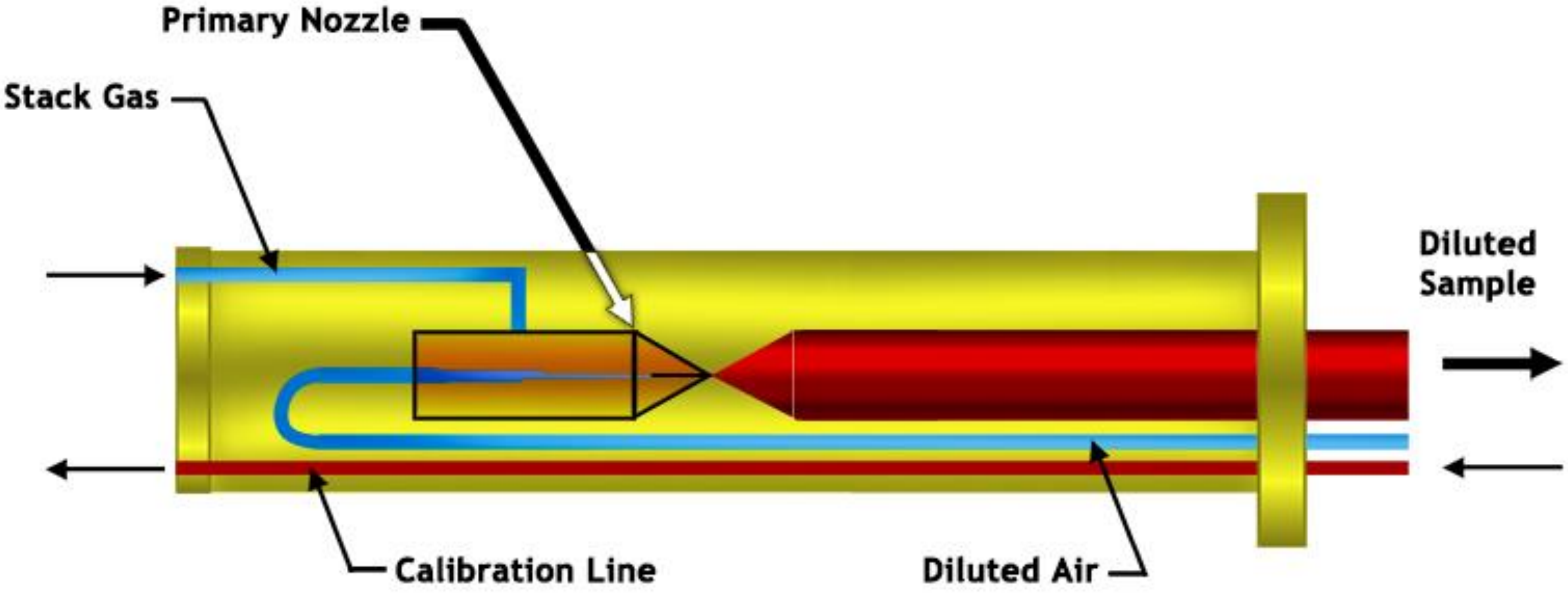
Internal Coarse Filter



Inertial Filter



Example of How a Dilution Probe Works



1. Let’s Test Your Knowledge!

Feedback

The answer is D. Source Level Extractive

CEMS Design – Question 1

1. __________ systems condition the sample gas before analysis.

A. In-situ

B. Opacity

C. Dilution Extractive

D. Source Level Extractive

Feedback

The answer is B. Less.

CEMS Design – Question 2

2. In-situ CEMS require __________ equipment for a single sample point compared to extractive CEMS.

A. More

B. Less

C. The same amount of

Feedback

It's false. Actually, opacity is the percentage of light that is attenuated by an optical medium. In our case, the effluent gas stream. Whereas, transmittance is the percentage of light that is transmitted through an optical medium.

