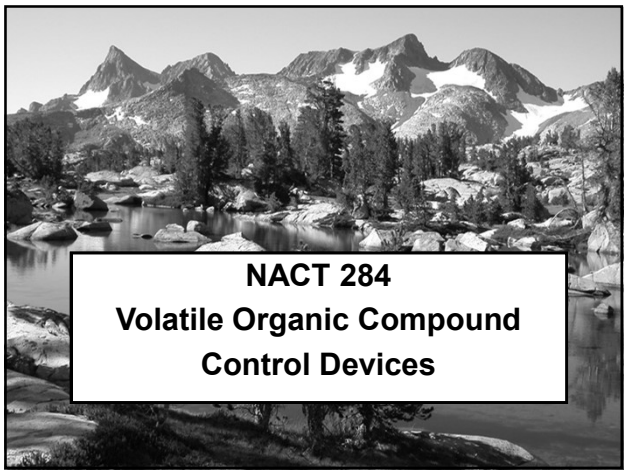


1

Course Overview

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

2

Volatile Organic Compounds

Chemical definition of VOCs:

- Molecules which contain carbon
  &
- High evaporative rate at low temperatures
- [VP > 0.1mm Hg]

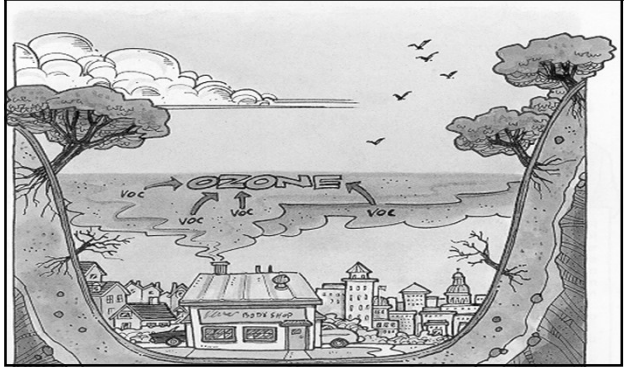
3

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

4

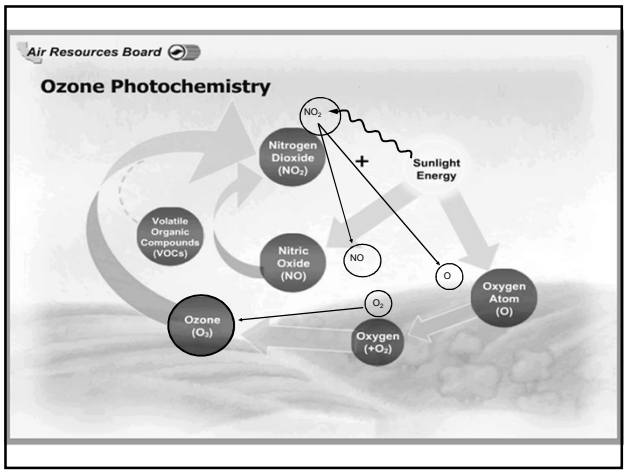
Why are VOCs Regulated?



5

Why is Ozone Regulated?

6



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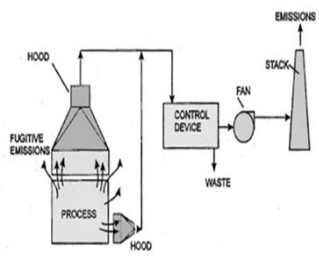
Ozone Formation

- VOCs + NO_x + sunlight > O_3
- Ozone is formed when NO_x and Volatile Organic Compounds react in sunlight

8

VOC Control Process



- Capture
- Control

  Recovery, Disposal or Destruction

9

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

10

VOC Capture Efficiency *

$$\text{VOC Capture Efficiency} = \frac{\text{VOCs captured}}{\text{VOCs used}} \times 100$$

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

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

11

VOC Capture Efficiency *

$$\text{VOC Capture Efficiency} = \frac{\text{VOCs captured}}{\text{VOCs used}} \times 100$$

