Course Overview

- Regulated Facilities
- Components
- Estimating Emissions
- Regulations and Standards
- Method 21
- Field Inspections

DEFINITION OF LDAR

LDAR is a work practice designed to identify leaking equipment so that emissions can be reduced through repairs. A component that is subject to LDAR requirements must be monitored at specified, regular intervals to determine whether or not it is leaking. Any leaking component must then be repaired or replaced within a specified time frame.
Elements of an LDAR Program

- LDAR programs. Identifying Components
- Leak Definition
- Monitoring Components
- Repairing Components
- Recordkeeping

Why Check for Leaks?

- Public Health
- Safety
- Reliability
- Economic

The Bad Guys

Reactive Organic Compounds (ROCs, ROGs, VOCs)
Non-Reactive Organic Compounds
Total Hydrocarbons
Hazardous Air Pollutants (HAPs)
CARB 262 – Fugitive VOC Inspections

[Image of industrial facility]

[Image of tanks labeled 'Toluene']

[Image of tanks labeled 'West Sacramento Plant']

[Image of tanks labeled 'Toluene']
CARB 262 – Fugitive VOC Inspections

EPA Source Categories

- **NSPS** (40 CFR 60)
  - SOCMI (Subpart VV)
  - Petroleum Refineries (Subpart GGG)
  - Natural Gas Processing Plants (Subpart KKK)
  - Polymer Manufacturing Plants (Subpart DDD)
- **NESHAP** (40 CFR 61)
  - Benzene (Subparts J & V)
  - Vinyl Chloride (Subpart F)
- **HON** (40 CFR 63, Subpart H)
- **RCRA** (40 CFR 264, 265, Subparts AA, BB)
  - Hazardous Waste TSDFs

Appendix A

Federal Regulations That Require a Formal LDAR Program With Method 21

<table>
<thead>
<tr>
<th>Part</th>
<th>Subpart</th>
<th>Regulation Title</th>
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<tbody>
<tr>
<td>60</td>
<td>VV</td>
<td>SOCMI VOC Equipment Leaks NSPS</td>
</tr>
<tr>
<td>60</td>
<td>DDD</td>
<td>Volatile Organic Compound (VOC) Emissions from the Polymer Manufacturing Industry</td>
</tr>
<tr>
<td>60</td>
<td>GGG</td>
<td>Petroleum Refinery VOC Equipment Leaks NSPS</td>
</tr>
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<td>60</td>
<td>KKK</td>
<td>Onshore Natural Gas Processing Plant VOC Equipment Leaks NSPS</td>
</tr>
<tr>
<td>61</td>
<td>J</td>
<td>National Emission Standard for Equipment Leaks (Fugitive Emission Sources) of Benzene</td>
</tr>
<tr>
<td>61</td>
<td>V</td>
<td>Equipment Leaks NESHAP</td>
</tr>
<tr>
<td>63</td>
<td>H</td>
<td>Organic HAP Equipment Leak NESHAP (HON)</td>
</tr>
<tr>
<td>63</td>
<td>I</td>
<td>Organic HAP Equipment Leak NESHAP for Certain Processes</td>
</tr>
<tr>
<td>63</td>
<td>J</td>
<td>Polyvinyl Chloride and Copolymers Production NESHAP</td>
</tr>
<tr>
<td>63</td>
<td>R</td>
<td>Gasoline Distribution Facilities (Bulk Gasoline Terminals and Pipeline Breakout Stations)</td>
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<tr>
<td>63</td>
<td>CC</td>
<td>Hazardous Air Pollutants from Petroleum Refineries</td>
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<tr>
<td>63</td>
<td>DD</td>
<td>Hazardous Air Pollutants from Off-Site Waste and Recovery Operations</td>
</tr>
<tr>
<td>63</td>
<td>SS</td>
<td>Closed Vent Systems, Control Devices, Recovery Devices and Routing to a Fuel Gas System or a Process</td>
</tr>
<tr>
<td>63</td>
<td>TT</td>
<td>Equipment Leaks – Control Level 1</td>
</tr>
<tr>
<td>63</td>
<td>UU</td>
<td>Equipment Leaks – Control Level 2</td>
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<tr>
<td>63</td>
<td>YY</td>
<td>Hazardous Air Pollutants for Source Categories: Generic Maximum Achievable Control Technology Standards</td>
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<tr>
<td>63</td>
<td>GGGG</td>
<td>Hazardous Air Pollutants: Site Remediation</td>
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<td>63</td>
<td>HHHH</td>
<td>Hazardous Air Pollutants: Miscellaneous Coating Manufacturing</td>
</tr>
</tbody>
</table>