CEMS Design – Question 3

3. Transmittance is the percentage of light that is attenuated by an optical medium.

True

False

CEMS that Include a Flow Monitor (Continuous Emission Rate Monitoring Systems or CERMS)

Continuous Emission Rate Monitoring Systems (CERMS)

CERMS are:

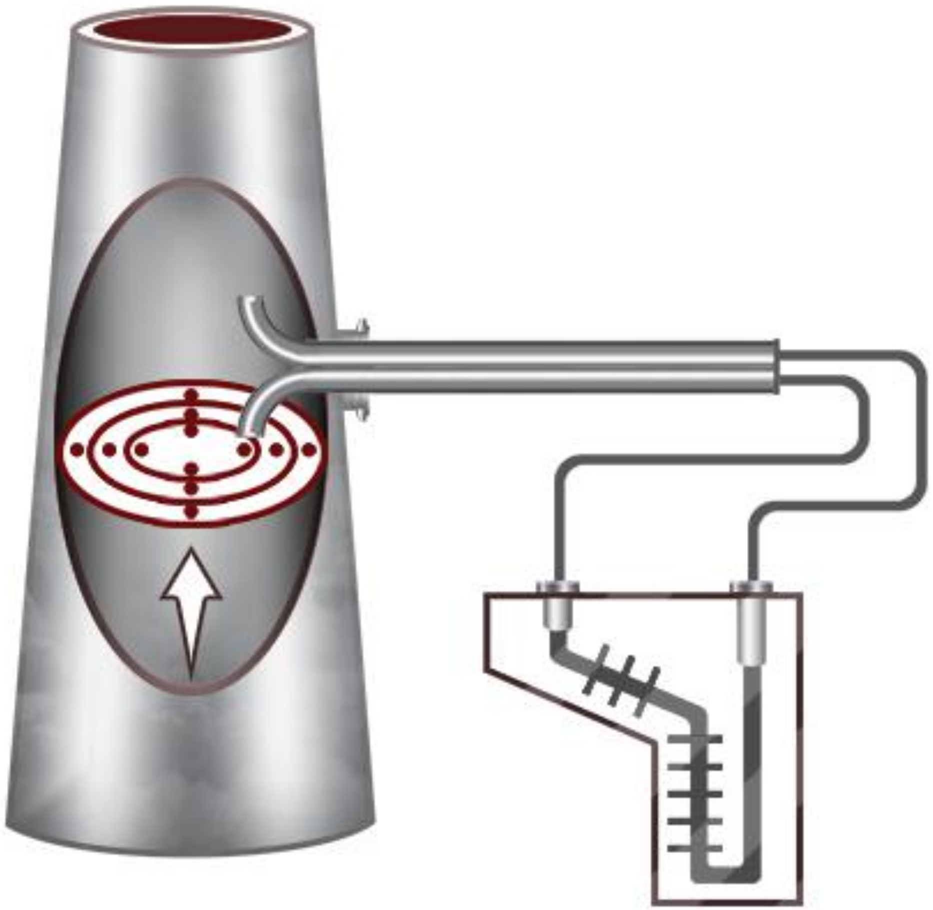
- Used in conjunction with gas concentration measurements, to calculate mass emission rates.
- Required for most sources subject to 40 CFR Part 75.

Pollutant Mass Emission Rate (PMER) = C_S A_S V_S

C_S = Concentration
A_S = Stack Area
V_S = Stack Gas Velocity

lbs/hr = (lb/ft^3) (ft^2) (ft/hr)

