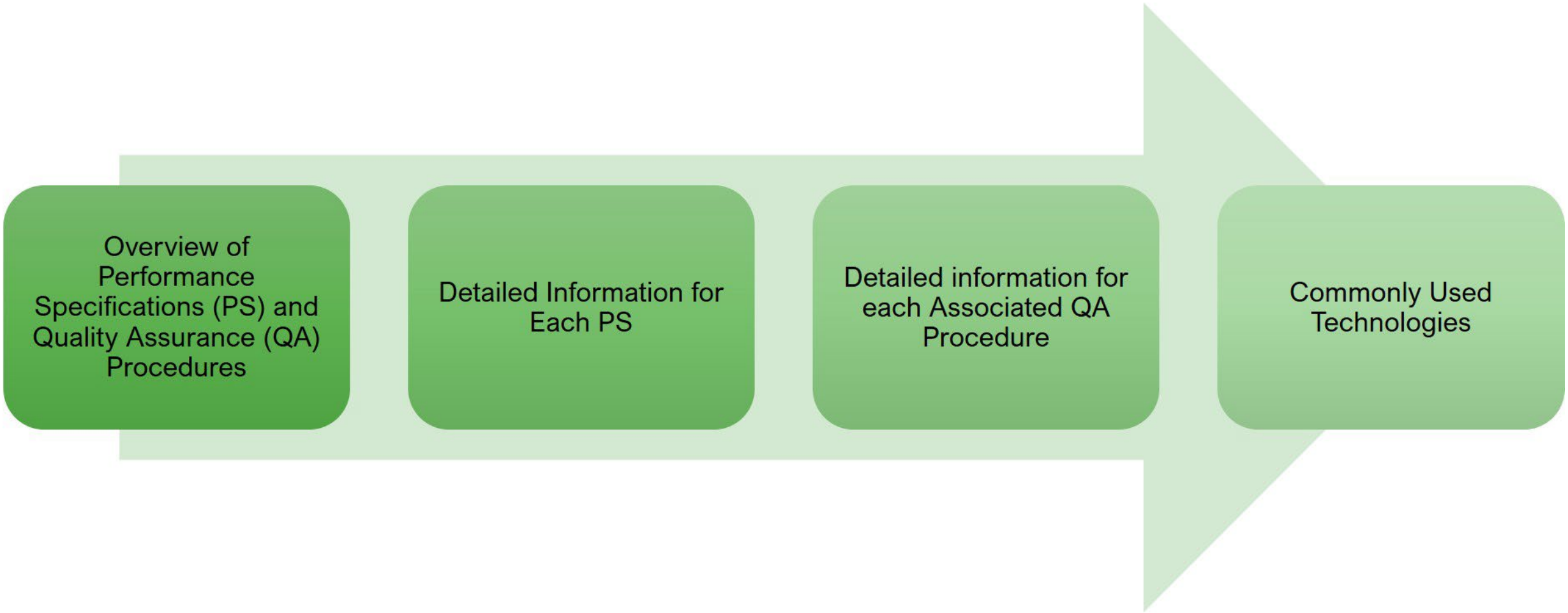
# Module 3: Performance Specifications, Quality Assurance, and Commonly Used Technologies

# Module 3 Outline



# 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

# 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

# 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.

# Introduction to Quality Control and Quality Assurance

## 1. Quality Control

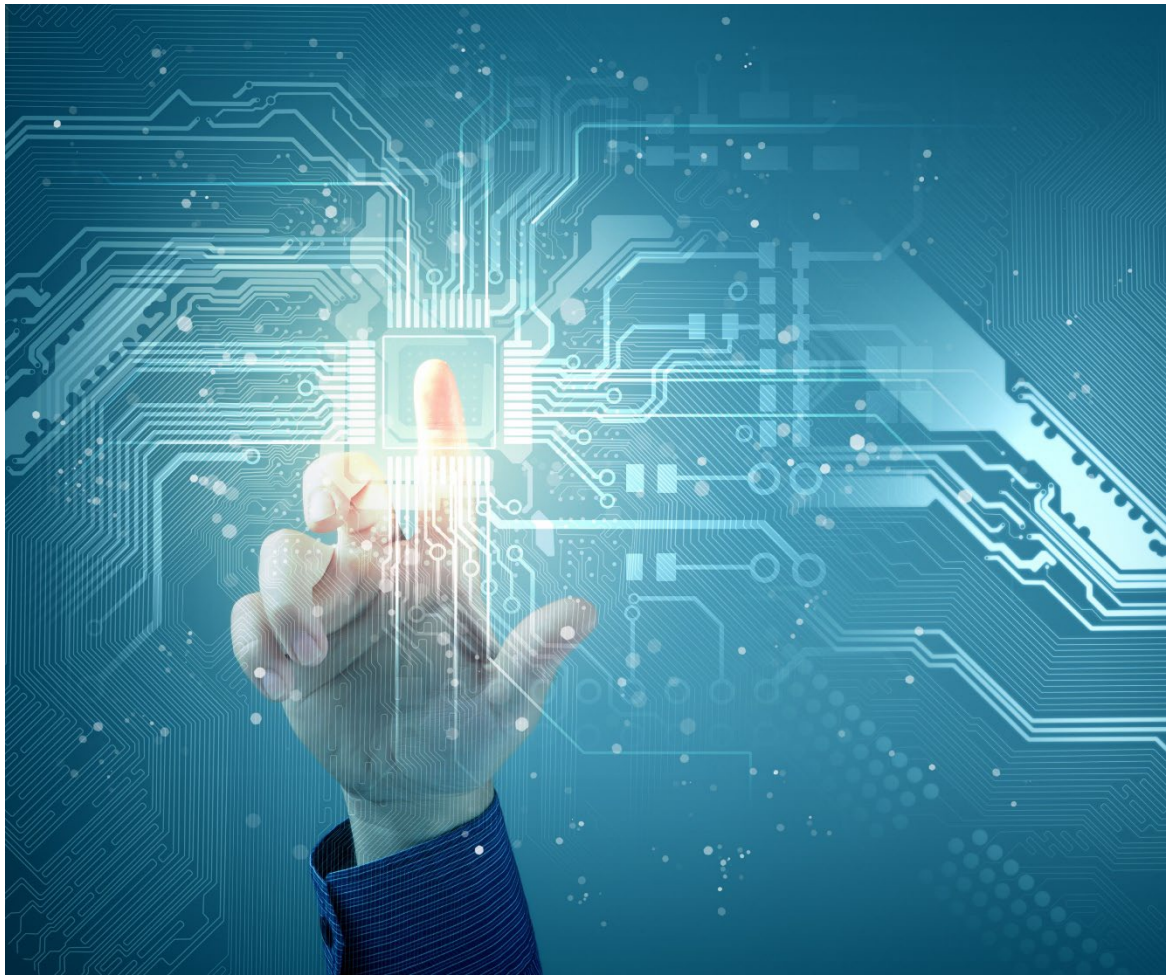
- Quality control (QC) is the procedures, policies, and corrective actions necessary to ensure product quality.

## 2. Quality Assurance

- Quality assurance (QA) procedures are used to evaluate the effectiveness of QC and the quality of data produced by any CMS 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.

# 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.



# 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 |

# 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.

# 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.

# 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.

# Quality Assurance Procedure Audits

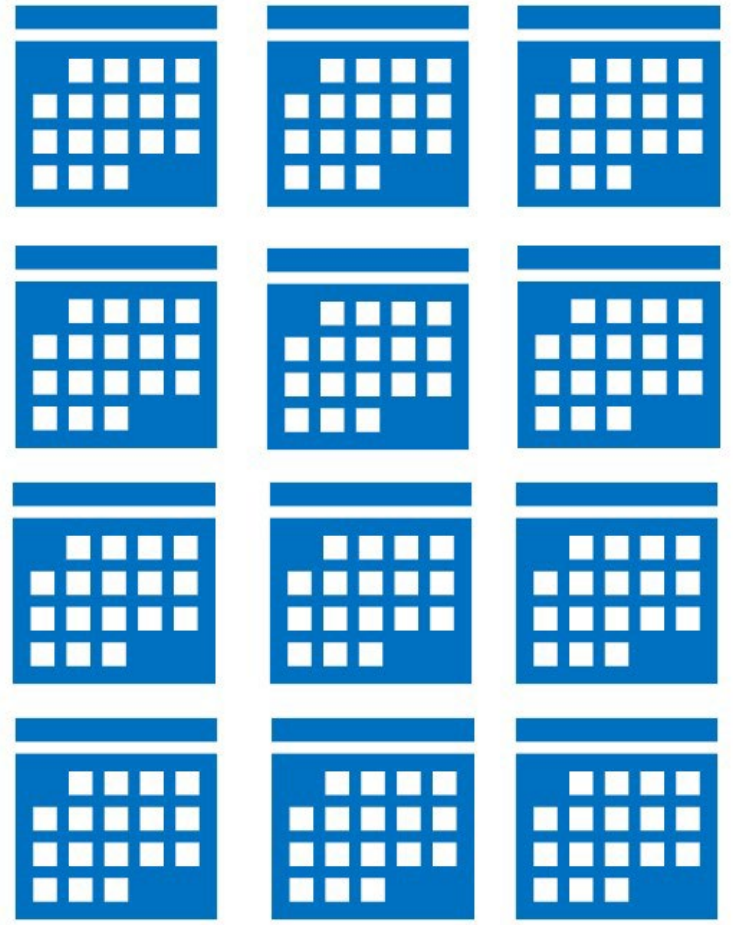
Audit procedures are critical for verifying proper performance of the monitoring systems and identifying problems which may lead to inaccurate emissions accounting.

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)

# 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

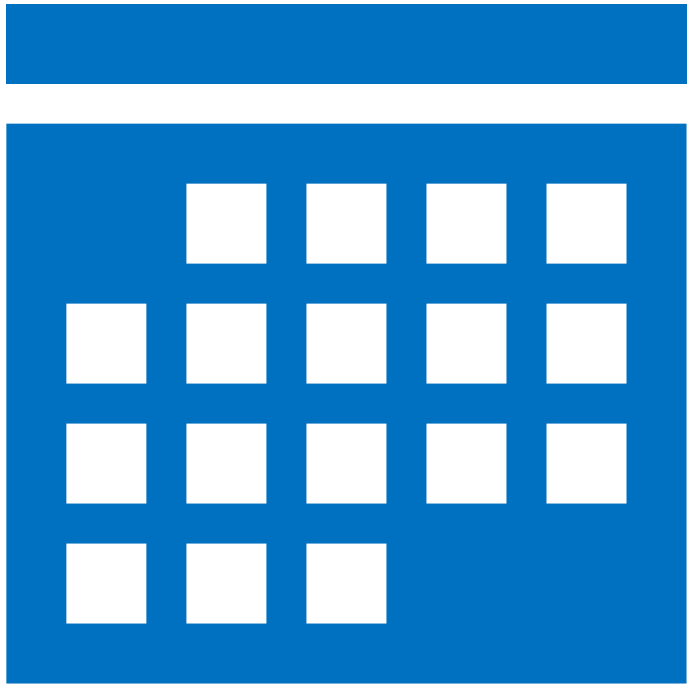


# What is a Cylinder Gas Audit?

- 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)

# 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



# 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

# Performance Specification 1 (PS-1)

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

# PS-1 Requirements

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

# 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.

# 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?

# 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: ≤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 ± 2% opacity
  - Data recorder: resolution ≤ 0.5% opacity

# 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

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

## What are the basic functions of Procedure 3?

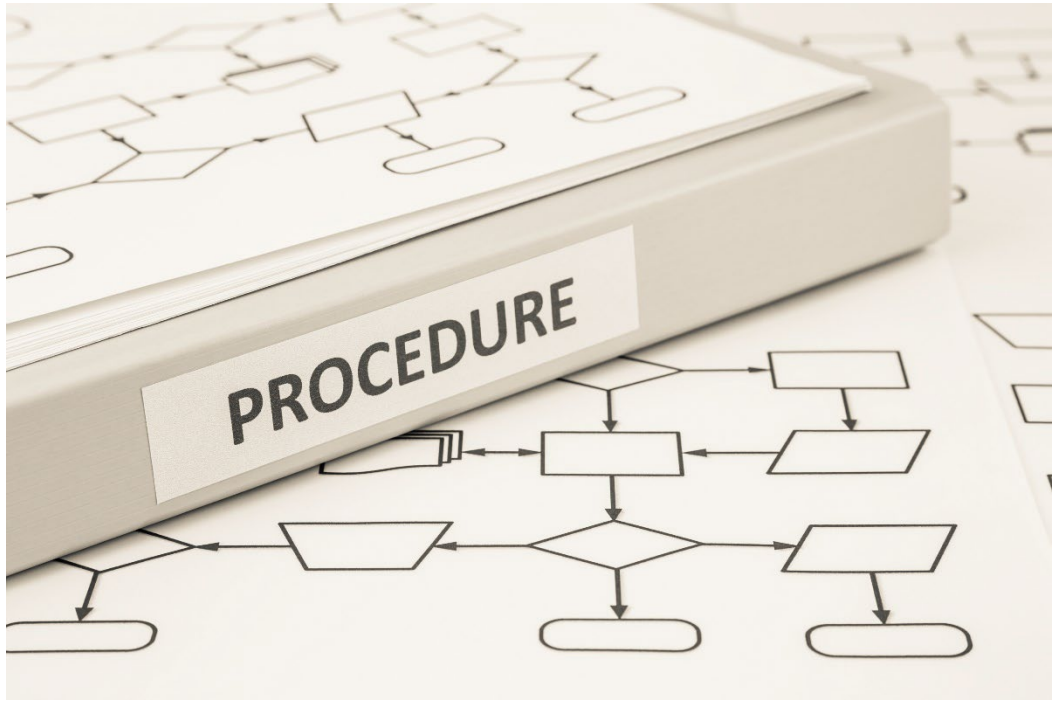
- Assessment of the quality of your COMS data
- Control and improvement of the quality of your COMS data by implementing QC requirements and corrective actions

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

# Procedure 3 - Limitations

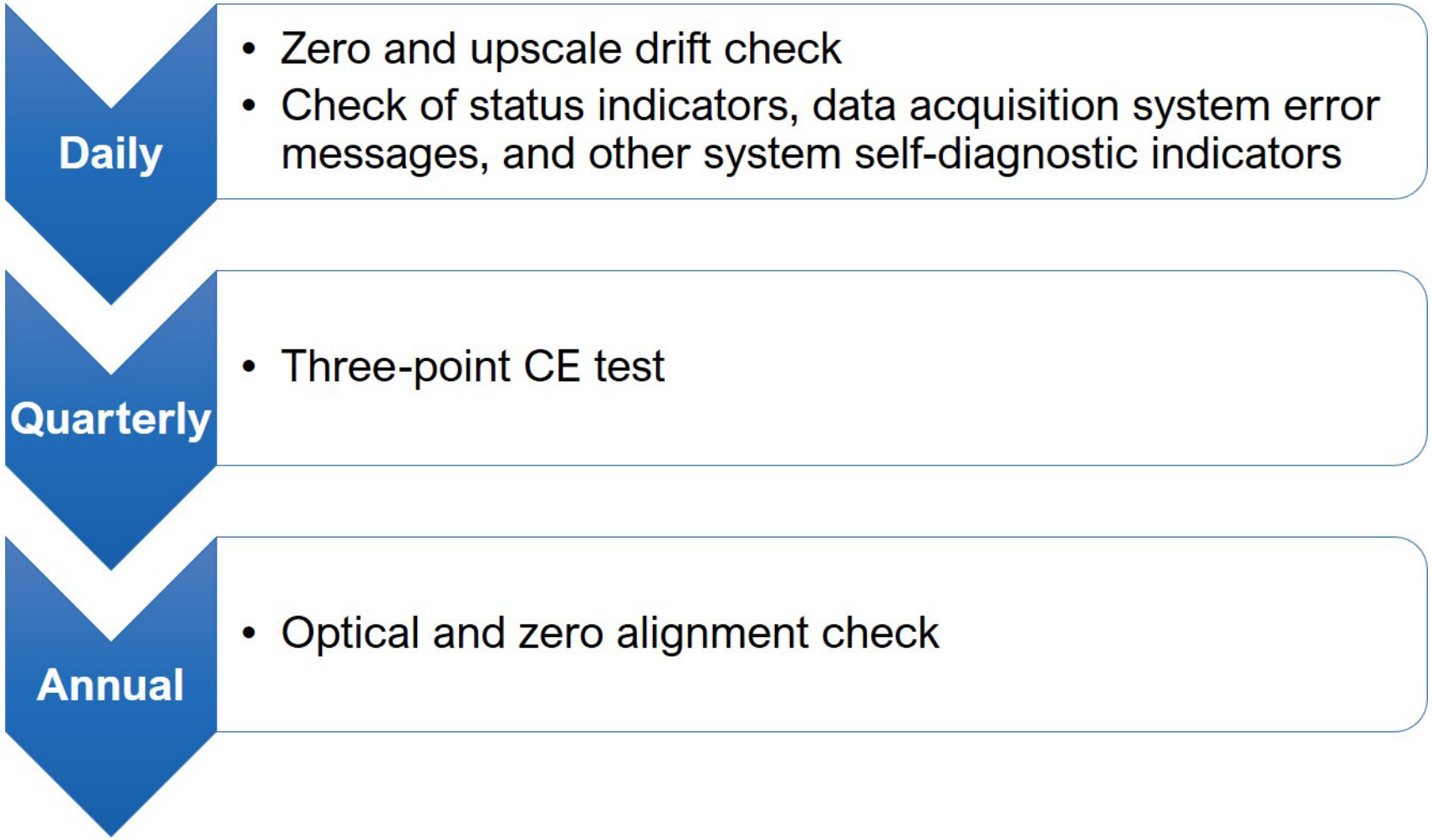
Opacity cannot be measured accurately in the presence of condensed water vapor. Thus, COMS opacity compliance determinations cannot be made when condensed water vapor is present, such as downstream of a wet scrubber without a reheater or at other saturated flue gas locations.

# 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.

# Procedure 3 – Auditing Requirements



# 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.

# Procedure 3 – Corrective Actions

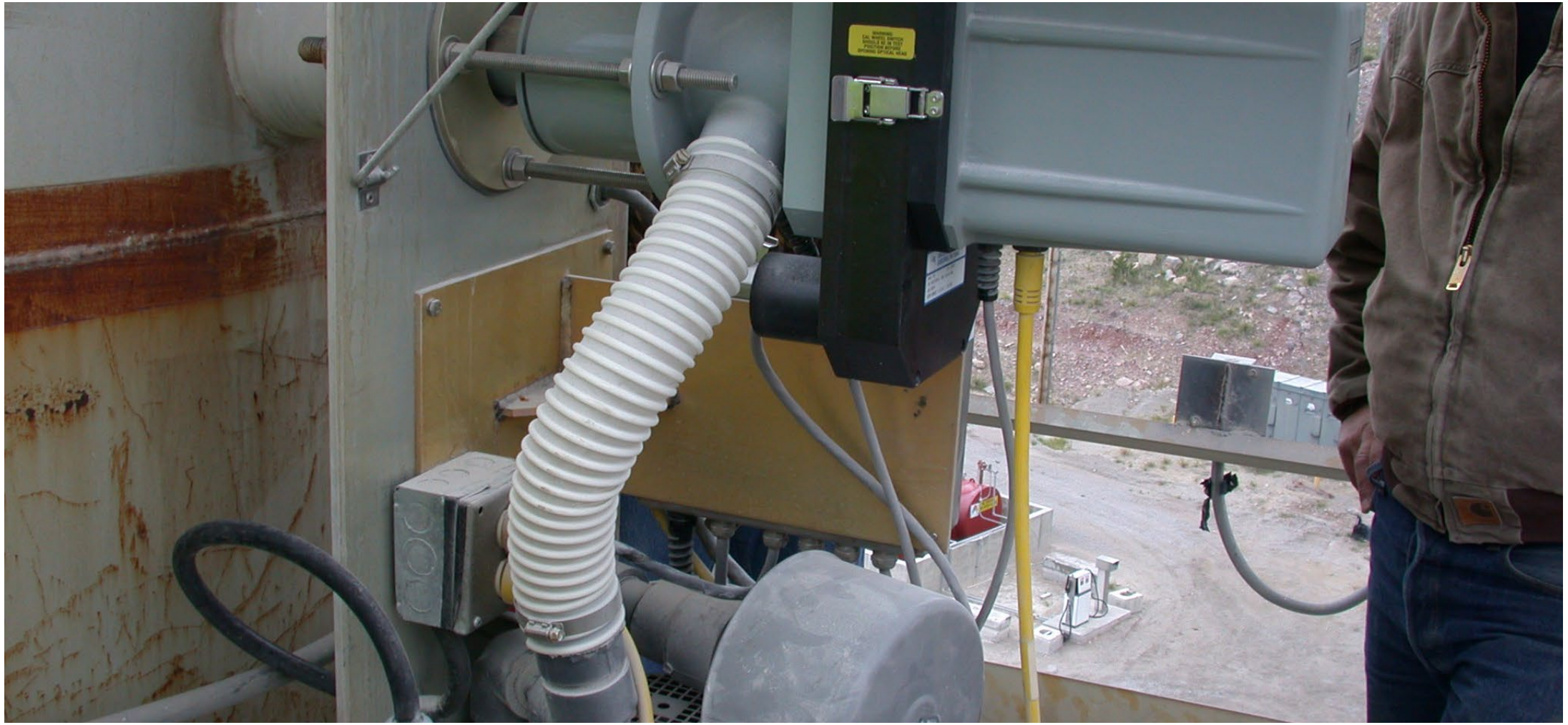
A corrective action program must be in place to address the repair and/or maintenance of your COMS. The corrective action program must:

- 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

# Opacity Transceiver

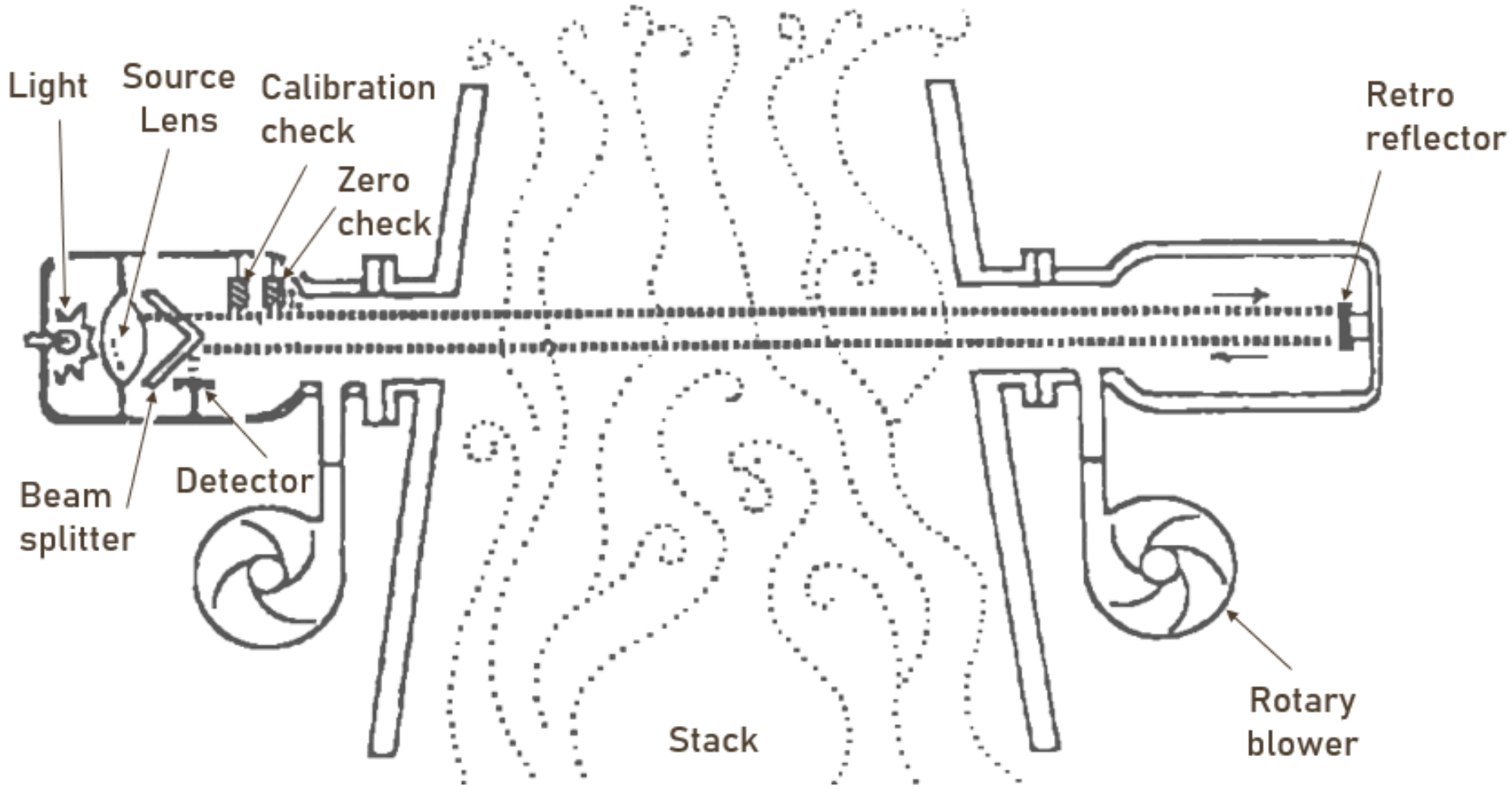


# Commonly Used Technology - Transmissometry

## Transmissometry

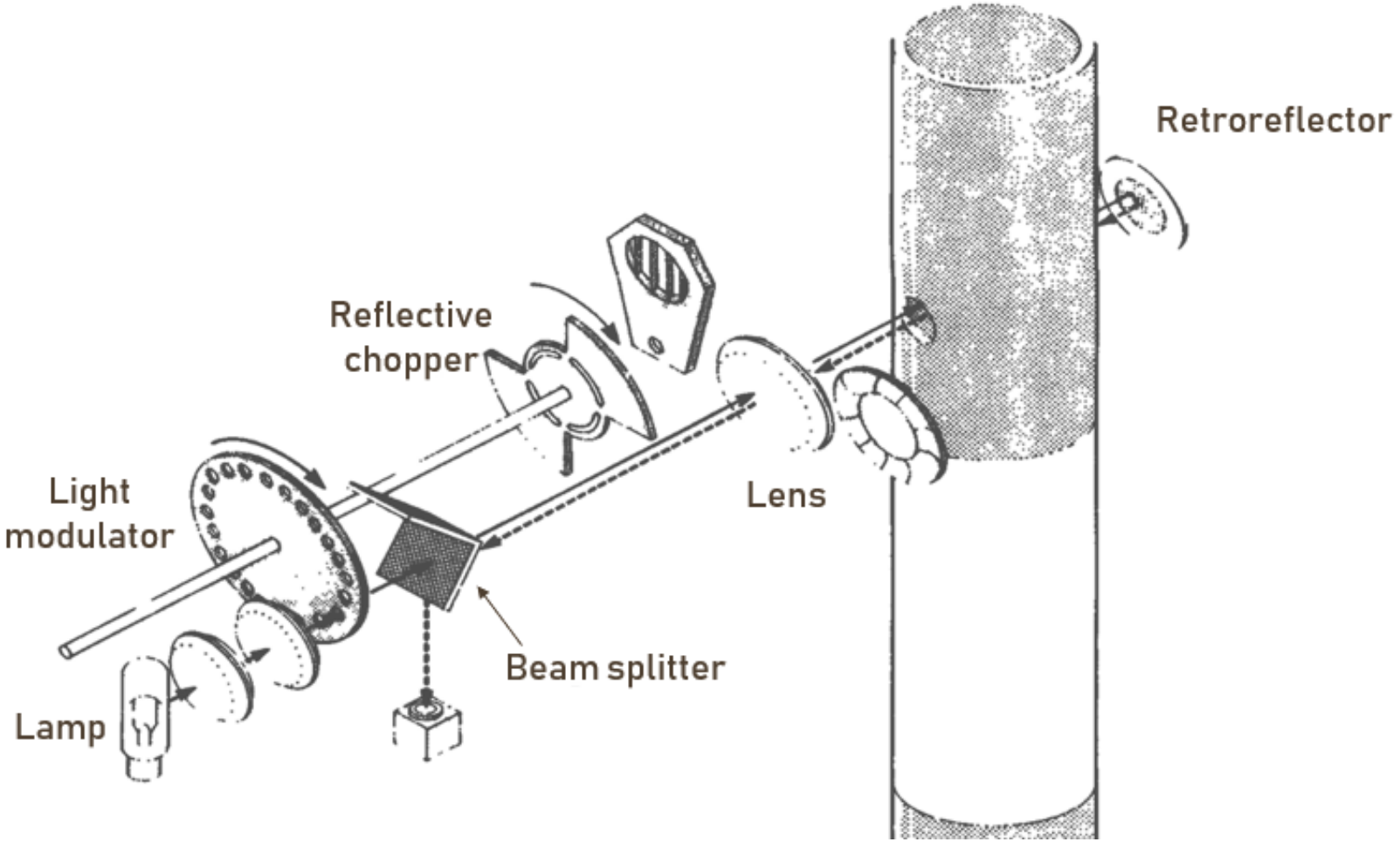
- The measurement of the amount of light that can be transmitted through a stack exhaust.
  - The intensity of the light is attenuated by scattering and absorption by PM in the stack exhaust.
  - The amount of attenuation is measured as percent opacity, and is a function of the amount, type, and distribution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

# Double Pass Transmissometer




*Courtesy of Janke 1979*

# Double Pass Transmissometer (Cont'd)

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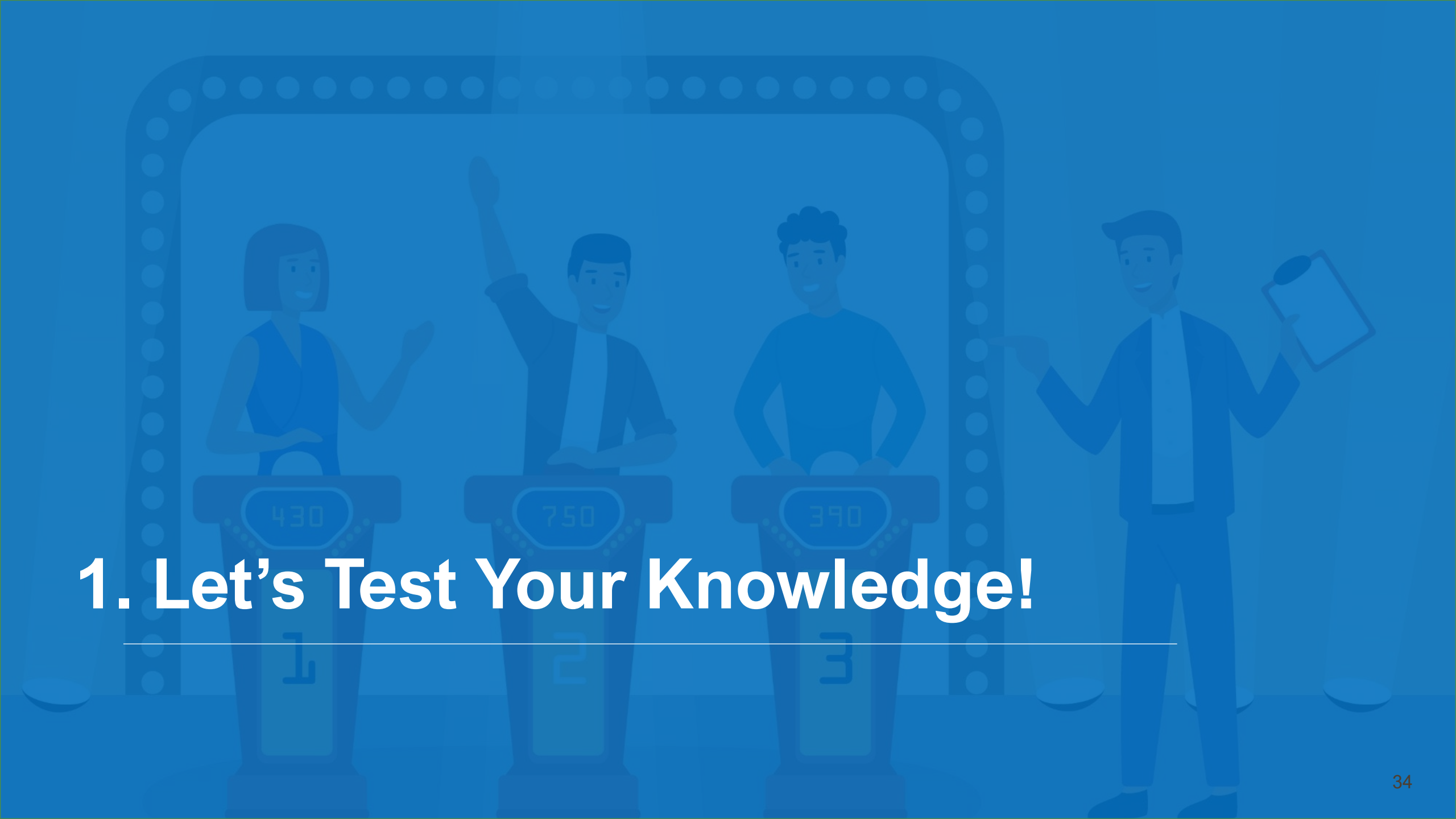



# 1. Let’s Test Your Knowledge!

# Feedback

4. 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.

# 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

# Performance Specification 2 (PS-2)

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

# 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™*

# 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

# 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

# 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

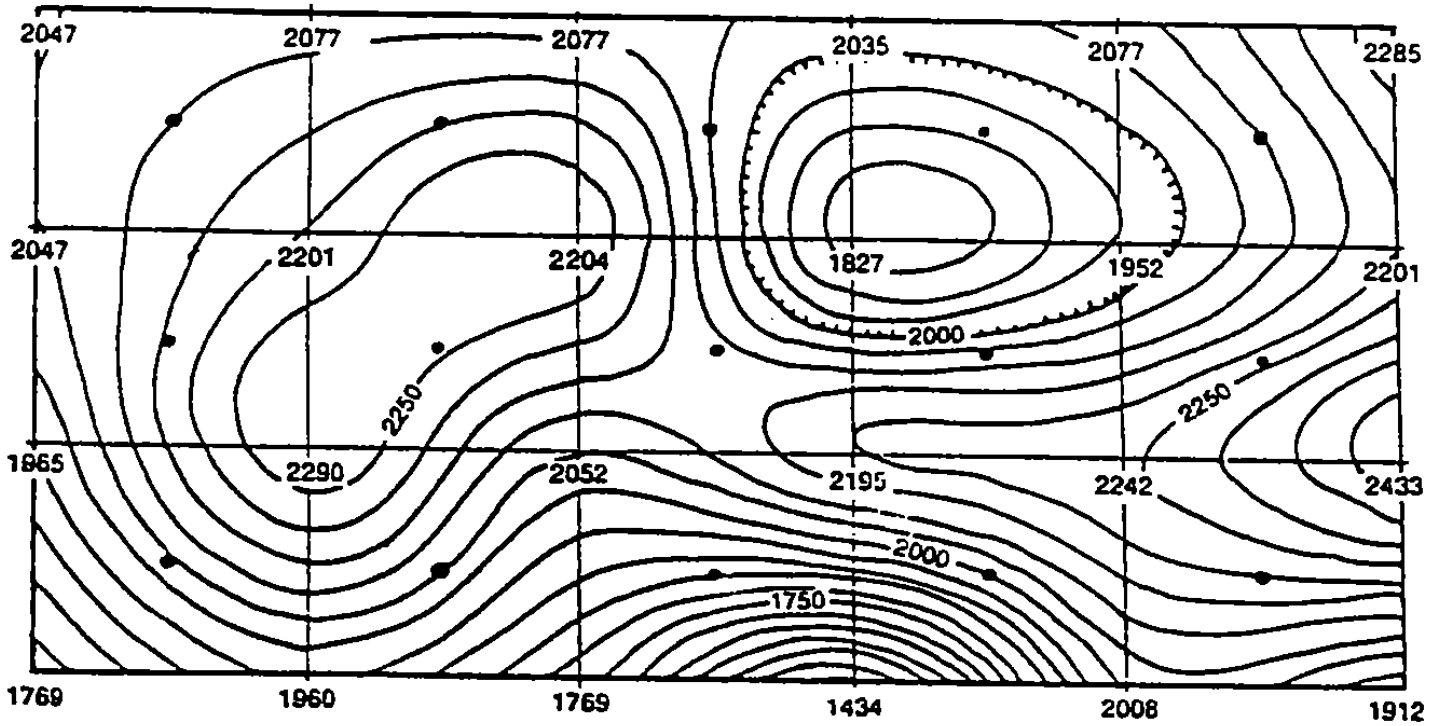
Select appropriate sampling location.

To determine if stratification is present:

- Use 9 sample points in the cross section, for rectangular ducts.
- Use 12-point traverse, for circular ducts.

# 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



# Reference Method Traverse Points Minimum Requirements

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

- 16.8,
- 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.

# 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.

# 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% |

# 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

# Procedure 1 – Checks/Auditing Requirements

## Daily Checks

- CD at two concentration values – zero and high-level

## Quarterly Checks

- 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

## Annual Checks

- RATA – conducted at least once every four calendar quarters except for other alternative audits

# 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 on any one day. If so, the CEMS is considered OOC | • Must be less than ± 15% of the average audit value or ± 5 ppm, whichever is greater, or the CEMS is OOC | • Same as the RA requirement in the applicable PS or the CEMS is OOC |

# 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.

# $SO_2$ Analyzer

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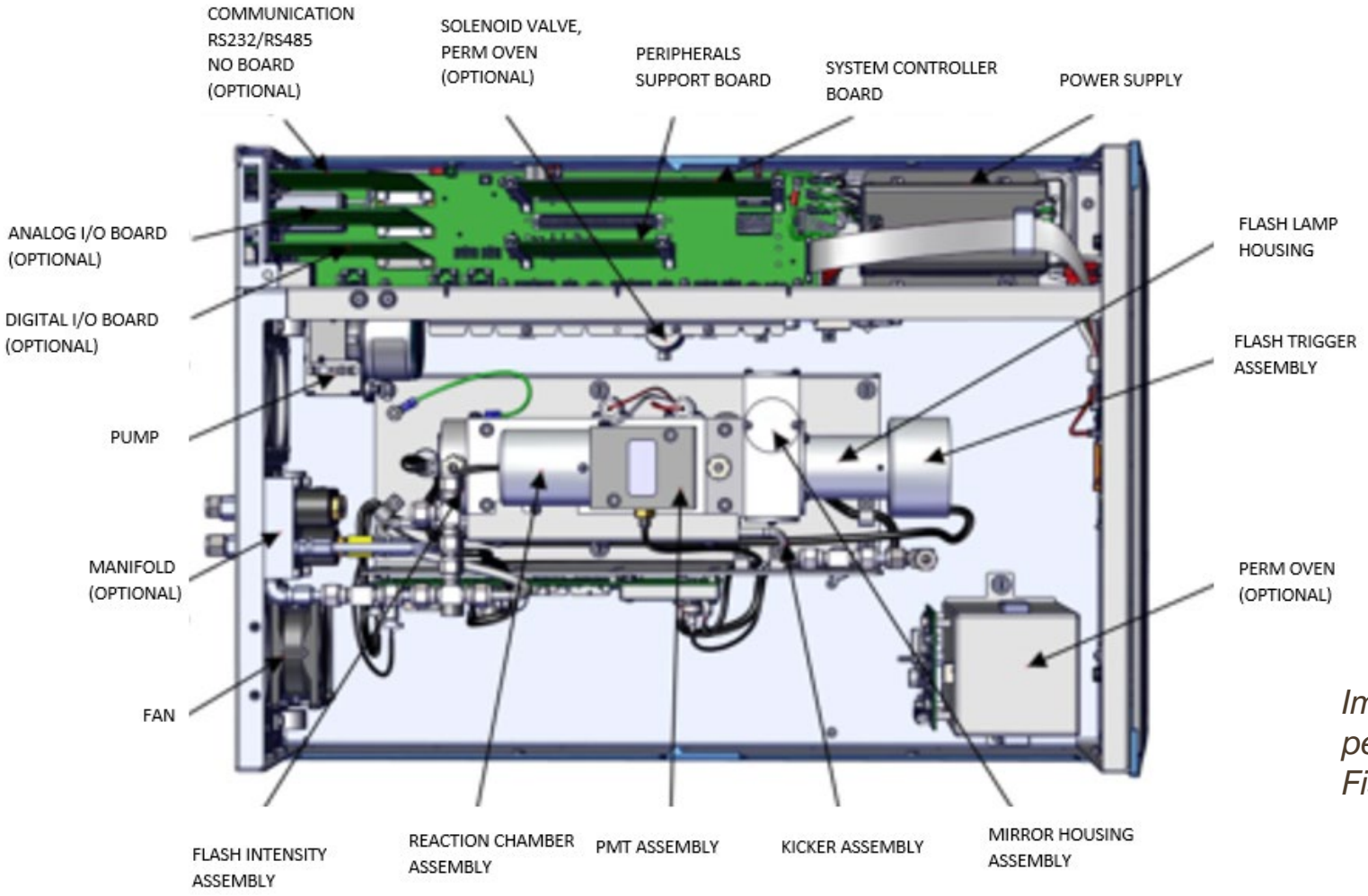
# $SO_2$ Monitor

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# Chemiluminescence NOx Analyzer


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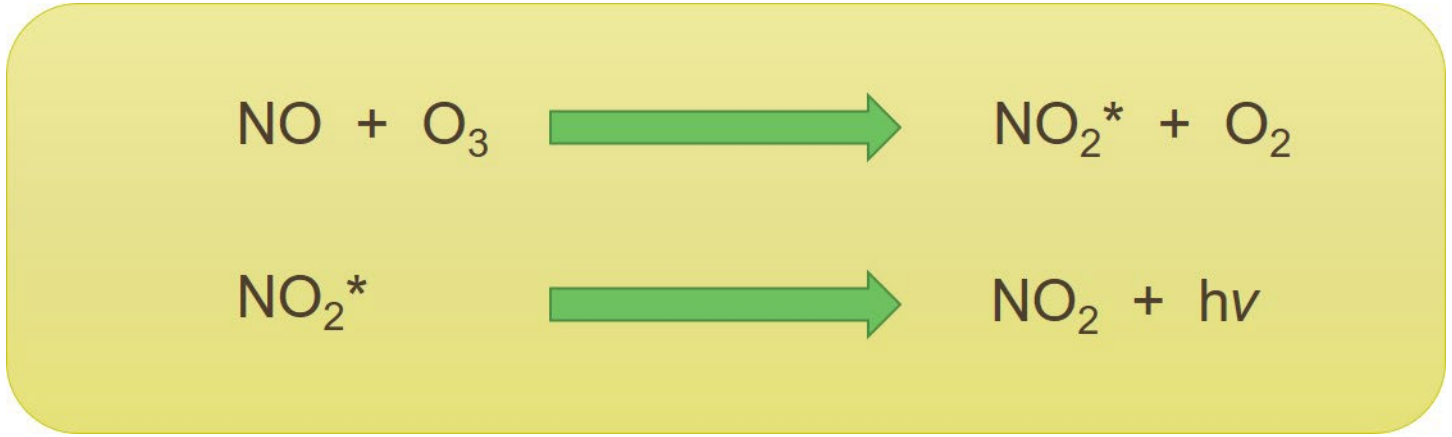
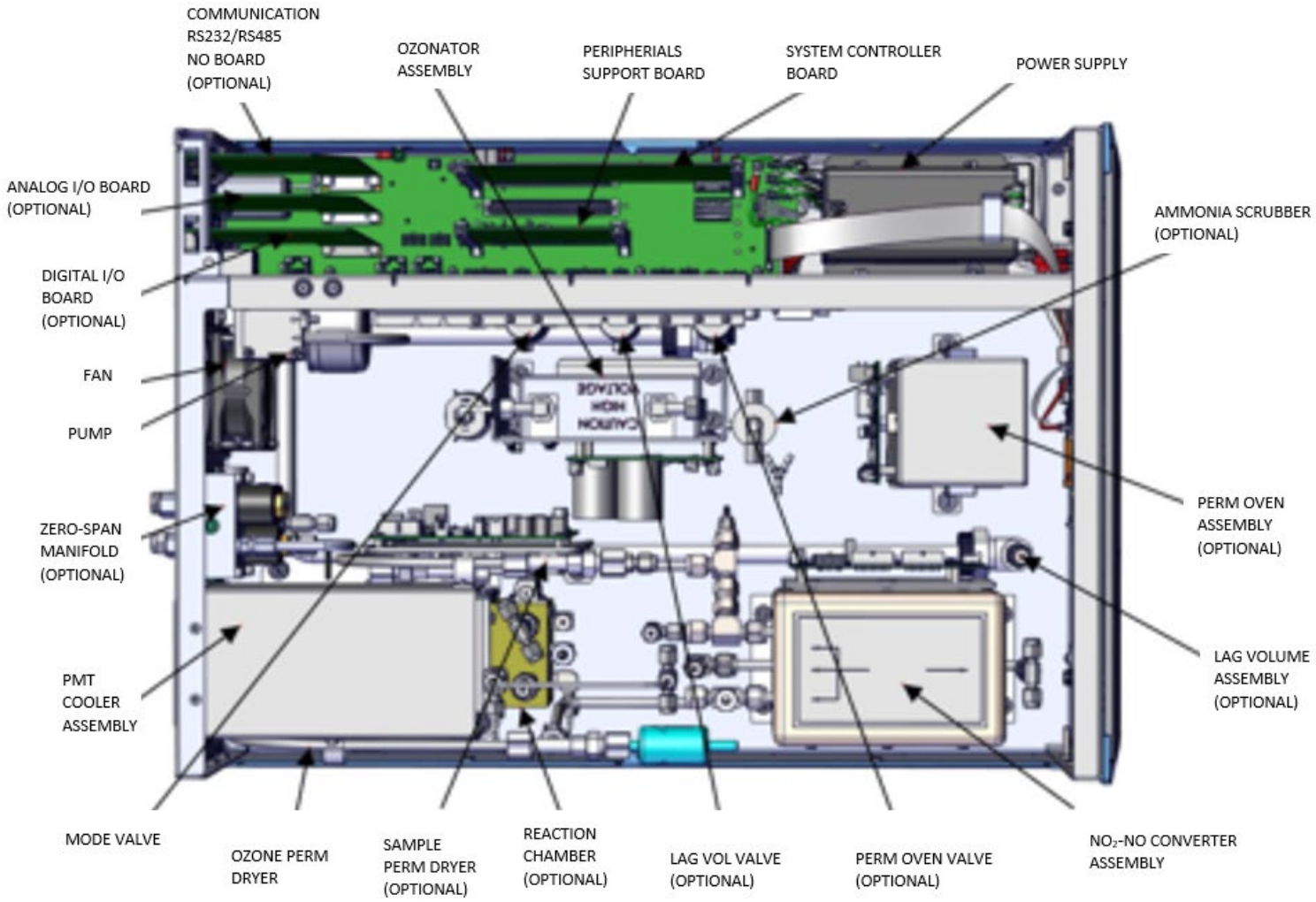
# How is $NO_X$ Measured?

