UNITED STATES
ENVIRONMENTAL
PROTECTION AGENCY

CONTINUOUS MONITORING SYSTEMS COURSE

PARTICIPANT GUIDE

TABLE OF CONTENTS

Welcome!

About this Course

Course Description

This three-day classroom *Continuous Monitoring Systems (CMS) Course* provides you with a basic understanding of CMS. It provides an overview of how to perform regulatory reviews and includes key concepts and information on CMS, including types, regulations, analytical techniques, systems design and components, performance specifications, quality assurance (QA) requirements, commonly used technologies, audits/inspections, and enforcement procedures. In addition to the instructor presentation and lecture, you will have opportunities to apply your knowledge through practical exercises, facilitated discussions, and knowledge check games.

Course Goal(s)

The CMS course has been designed as a three-day classroom immersion into:

- Key concepts pertaining to CMS
- Terminology and techniques that are common in the field
- Performance specifications and QA procedures
- How to use the performance specifications and where to locate requirements
- Different types of audits and enforcement procedures

Course Organization

There are four modules in this course and an introductory module:

- Course Introduction
- Module 1: Introduction to Continuous Monitoring Systems (CMS)
- Module 2: Overview of CMS and CMS Design and Components
- Module 3: Performance Specifications, Quality Assurance, and Commonly Used Technologies
- Module 4: Audits/Inspection and Enforcement

Target Audience

This course is intended for a fairly broad audience and could include participants with non-technical backgrounds (e.g., a basic degree in science) as well as technical backgrounds (e.g., a chemical engineering degree). No prior knowledge of CMS is presumed. This course is intended primarily for new hires or any participants who need an understanding of CMS in their job responsibilities.

Staff who could benefit from the course include, but are not limited to the following:

- Staff who are inspection and/or enforcement personnel
- Staff who observe stack test and CMS certifications
- Staff who are reviewing audit reports
- Staff who work on permits

Prerequisites

There are no prerequisites for this course.

Evaluation

The following types of evaluation will be conducted:

- Level 1 evaluation (reaction): accomplished through the use of the standard EPA end-of-course evaluation
- Level 2 evaluation (learning): accomplished through the completion of a course exam and optional activities conducted throughout the course

Course Agenda

Scheduled Time	Module	Duration
Day 1		
8:30 am – 9:00 am	Course Introduction	30 minutes
9:00 am – 10:00 am	Module 1: Introduction to Continuous Monitoring Systems (CMS)	60 minutes
10:00 am – 10:30 am	Break	15 minutes
10:30 am – 12:00 pm	Continue Module 1: Introduction to Continuous Monitoring Systems (CMS)	90 minutes
12:00 pm – 1:00 pm	Lunch	60 minutes
1:00 pm – 1:30 pm	Wrap-up Module 1: Overview of the Course	30 minutes
1:30 pm – 2:00 pm	Module 2: Overview of CMS and CMS Design and Components	30 minutes
2:00 pm – 2:15 pm	Break	15 minutes
2:15 pm – 4:00 pm	Wrap-up Module 2: Overview of CMS and CMS Design and Components	105 minutes
	Total:	**435 minutes (7.5 hours)**
Day 2		
8:30 am – 10:00 am	Begin Module 3: Performance Specifications, Quality Assurance, and Commonly Used Technologies	90 minutes
10:00 am – 10:15 am	Break	15 minutes
10:15 am – 12:00 pm	Continue Module 3: Performance Specifications, Quality Assurance, and Commonly Used Technologies	105 minutes
12:00 pm – 1:00 pm	Lunch	60 minutes
1:00 pm – 2:00 pm	Continue Module 3: Performance Specifications, Quality Assurance, and Commonly Used Technologies	60 minutes
2:00 pm – 2:15 pm	Break	15 minutes
2:15 pm – 4:00 pm	Continue Module 3: Performance Specifications, Quality Assurance, and Commonly Used Technologies	105 minutes
	Total:	**450 minutes (7.5 hours)**

Day 3		
8:30 am – 9:45 am	Module 3 and Wrap Up: Performance Specifications, Quality Assurance, and Commonly Used Technologies	75 minutes
9:45 am –10:00 am	Break	15 minutes
10:00 am – 12:00 pm	Begin Module 4: Audits/Inspections and Enforcement	120 minutes
12:00 pm – 1:00 pm	Lunch	60 minutes
1:00 pm – 2:00 pm	Module 4: Audits/Inspections and Enforcement	60 minutes
2:00 pm – 3:00 pm	Course Wrap-up, Post-Training Assessment (optional) and Exam	60 minutes
	Total:	**390 minutes (6.5 hours)**

About the Participant Guide

PowerPoint Slides

This participant guide contains a copy of the PowerPoint presentation slides that the instructor(s) will use to teach this course. This includes PowerPoint slides for the course introduction and for modules 1-4. This participant guide is yours to keep, so feel free to take class notes on the lines provided below each slide.

Appendices

There are three appendices associated with this course, which will be provided to you by your instructor:

- **Appendix A: Master Glossary** – The glossary encompasses a complete list of terms and definitions for all of modules in this course.
- **Appendix B: Master Resources** – A list of resources, including helpful website links, are provided per module.
- **Appendix C**: **Pre and Post Self-Assessment** – Your instructor may direct you to complete a self-assessment prior to and after the course. These self-assessments will help you to establish a baseline of what you may already know about the information contained in this course. Then, a post self-assessment will allow you to compare how your knowledge and skills have changed as a result of completing the course.

Handouts

In addition to the appendices listed above, there are several handouts associated with this course, which will be provided to you by your instructor:

- General provisions
- Properties of light
- Performance testing
- Commonly used technologies
- Commonly used acronyms
- Performance specifications
- CMS definitions by performance specification (PS)
- Preventative maintenance examples

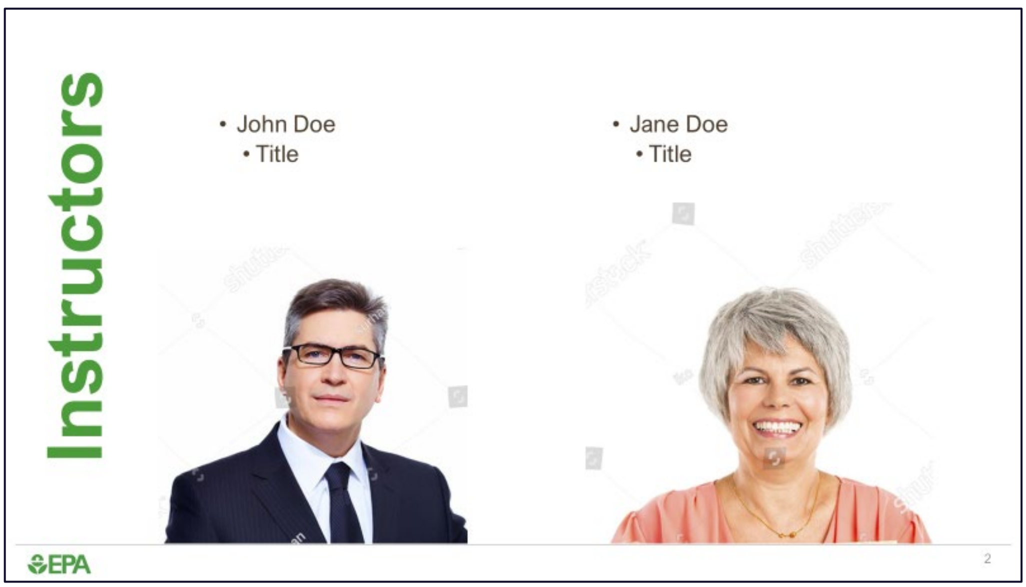
COURSE INTRODUCTION

Course Introduction

Course Introduction Description:

The course introduction serves as an overview of the CMS course. This overview includes the course goal, as well as an outline of the modules covered in the course. The course introduction also gives you a chance to meet the instructors, as well as the other participants taking the course. Instructors also use this time to cover administrative aspects of the course including a review of the course materials and course agenda.


WELCOME!
Continuous Monitoring Systems Course
EPA
Disclaimer: Any pictures herein are for educational purposes only and not intended to be an endorsement of any particular manufacturer, vendor, or product


Instructors
• John Doe
• Title
• Jane Doe
• Title
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01 Name
02 Job Title
03 Expectation

INTRODUCTIONS

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Course Introduction

01 Course Goal
02 Course Outline/Topics
03 Course Schedule
04 Course Materials
05 Administrative Information

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Course Goal

Upon completing this course, you will gain a basic understanding of Continuous Monitoring Systems (CMS). You will be able to use the knowledge gained on the following topics to assess the accurac data and the ongoing compliance of sources monitored by CM

- Types and purposes of CMS
- Review of regulatory basis for CMS
- Analytical techniques
- Systems design and components
- Performance specifications and quality assurance requir
- Commonly used technologies
- Audits and inspections
- Enforcement procedures

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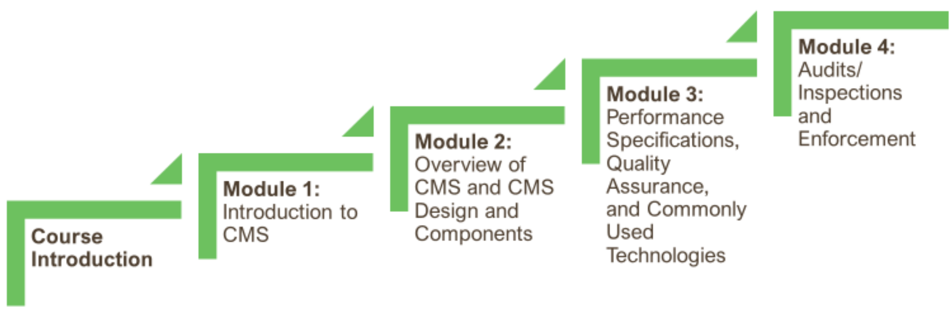
Course Outline

This course is arranged into four modules:



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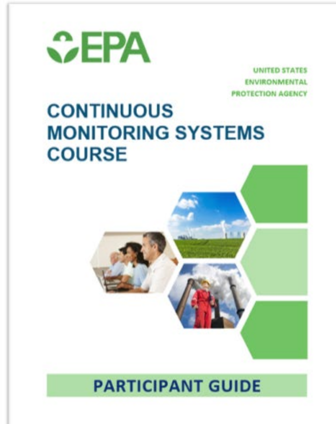
Course Materials

You should have the following course materials:

- Participant Guide
- Handouts



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Course Schedule

Day 1	Course Introduction
	Module 1: Introduction to CMS
	Module 2: Overview of CMS and CMS Design and Components
Day 2	Module 3: Performance Specifications, Quality Assurance, and Commonly Used Technologies
Day 3	Module 3 and Wrap Up
	Module 4: Audits/Inspections and Enforcement
	Post-Training Assessment and Course Exam

EPA

Ground Rules

- Start and Stop on-time
- Silence cell phones
- Be respectful and courteous
- Ask questions as you think of them
- Return promptly from breaks and lunch

EPA 9

Where's the Coffee?

- Location of restrooms, coffee and vending areas, lunch options
- Emergency evacuation information
- Smoking area
- Parking

EPA 10


Questions
EPA
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MODULE 1: INTRODUCTION TO CMS

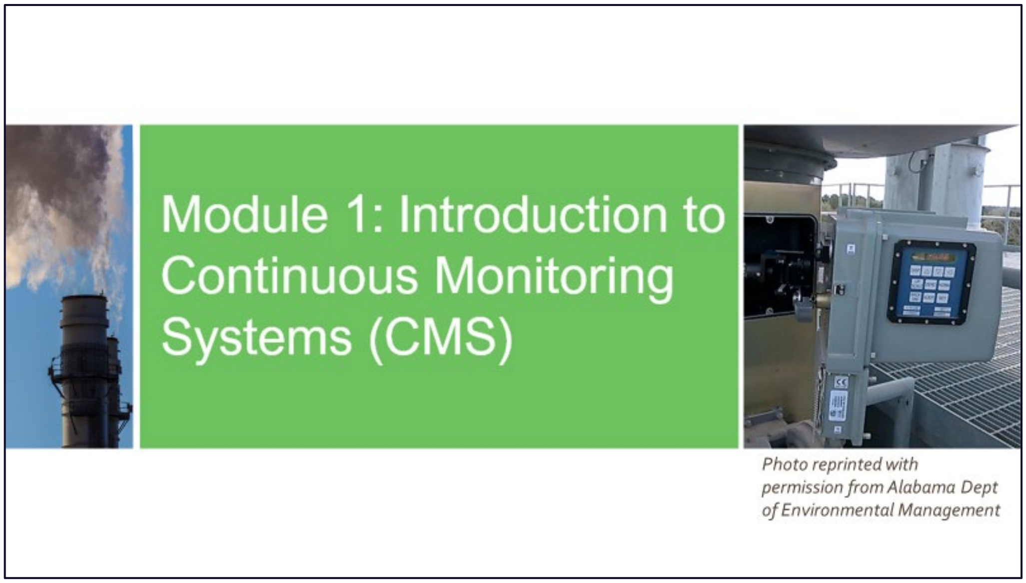
Module 1: Introduction to CMS

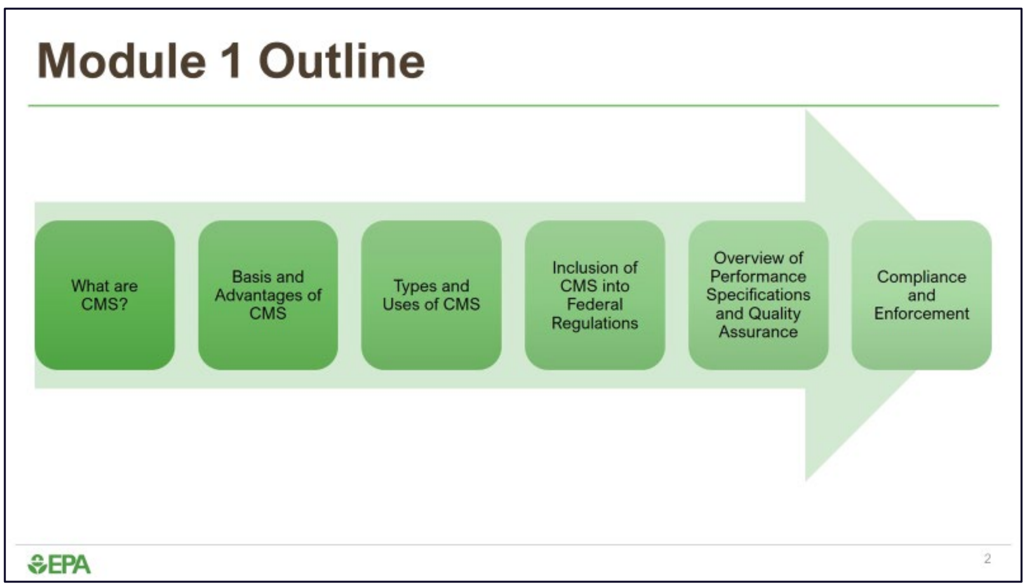
Module 1 Description:

In Module 1, you will gain a basic understanding of continuous monitoring systems (CMS), including learning about the four different types of CMS. You will learn the reasons why CMS are important, as well as their many uses. Additionally, you will learn about the inclusion of CMS into Federal regulations. This module will introduce performance specifications and quality assurance as it relates to continuous emission monitoring systems (CEMS) and the use of CEMS data for enforcement.

Module 1 Objectives:

- Recognize the different types and uses of CMS
- Identify the regulations that contain CMS requirements
- Recognize, in general, what performance specifications are and how they are used
- Recall enforcement aspects of CMS


Module 1: Introduction to Continuous Monitoring Systems (CMS)
Photo reprinted with permission from Alabama Dept of Environmental Management


Module 1 Outline
What are CMS?
Basis and Advantages of CMS
Types and Uses of CMS
Inclusion of CMS into Federal Regulations
Overview of Performance Specifications and Quality Assurance
Compliance and Enforcement
EPA
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Module 1 Learning Objectives

At the end of Module 1, learners will be able to:

- Recognize the different types and uses of CMS
- Identify the regulations that contain CMS requirements
- Recognize, in general, what performance specifications are and how they are used
- Recall enforcement aspects of CMS

EPA 3

What are CMS?

Continuous monitoring systems (CMS) **means "the total equipment, required under the emission monitoring sections in applicable subparts, used to sample and condition (if applicable), to analyze, and to provide a permanent record of emissions..."** ***40 CFR Part 60***

EPA 4

Why CMS?

CMS are required under some of the EPA regulations for either continual compliance determinations or determination of exceedances of the emissions standards.

The individual subparts of the EPA rules specify the reference methods that are used to substantiate the accuracy and precision of the CMS.

EPA 5

Basis for CMS Programs

- As a result of the Clean Air Act (CAA), many pollution control devices such as baghouses, scrubbers, and electrostatic precipitators have been installed.
- After the equipment is installed and operating, an air pollution control agency needs to know if the equipment is actually reducing emissions and if the facility is meeting its emissions standards.
- CMS programs are one of the methods used to measure emissions from stationary sources.

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Basis for CMS Programs (Cont'd)

EPA established two methods to measure concentrations of pollutants from regulated sources:

1. EPA Reference Methods
2. CMS

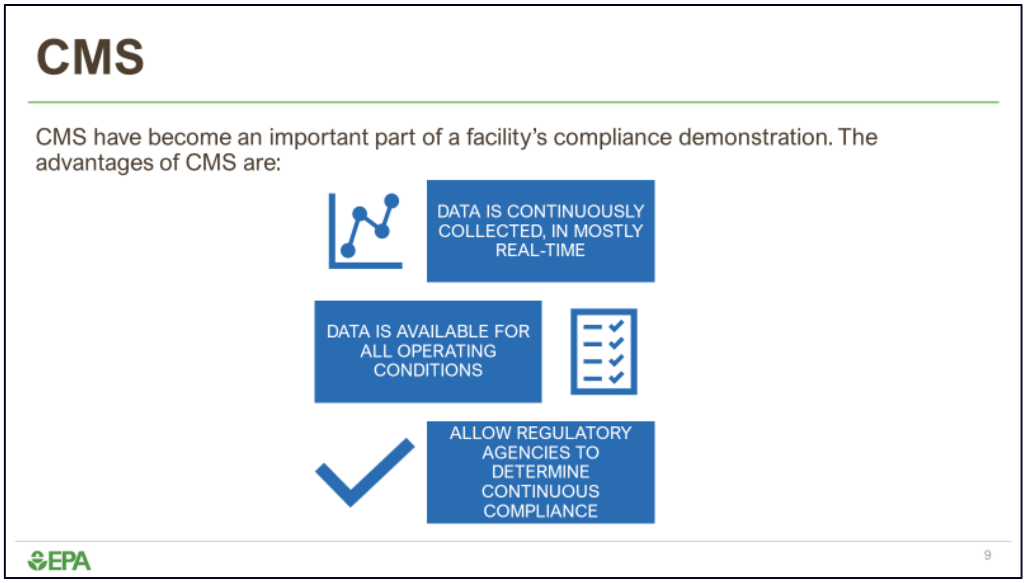
EPA 7

Reference Methods

Reference methods are beneficial, but may have disadvantages when compared to using a CMS:

- Performed infrequently and for a relatively short period of time (hours)
- Often conducted when the source is operating under optimal conditions, which may not result in producing normal, day-to-day emission values

EPA 8


CMS
CMS have become an important part of a facility's compliance demonstration. The advantages of CMS are:
DATA IS CONTINUOUSLY COLLECTED, IN MOSTLY REAL-TIME
DATA IS AVAILABLE FOR ALL OPERATING CONDITIONS
ALLOW REGULATORY AGENCIES TO DETERMINE CONTINUOUS COMPLIANCE
EPA
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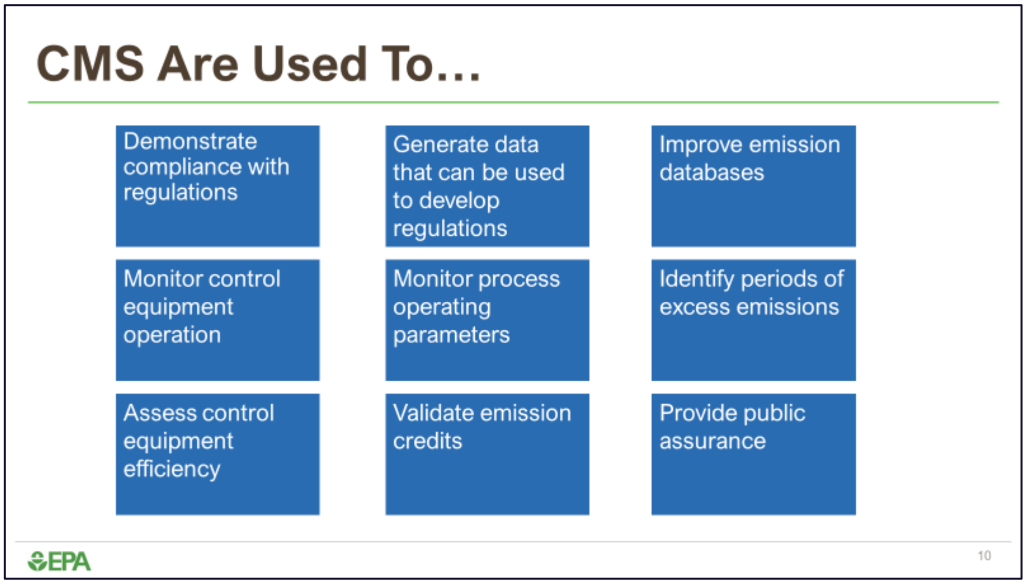
CMS Are Used To…
Demonstrate compliance with regulations
Generate data that can be used to develop regulations
Improve emission databases
Monitor control equipment operation
Monitor process operating parameters
Identify periods of excess emissions
Assess control equipment efficiency
Validate emission credits
Provide public assurance
EPA
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Types of CMS

- The four types of CMS:
  - Continuous Opacity Monitoring Systems (COMS)
  - Continuous Emission Monitoring Systems (CEMS)
  - Predictive Emission Monitoring Systems (PEMS)
  - Continuous Emission Rate Monitoring Systems (CERMS)

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Continuous Opacity Monitoring Systems (COMS)

EPA 12

COMS

- COMS consist of the **total equipment** used to sample, analyze, and provide a permanent record of opacity.
- COMS use light to determine opacity levels.
- Due to absorption and scattering of light by dust, smoke, and/or particulate present in the gas stream, there will be an attenuation of the transmitted light and a decrease in the light intensity that is measured.
- COMS can be "single pass" or "double pass."

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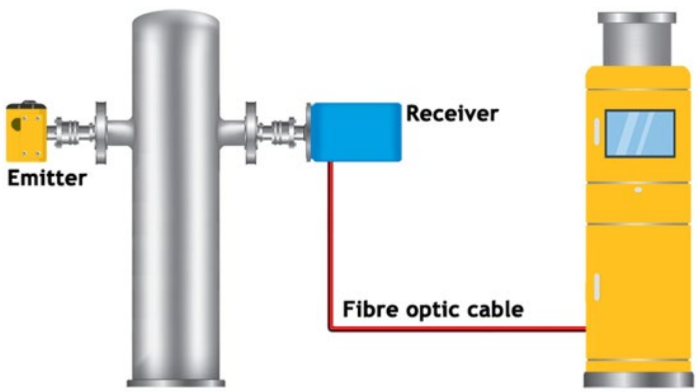
COMS (Cont'd)



EPA 14

Typical Sources with COMS Requirements

- COMS are typically used by facilities that rely on waste materials, oil, coal, wood, or other fossils fuels for combustion.
- Examples of sources are:
  - Utilities
  - Boilers
  - Flares

EPA 15

Continuous Emission Monitoring Systems (CEMS)

EPA 16

CEMS Definition

CEMS consists of the **total equipment** necessary to determine a gas or particulate matter emission concentration.

Image courtesy of Thermo Fisher Scientific™

EPA 17

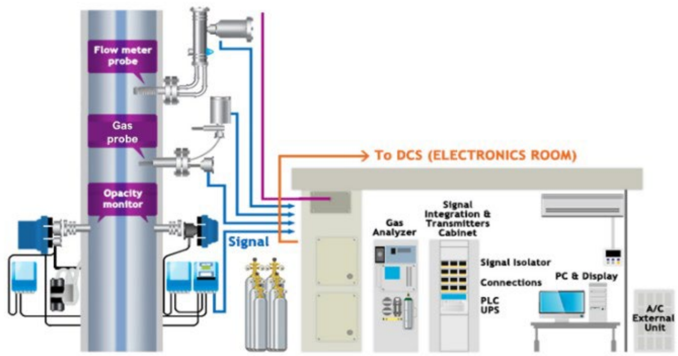
CEMS

CEMS:

- Continuously measures actual emissions from stationary sources by extracting a sample of gas from the emission source:
  - Sample gas may be filtered, transported, conditioned, or diluted before being presented to the analysis system.
  - Gas concentrations are measured, recorded, and stored as data.
- May also include components for measuring particulate matter, and stack gas flowrate

EPA 18

CEMS: Illustrative Example



EPA 19

Basic CEMS Components

CEMS consist of the following:

Sample Interface. The portion of the system that is used for one or more of the following:
- sample acquisition,
- sample transportation,
- sample conditioning, or
- protection of the analyzer from the effects of the stack effluent.

Analyzer/Measurement Method. The portion of the system that senses the gas or particulate and generates an output proportional to the gas or particulate concentration.

Data Acquisition System. The portion of the system that records a permanent record of the measurement values. The data acquisition system, or DAS, may include automatic data reduction capabilities.

EPA 20

Major Components of CEMS

- Sample Probe
- Filter
- Sample Line (umbilical)
- Gas Conditioning System
- Calibration Gas System
- Gas Analyzers (may include more than one)
- Data Acquisition Systems (DAS)

Data Acquisition System

Extractive Conditioning System

Gas Analyzers

EPA 21

Cylinders of EPA Certified Gases and CEMS Cabinet

Cylinders of EPA Certified Gases

Inside a CEMS Shelter

Outside a CEMS Shelter

EPA 22

CEMS Unit Shelter

EPA 23

Typical Sources with CEMS Requirements

CEMS are generally required on larger emitting stationary sources. Below are a few examples:

- Utilities
- Cement Plants
- Municipal Waste Combustors
- Nitric and Sulfuric Acid Plants
- Petroleum Refineries
- Copper, Zinc, and Lead Smelters
- Steel and Ferroalloy Plants
- Kraft Pulp Mills
- Glass Manufacturing Plants
- Magnetic Tape Production
- Phosphate Plants

EPA 24

Predictive Emission Monitoring Systems (PEMS)

EPA 25

PEMS

- The **total equipment necessary** to predict an emission concentration or emission rate.
- The system may consist of any of the following major subsystems: sensors and sensor interfaces, emission model, algorithm, or equation that uses process data to generate an output that is proportional to the emission concentration or emission rate, diluent emission model, data recorder, and sensor evaluation system.

EPA 26

PEMS (Cont'd)

- **Software-based system** which uses process values as input variables to provide a real-time estimation of emissions by means of derived mathematical or statistical algorithm
- PEMS are an acceptable regulatory alternative to CEMS for source emission compliance in some regulations.

Examples of Input Variables

Feed Type	Firing Rate	Fuel Gas Density
Furnace Air Preheat Temperature	Percent Excess Oxygen	Stack Temperature
Inlet Air Humidity	Inlet Air Temperature	

EPA 27

Continuous Emission Rate Monitoring Systems (CERMS)

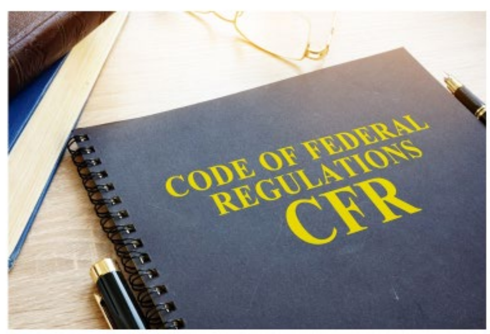
EPA 28

CERMS

- Is the **total equipment required** for determining and recording the pollutant mass emission rate (in terms of mass per unit of time)
- Includes the use of a flow rate monitor to measure the volumetric flow rate of the emission stream and generate an output proportional to that flow rate

EPA 29

CMS in Federal Regulations



EPA 30

40 CFR, Part 60 - New Source Performance Standards (NSPS)

- CAA, Section 111 establishes mechanisms for controlling emissions of air pollutants from stationary sources:
  - Section 111(b) provides authority for EPA to promulgate new source performance standards (NSPS) which apply only to new and modified sources.
  - Section 111(d) requires regulation of existing sources.
- These standards limit the amount of air emissions (SO_2, NOx, etc.) that may be emitted from stack sources.
- The performance specifications and quality assurance procedures for CMS are found in Appendix B and F of 40 CFR, Part 60.

EPA 31

40 CFR Part 61 - National Emission Standards For Hazardous Air Pollutants (NESHAP)

- Established under Section 112 of the CAA
- Promulgated prior to November 15, 1990, the date of enactment of the CAA amendments of 1990
- National emission standards for hazardous air pollutants (NESHAP) contained in this part remain in effect until they are amended, and if appropriate, added to Part 63.

EPA 32

40 CFR, Part 63 - National Emission Standards for Hazardous Air Pollutants (NESHAP) for Source Categories

- Established under Section 112 of the 1990 amendments to the CAA
- These standards regulate specific categories of stationary sources that emit (or have the potential to emit) one or more hazardous air pollutants listed in this part.
- The standards in this part are independent of the NESHAP contained in 40 CFR Part 61.

EPA 33

40 CFR, Part 75 – Acid Rain Program

- Established under Title IV of the CAA of 1990
- First national cap and trade program in the country
- Requires major emission reductions of SO_2 and NO_X from the power sector
- SO_2 and NO_X are the primary precursors for acid rain.
- Since Part 75 is handled by EPA's Clean Air Markets Division (CAMD), the Part 75 monitoring requirements are not the focus of this training.

EPA 34

Performance Specifications and Quality Assurance

Performance Specifications are used for evaluating the acceptability of the CMS at the time of, or soon after installation, or whenever specified in the regulations.

Quality Assurance (QA) procedures are used to evaluate the effectiveness of quality control (QC) and the quality of data produced by any CMS that is used for determining compliance with the emission standards as specified in the applicable regulation.

Performance specifications and QA procedures can be found in 40 CFR, Part 60 Appendices B and F, respectively.

EPA 35

Use of CEMS Data for Enforcement

- CEMS can provide accurate data regarding a source's compliance with the emissions limits and standards.
  - CEMS data can be more representative of a source's ongoing compliance status when compared to infrequent performance testing, and
  - CEMS data typically can cover a greater percentage of a source's time in operation.

EPA 36

Use of CEMS Data for Enforcement (Cont'd)

CEMS data is important to enforcement, irrespective of whether the legal requirement being enforced specifies CEMS as the compliance method.

- The CAA authorizes EPA to bring an administrative, civil, or criminal enforcement action "on the basis of any information available to the administrator."
- The 1997 "Credible Evidence" revisions to 40 CFR Parts 51, 52, 60, and 61 clarified that non-reference test data, including CEMs, can be used for establishing whether or not the source has violated or is in violation of any standard of that part.

EPA 37

Enforcement Applications of CEMS

- The governing regulation* specifies CEMS as the compliance method.
- The governing regulation* specifies some method other than CEMS as the compliance method, or the governing regulation doesn't specify a compliance method.

* e.g., 40 CFR Part 60

EPA 38

CEMS is the Compliance Method

- Required by some NSPS, National Emission Standards for Hazardous Air Pollutants (NESHAPS) and State Implementation Plans (SIPs)
- Includes data validation requirements
- Requires monitoring against emission limits with long averaging time
- Data documents compliance against the emissions standard

EPA 39

CEMS is not the Compliance Method

CEMS data is "Credible Evidence:"

- Data is used for initiating and supporting enforcement cases alleging emissions violations.
- CEMs data may provide a basis to issue a Section 114 request for compliance method data.
- CEMs data may be used to enforce operation and maintenance, monitoring and recordkeeping and reporting requirements, when the regulation does not specify a compliance method or an emissions standard (e.g. General Duty Clause).

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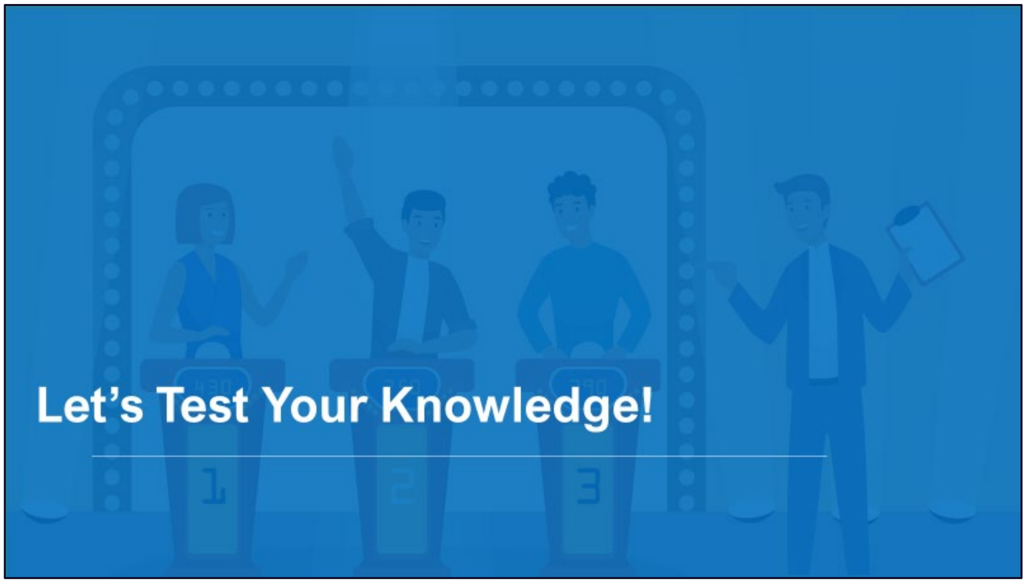
Let's Test Your Knowledge!
1
2
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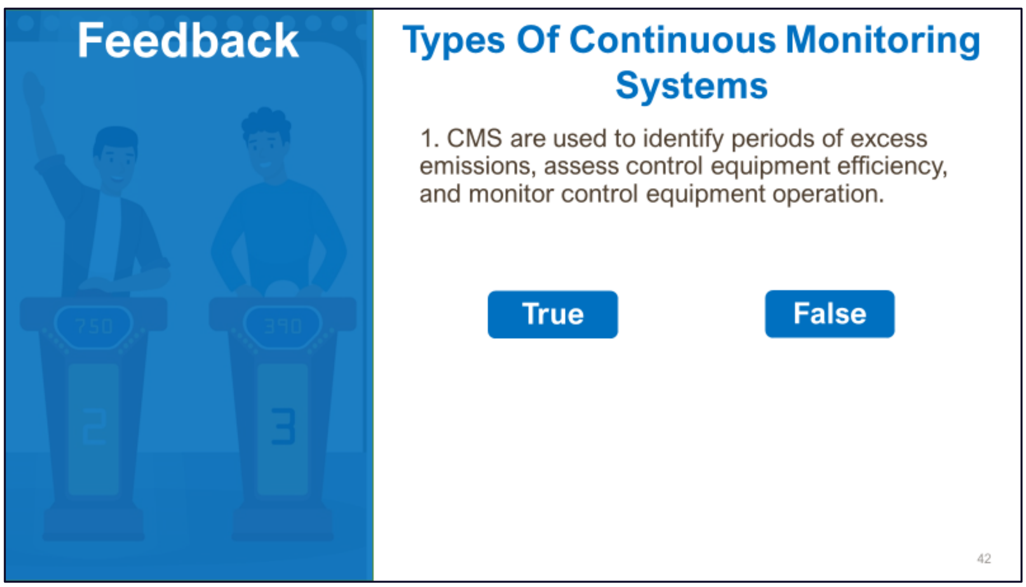
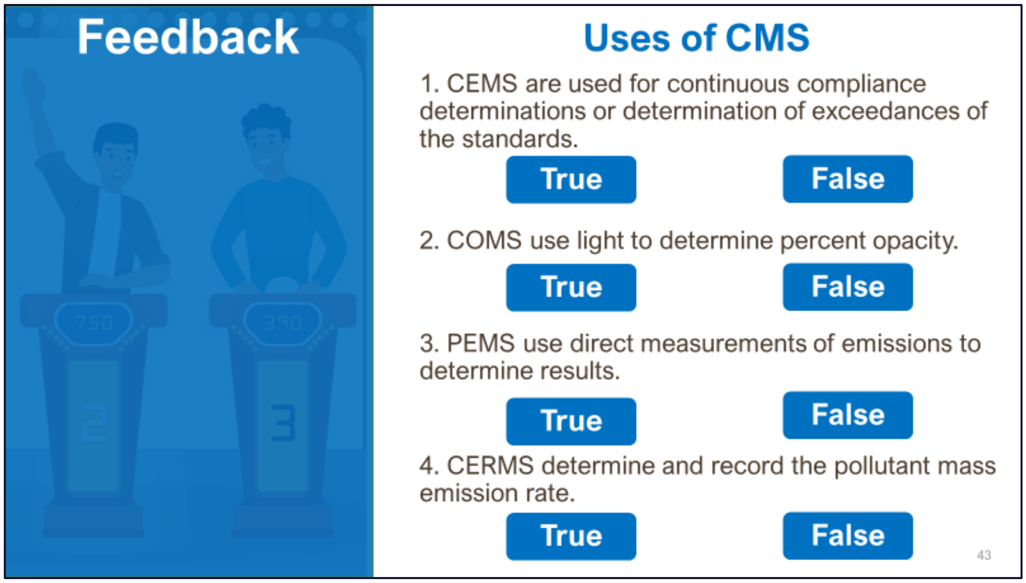
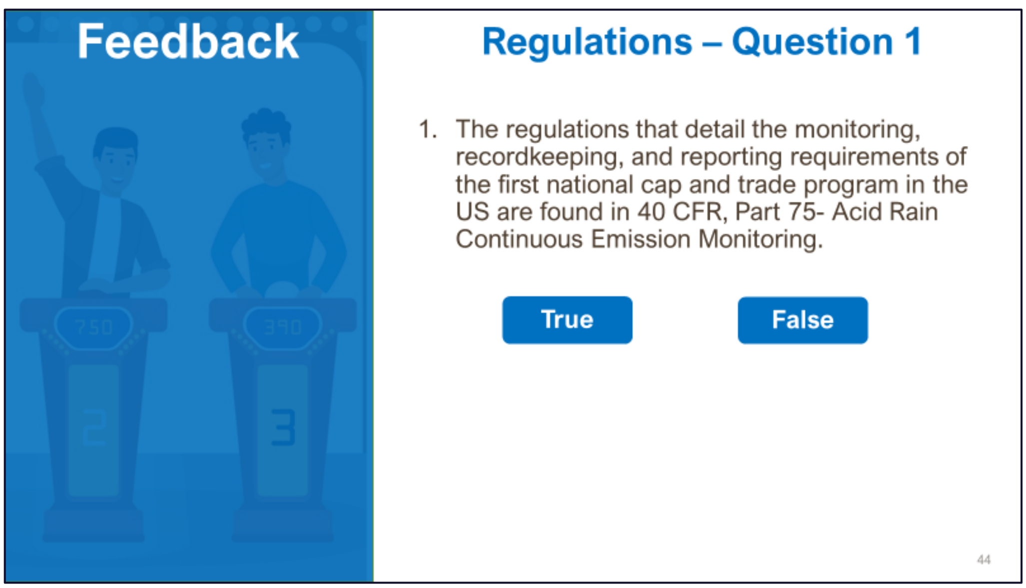
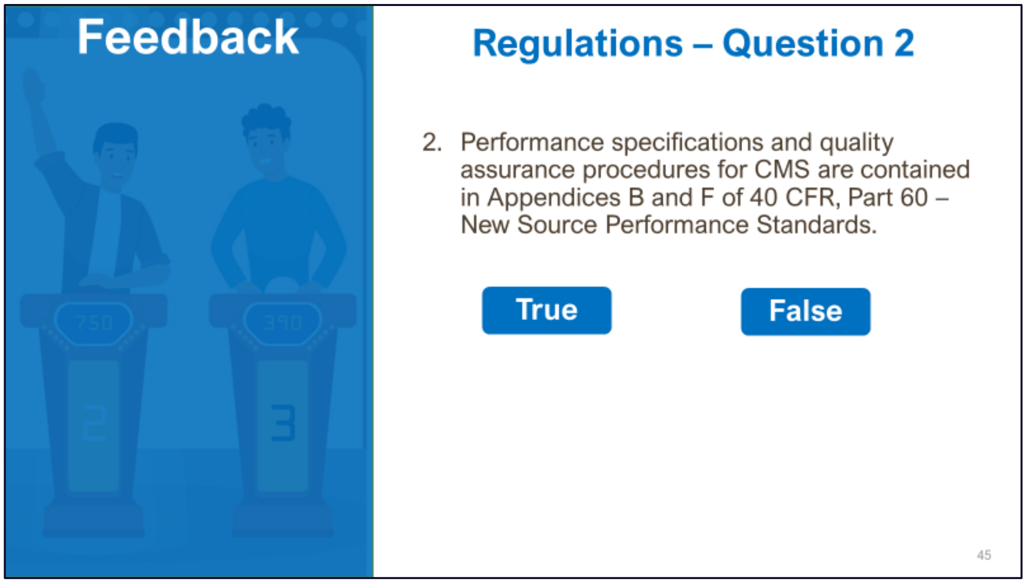
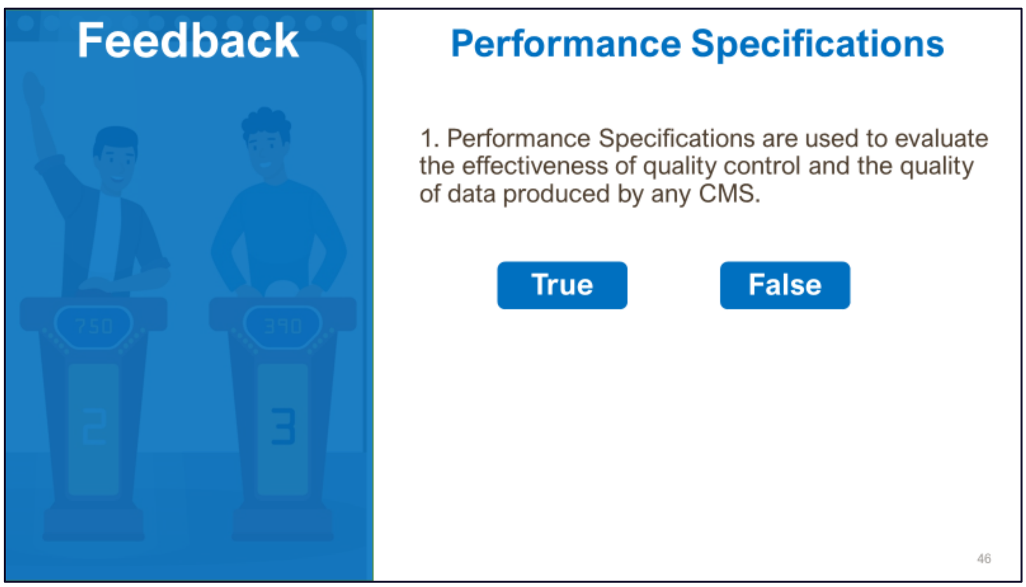

