NACT 284
Volatile Organic Compound
Control Devices

Course Overview

• Volatile Organic Compound (VOC) Controls
• Examples of VOC Calculations
• Particulate Matter (PM) Options
• Inspection Strategies

Volatile Organic Compounds

Chemical definition of VOCs:
• Molecules which contain carbon &
• High evaporative rate at low temperatures
• \[ VP > 0.1 \text{mm Hg} \]
Legal Definition of VOCs

- Federal and State laws & regulations
  * 40CFR51 § 51.100
  * Latest Definitions of VOCs and ROGs as of...
- Total Organic Gases (TOGs)
- Reactive Organic Gases (ROGs)
- Fraction of Organic Gases (FROGS)
- Local Agency rules and permit conditions

Why are VOCs Regulated?

Why is Ozone Regulated?
Ozone Formation

- VOCs + NO\textsubscript{x} + sunlight > O\textsubscript{3}
- Ozone is formed when NO\textsubscript{x} and Volatile Organic Compounds react in sunlight

VOC Control Process

- Capture
- Control
  - Recovery, Disposal or Destruction
VOC Calculations: Capture & Control & Retention

- General Categories of VOC Emissions
  - Fugitive (Not reasonably captured)
  - Captured > Ducted to control device
  - Consumed > Oxidized
  - Retained > Retention factors vary

VOC Capture Efficiency *

\[
\frac{\text{VOCs captured}}{\text{VOCs used}} \times 100
\]

VOCs used (and therefore emitted) 100 lbs
VOCs captured (entering control device) 80 lbs
VOC capture efficiency (by calculation) 80%

* Capture Efficiency is the percentage of emissions captured and vented to a control device. -- EPA
VOC Control Efficiency

% CE = \left[ 1 - \frac{\text{outlet emission rate}}{\text{inlet emission rate}} \right] \times 100

% CE = \left[ 1 - \frac{2 \text{ lbs/hr}}{100 \text{ lbs/hr}} \right] \times 100 = 98

Examples of VOC Calculations

Graphic Arts Operations

With VOC Retained in Substrate

Graphic Arts Operation
**VOC Calculations**

- A facility uses 100 lbs/hr of ink that has a VOC content of 35% by weight.
- 20% of the VOC is retained in the substrate.
- The incinerator has a 95% control efficiency.

How many lbs/hr of VOC is emitted?

\[
\text{VOC Emissions} = (100 \text{ lbs/hr})(0.35)(1-0.20)(1-0.95) = 1.4 \text{ lbs/hr}
\]

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**Let’s Discuss Control of VOC**

- Containment
- Transfer Efficiency
- Absorption
- Adsorption
- Condensation
- Oxidation

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**Controlled Spraying**

*aka Pollution Prevention*

- Reduces VOC emissions
- Increases transfer efficiency
- Low fluid tip pressure
- Employee gun handling training
High Volume Low Pressure (HVLP) Spray Guns

(HVLP) Spray Gun: Polyester Resin Operations

Fluid Impingement Technology: Polyester Resin Operations
Gel Coat Application in a Spray Booth

Let's Discuss Adsorption Systems

Adsorption Mechanism

Gas + Solid surface
Adsorption Mechanism

Step 1. VOC diffuses to adsorbent surface
Step 2. VOC migrates into pores
Step 3. VOC adsorbed and builds up on adsorbent

• Chemically unchanged
• Desorbed and recovered
• Polar and non-polar adsorbates
• Mixed adsorbates separated by distillation

Adsorption

• Adsorption materials (adsorbents)
  * Activated carbon
  * Hydrous oxides
    • Silica gel
    • Aluminum oxide
    • Magnesium silicate
  * Zeolites (molecular sieves)
  * Naturals
    • Clays
    • Bauxite
    • Fuller’s Earth
  * Metals

26 27 28
Factors Affecting Adsorption

- Temperature
- Pressure
- Gas velocity
- Particulate matter

Adsorber Design Considerations

- Porosity of Adsorbent
- Bed Cross-Sectional Area
- Bed Length
- Multiple Organic Compounds
- Steaming Requirements
- Fouling
- Timers/Monitors
- Channeling
**Pore Space Representation**

- A = Residual VOCs or heel
- B = Working capacity
- C = Equilibrium Capacity
- D = Empty pore space
- E = Total pore space (total capacity)

**Carbon Adsorption Keywords**

- **Fresh zone**
  * Area where adsorption will occur
- **Mass transfer zone**
  * Where adsorption occurs
- **Saturated zone**
  * Area where adsorption has already occurred