Chemiluminescence Technique




**Intensity of emitted light is proportional to NO concentration**

# $NO_X$ Monitor

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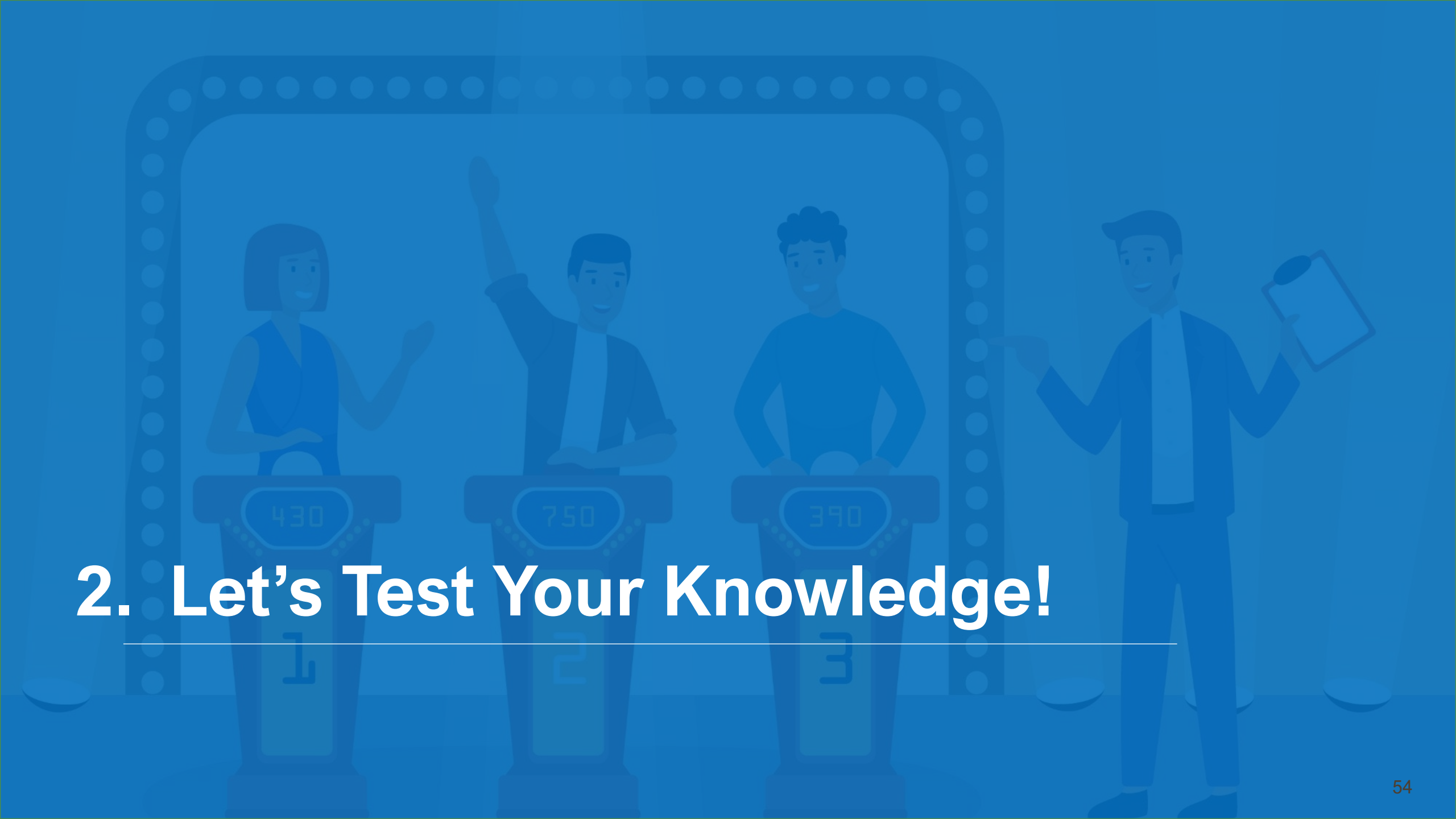



# 2. Let’s Test Your Knowledge!

# Feedback

1. D. No operating load is specified.

# 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.**

# Feedback

2. A. The source is stratified.

# 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**

# Feedback

3. False. The CEMS must be installed before certification testing can begin.

# PS-2 – Question 3

3. The relative accuracy test audit, or RATA, must be passed prior to installation of the CEMS.

True

False

# Feedback

3. At a minimum, each QC program must include written procedures in detail on step-by-step procedures for each of the following:

- Calibration of CEMS.
- CD determination and adjustment of CEMS.
- Preventive maintenance of CEMS (including spare parts inventory).
- Data recording, calculations, and reporting.
- Accuracy audit procedures including sampling and analysis methods.
- Program of corrective action for malfunctioning CEMS.

# Procedure 1

1. Name three types of quarterly audits.

Check Answer

2. When should a RATA be performed?

Check Answer

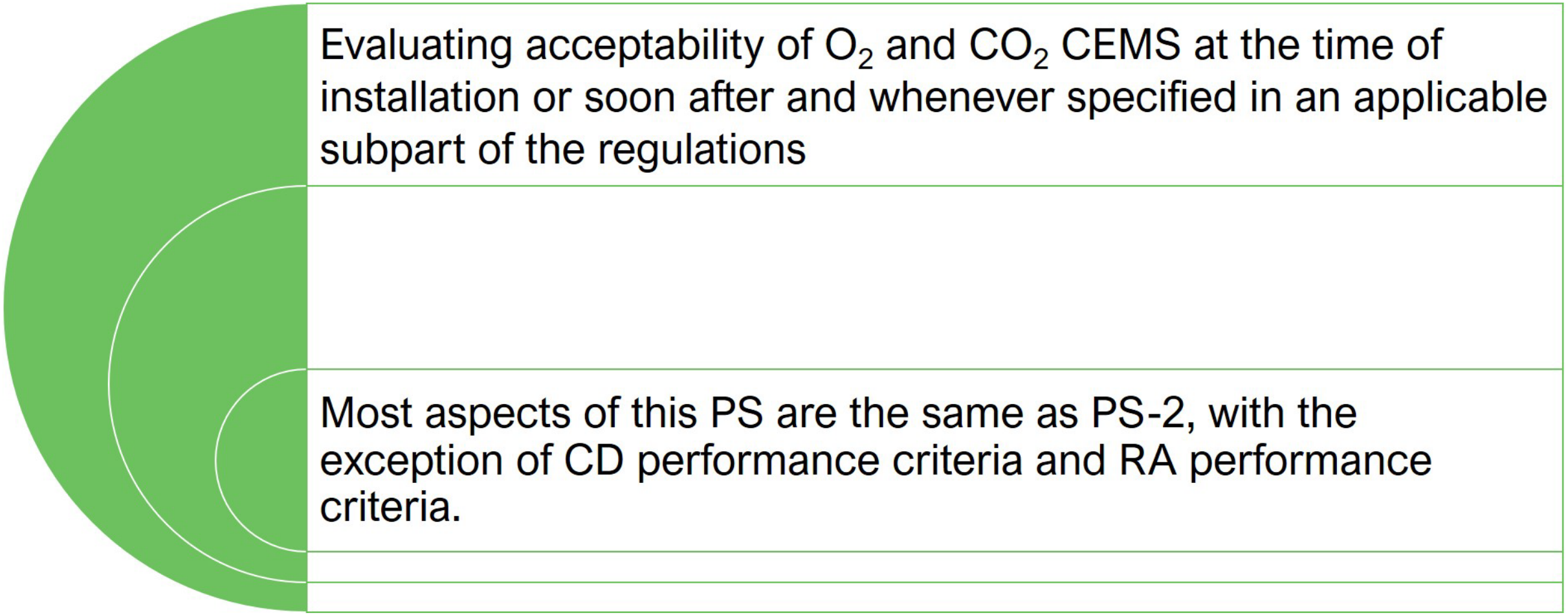
3. What are the QC requirements of procedure 1?

Check Answer

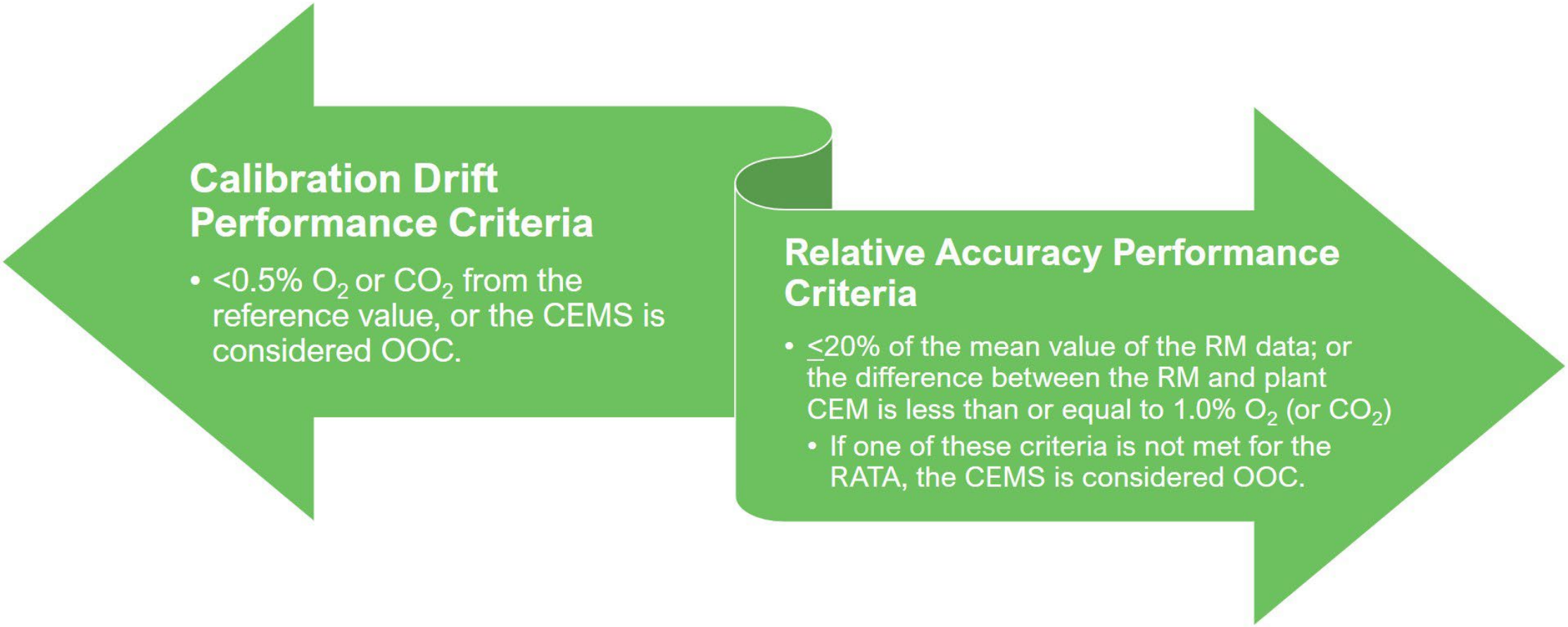
# Performance Specification 3 (PS-3)

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

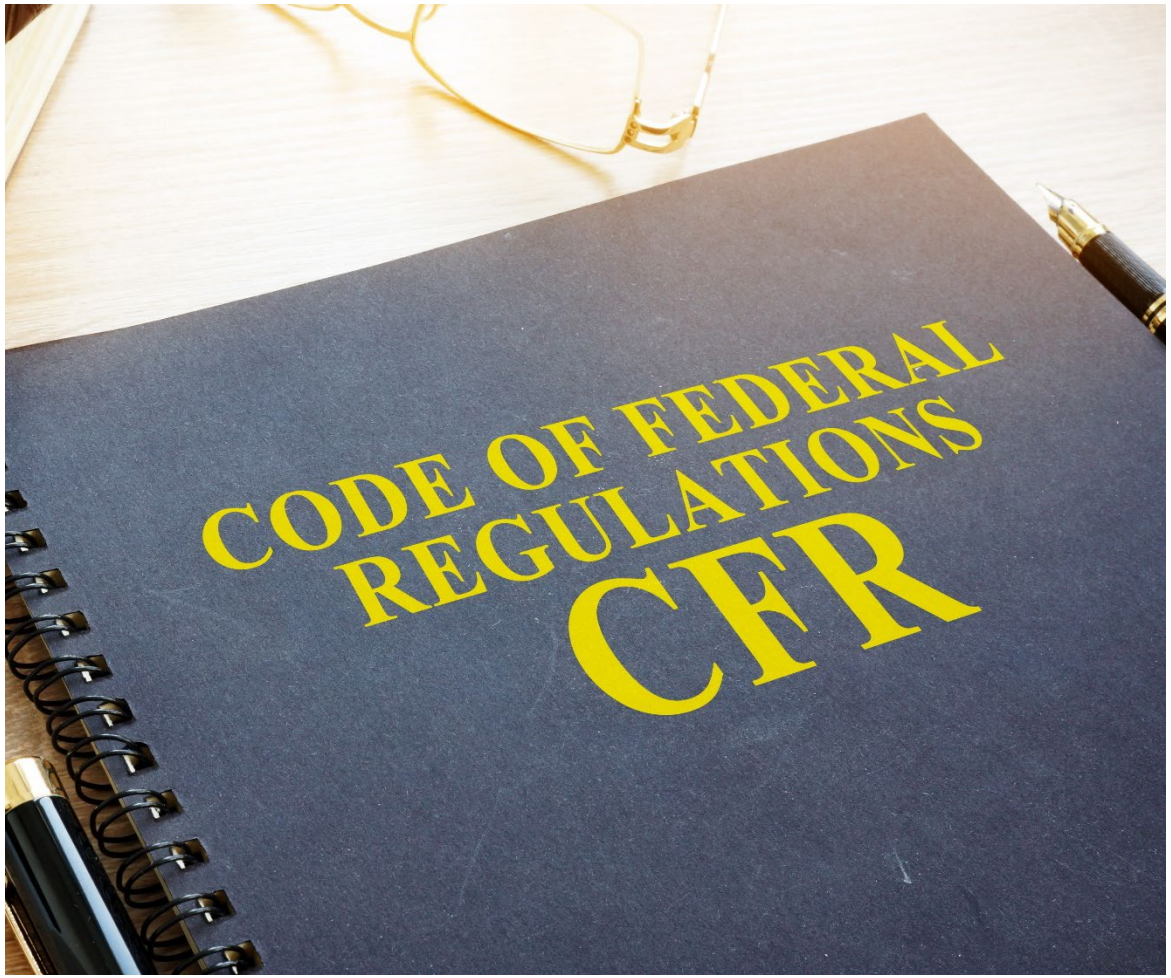
# Overview of PS-3



# Calibration Drift and Relative Accuracy Performance Criteria – PS-3



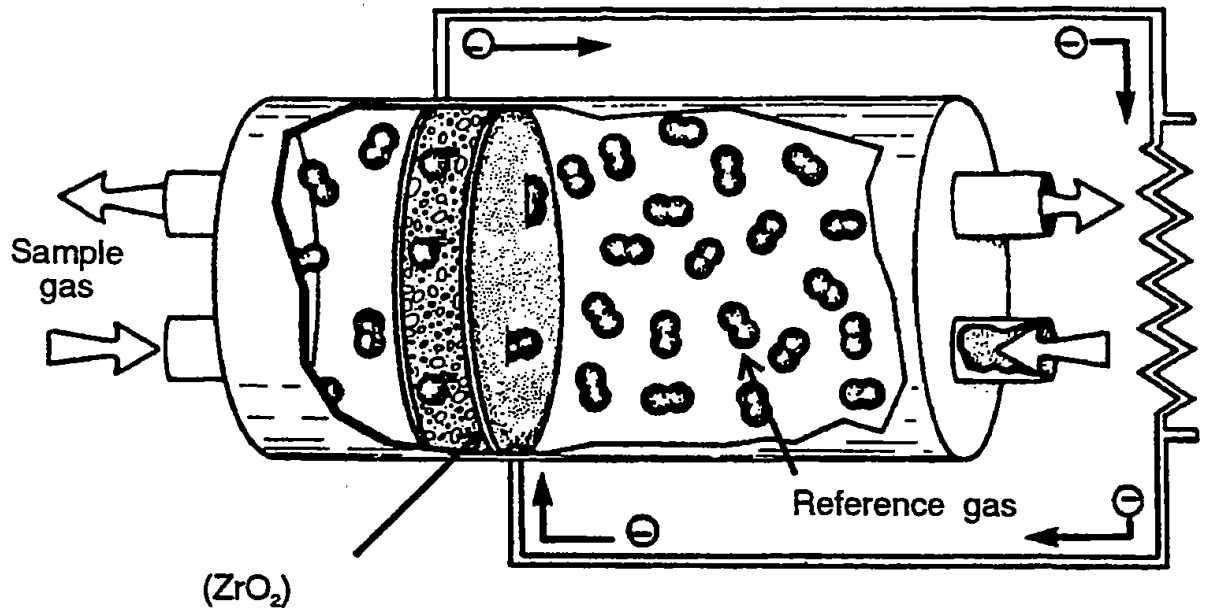
# Quality Assurance Procedure 1




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

# 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.



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

## $O_2$ & $CO_2$ Analyzer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# 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.

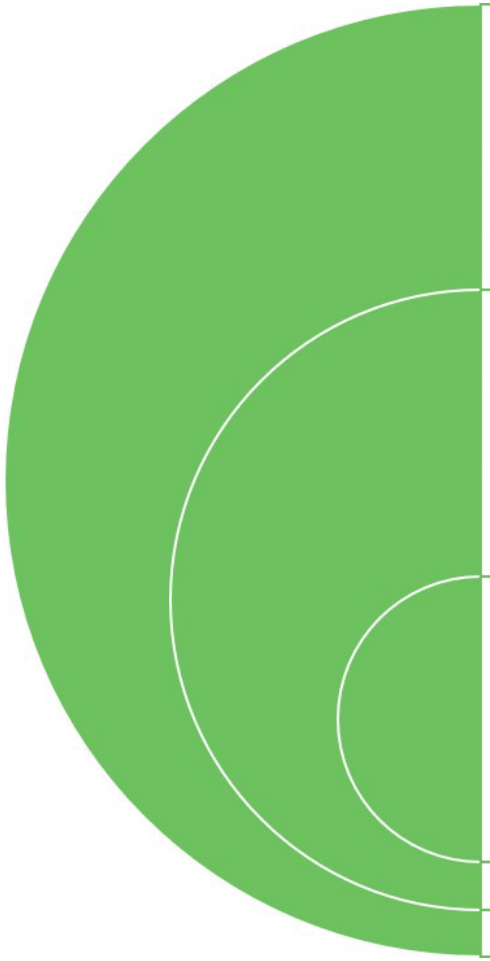
## Non-Dispersive Infrared

- 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.

# Performance Specification 4 (PS-4)

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

# Overview of PS-4

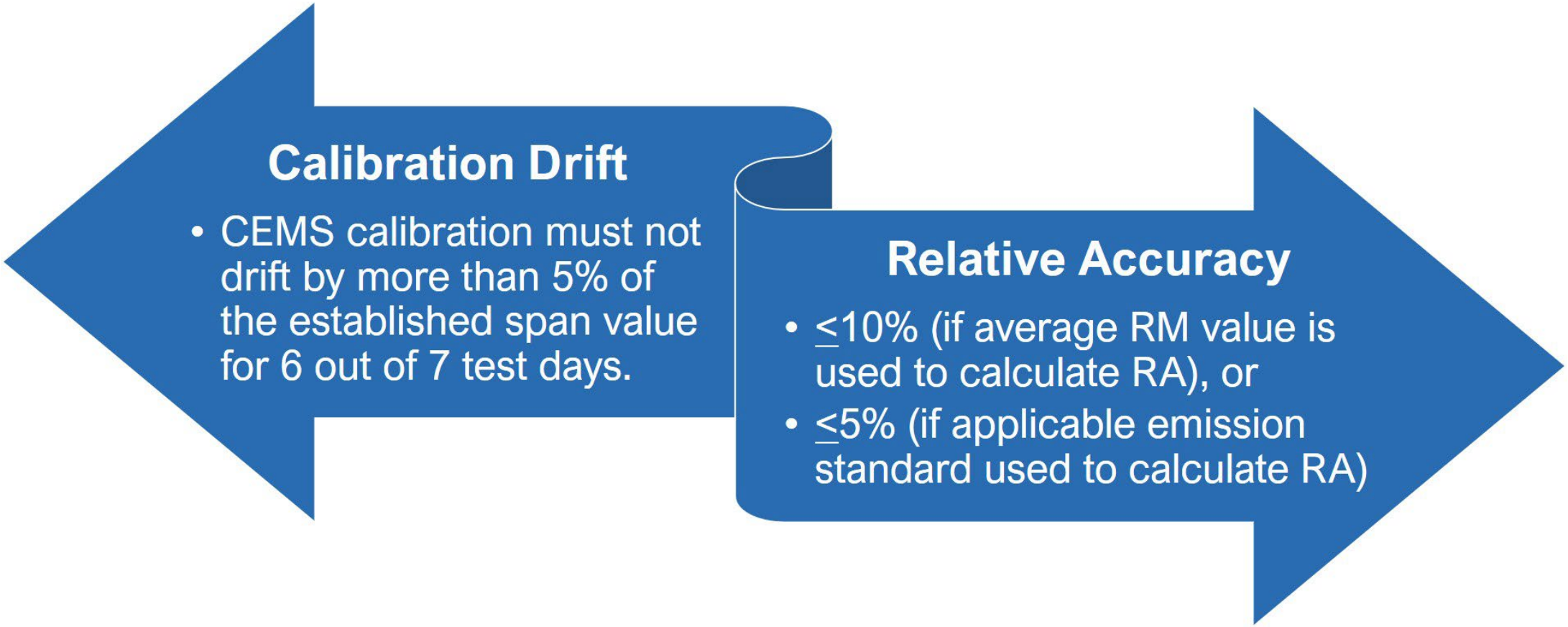


Evaluating the acceptability of carbon monoxide (CO) continuous emission monitoring systems (CEMS) at the time of installation or soon after and whenever specified in an applicable subpart of the regulations

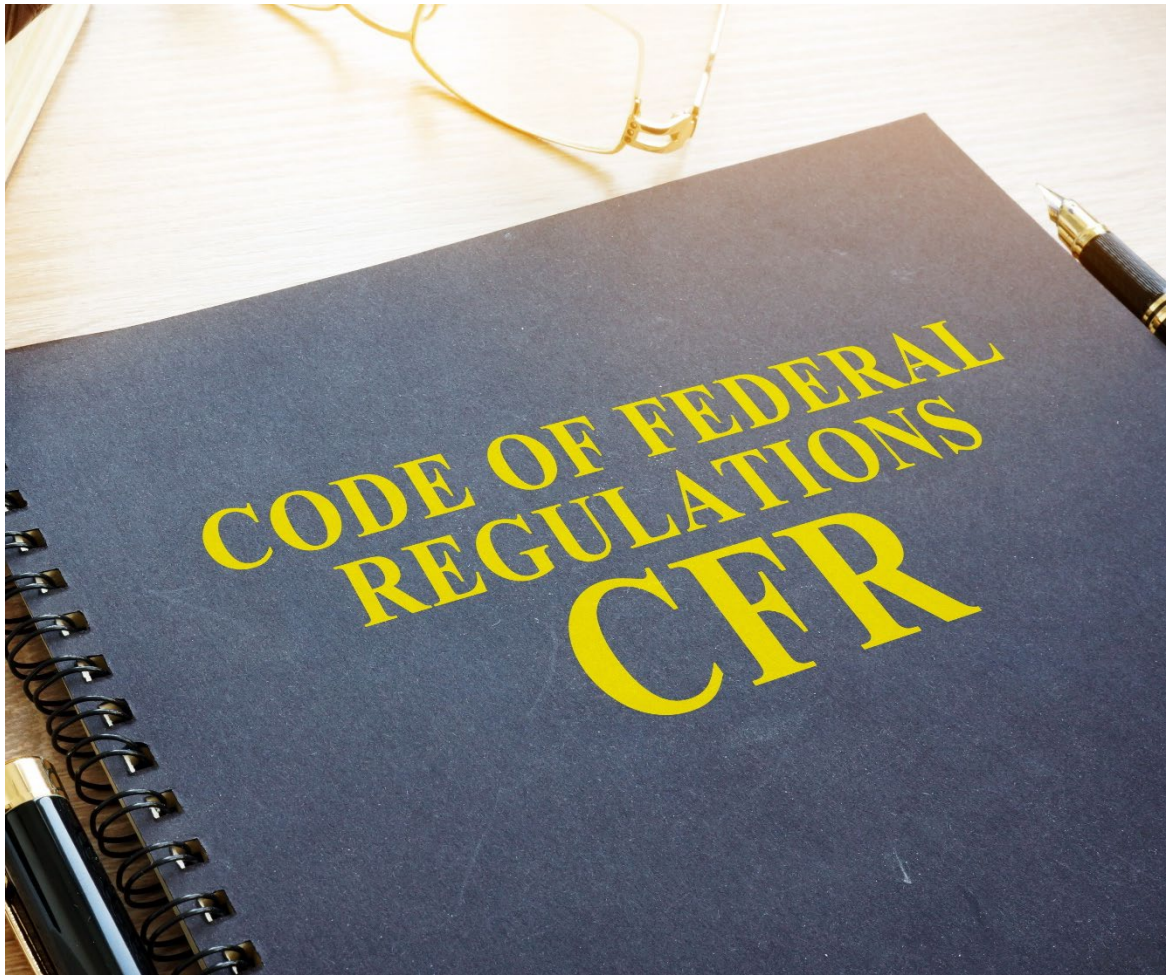
This specification was developed primarily for CEMS having span values of 1,000 ppmv CO

Most aspects of this PS are the same as PS-2, with the exception of CD performance criteria and RA performance criteria.