Feedback
Types Of Continuous Monitoring Systems
1. CMS are used to identify periods of excess emissions, assess control equipment efficiency, and monitor control equipment operation.
True
False
42


Feedback
Uses of CMS
1. CEMS are used for continuous compliance determinations or determination of exceedances of the standards.
True
False
2. COMS use light to determine percent opacity.
True
False
3. PEMS use direct measurements of emissions to determine results.
True
False
4. CERMS determine and record the pollutant mass emission rate.
True
False
43


Feedback
Regulations – Question 1
1. The regulations that detail the monitoring, recordkeeping, and reporting requirements of the first national cap and trade program in the US are found in 40 CFR, Part 75- Acid Rain Continuous Emission Monitoring.
True
False
44


Feedback
Regulations – Question 2
2. Performance specifications and quality assurance procedures for CMS are contained in Appendices B and F of 40 CFR, Part 60 – New Source Performance Standards.
True
False
45


Feedback
Performance Specifications
1. Performance Specifications are used to evaluate the effectiveness of quality control and the quality of data produced by any CMS.
True
False
46


Activity
Title: Group Experts
Purpose: To become an "expert" on the knowledge learned from Module 1 for an assigned CMS. Share information and help your peers understand and retain this information.
Time: 40 minutes
• 20 minutes in groups
• 20 minutes group debrief


Activity Debrief
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Module 1 Summary

Now that you have completed Module 1, you should be able to:

- Recognize the different types and uses of CMS
- Identify the regulations that contain CMS requirements
- Recognize, in general, what performance specifications are and how they are used
- Recall enforcement aspects of CMS

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MODULE 2: OVERVIEW OF CMS AND CMS DESIGN AND COMPONENTS

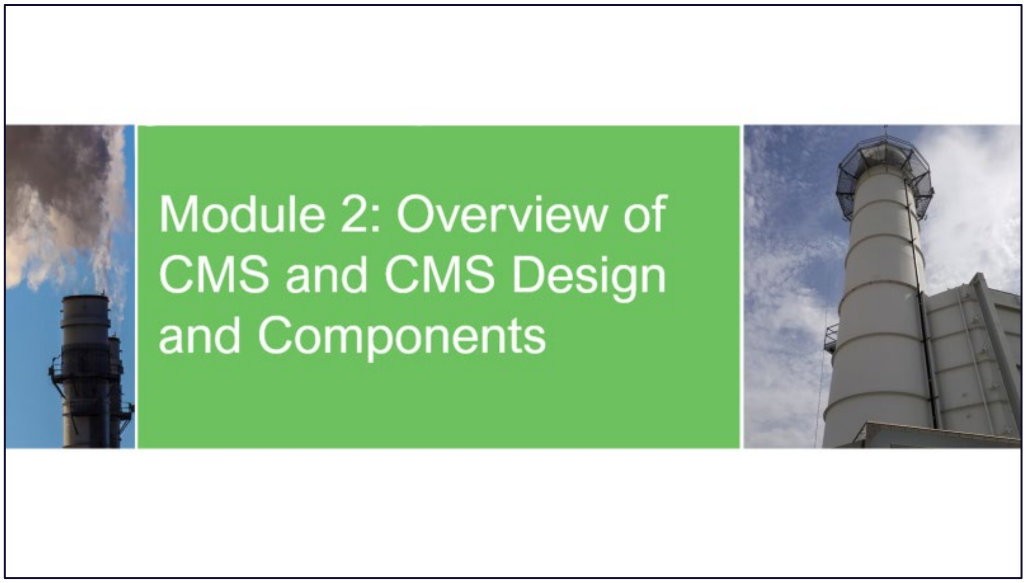
Module 2: Overview of CMS and CMS Design and Components

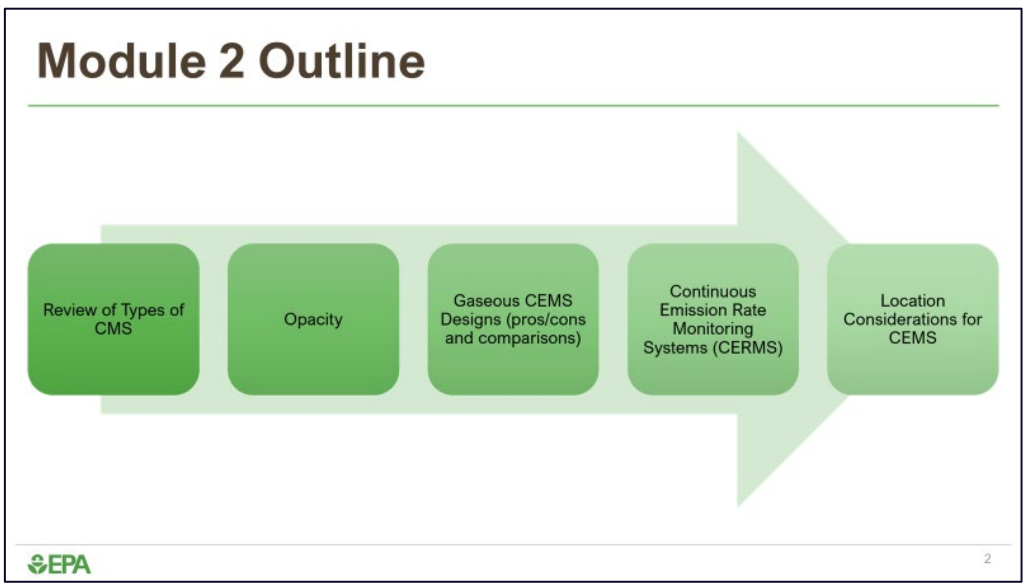
Module 2 Description:

In Module 2, you will be provided an overview of continuous monitoring systems (CMS) and their components and design. You will learn about opacity and how continuous opacity monitoring systems (COMS) are used. In addition, you will learn about CMS pollutant parameters, extractive and in-situ systems, and CEMS location and siting considerations. This module will also describe how continuous emission rate monitoring systems (CERMS) function.

Module 2 Objectives:

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


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
EPA
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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

EPA 3

Types of CMS

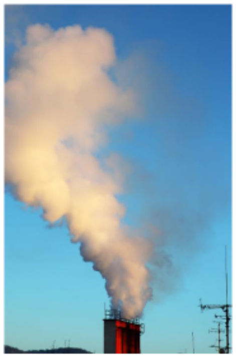
Reminder: There are four main types of CMS. These are:

- 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.

EPA 4

Pollutant Parameters

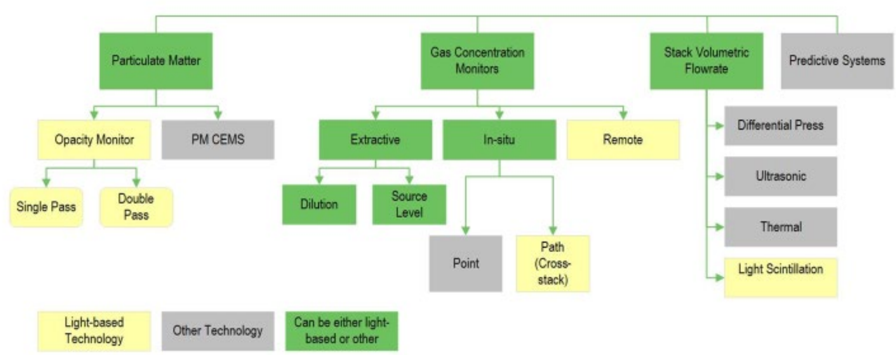


Continuous Monitoring Systems (CMS) may be used to measure the following:

- 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)

EPA 5

General Categories of CMS



EPA 6

Opacity and COMS

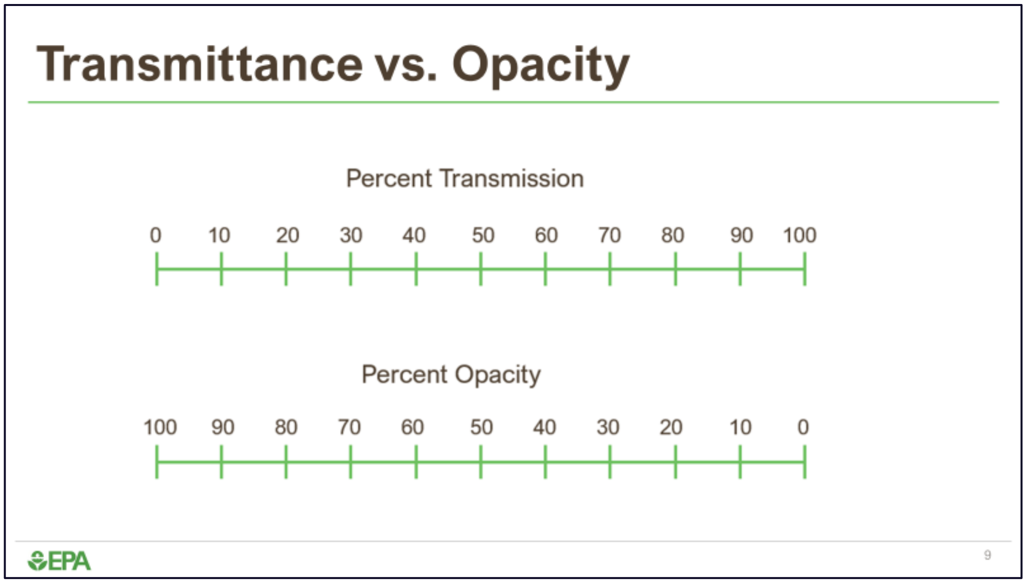
EPA 7

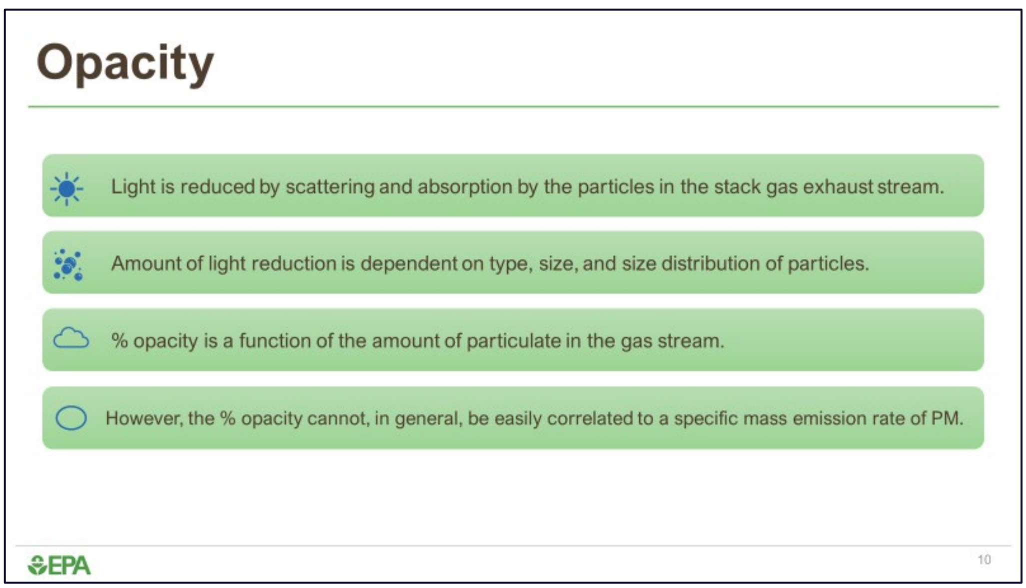
Opacity – Setting the Stage

- **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.

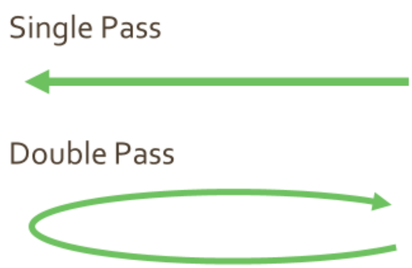
  Therefore, Op = 100 - Tr

EPA 8


Transmittance vs. Opacity
Percent Transmission
0 10 20 30 40 50 60 70 80 90 100
Percent Opacity
100 90 80 70 60 50 40 30 20 10 0
EPA
9


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.
EPA
10

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.

EPA 11

CEMS Design

EPA 12

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.

EPA 13

General Extractive System – Conditioning Cabinet

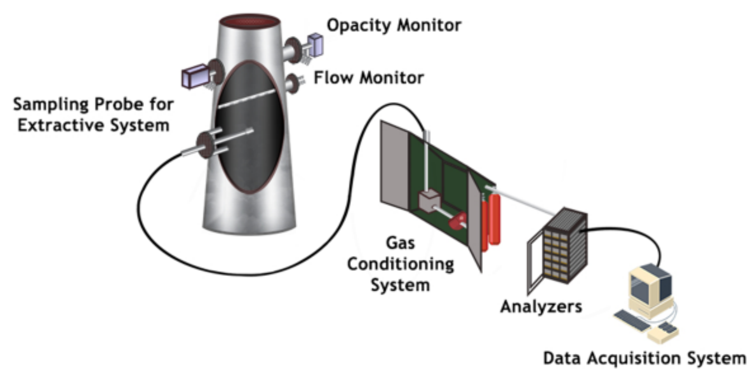
EPA 14

General Extractive System Components

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

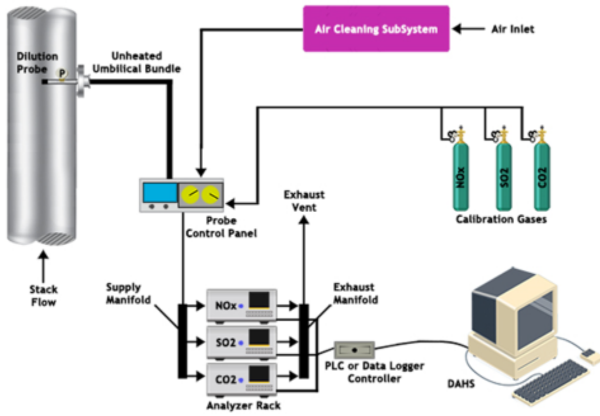
EPA 15

Source-Level Extractive System



EPA 16

Dilution Extractive Systems



EPA 17

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.

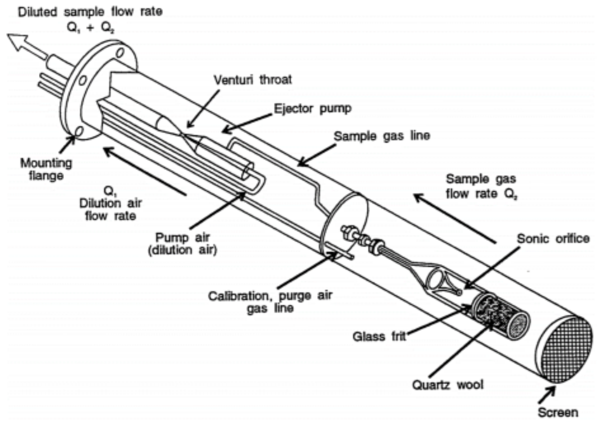
The most unique component of a dilution-extractive system is the dilution sampling probe.

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

- In-stack
- Out of stack

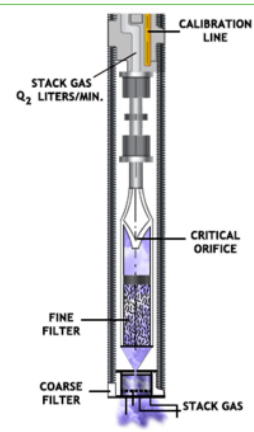
EPA 18

Dilution Probe



19

Dilution Probe Orifice



20

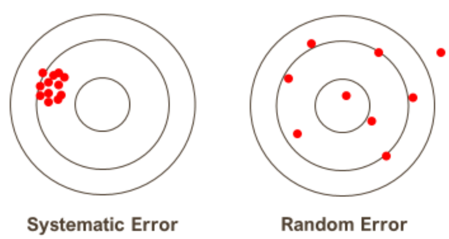
Reasons to Consider Using Dilution Probes

- 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

21

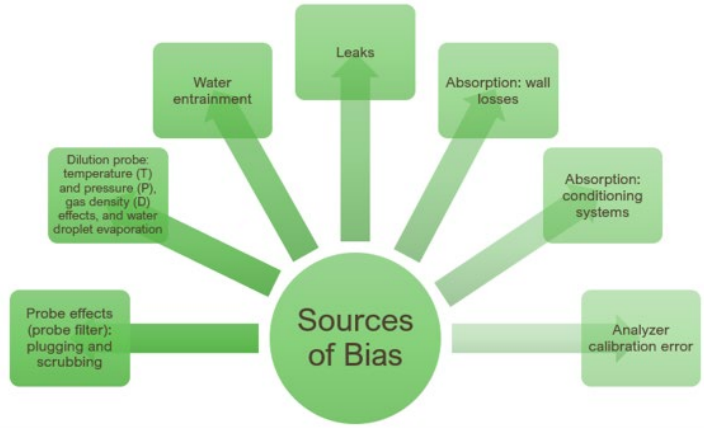
Overview of Measurement Bias

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



22

General Sources of Bias for Extractive Systems



EPA 23

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.

EPA 24

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

EPA 25

In-Situ Systems

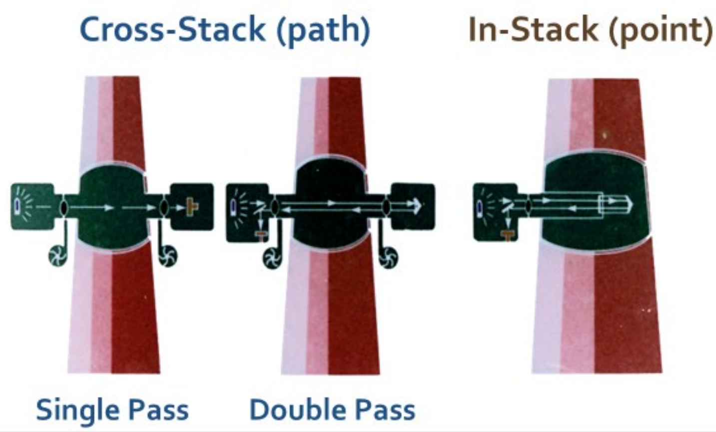
- Perform analysis at the stack
  - Lack of conditioning and transport sub-systems, hence, generally less equipment required than extractive systems
- EPA distinguishes between point and path monitors by the amount of gas stream that the probe is blocking.
  - Usually "very small" segment (point), or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

EPA 26

In-Situ Monitors

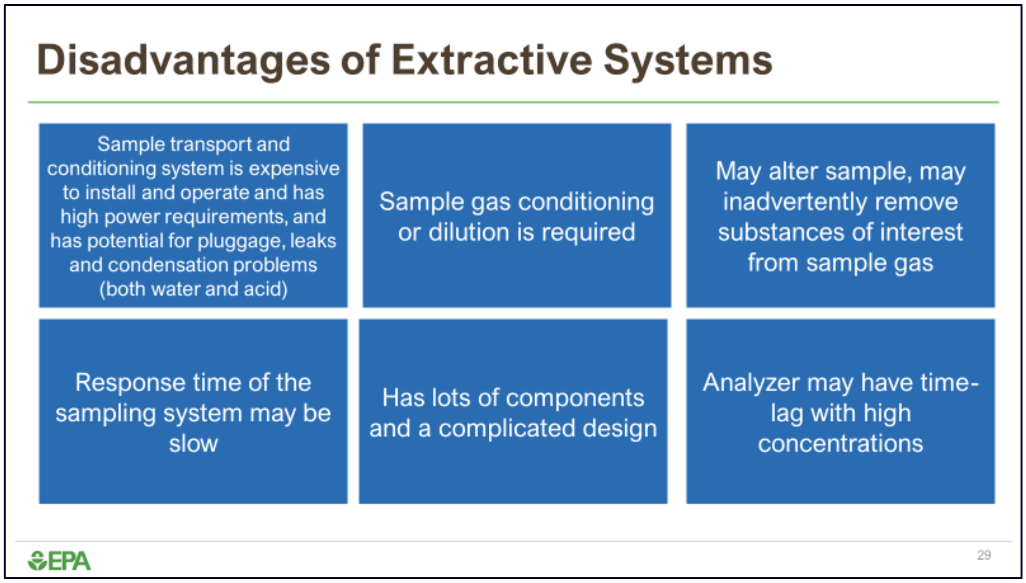


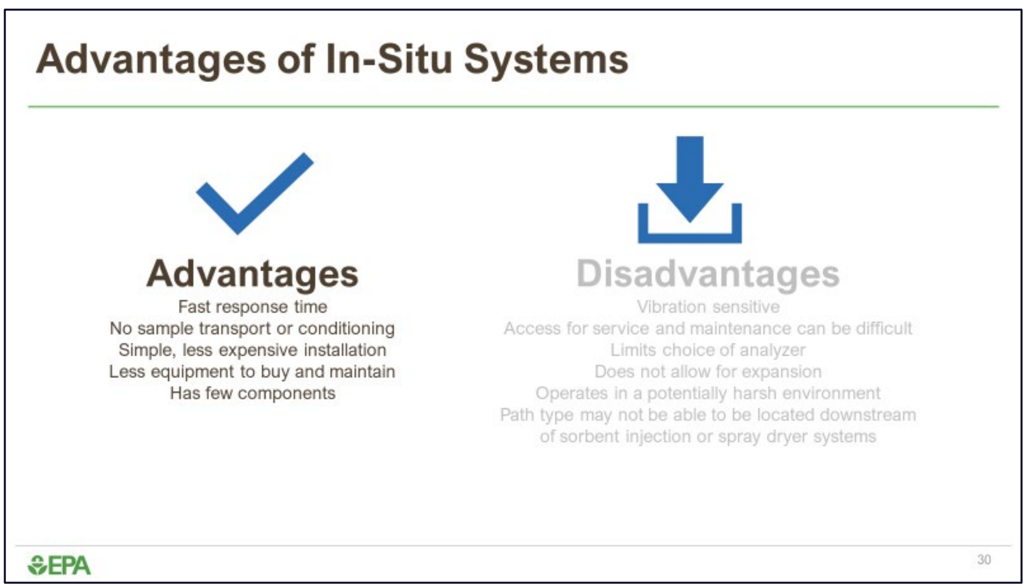
EPA 27

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

EPA 28


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
EPA
29


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
EPA
30

Disadvantages 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

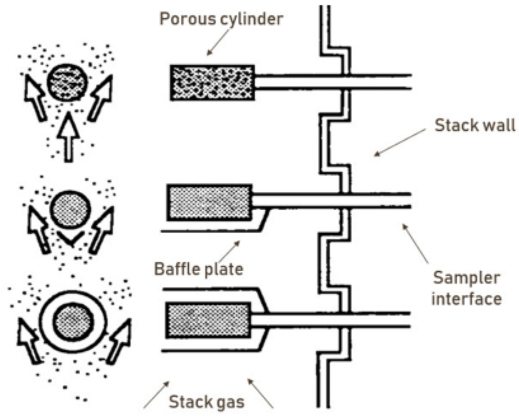
Vibration sensitive
Access for service and maintenance can be difficult
Limits choice of analyzer
Does not allow for expansion
Operates in a potentially harsh environment
Path type may not be able to be located downstream of sorbent injection or spray dryer systems

EPA 31

CEMS Components

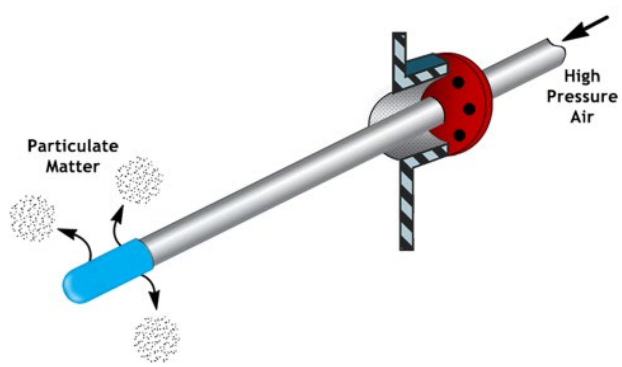
EPA 32

External Probe Filters



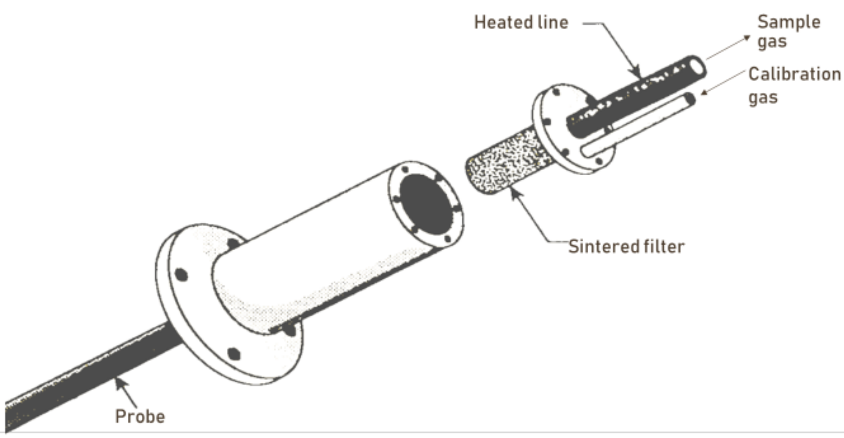
33

Filter Blow Back



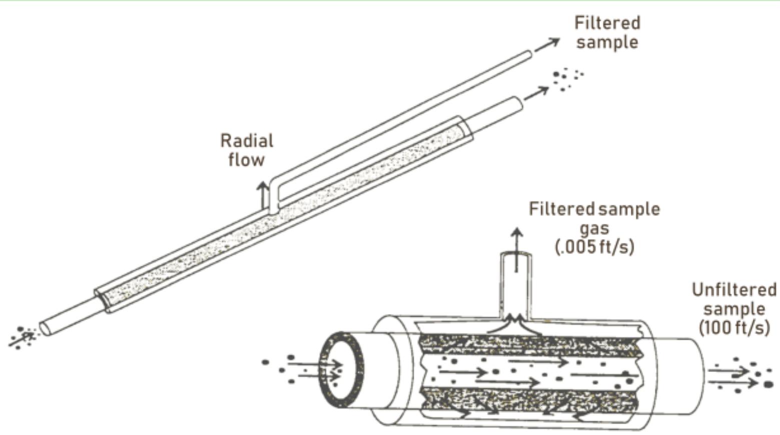
34

Internal Course Filter

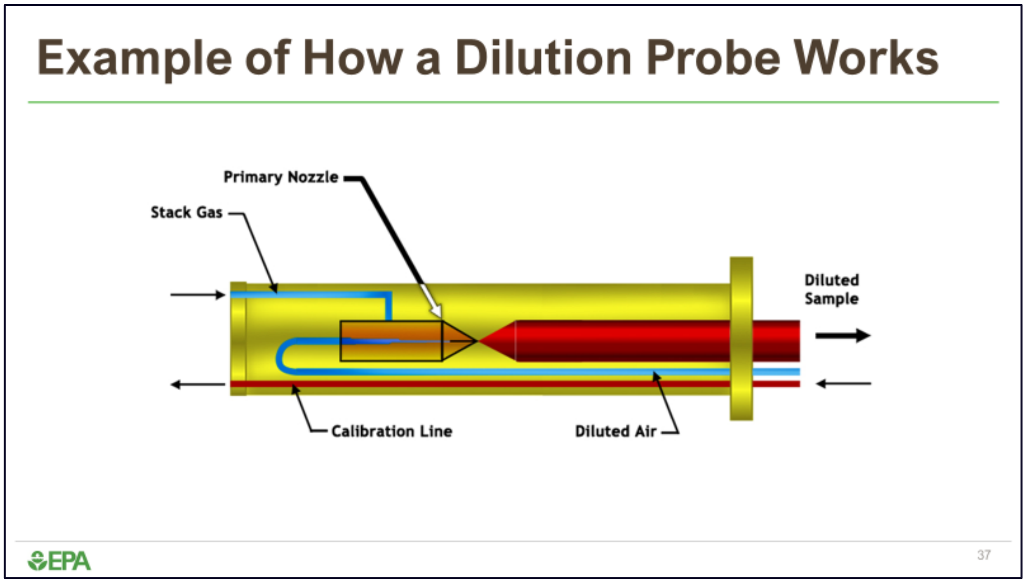


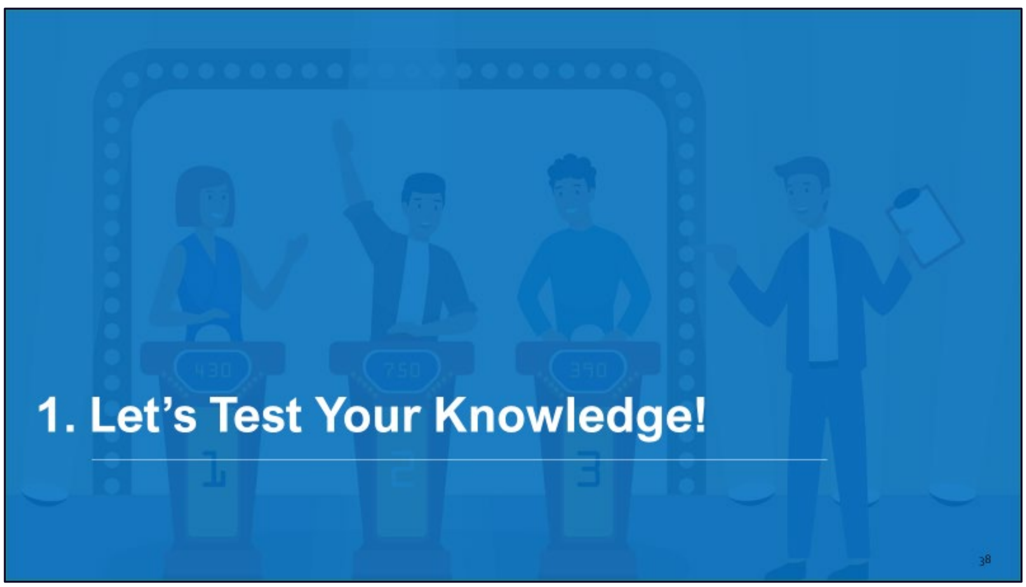
EPA 35

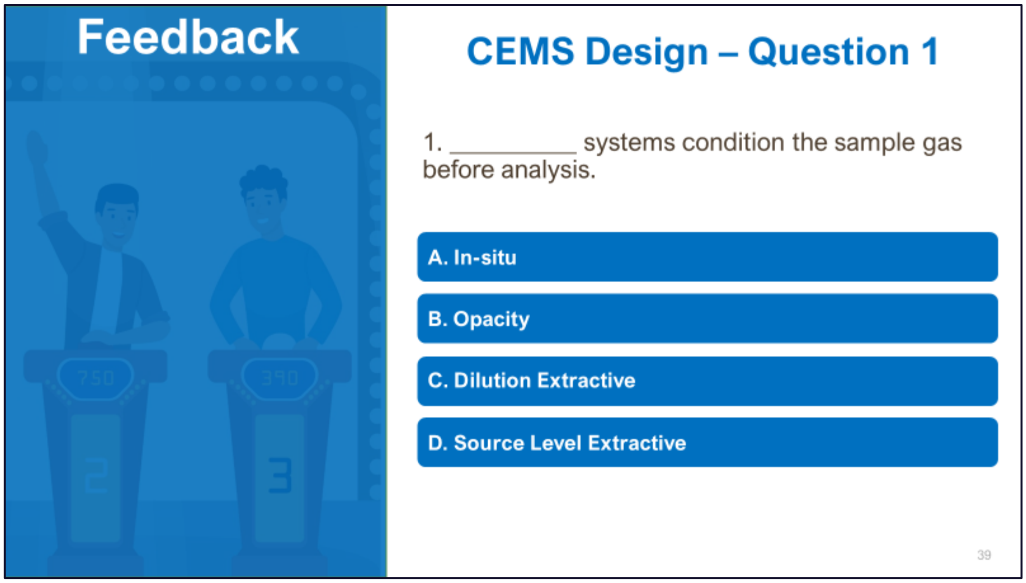
Inertial Filter

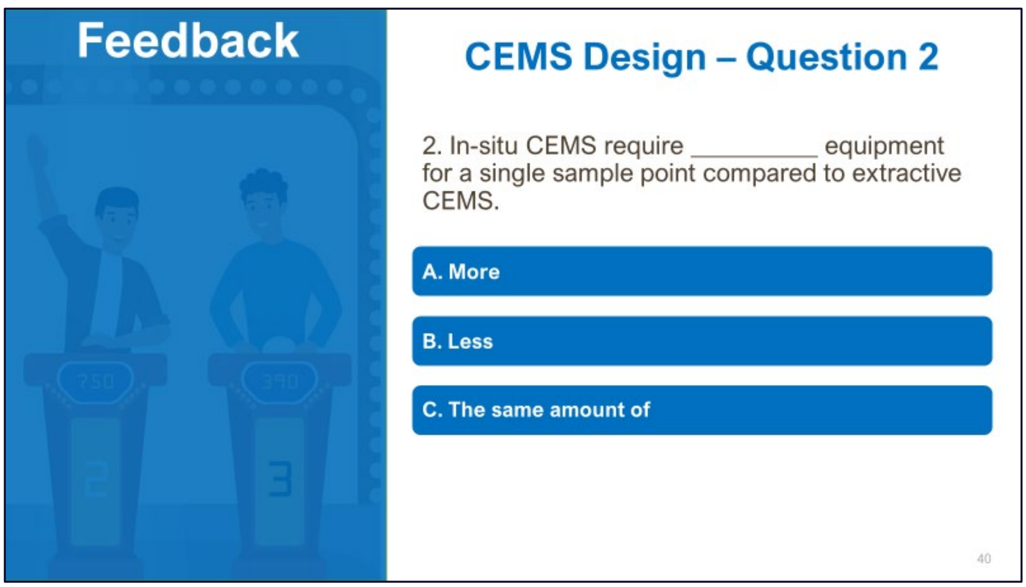


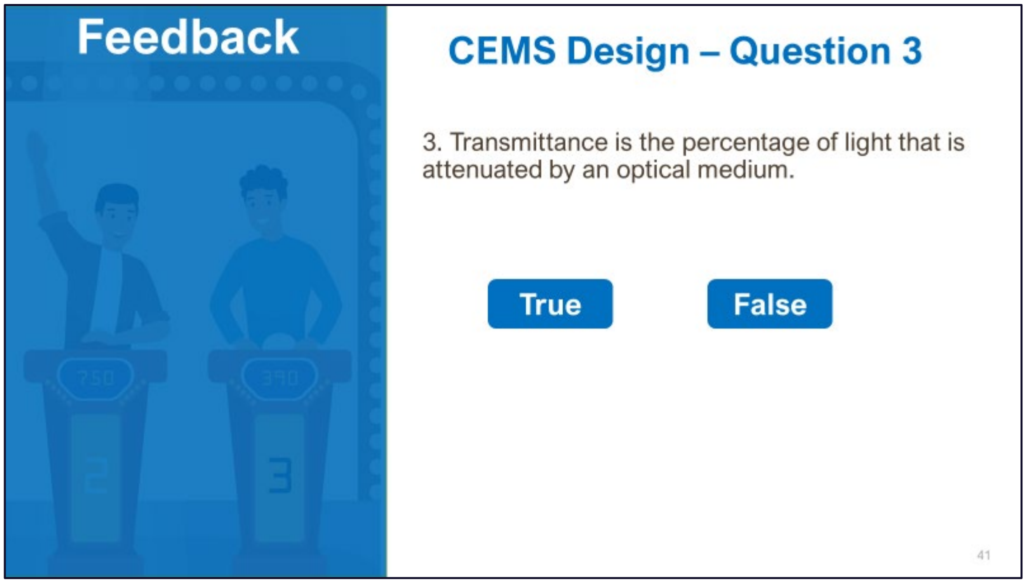
EPA 36


Example of How a Dilution Probe Works
Primary Nozzle
Stack Gas
Diluted Sample
Calibration Line
Diluted Air
EPA
37


1. Let's Test Your Knowledge!
38


Feedback
CEMS Design – Question 1
1. _________ systems condition the sample gas before analysis.
A. In-situ
B. Opacity
C. Dilution Extractive
D. Source Level Extractive
39


Feedback
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
40


Feedback
CEMS Design – Question 3
3. Transmittance is the percentage of light that is attenuated by an optical medium.
True
False
41


CEMS that Include a Flow Monitor (Continuous Emission Rate Monitoring Systems or CERMS)
EPA
42

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.