Note: Many of these regulations have identical requirements, but some have different applicability and control requirements.
## SOURCES OF EQUIPMENT LEAKS

- Pumps
- Valves
- Connectors
- Sampling connections
- Compressors
- Pressure relief devices
- Open-ended lines

### Equipment component counts at a typical refinery or chemical plant (1995)

<table>
<thead>
<tr>
<th>Component</th>
<th>Range</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pumps</td>
<td>10 – 360</td>
<td>100</td>
</tr>
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<td>Valves</td>
<td>150 – 46,000</td>
<td>7,400</td>
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<td>Connectors</td>
<td>600 – 60,000</td>
<td>12,000</td>
</tr>
<tr>
<td>Open-ended lines</td>
<td>1 – 1,600</td>
<td>560</td>
</tr>
<tr>
<td>Samp connections</td>
<td>20 – 200</td>
<td>80</td>
</tr>
<tr>
<td>Pressure relief valv</td>
<td>5 – 360</td>
<td>90</td>
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Equipment component counts at a typical refinery or chemical plant (1995)

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</tr>
<tr>
<td>Pressure relief valv</td>
<td>5 – 360</td>
<td>90</td>
</tr>
</tbody>
</table>

Uncontrolled VOC emissions at a typical facility (1995)

<table>
<thead>
<tr>
<th>Component</th>
<th>Percent of Total Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pumps</td>
<td>3</td>
</tr>
<tr>
<td>Valves</td>
<td>62</td>
</tr>
<tr>
<td>Connectors</td>
<td>31</td>
</tr>
<tr>
<td>Open-ended lines</td>
<td>1</td>
</tr>
<tr>
<td>Sampling connections</td>
<td>2</td>
</tr>
<tr>
<td>Pressure relief valves</td>
<td>1</td>
</tr>
<tr>
<td>Total uncontrolled emissions</td>
<td>653T/y</td>
</tr>
</tbody>
</table>
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Control Valve

Potential Leak Areas

Ball Valve
Types of Valve Seals

- Packing Gland
- O-Rings
- Bellows Seal
- Diaphragm

Bellows Valve/Seal

Diaphragm Valves

Weir Diaphragm Seal  Bonnet Diaphragm Seal
First Attempt at Repair for Valves

- Tightening bonnet bolts
- Replacing bonnet bolts
- Tightening packing gland nuts
- Injecting lubricant into lubricated packing

Manual Globe Valve

- Handwheel
- Stem
- Packing
- Packing Nut
- Bonnet
- Disk
- Seat

Types of Pumps

- Centifugal
- Rotary
- Reciprocating
- Canned
- Diaphragm
- Magnet Drive
Types of Pump Seals

- Simple Packed Seal
- Basic Single Mechanical Seal
- Dual Mechanical Seal
- Seal-Less
- Diaphragm Pump
- Magnet Drive Pump

Simple Packed Seal

Basic Single Mechanical Seal
CARB 262 – Fugitive VOC Inspections

Seal-Less Canned Motor Pump

Diaphragm Pump

Magnet Drive Pump
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Magnet Drive Pump