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*

12

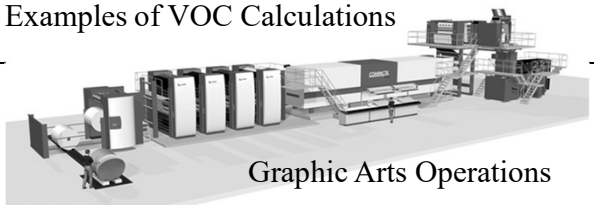
VOC Control Efficiency

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

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

13

Examples of VOC Calculations

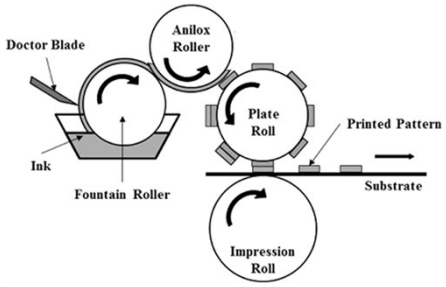


Graphic Arts Operations

With VOC Retained in Substrate

14

Graphic Arts Operation



15

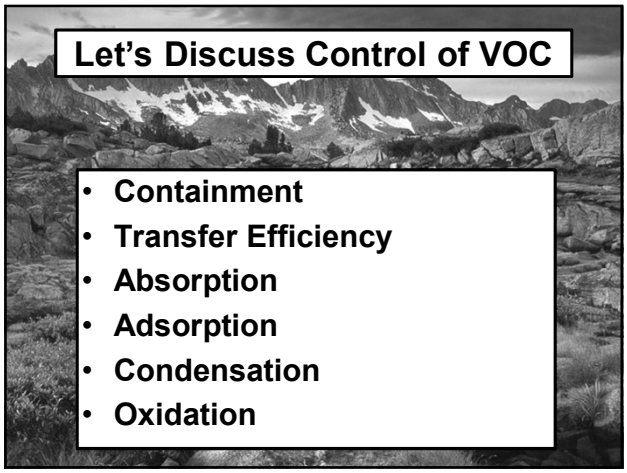
VOC Calculations

- 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?

VOC Emissions = (100 lbs/hr) (0.35) (1-0.20) (1-0.95) = 1.4 lbs/hr

16



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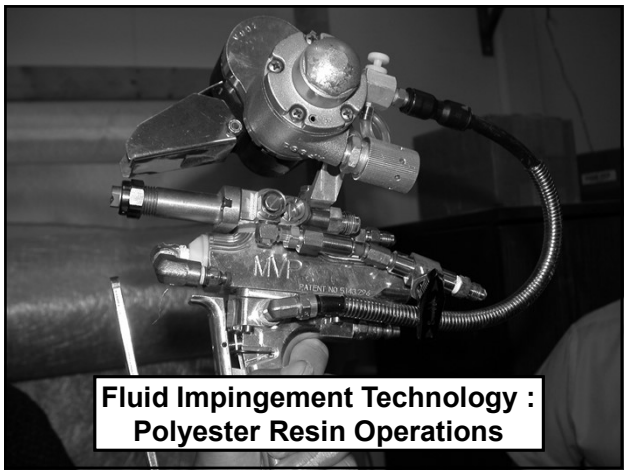
19

High Volume Low Pressure (HVLP) Spray Guns

20

(HVLP) Spray Gun : Polyester Resin Operations

21



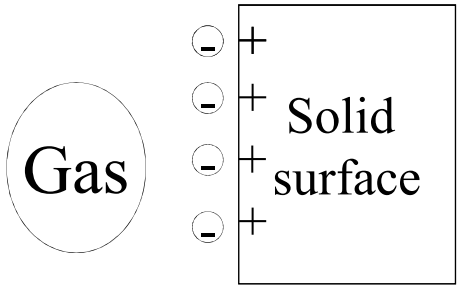
Fluid Impingement Technology : Polyester Resin Operations

22

23

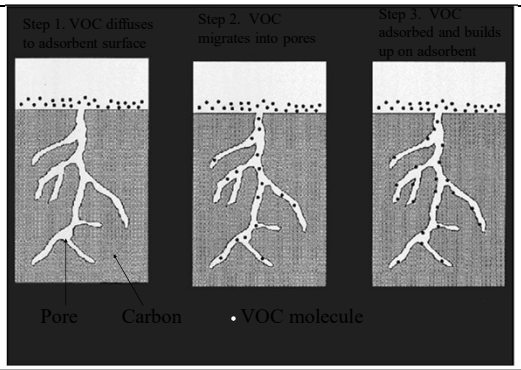
24

Adsorption Mechanism



25

Adsorption Mechanism



26

Adsorption Mechanism

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

27

Adsorption

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

28

Carbon Adsorbers at a Soil Remediation Site

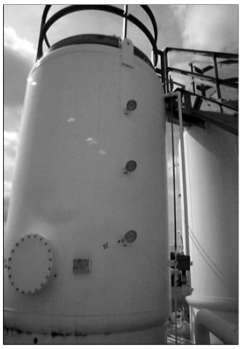
29

Factors Affecting Adsorption

- Temperature
- Pressure
- Gas velocity
- Particulate matter

30

Adsorber Design Considerations

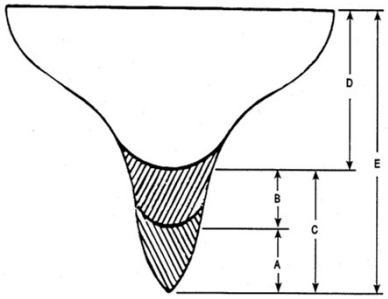


- Porosity of Adsorbent
- Bed Cross-Sectional Area
- Bed Length
- Multiple Organic Compounds
- Steaming Requirements
- Fouling
- Timers/Monitors
- Channeling

31

Pore Space Representation

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



32

Carbon Adsorption Keywords

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

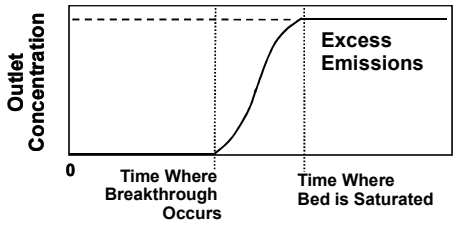
33

Keywords (continued)