**Keywords (continued)**

- **Heel**
  * Amount of VOCs left in the carbon after regeneration
- **Breakthrough**
  * VOCs that do not get captured
Adsorber Breakthrough

Outlet Concentration

Excess Emissions

Time Where Breakthrough Occurs

Time Where Bed is Saturated

Types of Adsorption Systems

* Non-regenerative systems

* Regenerative systems
  - on site
  - off site

Characteristics of Activated Carbon

* Sources
  - Wood, coal, peat, nut shells

* Porosity
  - 600-1600 m$^2$/g (2-3 football fields per 1/28 ounce)

* Preparation
  - Anaerobic heat then steam or CO$_2$

* Degree of adsorption depends on adsorbate
  - MW, BP, polarity, surfactive index, solubility
Examples of Activated Carbon

Types of Carbon Adsorption Systems

- Open
- Closed
- Rotary
- Fluidized bed
- Bulk plant adsorber and absorber
Adsorber Inspections

- Hood static pressures
- Inlet VOC concentrations
- Inlet temperatures
- Inlet VOC concentration not > 25% LEL
- Outlet VOC concentrations
- Fan motor current
- Solvent recovery rates

Let's Discuss Absorbers

Absorbers

- Pollutants dissolved in liquid
- Absorbate dissolves in absorbent
### Factors Favoring Absorption

- Pollutant solubility in liquid
- Adequate diffusion at liquid / gas interface
- Maximized contact between gas and liquid

### Absorber Design

- Produce large surface area
- Minimize air flow resistance to reduce pressure drop
- Inlet pressure - outlet pressure = pressure drop

### Pressure Drop: Magnehelic

![Magnehelic Pressure Drop Meter](image)
Absorber Design Factors

- Select liquid solvent
- Column material
- Column size
- Column height
- Number of plates
- Pressure drop
Absorbers: Packed Columns

- Flow patterns
- Liquid reuse and treatment
- Packing material
- Packing quality

Absorbers: Plate Columns

- Maximize contact between liquid & gas
- Diameter of column
- Plates
  * Number
  * Type
  * Layout
Packed vs Plate Columns

• Packed columns
  + More common
  – Plugged by particles
  + Better for corrosive pollutants
  + Lighter than plate

Packed versus Plate Columns

• Plate columns are better for:
  + Large temperature changes
  + Lower liquid flow rates
  + Higher gas flow rates
  + Foaming liquids
  + Chemical reactions
  + Large systems

Let's Discuss Condensers
Condensation = Process of changing a gas to a liquid.
Condensation allows recovery of solvents and air pollution control

Contact Condensers

Contact condensers +/-
+ Cheaper
+ More flexible
+ Less repair time
– Wet waste disposal problem
Surface Condensers

* Shell and tube (most common)
* Fin Fan
* Tubular
* Double pipe
* Spiral plate
* Flat plate

Condensers

- Surface condensers +/-
  + Better recovery
  + Commonly used for air pollutants
  + Reduced waste disposal problems
  - More costly

Shell and Tube
### Condenser Concerns

- Freezing
- Fouling
- Cleaning
- Pressure drop
Condenser Inspection

- Look for
  - Excessive corrosion and rusting
  - Leaking coolant or VOC
  - Excessive odors
  - Continuous emissions monitor

Condenser Inspection

- Record
  - VOC outlet concentration
  - Waste stream flow rate
  - Condenser pressure drop
  - Coolant pressure
  - Coolant flow rate

Let's Discuss Oxidizers
**Oxidation**

- Destruction of VOCs by Combustion

Reactions with oxygen

\[ C_7H_8 + 9O_2 = 7CO_2 + 4H_2O \]

Toluene + Oxygen = Carbon Dioxide + Water

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**Combustion Considerations**

- Time
- Temperature
- Turbulence (mixing)
- Oxygen (air)
- Nitrogen (air)

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[Diagram of excess fuel and excess air]
Combustion Devices

- Thermal incinerator (uses a flame)
- Catalytic incinerators (uses a catalyst)
- Boilers (burn VOCs to make steam)
- Process heaters (burn VOCs to add heat in chemical plants and refineries)
- Flares (simple flame)

Thermal Oxidizer/Afterburner

Thermal Incinerator
Can Type RTO

In the regenerative thermal oxidizer, the single rotary valve controls access to open air paths and automatically seals it off by restricting the heat set position. A continuous air purge prevents any creeping drip into the exhaust and ensures the treatment in the reactor.

