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:

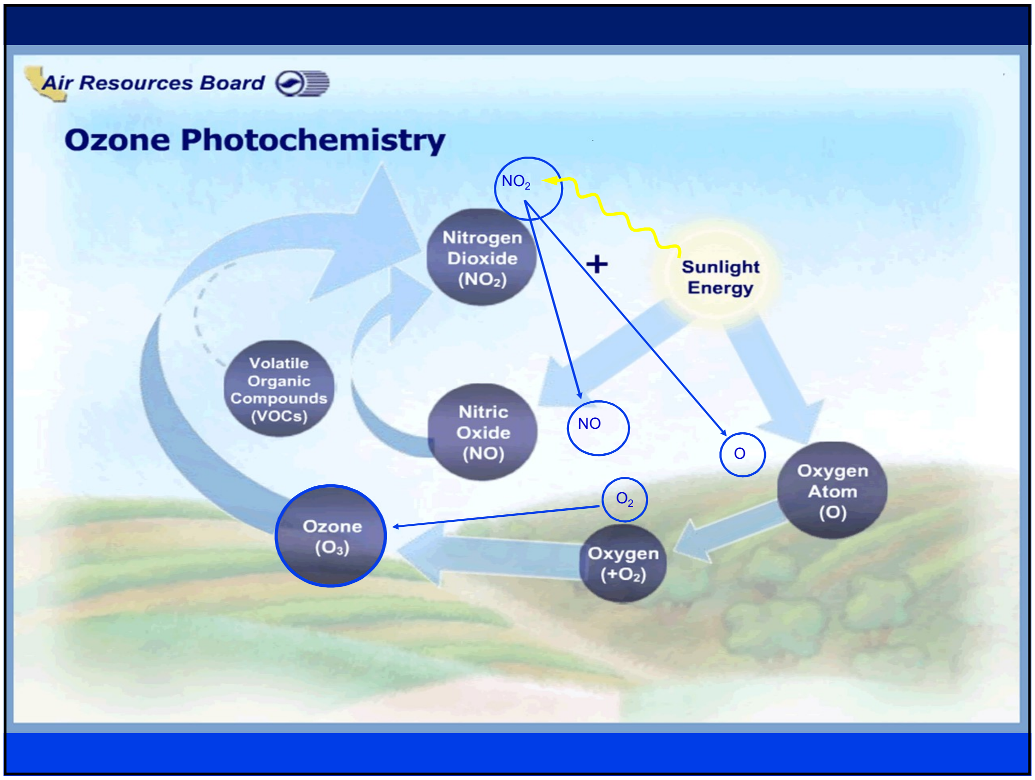
- Molecules which contain carbon
  &
- High evaporative rate at low temperatures
- [VP > 0.1mm Hg]

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?

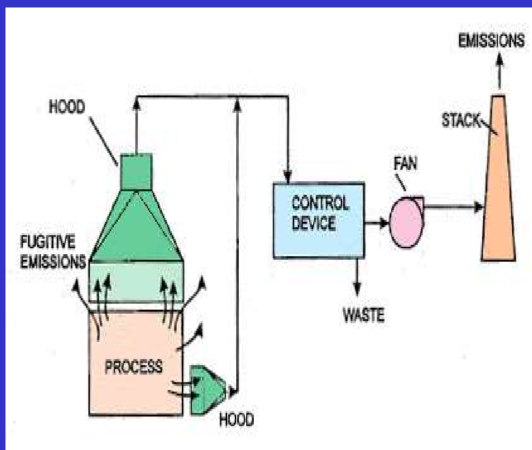
Why is Ozone Regulated?



Ozone Formation

- VOCs + NO_x + sunlight > O_3
- Ozone is formed when NO_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 *

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

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*

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%

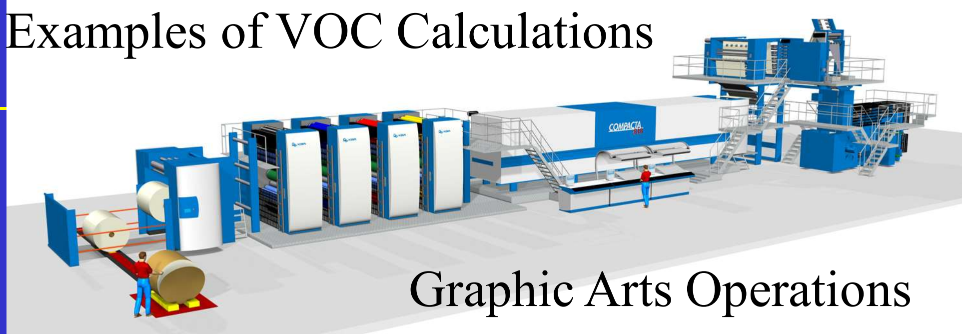
** Capture Efficiency is the percentage of emissions captured and vented to a control device. -- EPA*

VOC Control Efficiency

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

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

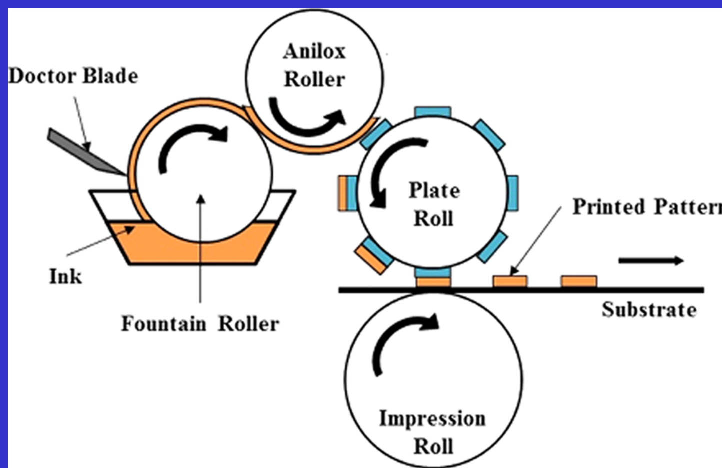
Examples of VOC Calculations



Graphic Arts Operations

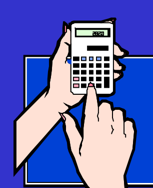
With VOC Retained in Substrate

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?