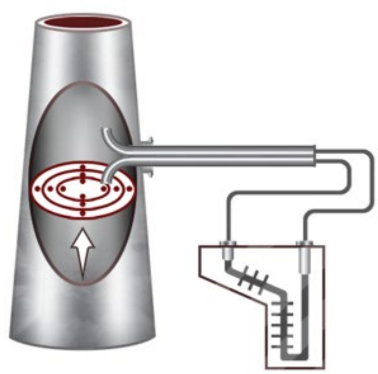
Pollutant Mass Emission Rate (PMER) = $C_S A_S V_S$

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

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

EPA 43

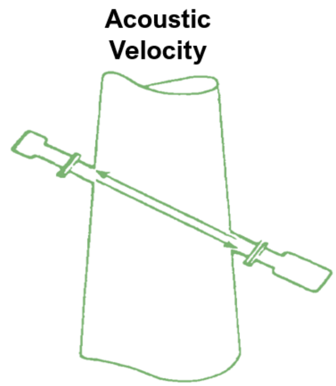
Differential Pressure Measuring



EPA 44

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.



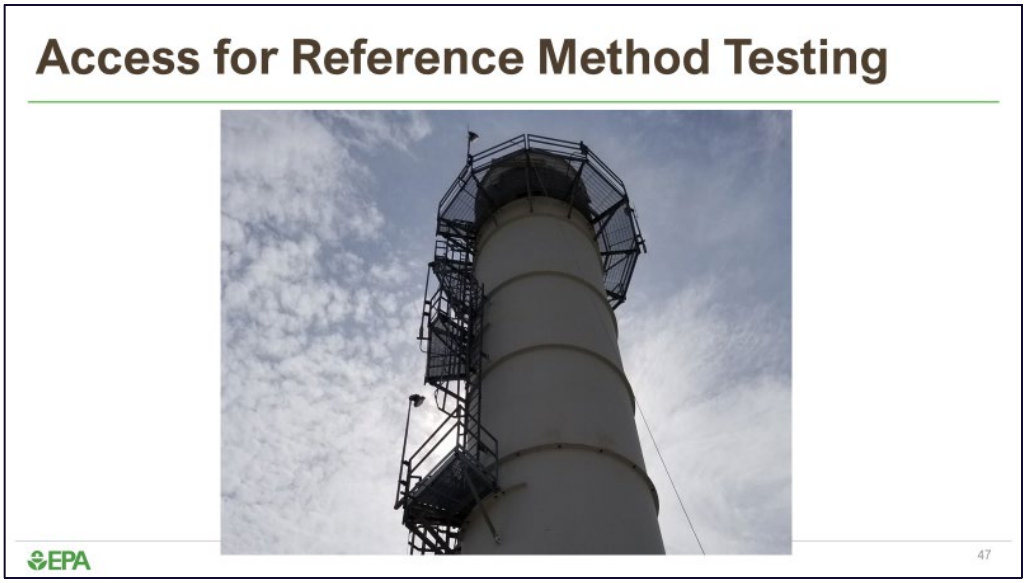
EPA 45

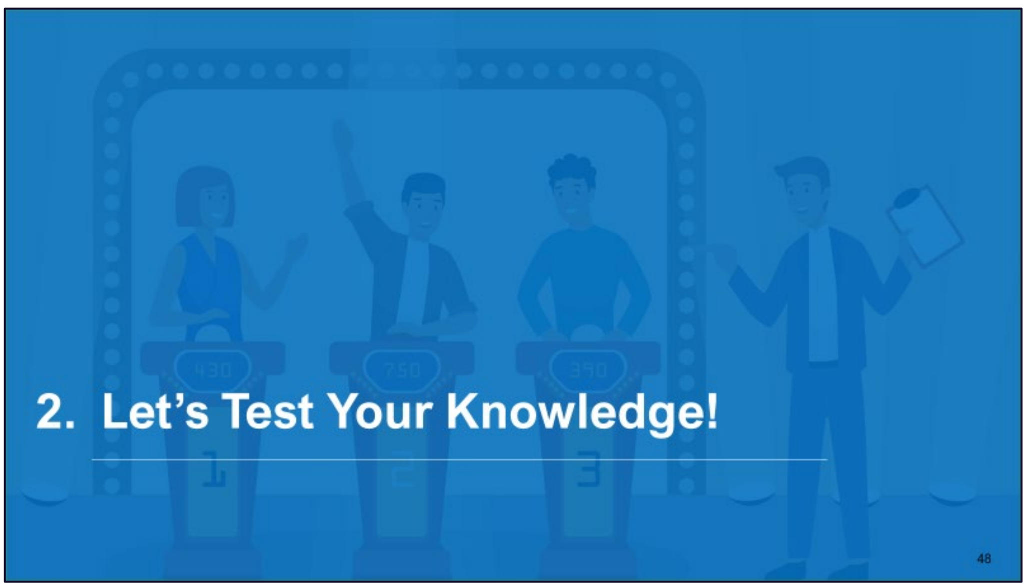
Considerations When Choosing a Location for CEMS

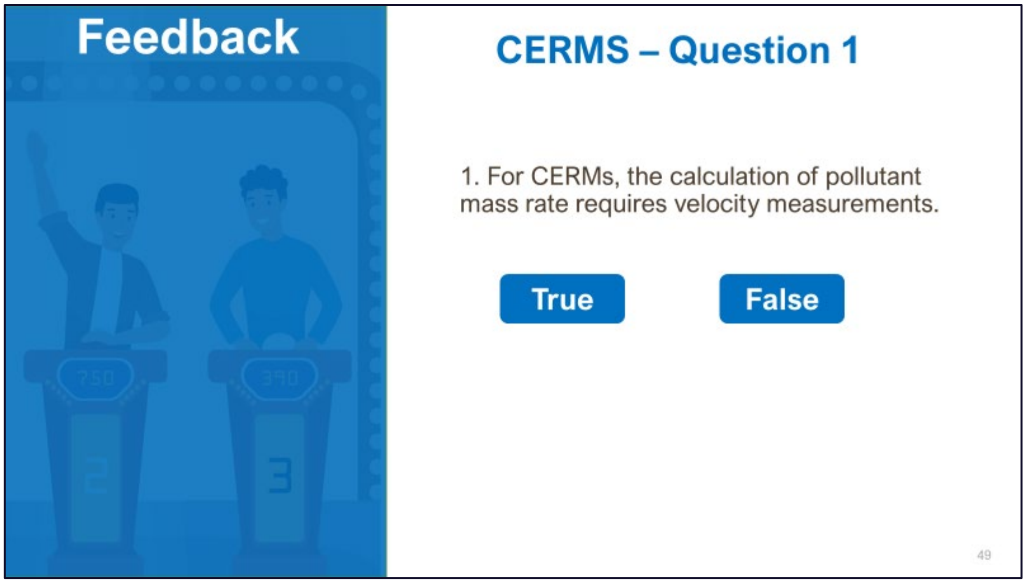
- Representative Emissions (well-mixed and laminar flow)
- Accessibility for routine maintenance and repairs and performance of calibration audits and checks
- Sufficient distance from flow disturbances, such as bends from changes in stack/duct diameter, and control equipment
- Protection from weather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

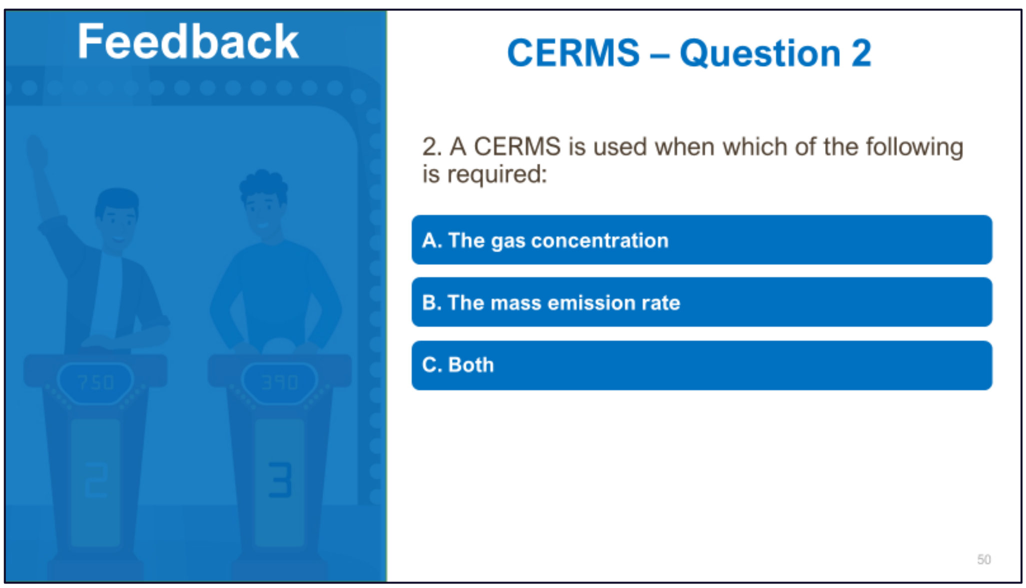
For specific requirements, see applicable performance specification.

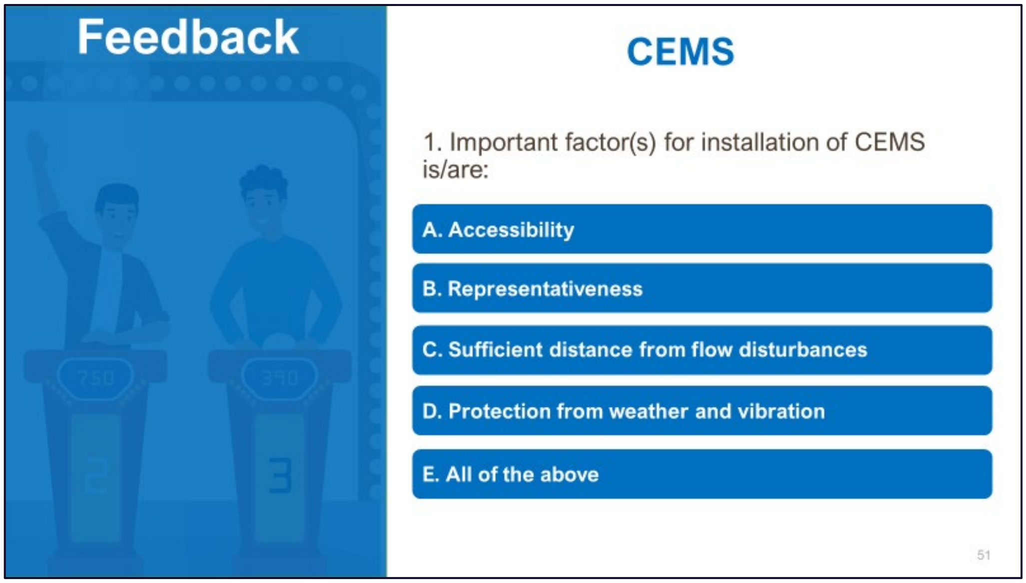
EPA 46


Access for Reference Method Testing
EPA
47


2. Let's Test Your Knowledge!
48


Feedback
CERMS – Question 1
1. For CERMs, the calculation of pollutant mass rate requires velocity measurements.
True
False
49


Feedback
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
50


Feedback
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
51


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
52

Activity Debrief

53

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

EPA 54

MODULE 3: PERFORMANCE SPECIFICATIONS, QUALITY ASSURANCE, AND COMMONLY USED TECHNOLOGIES

Module 3: Performance Specifications, Quality Assurance, and Commonly Used Technologies

Module 3 Description:

In Module 3, participants will be provided an overview of performance specifications (PS) used for evaluating the acceptability of continuous monitoring systems (CMS) at the time of, or soon after, installation and wherever specified in the regulation. They will also learn about the associated quality assurance (QA) procedures, detailed information about each PS, and commonly used technologies.

Module 3 Objectives:

- Define key terms, such as calibration drift (CD), relative accuracy (RA), span value, etc.
- Compare performance specification (PS) and quality assurance (QA) procedures by pollutant, where relevant
- List relevant QA procedures by PS
- Provide examples of technologies that can be used for each PS
- Recognize why predictive emission monitoring systems (PEMS) PS are different from others

Module 3: Performance Specifications, Quality Assurance, and Commonly Used Technologies

Module 3 Outline

1. Overview of Performance Specifications (PS) and Quality Assurance (QA) Procedures
2. Detailed Information for Each PS
3. Detailed information for each Associated QA Procedure
4. Commonly Used Technologies

EPA 2

Module 3 Learning Objectives

At the end of Module 3, learners will be able to:

- Define key terms, such as calibration drift (CD), relative accuracy (RA), span value, etc.
- Compare performance specification (PS) and quality assurance (QA) procedures by pollutant, where relevant
- List relevant QA procedures by PS
- Provide examples of technologies that can be used for each PS
- Recognize why predictive emission monitoring systems (PEMS) PS are different from others

EPA 3

Introduction to Performance Specifications

Performance specifications are used for evaluating the acceptability of continuous monitoring systems (CMS) at the time of, or soon after, installation and whenever specified in the regulations

Performance specifications are published in the Code of Federal Regulations (CFR), under Title 40 CFR Appendix B to Part 60

There are a total of 18 performance specifications. Most, but not all are pollutant specific

For those performance specifications that are pollutant-specific, this module covers commonly used technologies for analysis as well as QA

EPA 4

Introduction to Performance Specifications (Cont'd)

Performance specifications are **not** designed to evaluate the installed CMS performance over an extended period of time.

Ongoing QA requirements are covered under 40 CFR Part 60, Appendix F.

The source owner or operator is responsible for calibrating, maintaining, and operating the CMS properly.

It should be noted that in many cases, the definitions, installation, and measurement location specifications, calculations and data analysis, and reference for the PS are the same as in PS-2, which we provide details for later in this presentation.

If these details differ, specific details will be provided for the relevant PS.

EPA 5

Introduction to Quality Control and Quality Assurance

1. Quality Control

- Quality control (QC) is the procedures, policies, and corrective actions necessary to ensure product quality.

2. Quality Assurance

- Quality assurance (QA) procedures are used to evaluate the effectiveness of QC and the quality of data produced by any CEMS that are used for determining compliance with the emission standards on a continuous basis as specified in the applicable regulation.
- These procedures are pollutant-specific and published in Appendix F of 40 CFR 60.

EPA 6

Technology Neutral

- The majority of the performance specification and QA procedures do not specify the use of a specific measurement technology or are technology neutral.
- This means that any sampling system using any technology that can, after being installed at the sampling location, pass the requirements of the PS and QA procedures is acceptable.

EPA 7

To Be Covered….

PS	Pollutants Covered	QA Procedure
PS-1	Opacity – Continuous Opacity Monitoring Systems (COMS)	Procedure 3
PS-2	Sulfur Dioxide (SO_2) and Oxides of Nitrogen (NO_X)	Procedure 1
PS-3	Oxygen (O_2) and Carbon Dioxide (CO_2)	Procedure 1
PS-4, 4A and 4B	Carbon Monoxide (CO) for PS-4 and 4A; and CO and O_2 for PS-4B	Procedure 1
PS-5	Total Reduced Sulfur (TRS)	
PS-6	Flow Rate – Continuous Emission Rate Monitoring Systems (CERMS)	
PS-7	Hydrogen Sulfide (H_2S)	
PS-8	Volatile Organic Carbon (VOC)	
PS-8A	Total Hydrocarbons (THC)	
PS-9	Gas Chromatography (GC)	
PS-11	Particulate Matter (PM)	Procedure 2
PS-12A and 12B	Mercury (Hg)	Procedure 5
PS-15	Fourier Transform Infrared (FTIR)	
PS-16	PEMS	
PS-18	Hydrogen Chloride (HCl)	Procedure 6

EPA 8

Setting the Stage: Commonly Used Terms

Centroid Area

- Centroid area is a concentric area that is geometrically similar to the stack or duct cross section and is no greater than 1% of the stack or duct cross-sectional area.

Measurement Range

- Measurement range is the full range of values that an analyzer is capable of measuring.

Span Value

- Span values is the calibration portion of the measurement range as specified in the applicable regulation or other requirement.

EPA 9

Setting the Stage: Calibration Error and Calibration Drift

Calibration Error

- Calibration error (CE) is the difference between the concentration indicated by the CEMS and the known concentration generated by a calibration source when the entire CEMS (including the sampling interface) is challenged; CE test is performed to document the accuracy and linearity of the CEMS over the entire measurement range.

Calibration Drift

- Calibration drift (CD) is the difference in the CEMS output readings from the established reference value after a stated period of operation during which no unscheduled maintenance, repair, or adjustment took place.

EPA 10

Setting the Stage: Response Time and Out-of-Control

Response Time

- Response time is the time interval between the start of a step change in the system input and when the pollutant analyzer output reaches 95% of the final value.

Out-of-Control

- An out-of-control (OOC) period occurs when a CEMS fails to meet the performance requirements. During an OOC period the data generated may not be used.

EPA 11

Quality Assurance Procedure Audits

Audit procedures are critical for verifying proper performance of the monitoring systems and identifying problems which may lead to inaccurate emissions accounting.

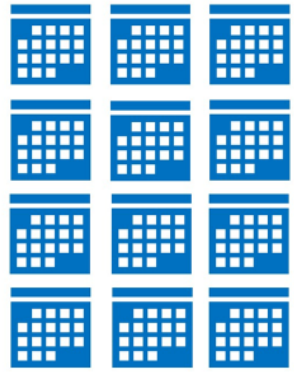
There are four main types of audits discussed in QA procedures:

Relative Accuracy Test Audit (RATA)	Cylinder Gas Audit (CGA)
Calibration Drift Assessment	Relative Accuracy Audit (RAA)

EPA 12

What is a Relative Accuracy Test Audit?

- The **ANNUAL** comparative evaluation of the CEMS performance using a RM
- Consists of:
  - 9 or more RM test runs
  - Usually 21 minutes in duration



EPA 13

What is a Cylinder Gas Audit?

- Usually performed **QUARTERLY** – in three of four quarters, annually
  - With RATA conducted in the fourth quarter
- Gases needed and methodology used are found in applicable QA procedure
- Audit gases must be certified by or traceable to National Institute of Standards and Technology (NIST)

EPA 14

What is a Calibration Drift Assessment?

- The **DAILY** check of the difference in the CEMS readings from a known value, usually a calibration gas
- Performed to demonstrate the stability of the CEMS calibration – how does it fluctuate over time?
- Initial certification usually requires a 7-day drift test
- Daily drift test required for ongoing operation

EPA 15

What is a Relative Accuracy Audit?

- An alternative **QUARTERLY** audit procedure which correlates the CEMS data to simultaneously collected RM data
- Performed like a RATA, but only requires three RM test runs
- Not used very often, but is an option

EPA 16

Performance Specification 1 (PS-1)

Specifications and Test Procedures for Continuous Opacity Monitoring Systems (COMS) in Stationary Sources

EPA 17

PS-1 Requirements

- PS-1 contains requirements for:
  - Manufacturers
  - Owners/operators
    - Installation
    - Performance test requirements

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EPA 18

Requirements for Manufacturers

Opacity manufacturers must comply with a comprehensive series of design and performance specifications and test procedures to certify opacity monitoring equipment before shipment to the end user.

EPA 19

Requirements for Owners/Operators: Installation

Install COMS at a location where the opacity measurements are representative of the total emissions from the affected source:

- 4 duct diameters downstream from any disturbance
- 2 duct diameters upstream from any disturbance
- Condensed H_2O vapor is not present

NOTE: Additionally, installed COMS must be accessible for maintenance.

EPA 20

Requirements for Owners/Operators: Performance Tests

Calibration Error Check

- A three-point CE check
- Criteria: <3% opacity

Optical Alignment Assessment

- Verify and record that all alignment indicator devices show proper alignment
- Criteria: Is it aligned?

EPA 21

Requirements for Owners/Operators: Performance Tests (Cont'd)

System Response Time

- Measure the amount of time needed for a 95% step change in the COMS data recorder
- Criteria: $\leq$10 sec

Averaging Period Calculation and Recording Check

- Following the CE check, conduct a check of the averaging period calculation and recording
- Criteria:
  - Averaging period check $\pm$ 2% opacity
  - Data recorder: resolution $\leq$ 0.5% opacity

EPA 22

Operational Test Period

- Total time of 168 hours (7-day drift test) at normal operation
  - Includes shut-downs, if normal occurrences, but total operating time during the test must be 168 hours
  - Batch cycles must include at least one full batch cycle

EPA 23

Procedure 3 – Quality Assurance Requirements for Continuous Opacity Monitoring Systems at Stationary Sources

What are the basic functions of Procedure 3?

- Assessment of the quality of your COMS data
- Control and improvement of the quality of your COMS data by implementing QC requirements and corrective actions

- Requires:
  - Daily instrument drift checks
  - Status indicator checks
  - Quarterly performance audits
    - Optical alignment
    - CE
    - Zero compensation
  - Annual zero alignment

EPA 24

Procedure 3 - Limitations

Opacity cannot be measured accurately in the presence of condensed water vapor. Thus, COMS opacity compliance determinations cannot be made when condensed water vapor is present, such as downstream of a wet scrubber without a reheater or at other saturated flue gas locations.

EPA 25

Procedure 3 – Required Quality Control Program

- A QC program must, at a minimum, include written procedures which describe in detail complete step-by-step procedures and operations for these activities:
  - Performing drift checks,
  - Performing quarterly performance audits,
  - Checking the zero alignment of the COMS, and
  - Corrective action for a malfunctioning COMS.
- It is required to keep the QA/QC written procedures on site and available for inspection by Federal, state, and/or local enforcement agencies.

EPA 26

Procedure 3 – Auditing Requirements

Daily
- Zero and upscale drift check
- Check of status indicators, data acquisition system error messages, and other system self-diagnostic indicators

Quarterly
- Three-point CE test

Annual
- Optical and zero alignment check

EPA 27

Procedure 3 – Limits for Excessive Inaccuracy

Excessive zero or upscale drift

- Your COMS is out-of-control if either the zero drift check or upscale drift check exceeds twice the applicable drift specification in PS-1 for any one day.

Excessive zero alignment

- Your COMS is out-of-control if the zero alignment error exceeds 2 percent opacity.

Quarterly performance audit

- Your COMS is out-of-control if the results of a quarterly performance audit indicate noncompliance with the following criteria:
  - The optical alignment indicator does not show proper alignment,
  - The zero compensation exceeds 4 percent opacity, or
  - The calibration error exceeds 3 percent opacity.

Note: You must adhere to the data capture criterion specified in the applicable subpart.

EPA 28

Procedure 3 – Corrective Actions

A corrective action program must be in place to address the repair and/or maintenance of your COMS. The corrective action program must:

- Address routine/preventative maintenance and various types of analyzer repairs, and
- Establish what diagnostic testing must be performed to ensure that the COMS is collecting valid, quality-assured data.

NOTE: Recommended maintenance and repair procedures and diagnostic testing after repairs may be found in an associated guidance document.

https://www3.epa.gov/ttn/emc/perfspec/suggested_COMS_diagnostic_tests.pdf

EPA 29

Opacity Transceiver

EPA 30

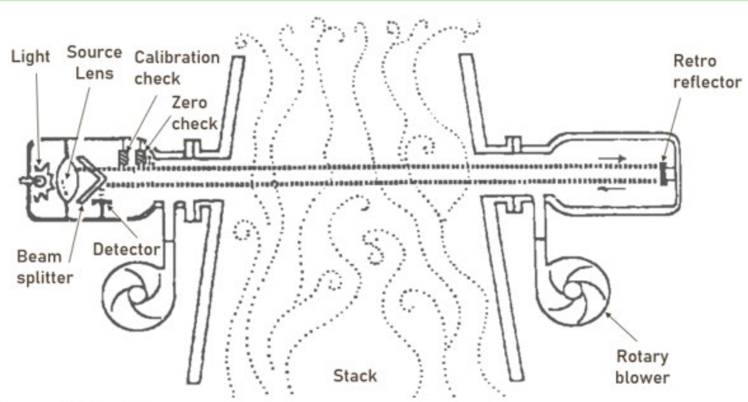
Commonly Used Technology - Transmissometry

Transmissometry

- The measurement of the amount of light that can be transmitted through a stack exhaust.
  - The intensity of the light is attenuated by scattering and absorption by PM in the stack exhaust.
  - The amount of attenuation is measured as percent opacity, and is a function of the amount, type, and distribution of PM in the stack gas.

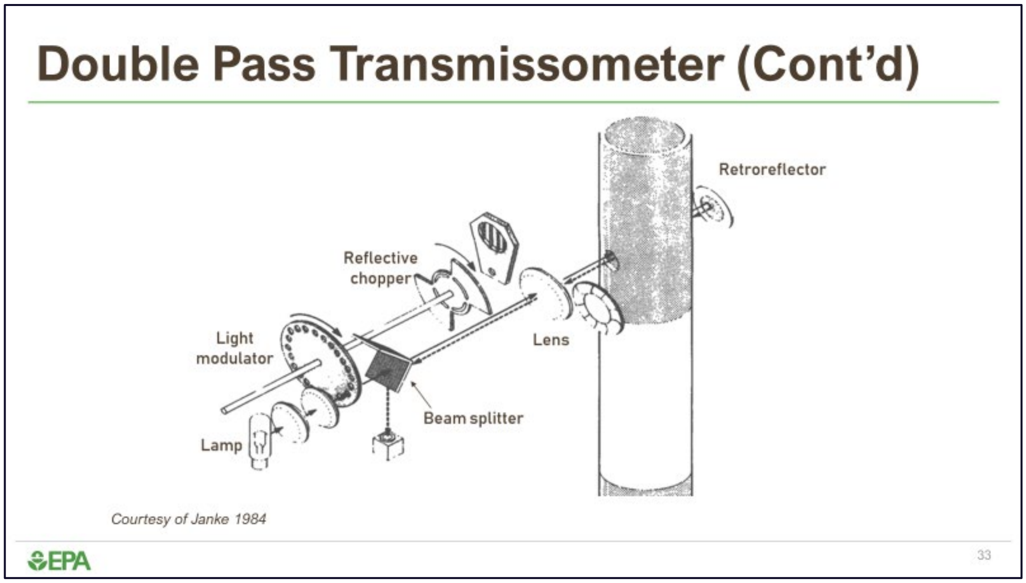
EPA 31

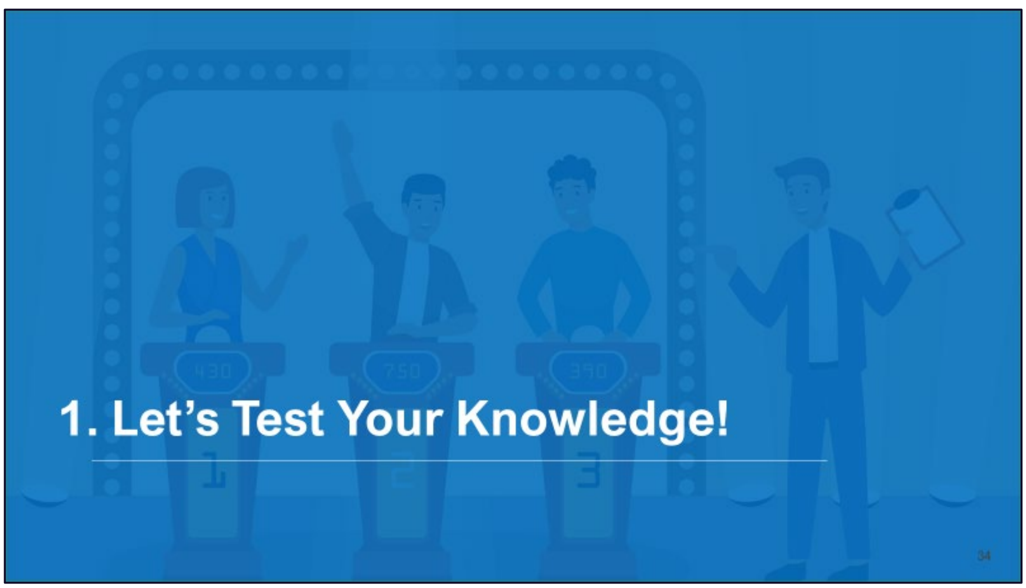
Double Pass Transmissometer



Courtesy of Janke 1979

EPA 32


Double Pass Transmissometer (Cont'd)
Retroreflector
Reflective chopper
Light modulator
Lens
Beam splitter
Lamp
Courtesy of Janke 1984
EPA
33


1. Let's Test Your Knowledge!
34

Feedback

PS-1 and Procedure 3

1. What are the requirements of the CD test under PS-1?

Check Answer

2. How is system response time determined?

Check Answer

3. What is the OOC period for each audit in procedure 3?

Check Answer

4. What are the responsibilities of the opacity monitor manufacturer?

Check Answer

35

Performance Specification 2 (PS-2)

Specifications and Test Procedures for Sulfur Dioxide (SO_2) and Oxides of Nitrogen (NO_X) in Stationary Sources

EPA

36

Overview of PS-2

- Evaluates the acceptability of SO_2 and NO_X CEMS at the time of installation or soon after
  - The CEMS may include, a diluent (O_2 or CO_2) monitor
- Includes installation and measurement specifications as well as requirements for:
  - 7-day CD test
  - RATA

NOTE: PS-2 serves as the framework for most other performance specifications.

Image courtesy of Thermo Fisher Scientific™

EPA 37

CEMS Installation and Measurement Location Specifications

- Must be accessible and representative.
- At least two equivalent diameters downstream and one-half an equivalent diameters upstream from any flow disturbance
- Not required that RM sampling location to be the same as CEMS location

EPA 38

Calibration Drift Test

- Determine the magnitude of the CD each day for 7 consecutive calendar days.
- Conducted at the zero and span values.
- Must not deviate from the reference value by more than 2.5% of the span value

EPA 39

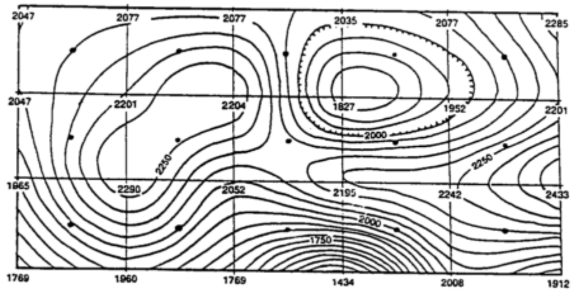
Relative Accuracy Test Audit

- Conduct the RATA while the facility is operating at more than 50% of normal load.
- Evaluate system performance by comparing to independent RM
- Select appropriate sampling location.
- To determine in stratification is present:
  - Use 9 sample points in the cross section, for rectangular ducts.
  - Use 12-point traverse, for circular ducts.

EPA 40

Determining if Stratification Exists

- Calculate the mean value of all the sample points
- Find the difference between the mean value and each individual sample value
  - If the mean pollutant concentration is more than 10% different from any single sample point, then stratification exists
    - Must use the points located at 16.7, 50.0, and 83.3 % of the entire measurement line
- Conduct all necessary RM tests within 3 cm (1.2 in.) of the traverse points, but no closer than 3 cm (1.2 in.) to the stack or duct wall



EPA 41

Reference Method Traverse Points Minimum Requirements

Establish a measurement line through the stack centroid that includes three traverse points at:

- 16.7,
- 50.0, and
- 83.3% of the duct/stack diameter

If a measurement line is longer than 2.4 m (7.8 ft) and stratification is not expected, then use traverse points at:

- 0.4,
- 1.2, and
- 2m from stack/duct wall for the traverse points.

Note: This option cannot be used with a wet scrubber or at points where two streams with different pollutant concentrations combine.

EPA 42

Relative Accuracy Test Audit Procedure

Number of RM Tests:
- Conduct a minimum of nine test runs
- Data from all test runs must be reported, including the rejected runs

Calculate:
- Mean difference between the RM and CEMS values in the units of the emission standard,
- Standard deviation,
- Confidence coefficient, and
- RA according to the procedures in section 12.0.

EPA 43

Relative Accuracy Performance Criteria

	Calculate…	Relative Accuracy Criteria
If average emissions during the RATA are ≥50% of emission standard	Use Eq. 2-6, with RM in the denominator	≤20%
If average emissions during the RATA are <50% of emission standard	Use Eq. 2-6, emission standard in the denominator	≤10%
For SO_2 emission standards ≤ 130 but ≥ 86 ng/J (0.30 and 0.20 lb/million Btu)	Use Eq. 2-6, emission standard in the denominator	≤15%
For SO_2 emission standards <86 ng/J (0.20 lb/million Btu)	Use Eq. 2-6, emission standard in the denominator	≤20%

EPA 44

Procedure 1 – Quality Assurance Requirements for Gas CEMS Used for Compliance Determination

What are the basic functions of Procedure 1?

- Evaluates the effectiveness of QA/QC procedures and the quality of data produced by any CEMS used for determining compliance
- Specifies the minimum QA requirements necessary for the control and assessment of the quality of CEMS data submitted
- Consists of two distinct and equally important functions:
  - The assessment of the quality of the CEMS data by estimating accuracy
  - The control and improvement of the quality of the CEMS data by implementing QC policies and corrective actions

EPA 45

Procedure 1 – Checks/Auditing Requirements

Daily Checks	Quarterly Checks	Annual Checks
• CD at two concentration values – zero and high-level	• CGA – if applicable, may be conducted in three of four calendar quarters, but in no more than three quarters in succession • RAA – may be conducted three of four calendar quarters, but in no more than three quarters in succession • Other Alternative Audits – may be conducted as approved by the administrator for three of four calendar quarters	• RATA – conducted at least once every four calendar quarters except for other alternative audits

EPA 46

Procedure 1 – Performance Criteria

Calibration Drift	Cylinder Gas Audit	Relative Accuracy Test Audit
• Must not exceed twice the applicable drift specification found in Appendix B for five consecutive days, or four times the applicable drift specification in Appendix B (i.e., 2.5%) on any one day. If so, the CEMS is considered OOC	• Must be less than $\pm$ 15% of the average audit value or $\pm$ 5 ppm, whichever is greater, or the CEMS is OOC	• Same as the RA requirement in the applicable PS or the CEMS is OOC

EPA 47

Commonly Used Technologies: Pulsed Fluorescence and Chemiluminescence Analyzer

Pulsed Fluorescence

- Uses the property of SO_2 molecules to absorb ultraviolet (UV) light and become excited at one wavelength, then decay to a lower energy state emitting UV light at a different wavelength, the measured emitted light corresponding to the concentration of SO_2 in the sample gas
  - The pulsing of the UV source lamp allows the analyzer to use both the light and dark phases of the pulsed light to continuously detect and correct for electronic noise, and to measure lower pollutant concentrations.

Chemiluminescence Analyzer

- Uses the light-emitting chemical reaction of NO and analyzer-generated ozone to measure the concentration of the NO in a gas sample. A successive measurement of the NO, plus NO converted from the NO_2 in the sample, gives a total NOx measurement; the difference between the two measurements is equal to the NO_2 concentration in the sample.

EPA 48

SO_2 Analyzer

- Microprocessor control
- SO_2 specific
- Reflective UV filtering
- Hermetically sealed UV lamp
- No consumables

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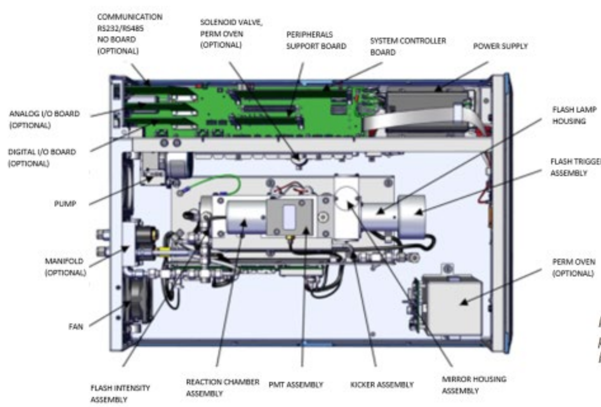
EPA 49

SO_2 Monitor



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EPA 50

Chemiluminescence NOx Analyzer

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EPA 51

How is NO_X Measured?