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

34

Adsorber Breakthrough



35

Types of Adsorption Systems

*Non-regenerative systems

*Regenerative systems
- on site
- off site

36

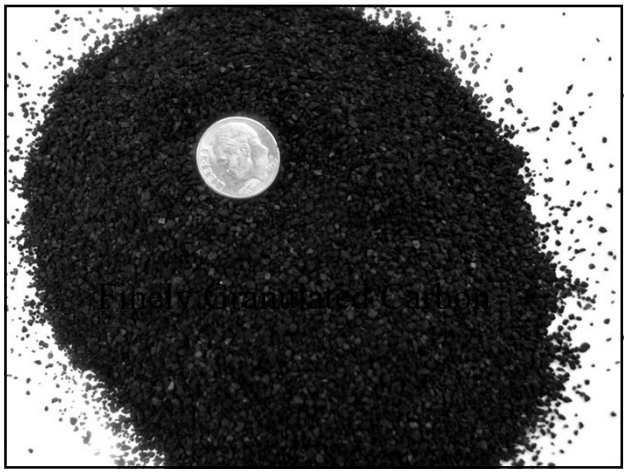
Characteristics of Activated Carbon

- 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

37

Examples of Activated Carbon

38



39

Types of Carbon Adsorption Systems

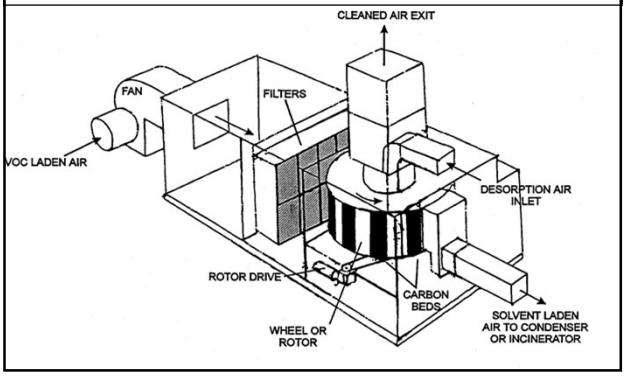
- Open
- Closed
- Rotary
- Fluidized bed
- Bulk plant adsorber and absorber

40

Bulk plant adsorber & absorber

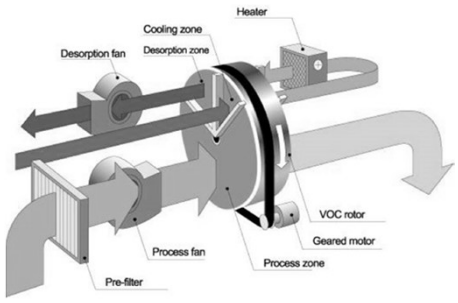
41

Rotary Concentrator Adsorption System



42

Rotary Concentrator Adsorption System



43

Adsorber Inspections

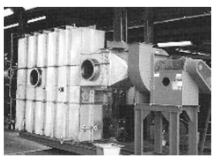
- Hood static pressures
- Inlet VOC concentrations
- Inlet temperatures
- Inlet VOC concentration not > 25% LEL
- Outlet VOC concentrations
- Fan motor current
- Solvent recovery rates

44

45

Absorbers





- Pollutants dissolved in liquid
- Absorbate dissolves in absorbent

46

Factors Favoring Absorption

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

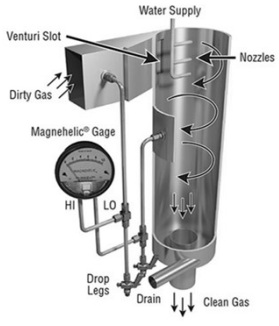
47

Absorber Design

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

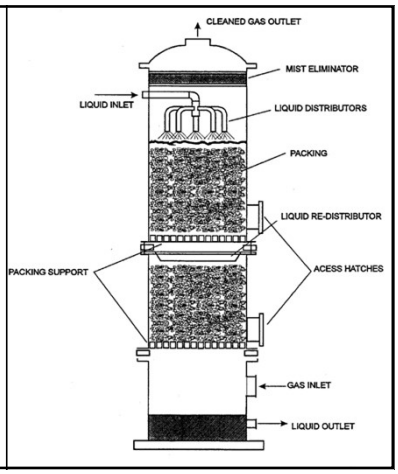
48

Pressure Drop : Magnehelic



49

Packed Bed Wet Scrubber



50

51

Absorber Design Factors

- Select liquid solvent
- Column material
- Column size
- Column height
- Number of plates
- Pressure drop

