NACT 224
Observing Source Tests

Course Overview

- Planning a Source Test
- Source Test Basics
- Observing the Test
- Problem Areas
- Reviewing Test Data

Method 5 Sampling Train

Impinger train optional, may be replaced by an equivalent condenser.

Temperature sensor
Reverse-type pilot tube
Stack wall

Fiber holder

Thermometers

Heated area

Check valve

Vacuum line

Thermometers

Main valve

By-pass valve

Method 5 Sampling Train

Impingers

Vacuum gauge

Dry gas meter

Air tight pump

Impinger train optional, may be replaced by an equivalent condenser.
Purpose of Source Testing

For the Agency:
- Provide Data to Evaluate Compliance
- Provide Data to Formulate Control Strategies
- Provide Data for Regulation Development

For the Facility:
- Provide Data to Evaluate Compliance Status
- Meet Permit-To-Operate (PTO) Conditions
- Provide Info. on Control Device Efficiency
- Provide Info. for Design of New Processes
- Provide Info. on Process Operation
- Certify CEMs
- Certify PEMS

Federal & State Regulations
Authorities Requiring Source Testing

- Federal
  - NSPS
  - NESHAP
  - Title V Permits
- State and Local Requirements
  - Enforcement
  - Permitting
  - Emissions Inventory

Role of the Observer

- Evaluate Representativeness of a Test
  - Process & Control Equipment Operation
  - Sampling Port Location
  - Sample Collected
  - Sample Recovery & Analysis
  - Report

- Represent the Interests of Agency
  - Tests Satisfy the Needs of the Agency
  - Planning & Pretest
  - During the Test
  - Post Test
- QA/QC Officer
Role of the Observer

- Is the Source Test Legally Defensible?
  - Evaluate the Test Activities
  - Evaluate the Test Company/Team Qualifications & Competence
  - Evaluate the Laboratory Qualifications & Competence
  - Reliable & Appropriate Test Methods
  - Chain-of-Custody

Role of the Observer

- Observer Behavior
  - Test is Successful
  - Cooperate with Both Facility & Testers
  - Specific & Firm Requests
  - DO NOT Intrude or Interfere Unnecessarily

Test Protocol
Test Protocol

- Name & Location of Tested Facility
- When is Test (Adequate Notification?)
- Purpose of Test
- Testing Contractor (AETB?)
- Facility Description
- Process Description
- What is to be Tested

Test Protocol

- Regulatory Requirements
- Test Methods to be Used
- Schedule of the Test
- Test Location Configuration & Type
- Number & Size of Test Ports
- Process Rate to be Tested
- Report Requirements
- Unusual Requirements
Testing Access

- **Access to the Stack**
  - Getting Equipment to the Stack, Vehicle Access
  - How far up is the Testing Platform?
  - Getting Personnel & Equipment up the Stack
  - Is the Platform Secure?

- **Logistics**
  - Are there Electrical Outlets at the Stack?
  - What Load will the Electrical Circuits Hold?
  - Explosion Proof Electrical Equipment Required?
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Hazards
- What are the Stack Emissions?
- What Heat & Gas Hazards Exist?
- What are the Facility Health & Safety Procedures?
- Are Entry, Confined Space, or Other Permits Required?

Hazards:
- Heat, Gas Weather

Hazards
- What Protective Equipment is Needed?
  - Normally?
  - In the Event of an Accident or Plant Upset?
  - What are the Plant Safety Warnings?
- Weather Hazards
  - High Winds
  - Heat Lightning
  - Cold, ice, & Snow
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Problem Sources

- Eccentric & Tapered Stacks
- Horizontal Ducts
- Unconfined Flow
- High Temperatures
- Saturated Stack Gas

Saturated Exhaust

High Temp. Exhaust
Problem Sources

- Low Flow Rate
- Cyclonic Flow
- Condensables
- Reactive Compounds
- Soot Blowing

High Pressure Steam

Stack Access
Observing the Source Test

- Physical Inspection Points
- Procedural Inspection Points
- Calculation Inspection Points
- Preliminary Data Collection
- QC Audits

Documentation

- What Process & Control Room Data Area Available?
- What Data Are Required for the Test?
- What Data Are Required to Document Process Conditions?
- What Data Are Required to Document Continued Compliance?
- Is Any Control Room Data Confidential?