Chemiluminescence Technique

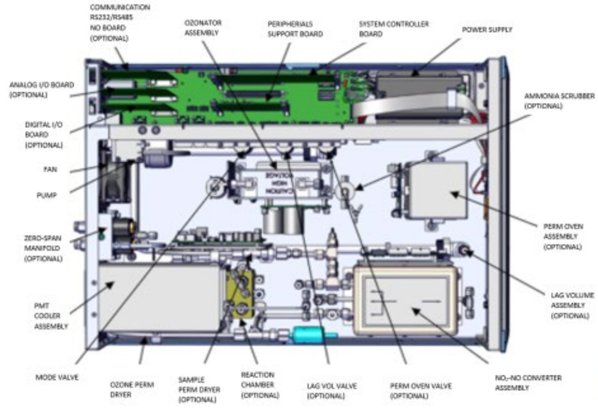
$$NO + O_3 \rightarrow NO_2^* + O_2$$

$$NO_2^* \rightarrow NO_2 + h\nu$$

Intensity of emitted light is proportional to NO concentration

EPA 52

NO_X Monitor



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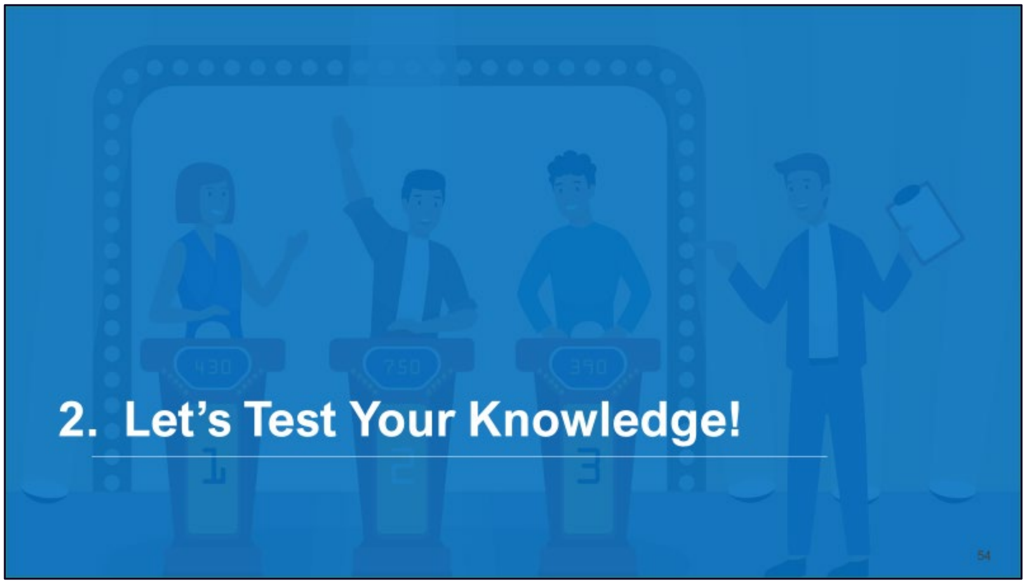
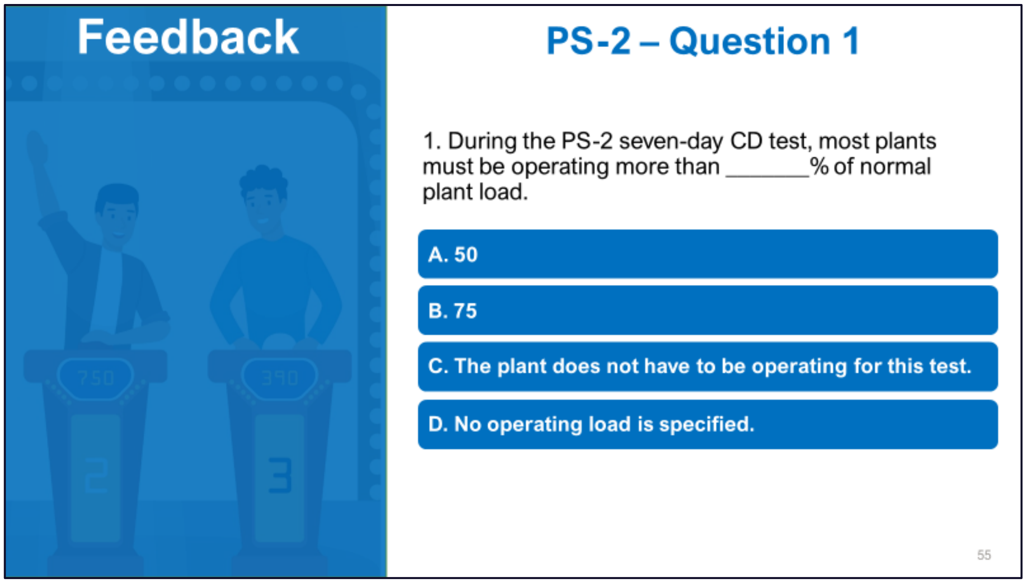
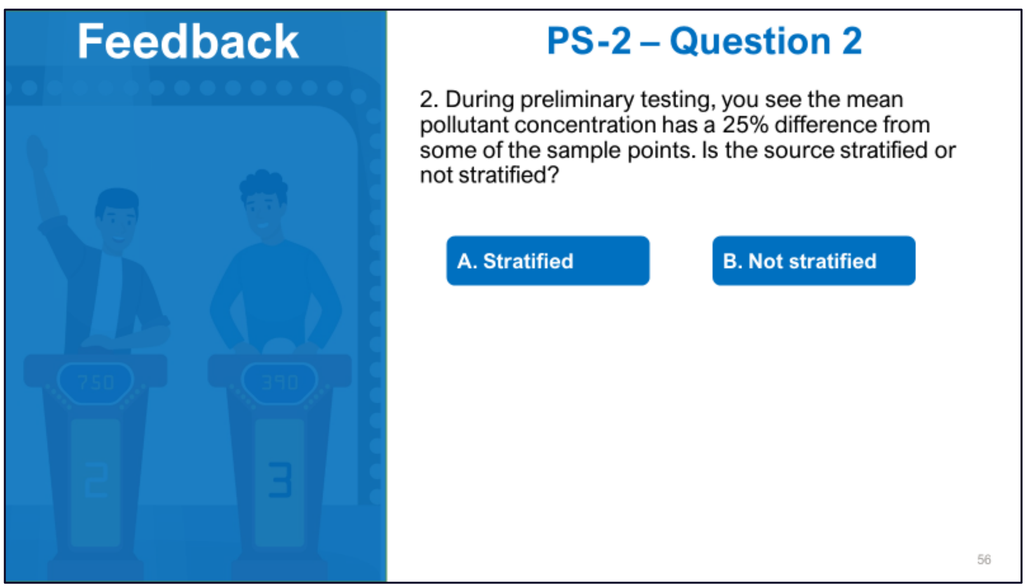
EPA 53

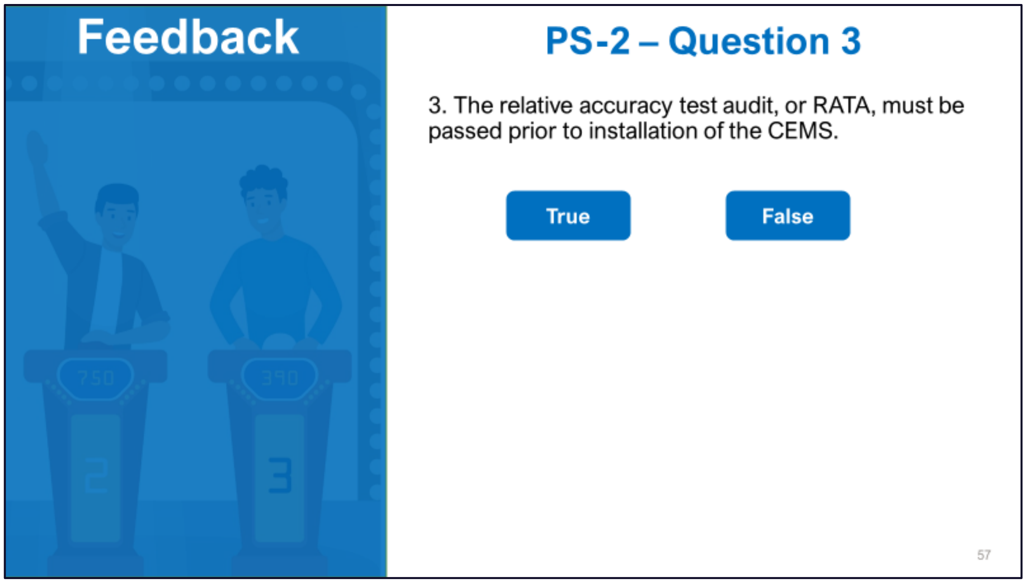


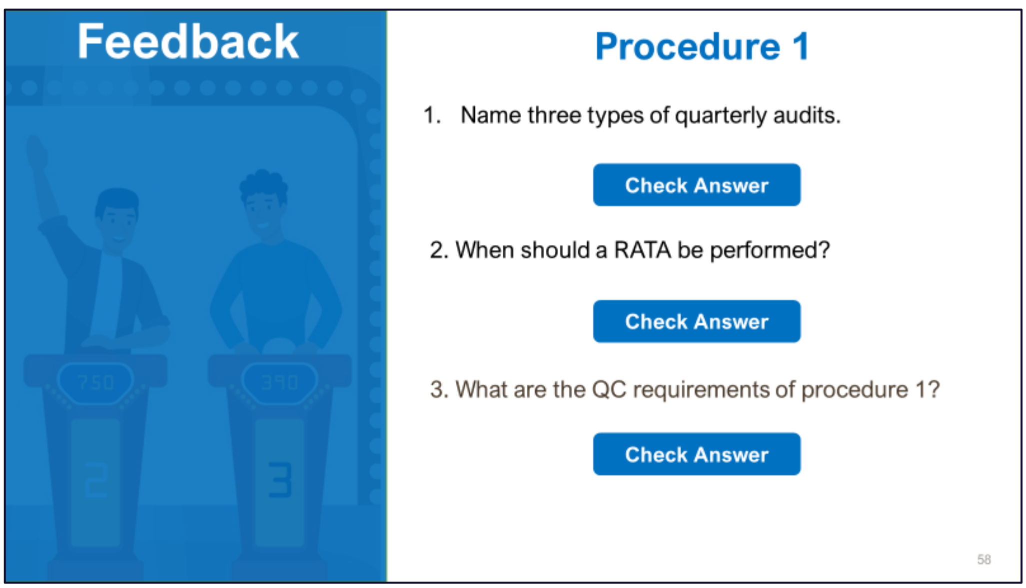
2. Let's Test Your Knowledge!

54


Feedback
PS-2 – Question 1
1. During the PS-2 seven-day CD test, most plants must be operating more than _______% of normal plant load.
A. 50
B. 75
C. The plant does not have to be operating for this test.
D. No operating load is specified.
55


Feedback
PS-2 – Question 2
2. During preliminary testing, you see the mean pollutant concentration has a 25% difference from some of the sample points. Is the source stratified or not stratified?
A. Stratified
B. Not stratified
56


Feedback
PS-2 – Question 3
3. The relative accuracy test audit, or RATA, must be passed prior to installation of the CEMS.
True
False
57


Feedback
Procedure 1
1. Name three types of quarterly audits.
Check Answer
2. When should a RATA be performed?
Check Answer
3. What are the QC requirements of procedure 1?
Check Answer
58

Performance Specification 3 (PS-3)

Specifications and Test Procedures for Oxygen (O_2) and Carbon Dioxide (CO_2) Continuous Emission Monitoring Systems (CEMS) in Stationary Sources

EPA 59

Overview of PS-3

- Evaluating acceptability of O_2 and CO_2 CEMS at the time of installation or soon after and whenever specified in an applicable subpart of the regulations
- Most aspects of this PS are the same as PS-2, with the exception of CD performance criteria and RA performance criteria.

EPA 60

Calibration Drift and Relative Accuracy Performance Criteria – PS-3

Calibration Drift Performance Criteria

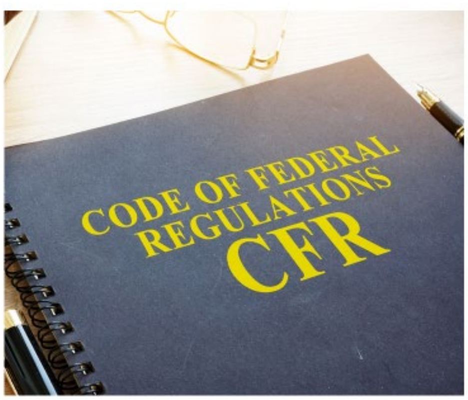
- <0.5% O_2 or CO_2 from the reference value, or the CEMS is considered OOC.

Relative Accuracy Performance Criteria

- $\leq$20% of the mean value of the RM data; or the difference between the RM and plant CEM is less than or equal to 1.0% O_2 (or CO_2)
  - If one of these criteria is not met for the RATA, the CEMS is considered OOC.

EPA 61

Quality Assurance Procedure 1

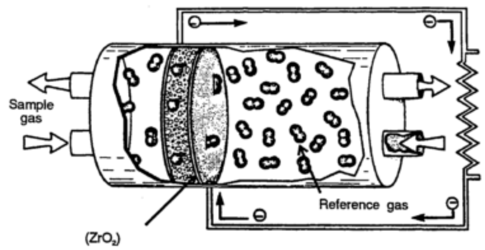


- PS-2, 3, and 4 use QA procedure 1.
- For more information, review slides under PS-2.

EPA 62

Commonly Used Technologies for PS-3

A zirconium oxide O_2 analyzer is an electrochemical cell which is porous to O_2 when heated to high temperature, allowing the O_2 to pass from the high concentration side (reference) to low concentration side (sample) and generating a voltage proportional to the difference in O_2 concentrations.



EPA 63

Commonly Used Technologies for PS-3: O_2 & CO_2 Analyzer

O_2 & CO_2 Analyzer

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EPA 64

Commonly Used Technologies for PS-3: Paramagnetic O_2 Analyzer and Non-Dispersive Infrared

Paramagnetic O_2 Analyzer

- In a paramagnetic O_2 analyzer, a sample gas containing O_2 is drawn into two parallel sample paths, one passing through a magnetic field and one not. The O_2 is attracted into the magnetic field path, with the rest of the sample being split between the two paths, and the difference between the two measured gas flow rates is proportional to the O_2 content of the sample.

Non-Dispersive Infrared

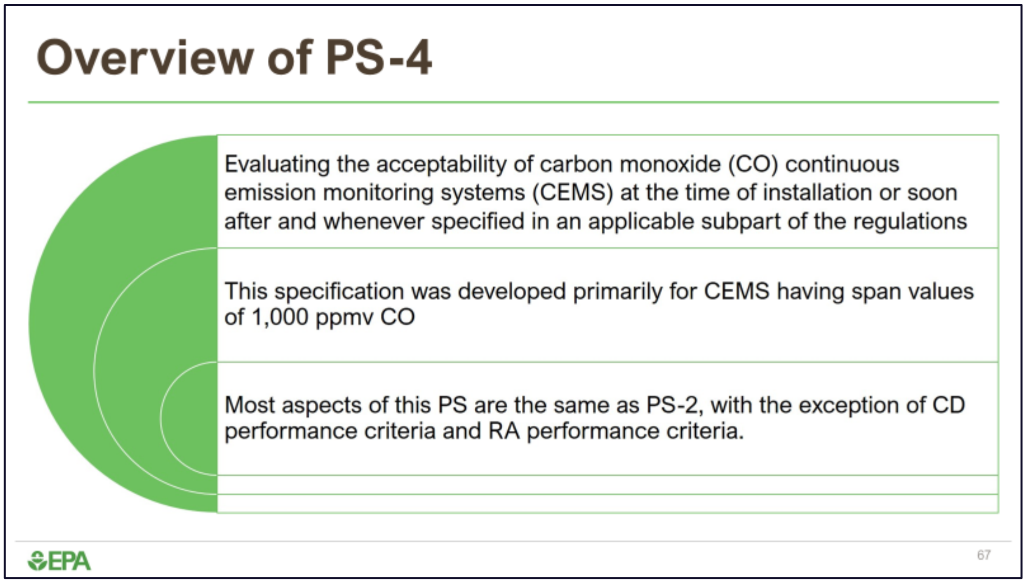
- Non-dispersive infrared (NDIR) is a type of infrared (IR) absorption spectroscopy using parallel sample and reference (non-absorbing) cells.
- It is one of the most commonly used IR methods.
- The IR light is filtered for a specific wavelength that is absorbed by CO_2, and the difference in intensity of that specific IR wavelength after passing through each of the two cells is proportional to the CO_2 concentration in the sample gas.

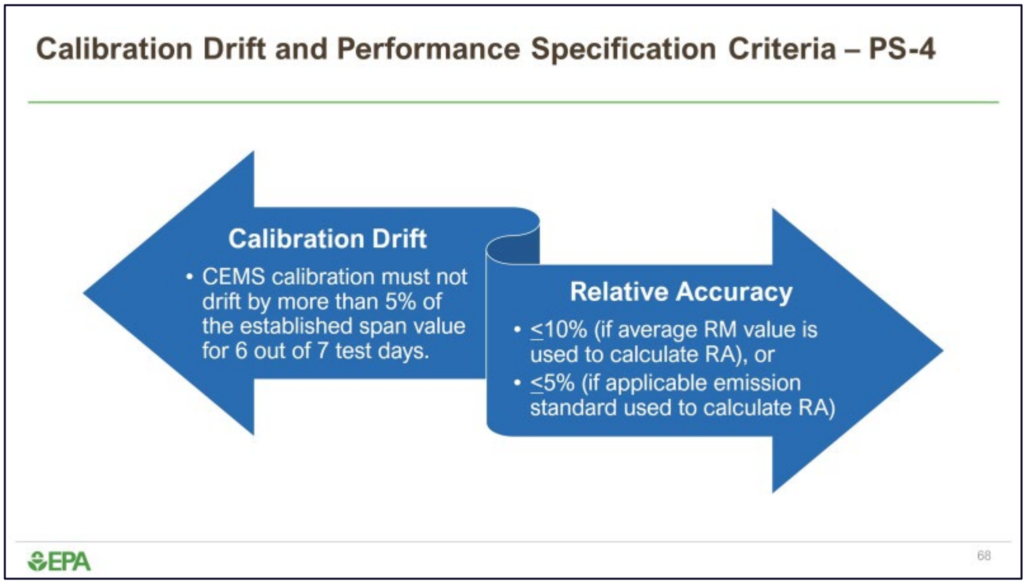
EPA 65

Performance Specification 4 (PS-4)

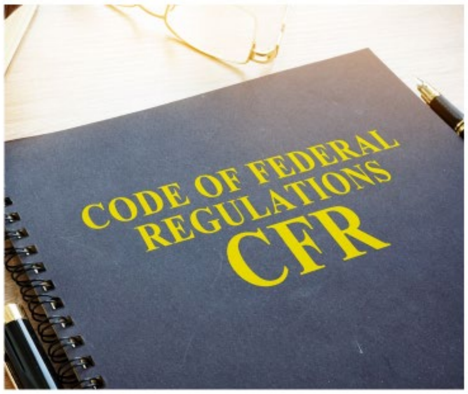
Specifications and Test Procedures for Carbon Monoxide (CO) Continuous Emission Monitoring Systems (CEMS) in Stationary Sources

EPA 66


Overview of PS-4
Evaluating the acceptability of carbon monoxide (CO) continuous emission monitoring systems (CEMS) at the time of installation or soon after and whenever specified in an applicable subpart of the regulations
This specification was developed primarily for CEMS having span values of 1,000 ppmv CO
Most aspects of this PS are the same as PS-2, with the exception of CD performance criteria and RA performance criteria.
EPA
67


Calibration Drift and Performance Specification Criteria – PS-4
Calibration Drift
• CEMS calibration must not drift by more than 5% of the established span value for 6 out of 7 test days.
Relative Accuracy
• ≤10% (if average RM value is used to calculate RA), or
• ≤5% (if applicable emission standard used to calculate RA)
EPA
68

Quality Assurance - Procedure 1

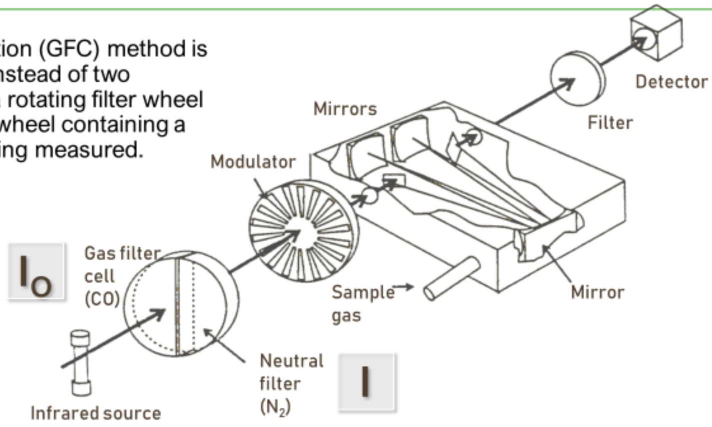


- PS-2, 3, and 4 use QA procedure 1.
- For more information, review slides under PS-2.

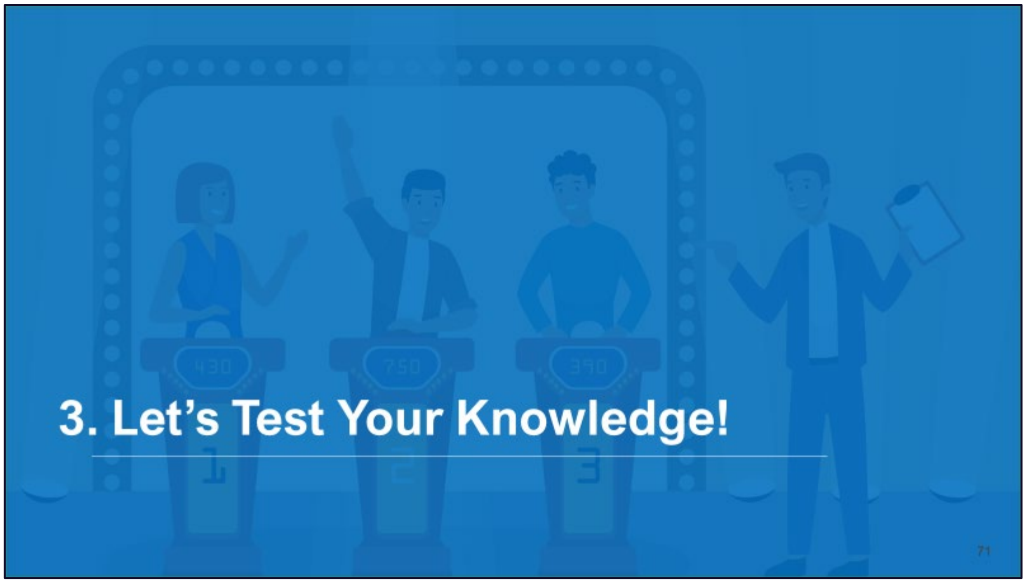
EPA 69

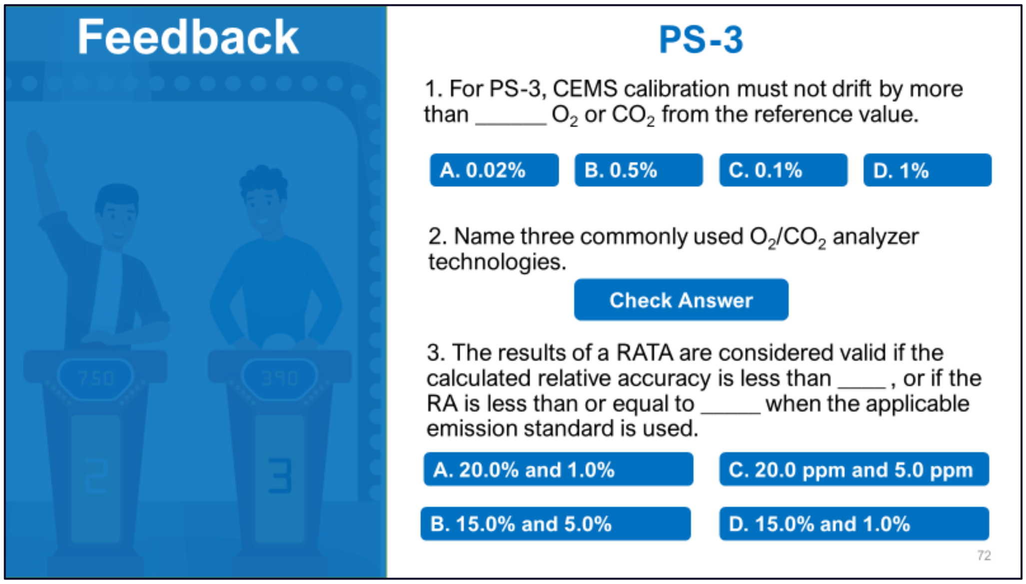
Commonly Used Technology for PS-4

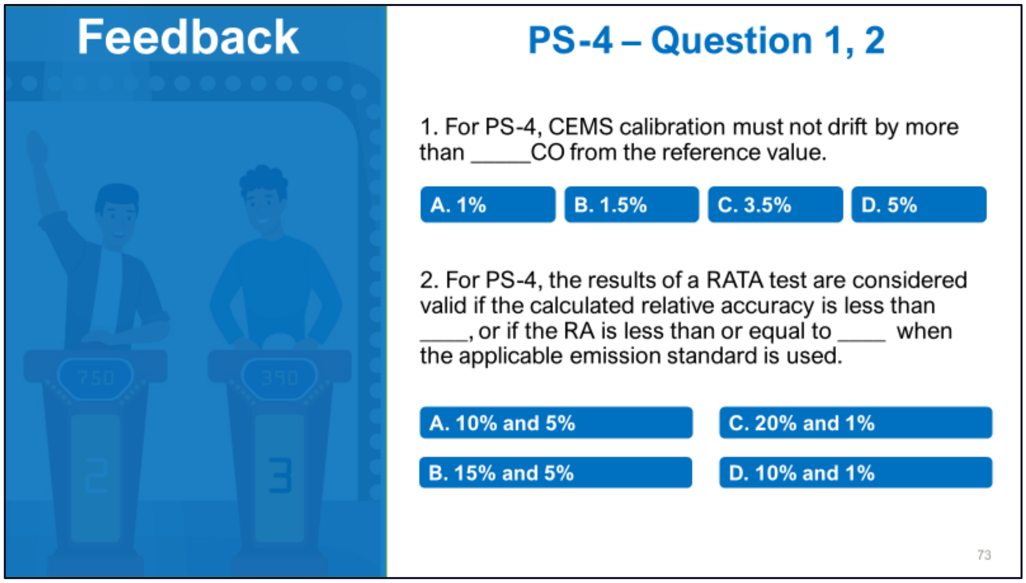
The gas filter correlation (GFC) method is similar to NDIR, but instead of two parallel cells it uses a rotating filter wheel with a section of the wheel containing a sample of the gas being measured.

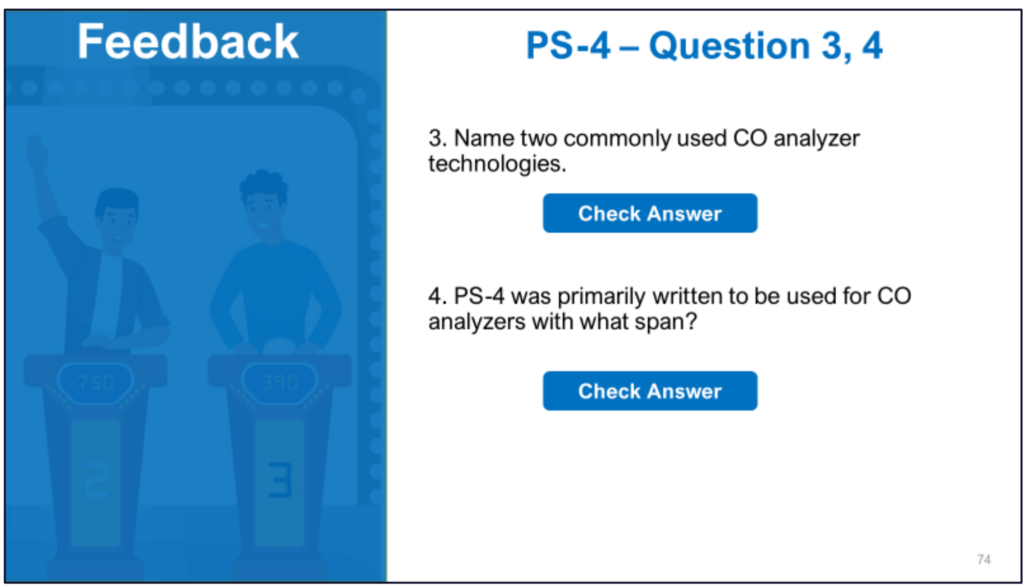


EPA 70


3. Let's Test Your Knowledge!
71


Feedback
PS-3
1. For PS-3, CEMS calibration must not drift by more than ______ O_2 or CO_2 from the reference value.
A. 0.02%
B. 0.5%
C. 0.1%
D. 1%
2. Name three commonly used O_2/CO_2 analyzer technologies.
Check Answer
3. The results of a RATA are considered valid if the calculated relative accuracy is less than ____ , or if the RA is less than or equal to _____ when the applicable emission standard is used.
A. 20.0% and 1.0%
C. 20.0 ppm and 5.0 ppm
B. 15.0% and 5.0%
D. 15.0% and 1.0%
72


Feedback
PS-4 – Question 1, 2
1. For PS-4, CEMS calibration must not drift by more than _____CO from the reference value.
A. 1%
B. 1.5%
C. 3.5%
D. 5%
2. For PS-4, the results of a RATA test are considered valid if the calculated relative accuracy is less than ____, or if the RA is less than or equal to ____ when the applicable emission standard is used.
A. 10% and 5%
C. 20% and 1%
B. 15% and 5%
D. 10% and 1%
73


Feedback
PS-4 – Question 3, 4
3. Name two commonly used CO analyzer technologies.
Check Answer
4. PS-4 was primarily written to be used for CO analyzers with what span?
Check Answer
74

Performance Specification 4A (PS-4A)

Specifications and Test Procedures for Carbon Monoxide (CO) Continuous Emission Monitoring Systems (CEMS) in Stationary Sources

EPA 75

PS-4A Overview

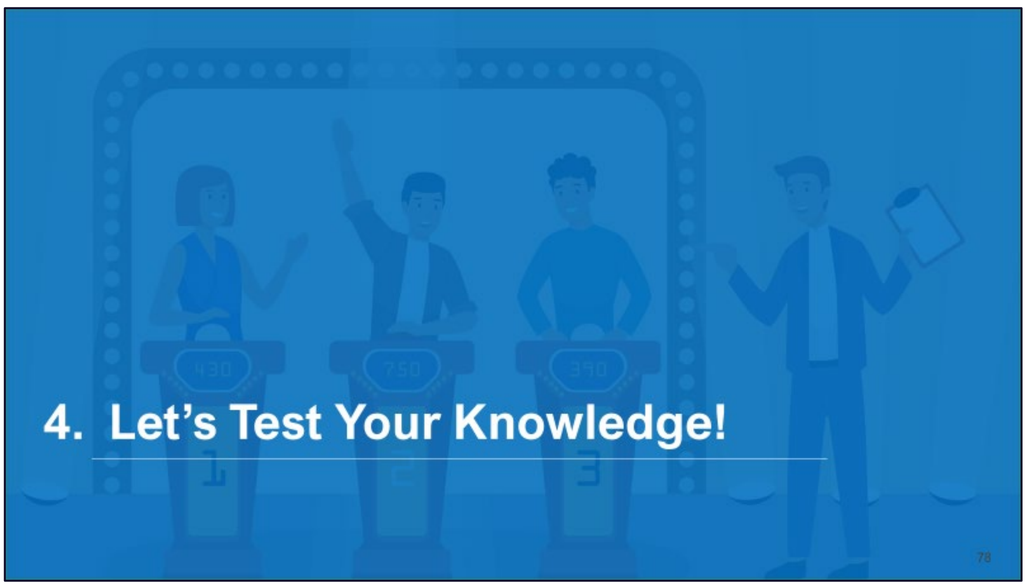
- PS-4A is for evaluating the acceptability of CO CEMS at the time of installation or soon after and whenever specified in an applicable subpart of the regulations.
  - The main difference between this PS and PS-4 is that it was developed primarily for CEMS that comply with low emission standards (less than 200 ppmv).

EPA 76

PS-4A Requirements

- Most aspects of this PS are the same as PS-2, with the exception of:
  - CD performance criteria - same as PS-4, refer to previous slides
  - RA performance criteria - same as PS-4, refer to previous slides
  - Response time
    - The CEMS response time shall not exceed 240 seconds to achieve 95% of the final stable value.
- Reference methods for PS-4A are 10, 10A, and 10B

EPA 77



Feedback

PS-4A

1. For PS-4A, the results of a RATA test are considered valid if the calculated RA is less than ____, or if the RA is less than or equal to ____ when the applicable emission standard is used.

A. 10% and 5%
C. 20% and 1%
B. 10 ppm and 5 ppm
D. 10% and 1%

2. Name three reference methods that are associated with PS-4A.

Check Answer

3. PS-4A was primarily written to be used for CO analyzers with what span?

Check Answer

79

Performance Specification 4B (PS-4B)

Specifications and Test Procedures for Carbon Monoxide (CO) and Oxygen (O_2) Continuous Emission Monitoring Systems (CEMS) in Stationary Sources

EPA

80

PS-4B Overview

PS-4B is to be used for evaluating the acceptability of CO and O_2 CEMS at the time of or soon after installation and whenever specified in the regulations.

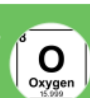
The CEMS may include, for certain stationary sources:

- flow monitoring equipment to allow measurement of the dry volume of stack effluent sampled, and
- an automatic sampling system.

Performance and Equipment Specifications: Data Recorder Scale: O_2 and Data Recorder Scale: CO

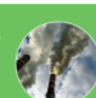
- The output range must include the full range of expected concentration values in the gas stream including the zero and span values
- Span must be 25%; can be higher if O_2 concentration at sampling point can exceed 25%
- Must record all readings within a measurement range with a resolution of 0.5%

Data Recorder Scale: O_2



- Low – range span must be 200 ppm
- High – range span must be 3000 ppm
- Must record all readings within a measurement range with a resolution of 0.5%

Data Recorder Scale: CO



Performance and Equipment Specifications: Calibration Drift and Calibration Error

Calibration Drift

- O_2: Same as PS-3
- CO: Same as PS-4, except it must not drift by more than 3% of the span value

Calibration Error

- O_2: Mean difference between CEMS and reference values at all 3 test points must be ≤ 0.5% O_2
- CO: Mean difference between CEMS and reference values at all 3 test points ≤ 5.0% of span

NOTE: CE and response time tests should be conducted during the CD test period. Response time must not exceed 240 seconds.

EPA 83

Performance and Equipment Specifications: Relative Accuracy: CO and O_2

Relative Accuracy: CO and O_2

- For O_2, same as PS-3 and for CO, same as PS-4A

EPA 84

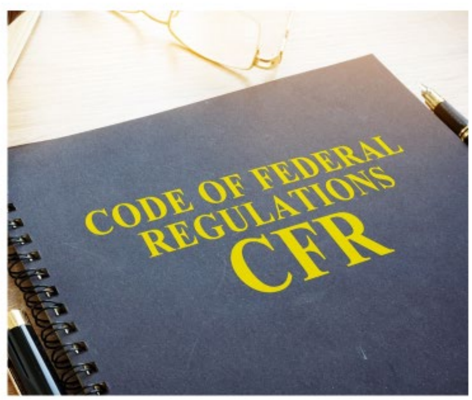
Alternative Relative Accuracy Procedures

- Conduct complete CEMS status check per manufacturer's written instructions
- Instrument must pass CE and CD specifications and have administrator approval

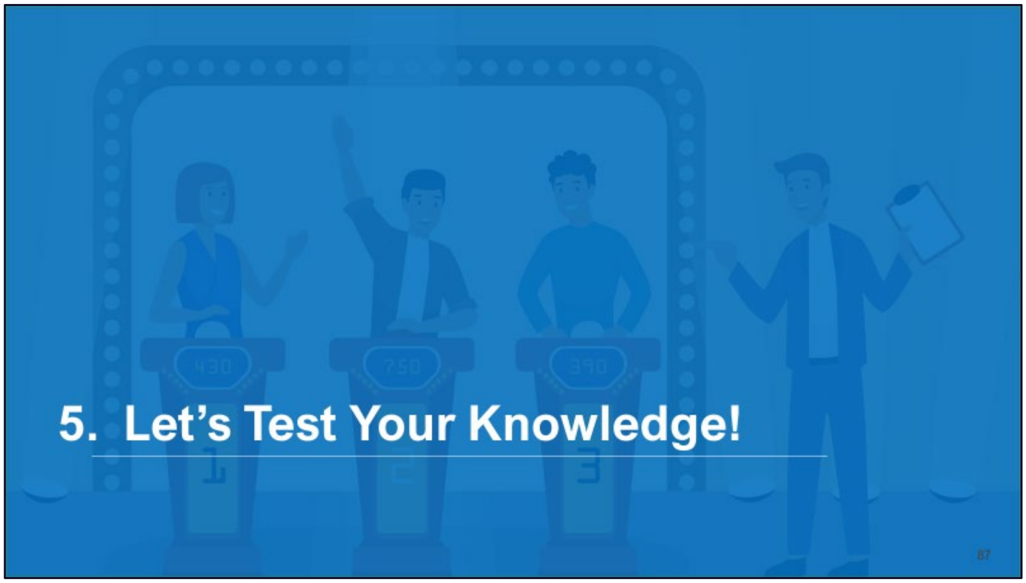
EPA 85

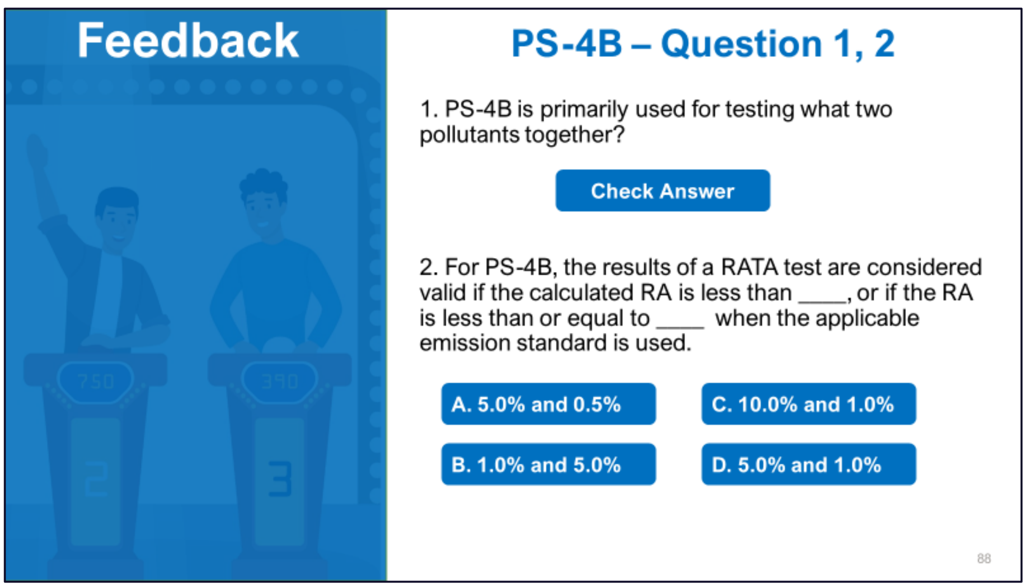
Quality Assurance Procedure 1 and Commonly Used Technology

- PS-2, 3, and 4, 4A, and 4B use QA procedure 1. For more information, review slides under PS-2.
- Commonly used technology is a GFC, same as PS-4

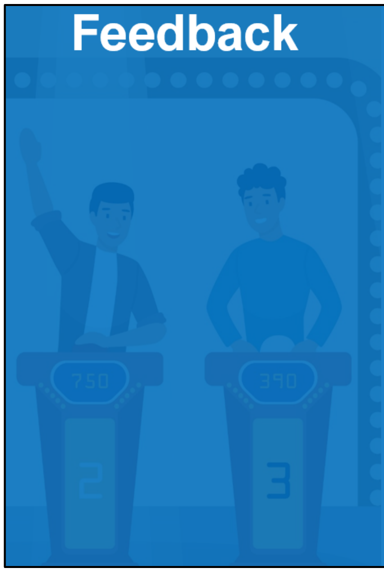


EPA 86


5. Let's Test Your Knowledge!
87


Feedback
PS-4B – Question 1, 2
1. PS-4B is primarily used for testing what two pollutants together?
Check Answer
2. For PS-4B, the results of a RATA test are considered valid if the calculated RA is less than ____, or if the RA is less than or equal to ____ when the applicable emission standard is used.
A. 5.0% and 0.5%
C. 10.0% and 1.0%
B. 1.0% and 5.0%
D. 5.0% and 1.0%
88

Feedback



PS-4B – Question 3, 4

3. For PS-4B CE, the mean difference between CEMS and reference values at all 3 test points must be ≤ 0.5% for which pollutant(s)?