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

VOC Calculations

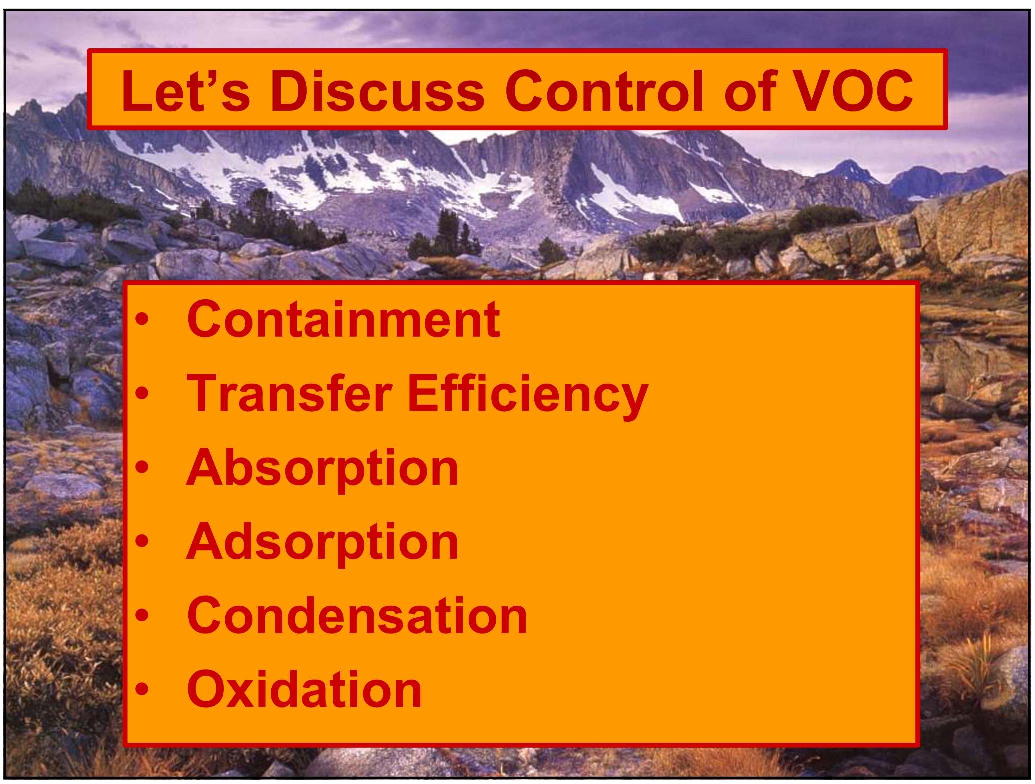
Including W/E

$$\text{VOC g/l} = \frac{W_m - W_w - W_{ec}}{V_m}$$

Excluding W/E

$$\text{VOC g/l} = \frac{W_m - W_w - W_{ec}}{V_m - V_w - V_{ec}}$$

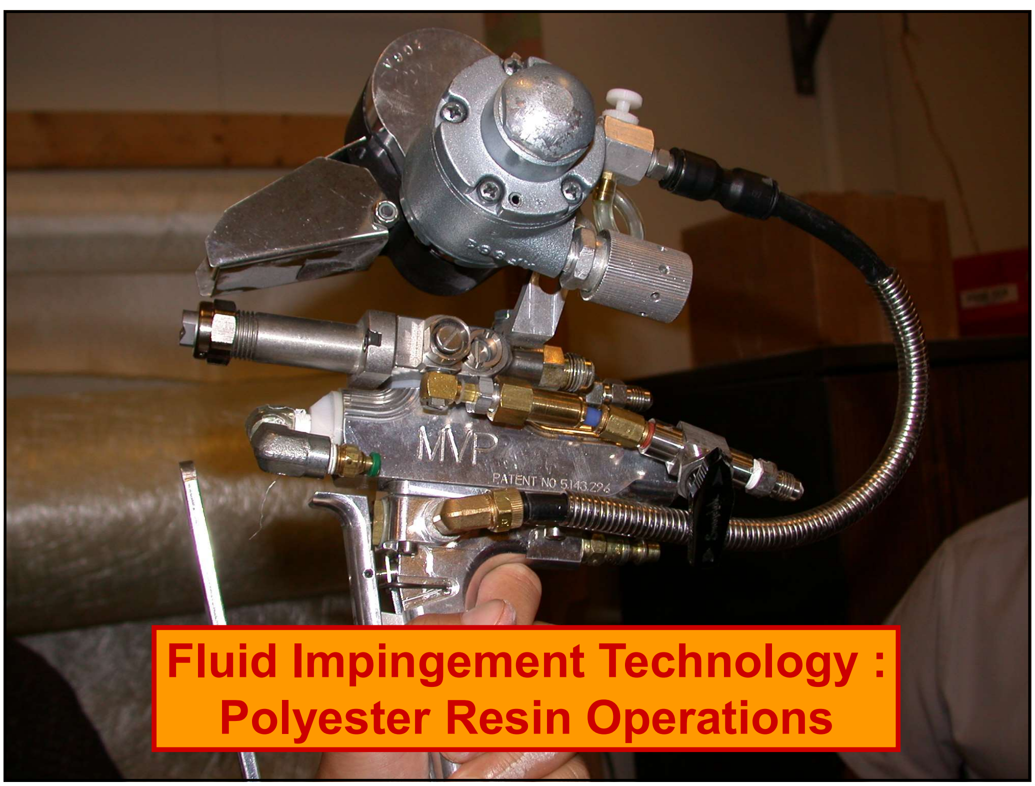
Wm = Weight of material, as applied, in grams
Ww = Weight of water, in grams
Wec = Weight of exempt compounds, in grams
Vm = Volume of material applied, in liters
Vw = Volume of water, in liters
Vec = Volume of exempt compounds, in liters



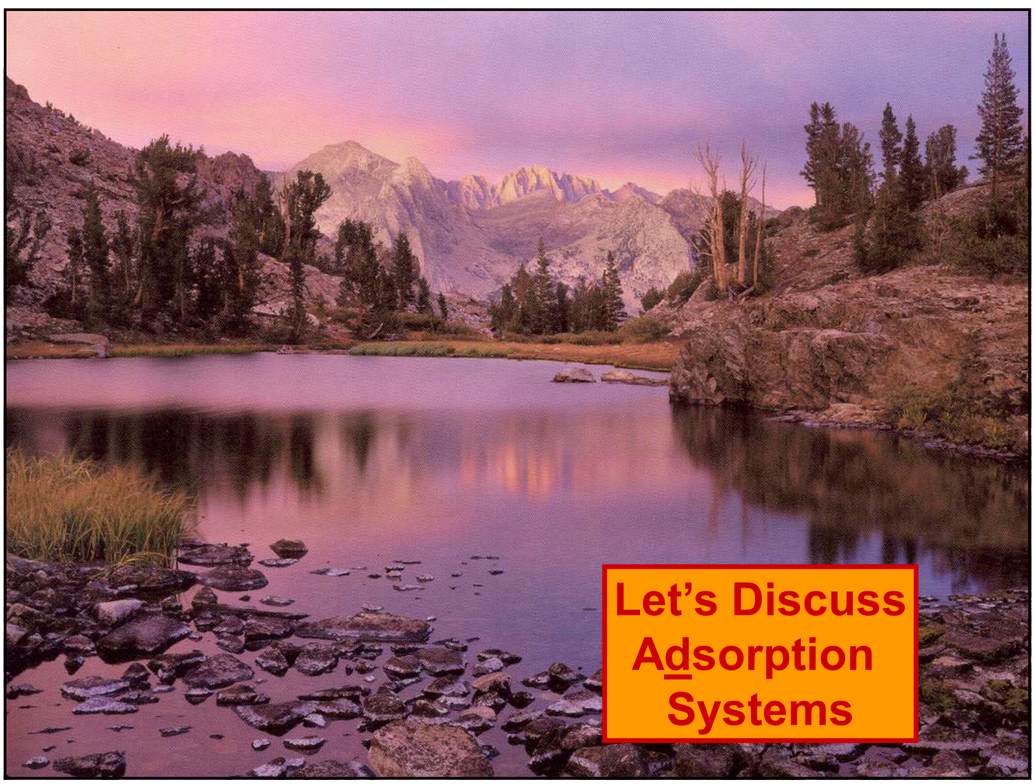

Controlled Spraying
aka
Pollution Prevention
Reduces VOC emissions
Increases transfer efficiency
Low fluid tip pressure
Employee gun handling training