# Calibration Drift and Performance Specification Criteria – PS-4



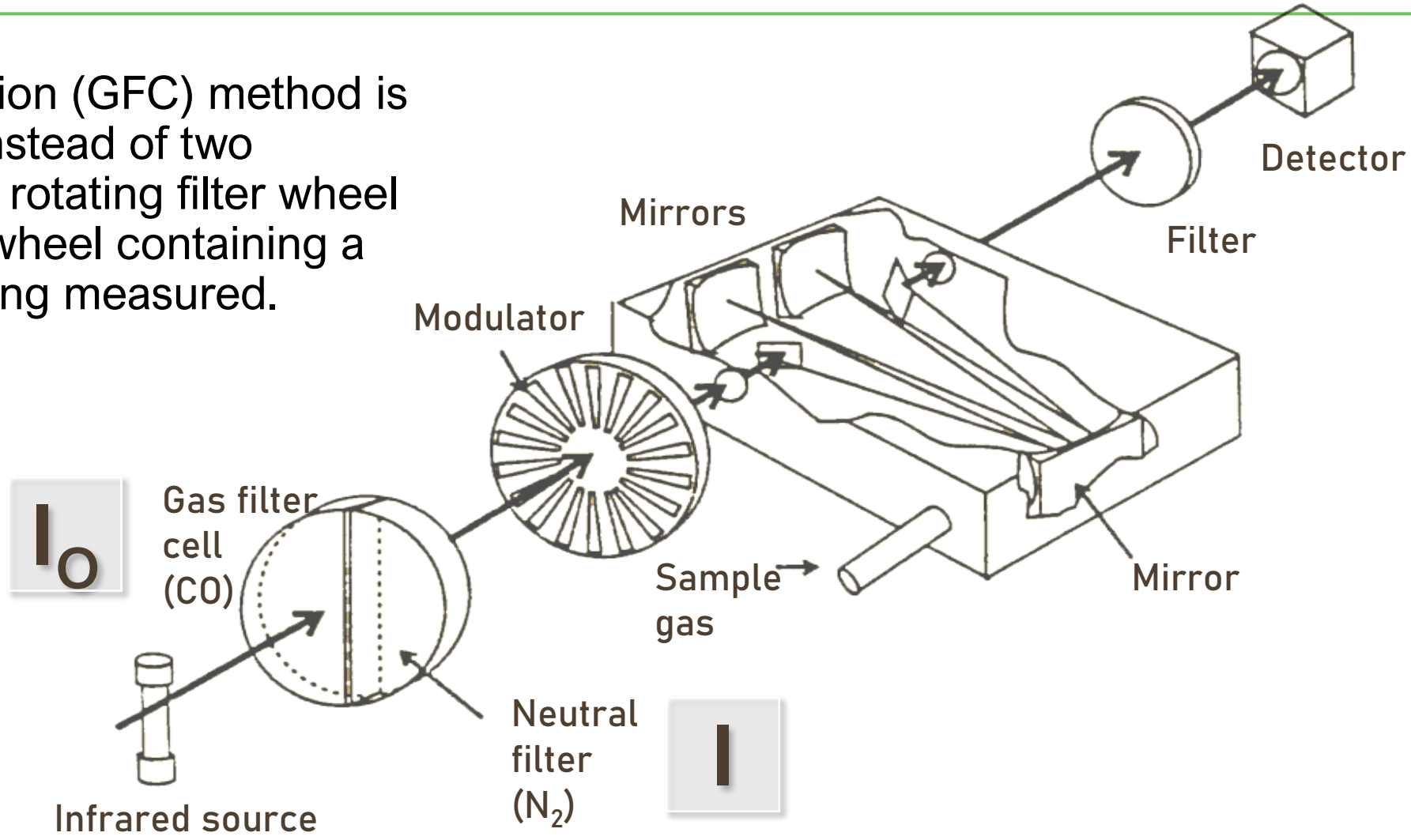
# Quality Assurance - Procedure 1

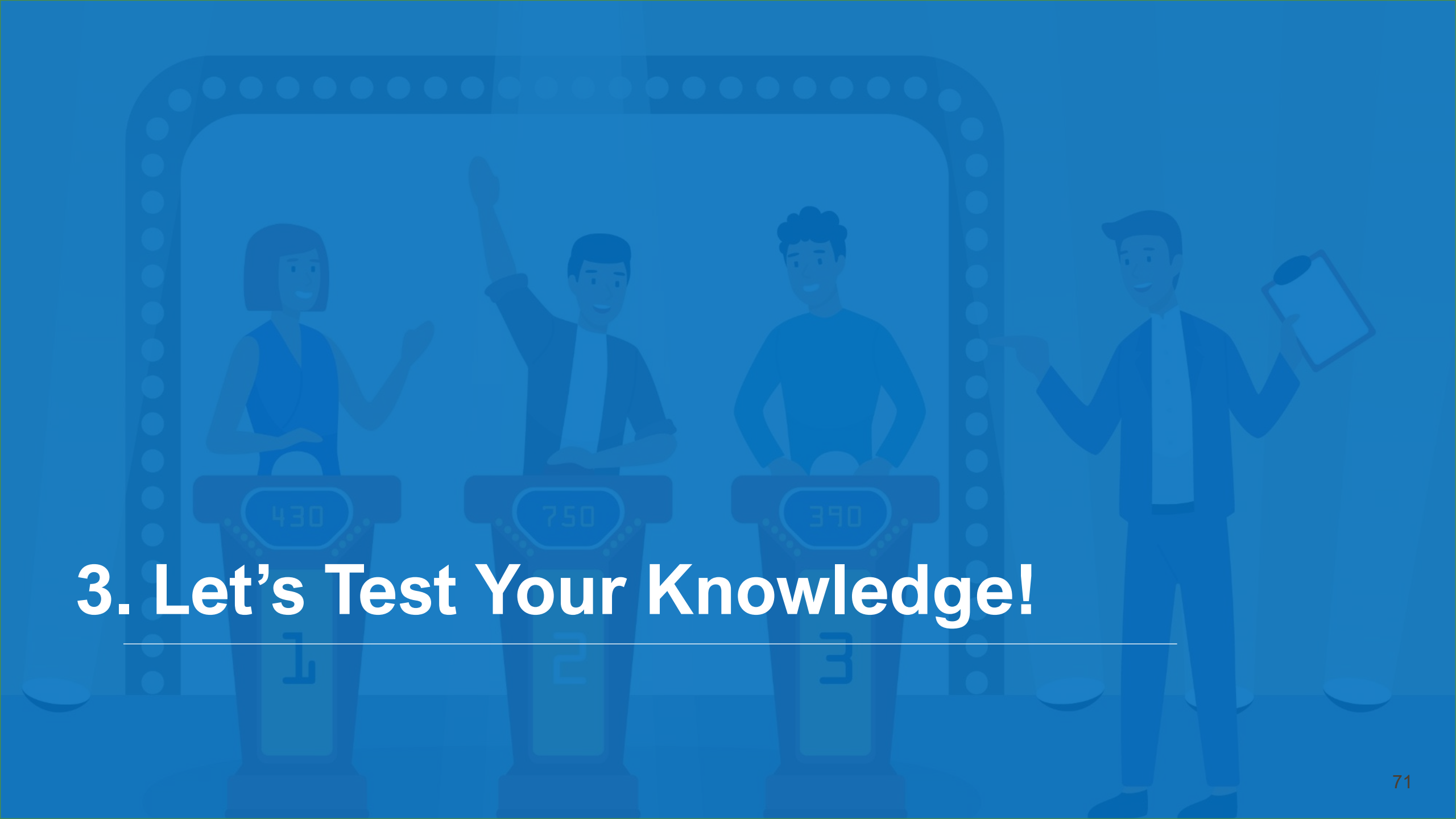



- PS-2, 3, and 4 use QA procedure 1.
- For more information, review slides under PS-2.

# 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.






# 3. Let’s Test Your Knowledge!

# Feedback

3. A. The results of a RATA are considered valid if the calculated relative accuracy is less than 20.0%, or if the RA is less than or equal to 1.0% when the applicable emission standard is used.

# 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%

# Feedback

2. A. For PS-4, the results of a RATA test are considered valid if the calculated relative accuracy is less than 10%, or if the RA is less than or equal to 5% when the applicable emission standard is used.

# 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%

# Feedback

4. PS-4 was primarily written to be used for CO analyzers with a 1000 ppmv.

# 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

# Performance Specification 4A (PS-4A)

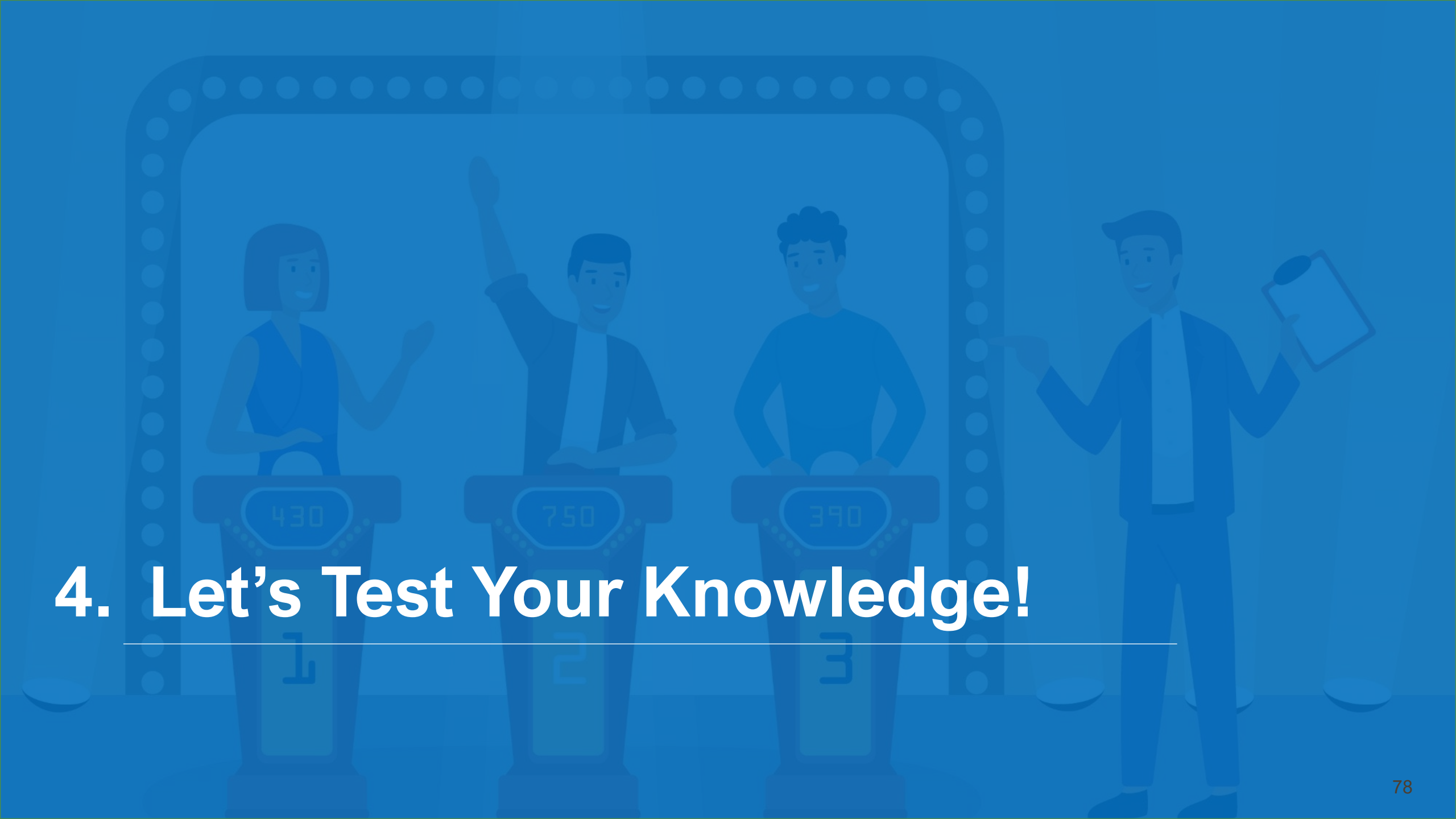
Specifications and Test Procedures for Carbon Monoxide (CO) Continuous Emission Monitoring Systems (CEMS) in Stationary Sources

# 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).

# 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.




# 4. Let’s Test Your Knowledge!

# Feedback

3. PS-4A was primarily written to be used for CO analyzers with less than 200 ppmv.

# 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

# 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

# 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

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

## Calibration Drift

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

## Calibration Error

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

# Performance and Equipment Specifications: Relative Accuracy: CO and $O_2$

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

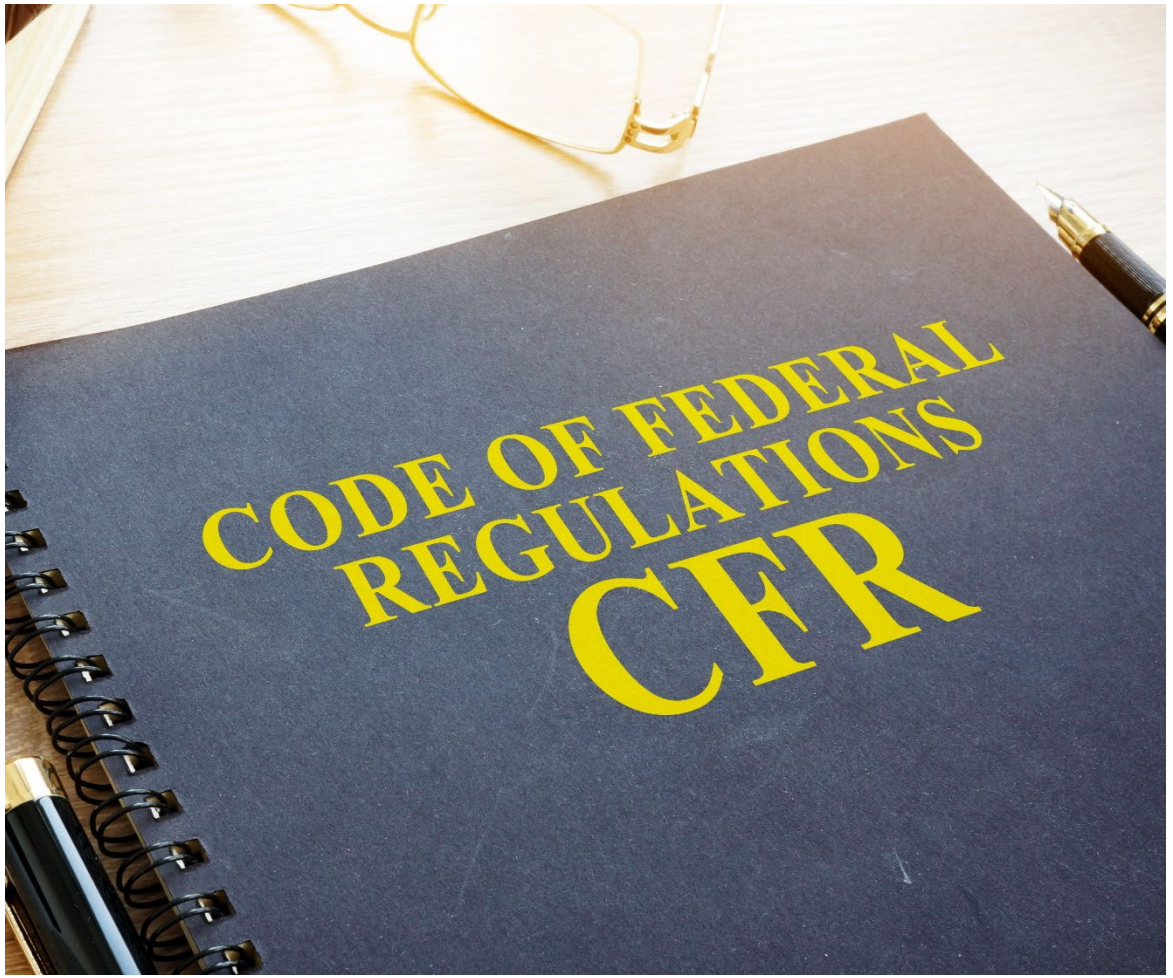
Relative Accuracy: CO and $O_2$

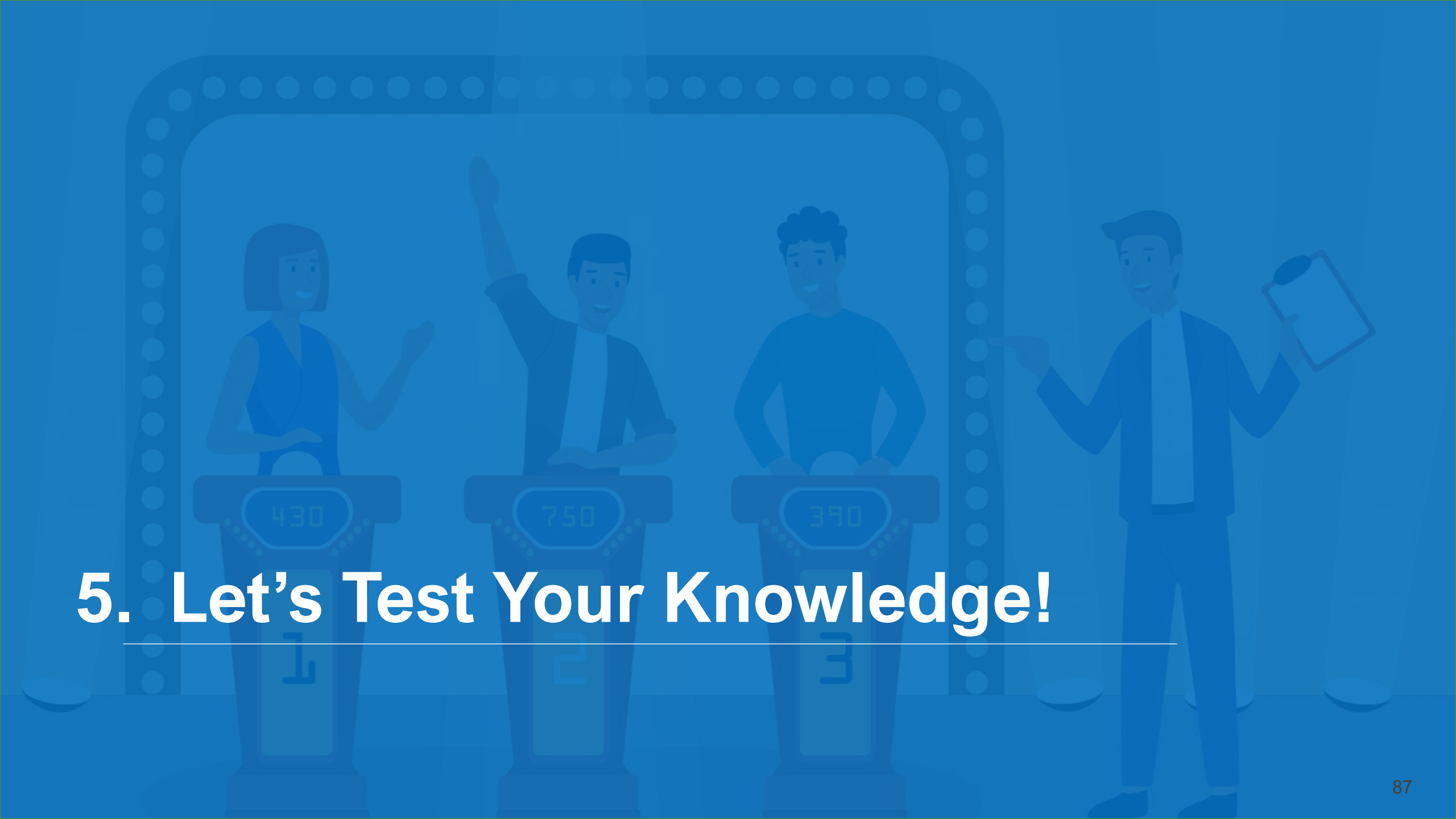
# Alternative Relative Accuracy Procedures

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

# 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






# 5. Let’s Test Your Knowledge!

# Feedback

2. A. For PS-4B, the results of a RATA test are considered valid if the calculated RA is less than 5.0%, or if the RA is less than or equal to 0.5% when the applicable emission standard is used.

# 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%

# Feedback

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

# PS-4B – Question 3, 4

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

A. CO

C. CO and $O_2$

B. $O_2$

D. None of the above

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

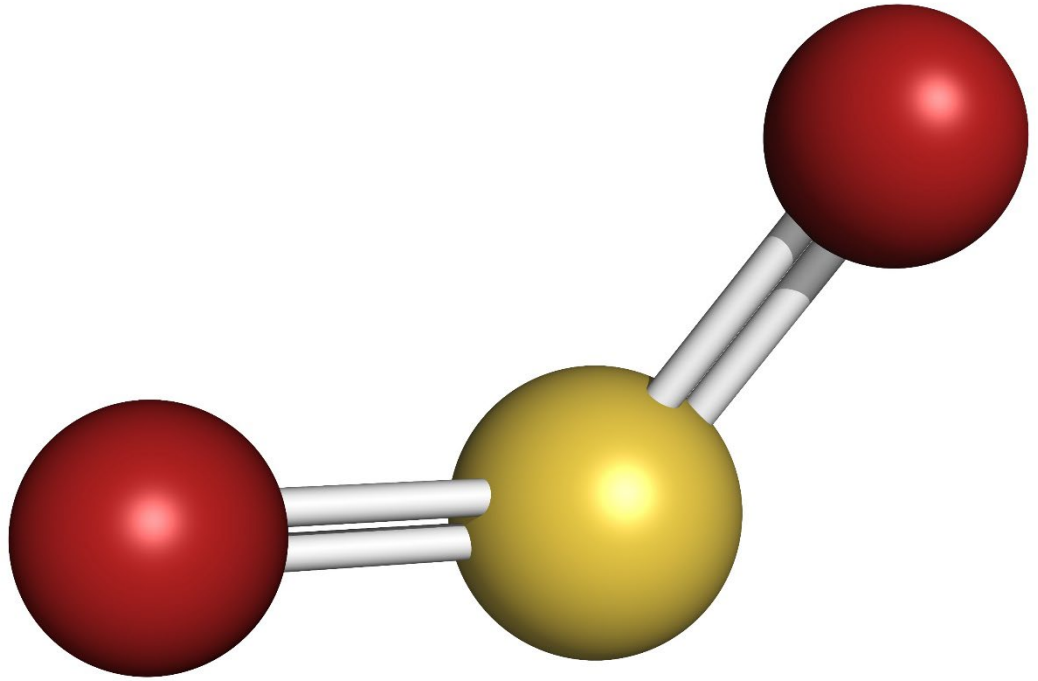
Check Answer

# Performance Specification 5 (PS-5)

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

# 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.
- 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



# 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.

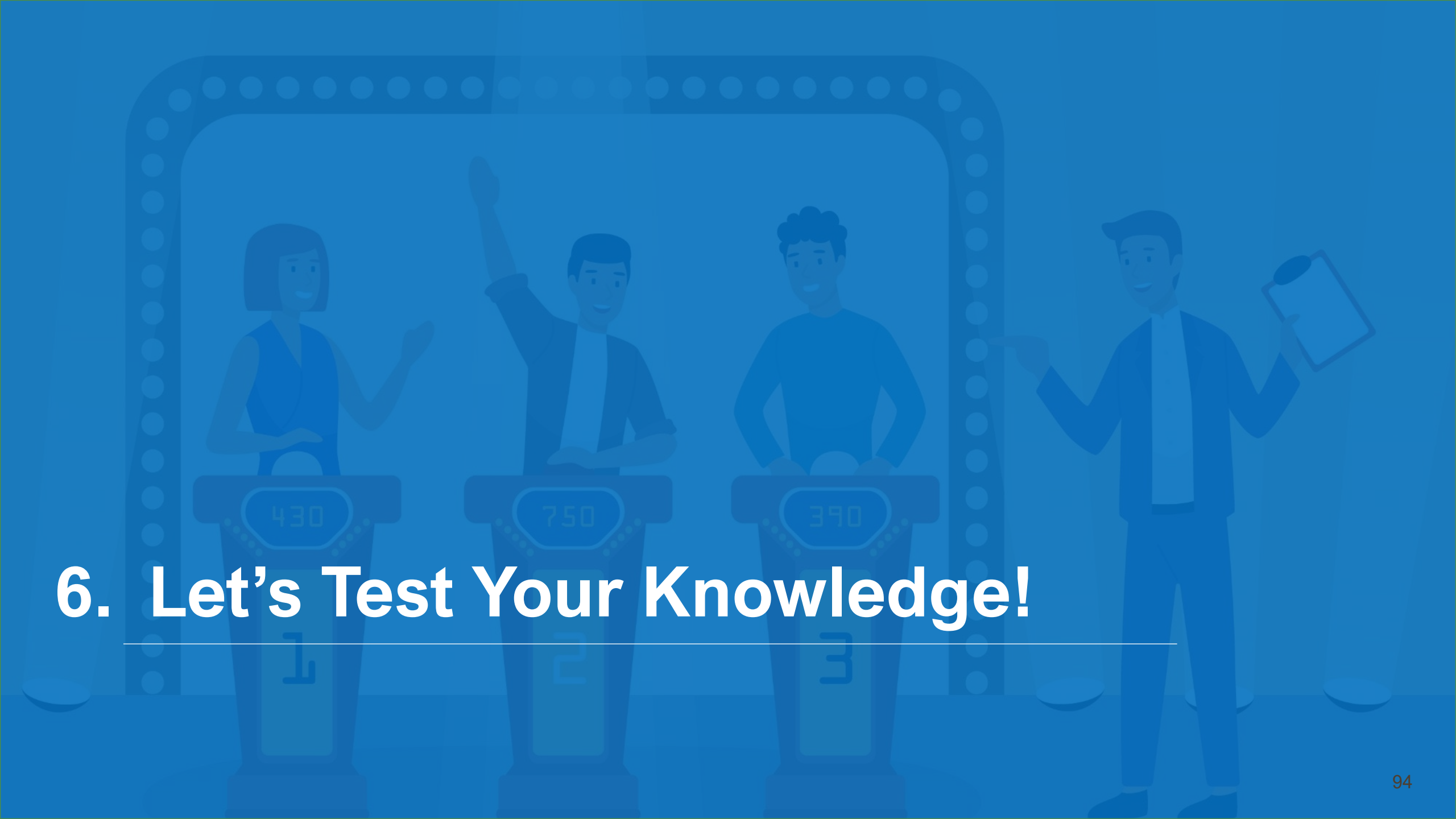
**NOTE:** There is no promulgated QA procedure for TRS monitors, however, subparts or regulations may require ongoing QA.