- A. CO
- B. O_2
- C. CO and O_2
- D. None of the above

4. What is one commonly used technology associated with PS-4B?

Check Answer

2

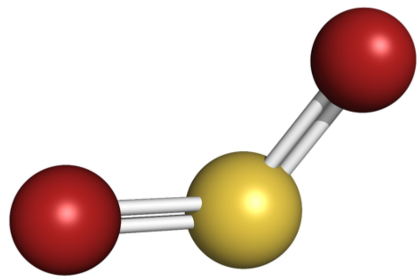
Performance Specification 5 (PS-5)

Specifications and Test Procedures for Total Reduced Sulfur (TRS) Continuous Emission Monitoring Systems (CEMS) in Stationary Sources

EPA 90

PS-5 Overview

- Evaluating the applicability of TRS CEMS at the time of installation or soon after and whenever specified in an applicable subpart of the regulations.
- Three reference methods, which are 16, 16A, and 16B.
- The CEMS may include O_2 monitors which are subject to PS-3.
  - Most aspects of this PS are the same as PS-2, with the exception of:
    - CD performance criteria
    - RA performance criteria



EPA 91

Calibration Drift and Relative Accuracy

- Method Performance: Must perform CD test and relative RA test at time of initial installation or soon after.

Calibration Drift

- CEMS must not drift from the reference value of the calibration gas by no more than 5% of CEMS span value for 6 out of 7 days.
  - No adjustments to CEMS prior to daily measurement
  - Conduct CD test at 2 points (0-20% and 50-100% of full scale) (PS-2- 6.1.2)
  - Must determine CD of diluent monitor separately (PS-3)

Relative Accuracy

- RA Test- RA of CEMS must be no greater than 20% of average RM or 10% when the applicable standard is used to calculate RA.

NOTE: There is no promulgated QA procedure for TRS monitors, however, subparts or regulations may require ongoing QA.

EPA 92

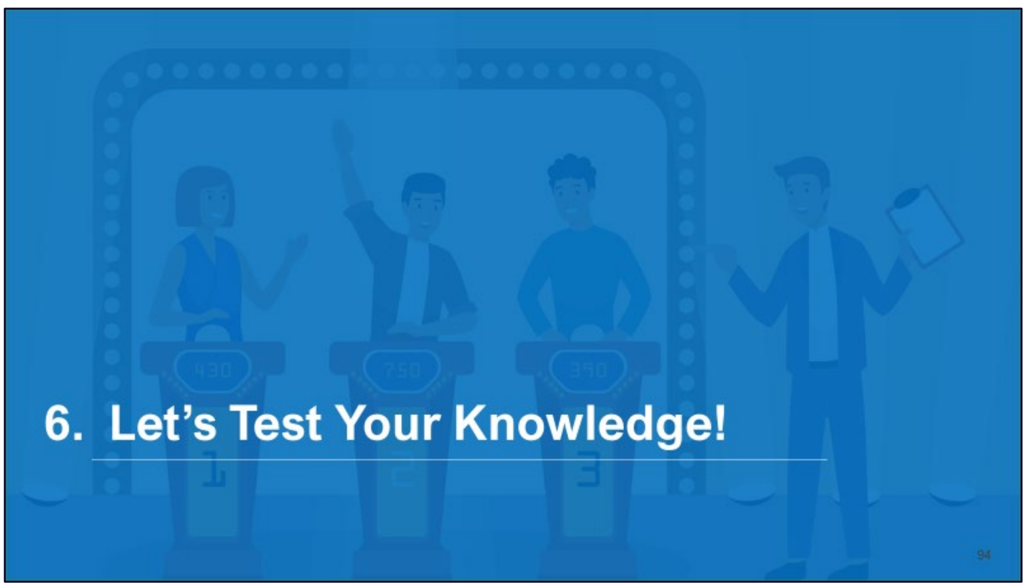
Commonly Used Technology for PS-5

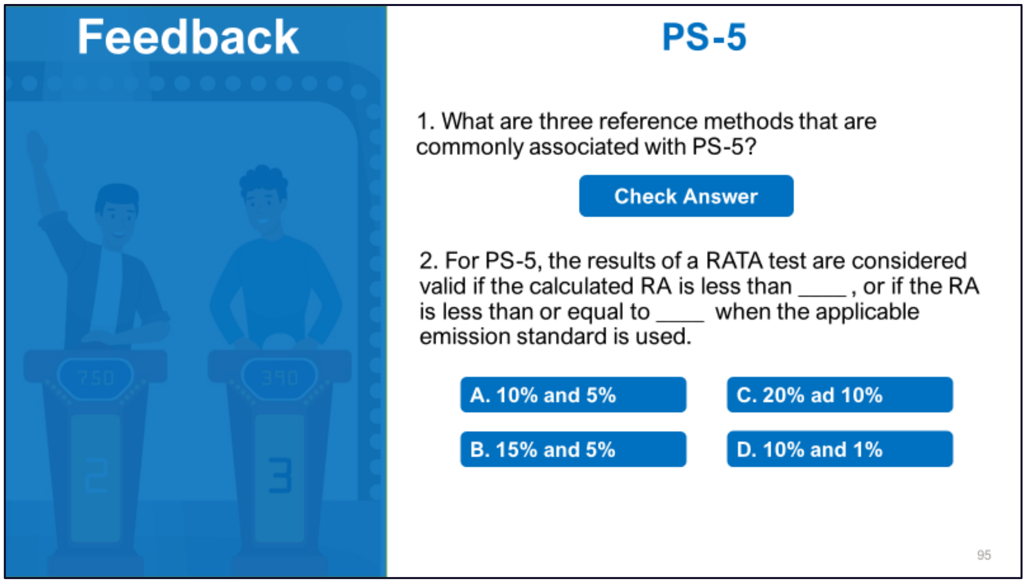
Gas Chromatography

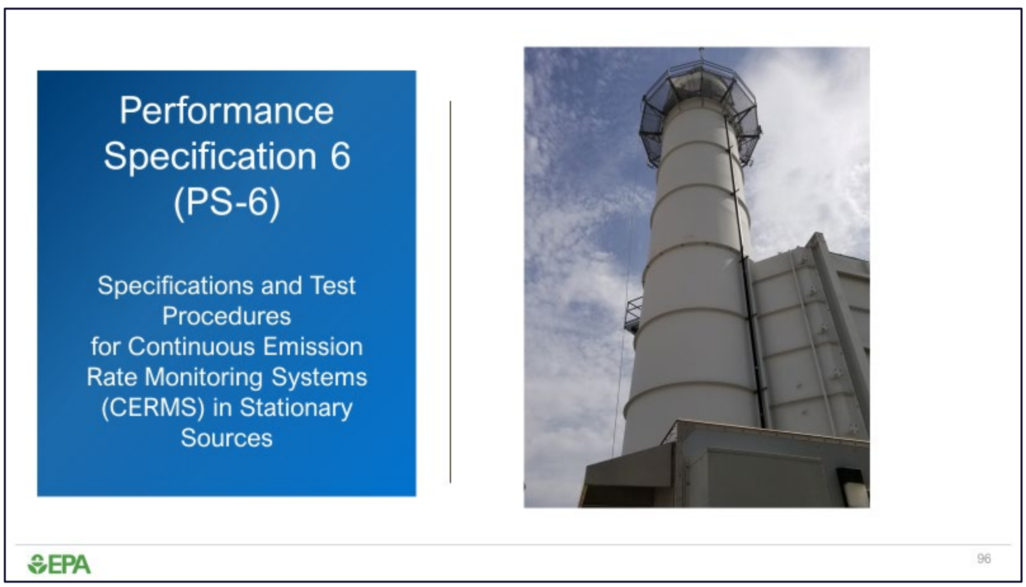
- Uses an inert carrier gas to transport the sample through a capillary column and separates the chemical constituents in the sample by their relative affinity for the column material.
  - The constituents come off, or elute, from the column at different retention times, based on their specific chemical properties, and are measured by the chosen detector type, usually a flame photometric detector (FPD) or thermal-conductivity detector (TCD) for H_2S measurement.

NOTE: Pulsed Fluorescence – see details under PS-2

EPA 93




Feedback
PS-5
1. What are three reference methods that are commonly associated with PS-5?
Check Answer
2. For PS-5, the results of a RATA test are considered valid if the calculated RA is less than ____ , or if the RA is less than or equal to ____ when the applicable emission standard is used.
A. 10% and 5%
C. 20% ad 10%
B. 15% and 5%
D. 10% and 1%
95


Performance Specification 6 (PS-6)
Specifications and Test Procedures for Continuous Emission Rate Monitoring Systems (CERMS) in Stationary Sources
EPA
96

Overview of PS-6

- Evaluating the acceptability of CERMS. Definitions are the same as those in PS-2 with the exceptions of:
  - CERMS—the total equipment required for the determining and recording the pollutant mass emission rate (in terms of mass per unit of time); and
  - Flow Rate Sensor—portion of the CERMS that senses the volumetric flow rate and generates an output proportional to that flow rate. The flow rate sensor shall have provisions to check the CD for each flow rate parameter that it measures individually (*e.g.,* velocity, pressure).
- The CD and RA tests are conducted to determine conformance of the CERMS to the specification.
- Reference methods used for determining flow under PS-6 are 2, 2A, 2B, 2C, and 2D.

EPA 97

Calibration Drift

- Determined separately for each analyzer
  - Shall not exceed 3% of the high-level value
- Conduct the CD tests for pollutant concentration at the two values specified in section 6.1.2 of PS-2.
- For other parameters (e.g., velocity, pressure, flow rate), use two analogous values (e.g., Low: 0-20% of full scale, High: 50-100% of full scale).

EPA 98

Relative Accuracy

The RA of the CERMS shall be no greater than 20% of the mean value of the RM's test data in terms of the units of the emission standard, or 10% of the applicable standard, whichever is greater.

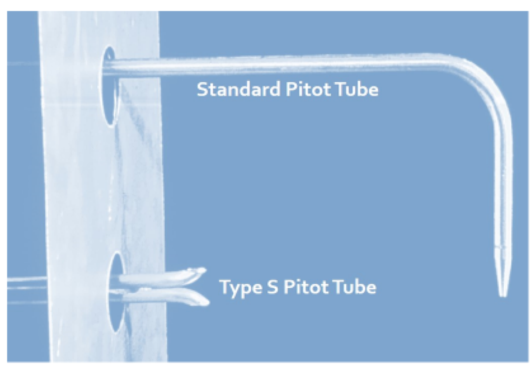
EPA

99

scr

Commonly Used Technologies for PS-6

Pitot tubes use the differential pressure between the measurements of total pressure and the static pressure at a point in the stack to calculate the stack gas velocity and volumetric flowrate.

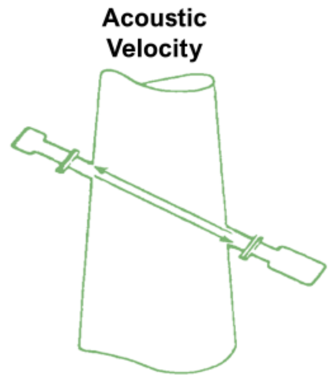


EPA

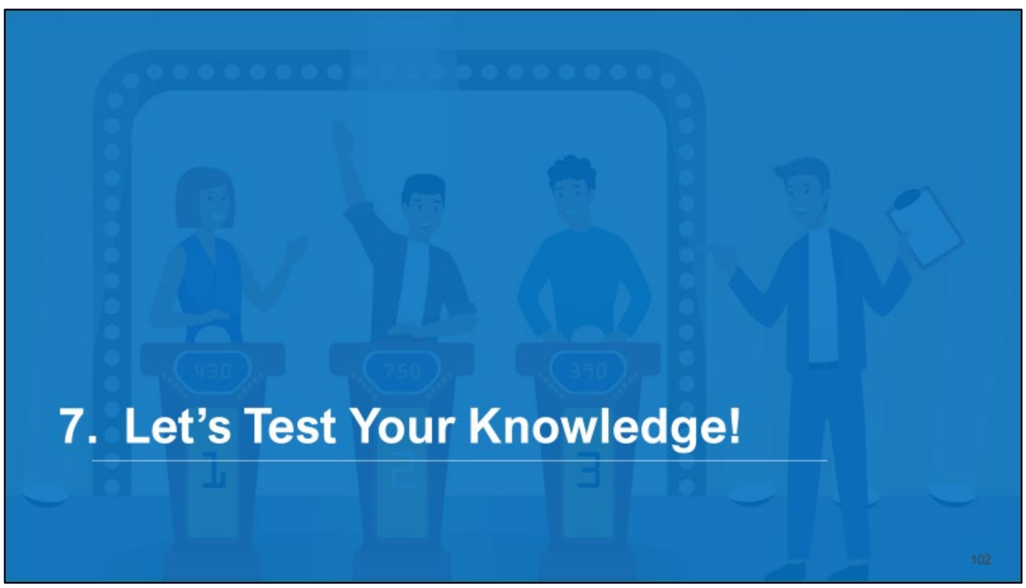
100

Commonly Used Technologies for PS-6 (Cont'd)

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.



EPA 101



Feedback

PS-6

1. What is PS-6 primarily used for to perform?

Check Answer

2. For PS-6, CERMS calibration must not drift by more than ___% from the reference value.

A. 3% B. 5% C. 2% D. 0.5%

3. What reference methods are used for determining flow under PS-6?

Check Answer

4. When measuring flow rates, what are two commonly used techniques?

Check Answer

103

Performance Specification 7 (PS-7)

Specifications and Test Procedures for Hydrogen Sulfide (H2S) Continuous Emission Monitoring Systems (CEMS) in Stationary Sources

EPA

104

PS-7 Overview

Evaluating the acceptability of H_2S CEMS at the time of or soon after installation and whenever specified in an applicable subpart of the regulations

Most aspects of PS-7 are covered under PS-2 with the exception of CD and RA.

EPA 105

PS-7 Calibration Drift and Relative Accuracy

Calibration Drift

- CEMS must not drift from the reference value of the calibration gas by any more than 5% of CEMS span value for 6 out of 7 days
- No adjustments to CEMS prior to daily measurement
- Conduct CD test at 2 points (0-20% and 50-100% of full scale)

Relative Accuracy

- CEMS RA must be no greater than 20% of average RM or 10% of the applicable standard
- RA Test - Perform minimum of 9 RM test runs, may do more, but only a maximum of 3 runs may be discarded. Must report 9 runs.
- Use RM 11, 15, 16
  - RM 11 sample run times shall be at least 10-minutes and (0.35 dscf or 0.010 dscm) and taken at 30-minute intervals
  - RM 15 and 16 sample runs shall consist of 2 injections equally spaced over 30-minute period

NOTE: Some aspects of this PS are the same as PS-2.

EPA 106


Commonly Used Technology for PS-7
GC—see description in PS-5
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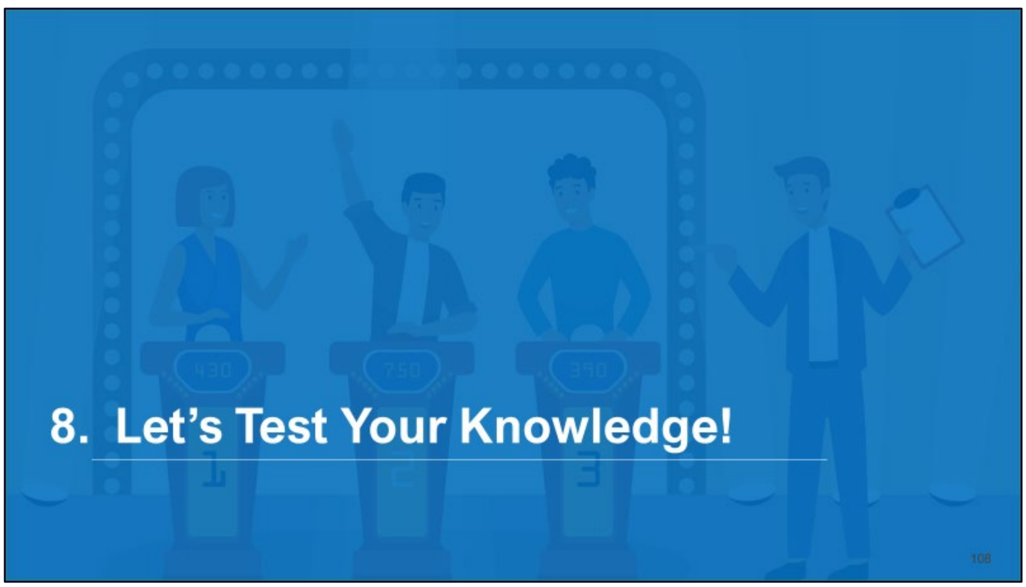
EPA
107


8. Let's Test Your Knowledge!
108

Feedback

PS-7

1. What is PS-7 primarily used to certify?

Check Answer

2. What reference methods are associated with PS-7?

Check Answer

3. What is a commonly used technology that is associated with PS-7?

Check Answer

109

Performance Specification 8 (PS-8)

Specifications and Test Procedures for Volatile Organic Compounds (VOC) Continuous Emission Monitoring Systems (CEMS) in Stationary Sources

EPA

110

PS-8 Overview

Evaluating a CEMS that measures a mixture of VOC and generates a single combined response value

- Must select the same measurement technology as the reference method or if not specified, the technology is based on knowledge of the source emissions.

Most aspects of PS-8 are covered under PS-2 except for CD and RA.

EPA 111

PS-8 Calibration Drift and Relative Accuracy

Calibration Drift	Relative Accuracy
• < 2.5% of span value • No adjustments to CEMS prior to daily measurement	• < 20% of average RM or < 10% of the applicable standard • Use RM as specified in applicable subpart or regulation

NOTE: Subparts or regulations may require on-going QA.

EPA 112

Commonly Used Technology for PS-8

- A flame ionization detector (FID) measures the current induced by ions attracted to and hitting a collector plate. The ions are formed by the combustion of organic compounds in a sample gas.
- A gas sample is extracted from the source through a heated sample line and heated filter to an FID.
- An FID measures the current, which is directly proportional to the concentration of VOC in the sample.
  - Results are reported as volume concentration equivalents of propane.

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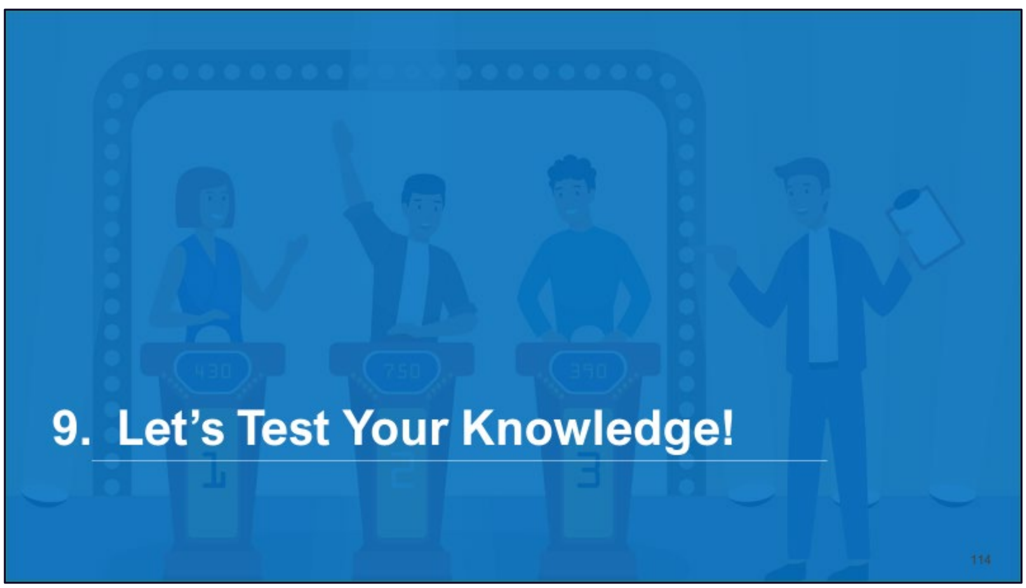
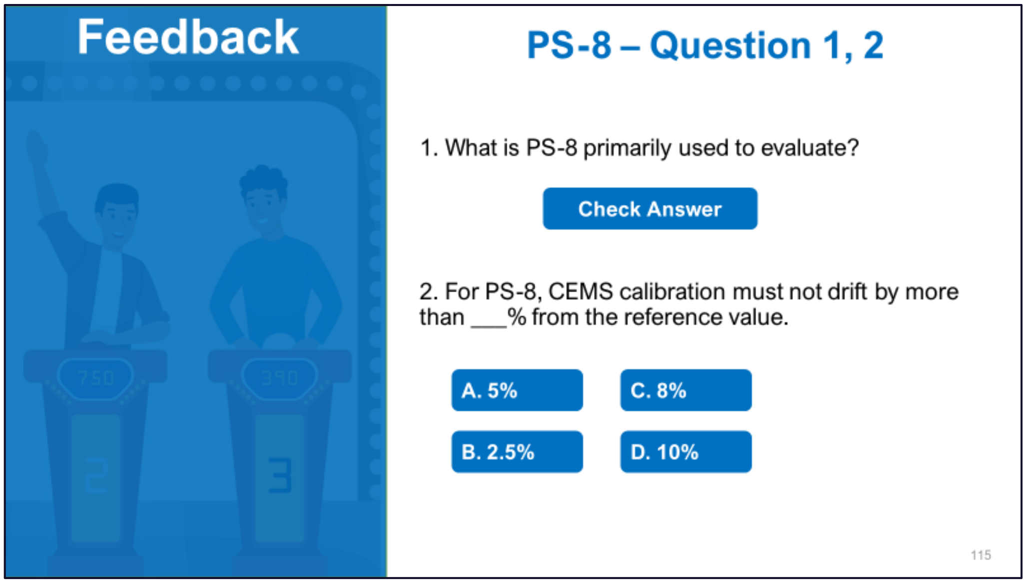
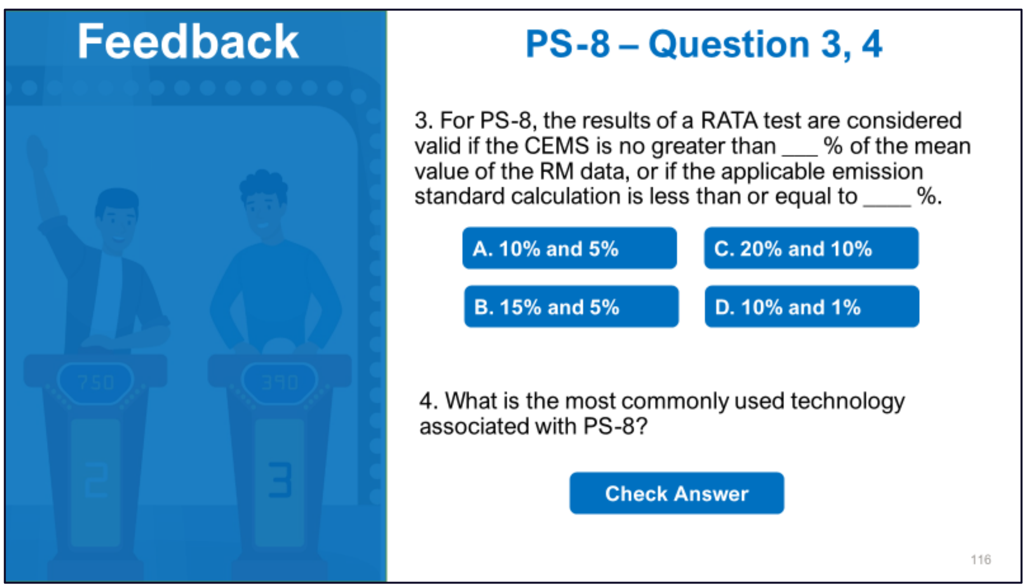
EPA 113




Feedback
PS-8 – Question 1, 2
1. What is PS-8 primarily used to evaluate?
Check Answer
2. For PS-8, CEMS calibration must not drift by more than ___% from the reference value.
A. 5%
C. 8%
B. 2.5%
D. 10%
115


Feedback
PS-8 – Question 3, 4
3. For PS-8, the results of a RATA test are considered valid if the CEMS is no greater than ___ % of the mean value of the RM data, or if the applicable emission standard calculation is less than or equal to ____ %.
A. 10% and 5%
C. 20% and 10%
B. 15% and 5%
D. 10% and 1%
4. What is the most commonly used technology associated with PS-8?
Check Answer
116

Performance Specification 8A (PS-8A)

Specifications and Test Procedures for Total Hydrocarbons (THC) Continuous Emission Monitoring Systems (CEMS) in Stationary Sources

EPA 117

PS-8A Overview

- PS-8A applies to THC CEMS installed on stationary sources.
- Includes procedures intended to be used to evaluate the acceptability of the CEMS at the time of its installation or whenever specified in regulations or permits.
- A gas sample is extracted from the source through a heated sample line and heated filter, transported to an FID.
- Results are reported as volume concentration equivalents of propane.

EPA 118

PS-8A Requirements

RATA and absolute calibration audits (ACA) are not required. The CD, CE, and response time tests are performed in lieu of a RA or ACA. If not passed they must be performed again until all are passed.

Calibration Drift Test Period

- While a unit is operating, determine the CD for seven consecutive operating days, make no adjustment to system prior to performing CD test.
- The CEMS must not drift by ±3ppm or ±3% of span value after each 24-hour period of the 7-day drift test for both the zero and span gases.

Calibration Error Test and Response Time Test

- Conduct the CE and response time tests during the CD test period.
- The mean difference between the CEMS and reference values at all three test points must be no greater than 5 ppm (±5% of the span value).

EPA 119

Commonly Used Technology for PS-8A

FID - see details under PS-8

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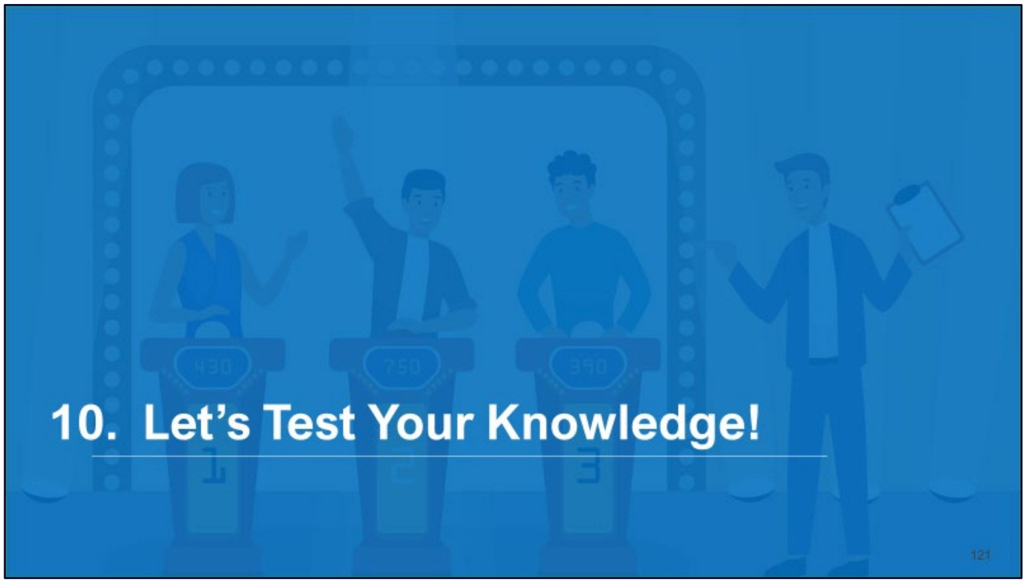
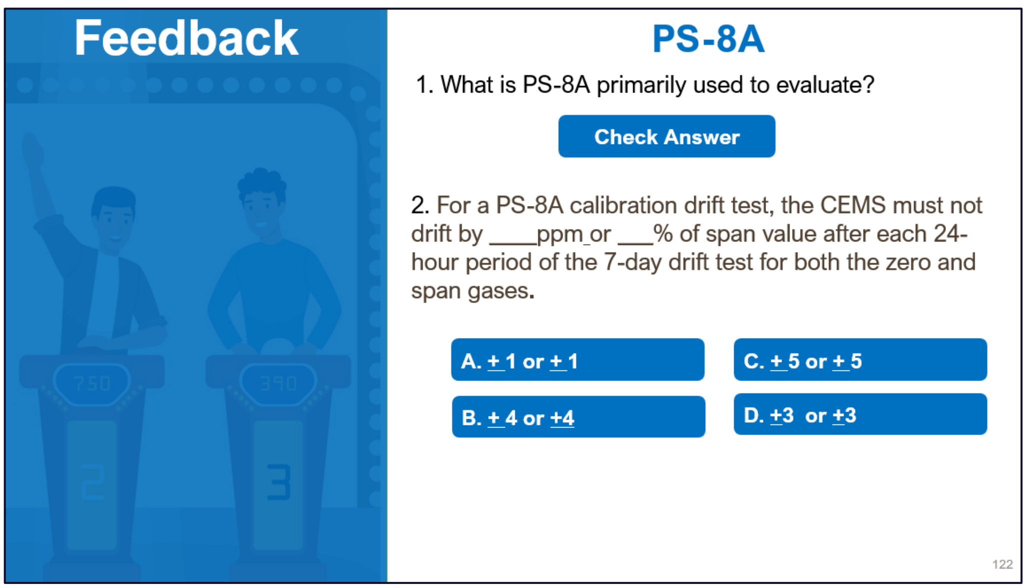
EPA 120


430
750
390
10. Let's Test Your Knowledge!
121


Feedback
750
390
PS-8A
1. What is PS-8A primarily used to evaluate?
Check Answer
2. For a PS-8A calibration drift test, the CEMS must not drift by ____ppm or ___% of span value after each 24-hour period of the 7-day drift test for both the zero and span gases.
A. ± 1 or ± 1
C. ± 5 or ± 5
B. ± 4 or ±4
D. ±3 or ±3
122

Performance Specification 9 (PS-9)

Specifications and Test Procedures for Gas Chromatography (GC) Continuous Emission Monitoring Systems (CEMS) in Stationary Sources

EPA 123

PS-9 Overview

Applies to CEMS that use GC to measure a specific target list of organic compounds.

- GC is defined as that portion of the system that separates and detects organic analytes and generates an output proportional to the gas concentration. The GC must be temperature controlled.

Definitions unique to this PS are included in the subsequent slides.

Calibration precision, CE, and performance audit tests are conducted to determine conformance of the CEMS with these specifications. Daily calibration and maintenance requirements are also specified.

EPA 124

Sample Collection, Preservation, Storage and Transport

Installation and Measurement Location Specifications

- Install CEMS where measurements are representative of the source.
- Sampling location should be at least two equivalent duct diameters from control device, point of pollutant generation, or any point that might cause a change in pollutant concentrations.

Pre-Test Preparation Period

- Use the procedures in method 18 of 40 CFR Part 60, Appendix A to perform initial tests to determine the proper GC conditions that provide good resolution and minimum analysis time for the analytes of interest.

EPA 125

Performance Audits and Calibration

Performance Audit Test Periods

- A performance audit test must be conducted during a 7-day CE test and quarterly thereafter.
- The audit gas cylinder must be analyzed three times.

Calibration and Standardization

- Initial Multi-Point Calibration
  - Conduct a multi-point calibration of the GC during initial set-up and after routine maintenance or repair, or at least once per month.

Daily Calibration

- Once every 24-hours, analyze the mid-level calibration standard in triplicate. The average response for each analyte shall not vary by more than 10 % of the certified concentration.

EPA 126

Calibration Error

Calibration Error

- Must be determined at 3 calibration levels
- The average CEMS calibration response must not differ by more than 10% of the certified cylinder value for each analyte.

Calibration Precision and Linearity

- Each triplicate injection of calibration gas may not differ by more than 5% of average response. The r^2 value for all three levels must be $\geq$0.995.

Measurement Frequency

- The sampling system time constant shall be $\leq$5 minutes or the sampling frequency specified in the applicable regulation.

Relative accuracy test audits are not required.

EPA 127

Commonly Used Technology for PS-9

GC—see description in PS-7

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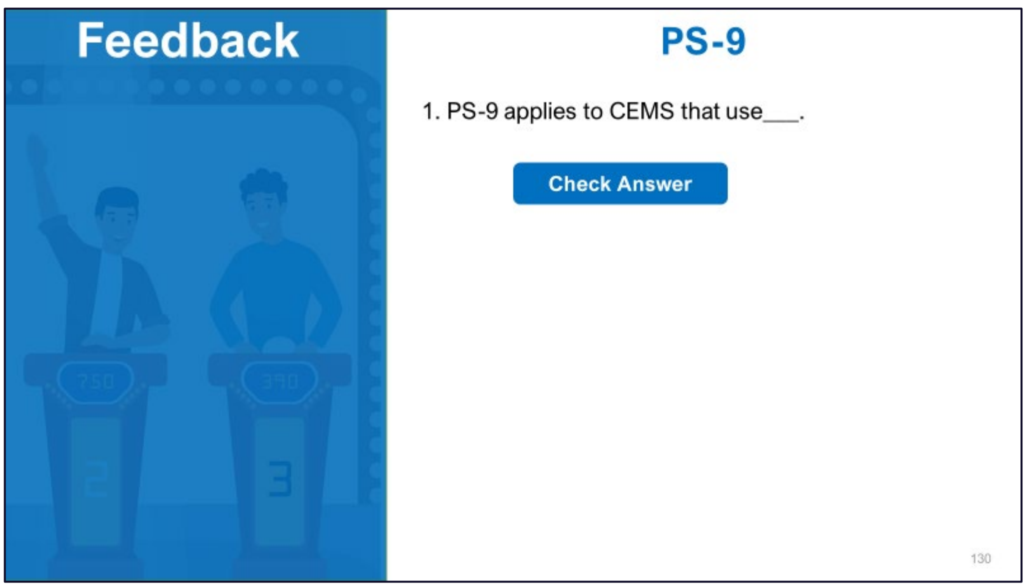
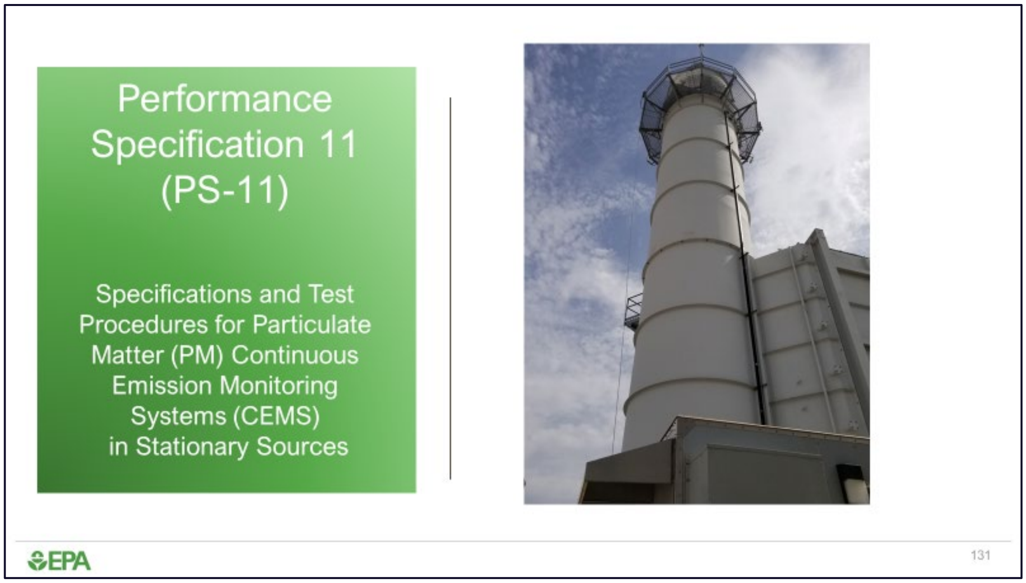
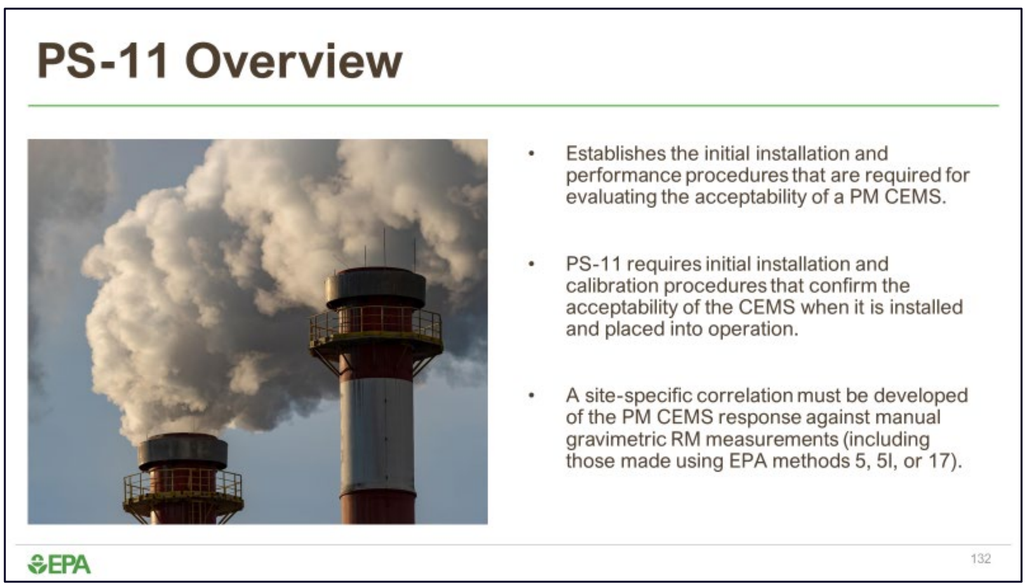
EPA 128


11. Let's Test Your Knowledge!
129


Feedback
PS-9
1. PS-9 applies to CEMS that use___.
Check Answer
130


Performance Specification 11 (PS-11)
Specifications and Test Procedures for Particulate Matter (PM) Continuous Emission Monitoring Systems (CEMS) in Stationary Sources
EPA
131


PS-11 Overview
Establishes the initial installation and performance procedures that are required for evaluating the acceptability of a PM CEMS.
PS-11 requires initial installation and calibration procedures that confirm the acceptability of the CEMS when it is installed and placed into operation.
A site-specific correlation must be developed of the PM CEMS response against manual gravimetric RM measurements (including those made using EPA methods 5, 5I, or 17).
EPA
132

Installation and Performance

- Initial installation and performance may include:
  - Diluent monitor - O_2, CO_2, or other monitors specified in applicable regulation.
  - Auxiliary monitoring equipment for temperature, pressure, moisture content and/or volume of stack effluent.
  - Automatic sampling system that measures in units of mass concentration.