HVLP
High Volume Low Pressure
(HVLP) Spray Guns

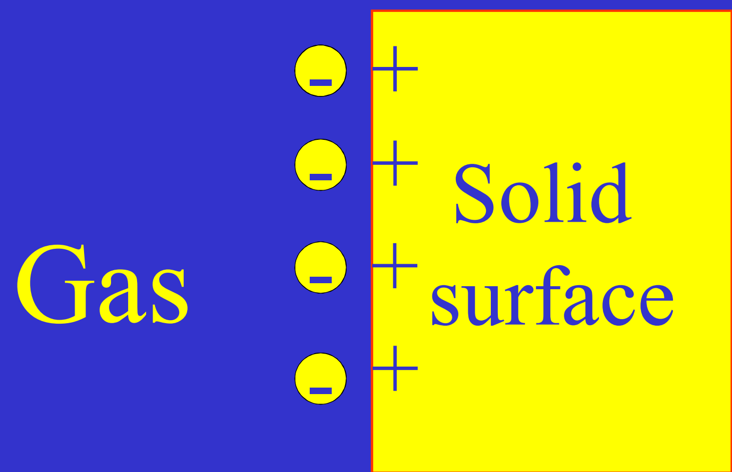

(HVLP) Spray Gun :
Polyester Resin Operations


MVP
Fluid Impingement Technology :
Polyester Resin Operations

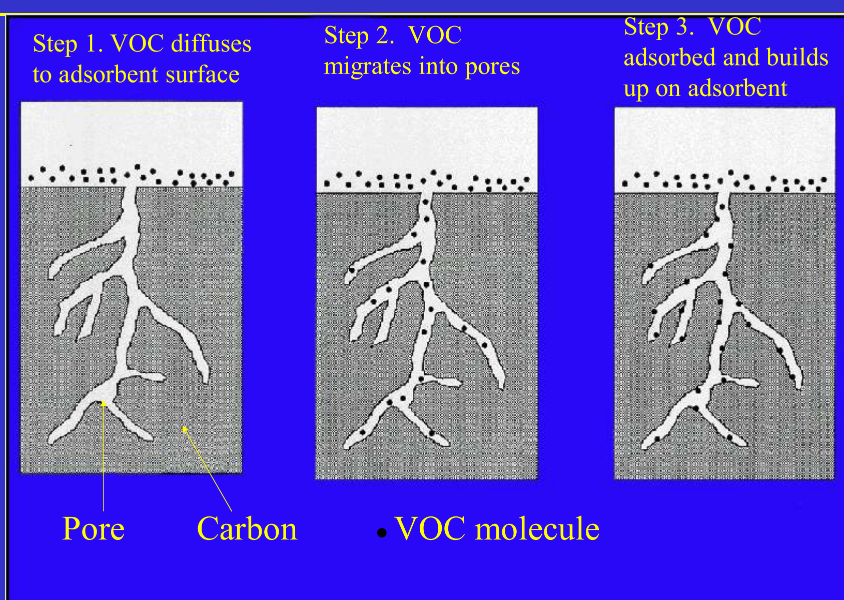

Gel Coat Application in a Spray Booth


Let's Discuss
Adsorption
Systems

Adsorption Mechanism



Adsorption Mechanism



Adsorption Mechanism

- 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

Carbon Adsorbers at a Soil Remediation Site

Factors Affecting Adsorption

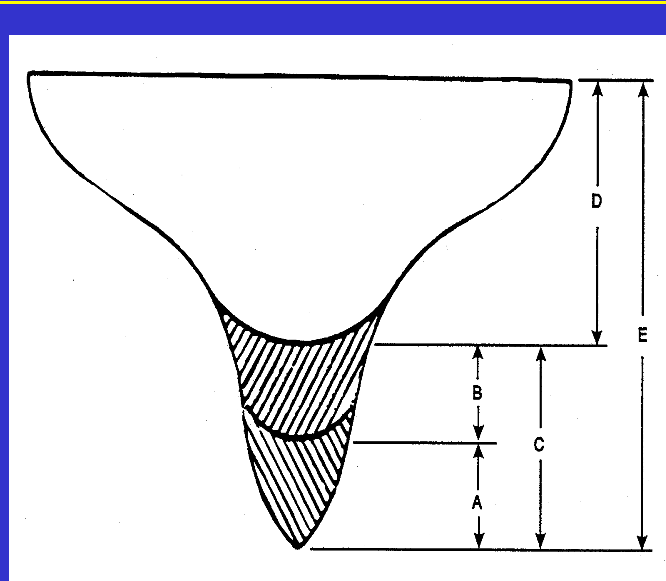
- Temperature
- Pressure
- Gas velocity
- Particulate matter

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)



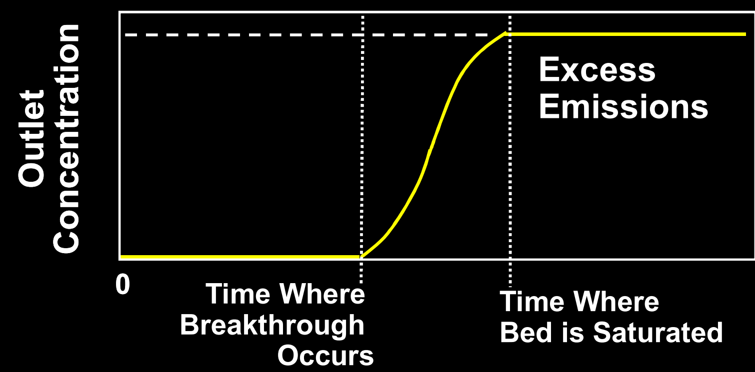
Carbon Adsorption Keywords

- 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



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

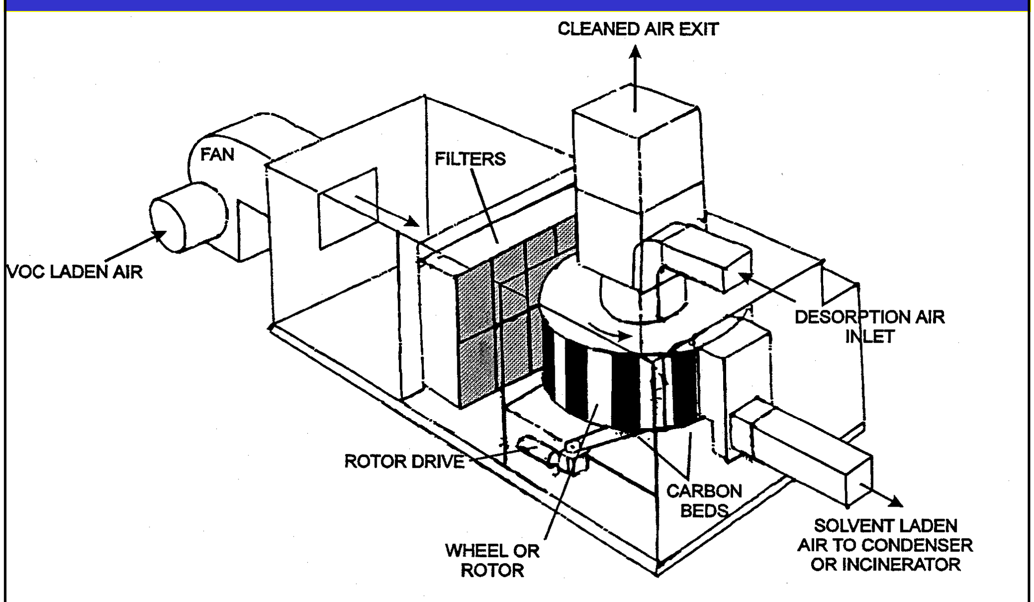
Examples of Activated Carbon

Types of Carbon Adsorption Systems

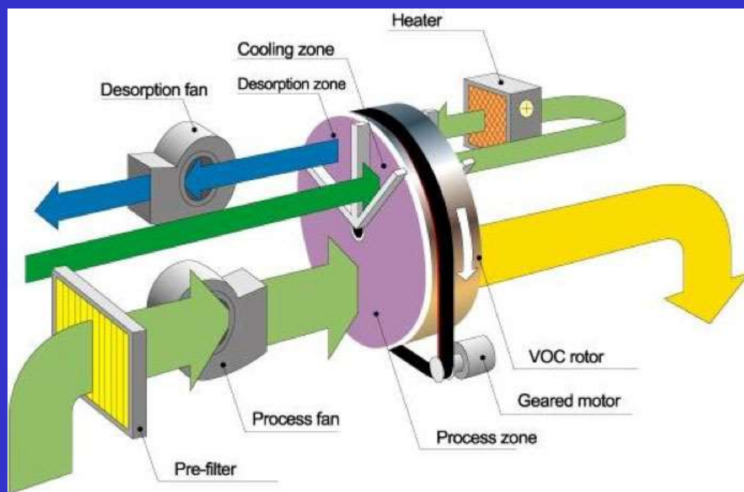
- Open
- Closed
- Rotary
- Fluidized bed
- Bulk plant adsorber and absorber