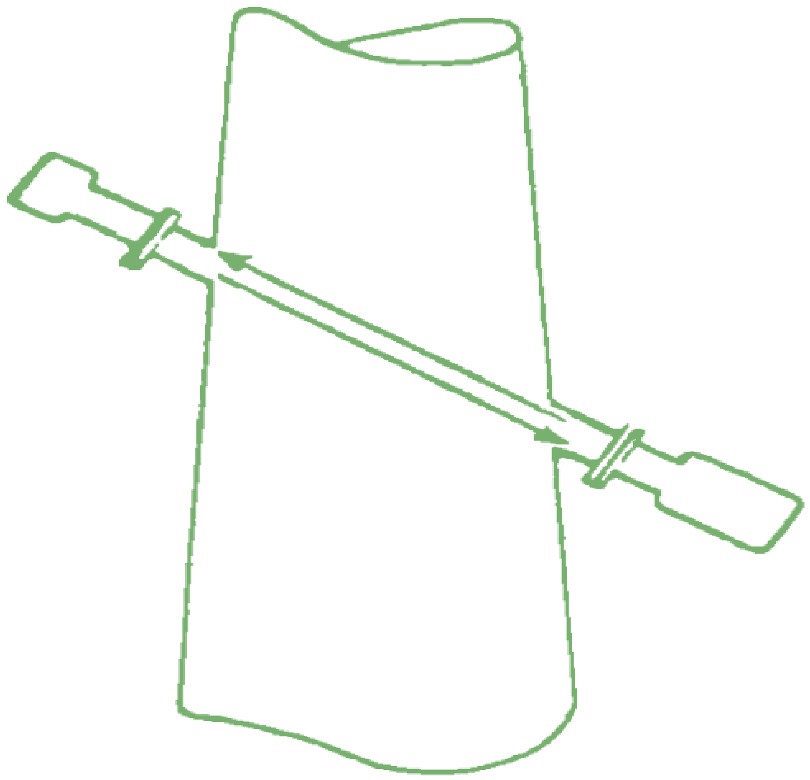
Differential Pressure Measuring



Ultrasonic Flowmeter

An *ultrasonic flowmeter* uses a pair of transmitter/receivers mounted on opposite sides of the stack, with one upstream from the other. The signal is alternated between them, sending it in the direction of stack gas flow, where it is speeded up, and then against the direction of flow, where it is slowed down. The difference in the time between the two signals is proportional to the stack gas velocity.