Types of Compressors

- Centrifugal
- Reciprocating
- Rotary

Types of Compressor Seals

- Labyrinth
- Restrictive Ring
- Mechanical
- Packed
- Liquid-Film

pp. 29-31

020811 16
Closed Vent Systems

- Designed and operated for no detectable emissions
- Monitored at startup, annually, and as required by agency
- Facility owner/operator must verify operating parameters

Control Devices

- **Vapor Recovery Systems**
  - 95% efficient
- **Incinerators/Oxidizers**
  - 95% efficient or minimum residence time and temperature
- **Flares**
  - Several conditions

Pressure Relief Devices
PRV with Rupture Disk

Screening Non-Vented PRVs

Open-Ended Line
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Sight Glass

Connectors
- Flanges
- Threaded
- Welded

Flanges
and now to put it all together
How many components do you count?

Estimating Component Emissions

- Average Emission Factors
- Screening Value Ranges
- Correlation Equations
- Unit-Specific Correlation Equations

Types of service

- Gas/vapor service
- Liquid service
  - light liquid service
  - heavy liquid service
**In VOC or HAP service**

- VOC – 10% by weight VOC<br>  NSPS<br>  oHAP – 5% by weight total oHAPs<br>  MACT/NESHAPs

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**Gas/Vapor service**

- The equipment is in gas or vapor phase at the operating conditions<br>  (temp/pressure)

---

**Liquid service**

- The equipment is not in gas or vapor service
The total concentration of the organic compounds having a vapor pressure > 0.3 kPa at 20 °C and =>20% by weight of the total process stream and Is a liquid

Light liquid service

- Means a piece of equipment is not in gas/vapor or in light liquid service

<table>
<thead>
<tr>
<th>Component</th>
<th>Service</th>
<th>Emission Factor (kg/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valves</td>
<td>Gas/Vapor</td>
<td>0.0268</td>
</tr>
<tr>
<td></td>
<td>Light Liquid</td>
<td>0.0109</td>
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<tr>
<td></td>
<td>Heavy Liquid</td>
<td>0.00023</td>
</tr>
<tr>
<td>Pump Seals</td>
<td>Light Liquid</td>
<td>0.114</td>
</tr>
<tr>
<td></td>
<td>Heavy Liquid</td>
<td>0.0210</td>
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<tr>
<td>Compressor Seals</td>
<td>Gas/Vapor</td>
<td>0.636</td>
</tr>
<tr>
<td>Pressure Relief Valve</td>
<td>Gas/Vapor</td>
<td>0.160</td>
</tr>
<tr>
<td>Connectors</td>
<td>All</td>
<td>0.00025</td>
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<tr>
<td>Open-Ended Lines</td>
<td>All</td>
<td>0.00230</td>
</tr>
<tr>
<td>Sampling Connections</td>
<td>All</td>
<td>0.0150</td>
</tr>
</tbody>
</table>
### 1995 EPA Protocol Refinery Screening Value Range Emission Factors

<table>
<thead>
<tr>
<th>Component</th>
<th>Service</th>
<th>&lt; 10,000 ppm Factor (kg/hr)</th>
<th>10,000 ppm Factor (kg/hr)</th>
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</thead>
<tbody>
<tr>
<td>Valves</td>
<td>Gas/Vapor</td>
<td>0.00060</td>
<td>0.2626</td>
</tr>
<tr>
<td></td>
<td>Light Liquid</td>
<td>0.0017</td>
<td>0.0088</td>
</tr>
<tr>
<td></td>
<td>Heavy Liquid</td>
<td>0.00023</td>
<td>0.00023</td>
</tr>
<tr>
<td>Pump Seals</td>
<td>Light Liquid</td>
<td>0.0120</td>
<td>0.437</td>
</tr>
<tr>
<td></td>
<td>Heavy Liquid</td>
<td>0.0135</td>
<td>0.3888</td>
</tr>
<tr>
<td>Compressor Seals</td>
<td>All</td>
<td>0.0894</td>
<td>1.608</td>
</tr>
<tr>
<td>Pressure Relief Valves</td>
<td>Gas</td>
<td>0.0447</td>
<td>1.691</td>
</tr>
<tr>
<td>Connectors</td>
<td>All</td>
<td>0.000060</td>
<td>0.0375</td>
</tr>
<tr>
<td>Open-Ended Lines</td>
<td>All</td>
<td>0.00150</td>
<td>0.01195</td>
</tr>
</tbody>
</table>