Bulk plant adsorber & absorber

Rotary Concentrator Adsorption System

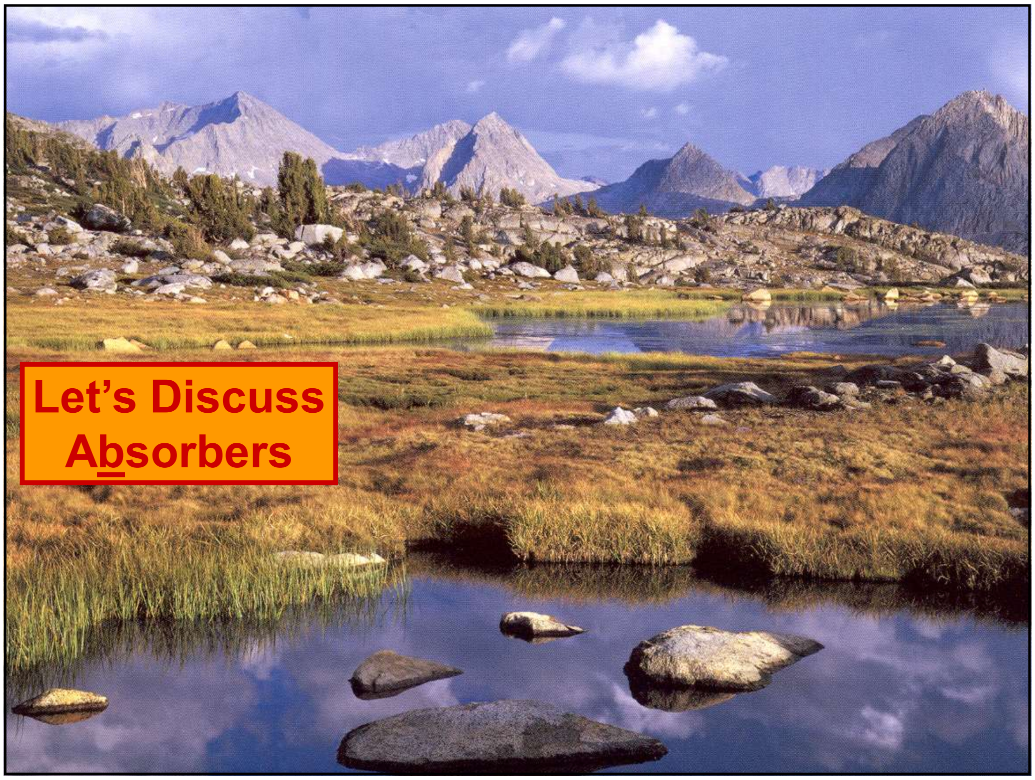


Rotary Concentrator Adsorption System



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



Absorbers

- Pollutants dissolved in liquid
- Absorbate dissolves in absorbent

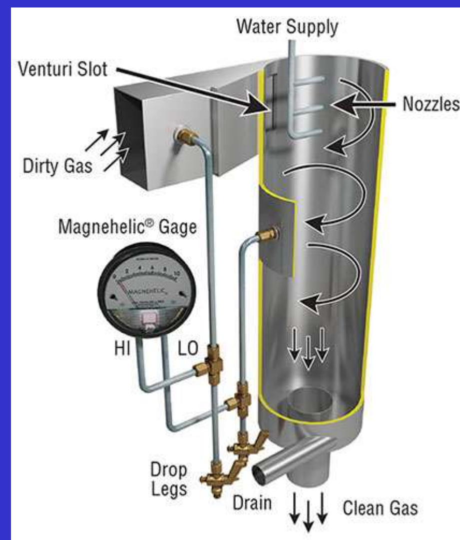
Factors Favoring Absorption

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

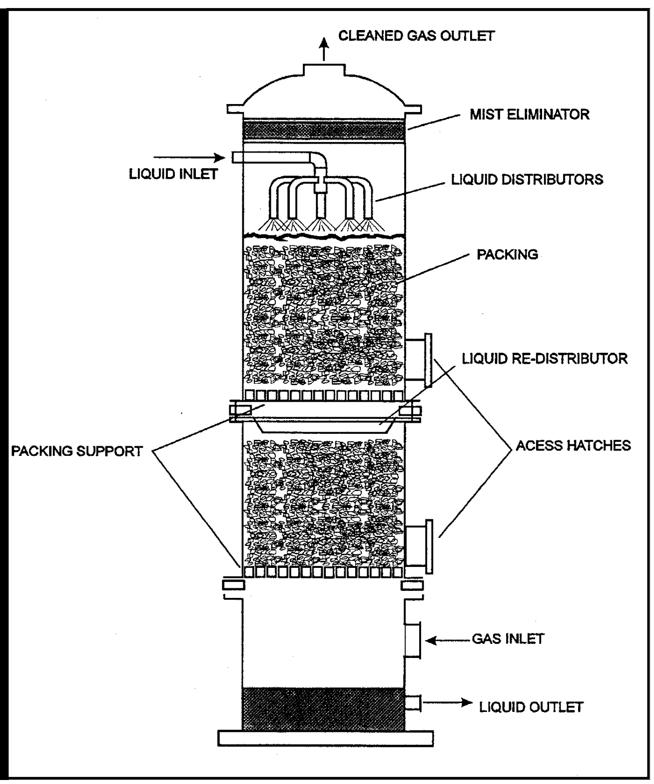
Absorber Design

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

Pressure Drop : Magnehelic



Packed Bed Wet Scrubber



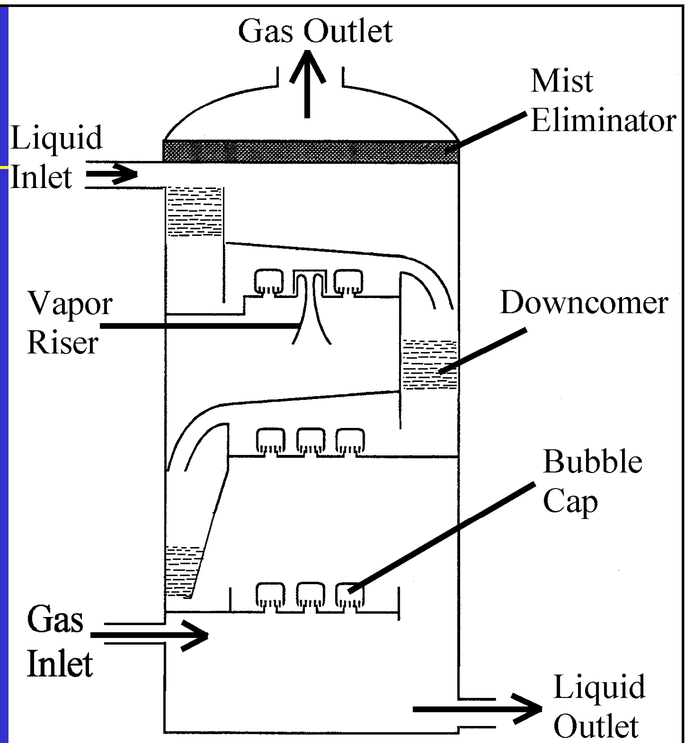
Absorber Design Factors

- 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



Absorbers: Plate Columns

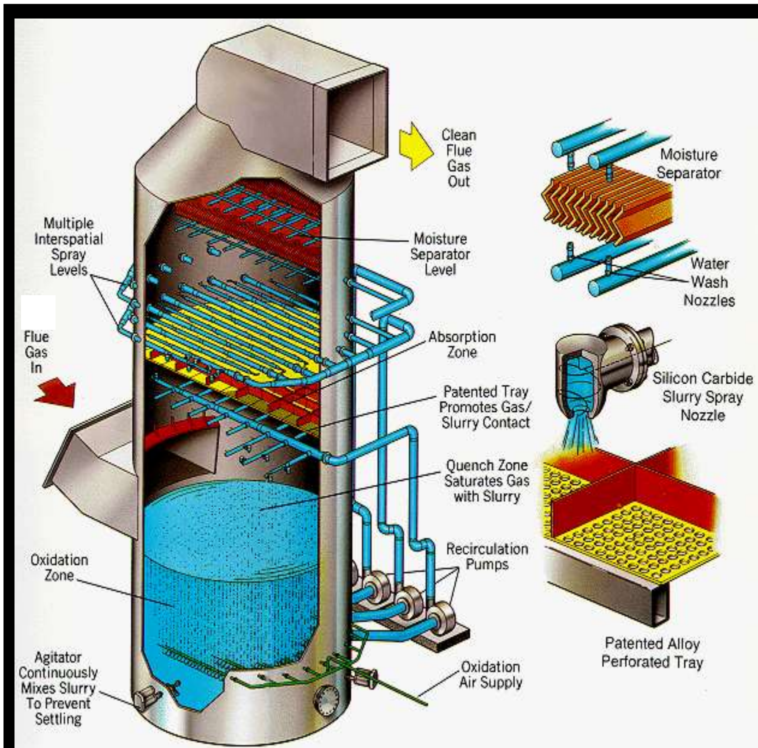
- Maximize contact between liquid & gas
- Diameter of column
- Plates
  * Number
  * Type
  * Layout