Acoustic Velocity

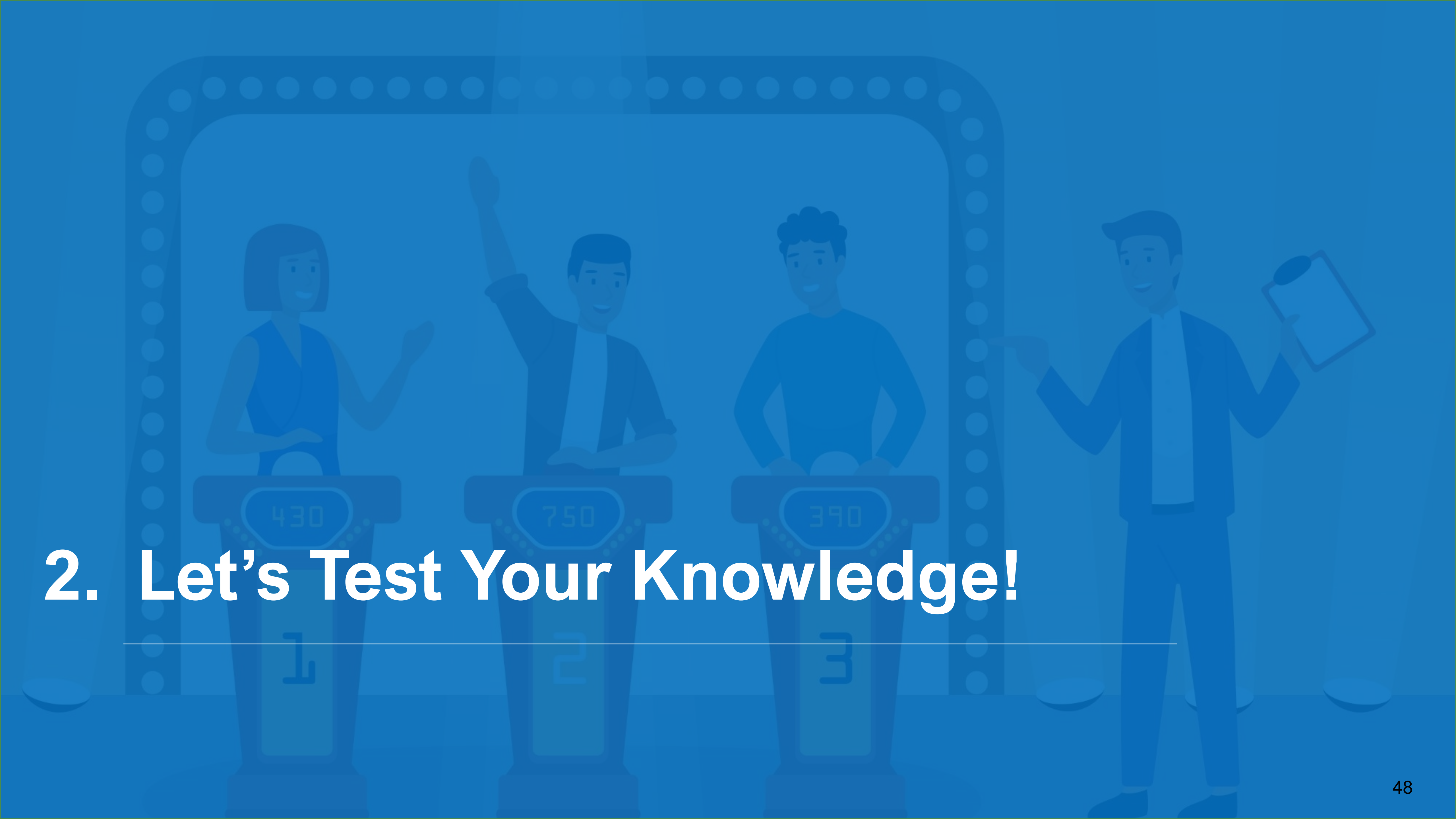


Considerations When Choosing a Location for CEMS

- Representative Emissions (well-mixed and laminar flow)
- Accessibility for routine maintenance and repairs and performance of calibration audits and checks
- Sufficient distance from flow disturbances, such as bends from changes in stack/duct diameter, and control equipment
- Protection from weather and vibration
- For opacity monitoring systems: no condensation inside stack near monitor and no ambient light

For specific requirements, see applicable performance specification.

Access for Reference Method Testing



2. Let’s Test Your Knowledge!

Feedback

It’s true! For CERMs, the calculation of pollutant mass rate requires velocity measurements.

CERMS – Question 1

1. For CERMs, the calculation of pollutant mass rate requires velocity measurements.

True

False

Feedback

The answer is B. A CERMS is needed to calculate the mass emission rate

CERMS – Question 2

2. A CERMS is used when which of the following is required:

A. The gas concentration

B. The mass emission rate

C. Both

Feedback

The answer is E, All of the above. All the factors are important for installation of CEMS.