Checklists

- Ensure All Inspection Points Are Covered
- Ensure All Data Points Are Properly Collected
- Should Be Reviewed & Modified for the Source Being Tested
### Let’s Discuss Basic Test Methods

- **Method 1 - Sampling Point Location**
- **Method 2 - Stack Gas Velocity**
- **Method 3 - Dry Molecular Weight**
- **Method 4 - Moisture Content of Stack Gases**
- **Method 5 - Particulate Emissions**
- **Method 6 - Sulfur Dioxide Emissions**
- **Method 7 - Nitrogen Oxide Emissions**
- **Method 10 - Carbon Monoxide Emissions**
Method 1

Sample & Velocity Traverses for Stationary Sources

- Specifies Both the Sampling Site Location & the Location of the Sampling Points
- The More Convoluted the Ductwork, the More Points that Will Need to be Tested

Stack Velocity Stratification

Stack Velocity Stratification

Cyclonic Flow
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**Sampling Site Criteria**

Ideal: Port is 8 duct diameters downstream of A and 2 duct diameters upstream of B

**Sampling Criteria**

**Sampling Criteria**
### Rectangular Duct Cross-Section Layout

<table>
<thead>
<tr>
<th># of Traverse Points</th>
<th>Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>3 x 3</td>
</tr>
<tr>
<td>12 (example on next slide)</td>
<td>4 x 3</td>
</tr>
<tr>
<td>16</td>
<td>4 x 4</td>
</tr>
<tr>
<td>20</td>
<td>5 x 4</td>
</tr>
<tr>
<td>25</td>
<td>5 x 5</td>
</tr>
<tr>
<td>30</td>
<td>6 x 5</td>
</tr>
<tr>
<td>36</td>
<td>6 x 6</td>
</tr>
<tr>
<td>42</td>
<td>7 x 6</td>
</tr>
<tr>
<td>49</td>
<td>7 x 7</td>
</tr>
</tbody>
</table>

### Rectangular Duct Traverse (12 points)

![Rectangular Duct Traverse (12 points)](image)

### Circular Stack Traverse (12 Points)

![Circular Stack Traverse (12 Points)](image)
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Location of Traverse Points in Circular Stacks

Particle Stratification & Plane of Bend

Cyclonic Flows
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**Calculation Inspections**

- **Confirm Input Data**
  - **Stack**
    - Dimensions
    - Calculate Equivalent Diameter (If Stack is Not Circular)
    - Location of Disturbances
  - **Traverse Points**
    - Evaluate Number of Points
    - Evaluate Location of Points

  **Equivalent Diameter**
  
  \[ D_e = \frac{2 \times LW}{L + W} \]

**Method 2**

**Determination of Stack Gas Velocity and Volumetric Flow Rate**

- **Method Uses Type S Pitot Tube**
- **Method Also Used to Certify Flow Monitors**

  Stack Volumetric Flow Rate: \[ Q_s = A_s \times V_s \]
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Volume of a Gas vs. Absolute Temperature

Absolute Temperature
Degrees Rankine: \( R = °F + 459.49 \)
Degrees Kelvin: \( K = °C + 273.16 \)

Atmospheric or Barometric Pressure

Gauge Pressure

Absolute Pressure
\( P_a = P_b + P_g \)

Differential Pressure Measuring
Differential Pressure Measuring

$V_s$ $P_s$ $P_v$ $P_v$

Stagnation pressure Static pressure Velocity pressure

Type “S” Pitot Tube & Orifice Meter

Standard Pitot Tube

Type S Pitot Tube
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Type S Pitot Tube Construction

Physical & Procedural Inspections
- Pitot tube
  - Construction & Condition
  - Alignment (Bent, etc.)
  - Orientation & Attachment to Probe
  - Calibration
  - Leak Checked (Both Sides)
- Pressure Instruments
  - Oil Manometer Leveled & Zeroed
  - Magnehelic Gauge Calibrated
- Cyclonic Flow Checked

Pitot Tube Roll and Pitch
- Roll angle
- Pitch angle
- Rotational
- Vertical
Calculation Inspections

- **Confirm Input Data**
  - Stack Pressures
  - Stack Temperature
  - Calibration Factors

Δp - Velocity pressure

The difference between the two pressure taps of a pitot tube (determined by averaging the square roots of all the Δp readings. Note -- DO NOT take average of readings and then take the square root).