Packed vs Plate Columns

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

Packed versus Plate Columns

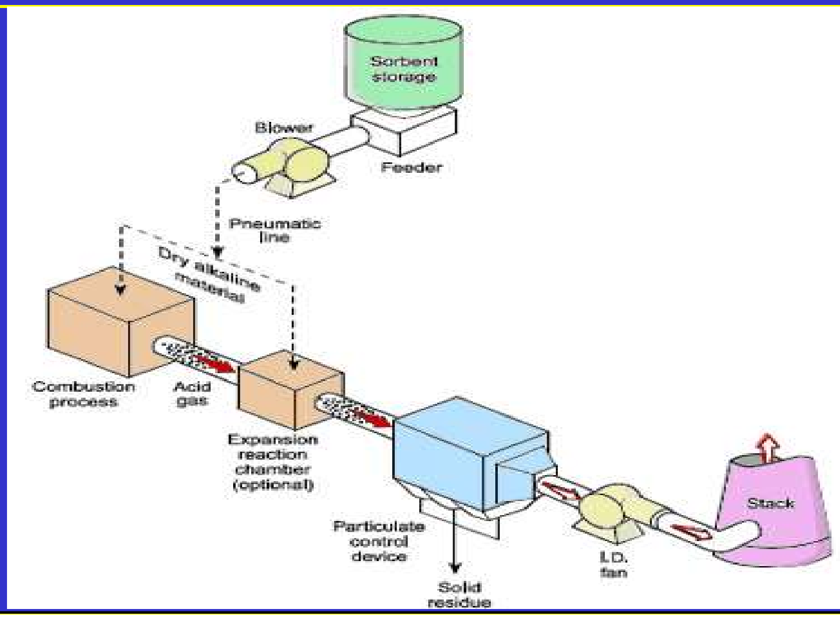
- Plate columns are better for:
  - + Large temperature changes
  - + Lower liquid flow rates
  - + Higher gas flow rates
  - + Foaming liquids
  - + Chemical reactions
  - + Large systems