CEMS

1. Important factor(s) for installation of CEMS is/are:

A. Accessibility

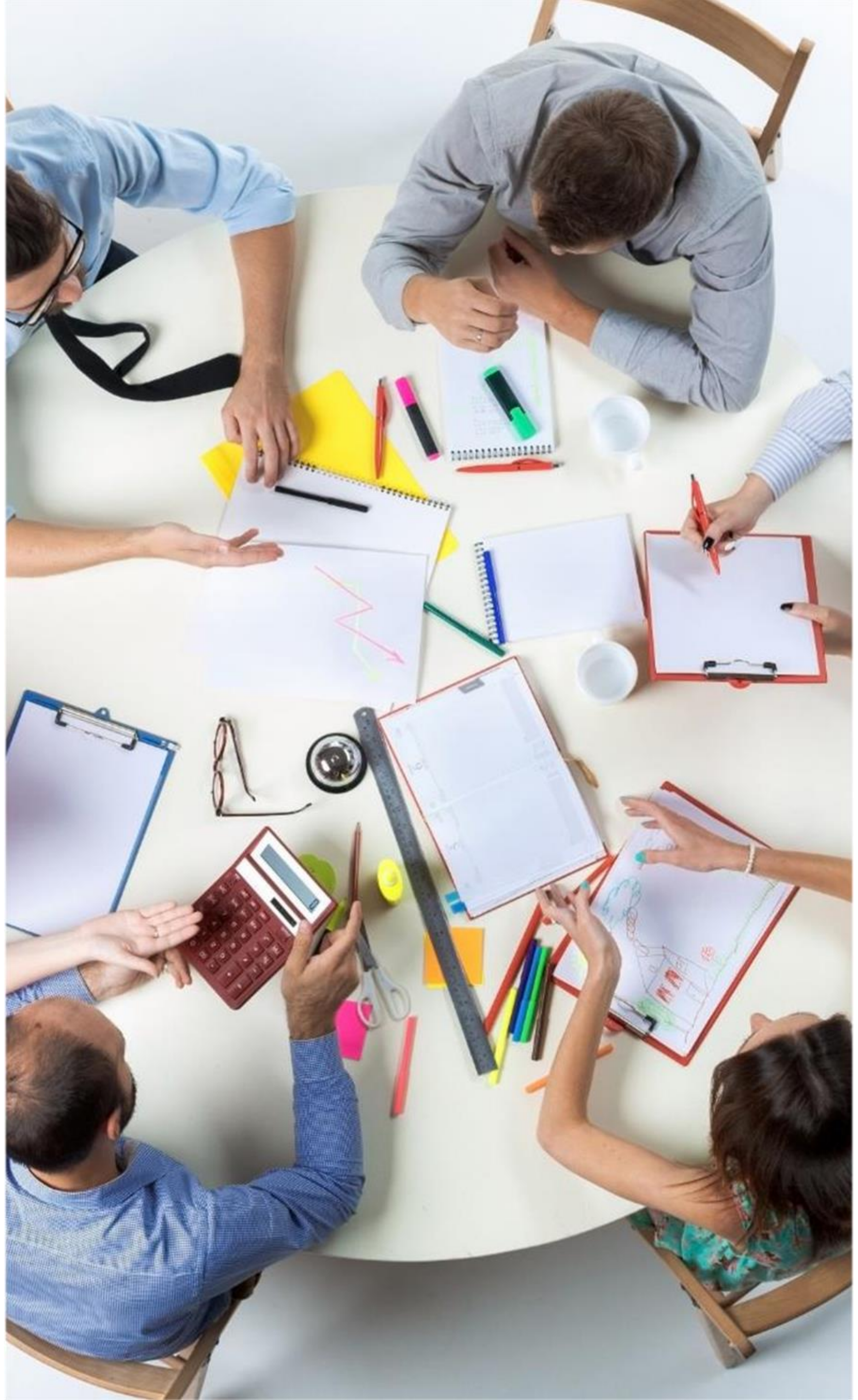
B. Representativeness

C. Sufficient distance from flow disturbances

D. Protection from weather and vibration

E. All of the above

Activity



Title: Top Ten

Purpose: To review the module content by sharing a list of top ten things learned about CMS and its design and components.

Time: 40 minutes

- 20 minutes in groups
- 20 minutes group debrief

Activity Debrief

Module 2 Summary

Now that you have completed Module 2, you should be able to:

- Define opacity and describe how continuous opacity monitoring systems (COMS) are used
- Recognize the pollutant parameters measured by continuous monitoring systems (CMS)
- Distinguish between extractive and in-situ systems
- Describe how continuous emission rate monitoring systems (CERMS) function
- Give examples of CEMS location and siting considerations