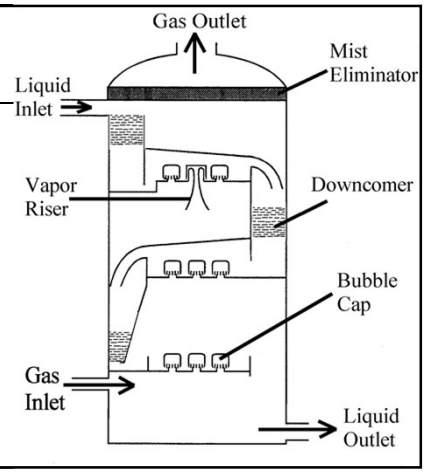
52

Absorbers: Packed Columns

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

53

Absorbers: Plate Columns



54

Absorbers: Plate Columns

- Maximize contact between liquid & gas
- Diameter of column
- Plates
  - * Number
  - * Type
  - * Layout

55

Packed vs Plate Columns

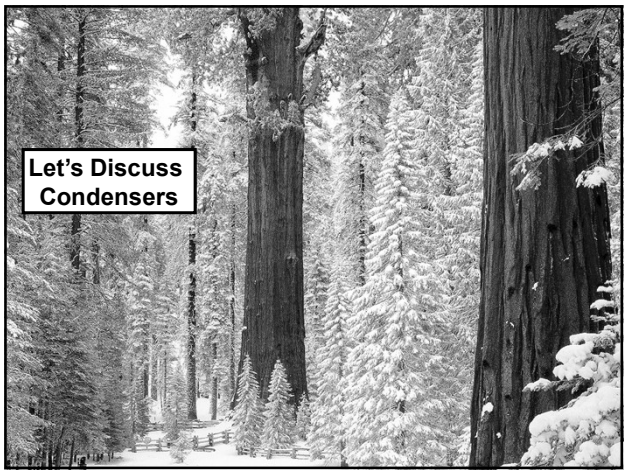
- Packed columns
  - +More common
  - –Plugged by particles
  - +Better for corrosive pollutants
  - +Lighter than plate

56

Packed versus Plate Columns

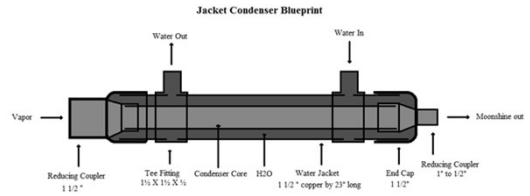
- Plate columns are better for:
  - +Large temperature changes
  - +Lower liquid flow rates
  - +Higher gas flow rates
  - +Foaming liquids
  - +Chemical reactions
  - +Large systems

57



61

Condensers : Surface & Contact



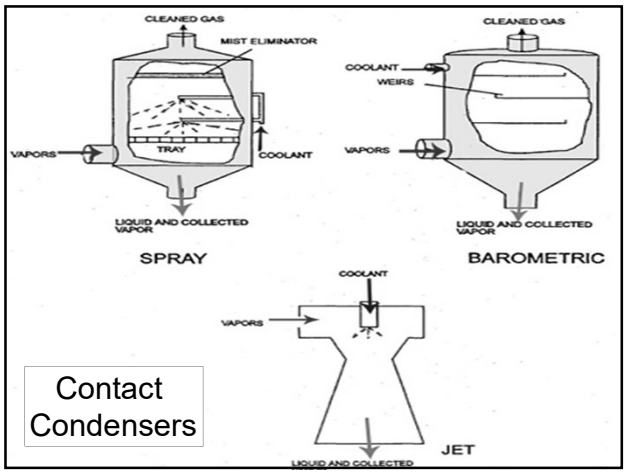
- Condensation = Process of changing a gas to a liquid.
- Condensation allows recovery of solvents and air pollution control

62

Contact Condensers

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

64



65

Surface Condensers

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

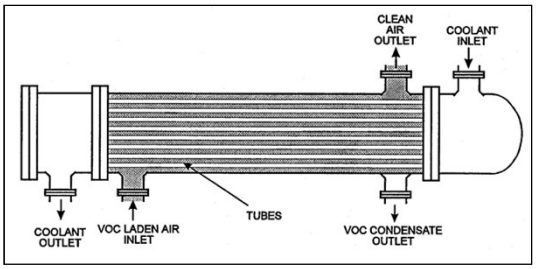
67

Condensers

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

68

Shell and Tube



69

70

71

Condenser Concerns

- Freezing
- Fouling
- Cleaning
- Pressure drop

72

Condenser Inspection

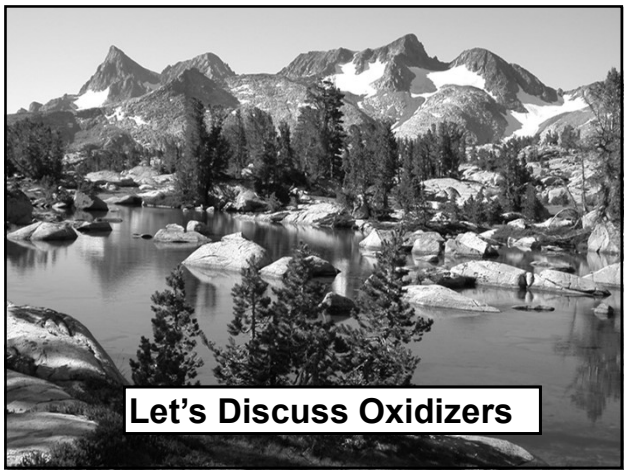
- Look for
  - Excessive corrosion and rusting
  - Leaking coolant or VOC
  - Excessive odors
  - Continuous emissions monitor