**Stack Gas Velocity**

- \( C_p = 0.84 \)
- \( t_s = 345^\circ C \)
- \( T_s = 345^\circ C + 273^\circ C \)
- \( \Delta p = 38.1 \text{ mm H}_2\text{O} \)
- \( P_s = 35 \text{ mm H}_2\text{O} \)
- \( K_p = 34.97 \text{ (metric)} \)

\[ v_s = K_p C_p \sqrt[1/2]{\frac{T_s \Delta p}{P_s M_s}} \]

\[ 32.5 \text{ m/s} = 34.97 \times 0.84 \sqrt[1/2]{\frac{(345+273) \times 38.1}{(680+35/13.6) \times 28.2}} \]

Calculation Inspections

- **Stack Volume**
  - Stack Area
  - Flow

Stack Gas Volumetric Flow Rate

\[ Q_s = A_s V_s \]

\[ Q_s = A_s K_p C_p \left( \frac{T_s \Delta p}{P_s M_s} \right)^{1/2} \]

\[ Q_{sd} \text{ (ft}^3/\text{hr}) = 3600 \times (1 - B_{ws}) A_s V_s \frac{T_{STD} P_s}{T_s P_{STD}} \]
Method 3
Gas Analysis for Determination of Dry Molecular Weight
- Determines %CO₂, %O₂, & CO
- Balance is N₂
- Needed for Both Pitot Tube Equation & Isokinetic Rate Equation
Fyrite Gas Analyzer for CO₂ or O₂

Electrocatalytic O₂ Analyzer

NDIR CO₂ Analyzer
**Molecular Weight by Mole Fraction**

- $\text{O}_2 = 55 \text{ mm Hg (8.1\%)}$
- $\text{CO}_2 = 65 \text{ mm Hg (9.6\%)}$
- $\text{CO} = 8 \text{ mm Hg (1.1\%)}$
- $\text{N}_2 = 552 \text{ mm Hg (81.2\%)}$
- $P_b = 680 \text{ mm Hg}$

\[
M = \sum B_i M_i = \frac{55}{680} \times 32 + \frac{8}{680} \times 28 + \frac{65}{680} \times 44 + \frac{552}{680} \times 28
\]

\[
= 30.0 \text{ g/mole}
\]
ORSAT Analysis Check by $F_o$

\[ O_2 = 8.1\% \quad CO_2 = 9.6\% \]

\[ F_o = \frac{20.9 - \%O_2}{\%CO_2} \]

\[ F_o = \frac{20.9 - 8.1}{9.6} = 1.33 \]

Table value for oil combustion = 1.260 - 1.413

ORSAT analysis is OK

Method 4

Determination of Moisture Content in Stack Gas

- Needed for Both Pitot Tube Equation & Isokinetic Rate Equation
- 4 Methods Can be Used
  - Saturation Pressure: $T_{GAS}$
  - Psychrometry: Wet & Dry Bulb Temp.
  - Adsorption: Silica Gel Tubes
  - Condensation: Impingers (Vol of $H_2O$ + Vol of Gas)
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Calculation & Procedural Inspections

- Recovery
  - No Spillage
  - Measured Correctly

- Moisture
  - Preliminary
  - Final
  - Dry vs Wet Molecular Weight

\[ M_{\text{saturated}} = M_{\text{dry}} (1 - B_{\text{ws}}) + 18B_{\text{ws}} \]

Wet Basis Molecular Weight

- \( M_d = 30.0 \) (dry)
- \( B_{\text{ws}} = 15\% \)

\[ M_s = M_d (1 - B_{\text{ws}}) + 18B_{\text{ws}} \]
\[ M_s = 30.0 (1 - 0.15) + 18 \times 0.15 \]
\[ = 28.2 \text{ g/mole} \]

\[ B_{\text{ws}} = \frac{\text{Vol of H}_2\text{O}}{\text{Vol of Gas}} \]

Method 5
**Isokinetic Sampling** -- The sample is drawn into the probe nozzle at the same rate as it is moving in the flue gas.