EPA 133

Drift and Correlation Test

- **Performance Criteria based on the following:**
  - 7-day drift test
  - Initial correlation test
  - Sampling periods
  - Cycle/Response time
- **7-Day Drift Test**
  - <2% of the upscale value (includes O_2, CO_2 monitors).
- **Initial Correlation Test**
  - Based on a technique of correlating PM CEMS responses relative to emission concentrations determined by the RM (EPA Method 5, 5I, 17). Unlike gaseous CEMS, these are site specific.

EPA 134

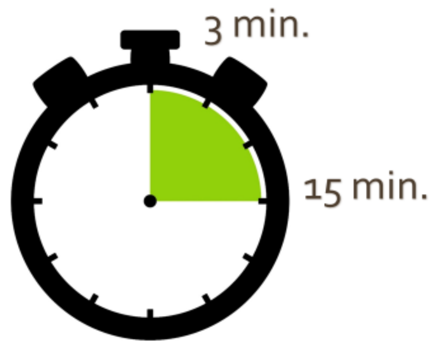
Performance Test

Sampling Period

- Must be no less than 30% of the cycle time for batch sampling CEMS.

Cycle/Response Time

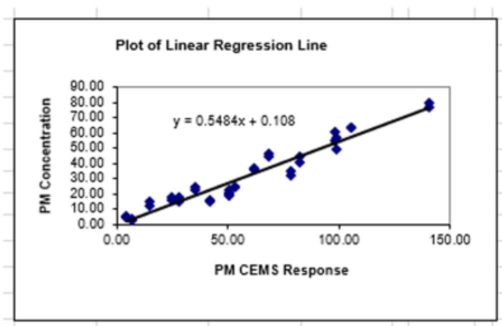
- The response time of PM CEMS, which is equivalent to the cycle time, must be no longer than **15 minutes**.
- In addition, the delay between the end of the sampling time and reporting of the sample analysis must be no greater than **3 minutes**. Must document any changes in the response time following installation.



EPA 135

Developing a PS-11 Correlation

- Minimum of 15 valid RM test runs
- Simultaneous PM CEMS data
- Plot RM data vs. CEM data
- Does data meet the criteria of PS-11?



EPA 136

Procedure 2 – Quality Assurance Requirements For Particulate Matter CEMS At Stationary Sources

What are the basic functions of Procedure 2?

- Assess the quality of your PM CEMS data by estimating measurement accuracy
- Control and improvement of the quality of your PM CEMS data by implementing QC requirements and corrective actions until the data quality is acceptable
- Specify the requirements for daily instrument zero and upscale drift checks and daily sample volume checks, as well as routine response correlation audits (RCA), absolute correlation audits, sample volume audits (SVA), and relative response audits (RRA)

NOTE: Requires periodic evaluations of PM CEMS performance and the development and implementation of QA/QC programs to ensure that PM CEMS data quality is maintained.

EPA 137

Procedure 2 – Quality Control Program

Your QC program must, at a minimum, include step-by-step procedures for the following:

- Performing drift checks,
- Methods for making adjustments to PM CEMS
- Preventative maintenance
- Data recording, calculations, and reporting
- Performing RCA and RRA procedures
- Performing absolute correlation audits (ACA) and SVA
- Corrective actions for malfunctioning PM CEMS, including flagged data periods
- Procedures for checking extractive system ducts for material accumulation

EPA 138

Procedure 2 – Auditing Requirements

Daily Checks	Quarterly Checks (performed 3 out of 4 quarters annually)	Annual Checks (frequency specified in permit or applicable regulation)
Zero and upscale drift	ACA	RRA – usually, annually, unless a RCA is performed
Check the system optics (light-scatter and extinction-type)	SVA	RCA – usually, once every three years
Sample volume check (if used in calculating output)		

EPA 139

Procedure 2 – Performance Criteria

Zero Or Upscale Drift	Sample Volume Measurement	Absolute Correlation Audits	Sample Volume Audits
Must be less than 4% for 5 consecutive day, or 8% for any one day	Must be less than 10% for 5 consecutive day, or 20% for any one day	Cannot exceed $\pm$10% of average audit value or 7.5% of applicable standard	Must be less than $\pm$5% of sample volume audit value

EPA 140

Procedure 2 – Performing Response Correlation Audit Performance Criteria

- For all 12 data points, the PM CEMS response value can be no greater than the greatest PM CEMS response value used to develop your correlation curve.
- At least 75% of a minimum number of 12 sets of PM CEMS and RM measurements must fall within a specified area on a graph of the correlation regression line.

Procedure 2 – Relative Response Audit Performance Criteria

- For all three data points, the PM CEMS response value can be no greater than the greatest PM CEMS response value used to develop your correlation curve.
- At least two of the three sets of PM CEMS and RM measurements must fall within the same specified area on a graph of the correlation regression line as required for the RCA and described on previous slide.

NOTE: If your PM CEMS fails to meet these RRA criteria, it is out of control.

Commonly Used Technologies for PS-11

- A light scattering PM CEMS measures the light scattered by the entrained particulate in the stack exhaust, the amount of scattering being proportional to the particulate concentration, and affected by particle size, shape, and color.

- A beta gauge PM CEMS uses a beta radiation source and an adhesive filter tape material which collects the PM material at predetermined intervals. The collected PM on the filter tape attenuates the beta radiation, the amount of attenuation being proportional to the mass of collected PM, and independent of particle characteristics.

NOTE: Both PM CEMS require site-specific correlation against manual gravimetric RM measurements.

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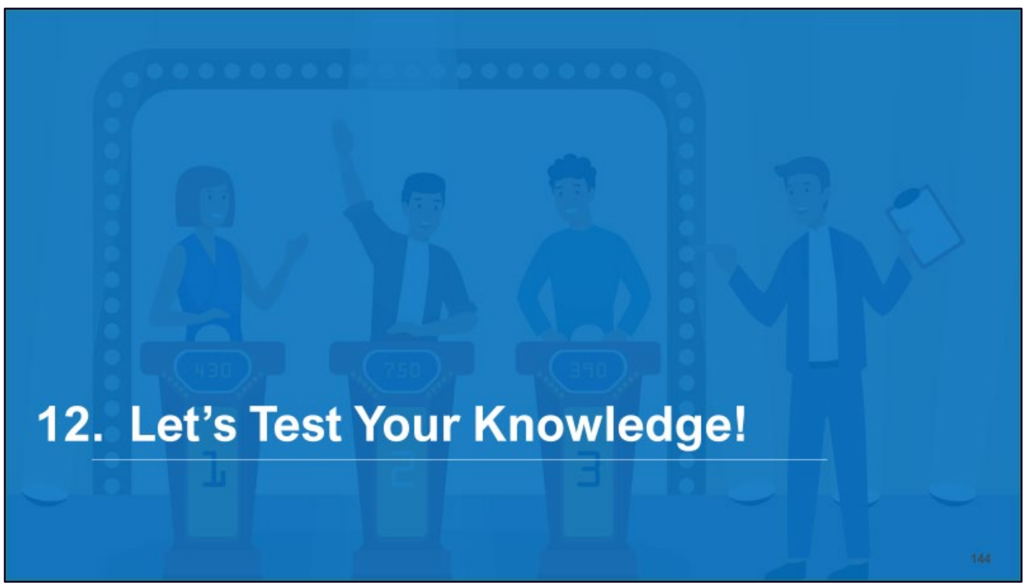
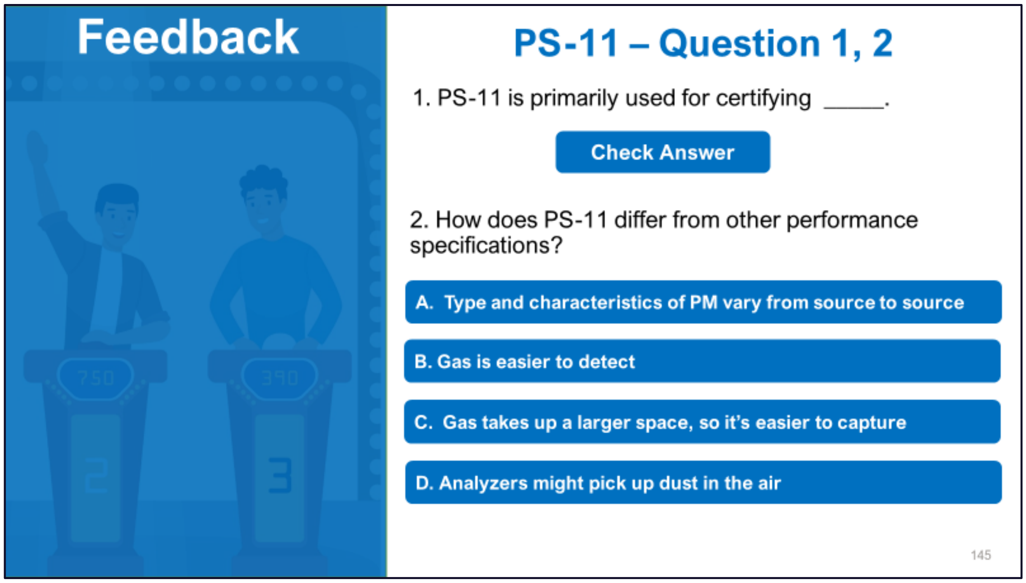
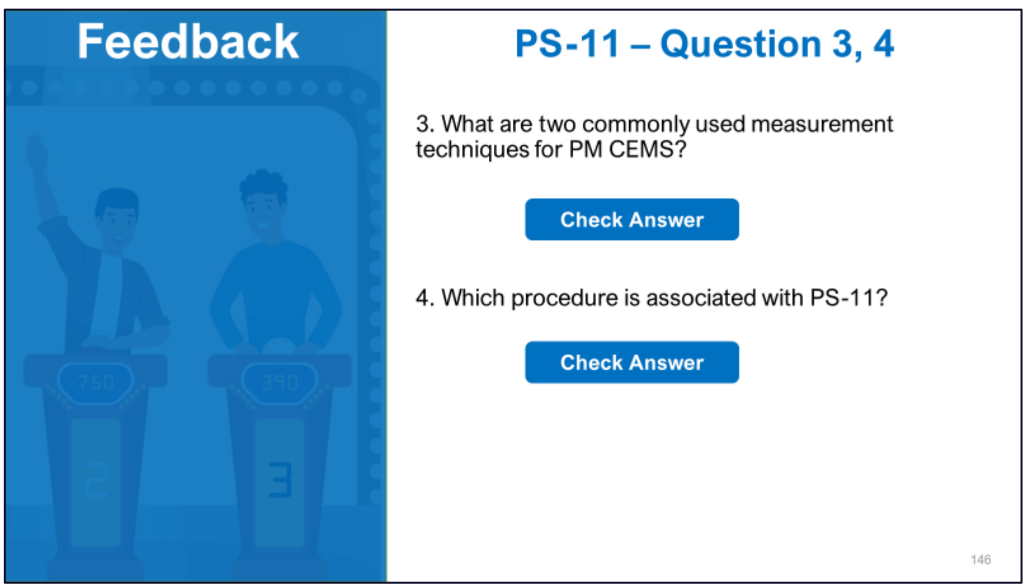
EPA 143




Feedback
PS-11 – Question 1, 2
1. PS-11 is primarily used for certifying _____.
Check Answer
2. How does PS-11 differ from other performance specifications?
A. Type and characteristics of PM vary from source to source
B. Gas is easier to detect
C. Gas takes up a larger space, so it's easier to capture
D. Analyzers might pick up dust in the air
145


Feedback
PS-11 – Question 3, 4
3. What are two commonly used measurement techniques for PM CEMS?
Check Answer
4. Which procedure is associated with PS-11?
Check Answer
146

Performance Specification 12A (PS-12A)

Specifications and Test Procedures for Total Vapor Phase Mercury (Hg) Continuous Emission Monitoring Systems (CEMS) in Stationary Sources

147

PS-12A Overview

- Evaluates the acceptability of total vapor phase (gas-phase elemental and oxidized) Hg CEMS installed at stationary sources at the time of or soon after installation and whenever specified in the regulations.
  - Regardless of whether it addresses elemental or oxidized Hg, the CEMS must record concentrations at standard conditions on a wet or dry basis
- The Hg CEMS must be capable of measuring the total concentration in µg/m3 of vapor phase Hg, regardless of speciation, and recording that concentration at standard conditions on a wet or dry basis.
  - These specifications do not address measurement of particle bound Hg.

148

PS-12A Overview (Cont'd)

- CEMS must meet the specified ranges:
  - Zero-level gas - 0 to 20% of the span value
  - Mid-level gas - 50 to 60% of the span value
  - High-level gas - 80 to 100% of the span value

EPA 149

Measurement Error and Calibration Drift

Measurement Error Test	Calibration Drift Test
For Hg^o, the measurement error (ME) <5% of the span value at the zero-, mid-, and high-level reference gas concentrations.	CEMS <5% of the span value on any of the 7 days of the CD test. • Use zero-level gas and either mid- or high-level gas.
For $HgCl_2$, the ME <10% of the span value at the zero-, mid-, and high-level reference gas concentrations.	

NOTE: Must perform ME, CD, RA, and linearity.

EPA 150

Relative Accuracy and Reference Methods

Relative Accuracy Test	Reference Methods
CEMS <20% of the mean value of the RM test data in terms of units of µg/scm • Alternatively, if the mean RM <5.0 µg/scm, the results are acceptable if the absolute value of the difference between the mean RM and CEMS values <1.0 µg/scm.	Method 29 and ASTM 6784, filterable portion not included. • Determine number of sampling points by Method 1. • Minimum of nine 2-hour test runs.
	Method 30A and 30B • Use 12 sampling points according to Method 1. • Minimum of nine 30-minute test runs.

EPA 151

Procedure 5 - Quality Assurance Requirements For Vapor Phase Mercury CEMS And Sorbent Trap Monitoring Systems Used For Compliance Determination At Stationary Sources

What are the basic functions of Procedure 5?

- To ensure Hg CEMS (vapor recovery or sorbent trap) meet acceptable standards for determining compliance on an ongoing basis:
  - Assessment of the quality of Hg CEMS data
  - Control and improvement of the quality of Hg CEMS data by implementing QC requirements and corrective actions
  - Specification of QC requirements

EPA 152

Procedure 5: Quality Control Requirements

Minimum Requirements

- CD checks
- CD determination & adjustment
- Weekly system integrity check procedures
- Routine operation, maintenance & QA/QC procedures for the sorbent trap monitoring systems
- Routine & preventative maintenance procedures (including spare parts inventory)
- Data recording, calculations & reporting
- Accuracy audit procedures
- Program of corrective action for malfunctioning CEMS

EPA 153

Procedure 5: Calibration Drift Assessment

CD Requirement - Daily

Check, record & quantify CD at 2 concentrations; adjust CEMS calibration when one of the concentration CD exceeds 2 times the limits of the applicable PS

Recording Requirement for Automatic CD Adjusting CEMS

Must be programmed to record the unadjusted concentration measure in the CD prior to resetting the calibration, if performed, or to record the adjustment

Criteria for Excessive CD

- OOC Definition- completion of 5th daily check in excess of two times limit of PS or first daily check exceeding 4 times limit of PS to first CD back within PS limit
- CEMS Data Status During OOC Period - data cannot be used to determine compliance or to meet minimum data availability requirement

EPA 154

Procedure 5: Data Accuracy Assessment

Hg CEMS Audit Requirements - an accuracy audit must be performed at least once each calendar quarter; successive quarterly audits (if possible) must be performed no less than two months apart

Relative Accuracy Test Audit	Alternative Quarterly Audits	Sorbent Trap Monitoring System Audit Requirements -
At least once every 4 calendar quarters except as noted in Section 5.1.4 of Appendix B; follow Section 8.5 of PS-12A & calculate results according to Section 12.4 of PS-12A	• Quarterly Gas Audit (QGA) - may be conducted in 3 of 4 calendar quarters but no more than 3 quarters in succession; challenge the CEMS with a zero and 2 upscale level audit gases of known concentrations, (20-30% of span & 50-60% of span) first of elemental Hg and then of oxidized Hg • RAA - alternative to QGA; follow section 8.5 of PS-12A, but only 3 test runs required	RATA conducted at least once every 4 calendar quarters; perform the RATA as described in section 8.3 of PS-12B & calculate results per Section 12.4 in PS-12A

EPA 155

Procedure 5: Excessive Audit Inaccuracy

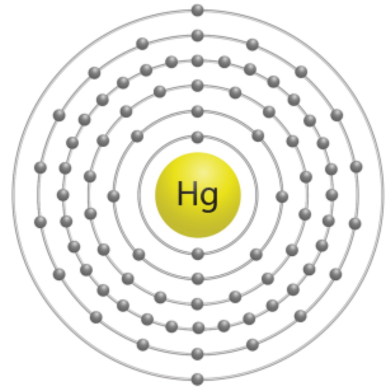
Out-of-Control Period Definition	Monitoring Data Status During Out-of-Control Period	Criteria for Excessive Audit Inaccuracy	Criteria for Acceptable QC Procedures
Hour immediately following the completion of failed RATA, RAA, or QGA or system integrity check until completion of subsequent successful test of the same type.	Cannot be used to determine compliance with an applicable emission limit or to meet minimum data availability requirements.	RATA: PS 12A& PS 12B – 20% or mean RM < 5.0 µg/scm if difference between CEMS and RM < 1.0 µg/scm QGA: +/- 15% of the average audit value or +/- 5 µg/m3 (whichever is greater) RAA: +/- 20% of the 3 run average or +/- 10% of the applicable standard, whichever is greater.	After 2 consecutive quarters with excessive inaccuracies, the owner/operator must revise the QC procedures or modify/repair/replace the CEMS which will require recertification of the CEMS.

EPA 156

Commonly Used Technology for PS-12A

Hg sample is extracted from the stack and analyzed using atomic fluorescence spectroscopy to measure the concentration of Hg vapor in the sample.

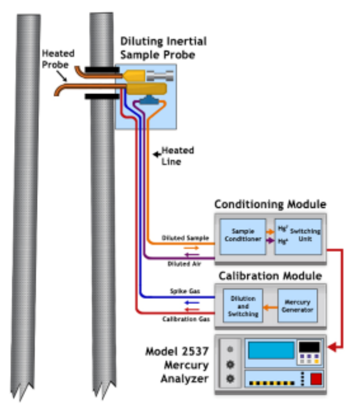
- When an Hg atom absorbs the energy from a specific UV wavelength, an electron transitions from a stable ground state to an unstable, excited state, and when the UV energy source is removed, the electron returns to its stable state and emits a photon of light.



EPA 157

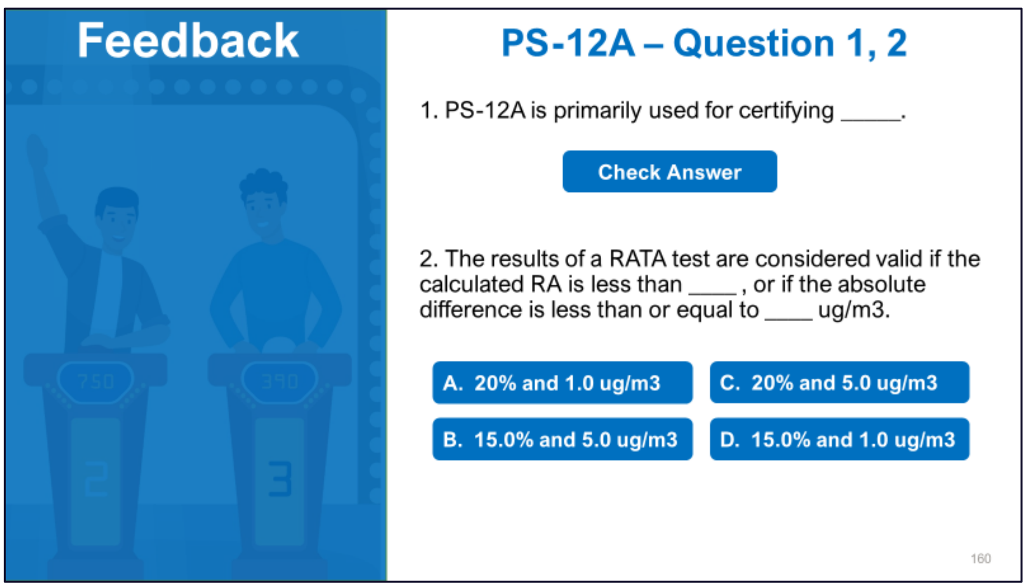
Hg CEMS Atomic Fluorescence

- Measure gaseous Hg
  - Elemental (Hg^0)
  - Oxidized (Hg^{2+})
- Almost all convert oxidized Hg to elemental Hg for measurement of total gaseous Hg
- Calibrate using NIST-traceable Hg gas generators or cylinders



EPA 158

13. Let's Test Your Knowledge!
159



Feedback
PS-12A – Question 1, 2
1. PS-12A is primarily used for certifying _____.
Check Answer
2. The results of a RATA test are considered valid if the calculated RA is less than ____ , or if the absolute difference is less than or equal to ____ ug/m3.
A. 20% and 1.0 ug/m3
C. 20% and 5.0 ug/m3
B. 15.0% and 5.0 ug/m3
D. 15.0% and 1.0 ug/m3
160

Feedback

PS-12A – Question 3, 4

3. What reference methods are commonly associated with PS-12A?

Check Answer

4. What are two measurement techniques used for PS-12A?

Check Answer

161

Performance Specification 12B (PS-12B)

Specifications and Test Procedures for Total Vapor Phase Mercury (Hg) Using Sorbent Traps in Stationary Sources

EPA

162

PS-12B Overview 1

- Establishes performance benchmarks for, and to evaluate the acceptability of, sorbent trap monitoring systems used to monitor total vapor-phase (gas-phase elemental and oxidized) Hg emissions in stationary source flue gas streams.
- These monitoring systems involve continuous repetitive in-stack sampling using paired sorbent media traps with periodic analysis of the time-integrated samples.
- The Hg monitoring system must be capable of measuring the total concentration of vapor phase Hg (regardless of speciation), in units of µg/dscm.
- These procedures are only intended for use under relatively low particulate conditions (e.g., monitoring after all pollution control devices).

EPA 163

PS-12B Overview 2

- Known volumes of flue gas are continuously extracted through paired, in-stack, pre-spiked sorbent media traps at appropriate nominal flow rates.
- Must use expected Hg concentration to determine sample flow rate and sorbent tube spike mass.
- The sorbent traps in the sampling system are periodically exchanged with new ones, prepared for analysis as needed, and analyzed by any technique that can meet the performance criteria.
- For QA purposes, a section of each sorbent trap is spiked with HgO_x prior to sampling.

Following sampling, this section is analyzed separately, and a specified minimum percentage of the spike must be recovered. Paired train sampling is required to determine method precision.

EPA 164

PS-12B Relative Accuracy and Reference Methods

- For initial certification of a sorbent trap monitoring system, an RA test is required.
- Sorbent trap used in RA must be same type material as used in daily operation.
- Use 12 sampling points according to method 1.
- The RA of the sorbent trap monitoring system must be <20% of the mean value of the RM test data in terms of units of µg/scm.
  - Alternatively, if the RM concentration is $\leq$5.0 µg/scm, then the RA results are acceptable if the absolute difference between the means of the RM and sorbent trap monitoring system values <1.0 µg/scm.

EPA 165

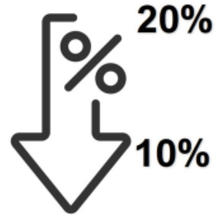
Quality Assurance/Quality Control Criteria for Sorbent Trap Monitoring Systems

Pre-test Leak Check	Post-test Leak Check	Ratio Of Stack Gas Flow Rate To Sample Flow Rate
< 4% of target sampling rate	< 4% of average sampling rate	<5% of the hourly ratios or 5 hourly ratios (whichever is less restrictive) may deviate from the reference ratio by more than ±25%.

EPA 166

Relative Deviation, Quality Assurance/Quality Control

- Paired sorbent trap agreement:
  - ≤10% Relative Deviation (RD) if the average concentration is > 1.0 µg/m3
  - ≤20% RD if the average concentration is ≤1.0 µg/m3 or if absolute difference between concentrations from paired traps is ≤ 0.03 µg/m3.



EPA 167

Quality Assurance/Quality Control

- Spike recovery study: average recovery between 85% and 115% for each of the three spike concentration levels.
- Multipoint analyzer calibration: each analyzer reading within ±10% of true value and $r^2 \geq 0.99$.
- Analysis of independent calibration standard: within ±10% of true value.
- Spike recovery from section 3 of both sorbent traps: 75-125% of spike amount.

EPA 168

Quality Assurance/Quality Control (Cont'd)

To validate sorbent trap monitoring system data, the acceptance criteria for the following five QC specifications must be met for both traps:

- Post-monitoring leak check
- Ratio of stack gas flow rate to sample flow rate
- Section 2 breakthrough
- Paired trap agreement
- Section 3 spike recovery

NOTE: To validate an RA test run, both traps must meet the acceptance criteria for all five QC specifications.

Must perform ongoing QA according to requirements of 40 CFR 60, Appendix F, Procedure 5 (See slides under PS-12A for more information).

EPA 169

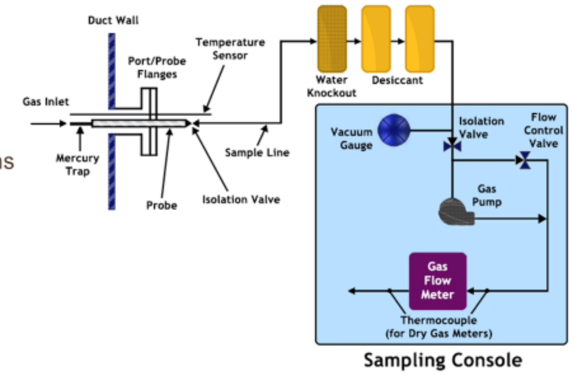
Common Technology

- Stack exhaust is sampled through a sorbent trap system which collects the gaseous elemental and oxidized Hg on the sorbent media.
- Sorbent traps are sent to the lab, where the Hg sample is extracted from the stack and analyzed using atomic fluorescence spectroscopy to measure the concentration of Hg vapor in the sample.
    - When a Hg atom absorbs the energy from a specific UV wavelength, an electron transitions from a stable ground state to an unstable, excited state, and when the UV energy source is removed, the electron returns to its stable state and emits a photon of light.

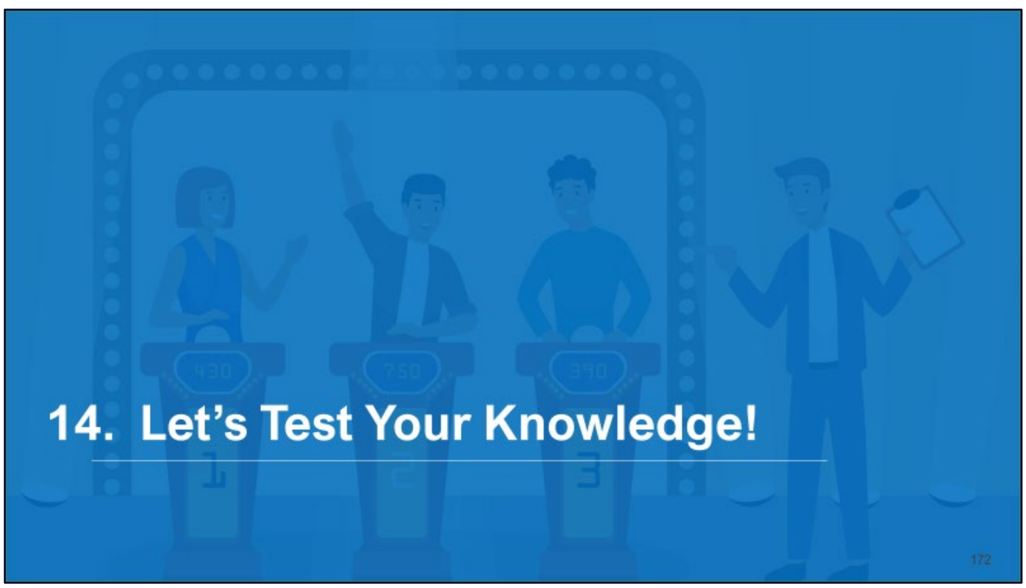
EPA 170

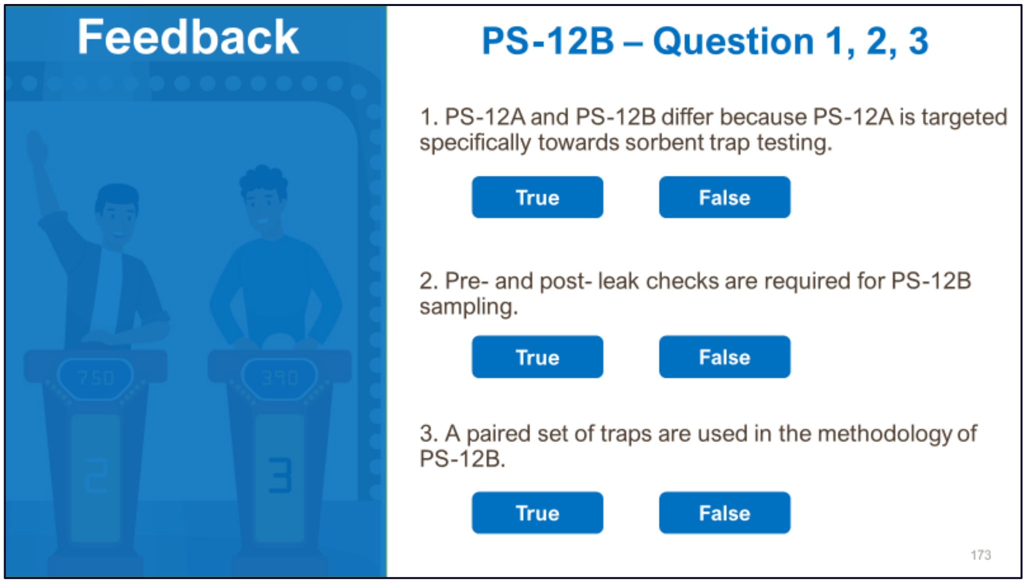
Sorbent Trap Monitoring System Background

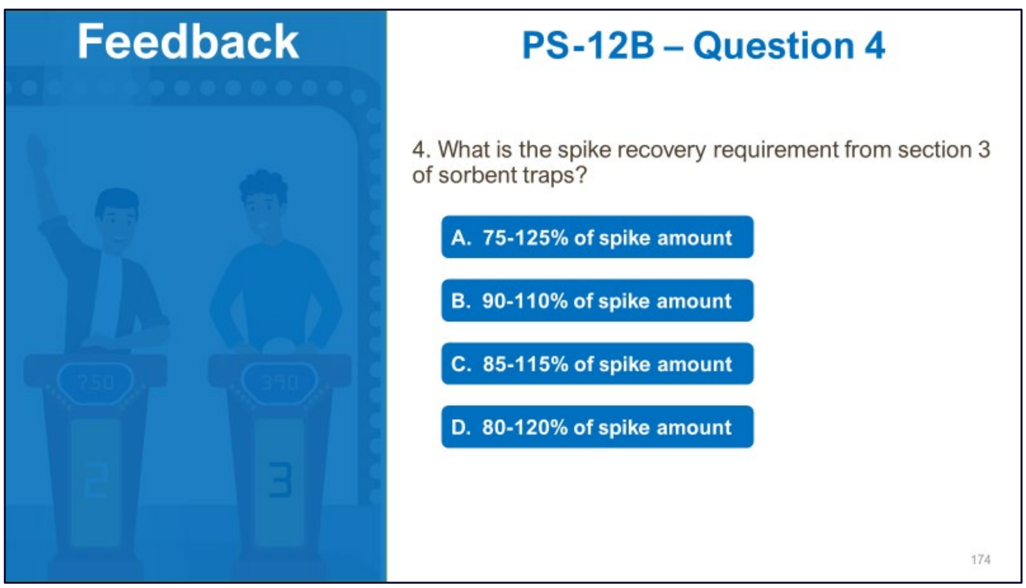
- Integrated sample measures total gaseous Hg
- For post-PM control locations
- Paired traps, in-stack with 3 sections
- Proportional sampling



171




Feedback
PS-12B – Question 1, 2, 3
1. PS-12A and PS-12B differ because PS-12A is targeted specifically towards sorbent trap testing.
True
False
2. Pre- and post- leak checks are required for PS-12B sampling.
True
False
3. A paired set of traps are used in the methodology of PS-12B.
True
False
173


Feedback
PS-12B – Question 4
4. What is the spike recovery requirement from section 3 of sorbent traps?
A. 75-125% of spike amount
B. 90-110% of spike amount
C. 85-115% of spike amount
D. 80-120% of spike amount
174

Performance Specification 15 (PS-15)

Specifications and Test Procedures for Extractive Fourier Transform Infrared (FTIR) Continuous Emission Monitoring Systems (CEMS) in Stationary Sources

EPA 175

PS-15 Overview

- PS-15 provides for measuring all hazardous air pollutants (HAPs), as well as volatile organic and inorganic species which absorb in the IR region and can be quantified using FTIR.
- Must meet performance criteria for each regulated pollutant and measure in the mid-IR spectral region to use FTIR system as a CEMS.
- Sample concentration expressed as the concentration-path length product, ppm (molar) concentration multiplied by the path length of the FTIR gas cell.

EPA 176

What is Fourier Transform Infrared ?

- FTIR is an analytical technique used to obtain an IR spectrum of absorption or emission of a gas.
- An FTIR spectrometer simultaneously collects high-spectral-resolution data over a *wide spectral range*. A fourier transform (a mathematical process) is required to convert the raw data into the actual spectrum which is compared to a library of spectra to find a match.

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EPA 177

Fourier Transform Infrared System Requirements

- FTIR CEMS must be equipped with reference spectra bracketing the range of path length-concentrations (absorbance intensities) to be measured for each analyte.
- The optical configuration of the FTIR system must be such that maximum absorbance of any target analyte is no greater than 1.0.
- Additionally, the minimum absorbance of any target analyte must be at least 10 times the root mean square deviation (RMSD) noise in the analytical region.
- Analytical package must:
  - Include data stored to write-protected medium
  - Store one interferogram per hour
  - Include all absorbance spectra, as well as all background spectra and interferograms
  - Include all calibration transfer standard (CTS) spectra and interferograms

EPA 178

Quality Assurance/Quality Control

Periodic Quarterly or Semiannual QA/QC Checks include:

- Audit Sample- Unknown target analyte(s) analyzed by a CEMS operator.
- Audit Spectra- Analytical results must be within ±5% of the certified audit concentration for each analyte (plus the uncertainty in the audit concentration).
  - Only tests the analytical program of FTIR CEMS

Independent Analysis of Spectra by EPA

- Submit three representative absorbance spectra
- Corresponding CTS spectra
- Corresponding background spectra and interferograms
- Spectra of associated spiked samples
- Analytical results for the sample spectra

EPA 179

Calibration and Standardization

Calibration and standardization includes:

CTS	Analyte Calibration
System Calibration	Analyte Spike

EPA 180

Analytical Procedure

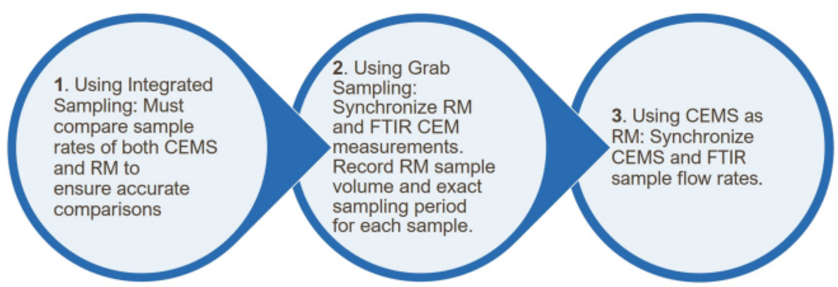
- **Initial Certification** - Perform evaluation procedures in section 6.0 FTIR Protocol using either:
  - Method 301 validation procedures; or
  - Comparison to applicable RM

- **Validation** - Use EPA method 301. Procedures include spiking known concentrations of analytes and tracer gas (SF_6) while sampling source gas. 2 options include:
  1. FTIR CEMS analyzing spectra collected sequentially (Validation run consists of 24 independent results- 12 spiked and 12 unspiked)
  2. FTIR CEMS operating side by side (Validation run consists of 24 independent results- 12 spiked and 12 unspiked)

- **Compare to a RM**. Perform 9 runs of at least 30 minutes consisting of at least 5 independent FTIR CEM samples.

EPA 181

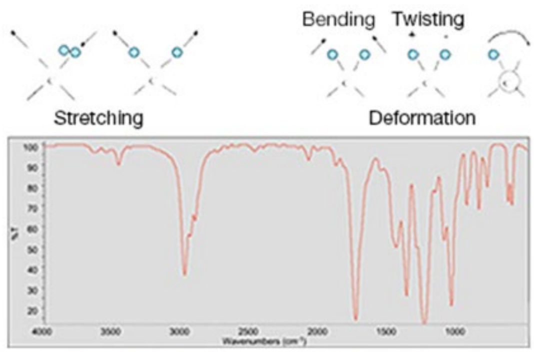
Analytical Procedure – 3 Methods



NOTE: For all three methods, use equations in PS-2 for RA determinations.