### Example

**Table 3-1. Screening Value Range Emission Factors**

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<td>Open-Ended Lines</td>
<td>All</td>
<td>0.00150</td>
<td>0.01195</td>
</tr>
</tbody>
</table>
Generic Fugitive VOC Emissions Regulations

- Applicability
- Exemptions
- Definitions
- Equipment Leak Standards/LDAR Standards
- Identification Requirements
- Recordkeeping Requirements
- Test Methods
- Compliance Schedule

Applicability

- Source Category
- Process Unit
- Equipment in process unit
- Process gas/fluid

pp. 13-15
Types of Standards

Performance Standards
Equipment Standards
Work Practice Standards (LDAR)

Leak Detection and Repair Standards

- Inspection Frequency
- Definition of Leak
- Repair Interval
- Percentage Leaking

Inspection Frequency

- Regular Compliance Inspection (monthly, quarterly, annually, etc.)
- Daily or Weekly Visual Inspections
- Inspection Interval After Repair
- Inspection Interval After Turnaround
### Definition of Leak

- Basic standard: 10,000 ppm
- Range: 50,000 ppm - 100 ppm
- Liquid leaks: 3 (or more) drops per minute
- Other definitions

### HON LDAR Standards for Valves

#### Quarterly LDAR

- ≥ 2% 500 ppm
- < 2% 500 ppm

#### Monthly LDAR

#### Semi-annual LDAR

- ≥ 1% 500 ppm
- < 1% 500 ppm

#### Annual LDAR

- ≥ 0.5% 500 ppm
- < 0.5% 500 ppm

### Repair Interval

- Basic standard: 15 days
- First attempt: 5 days
- Range: 1-15 days
- Repeat leakers: Possible replacement
- Delay of Repair: Until next shutdown (DOR) 6-month to 5-year limit
- Percentage awaiting repair
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Component Identification

- Tags
  - Inaccessible components tagged
  - Leaking components: brightly-colored, waterproof tag with date leak detected, other info
- P & IDs

Recordkeeping Requirements

1. Component ID code, description, process unit, service, material transported, concentration, compliance method
2. Dates of inspection
3. Emission levels (compliance or leak) and method of detection
4. Dates of repair (or attempt) and re-inspection
5. Emission levels after repair or replacement
6. Repair delayed, reason, expected date of repair
7. List and number of components awaiting repair
8. Portable monitoring instrument records

Reporting Requirements

(NPS, NESHAP)

- Notification of Construction or Reconstruction
- Initial Semiannual Reports
- Semiannual Reports
- Percentage of Valves Leaking

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Test Methods

- EPA Method 21
- EPA Method 25
- ASTM Methods
- Alternative methods

Portable Hydrocarbon Analyzers

- Types of VOC Analyzers
- Response Factors
- Method 21
- Factors in Selection and Use
- Safety Concerns

Types Analyzers Used for Fugitive Inspections

- Flame Ionization Detector (FID, OVA)
- Catalytic Combustion Analyzer (CCA, TLV)
- Photo Ionization Detector (PID)
1. Applicability/Principle
2. Definitions
3. Instrument/Calibration Gases
4. Procedures
Performance Specifications

(Method 21 - 3.1.1)

- Must respond to organic compounds being processed
- Must be intrinsically safe for operation in explosive atmospheres
- Must measure concentration specified in the regulation
- Scale must be readable to +/- 2.5 percent of defined leak concentration
- Must have nominal flow rate of 0.1-3.0 liter/min
- Probe must be < ¼ inch OD with 1 opening