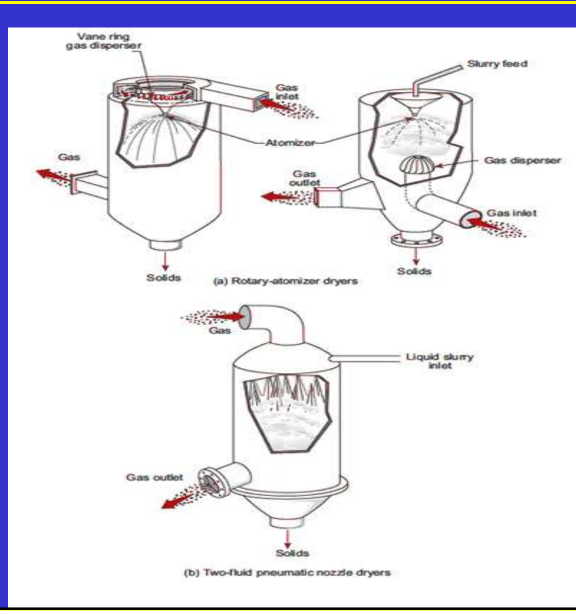
VOC Control

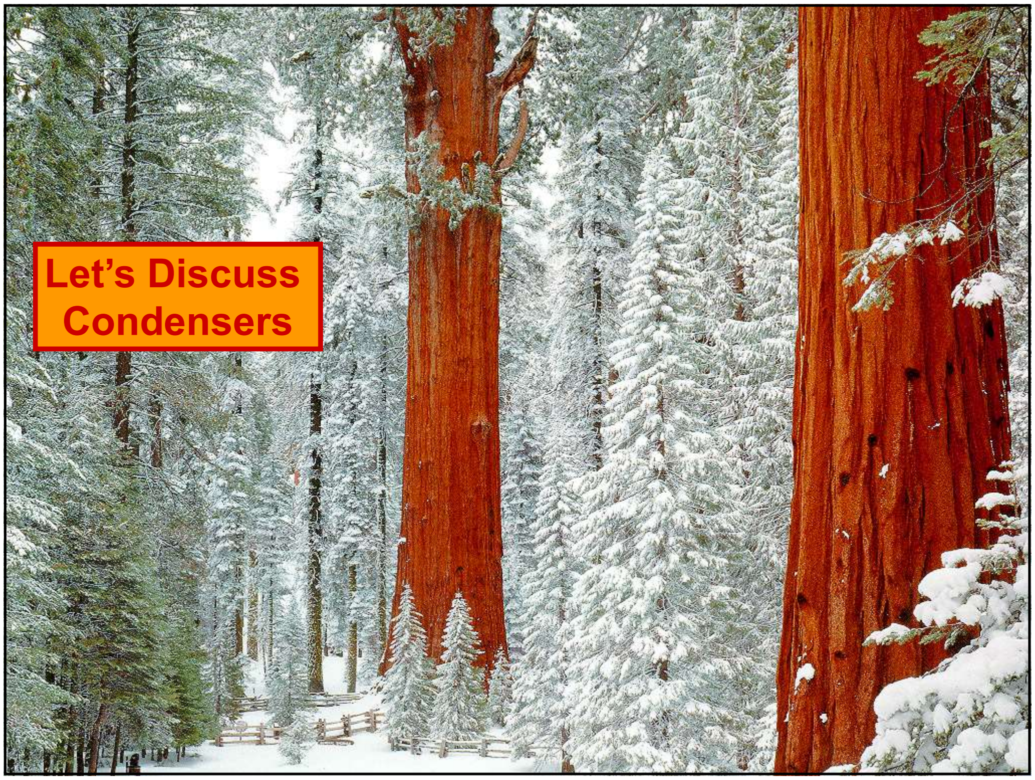
Wet Scrubber

Dry Sorbent Injection

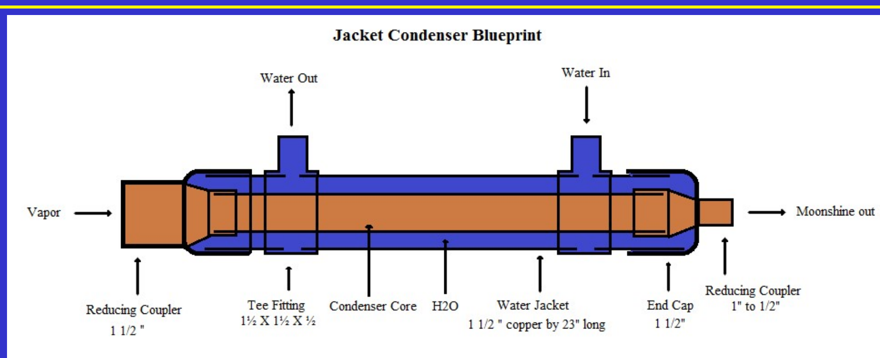


Spray Dryer Absorbers





Condensers : Surface & Contact



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

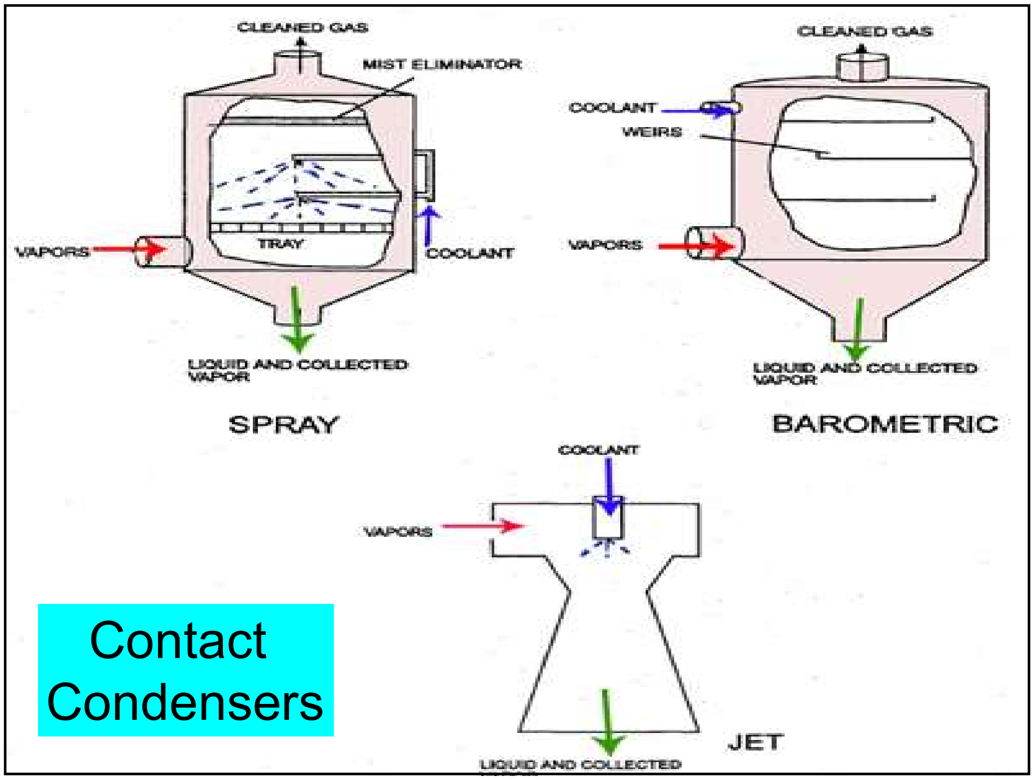
Condensers

Vapor ⟶ Liquid
Cold

- Condensation = Process of changing a gas to a liquid.
- Condensation allows recovery of solvents and air pollution control
- Decrease temperature, increase pressure

Contact Condensers

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



Contact Condensers

*Spray
*Jet
*Barometric

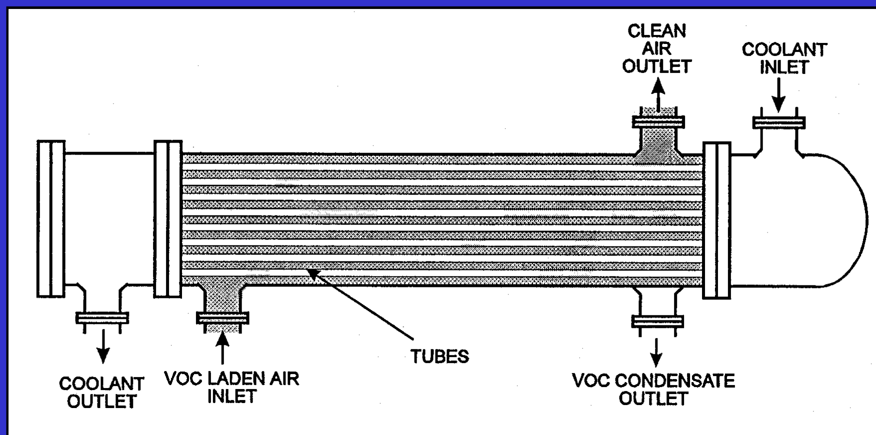
Surface Condensers

* 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 Concerns

– Vibration
– Leaking gaskets
– Leaking connections
– Start-up procedures
– Shut-down procedures