# 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




# 6. Let’s Test Your Knowledge!

# Feedback

2. C. For PS5, the results of a RATA test are considered valid if the calculated RA is less than 20%, or if the RA is less than or equal to 10% when the applicable emission standard is used.

# 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%

# Performance Specification 6 (PS-6)

Specifications and Test Procedures for Continuous Emission Rate Monitoring Systems (CERMS) in Stationary Sources

# 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.

# Calibration Drift

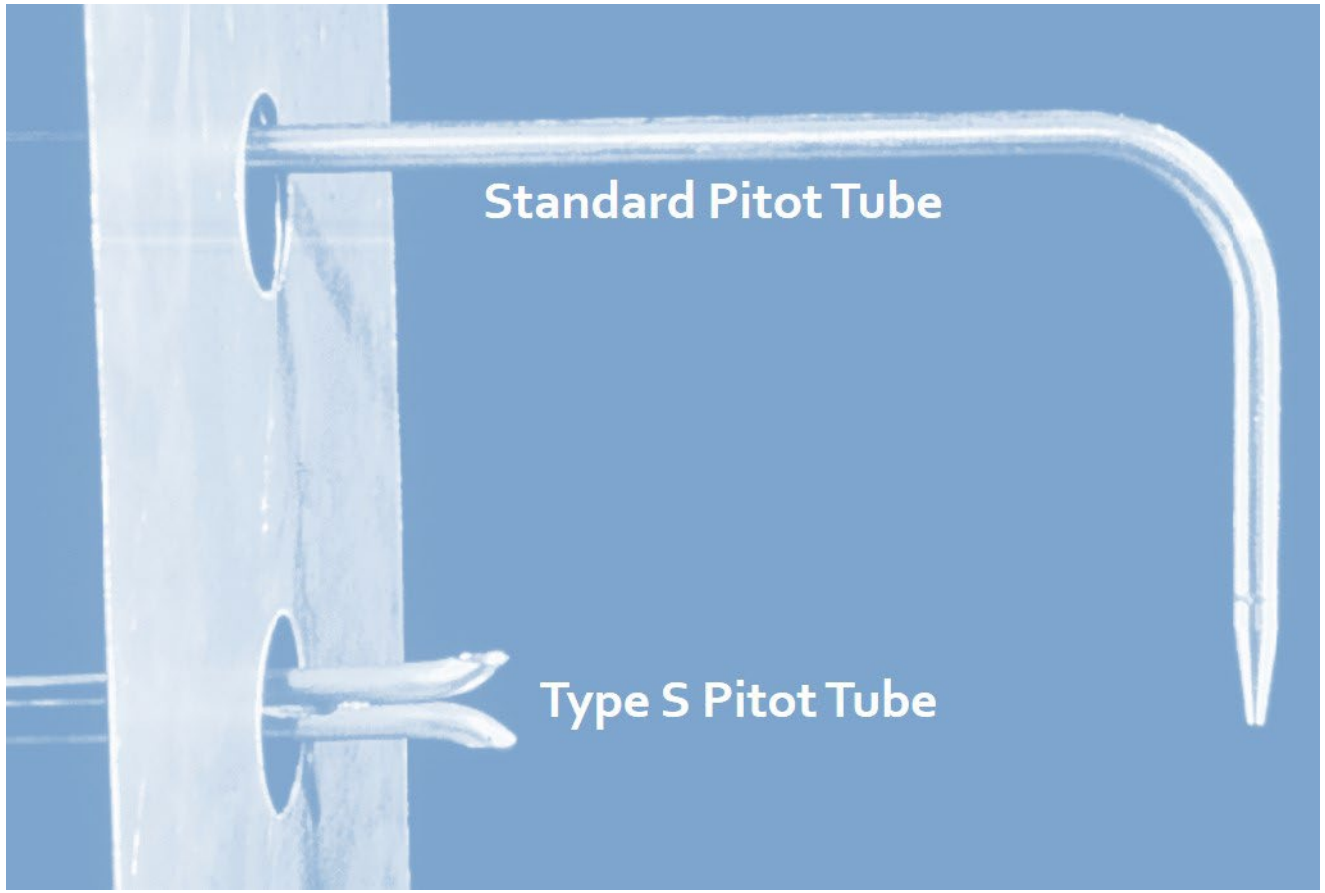
- Determined separately for each analyzer
  - Shall not exceed 3% of the high-level value
- Conduct the CD tests for pollutant concentration at the two values specified in section 6.1.2 of PS-2.
- For other parameters (e.g., velocity, pressure, flow rate), use two analogous values (e.g., Low: 0-20% of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

# 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.

# Commonly Used Technologies for PS-6

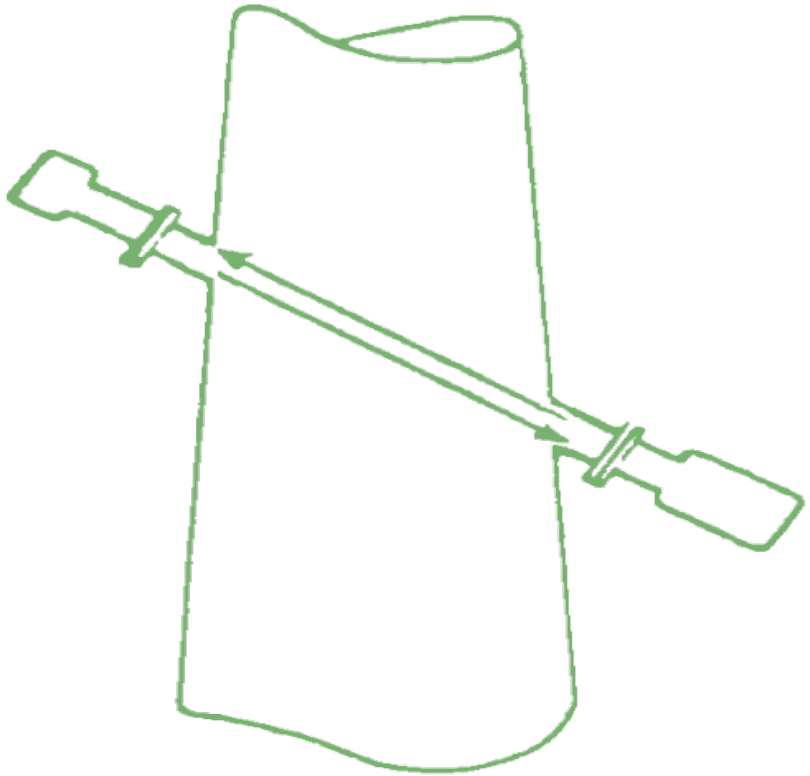
*Pitot tubes* use the differential pressure between the measurements of total pressure and the static pressure at a point in the stack to calculate the stack gas velocity and volumetric flowrate.

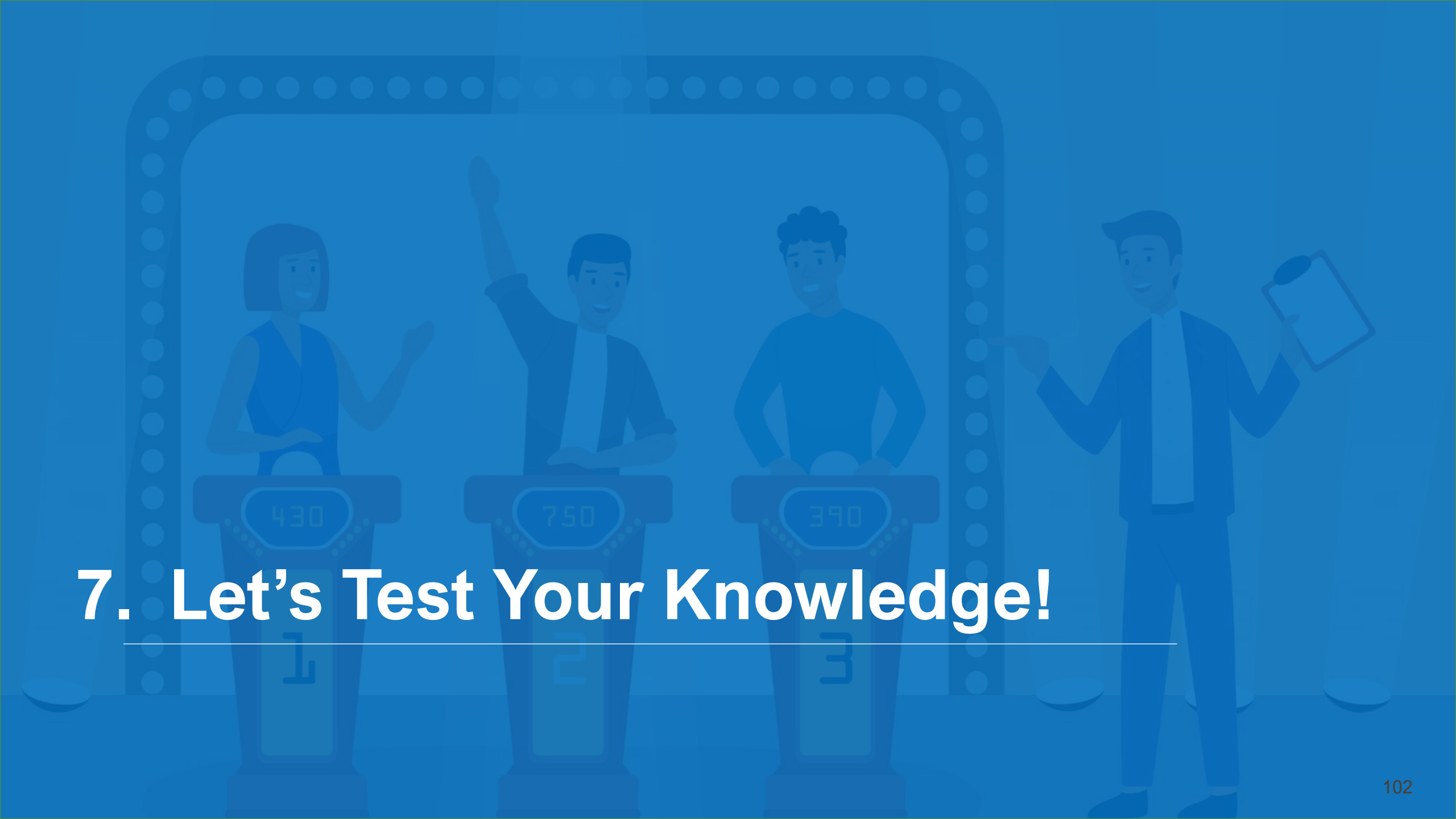


# Commonly Used Technologies for PS-6 (Cont'd)

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.

**Acoustic Velocity**






# 7. Let’s Test Your Knowledge!

# Feedback

4. When measuring flow rates, pilot tubes and ultrasonic flow meters are two commonly used techniques.

# 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

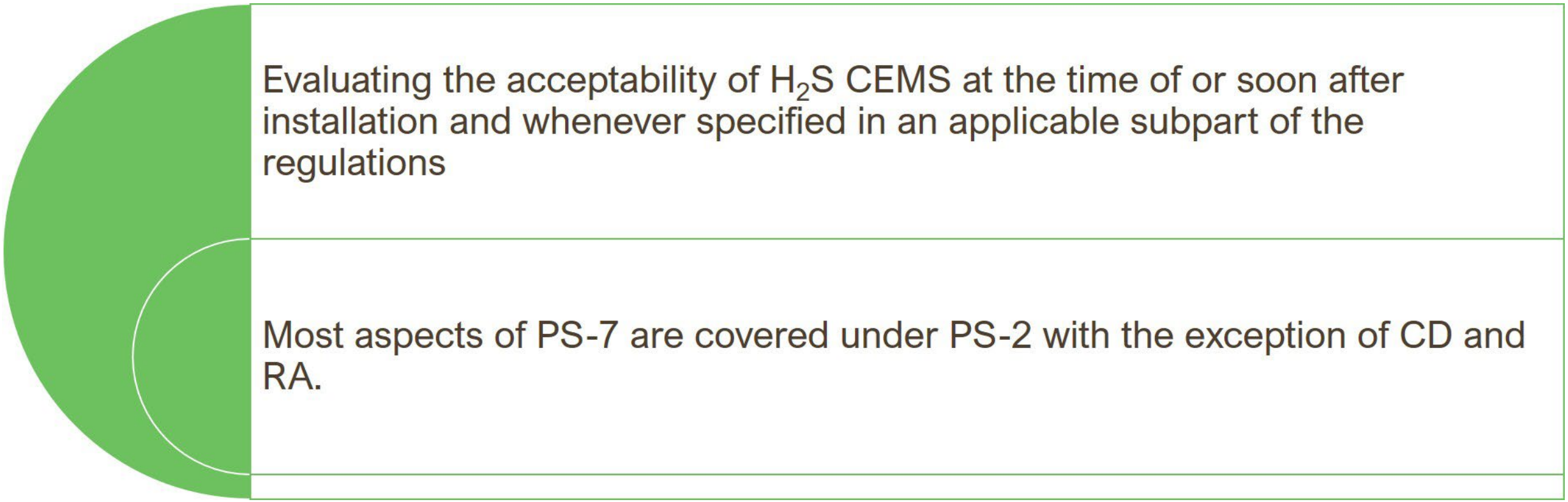
4. When measuring flow rates, what are two commonly used techniques?

Check Answer

# Performance Specification 7 (PS-7)

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

# PS-7 Overview



# PS-7 Calibration Drift and Relative Accuracy

## 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)

## 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, 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.**

# Commonly Used Technology for PS-7

GC—see description in PS-5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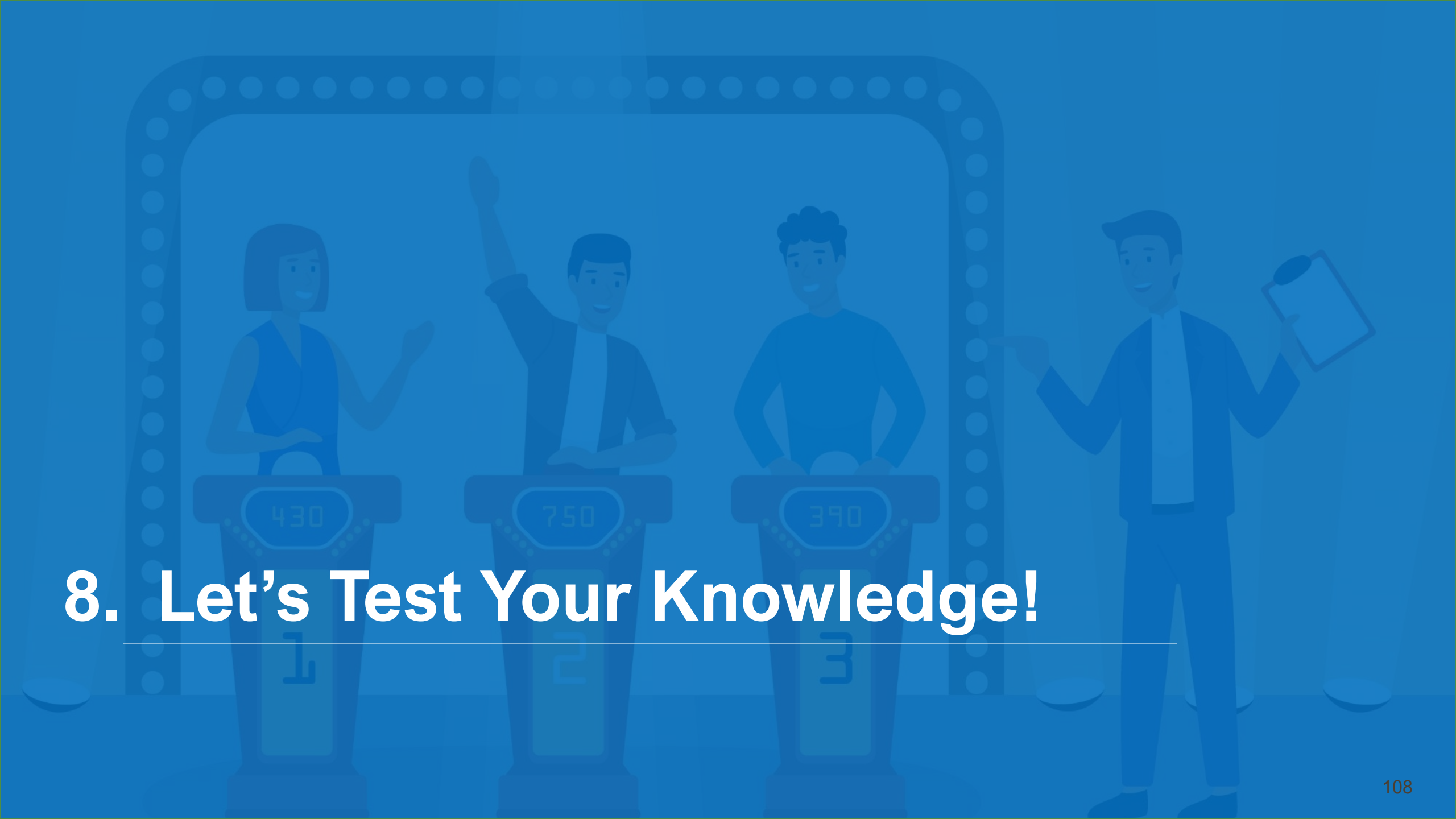



# 8. Let’s Test Your Knowledge!

# Feedback

3. A GC is a commonly used technology associated with PS-7.

# 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

# Performance Specification 8 (PS-8)

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

# 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.

# PS-8 Calibration Drift and Relative Accuracy

## Calibration Drift

- < 2.5% of span value
- No adjustments to CEMS prior to daily measurement

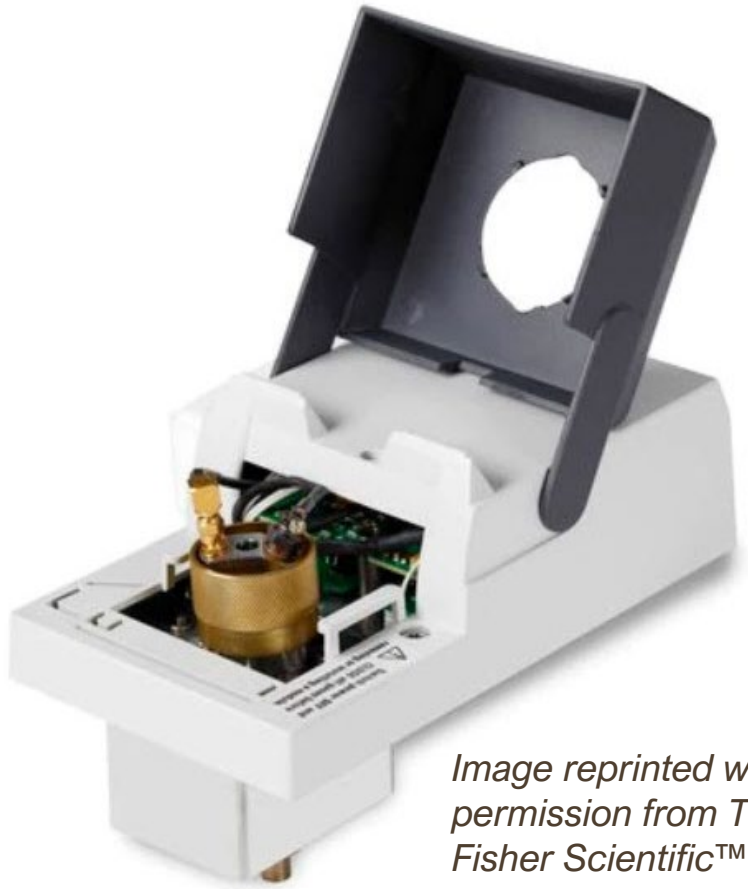
## Relative Accuracy

- < 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.

# 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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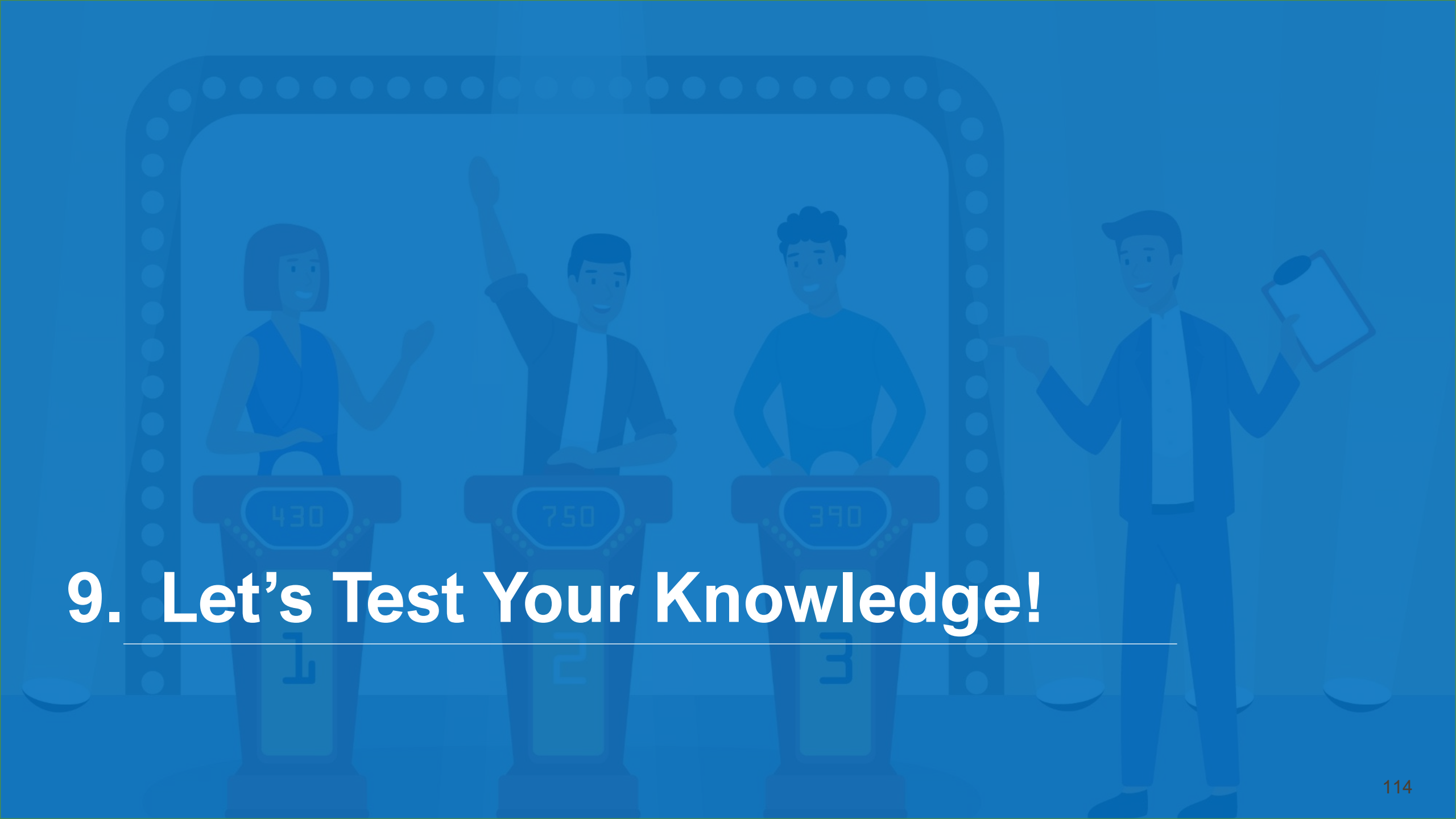



# 9. Let’s Test Your Knowledge!

# Feedback

2. B. 2.5%

# 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%

# Feedback

4. The most commonly used technology associated with PS-8 is an FID.

# 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%

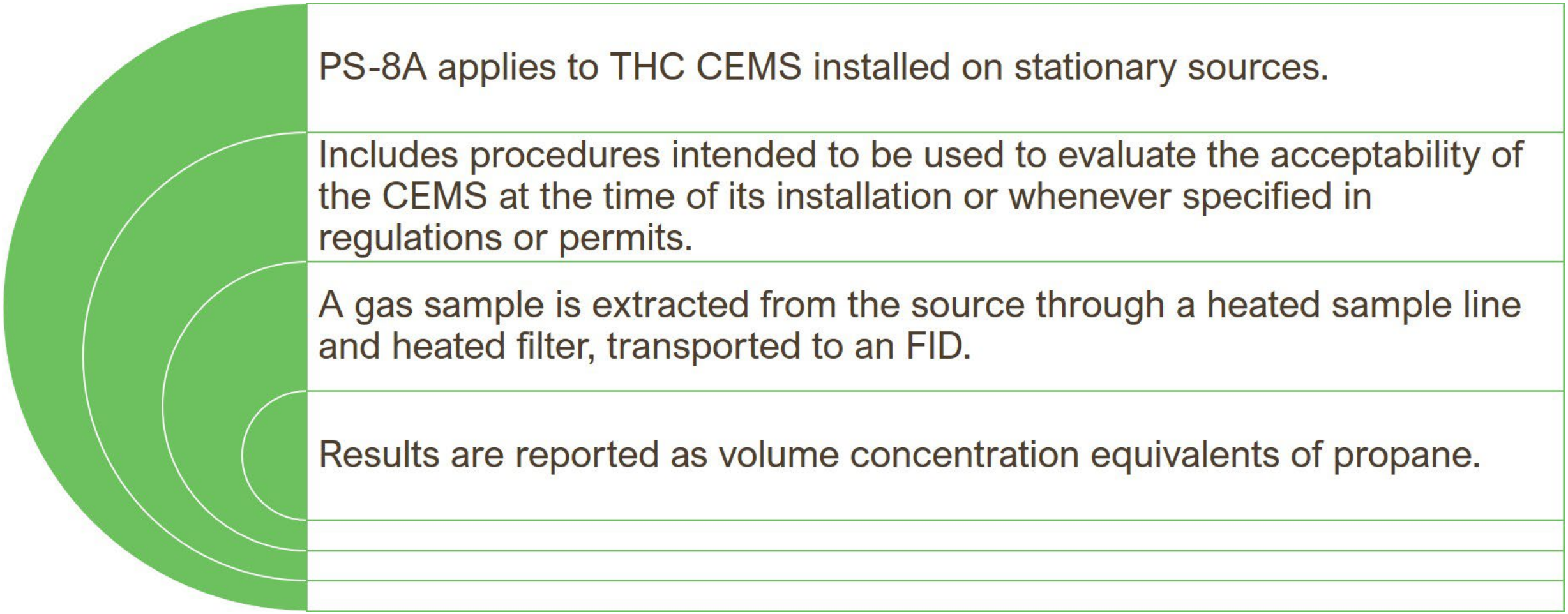
4. What is the most commonly used technology associated with PS-8?