74

Condenser Inspection

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

75



76

Oxidation

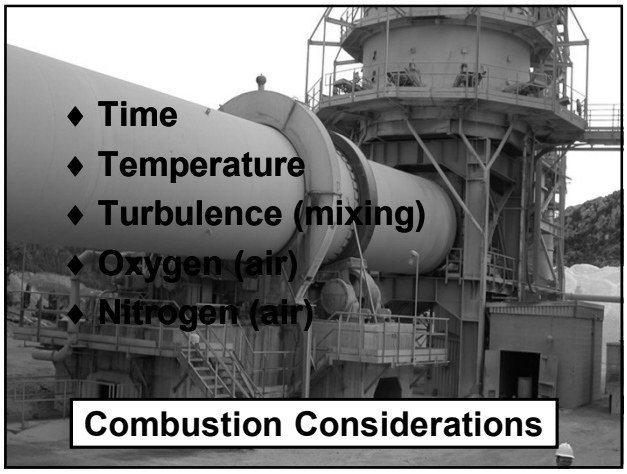
- Destruction of VOCs by Combustion

Reactions with oxygen

$C_7H_8 + 9O_2 = 7CO_2 + 4H_2O$

Toluene + Oxygen = Carbon Dioxide + Water

77



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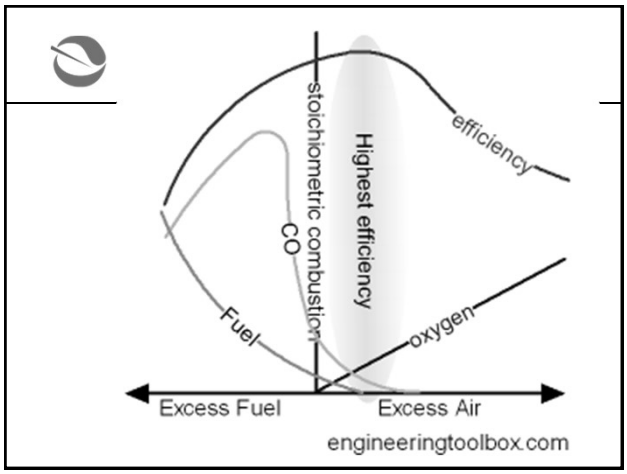


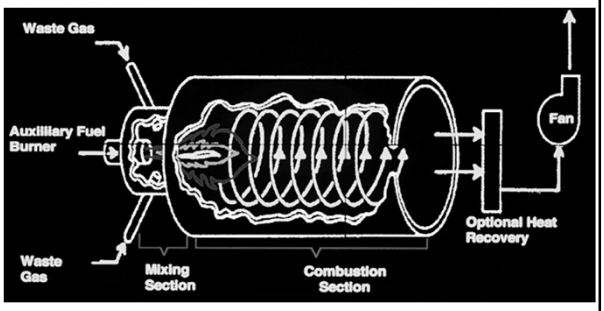
79

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)