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Requirement</th>
<th>Time Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response factor</td>
<td>Must be &lt;10 unless correction curve is used</td>
<td>One time before detector is put in service</td>
</tr>
<tr>
<td>Response time</td>
<td>Must be &lt;= 30 seconds</td>
<td>One time before detector is put in service if modification to sample pumping or flow conf is made a new test is req</td>
</tr>
<tr>
<td>Calibration precision</td>
<td>Must be &lt;= 10 percent of calibration gas value</td>
<td>Before detector is put in service and 3-month intervals or next use, whichever is later</td>
</tr>
</tbody>
</table>

Response Factor

- The ratio of the known conc of a VOC to the observed meter reading when measured by the instrument with a reference compound
Response Factor = \frac{Actual Concentration}{Instrument Indicated Concentration}

Response Factor Examples

Actual Concentration = 1,000 ppm
Instrument Gauge Reading = 3,000 ppm
Response Factor = ??

Actual Concentration = 100,000 ppm
Instrument Gauge Reading = 10,000 ppm
Response Factor = ??

Response time

The time interval from a step change in the VOC conc at the input on the sampling system to the time at which 90 percent of the value is reached on the readout meter
The degree of agreement between measurements of the same known value, expressed as the relative percentage of the avg diff between the meter readings and the known concentration.

**IR Camera Development**

- Is there a better way?
- Hydrocarbons absorb and emit infrared energy at specific wavelengths within the IR spectrum.
- Camera sees IR energy, but has a filter to allow only IR energy in the 3.3 – 3.5 µm wavelength band to be detected.
- Hydrocarbons that absorb IR energy in that range will be detected and imaged as a visible plume.

Common chemicals detectable by the camera:
- Benzene
- Butane
- Ethane
- Ethanol
- Ethylbenzene
- Heptane
- Hexane
- Methane
- Methanol
- Octane
- Pentane
- Propane
- Propylene
- Toluene
- Xylene

New “alternative work practice” promulgated to allow the use of optical gas imaging as a replacement for method 21.

40 CFR 60.11 (c), (d), and (e) and
40 CFR 60.18 (g), (h), and (i)
Expected Benefits
- In theory – ability to survey equipment faster
- Cheaper/less labor intensive

Actual Implementation
- Camera is not as sensitive
- The image can be manipulated – leaks can disappear or be seen more easily with certain camera settings
- Image affected by background, environmental conditions
- Daily calibration and recordkeeping of everything monitored
- Camera is not intrinsically safe
- Camera is very expensive

Examples From Real Inspections
- Compressor distance piece oil sump at a natural gas compressor station
  - Distance piece is designed to prevent lubricating oil from leaking into the compressor cylinder.
  - Distance piece also acts as a process gas leakage control device
  - In this case, compressed gas was leaking past the packing rings and carried over into the oil sump
Storage vessel bleeder vents must be closed at all times unless the tank roof is being landed or floated off the leg supports.

- Refinery Flare
- Excess steam = incomplete combustion of hydrocarbons

- Fruit processing plant waste dumped in a pit
- Exposure to air and decomposition caused it to heat up
- IR camera used to see elevated temperatures
CARB 262 – Fugitive VOC Inspections

Calibration

Calibration Gases
(Method 21 - 3.2)

- Zero air (< 10 ppm VOC)
- Span gas
- Cylinder cal gas mixtures
  - certified to ± 2 % accuracy
  - shelf life specified
- Prepared gases
  - accurate to ± 2 %
  - replaced each day

Preparing PIDs for Field Use

1. Check battery status
2. Check probe condition
3. Check for obvious deposits on optical window
4. Confirm detector response
5. Measure sample gas flow rate at probe inlet
6. Calibrate
Performance Criteria
(Method 21 - 3.1.2)

- Response Factor less than 10
- Response time of 30 seconds or less
- Calibration precision less than or equal to 10% of calibration gas value

Determining Flow Rate

- Highly recommended
- No official protocol
- Flow rate may be affected by contamination, battery life, etc.