Check Answer

# Performance Specification 8A (PS-8A)

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

# PS-8A Overview



# 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

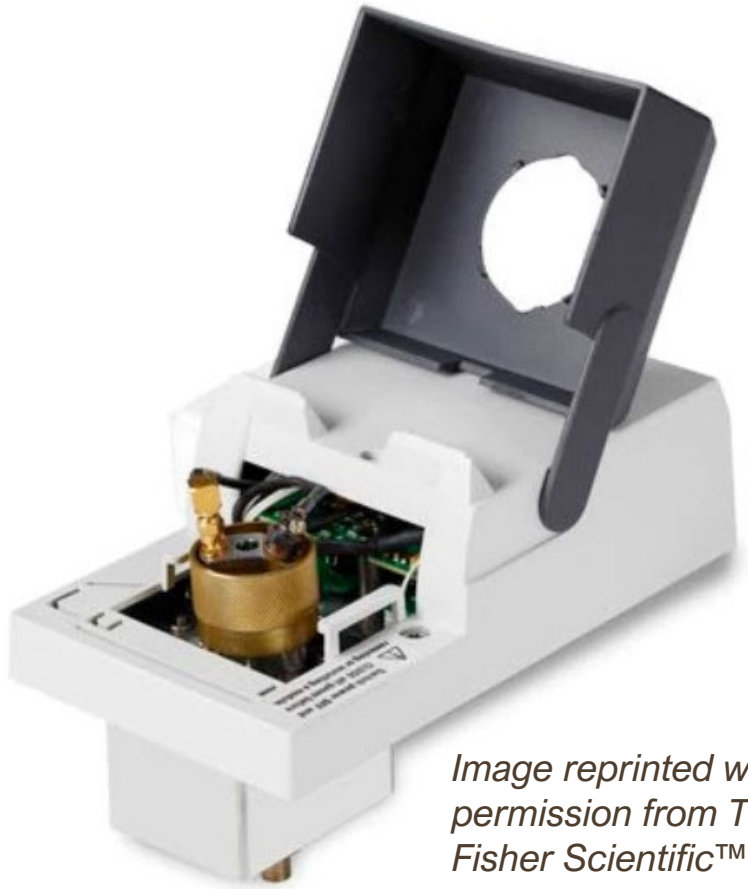
- While a unit is operating, determine the CD for seven consecutive operating days, make no adjustment to system prior to performing CD test.
- The CEMS must not drift by ±3ppm or ±3% of span value after each 24-hour period of the 7-day drift test for both the zero and span gases.

## 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).

# Commonly Used Technology for PS-8A

FID - see details under PS-8



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# 10. Let’s Test Your Knowledge!

# Feedback

3. D. For PS-8A, a low-level gas must be used at 0-0.1% of the span, and a high-level gas must be used at 70-80% of the span.

# PS-8A

1. What is PS-8A primarily used to evaluate?

Check Answer

2. For PS-8A, the instrument span value must be ____ as propane.

A. 90%

C. 100 ppm

B. 50 ppm

D. 10%

3. For PS-8A, a low-level gas must be used at ____% of the span, and a high-level gas must be used at ____% of the span.

A. 1-10% and 10-20%

C. 0-0.5% and 50-75%

B. 0-5% and 90-100%

D. 0-0.1% and 70-80%

# Performance Specification 9 (PS-9)

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

# PS-9 Overview

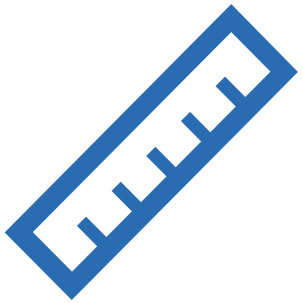
Applies to CEMS that use GC to measure a specific target list of organic compounds.

- 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.

# 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.

# 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.

# 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.

# Commonly Used Technology for PS-9

GC—see description in PS-7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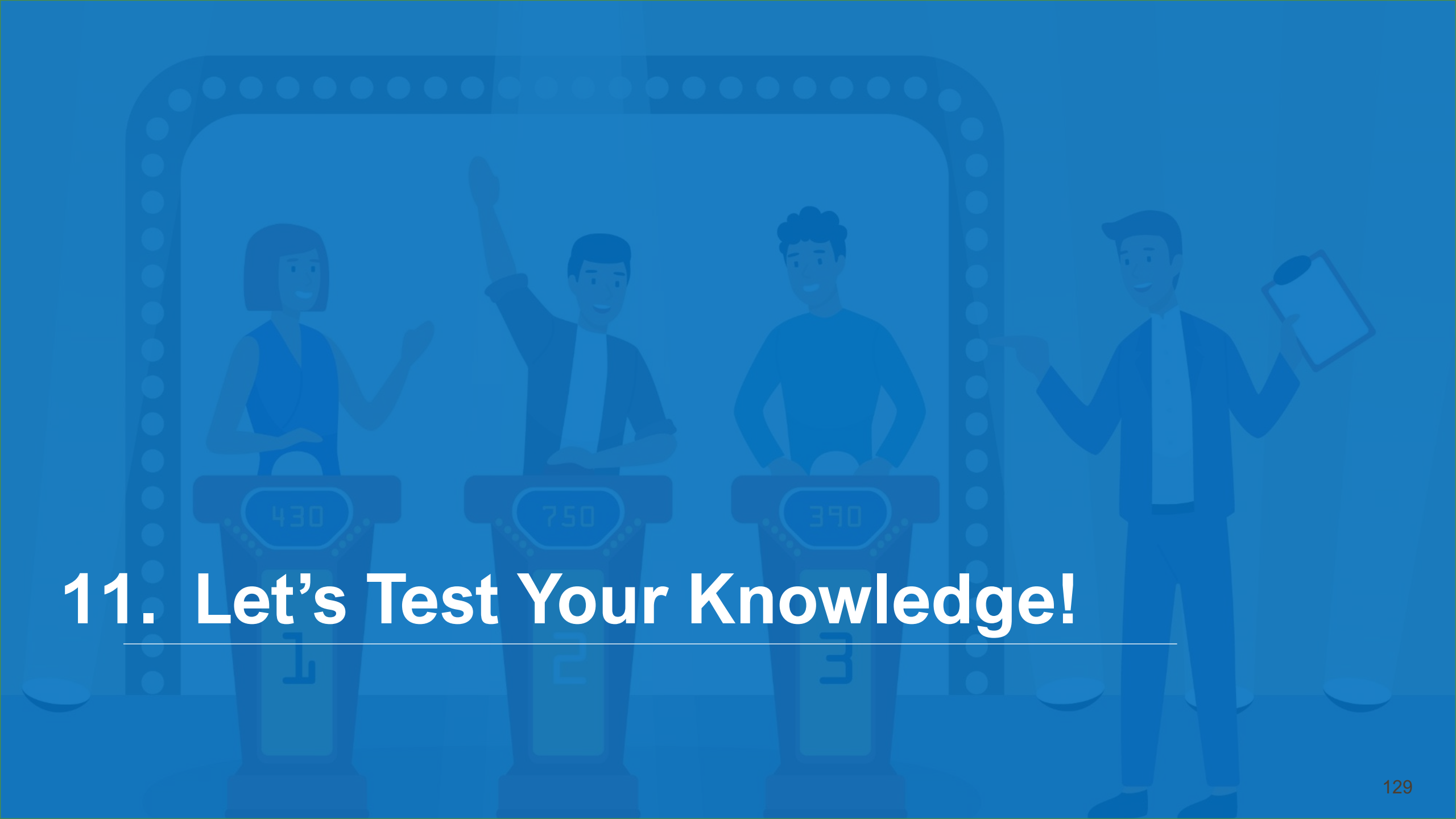



# 11. Let’s Test Your Knowledge!

# Feedback

1. PS-9 applies to CEMS that use GC to measure gaseous organic compound emissions.

# PS-9

1. PS-9 applies to CEMS that use___.

Check Answer

# Performance Specification 11 (PS-11)

Specifications and Test Procedures for Particulate Matter (PM) Continuous Emission Monitoring Systems (CEMS) in Stationary Sources

# 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).

# 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.

# 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.

# Performance Test

**Sampling Period**

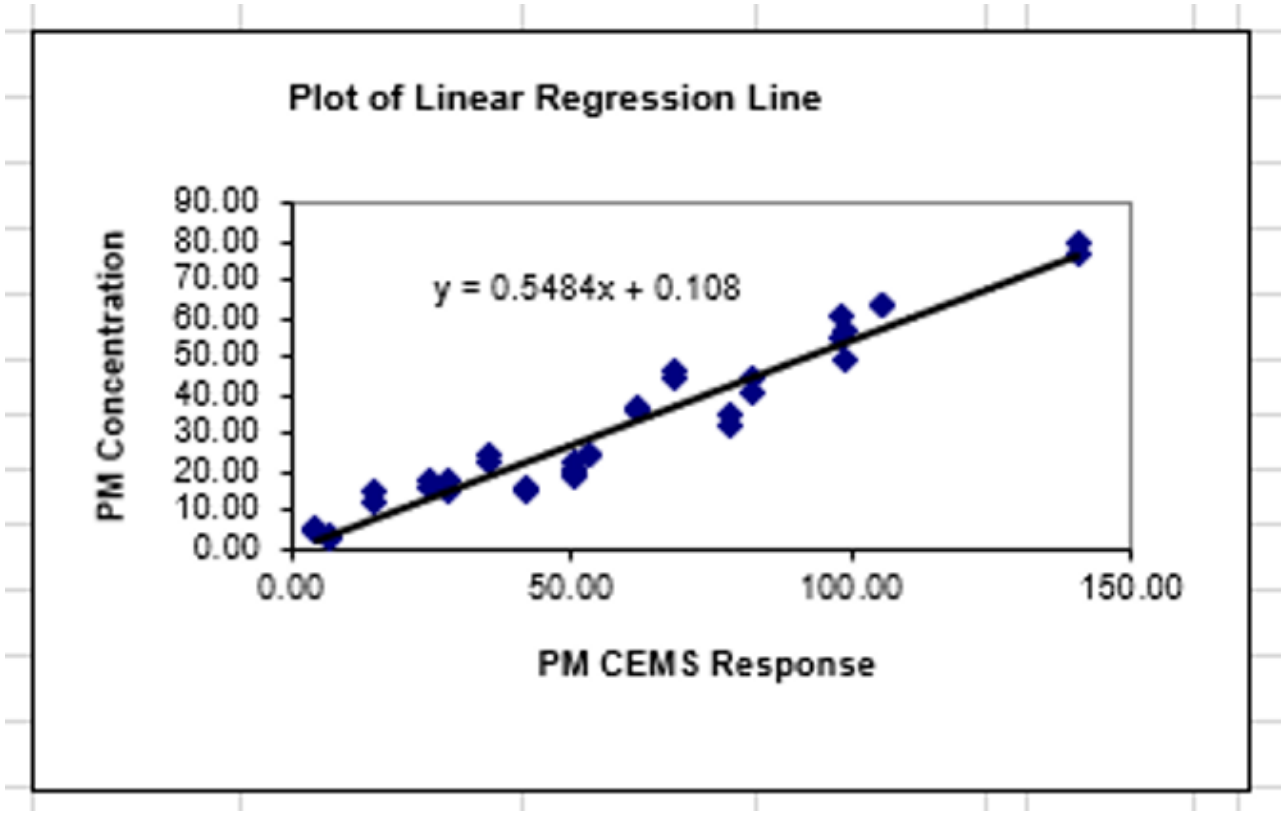
- Must be no less than 30% of the cycle time for batch sampling CEMS.

**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.

# Developing a PS-11 Correlation

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



# 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.

# 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

# 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 an 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) | | |

# 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 ±10% of average audit value or 7.5% of applicable standard | Must be less than ±5% of sample volume audit value |

# 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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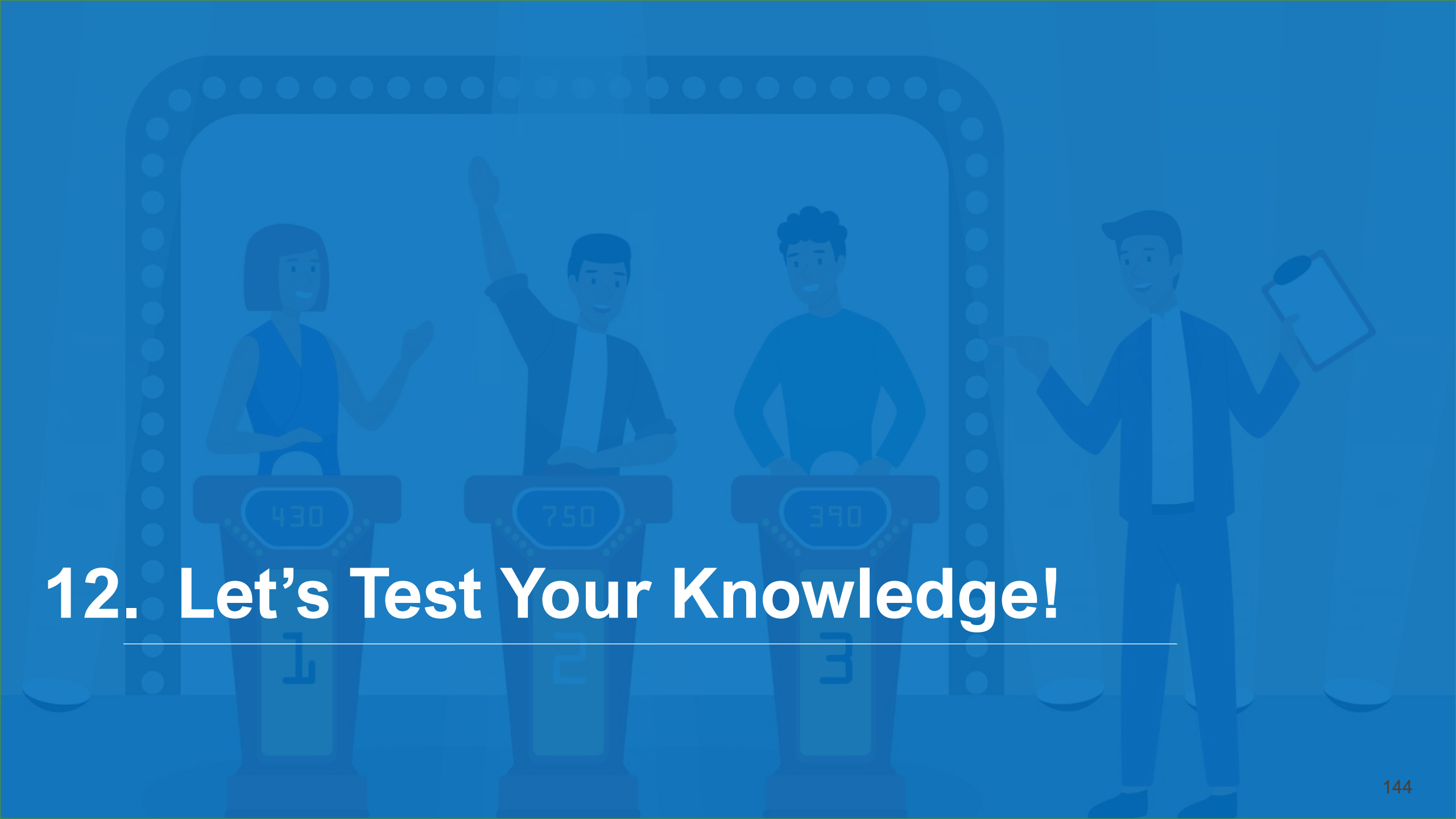



# 12. Let’s Test Your Knowledge!

# Feedback

2. A. Type and characteristics of PM vary from source to source.

# 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

# Feedback

4. Procedure 2 is associated with PS-11.

# 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

# Performance Specification 12A (PS-12A)

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

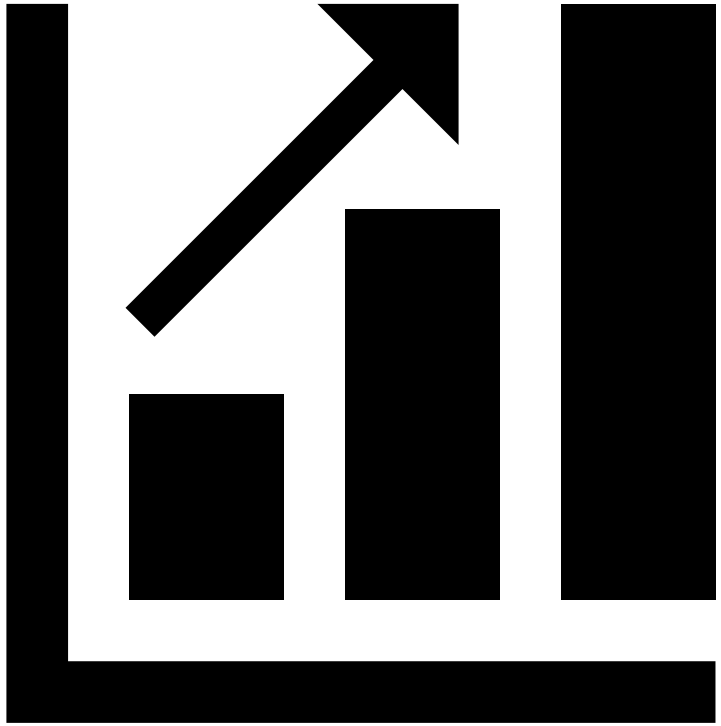
# PS-12A Overview

- 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.

# 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



# Measurement Error and Calibration Drift

| Measurement Error Test | Calibration Drift Test |
|---|---|
| For $HgO_x$ , 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.<br>• 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.

# 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<br><br>• 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.<br>• Determine number of sampling points by Method 1.<br>• Minimum of nine 2-hour test runs. |
| | Method 30A and 30B<br>• Use 12 sampling points according to Method 1.<br>• Minimum of nine 30-minute test runs. |

# 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

# 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

# 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

# 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 | • CGA - 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<br>• RAA - alternative to CGA; 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 |

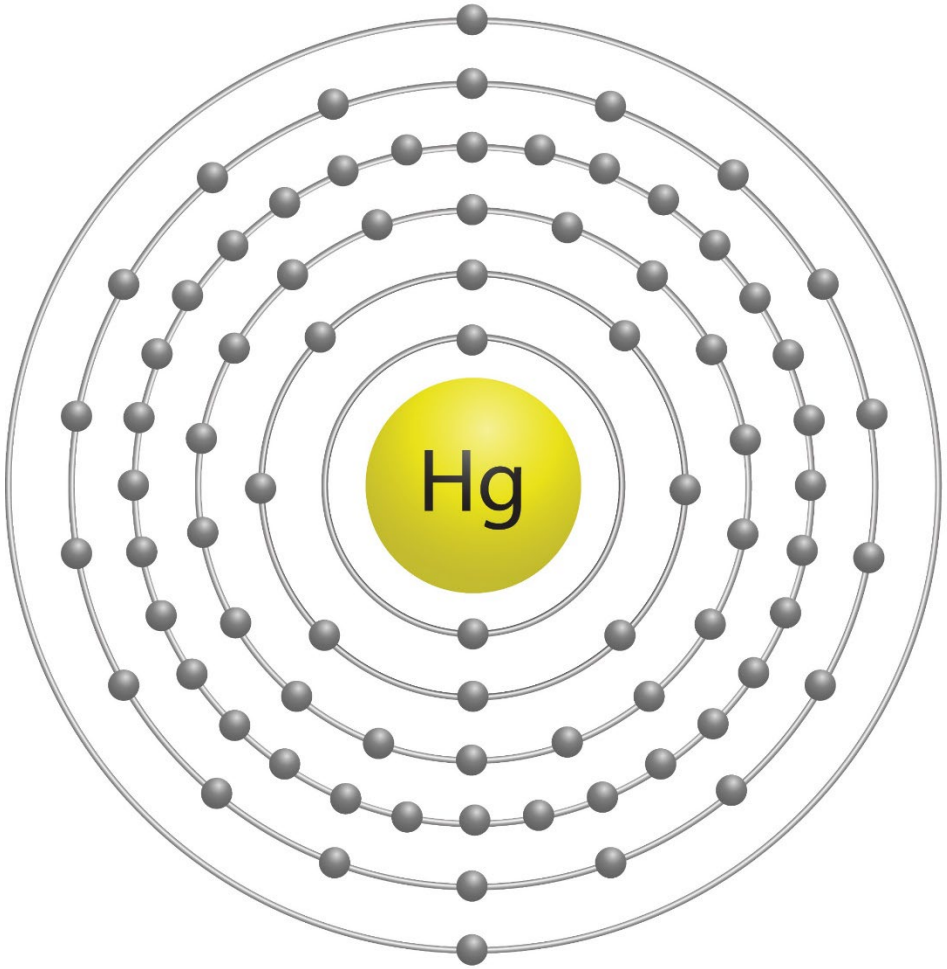
# Procedure 5: Excessive Audit Inaccuracy

| 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 quarterly gas audit (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/sc if difference between CEMS and RM < 1.0 µg/scm<br><br>QGA: +/- 15% of the average audit value or +/- 5 µg/m3 (whichever is greater)<br><br>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. |

# Commonly Used Technology for PS-12A

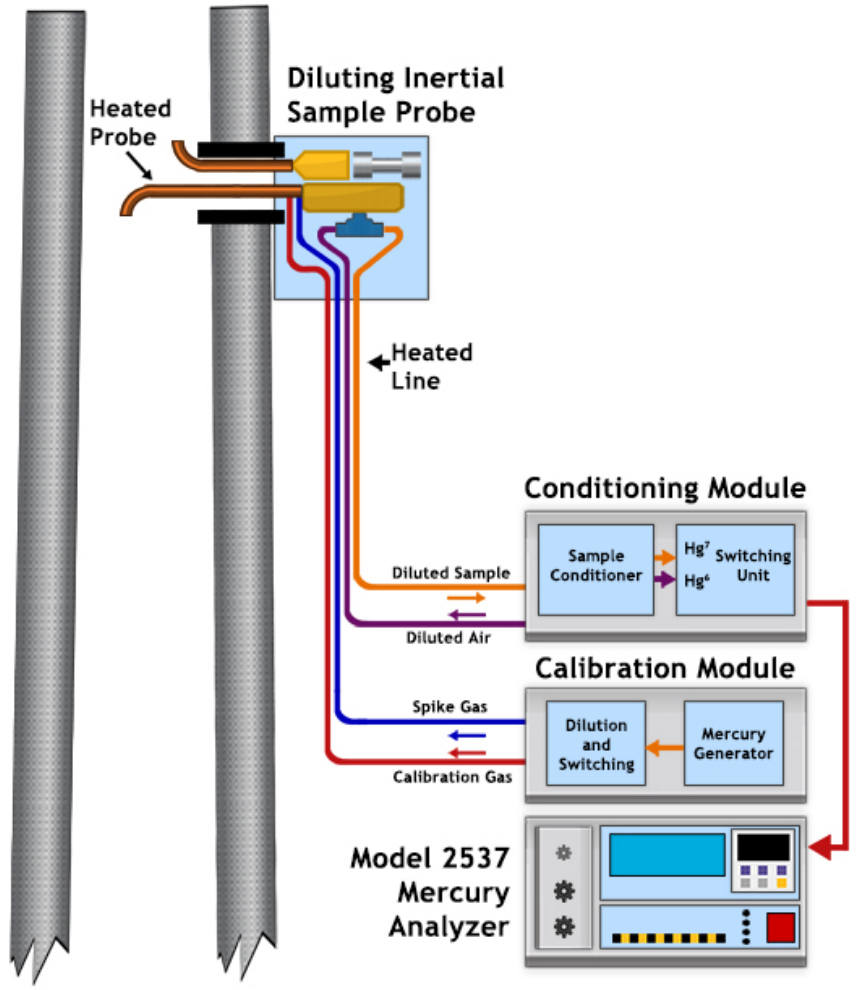
Hg sample is extracted from the stack and analyzed using atomic fluorescence spectroscopy to measure the concentration of Hg vapor in the sample.