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

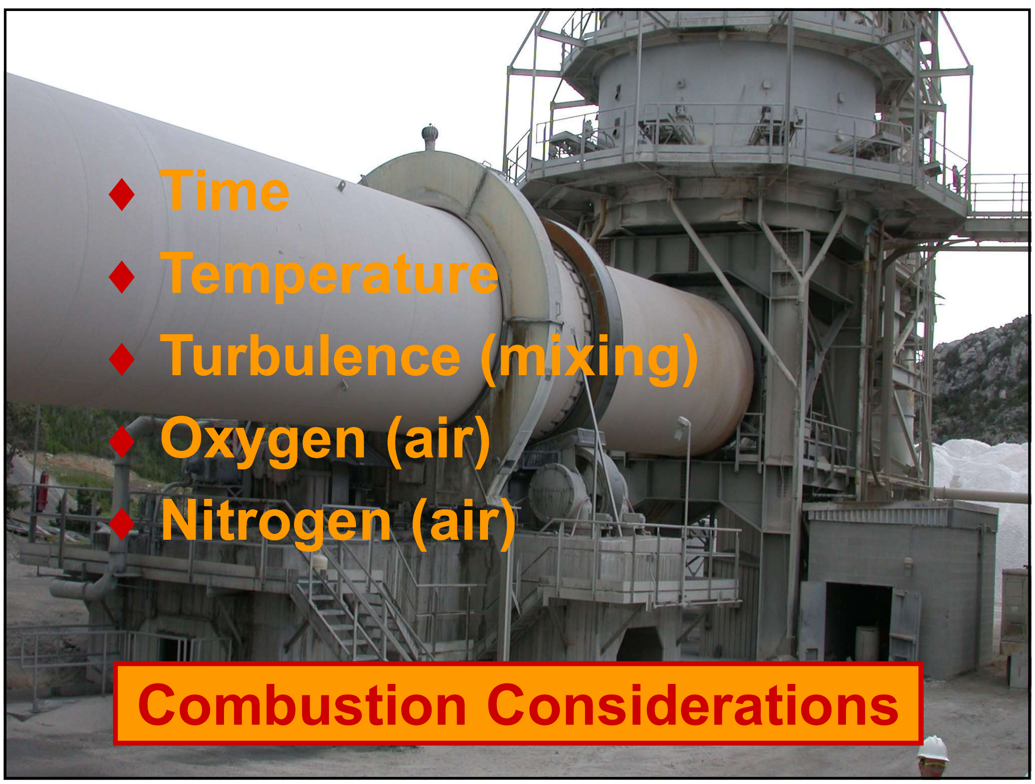
Oxidation

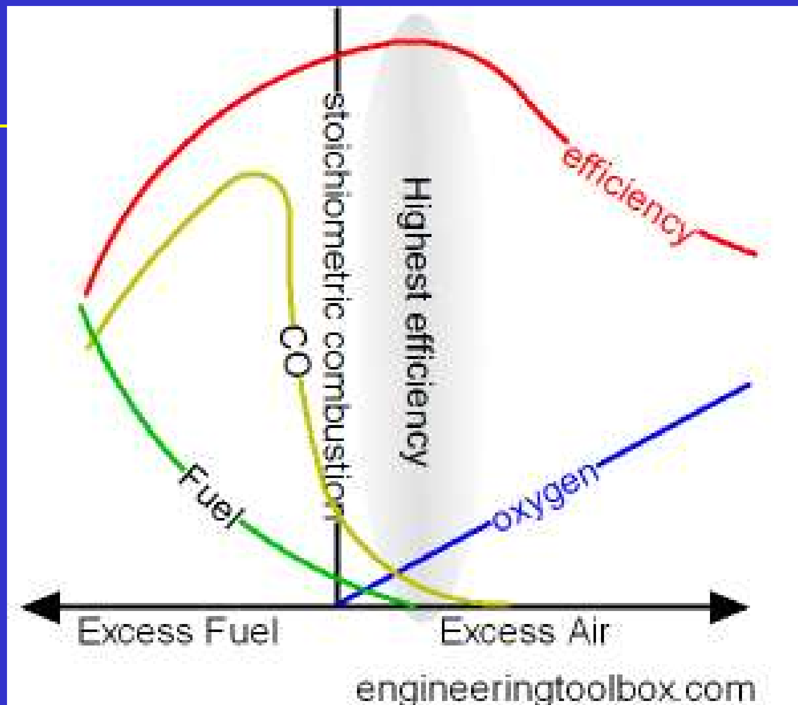
- Destruction of VOCs by Combustion

Reactions with oxygen

$C_7 H_8 + 9O_2 = 7CO_2 + 4H_2O$

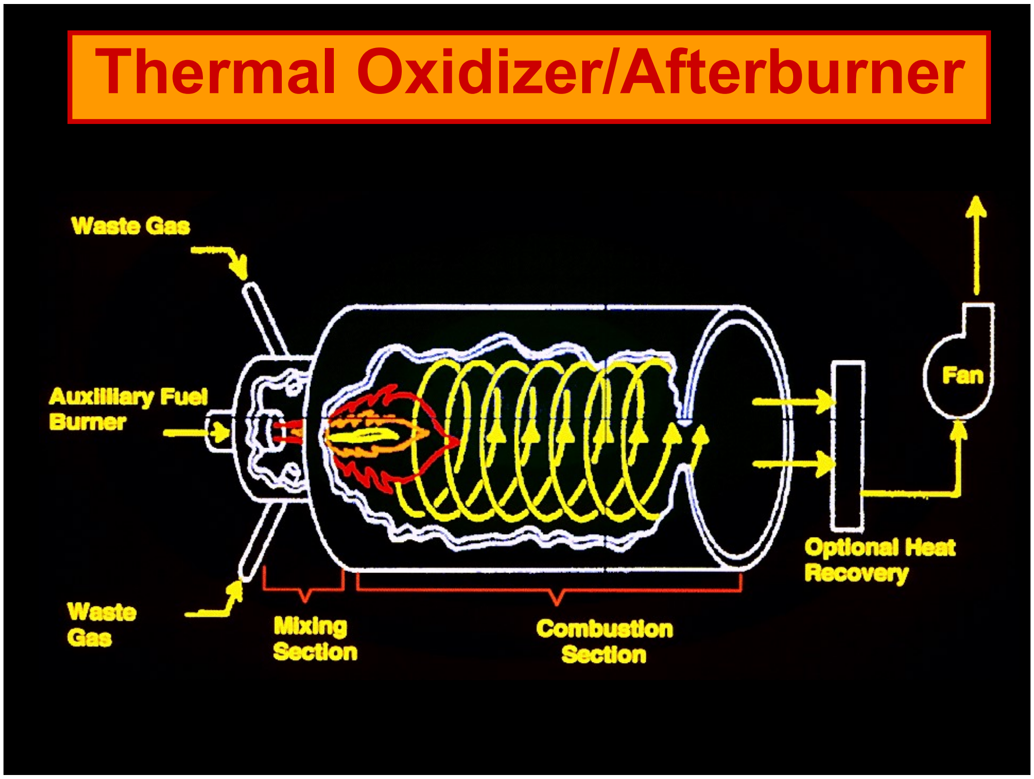
Toluene + Oxygen = Carbon Dioxide + Water



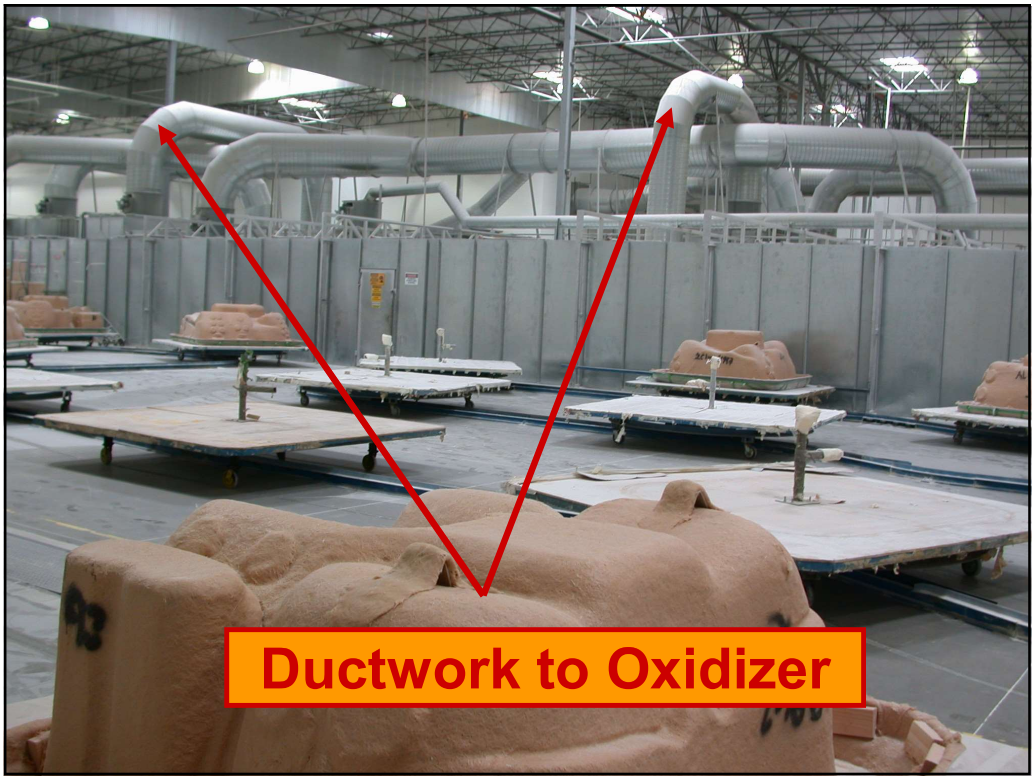


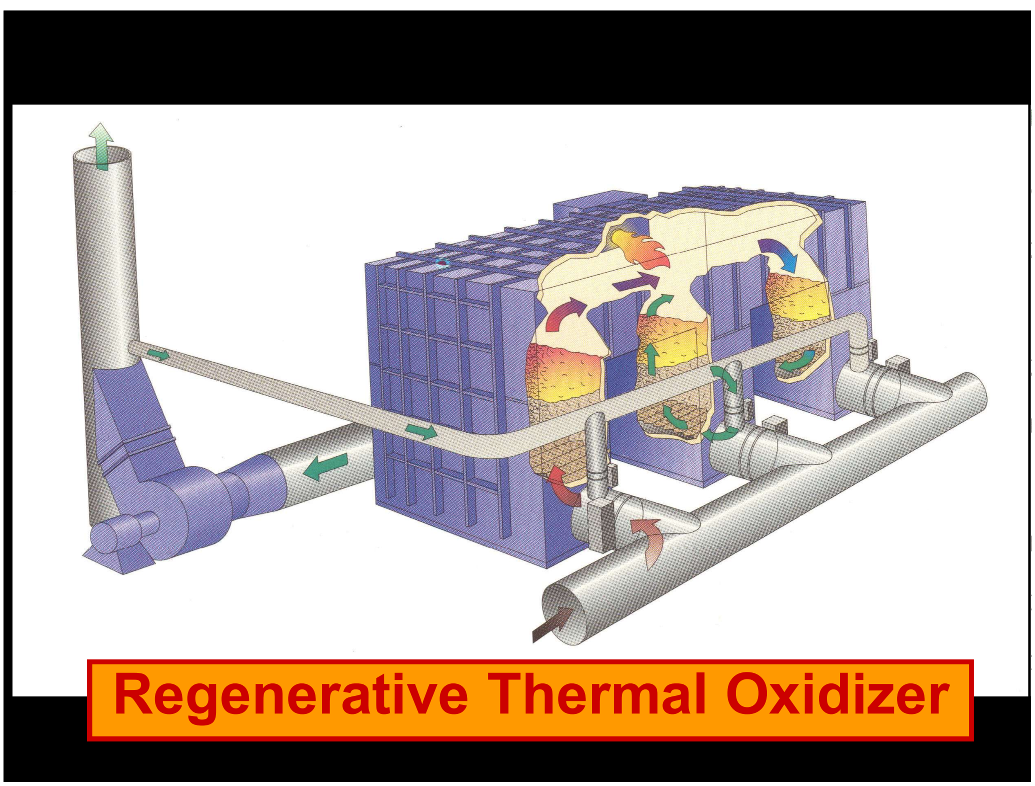
Combustion Devices

- 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)