EPA 182

Absorbance Spectrum Measured by Fourier Transform Infrared



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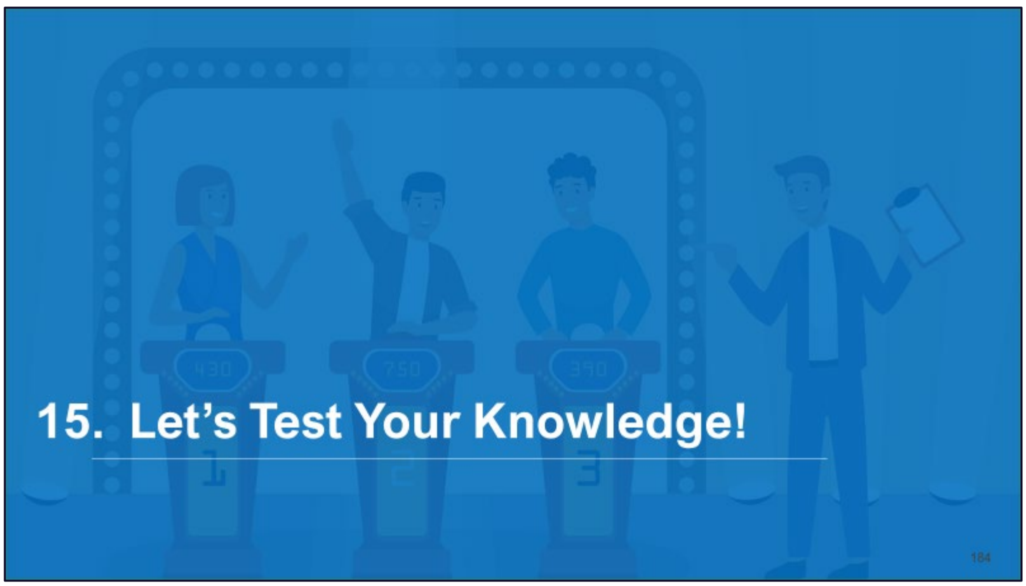
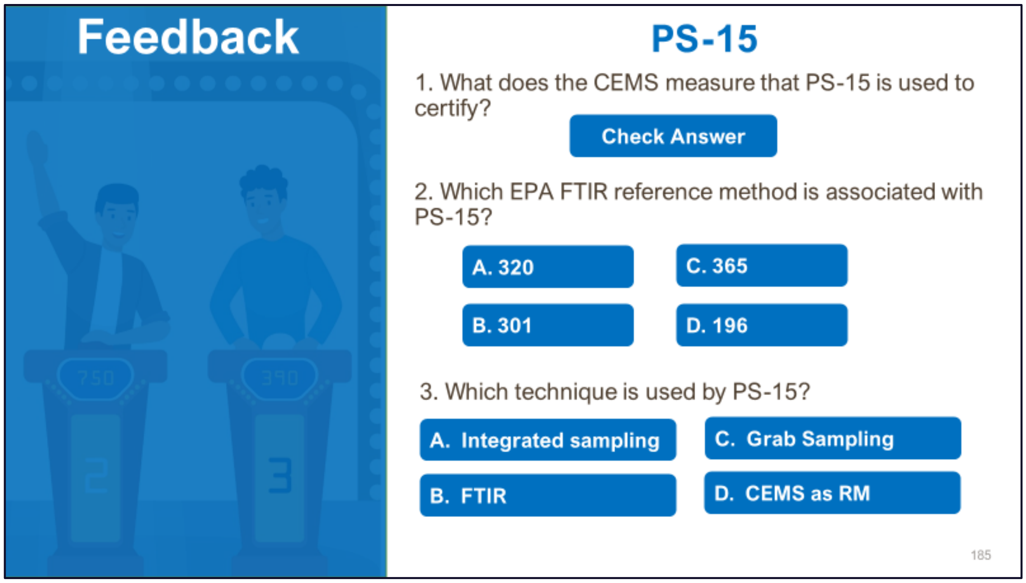
https://www.thermofisher.com/us/en/home/industrial/spectroscopy-elemental-isotope-analysis/spectroscopy-elemental-isotope-analysis-learning-center/molecular-spectroscopy-information/ftir-information/ftir-basics.html

EPA 183




Feedback
PS-15
1. What does the CEMS measure that PS-15 is used to certify?
Check Answer
2. Which EPA FTIR reference method is associated with PS-15?
A. 320
C. 365
B. 301
D. 196
3. Which technique is used by PS-15?
A. Integrated sampling
C. Grab Sampling
B. FTIR
D. CEMS as RM
185


Performance Specification 16 (PS-16)
Specifications and Test Procedures for Predictive Emission Monitoring Systems (PEMS) in Stationary Sources
EPA
186

What is a PEMS?

- PEMS refers to all the equipment that is required to predict an emission concentration or emission rate.
- Unlike a CEMS which uses sampling and analytical equipment to directly measure specific pollutant concentrations, a PEMS uses the continuous measurement of selected plant parameters and plant operating conditions with a software-based system of mathematical models to determine the pollutant emissions.

EPA 187

PS-16 Overview

- Applies to PEMS that are installed under 40 CFR 60, 61, and 63 after the effective date of the PS
- Must include a minimum of 3 variables to qualify as a PEMS
- PS-16 is used for determining whether a PEMS is acceptable for use in demonstrating compliance with applicable requirements.
- Certify a PEMS after initial installation and periodically thereafter to ensure the PEMS is operating properly.

EPA 188

PS-16 Overview (Cont'd)

Initial Certification: Must pass RA and statistical test to be acceptable for use in demonstrating compliance with applicable requirements

- Excess Emissions PEMS- minimum of 9 runs in total, 3-level RA test
- Compliance PEMS- minimum of 27 runs in total, 3-level RA test

Periodic QA Assessments: Owners and operators of all PEMS are required to conduct quarterly RAA and yearly RATA to assess ongoing PEMS operation.

EPA 189

Initial Certification

- RA must be <10% if PEMS measures >100 ppm or 0.2 lbs/mmBtu.
- RA must be <20% if PEMS measures <100 ppm (0.2 lb/mmbtu) and >10 ppm (0.02 lb/mmbtu).
- RA if PEMS measures < 10 ppm, the absolute mean difference between the PEMS measurements and the RM measurements must not exceed 2 ppm (0.01 lb/mmbtu).
- For diluent PEMS, an alternative criterion of ±1% absolute difference between the PEMS and RM may be used if less stringent.

EPA 190

Initial Certification (Cont'd)

- Must be performed at 3 load levels:
  - Low load (between minimum stable load and 50%)
  - Mid load (50 to 80%)
  - High load (80 to 100%)
- Bias Correction: If average difference < absolute value of confidence coefficient, no correction factor is needed.
- PEMS Training: If $F_{critical} \geq Fr \geq 0.8$, optional after initial and subsequent RATAs.
- Annual RATA testing must be performed at normal load.

EPA 191

Ongoing Quality Assurance Tests

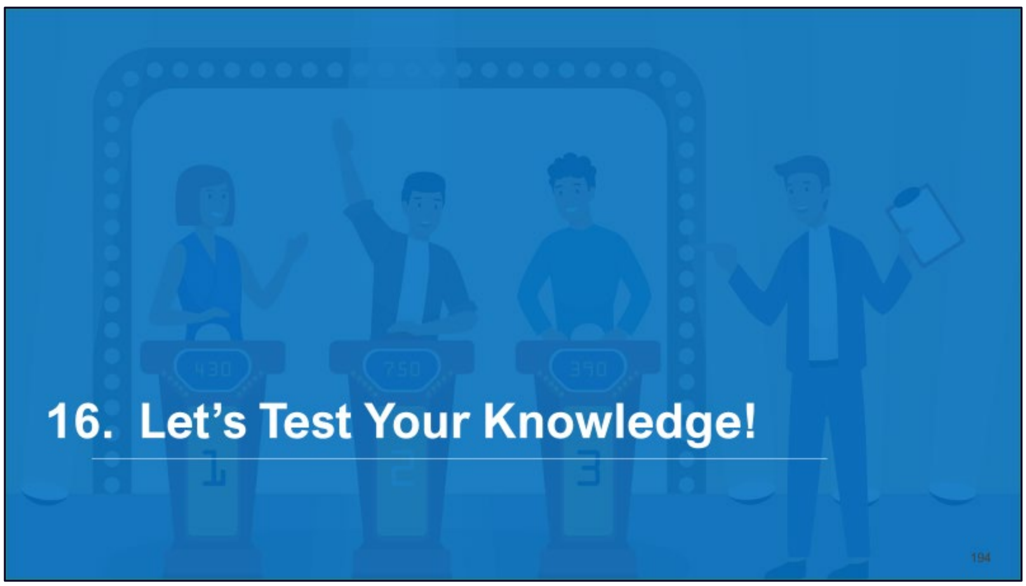
- Quarterly RAA
  - May use portable analyzer (must meet ASTM D6522-00) or RM testing
  - Three 30-minute test runs
- First year, a RAA must be performed in **3 of the 4 quarters**.
  - If all three pass, and the 2nd year RATA passes, then only a semi-annual RAA may be required.
  - If, at anytime, either a RAA or RATA test fails then quarterly RAAs must resume.

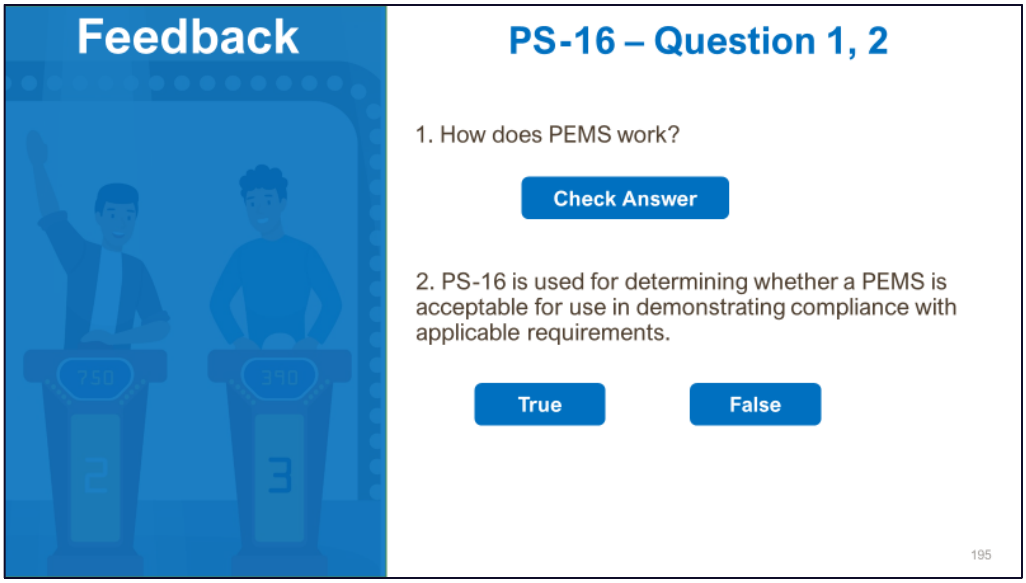
EPA 192

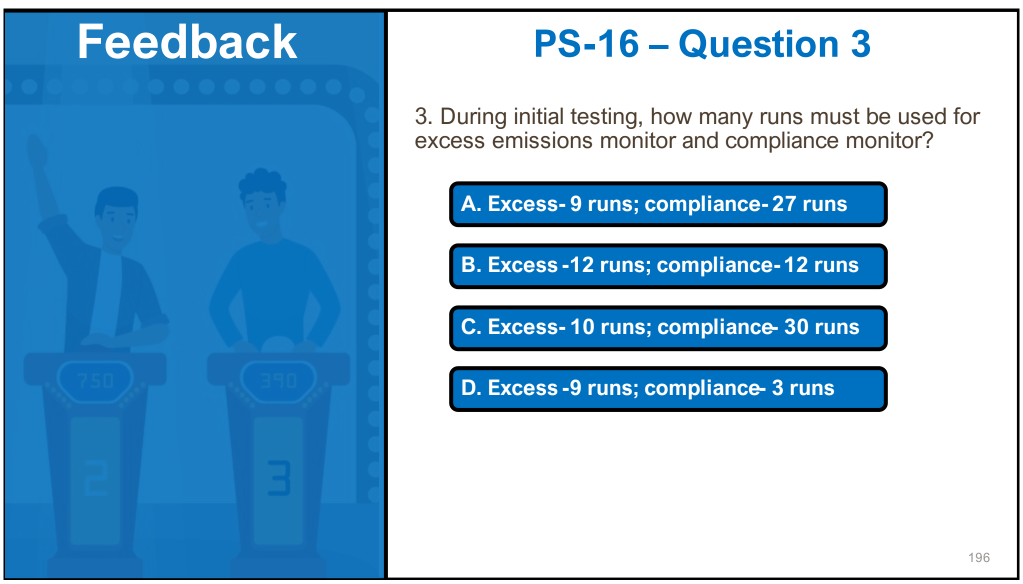
Ongoing Quality Assurance Tests (Cont'd)

Test	PEMS Regulatory Purpose	Acceptability	Frequency
Sensor Evaluation	All		Daily
RAA	All	3-test avg ≤10% of Simultaneous analyzer or RM average	Each quarter except quarter when RATA performed
Bias Correction	All	If davg ≥ |cc|	Bias test passed (no correction factor needed)
PEMS Training	All	If Fcritical ≥Fr≥0.8	Optional after initial and subsequent RATAs
Sensor Evaluation Alert Test (optional)	All	See Section 6.1.8	After each PEMS training

193




Feedback
PS-16 – Question 1, 2
1. How does PEMS work?
Check Answer
2. PS-16 is used for determining whether a PEMS is acceptable for use in demonstrating compliance with applicable requirements.
True
False
195


Feedback
PS-16 – Question 3
3. During initial testing, how many runs must be used for excess emissions monitor and compliance monitor?
A. Excess- 9 runs; compliance- 27 runs
B. Excess -12 runs; compliance- 12 runs
C. Excess- 10 runs; compliance- 30 runs
D. Excess -9 runs; compliance- 3 runs
196

Performance Specification 18 (PS-18)

Specifications and Test Procedures for Gaseous Hydrogen Chloride (HCl) Continuous Emission Monitoring Systems (CEMS) in Stationary Sources

EPA 197

PS-18 Overview

- Evaluate the acceptability of HCl CEMS at the time of installation or soon after and whenever specified in the regulations.
- Requirements for initial acceptance including instrument accuracy and stability assessments and use of audit samples if they are available.
- Must report or convert HCl concentration in units of the existing standard.
- Substantive changes require retesting like:
  - Major changes in dilution ratio
  - Changes in sampling conditioning and transport
  - Changes in probe design
  - Changes in materials of construction

NOTE: Extended performance assessment requirements found in App. F, Procedure 6.

EPA 198

Interference Test

- Interference response(s) must not be >2.5% of the calibration span or ±3.0% of the equivalent HCl concentration used for the interference test (whichever is less restrictive), or
- The sum of the interference response(s) does not exceed six times the level of detection (LOD) or 0.5 ppmv for a calibration span of 5 to 10 ppm, or 0.2 ppmv for a calibration span of less than 5 ppmv.

EPA 199

Beam Intensity and Temperature Verification

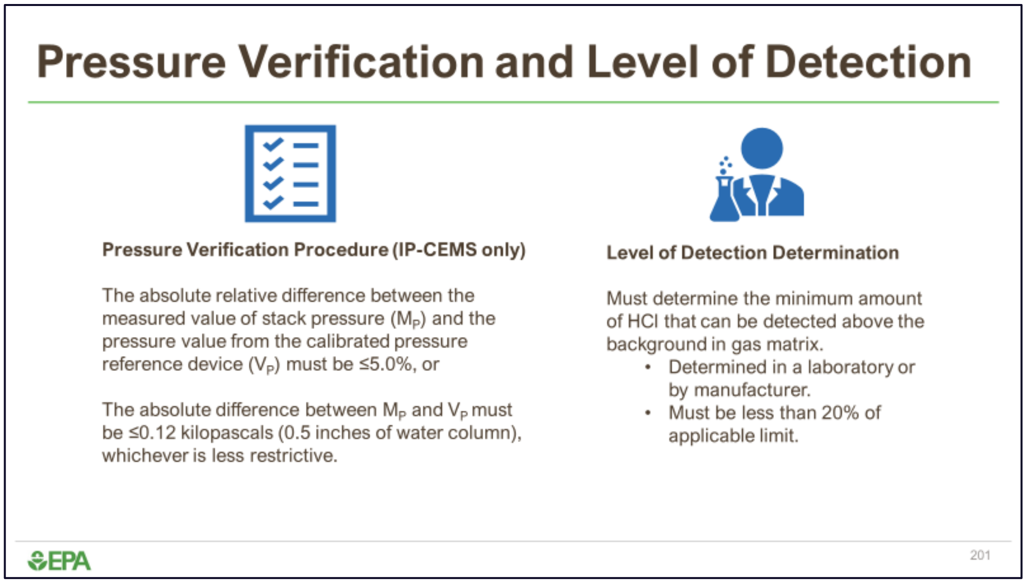
Beam Intensity Test (Integrated Path (IP-CEMS only)

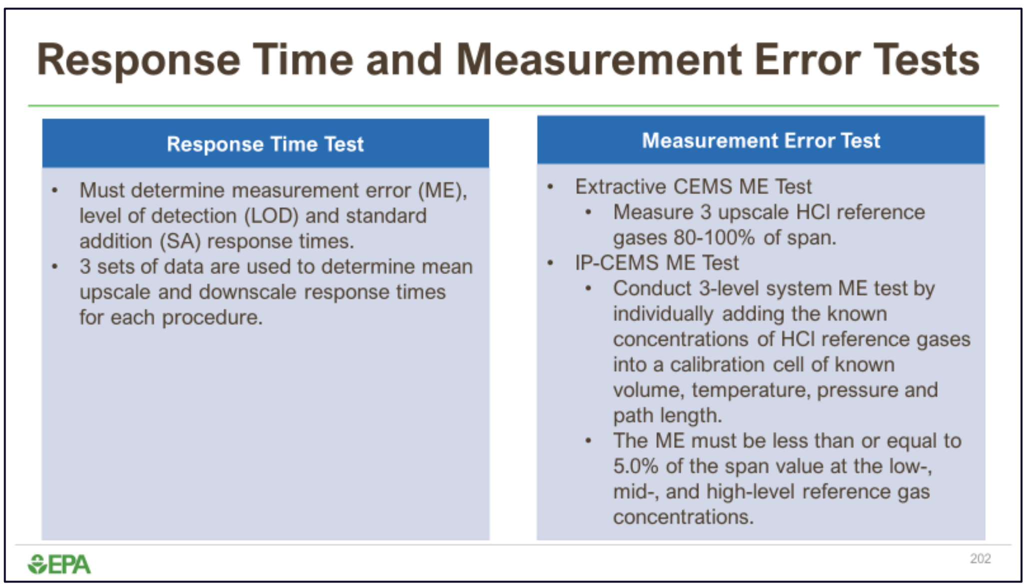
- The % difference between the measured concentration with and without attenuation of the light source must not exceed ±3.0%.

Temperature Verification Procedure (IP-CEMS only)

- The absolute relative difference between measured value of stack temperature (M_t) and the temperature value from the calibrated temperature reference device (V_t) is ≤1.0%, or
- The absolute difference between M_t and V_t is ≤2.8°C (5.0°F), whichever is less restrictive.

EPA 200


Pressure Verification and Level of Detection
Pressure Verification Procedure (IP-CEMS only)
The absolute relative difference between the measured value of stack pressure (M_P) and the pressure value from the calibrated pressure reference device (V_P) must be ≤5.0%, or
The absolute difference between M_P and V_P must be ≤0.12 kilopascals (0.5 inches of water column), whichever is less restrictive.
Level of Detection Determination
Must determine the minimum amount of HCl that can be detected above the background in gas matrix.
• Determined in a laboratory or by manufacturer.
• Must be less than 20% of applicable limit.
EPA
201


Response Time and Measurement Error Tests
Response Time Test
• Must determine measurement error (ME), level of detection (LOD) and standard addition (SA) response times.
• 3 sets of data are used to determine mean upscale and downscale response times for each procedure.
Measurement Error Test
• Extractive CEMS ME Test
• Measure 3 upscale HCl reference gases 80-100% of span.
• IP-CEMS ME Test
• Conduct 3-level system ME test by individually adding the known concentrations of HCl reference gases into a calibration cell of known volume, temperature, pressure and path length.
• The ME must be less than or equal to 5.0% of the span value at the low-, mid-, and high-level reference gas concentrations.
EPA
202

PS-18 Calibration Drift and Relative Accuracy

7-Day Calibration Drift Test

- Must complete before RA tests.
  - Determine magnitude of CD at 24-hour intervals for 7 consecutive operating days, not necessarily 7 calendar days.

Relative Accuracy

- Must be established against RM 26A, 320, 321, or ASTM D6348-12.
  - Conduct diluent, moisture, and pollutant measurements simultaneously.
  - Test at 12 points, 6 points, 3-point long line or, if a stratification test is passed, the 3-point short line.
  - Conduct a minimum of 9 RM runs.
  - RA must be < 20.0% of RM or < 15.0% of RM if average emission level is <75% of emission standard.

EPA 203

Quality Assurance Procedure 6

What are the basic functions of Procedure 6?

To ensure HCl CEMS data meets acceptable standards for determining compliance on an ongoing basis:

- Assessment of the quality of your HCl CEMS data
- Control and improvement of the quality of your HCl CEMS data by implementing QC requirements and corrective actions
- Specification of QC requirements

EPA 204

Procedure 6

- Requires that the CEMS is audited to assess the data accuracy
- Temperature and pressure measurement devices must be audited annually
- RATA must be conducted once every four calendar quarters
- If HCL concentration is < 20 % of the concentration equivalent to the applicable emission standard, you must perform a CGA or dynamic spiking at least one quarter. Otherwise RAA must be performed quarterly.

EPA 205

Procedure 6 (Cont'd)

- If CEMS is in-control for 8 consecutive quarters and emits ≤ 75 % of the concentration equivalent to the applicable standard, the auditing procedures may be revised to use CGA, RAA or dynamic spike audit (DSA) for 7 quarters before performing a RATA.
- At a reporting interval specified in the permit or applicable regulation; the results of the quarterly audits and annual accuracy audit results as well as the daily assessment results must be reported to the appropriate agency.

EPA 206

Commonly Used Technologies for PS-18

FTIR—refer to details for PS-15

Tunable diode laser (TDL) spectroscopy uses the absorbance spectra of target gases and the ability to tune the laser to a specific absorbance wavelength of the gas to measure the gas concentration. It can achieve very low detection limits (ppb), and it is also possible to determine the temperature, pressure, velocity and mass flux of the gas being measured. It is sometimes used as the light source in cavity ring-down spectroscopy (CRDS) (see details regarding this technology on the next slide).

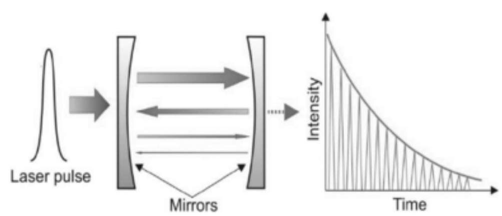
EPA 207

Commonly Used Technologies for PS-18 (Cont'd)

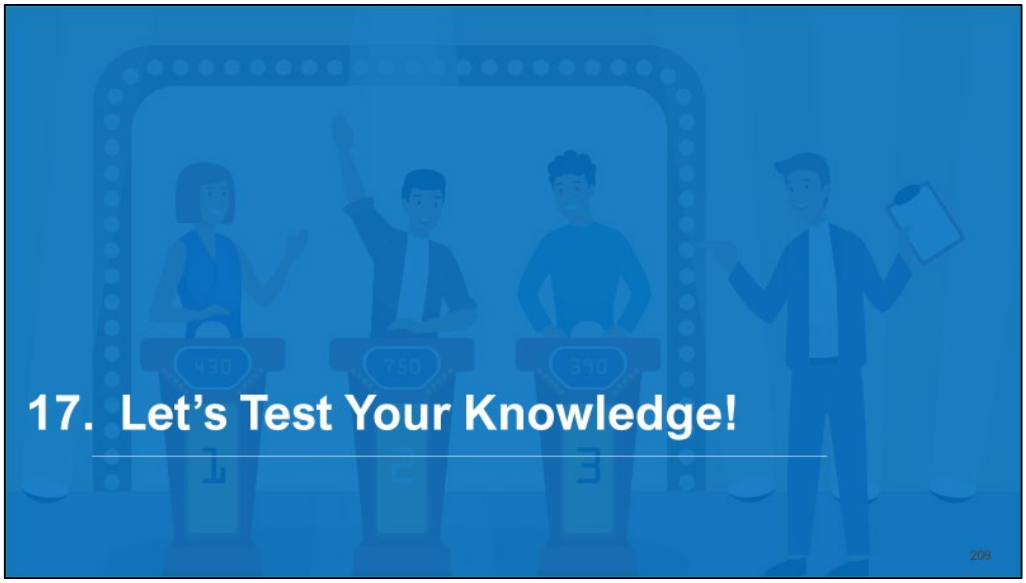
In CRDS, the beam from a single-frequency laser diode tuned to the absorbance of the gas being measured enters a cavity defined at least two high reflectivity mirrors with a path length in kilometers, making it extremely sensitive to very low concentrations of the target gas.

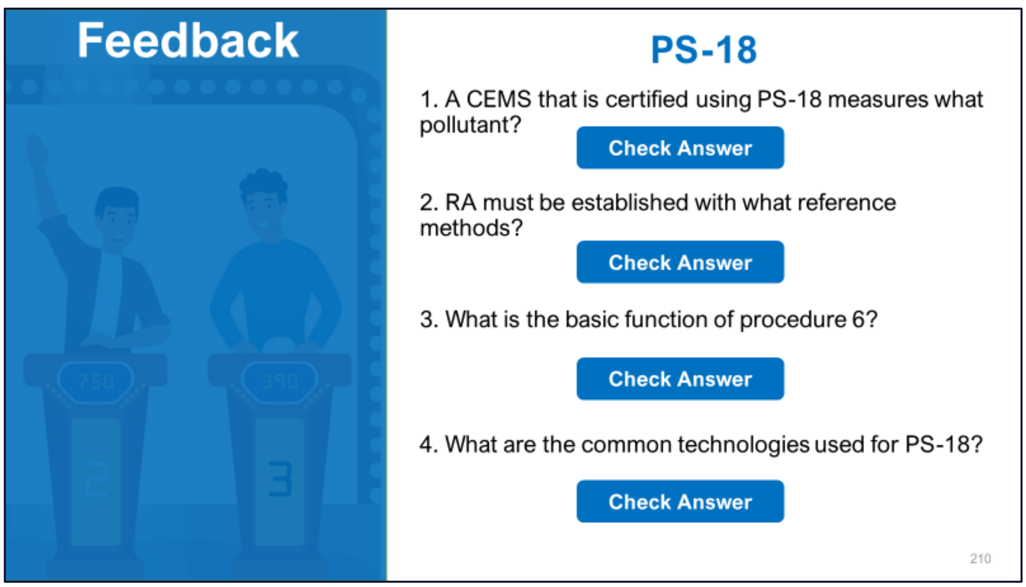
When the laser is on, the cavity quickly fills with reflected laser light.

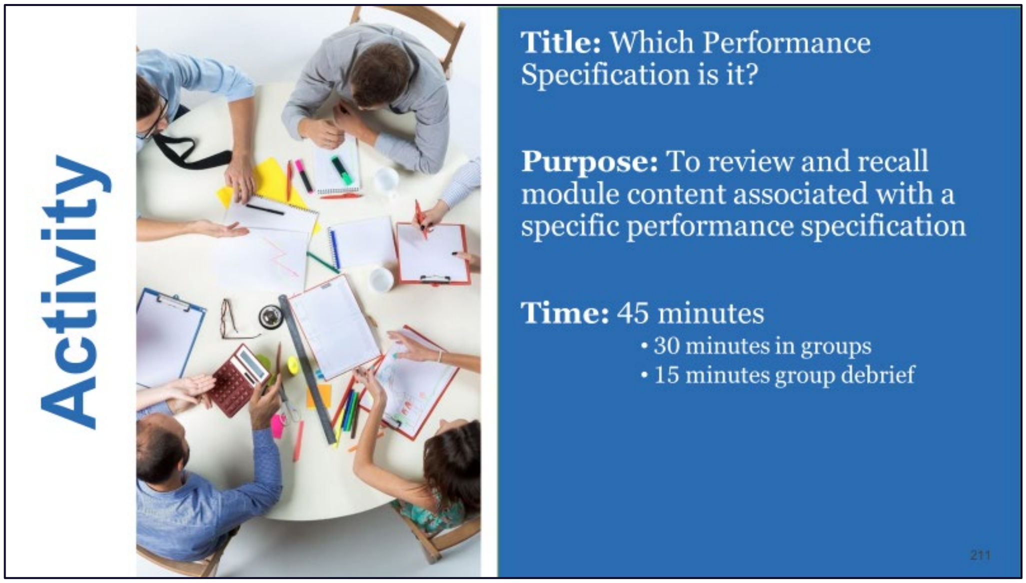
A photodetector senses the small amount of light leaking through one of the mirrors to produce a signal that is directly proportional to the intensity in the cavity.



EPA 208


17. Let's Test Your Knowledge!
209


Feedback
PS-18
1. A CEMS that is certified using PS-18 measures what pollutant?
Check Answer
2. RA must be established with what reference methods?
Check Answer
3. What is the basic function of procedure 6?
Check Answer
4. What are the common technologies used for PS-18?
Check Answer
210


Activity
Title: Which Performance Specification is it?
Purpose: To review and recall module content associated with a specific performance specification
Time: 45 minutes
• 30 minutes in groups
• 15 minutes group debrief
211


Activity Debrief
212

Module 3 Summary

Now that you have completed Module 3, you should be able to:

- Define key terms, such as calibration drift (CD), relative accuracy, span, etc.
- Compare performance specification (PS) and quality assurance (QA) procedures by pollutant, where relevant
- List relevant QA procedures by PS
- Provide examples of technologies that can be used for each PS
- Recognize why predictive emission monitoring systems (PEMS) performance specifications are different from others

EPA 213

MODULE 4: AUDITS/INSPECTIONS AND ENFORCEMENT

Module 4: Audits/Inspections and Enforcement

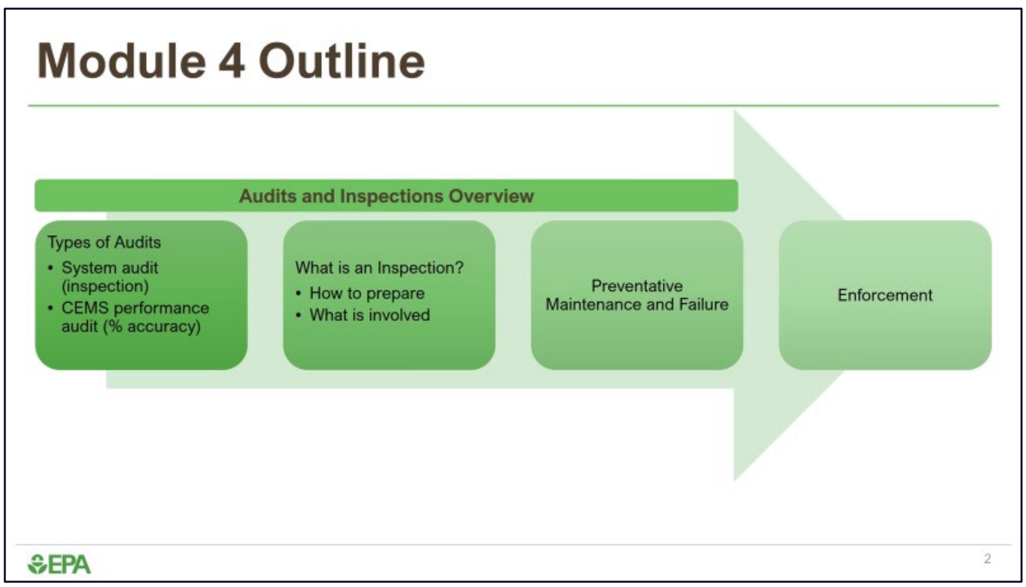
Module 4 Description:

In Module 4, you will be provided an overview of audits and inspections used for CMS. You will learn about the types of audits and what is involved in an inspection. In addition, you will learn about preventative maintenance and failure, as well as enforcement.

Module 4 Objectives:

- Distinguish the difference between performance audits and systems/field audits
- Explain the utility of performance audits and systems/field audits
- Describe the inspector's role during an audit
- Describe the procedures necessary to use CMS data in determining compliance
- Assess daily, weekly, monthly, quarterly, and annual required preventative maintenance and QA requirements
- Distinguish between CMS as compliance method and CMS data as credible evidence


Module 4:
Audits/Inspections
and Enforcement


Module 4 Outline
Audits and Inspections Overview
Types of Audits
• System audit (inspection)
• CEMS performance audit (% accuracy)
What is an Inspection?
• How to prepare
• What is involved
Preventative Maintenance and Failure
Enforcement
EPA
2

Module 4 Learning Objectives

At the end of Module 4, learners will be able to:

- Distinguish the difference between performance audits and systems/field audits
- Explain the utility of performance audits and systems/field audits
- Describe the inspector's role during an audit
- Describe the procedures necessary to use CMS data in determining compliance
- Assess daily, weekly, monthly, quarterly, and annual required preventative maintenance and QA requirements
- Distinguish between CMS as compliance method and CMS data as credible evidence

EPA 3

Overview of Audits and Inspections

Performance Audit	System/Field Audit
• A quantitative evaluation, which includes things such as*: • Cylinder Gas Audit (CGA) • Relative Accuracy Test Audit (RATA) • Relative Accuracy Audit (RAA)	• Qualitative evaluation involving an inspection

*These elements are covered in Module 3

EPA 4

Performance and System Audits

EPA relies on a combination of **performance** and **system/field auditing** to verify overall data integrity.

Performance Audit Procedures

- Performance audit procedures are critical for verifying proper performance of the monitoring systems and identifying problems which may lead to inaccurate emissions accounting.

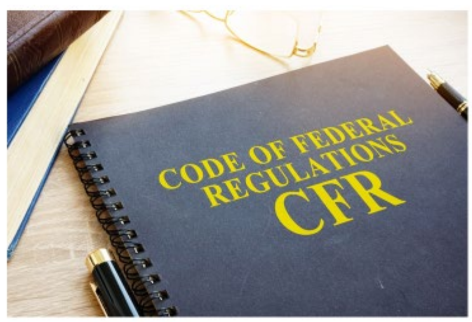
System or Field Audits

- System or field audits are an opportunity to provide information to the source on the regulatory requirements, and for the inspector to observe monitoring practices that may lead to regulatory problems.

EPA 5

Performance Audits

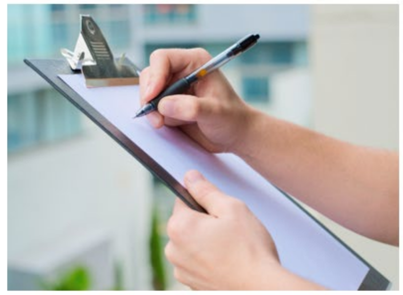
- Required by 40 CFR Part 60
- Found in performance specifications and QA procedures
- Include the daily, quarterly, and annual audit procedures
- Audit results usually submitted to agency for review



EPA 6

System/Field Audit or Inspection

- May be conducted in conjunction with a performance audit such as a RATA or RCA.
- Allows the observer to…
  - Physically inspect the CEMS,
  - Review the data collected, and
  - Review maintenance logs, etc.



Note: The audit procedures for Part 75 can be found here: https://www.epa.gov/airmarkets/field-audit-manual

EPA 7

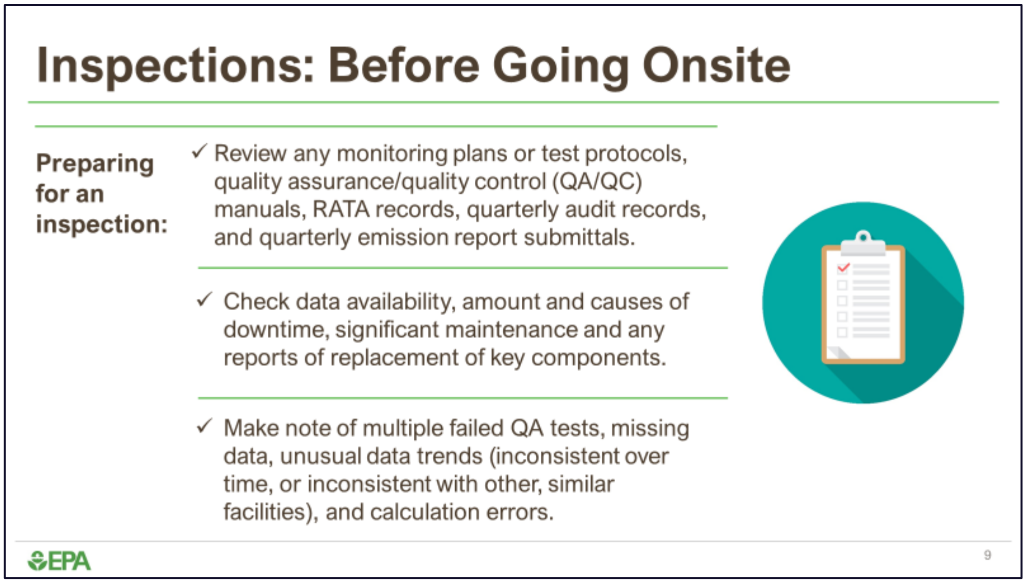
Inspector's Role in System/Field Audits

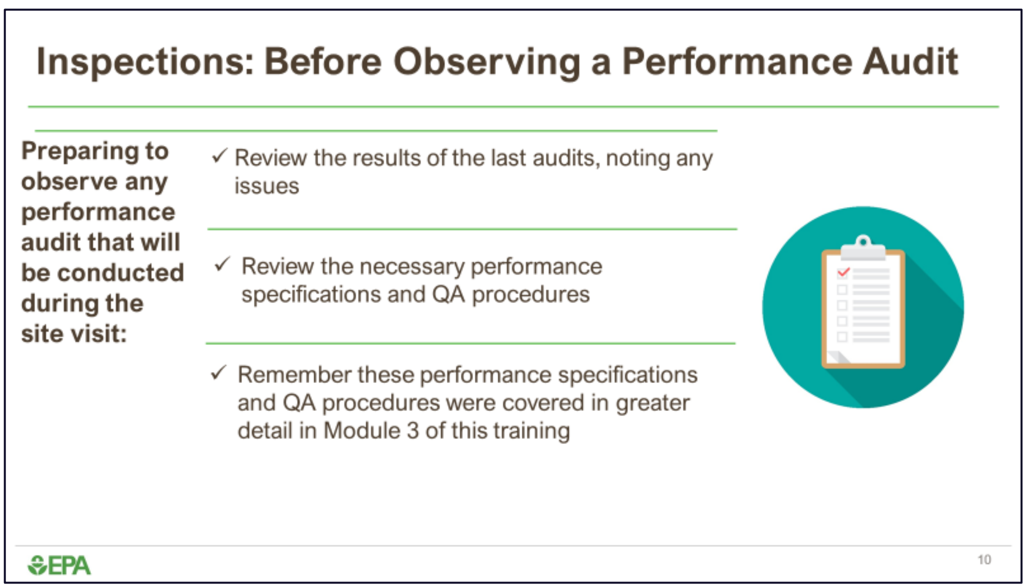
Every inspector should check with their agency to see exactly what their policies and procedures are before conducting an audit.