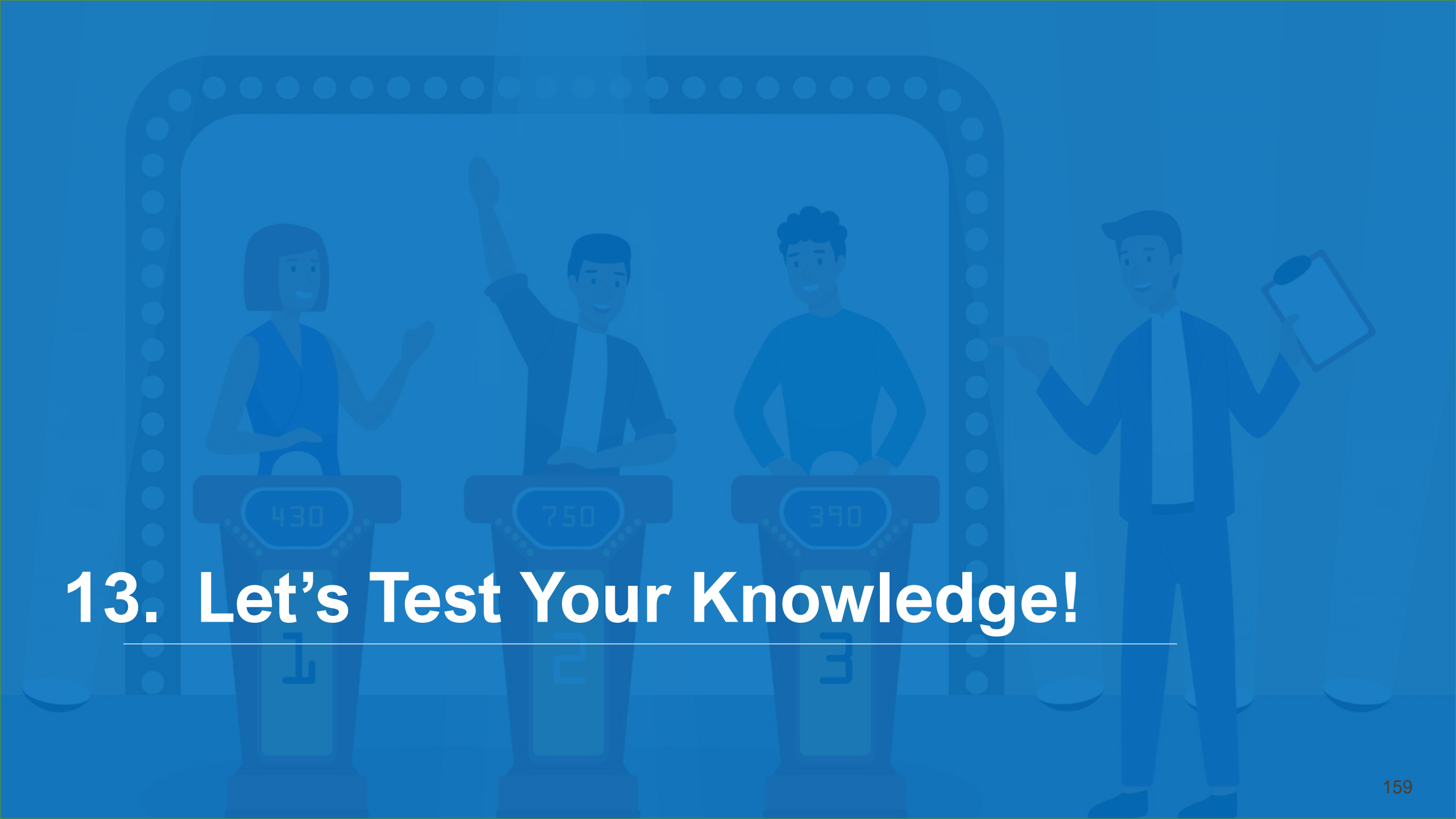
- When an Hg atom absorbs the energy from a specific UV wavelength, an electron transitions from a stable ground state to an unstable, excited state, and when the UV energy source is removed, the electron returns to its stable state and emits a photon of light.



# 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






# 13. Let’s Test Your Knowledge!

# Feedback

2. A. The results of a RATA test are considered valid if the calculated RA is less than 20%, or if the absolute difference is less than or equal to 1.0% ug/m3.

# 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

# Feedback

4. Sorbent traps and atomic fluorescent spectroscopy are two measurement techniques used for PS-12A.

# 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

# Performance Specification 12B (PS-12B)

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

# 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).

# 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.

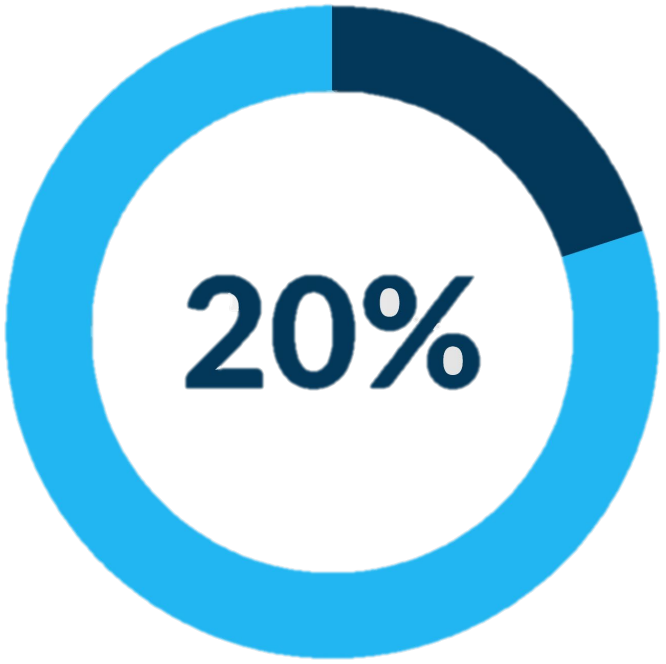
Must use expected Hg concentration to determine sample flow rate and sorbent tube spike mass.

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.

# PS-12B Relative Accuracy and Reference Methods



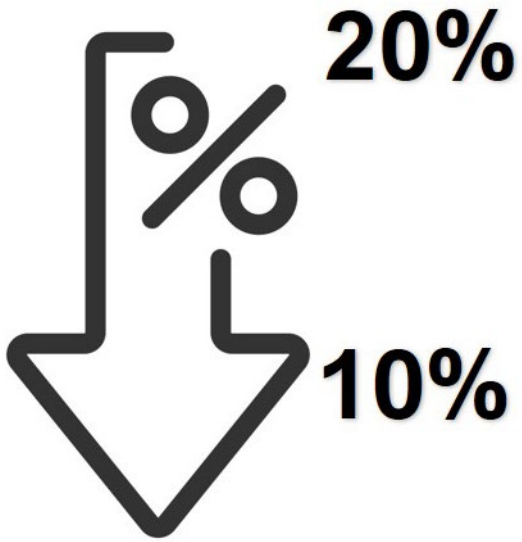

- For initial certification of a sorbent trap monitoring system, an RA test is required.
- Sorbent trap used in RA must be same type material as used in daily operation.
- Use 12 sampling points according to method 1.
- The RA of the sorbent trap monitoring system must be <20% of the mean value of the RM test data in terms of units of µg/scm.
  - Alternatively, if the RM concentration is ≤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.

# 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%. |

# 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.



# 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.

# 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:

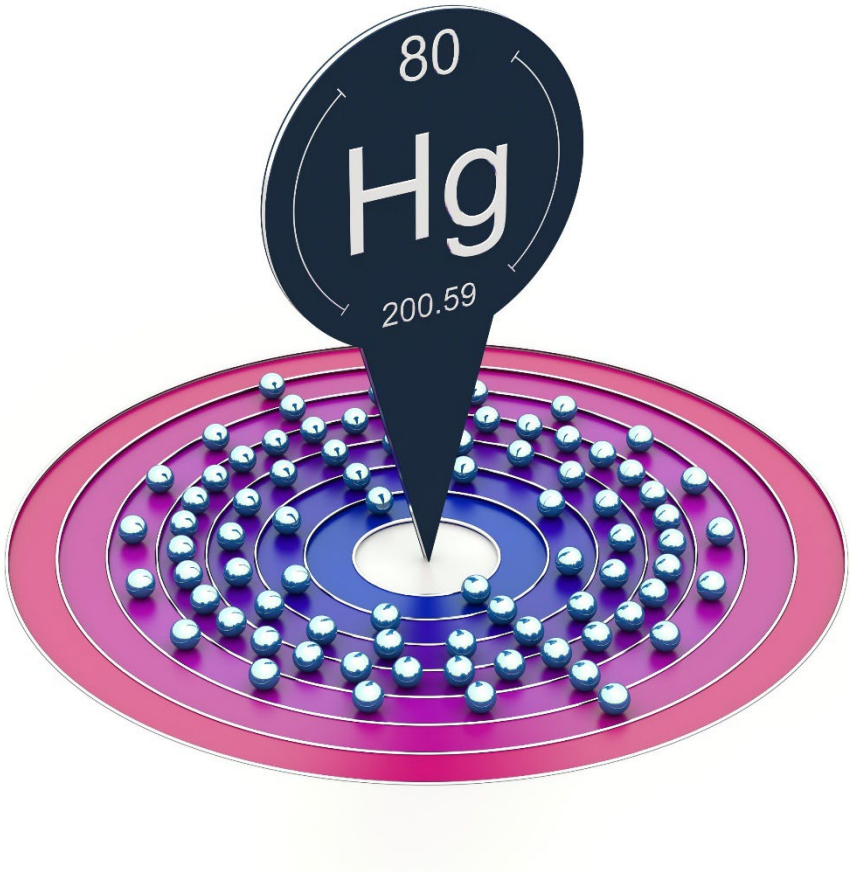
- **Post-monitoring leak check**
- **Ratio of stack gas flow rate to sample flow rate**
- **Section 2 breakthrough**
- **Paired trap agreement**
- **Section 3 spike recovery**

**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).

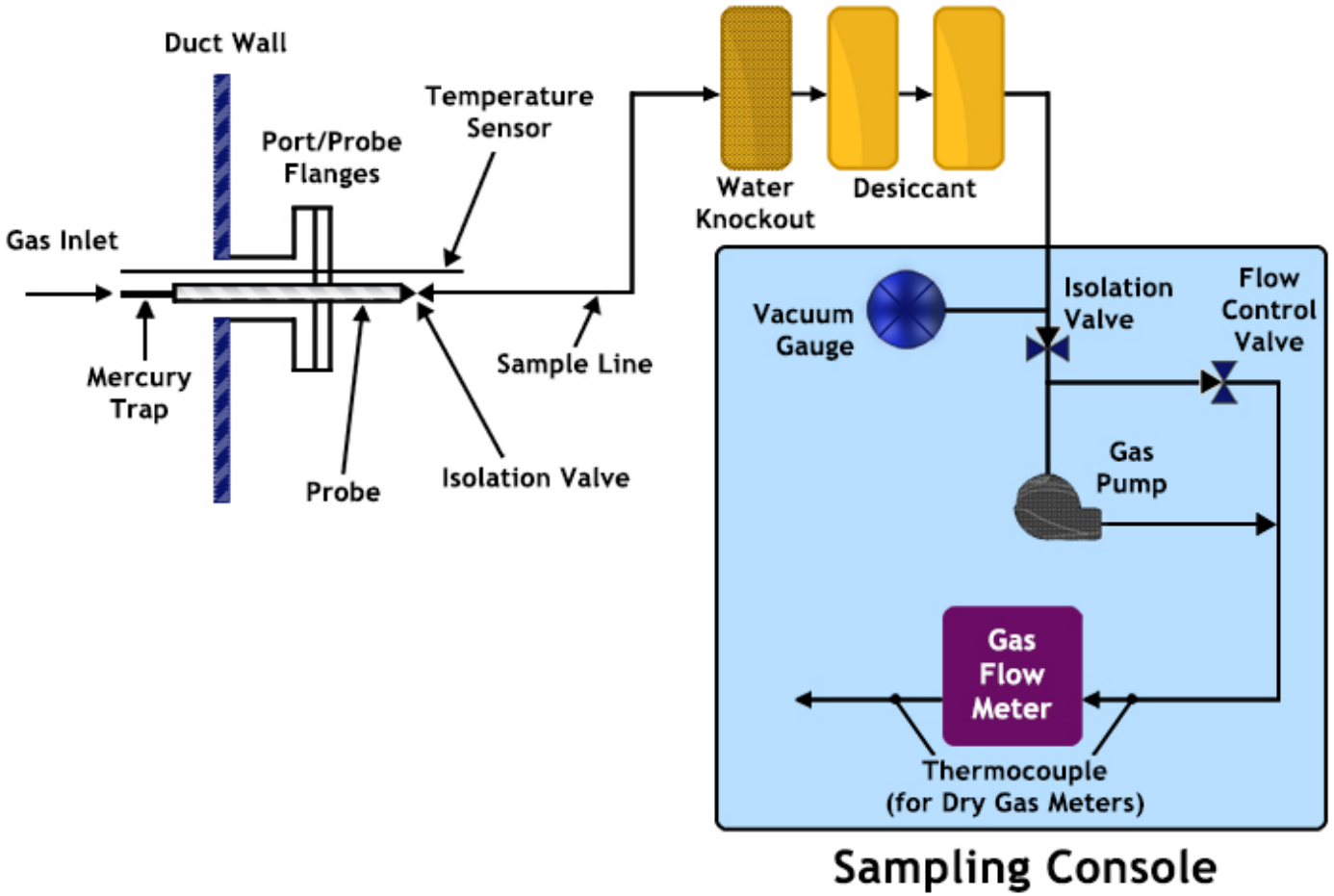
# Common Technology

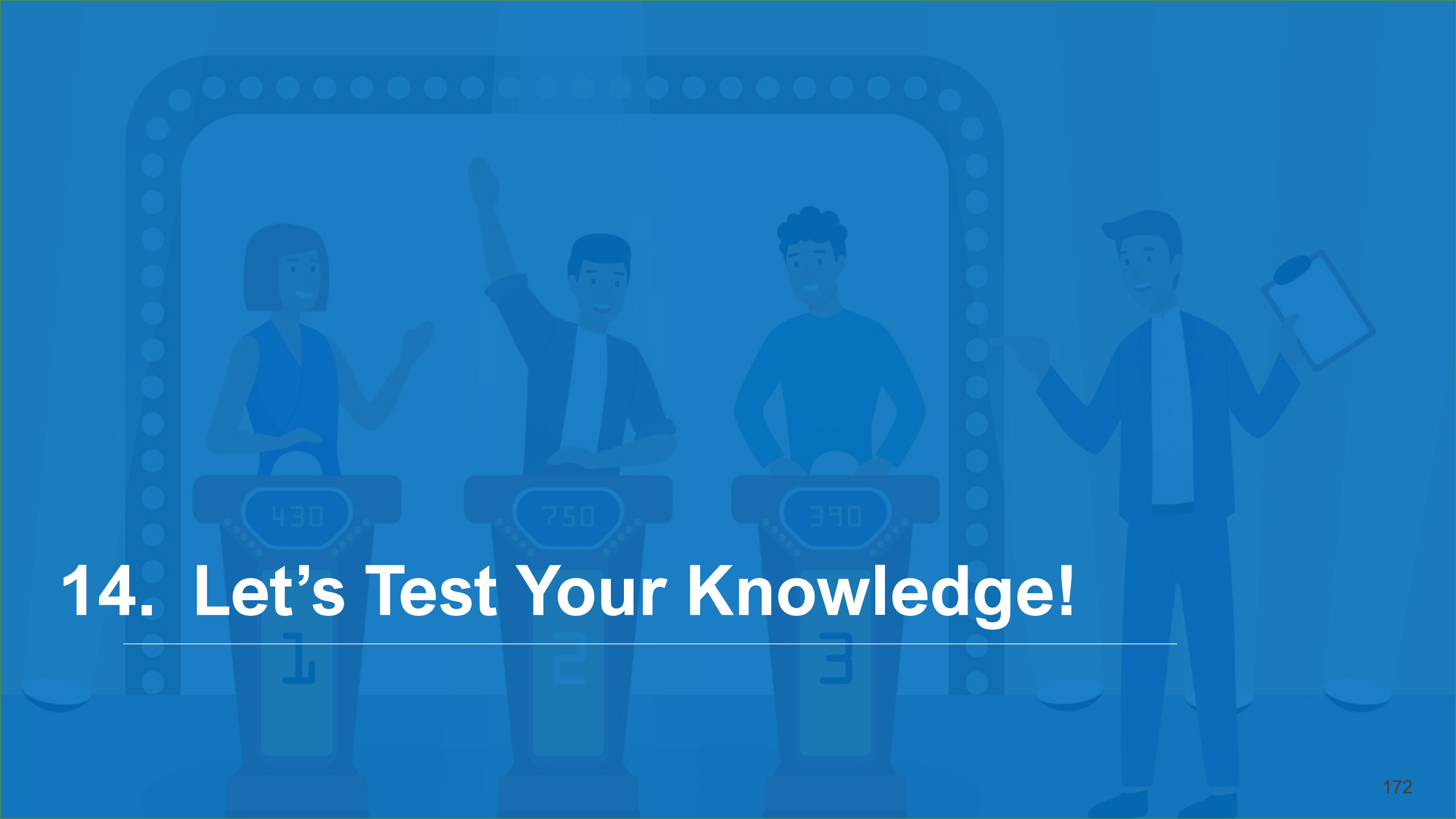
- Stack exhaust is sampled through a sorbent trap system which collects the gaseous elemental and oxidized Hg on the sorbent media.
- Sorbent traps are sent to the lab, where the Hg sample is extracted from the stack and analyzed using atomic fluorescence spectroscopy to measure the concentration of 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.



# 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






# 14. Let’s Test Your Knowledge!

# Feedback

3. True.

# 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

# Feedback

4. A. 75-125% of spike amount

# 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**

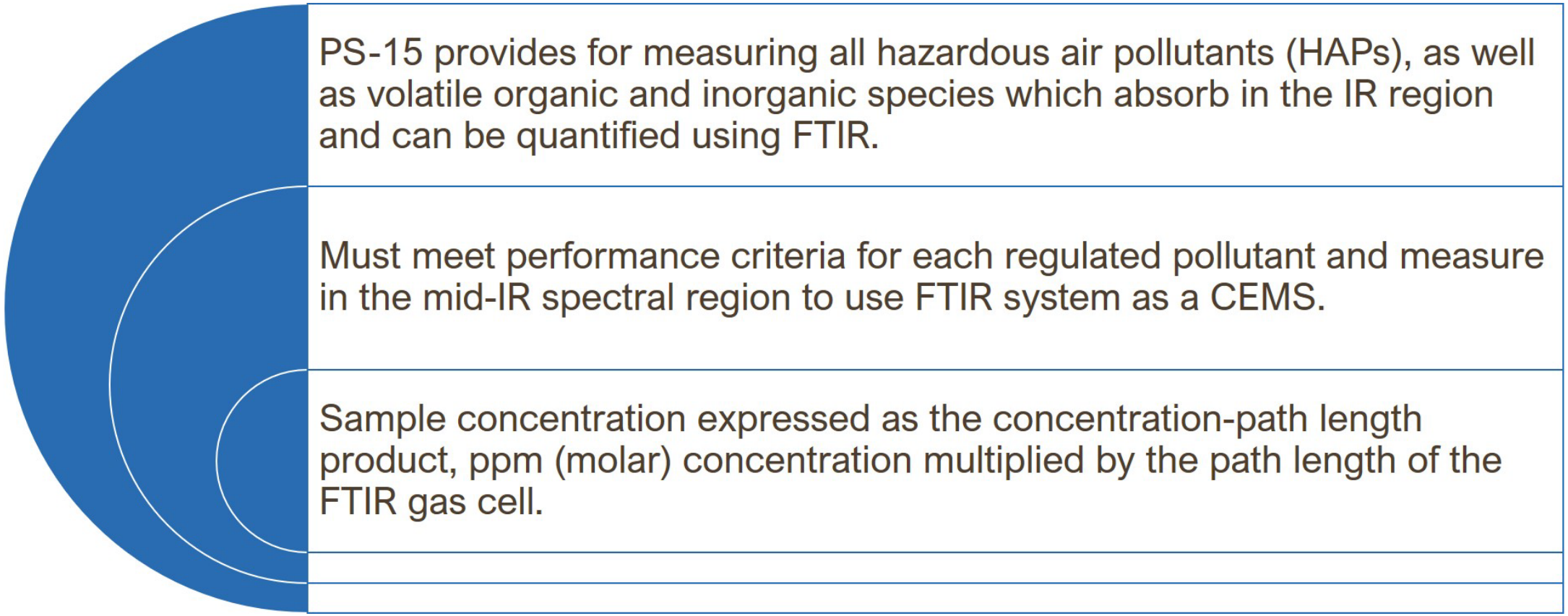
**C. 85-115% of spike amount**

**D. 80-120% of spike amount**

# Performance Specification 15 (PS-15)

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

# PS-15 Overview



# 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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# 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