**Isokinetic Source Sampling System**
Method 5 Sampling Train

Nozzle Design and Placement

Sample Nozzles
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Observing Source Tests

Sample Nozzles

Physical Inspections

- **Nozzle**
  - Construction (SS or Glass)
  - Alignment & Installation on the Probe
  - Dents, etc.
  - Calibration
  - Rinsed During Sample Recovery

Nozzle Inspection
Calculation Inspections

- **Nozzle Diameter**

\[
D_n = \sqrt{\frac{K_D Q_m P_m}{T_m C_p (1 - B_{ws})}} \frac{T_m M_s}{P_s \Delta P_{est}}
\]

\[K_D = 6.07 \text{ (0.0358 English units)}\]

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Nozzle Diameter

- \[K_D = 6.07\]
- \[Q_m = 0.021 \text{ m}^3\]
- \[P_m = 683.6 \text{ mm Hg}\]
- \[T_m = 28^o \text{C}\]
- \[C_p = 0.84\]

\[
B_{ws} = 0.15
\]

\[
T_s = 345^o \text{C}
\]

\[
M_s = 28.2 \text{ g/mole}
\]

\[
p_s = 35 \text{ mm H}_2\text{O}
\]

\[
\Delta p_{wat} = 38 \text{ mm H}_2\text{O}
\]

\[
D_n = \sqrt{\frac{6.07 \times 0.021 \times 683.6}{(28+273) \times 0.84 \times (1-0.15)}} \frac{(345+273) \times 28.2}{(680+35/13.6) \times 38}
\]

\[D_n = 0.576 \text{ cm}\]

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Probe Assembly
Physical Inspections

- **Temperature Probe**
  - Condition
  - Calibrated

- **Probe**
  - Long Enough to Reach, Not Too Long
  - Heated
  - SS or Glass Liner
  - Marked (Heat Resistant) for Traverse Points
  - Rinsed During Sample Recovery

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Modular Sample Unit

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Method 5
Glassware
Physical Inspections

- **Sampling Case - Hot Side**
  - Heated (Check Method for Proper Temperature)
    - Temperature Gauge Installed
  - Glassware Properly Assembled

- **Cold Side**
  - Glass Impingers
Observing Source Tests

- Impinger Ice Bath

Physical Inspections

- Sampling Case - Cold Side
  - Glassware Properly Set-Up
  - Proper Solutions in Impingers
  - Ice & Water Bath - Exit Temperature
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Umbilical Cord

Isokinetic Control Console
**Physical Inspections**

- **Pump**
  - Non-reactive and leak free
- **Dry gas meter**
  - Leak free
  - Calibrated
- **Orifice meter**
  - Calibrated

**Sampling Rate**

- **Constant Rate**
- **Proportional**
- **Isokinetic**
Let's Discuss
Isokinetic Sampling

Isokinetic Sampling

Stack → Nozzle

$\mathbf{v}_s = \mathbf{v}_n$

$m_s = 0.44 \text{ grams/min}$

$Q_s = 0.025 \text{ m}^3/\text{min}$

$c_s = 0.44/0.025 = 17.6 \text{ g/m}^3$

$c_s = 17.6 \text{ g/m}^3$

Over Isokinetic Sampling

Stack → Nozzle

$150\%$ Isokinetic

$\mathbf{v}_s = 1.5 \mathbf{v}_n$

$m_s = 0.46 \text{ grams/min}$

$Q_s = 0.0375 \text{ m}^3/\text{min}$

$c_s = 0.46/0.0375 = 12.8 \text{ g/m}^3$

$c_s = ? (c_s > c_s)$
Under Isokinetic Sampling

75% isokinetic

$$v_s = 0.75 \cdot v_i$$

$$m_i = 0.42 \text{ grams/min}$$

$$Q_s = 0.01875 \text{ m}^3/\text{min}$$

$$c_s = \frac{0.42}{0.01875} = 22.4 \text{ g/m}^3$$

$$c_s = ? (c_s < c_i)$$

Nozzle Misalignment

Calculation Inspections

Orifice Meter (Sample Flow Rate)