Effect of Flow Rate

Pump Flow Rate = 1.0 liters/min

Leak Rate = 10 milliliters/min

Meter Reading = 10,000 ppm

$0.010 \text{ liters} = 0.010000$
$1.0 \text{ liters}$
Pump Flow Rate = 0.5 liters/min

Leak Rate = 10 milliliters/min

Effect of Flow Rate

Meter Reading = 20,000 ppm

0.010 liters = 0.020 liters

CONDUCTING AN INSPECTION

1000’s to 100s of 1000’s of valves and connections that must be monitored for leaks

90 to 99% of valves and connections are not leaking

Costly, monotonous, time consuming

Work is contracted out to lowest bidder, technicians often uneducated and complacent
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EPA list of common problems leading to enforcement
- Failure to identify process units and components
- Failure to follow prescribed procedures
- Incorrect or expired calibration gases
- Failure to repair and retest leakers on time
- Failure to submit quarterly records
- Failure to maintain calibration and monitoring records

Pre-Inspection
- Regulation Review
- File Review
- Permit Check
- Equipment Check

On-Site Inspection
- Initial Interview
- Records Review
- Plant LDAR Program Evaluation
- Component Screening Strategies
- Leak Monitoring
**Records Review**

- Are records complete per regulations?
- Verify unsafe and difficult-to-monitor determinations listed
- Check process unit determinations

**Plant LDAR Program Evaluation**

- Evaluate tracking system for scheduling monitoring and repairing
- Interview plant personnel
- Observe calibration of leak detection equipment
- Observe leak detection monitoring

**Focusing the Inspection**

Most important components for monitoring:
- Components/process units with history of high leak rates
- Valves in gas and light-liquid service
- Pumps in light liquid service
- Compressors

Review component identification system
Locating Potential Leaks

- Individual Component Survey
  - visual, auditory, olfactory
  - soap solution screening
  - portable VOC analyzer
- Area Survey ("Walk-Through")
- Fixed Point Monitors
- Infrared imaging

Monitoring Individual Components
(Method 21 - 4.3.1)

- Measure background levels
- Probe at surface of component
- Move along interface periphery while observing readout
- If increase occurs, sample until maximum reading; leave probe tip at this location for approx. 2 times response time
- Record results

Screening Valves
Limitations and Problems Using Portable Instruments

- Poor capture capability & pinpoint nature of most leaks → probe should be oriented directly into plume
- Negative pressure sampling → limited capture distance
- Air drawn into probe from all directions → dilution
- All instruments sensitive to gas flow rates
- Cross-wind reduces capture efficiency

Effect of Wind Velocity on PPM Reading (probe tip 1/4” from leak source)

- Flame-ionization Detectors
  - Flame-out at sample concentrations above 70,000 to 100,000 ppm
  - Blinding of flame arrester
  - Sustained high observed readings due to condensation & revolatilization in sample lines

- Photo-ionization Detectors
  - Condensation of organic materials on the optical surface
  - Condensation and revolatilization

- Catalytic Combustion Analyzers
  - Volatilization of catalyst on detector wire
  - Condensation and revolatilization
CARB 262 – Fugitive VOC Inspections

**Post-Inspection**
- Compare field inspection observations with plant records
- Review findings with plant representative(s)
- List items to be checked during follow-up inspection(s)

**Inspection Safety**
- Calibrate in well-ventilated space
- Make sure all intrinsically-safe features are intact
- Review possible on-site hazards
- Wear long-sleeved, fire protective clothing
- Be trained in use of specialized equipment

**Pre-Field Safety**
- Calibrate in well-ventilated space
- Make sure all intrinsically-safe features are intact
- Review possible on-site hazards
- Wear long-sleeved, fire protective clothing
- Be trained in use of specialized equipment
Stay alert
Move at a reasonable pace
Be extremely cautious around hot (or cold) surfaces
Be extremely cautious monitoring components with rotating shafts
Stay upwind of components being screened
Keep both hands free when climbing ladders
Don't make "heroic" physical efforts to reach components