# Quality Assurance/Quality Control

**Periodic Quarterly or Semiannual QA/QC Checks include:**

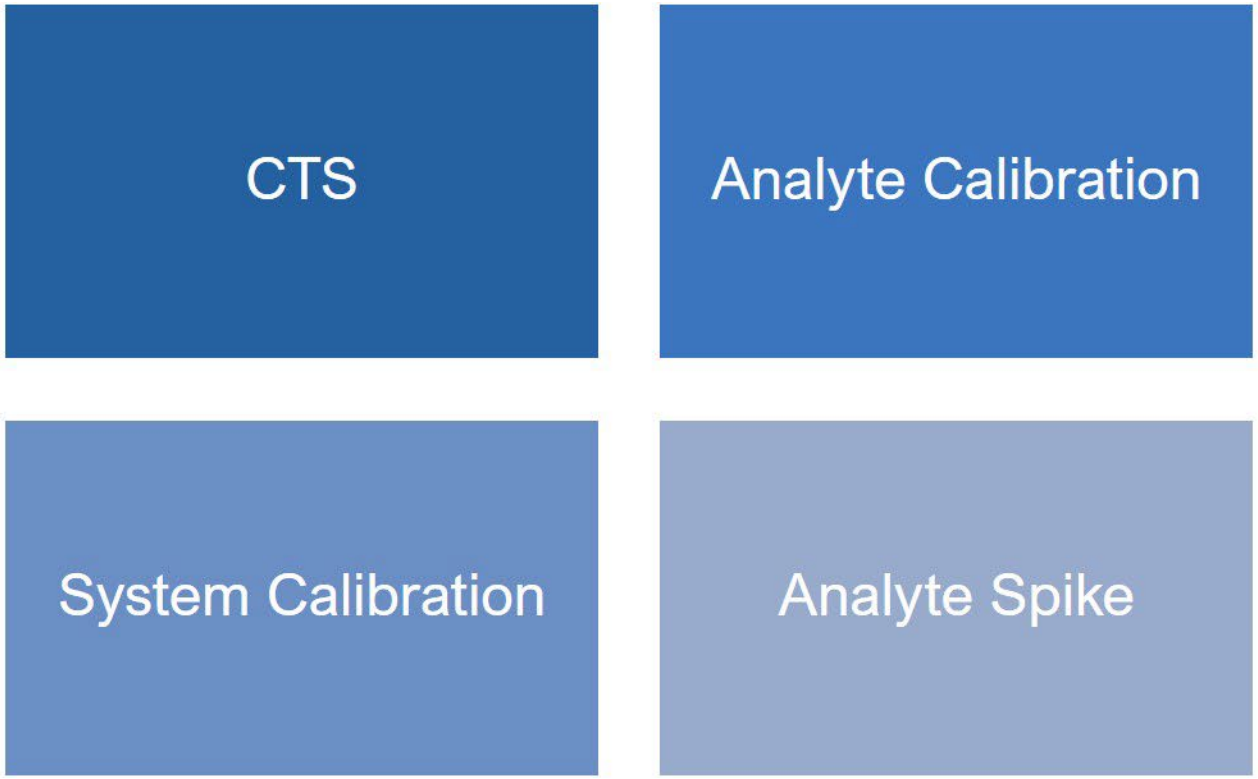
- Audit Sample- Unknown target analyte(s) analyzed by a CEMS operator.
- Audit Spectra- Analytical results must be within ±5% of the certified audit concentration for each analyte (plus the uncertainty in the audit concentration).
  - Only tests the analytical program of FTIR CEMS

**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

# Calibration and Standardization

Calibration and standardization includes:



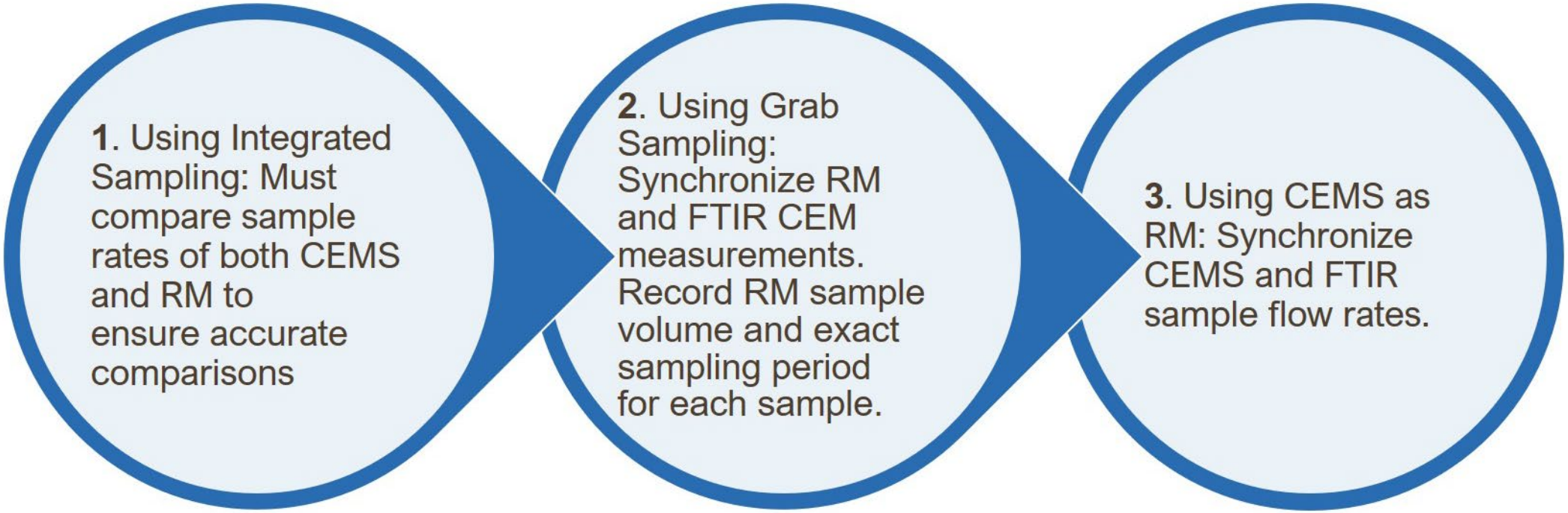
# Analytical Procedure

- **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)

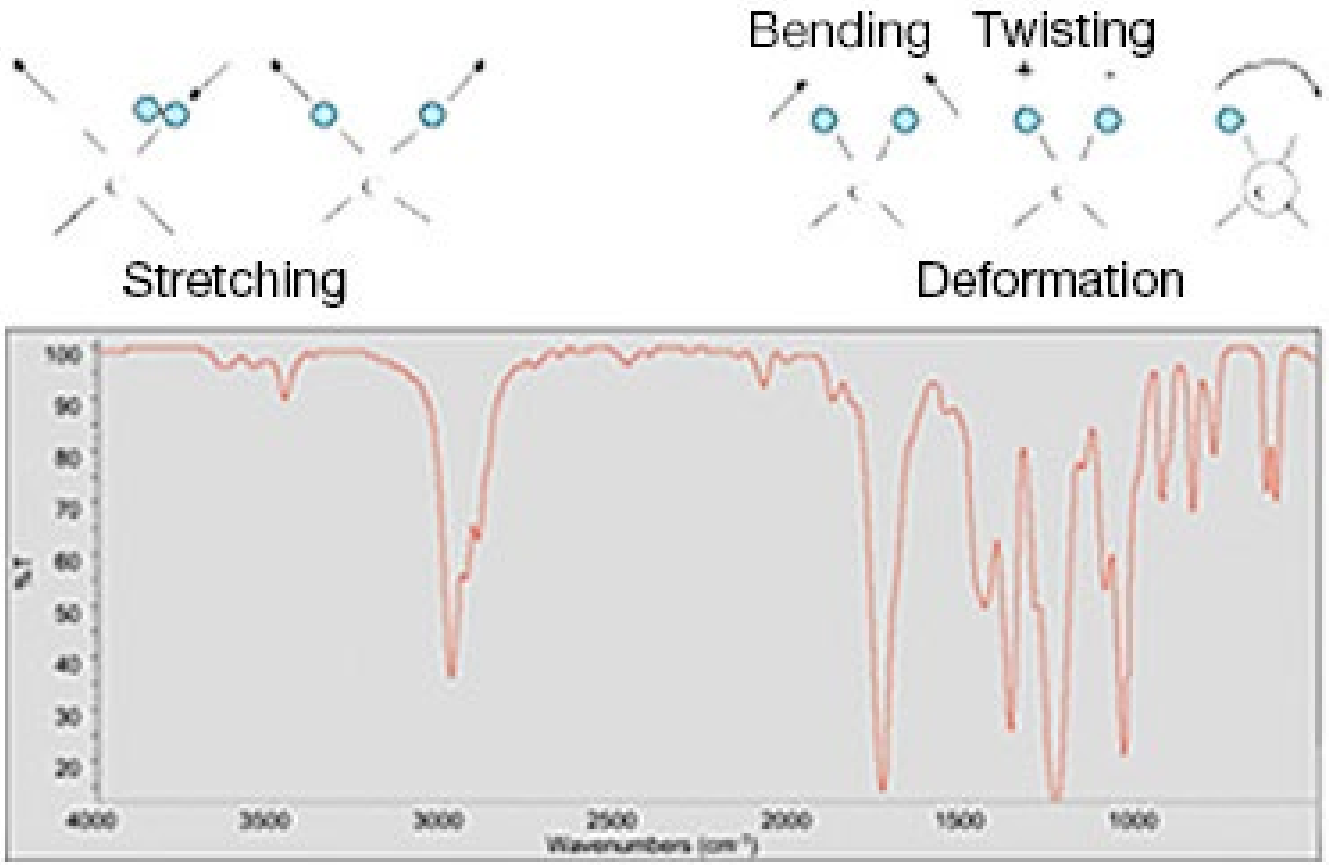
- **Compare to a RM**. Perform 9 runs of at least 30 minutes consisting of at least 5 independent FTIR CEM samples**.**

# Analytical Procedure – 3 Methods




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

# 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


# 15. Let’s Test Your Knowledge!

# Feedback

3. B. FTIR is a technique used by PS-15.

# 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

# Performance Specification 16 (PS-16)

Specifications and Test Procedures for Predictive Emission Monitoring Systems (PEMS) in Stationary Sources

# 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.

# 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.

# 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.**

# 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 (or 0.2 lb/mmBtu) and ≥10 ppm (or 0.05 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.
- For diluent PEMS, an alternative criterion of ±1% absolute difference between the PEMS and RM may be used if less stringent.

# 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.

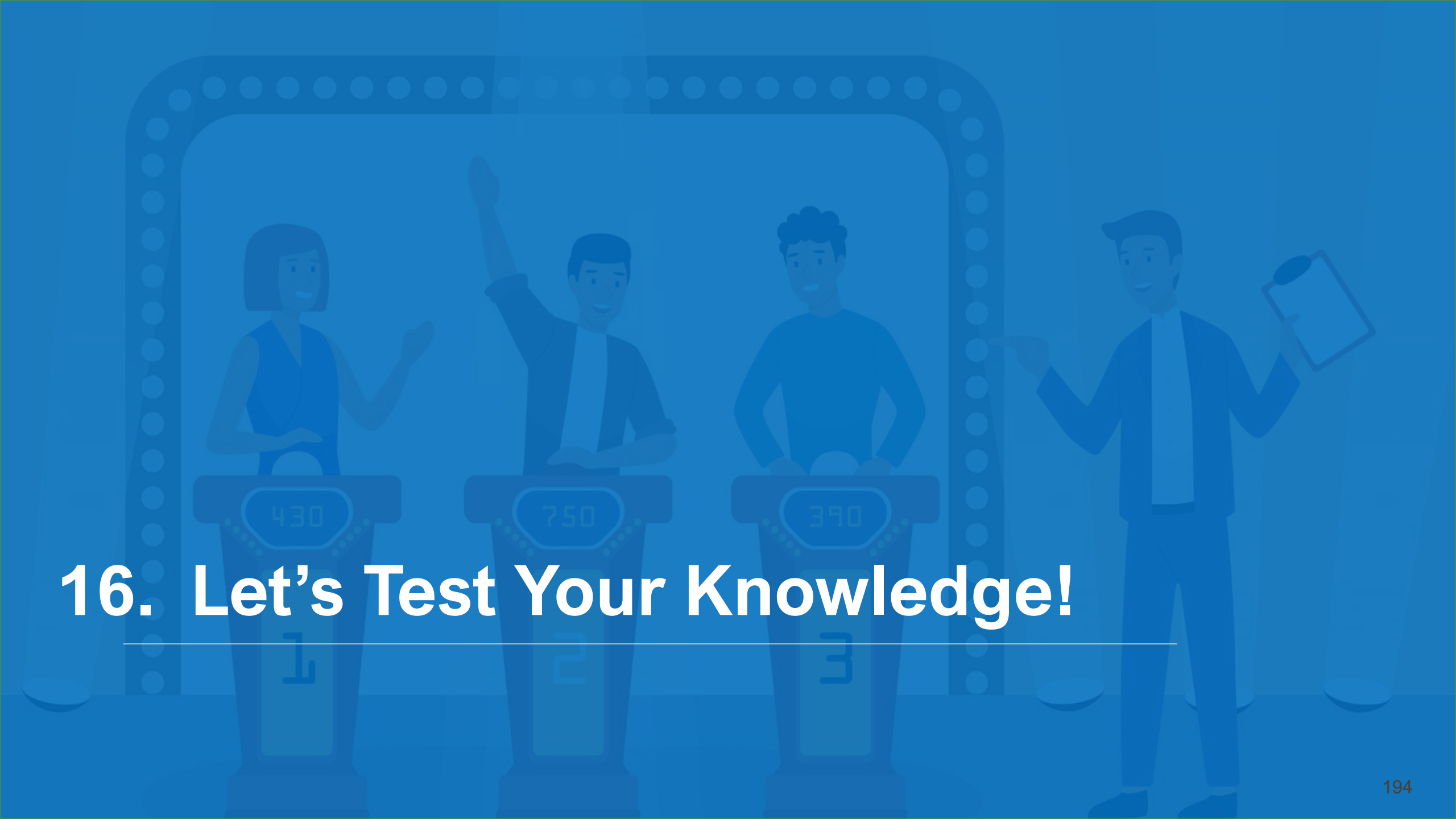
# Ongoing Quality Assurance Tests


- 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.

# Ongoing Quality Assurance Tests (Cont'd)

| Test | PEMS Regulatory Purpose | Acceptability | Frequency |
|---|---|---|---|
| **Sensor Evaluation** | All | | Daily |
| **RAA** | Compliance | 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 |




# 16. Let’s Test Your Knowledge!

# Feedback

2. True. PS-16 is used for determining whether a PEMS is acceptable for use in demonstrating compliance with applicable requirements.

# 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

# Feedback

3. A. Excess - 9 runs; Compliance- 27 runs

# PS-16 – Question 3

3. During initial testing, how many runs must be used for excess emissions and compliance emissions?

**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**

# Performance Specification 18 (PS-18)

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

# 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.

# 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.

# 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.

# 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.

# 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.

# 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.

# 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

# Procedure 6

Requires that the CEMS is audited to assess the data accuracy

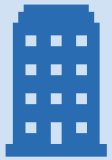
Temperature and pressure measurement devices must be audited annually

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.

# 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.

**NOTE:** See handout for more information on Procedure 6

# Commonly Used Technologies for PS-18

FTIR—refer to details for PS-15

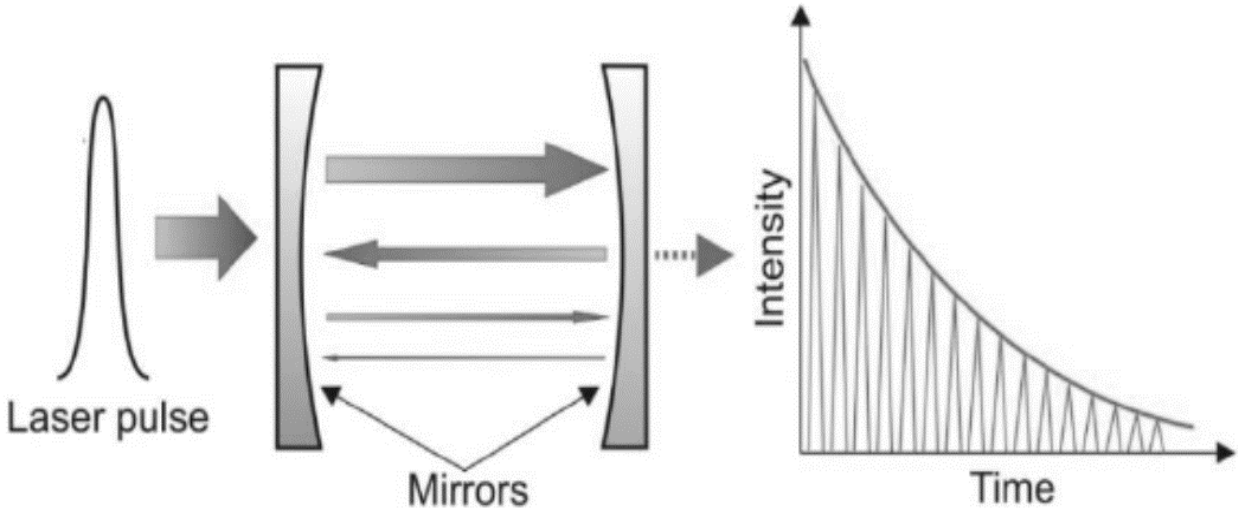
Tunable diode laser (TDL) spectroscopy uses the absorbance spectra of target gases and the ability to tune the laser to a specific absorbance wavelength of the gas to measure the gas concentration. It can achieve very low detection limits (ppb), and it is also possible to determine the temperature, pressure, 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).

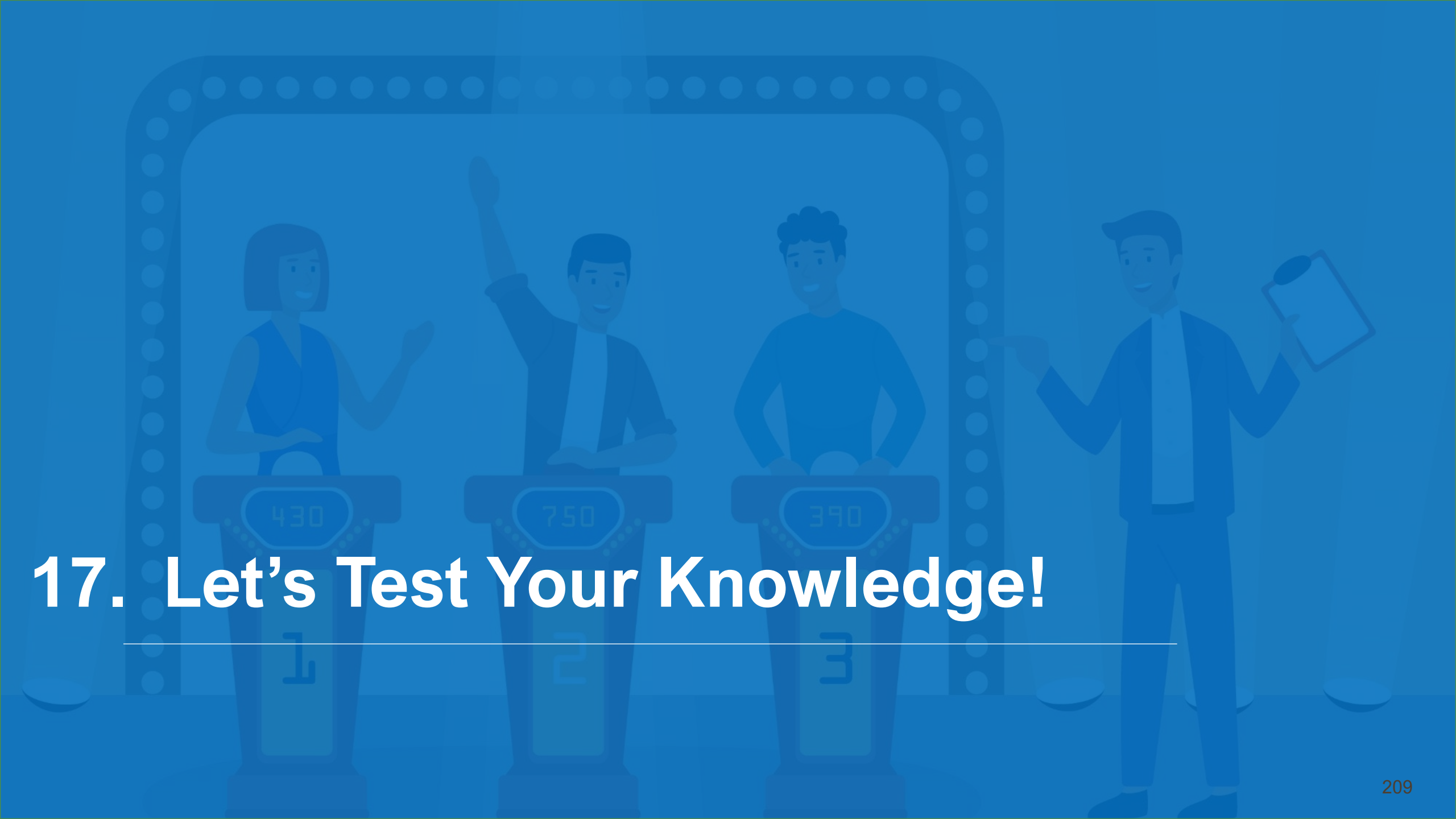
# Commonly Used Technologies for PS-18 (Cont'd)

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.






# 17. Let’s Test Your Knowledge!

# Feedback

4. Common technologies used for PS-18 include a TDL, CRDS, and FTI.

# 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

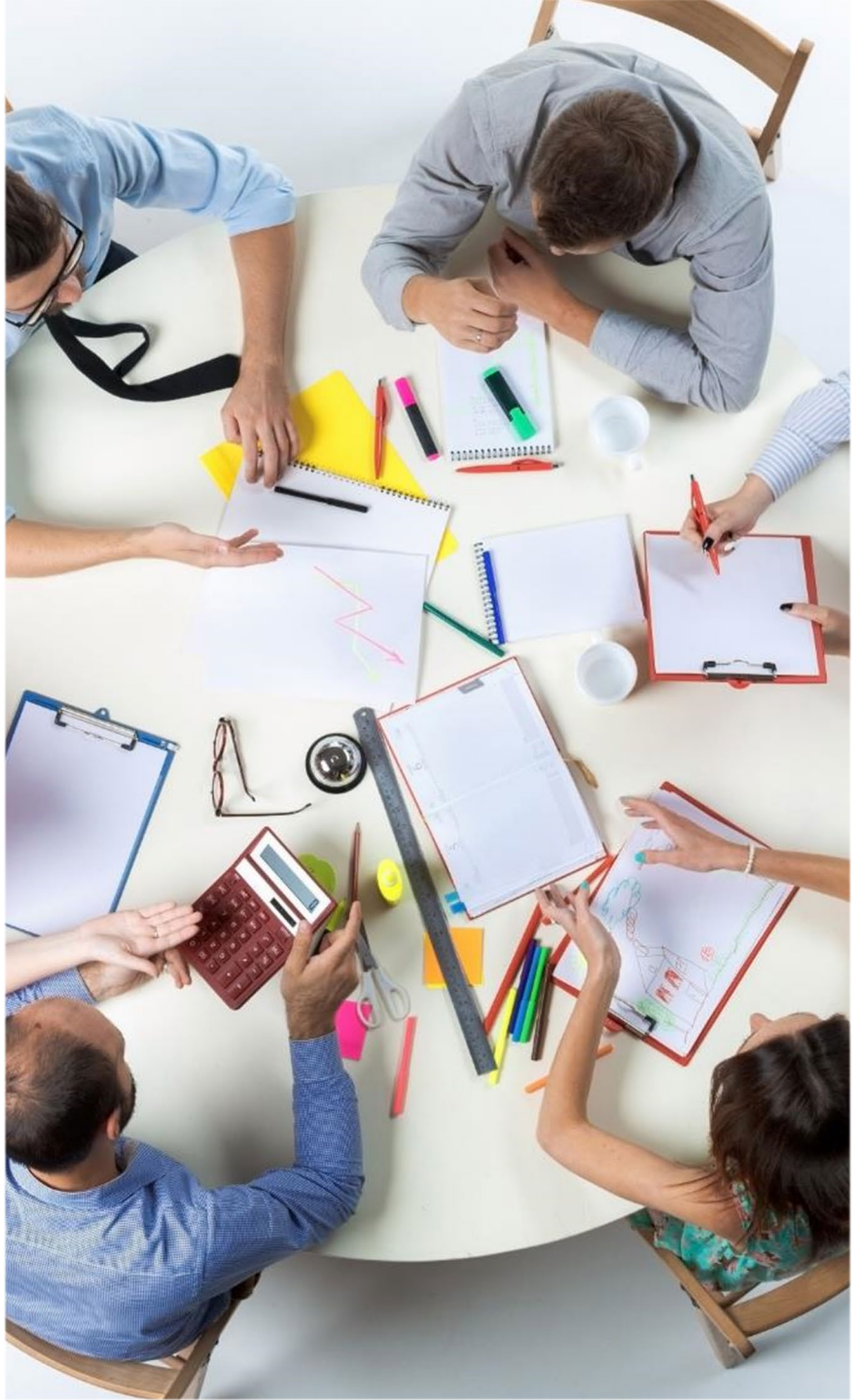
3. What is the basic function of procedure 6?

Check Answer

4. What are the common technologies used for PS-18?

Check Answer

# 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

# Activity Debrief

# 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