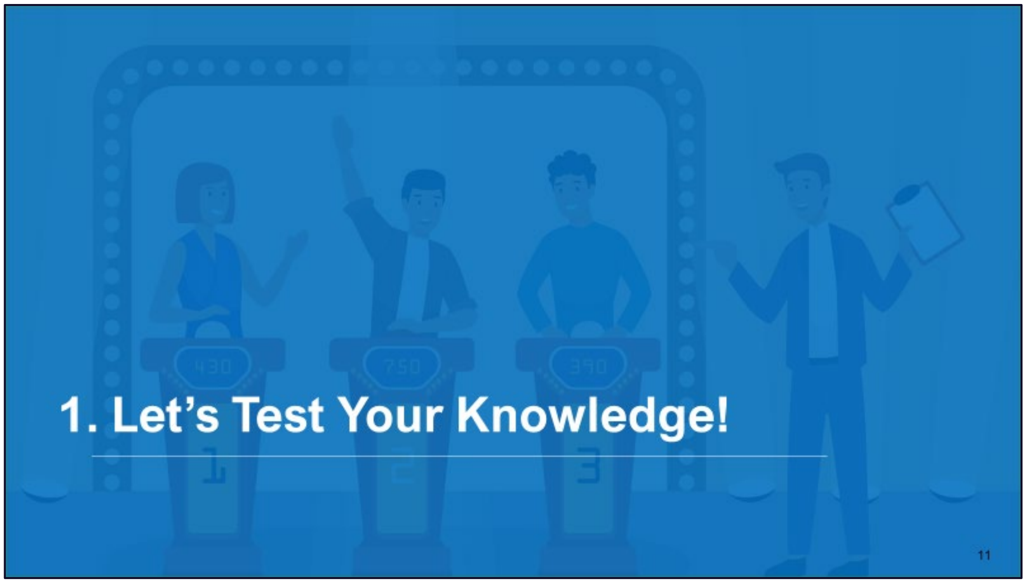
Typically, the inspector's role is not to provide technical advice or consulting on the operation of the monitoring equipment.

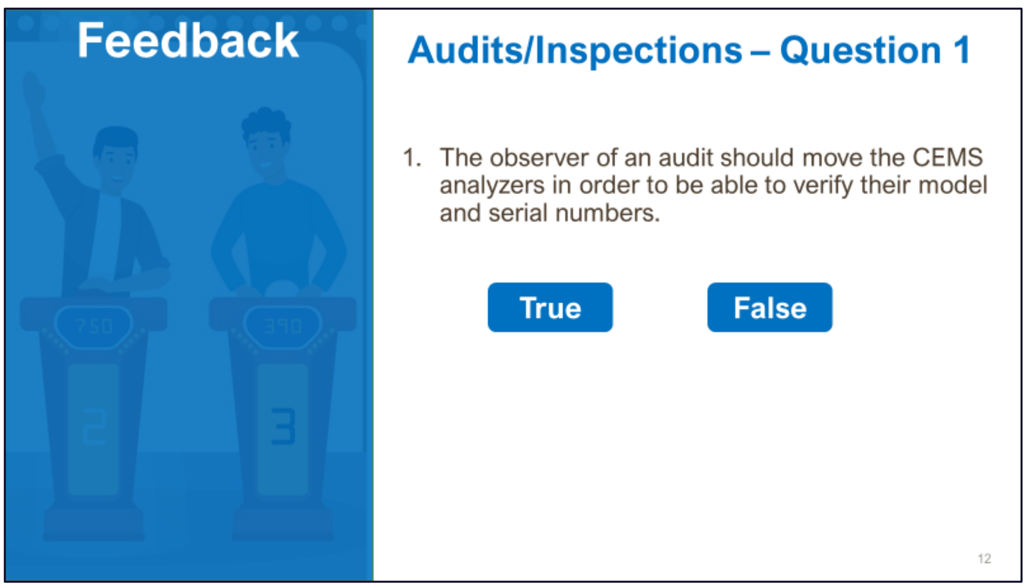
Usually a "hands off" approach is used when conducting the audit so that the inspector does not have any physical contact with the monitoring system hardware.

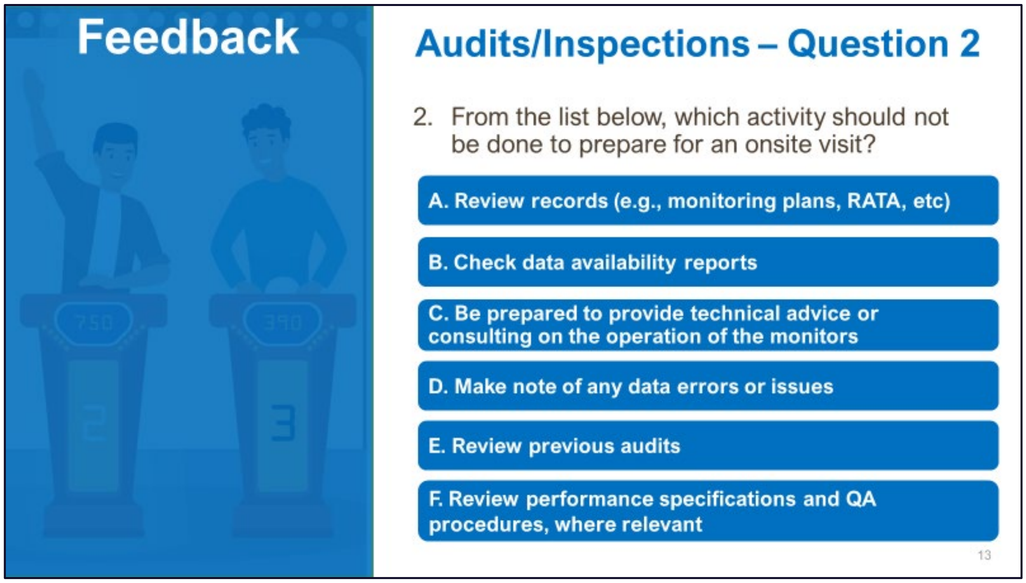
EPA 8

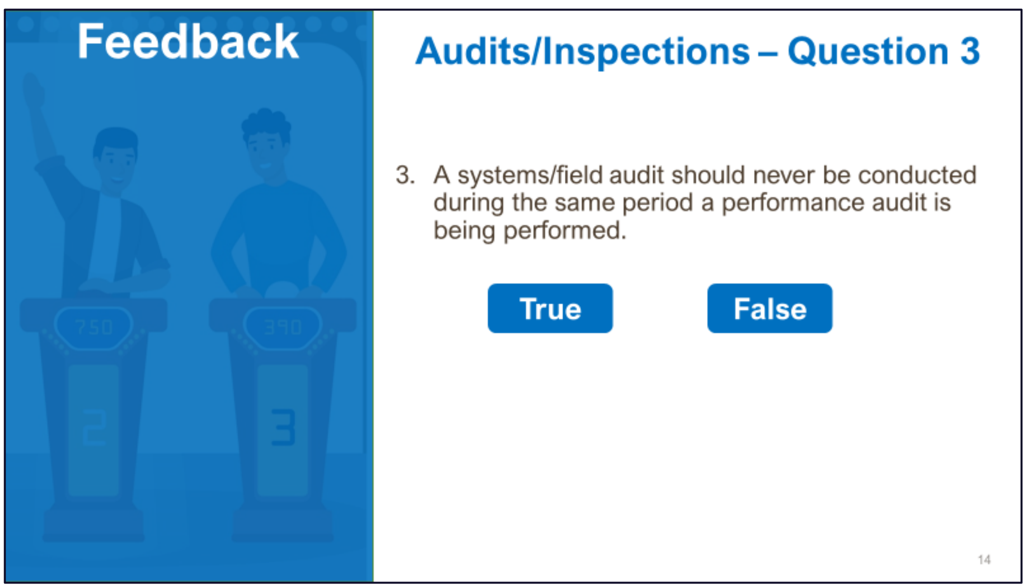

Inspections: Before Going Onsite
Preparing for an inspection:
✓ Review any monitoring plans or test protocols, quality assurance/quality control (QA/QC) manuals, RATA records, quarterly audit records, and quarterly emission report submittals.
✓ Check data availability, amount and causes of downtime, significant maintenance and any reports of replacement of key components.
✓ Make note of multiple failed QA tests, missing data, unusual data trends (inconsistent over time, or inconsistent with other, similar facilities), and calculation errors.
EPA
9


Inspections: Before Observing a Performance Audit
Preparing to observe any performance audit that will be conducted during the site visit:
✓ Review the results of the last audits, noting any issues
✓ Review the necessary performance specifications and QA procedures
✓ Remember these performance specifications and QA procedures were covered in greater detail in Module 3 of this training
EPA
10


1. Let's Test Your Knowledge!
11


Feedback
Audits/Inspections – Question 1
1. The observer of an audit should move the CEMS analyzers in order to be able to verify their model and serial numbers.
True
False
12


Feedback
Audits/Inspections – Question 2
2. From the list below, which activity should not be done to prepare for an onsite visit?
A. Review records (e.g., monitoring plans, RATA, etc)
B. Check data availability reports
C. Be prepared to provide technical advice or consulting on the operation of the monitors
D. Make note of any data errors or issues
E. Review previous audits
F. Review performance specifications and QA procedures, where relevant
13


Feedback
Audits/Inspections – Question 3
3. A systems/field audit should never be conducted during the same period a performance audit is being performed.
True
False
14

Inspections Process – At the Facility

Verify:
- Calibration and audit gas used, and
- General appearance of analyzers and sampling system

Check:
- Check if any alarms or warnings are indicated on DAS screen or system panels

Review:
- Additionally, review maintenance logs and verify regular maintenance (daily, weekly, monthly) activities.
  - Compare with description of these activities in QA/QC manual
  - Note any frequent or reoccurring problems

EPA 15

Visual Inspection of the CEMS

If possible, do a visual inspection of the CEMS from the sample probe location on the stack or duct, following the sample line to the CEMS shelter, and continuing inside the shelter through the gas conditioning system (if source-level extractive) to the analyzers.

- ✓ Does the system look to be well maintained?
- ✓ Are there low spots in the sample line where moisture might collect and scrub out pollutants? If the facility experiences cold winters, are all parts of the sampling system heated?
- ✓ Is the physical location of the CEMS probe reasonable to access for maintenance?

EPA 16

Visual Inspection of the CEMS (Cont'd)

Inside the CEMS shelter, check the condition of the sample gas conditioning system for any condensed liquid in Teflon lines.

- ✓ Where does the liquid drain?
- ✓ Could it get blocked or freeze?
- ✓ Are there signs of corrosion of valves and fittings?

EPA 17

CEMS Shelter

EPA 18

Calibration Gas Cylinders

EPA 19

Pressure on Gas Cylinder

EPA 20

CEMS Inspection

EPA 21

Measurement of Emissions

CEMS must be representative:

When the effluents from two or more emission points are combined before being released to the atmosphere, the owner or operator:

- May install applicable continuous monitoring systems on each effluent or on the combined effluent, if subject to the same emission standards
- Must install separate continuous monitoring systems on each effluent, if not subject to the same emissions standard.

EPA 22

Measurement of Emissions (Cont'd)

When the effluent from one affected facility is released to the atmosphere through more than one point, the owner or operator shall install an applicable continuous monitoring system on each separate effluent unless the installation of fewer systems is approved by the administrator.

Results must be reported for each CEMS.

EPA 23

Who, What, Where, and Why

- Importance of a pre-test meeting
  - Who should be at the test…
  - What will happen…
  - Where is the meeting to be held…
  - Why is this meeting necessary, etc.…

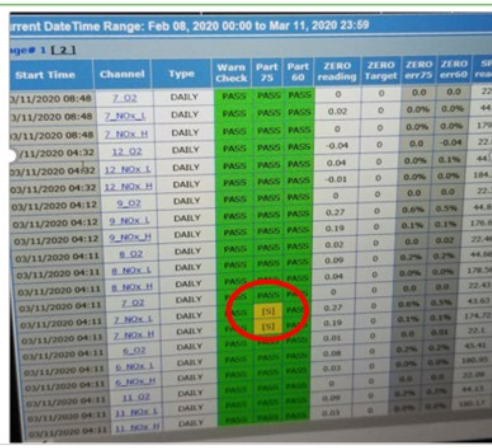
EPA 24

The Road to Continuous Compliance: Operation of CEMS

- Conduct Calibration Drift (CD) at least once per operating day: Zero and Span - New Source Performance Standards (NSPS)
- Must be in continuous operation. Except for system breakdowns, repairs, calibration checks, and zero and span adjustments. A “continuous operation” means a minimum of one cycle of operation (sampling, analyzing, and data recording) is completed or each successive 15-minute period.
- Maintain and operate the CEMS in a manner consistent with good air pollution control practices and manufacturer’s written specifications.
- Ensure the visual display or indication of operation is readily available on-site

EPA 25

Daily Data Readings



EPA 26

Road to Continuous Compliance Data Reduction

Data from CEMS shall be reduced to 1-hour averages of valid data as follows*:

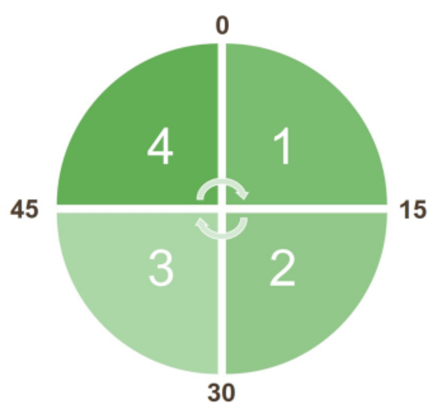
Operating Hour is a:	Valid Data Means:	What is excluded?
Full Hour (60 minutes of operation)	At least four data points – one data point in each 15-minutes quadrant of the hour	Unavoidable CMS breakdowns, out-of-control periods, repairs, maintenance periods, calibration checks, and zero (low-level) and high-level adjustments
Partial Hour (less than 60 minutes of operation)	At least one data point in each 15-minutes quadrant of the hour of operation	Same
Operating Hour with Maintenance or QA and the CMS operates:	Two or more quadrants of the hour - a minimum of two data points, separated by at least 15 minutes; One quadrant of the hour - at least one valid data point (not applicable for Part 63)	Same

*Note: the information presented here is aligned with the General Provisions and may vary by Subpart.

EPA 27

1-Hour Average Validation

….1-hour averages shall be computed as follows…for a full operating hour (any clock hour with 60 minutes of unit operation), at least four valid data points are required to calculate the hourly average, i.e., one data point in each of the 15-minute quadrants of the hour. [§ 60.13 (h)(1) & (h)(2)(i)]

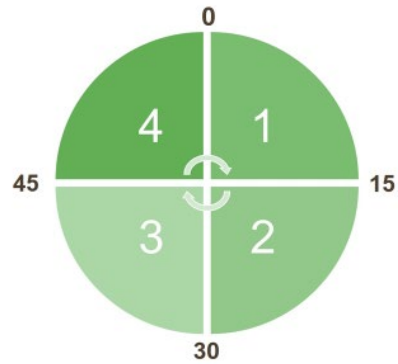


EPA 28

Hourly Validation Example

Minute	Value	Minute	Value	Minute	Value	Minute	Value
0	3	15	Invalid	30	2	45	2
1	4	16	Invalid	31	3	46	4
2	Invalid	17	Invalid	32	4	47	5
3	Invalid	18	Invalid	33	2	48	Invalid
4	Invalid	19	Invalid	34	3	49	Invalid
5	Invalid	20	Invalid	35	4	50	Invalid
6	Invalid	21	Invalid	36	4	51	5
7	Invalid	22	Invalid	37	5	52	4
8	Invalid	23	4	38	5	53	2
9	Invalid	24	4	39	Invalid	54	Invalid
10	Invalid	25	3	40	Invalid	55	Invalid
11	Invalid	26	3	41	Invalid	56	Invalid
12	Invalid	27	3	42	Invalid	57	Invalid
13	Invalid	28	2	43	Invalid	58	Invalid
14	Invalid	29	2	44	Invalid	59	Invalid

	No.		No.		No.		No.
Valid	2	Valid	7	Valid	9	Valid	6
Invalid	13	Invalid	8	Invalid	6	Invalid	9
Quadrant	Valid	Quadrant	Valid	Quadrant	Valid	Quadrant	Valid

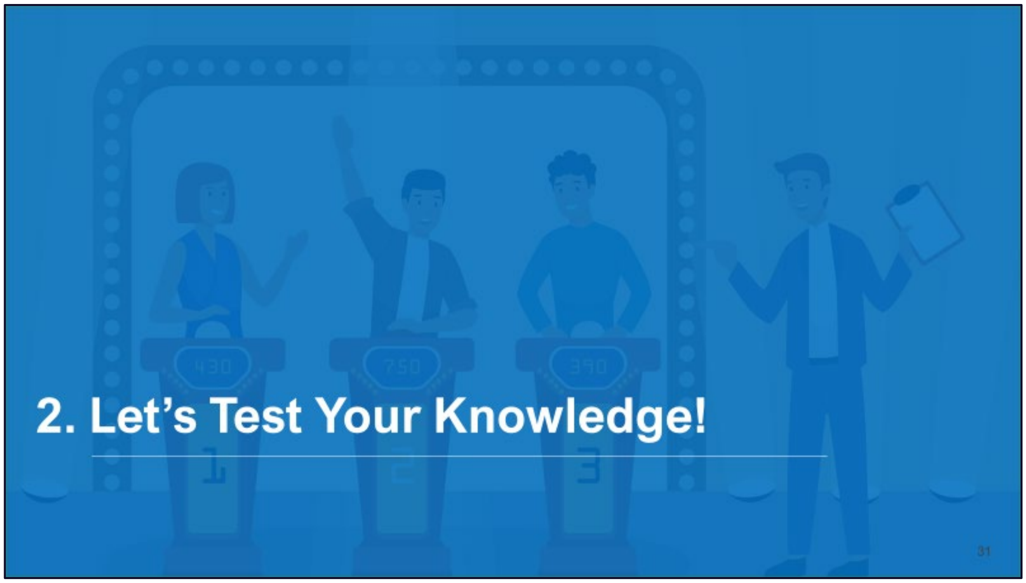


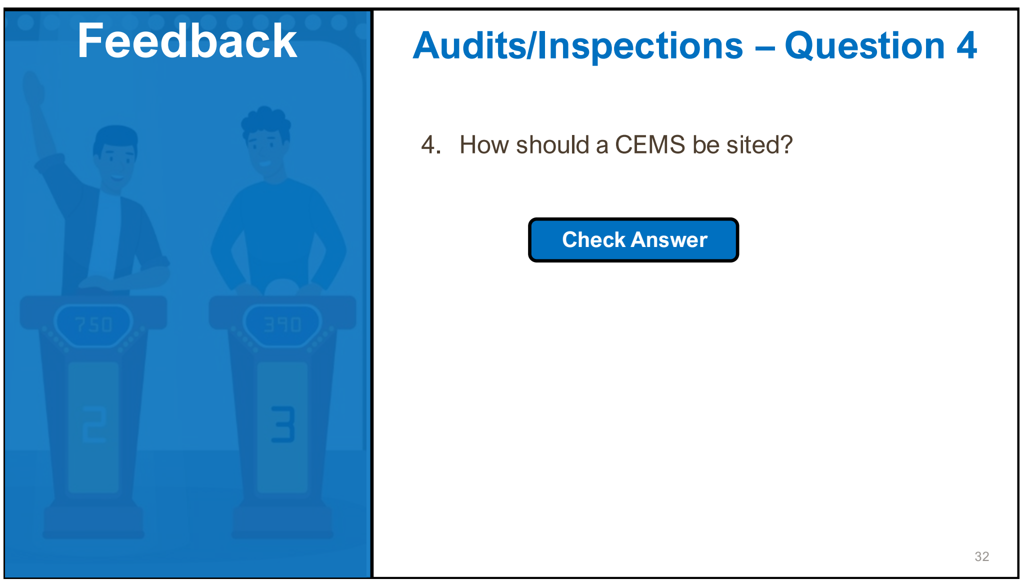
EPA 29

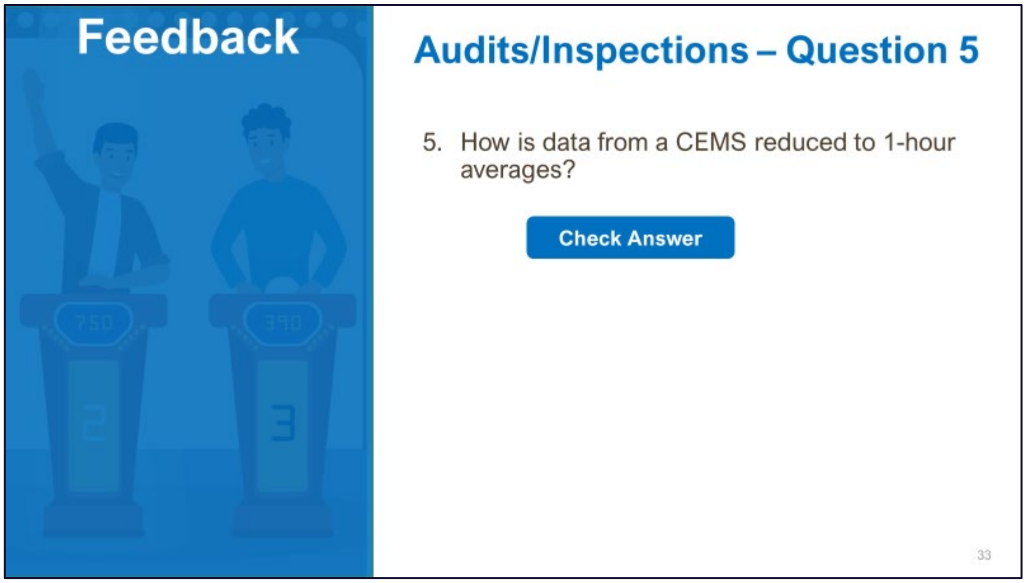
Preventative Maintenance Examples Handout

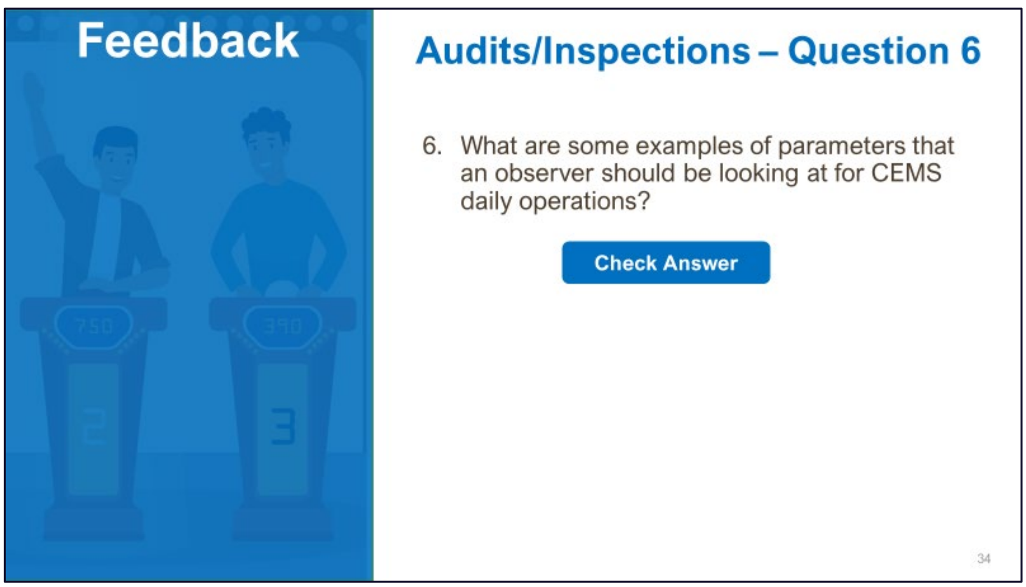
- Refer to the handout, "Daily, Weekly, Monthly, Quarterly, and Annual Preventative Maintenance Examples" in your participant guide.

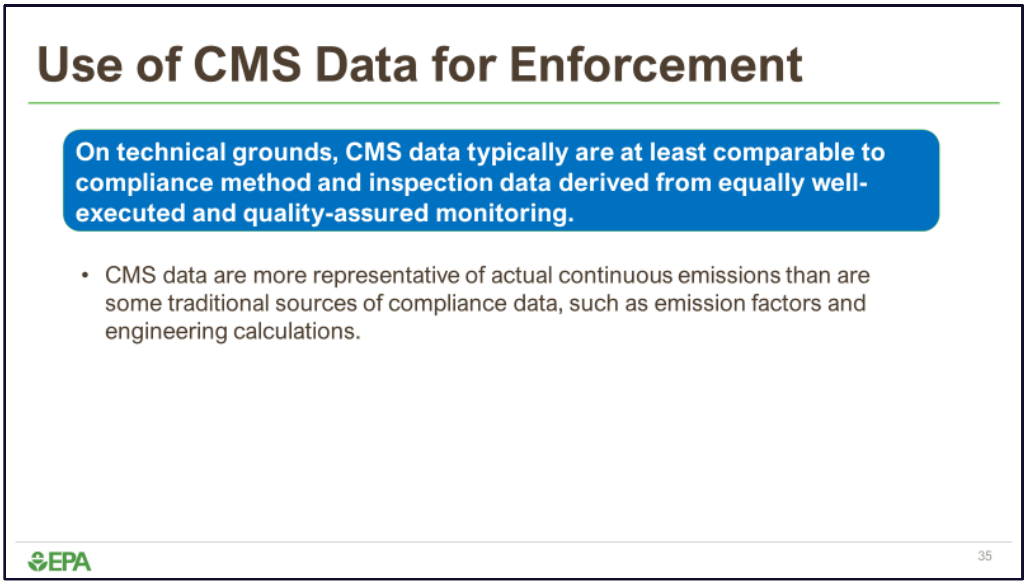
EPA 30

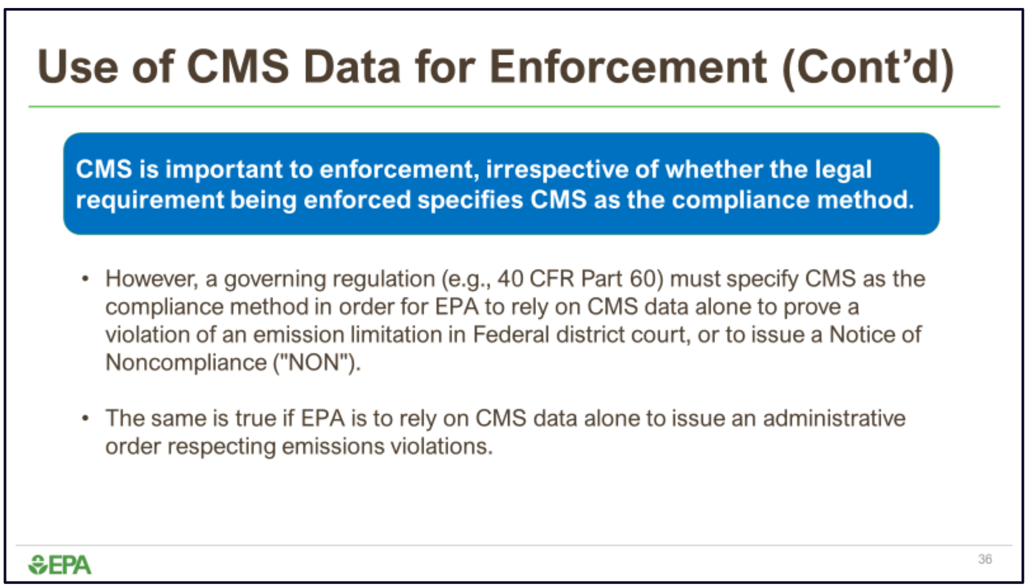

2. Let's Test Your Knowledge!
31


Feedback
Audits/Inspections – Question 4
4. How should a CEMS be sited?
Check Answer
32


Feedback
Audits/Inspections – Question 5
5. How is data from a CEMS reduced to 1-hour averages?
Check Answer
33


Feedback
Audits/Inspections – Question 6
6. What are some examples of parameters that an observer should be looking at for CEMS daily operations?
Check Answer
34


Use of CMS Data for Enforcement
On technical grounds, CMS data typically are at least comparable to compliance method and inspection data derived from equally well-executed and quality-assured monitoring.
• CMS data are more representative of actual continuous emissions than are some traditional sources of compliance data, such as emission factors and engineering calculations.
EPA
35


Use of CMS Data for Enforcement (Cont'd)
CMS is important to enforcement, irrespective of whether the legal requirement being enforced specifies CMS as the compliance method.
• However, a governing regulation (e.g., 40 CFR Part 60) must specify CMS as the compliance method in order for EPA to rely on CMS data alone to prove a violation of an emission limitation in Federal district court, or to issue a Notice of Noncompliance ("NON").
• The same is true if EPA is to rely on CMS data alone to issue an administrative order respecting emissions violations.
EPA
36

Enforcement Applications of CMS

- The governing regulation* specifies CMS as the compliance method
- The governing regulation* specifies some method other than CMS as the compliance method, or, the governing regulation doesn't specify a compliance method.

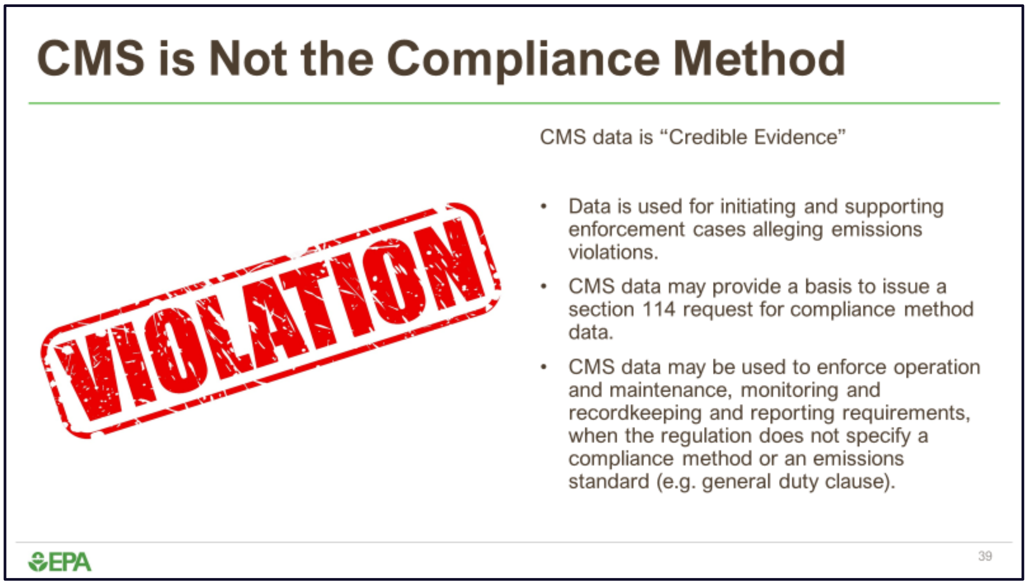
*e.g., 40 CFR Part 60
The next few slides will walk through these two enforcement applications.

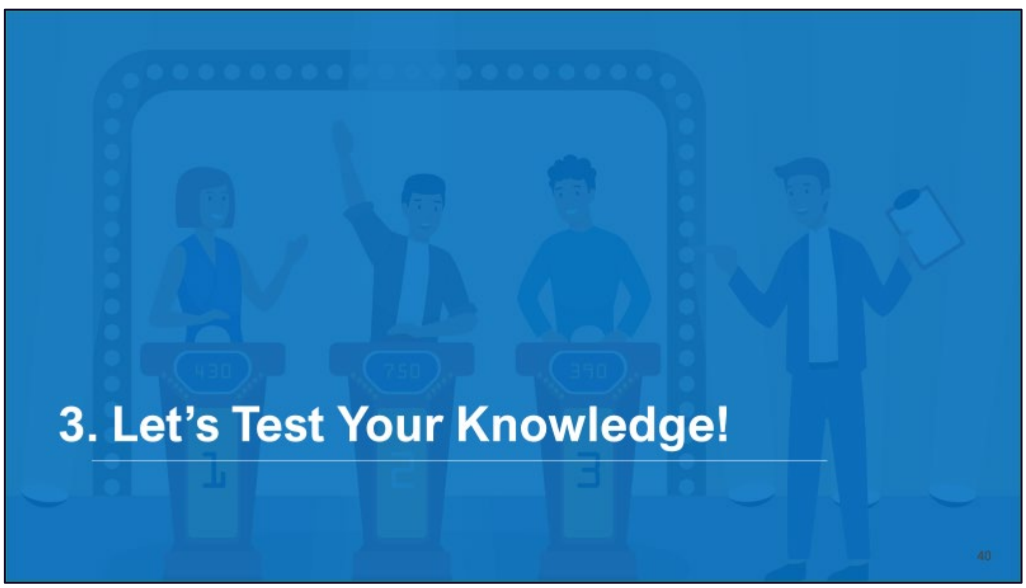
EPA 37

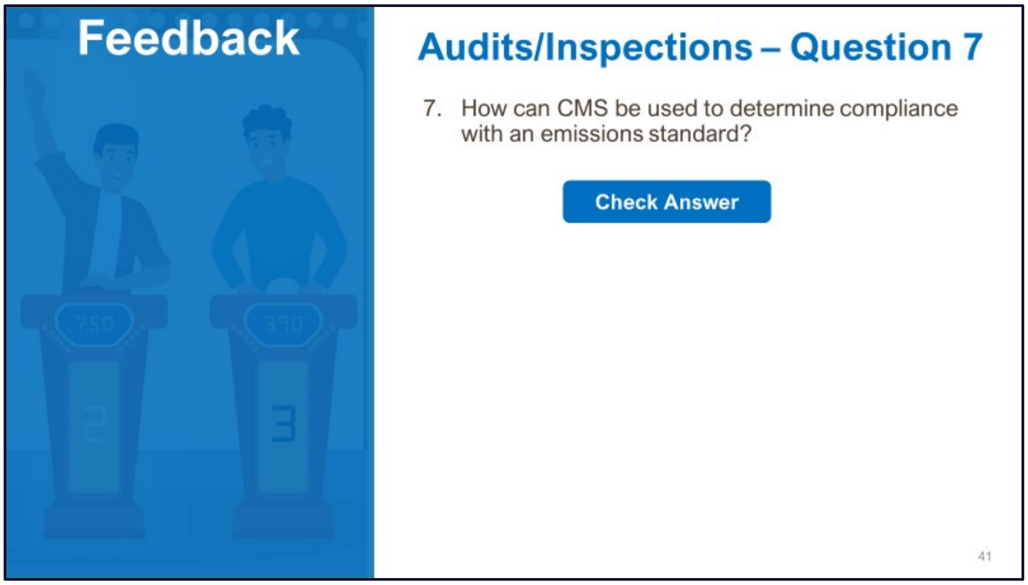
CMS is the Compliance Method

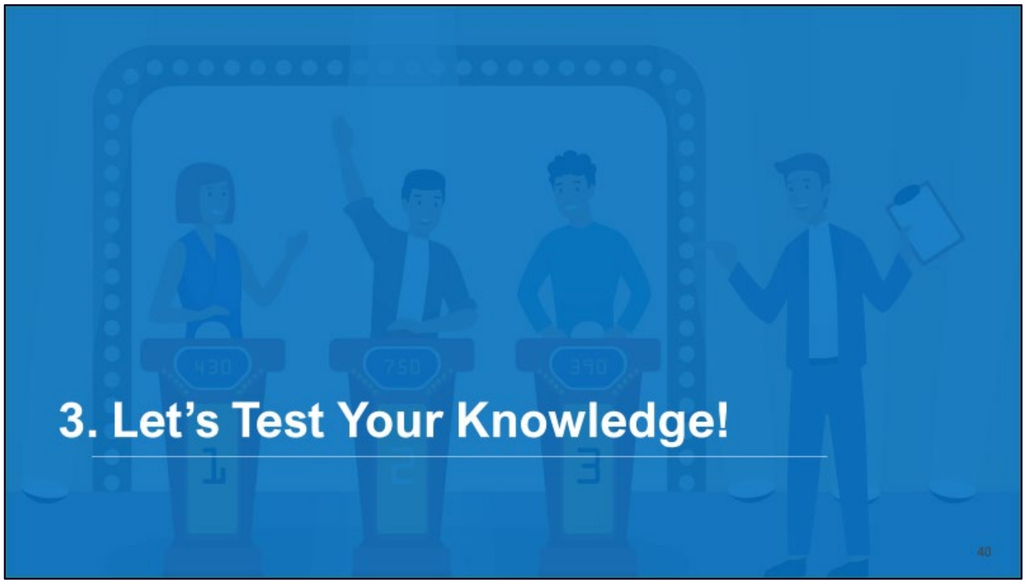
- Required by some NSPS, National Emission Standards for Hazardous Air Pollutants (NESHAPS), and State Implementation Plans (SIPs)
- Includes data validation requirements
- Requires monitoring against emission limits with long averaging time
- Data documents compliance against the emissions standard in the units of the emissions standard

EPA 38


CMS is Not the Compliance Method
VIOLATION
CMS data is "Credible Evidence"
• Data is used for initiating and supporting enforcement cases alleging emissions violations.
• CMS data may provide a basis to issue a section 114 request for compliance method data.
• CMS data may be used to enforce operation and maintenance, monitoring and recordkeeping and reporting requirements, when the regulation does not specify a compliance method or an emissions standard (e.g. general duty clause).
EPA
39


3. Let's Test Your Knowledge!
40


Feedback
Audits/Inspections – Question 7
7. How can CMS be used to determine compliance with an emissions standard?
Check Answer
41


3. Let's Test Your Knowledge!
40

Activity

Title: Geometric Close

Purpose: To review the module content by enabling participants to summarize what they learned.

Time: 40 minutes

- 20 minutes in groups
- 20 minutes group debrief

42

Activity Debrief

43

Module 4 Summary

Now that you have completed Module 4, you should be able to:

- Distinguish the difference between performance audits and systems/field audits
- Explain the utility of performance audits and systems/field audits
- Describe the inspector's role during an audit
- Describe the procedures necessary to use CMS data in determining compliance
- Assess daily, weekly, monthly, quarterly, and annual required preventative maintenance and QA requirements
- Distinguish between CMS as compliance method and CMS data as credible evidence

EPA 44