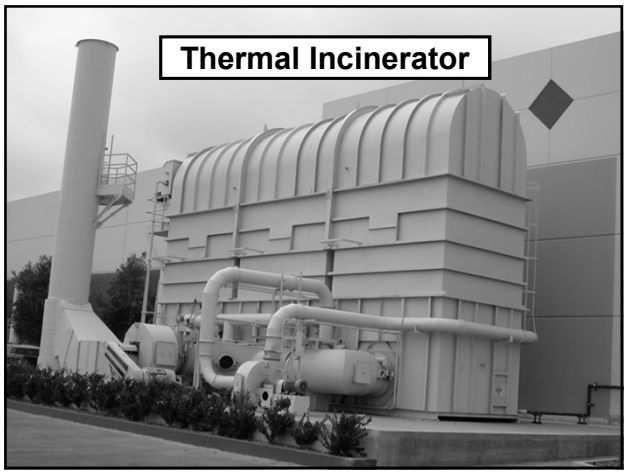
80

Thermal Oxidizer/Afterburner



81

Thermal Incinerator



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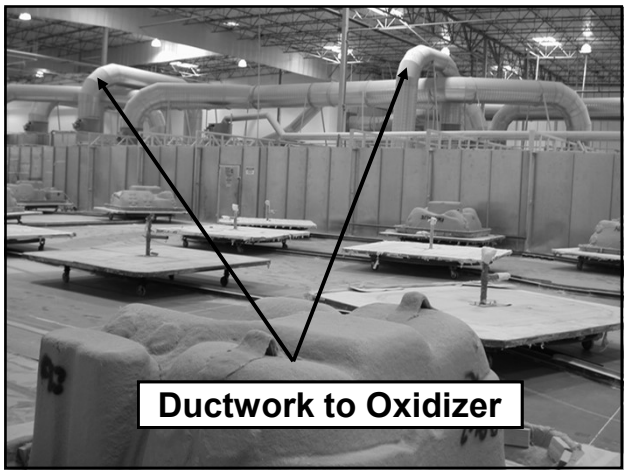
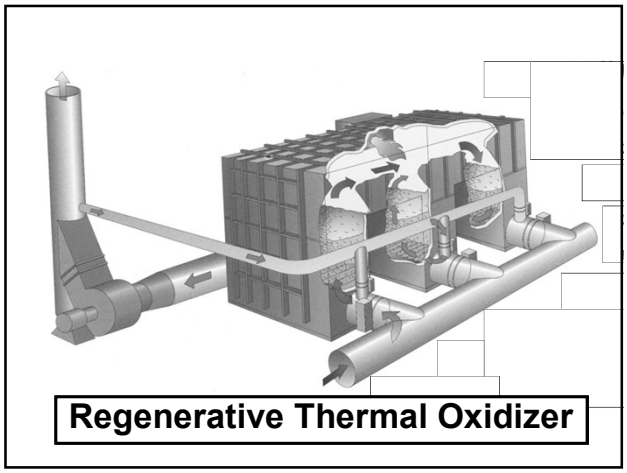
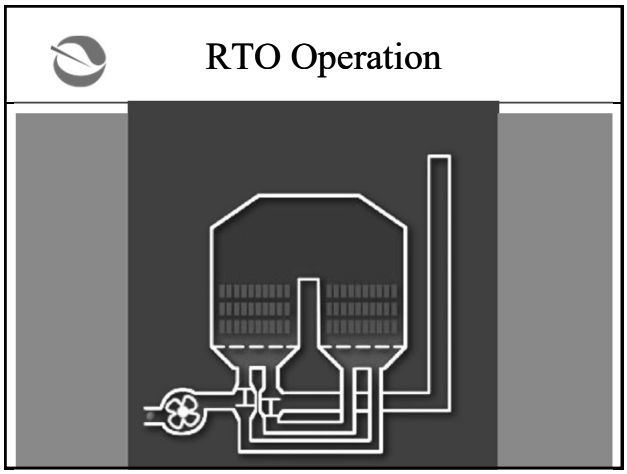

Ductwork to Oxidizer

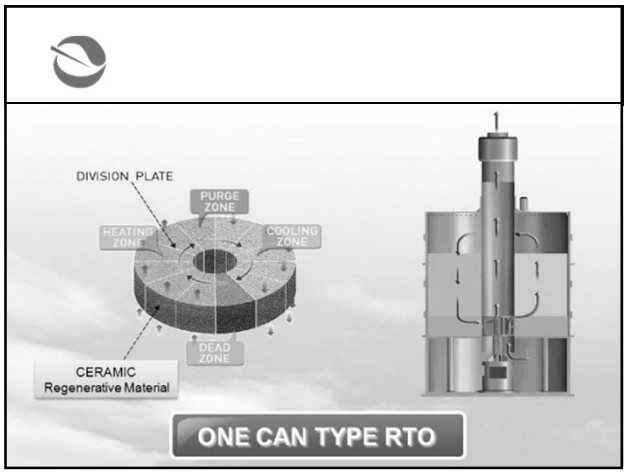
83


Regenerative Thermal Oxidizer

84

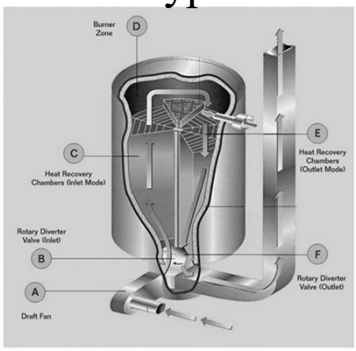

RTO Operation

85



86

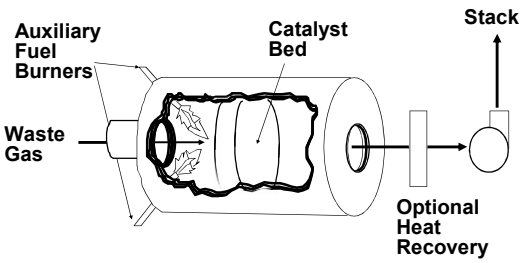
Can Type RTO



In the regenerative thermal oxidizer, the single rotary valve indexes across an open air path and methodically seals it off by reaching the next set position. A continuous air purge captures any scavenging dirty air in the switch and returns it for treatment in the oxidizer.

87

Catalytic Oxidizer/Incinerator



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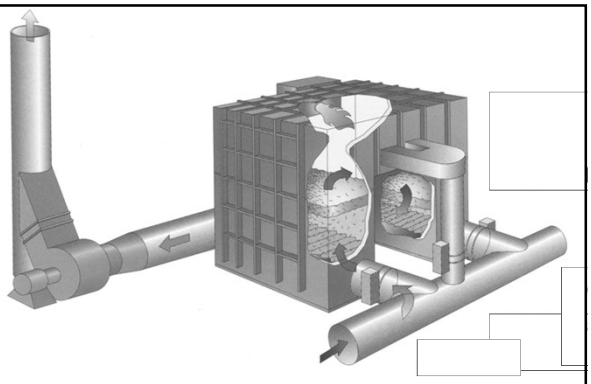