Catalytic Oxidizer/Incinerator

Auxiliary Fuel Burners

Waste Gas

Catalyst Bed

Stack

Optional Heat Recovery
Selection Criteria

• Type of VOCs
• Concentration of VOCs
• Process flow rate
• Economics

Catalytic vs. Thermal for VOC Control

<table>
<thead>
<tr>
<th>Catalytic</th>
<th>Thermal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Operating Temp. &amp; Lower</td>
<td>Higher Operating Temp. &amp; Higher</td>
</tr>
<tr>
<td>Fuel Usage</td>
<td>Fuel Usage</td>
</tr>
<tr>
<td>Higher Capital &amp; Maintenance</td>
<td>Lower Capital &amp; Maintenance Costs</td>
</tr>
<tr>
<td>Costs</td>
<td></td>
</tr>
<tr>
<td>Catalyst Fouling &amp; Poisoning</td>
<td>No Catalyst Involved Here</td>
</tr>
</tbody>
</table>
Catalyst Problems

- Scouring
- Thermal burnout
- Thermal aging
- Masking
- Catalyst fouling and poisoning

Catalytic Poisons

- Fast acting poisons
  * phosphorus P, bismuth Bi, lead Pb, arsenic As, antimony Sb, mercury Hg
- Slow acting
  * iron Fe, tin Sn, silica Si
- Reversible
  * sulfur S, zinc Zn, chlorine, bromine, fluorine etc. halogens

Catalyst Efficiency

- Operating temperature
- Space velocity
- VOC composition
- VOC concentration
- Catalyst properties
- Poisons and inhibitors
There are two basic types of heat exchangers used for thermal or catalytic oxidizers:

- Metal Heat Exchangers or “recuperative heat exchangers”
- Ceramic Bed Heat Exchangers or “regenerative heat exchangers”
**Thermal & Catalytic Oxidizer Heat Exchangers**

- DRE = \( \frac{1,000 - 30}{1,000} = 97\% \)
- 2% of 1000 ppm = 20 ppm

**Boilers, Process Heaters & Flares**

- Boilers make steam
- Process heaters add heat to material
- Flares are thermal incinerators without a combustion chamber

**Typical Boiler**
Let’s Discuss Flares

Flare Types – Open or Elevated

Flare Types – Enclosed or Ground
Flares

Gasoline Marketing:
Bulk Terminal

Bluff Road Municipal Solid Waste Landfill
Lincoln, NE

Waste Gas Collection & Flare
Shell Deer Park Refinery in Texas on the Houston Ship Channel.

Flaring gases from an oil platform.

Incinerator Inspection

- Look for
  - Excessive corrosion and rust
  - Holes in incinerator shell or ducts
  - Visible emissions
  - Excessive odors
  - Last time catalyst was replaced
Incinerator Inspection

- Record
  - VOC outlet concentration
  - Incinerator inlet temperature
  - Incinerator outlet temperature
  - Pressure drop
Three Stages

- Pre-Inspection
  * file review, rule review, inspection forms, copy of permit, safety equipment check
- Inspection
  * facility safety indoctrination, pre-inspection meeting
- Post-Inspection Interview

Pre-Inspection Guidelines

- Regulation review
- Equipment check
- Pre-entry and entry
- Pre-inspection meeting
- Permit check

Pre-Inspection Meeting

- Facility name and ownership
- Address including city and zip
- Contact name and title
- Phone number including area code
- Production rate
### Pre-Inspection Meeting

- Operating schedule
- Operation season
- Date of last source test
- Fuel usage and sulfur content

### Inspection Report

- Description of facility & processes
- Flowchart with equipment location & emission points
- Process diagram (materials handled, flow rates, temperatures, pressures)
- Statement as to compliance or non-compliance
- Enforcement action recommendation

### Usage Records

- Review usage records
- Obtain necessary copies
**Six points of Inspection**

Capture, Transport, Air Mover, Instrumentation, Control, Subsystem

- Are process emissions drawn into a control device at the point of release?
- Are they drawn into a collection device?

**Capture**

- Are process emissions drawn into a control device at the point of release?
- Are they drawn into a collection device?
Transport

- Are the emissions moved to the control device without loss?
- Are there any leaks?

Air Mover

- Is the fan big enough for the job?
- Is it operating as designed and permitted?
Instrumentation

- Are the proper instruments present?
- Are they functioning?
- Are they calibrated regularly?
- Are they showing the proper units?

Control Device

- Is it functioning?
- Are there any visible leaks?
- Can the device handle the job?
Subsystem

• What is the ultimate fate of captured or concentrated emissions?
• Pressure gauges for accuracy & change
• Fines system for leaks & proper discharge
• Motor for proper operation

The End