Settings

$$\Delta H = K_H D_n^4 \Delta H @ C_p^2 (1-B_{ws})^2 \frac{M_s T_s P_s}{M_s T_s P_m} \Delta P$$

K factor - used for rapid calculation of $\Delta H$

$$K_H = 0.803 \text{ (846.72 English units)}$$
K Factor and $\Delta H$

- $K = 0.803$
- $D_n = 0.576$ cm
- $\Delta H = 49.3$ mm H$_2$O
- $C_p = 0.84$
- $B_w = 15\%$
- $\Delta p = 38.1$ mm H$_2$O

$$\Delta H = 0.803 \times 0.576 \times 49.3 \times 0.84 \times (1 - 0.15) \times 38.1$$

$K$ factor = 1.15

$\Delta p = 38.1$

$\Delta H = K \times \Delta p = 43.81$

---

Procedural Inspections

- **Sampling Points**
  - Properly Laid Out
  - Move Between Points on Time
  - Move Between Points Quickly
  - Data Read & Recorded Quickly & Accurately
  - Delta H Calculated & Adjusted Quickly

- **Dry Gas Meter**
  - Start/Stop Times & Volume Readings Accurately Recorded
  - Sampling Times & Volume Requirements Met

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Console Adjustment

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Observing Source Tests

Calculation Inspections

- **Percent Isokinetic**

\[
\%I = 100 \times \frac{T_s[V_{ic}K + V_m/T_m(P_b + \Delta H/13.6)]}{60 \times A_n V_s P_s}
\]

\[K = 0.003454 \text{ mm Hg m}^3/\text{ml K}\]
\[0.002669 \text{ in Hg ft}^3/\text{ml } \text{°R}\]

Percent Isokinetic

- \(T_s = 345\)°C
- \(\Theta = 48\) min
- \(V_{ic} = 113\) ml
- \(V_m = 1.008\) m³
- \(T_m = 28\)°C

\[
\%I = 100 \times \frac{(345+273)(113x0.003454+1.008)(680+43/13.6)}{60\times48\times2.6\times10^{-5}\times32.5\times(680+35/13.6)}
\]

\[\%I = 99.7\%

Procedural Inspections
Procedural Inspections

- Sample Recovery
- Sampling Completion Procedure
- Leak-Check
- Cool-Down
- Probe & Glassware Cleanup
- Impinger Recovery
- Filter Recovery

Sampling Train Leak Test

Probe Brushing
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Observing Source Tests

Probe Rinse

Filter Recovery

Physical Inspections

- Sample Properly Recovered
  - Good Particulate Deposit - No Evidence of Leaks
  - Impinger Solution Weighed &/or Recovered After Sampling
  - Rinse Front Half of Filter Holder
    - Back Half Also
  - Probe Properly Cleaned
  - Filter Properly Weighed
Observing Source Tests

PM$_{10}$ - Sampling Train

Cascade or Inertial Impactor

EPA Particulate Reference Methods 5.1 for 201A: Sampling Components

04/18
Source Test Analytical Techniques

- Infrared Methods
  - Differential Absorption
  - Gas Filter Correlation
  - Fourier Transform Infrared
- Ultraviolet Methods
  - Differential Absorption
  - Second Derivative Spectroscopy
- Visible Light
  - Scattering & Absorption

Source Test Analytical Techniques

- Luminescence Methods
  - Fluorescence
  - Chemiluminescence
  - Flame Photometry
- Electroanalytical Methods
  - Polarography
  - Electrocatalytic
  - Paramagnetism
  - Conductivity