Regenerative Catalytic Oxidizer

89

Selection Criteria

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

90

Catalytic vs. Thermal for VOC Control

Catalytic	Thermal
Lower Operating Temp. & Lower Fuel Usage	Higher Operating Temp. & Higher Fuel Usage
Higher Capital & Maintenance Costs	Lower Capital & Maintenance Costs
Catalyst Fouling & Poisoning	No Catalyst Involved Here

91

Catalyst Problems

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

92

Catalytic Poisons

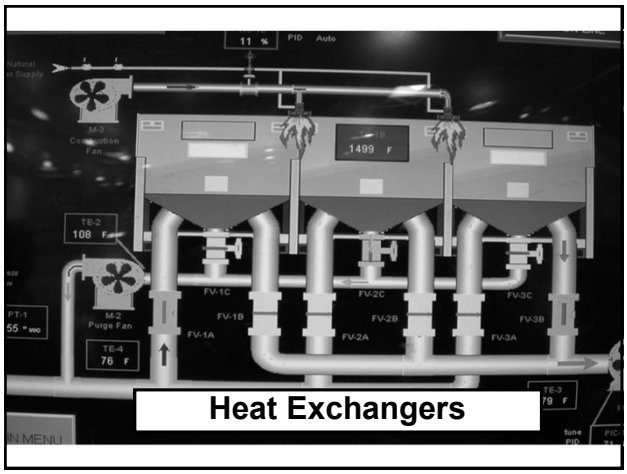
- Fast acting poisons
  * phosphorus P, bismuth Bi, lead Pb, arsenic As, antimony Sb, mercury Hg
- Slow acting
  * iron Fe, tin Sn, silica Si
- Reversible
  * sulfur S, zinc Zn, chlorine, bromine, fluorine etc. halogens

93

Catalyst Efficiency

- Operating temperature
- Space velocity
- VOC composition
- VOC concentration
- Catalyst properties
- Poisons and inhibitors

94



95

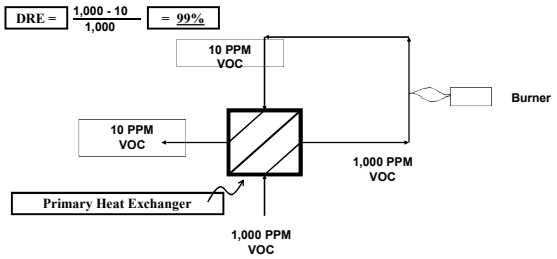
Thermal & Catalytic Oxidizer Heat Exchangers

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"

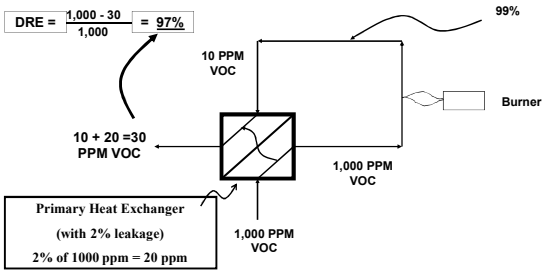
96

Thermal & Catalytic Oxidizer Heat Exchangers



97

Thermal & Catalytic Oxidizer Heat Exchangers

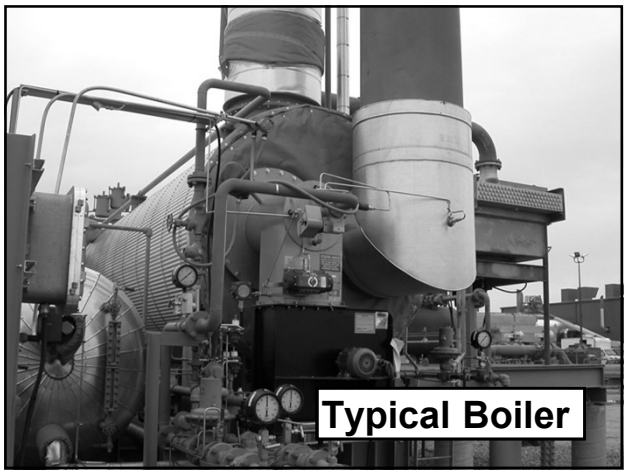


98

Boilers, Process Heaters & Flares

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

99



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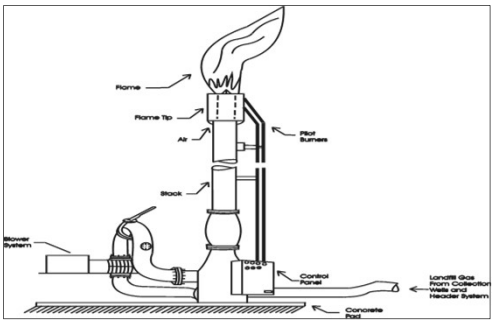
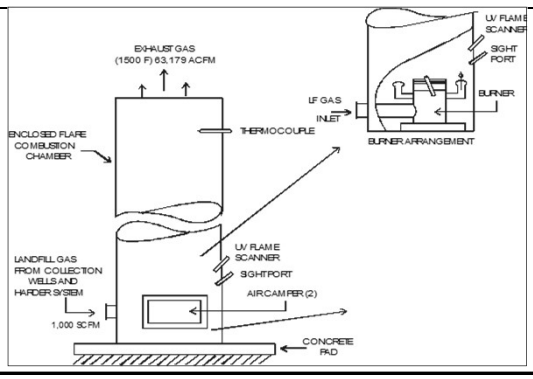
101

Flare Types – Open or Elevated



102

Flare Types – Enclosed or Ground



103

Flares

Gasoline Marketing:

Bulk Terminal

104

105

106

Shell Deer Park Refinery in Texas on the Houston Ship Channel.