Method 6C

Determination of SOx Emissions from Stationary Sources
Observing Source Tests

Fluorescence SO₂ Analyzer

Chemiluminescence NOₓ Analyzer

Determination of NOₓ Emissions from Stationary Sources

Method 7E

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Observing Source Tests

Method 10

Determination of CO Emissions from Stationary Sources

Gas Filter Correlation Analyzer
Instrument Inspections

- Always Check Applicable Method & Subpart
- Instrument Span
- Calibration Error
  - \( \pm 2\% \) of Span for Zero, Mid, & High Range Gases
- Sampling System Bias
  - \( \pm 5\% \) of Span for Zero & Mid or High Range Gases
- Zero Drift & Calibration Drift
  - \( \pm 3\% \) of Span Over the Period of Each Run
- Interference Check
Cal Gas Certificate Points

- Cylinder ID Number
- Balance Gas
- Cylinder Pressure
- Certification Date
- Expiration Date
- Lab & Analyst ID
- (PGVP – Part 75)

Reference Standard Data

- Statement of Procedures
- Certified Concentration
- Gas Analyzer ID & Cal Date
- Analyzer Readings & Calc Used
- Chronological Cert Record

Calibration Gas Hierarchy

Standard Reference Materials (SRMs) from NIST

- NIST Traceable Reference Materials (NTRMs)
- Gas Manufacturers Intermediate Standards (GMISs)

- Directly Traceable EPA Protocol Gases
- Indirectly Traceable EPA Protocol Gases
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Procedural Inspections

**Data Recording**
- Timely, Accurate, & Complete
- Standardized Form Used
- Computer Data Entry:
  - Automatic - Computer Controlled Equipment
  - On Site After Sampling or During Sample (Computer Data Entry Form)
  - After Sampling Completed

Procedural Inspections

**Sample Conservation**
- Container Material Must be Compatible with Sample
- Storage Conditions
  - Refrigerate the Samples if Held Overnight
- Blanks Properly Prepared & Shipped with Field Samples
- Sample Container Must be Labeled
- Shipping
- Chain-of-Custody
Procedural Inspections

Analysis

- **On Site**
  - Weights & Volumes
  - Some Simple Titration’s & Chemical Analysis can be Done on Site
  - Work Area Conditions must be Consistent with Good Laboratory Procedures
- **Off Site**
  - Analytical Lab Should be Certified
  - QA Samples

Lab Analysis

Emissions Calculations
Observing Source Tests

**Emission Calculations**

- **Emission rates**
  - Concentration ($c_s$) : (ppm, g/dscm, gr/dscf)
  - Pollutant mass rate ($pmr_s$) : (kg/hr, lb/hr)
  - Process rate ($E$) : (ng/J, lb/10^6 BTU, lb/ton)
  - Flow rates or F factors

\[
E = \frac{pmr_s}{Q_H} = \frac{csQ_H}{Q_H} = csF\left(\frac{20.9}{20.9 - \%O_2}\right)
\]

**Calculation Inspections**

- **Normalized to Diluent Gas**
  - $O_2$
  - $CO_2$

\[
c_s^{12\%CO_2} = \frac{12}{\%CO_2} ~ c_s^{6\%O_2} = \frac{15}{21 - \%O_2}
\]

**Effects of Errors**

- **Impact of Errors on Validity of Test**
  - What is the Data to be Used for?
  - What is the Direction & Magnitude of any Biases?
  - What is the Acceptable Bias Before Rejecting the Testing?
Effects of Errors

**Accuracy**
- Compares Well with the Correct Value

**Precision**
- Repeated Tests Give the Same Results

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**Accuracy & Precision**

- Accurate and Precise
- Accurate but not Precise
- Precise but not Accurate
- Neither Accurate nor Precise

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**Post Test Activities**

- Post Test Conference
- Observer’s Test Report
- Report Requirements & Submittal
- Test Report Review
  - Summary Data
  - Detailed Test Data
  - Raw Data
Post Test Activities

- Evaluation of Compliance in Light of the Test Result
  - Current Enforcement Action
  - Future Inspections
  - Enforcement

Inspector Safety

- Proper equipment
- Plant warnings
- Heat
- High pressure steam
- Electrical hazards
- Noise
- Moving parts
- Inhalation hazards
- Hazardous materials
- Machine disintegration
- Other hazards & traps

In Summary: Source Test Successful

If an Evaluator Can Evaluate Representativeness of:

- Process & Control Equipment Operation
- Sampling Port Location
- Sample Collected
- Sample Recovery & Analysis
- Final Report