107

Flaring gases from an oil platform.

108

Incinerator Inspection

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

109

Incinerator Inspection

- Record
  - * VOC outlet concentration
  - * Incinerator inlet temperature
  - * Incinerator outlet temperature
  - * Pressure drop

110

115

116

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

117

Pre-Inspection Guidelines

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

118

Pre-Inspection Meeting

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

119

Pre-Inspection Meeting

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

120

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

121

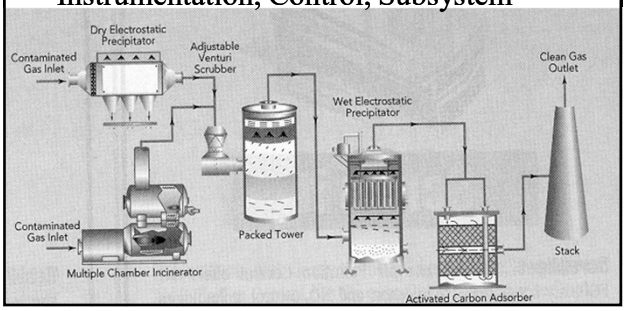
Usage Records

- Review usage records
- Obtain necessary copies

122

Six points of Inspection

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

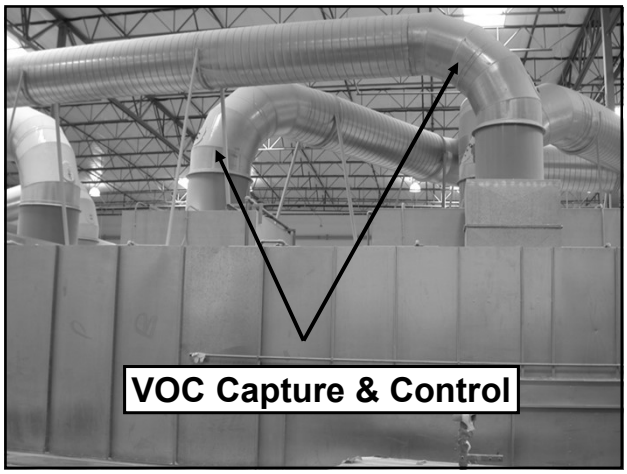


123

Capture

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

124



125

Transport

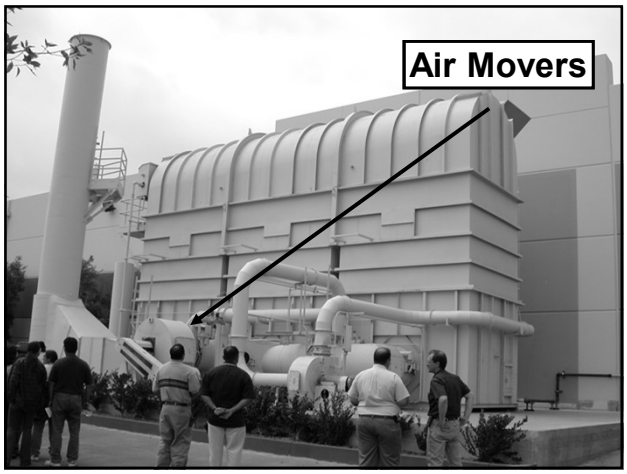
- Are the emissions moved to the control device without loss?
- Are there any leaks?

126

Air Mover

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

127



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Instrumentation

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

129

130

Control Device

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

131

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

132

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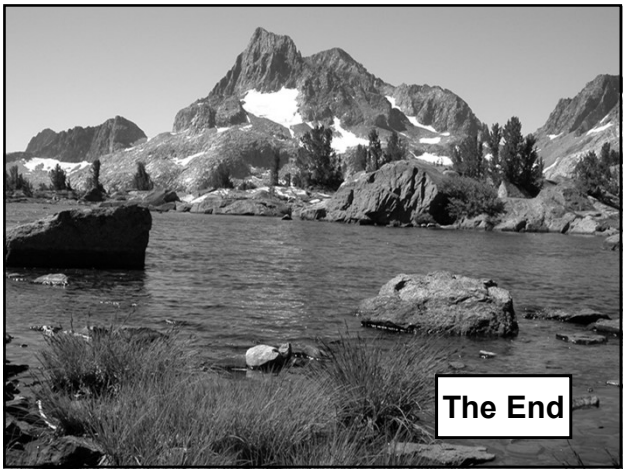

134