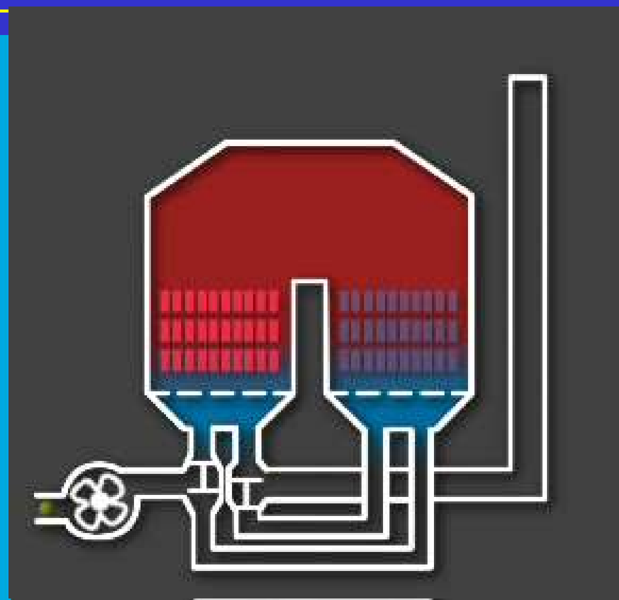

Thermal Oxidizer/Afterburner
Waste Gas
Auxiliary Fuel Burner
Waste Gas
Mixing Section
Combustion Section
Optional Heat Recovery
Fan

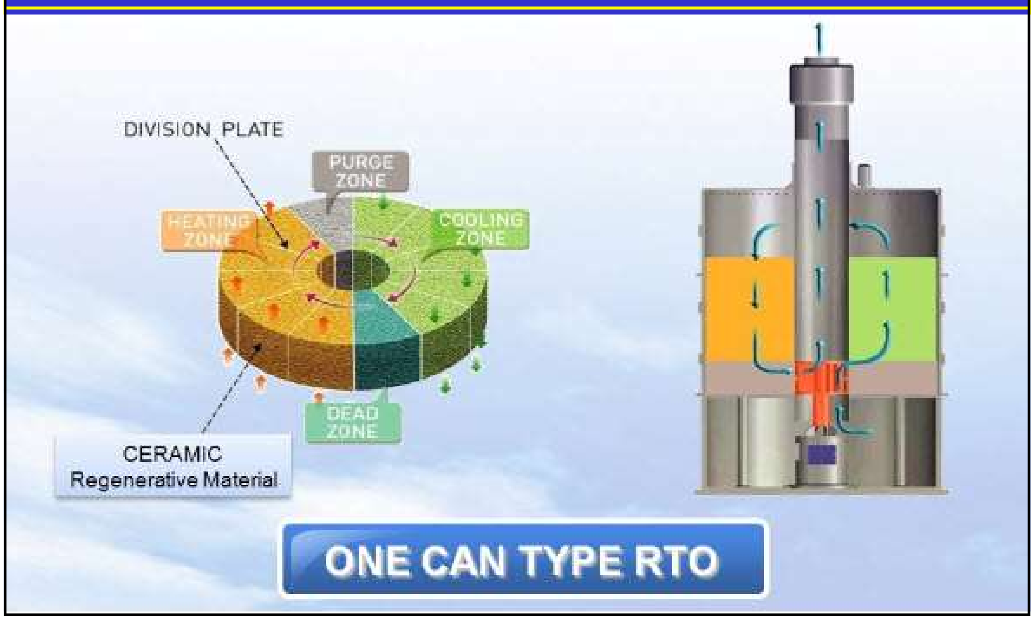

Thermal Incinerator


Ductwork to Oxidizer

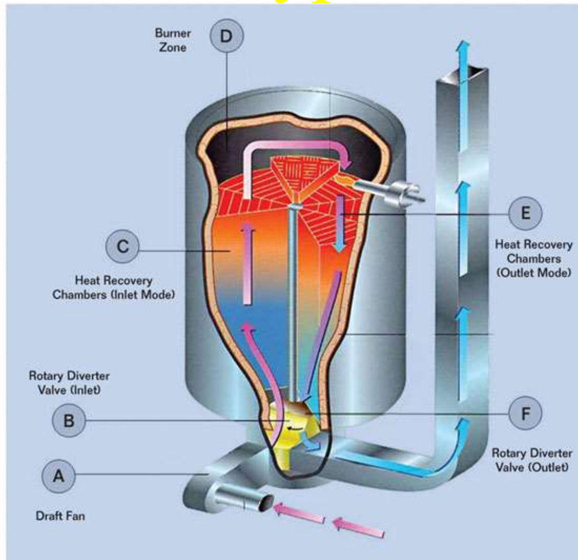

Regenerative Thermal Oxidizer

RTO Operation



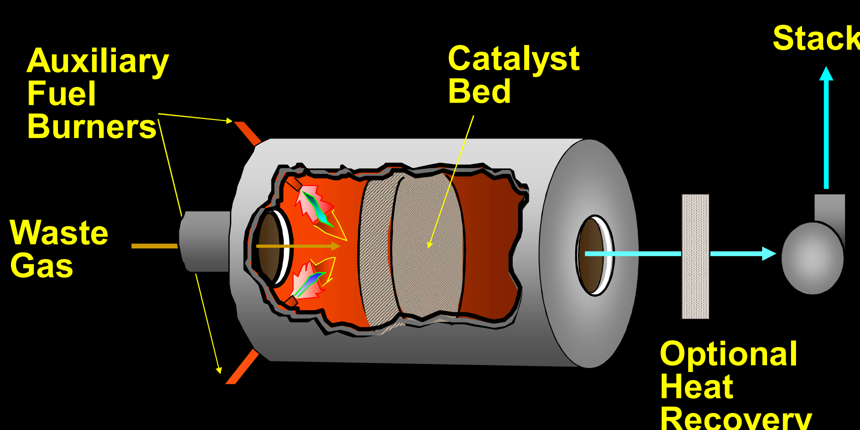


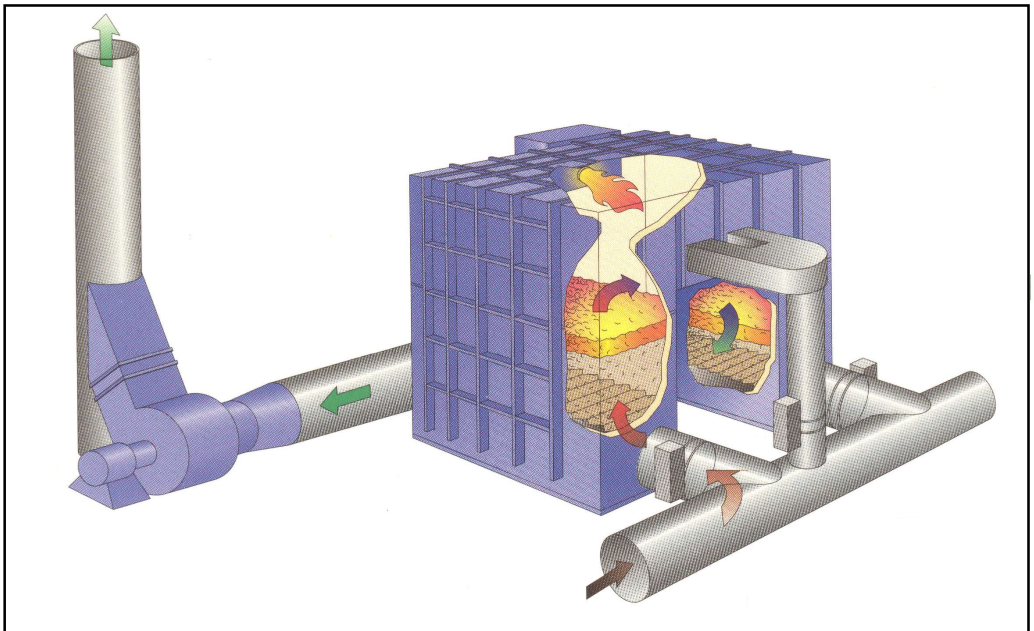
Can Type RTO



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.

Catalytic Oxidizer/Incinerator





Regenerative Catalytic Oxidizer

Selection Criteria

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

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

Catalyst Problems

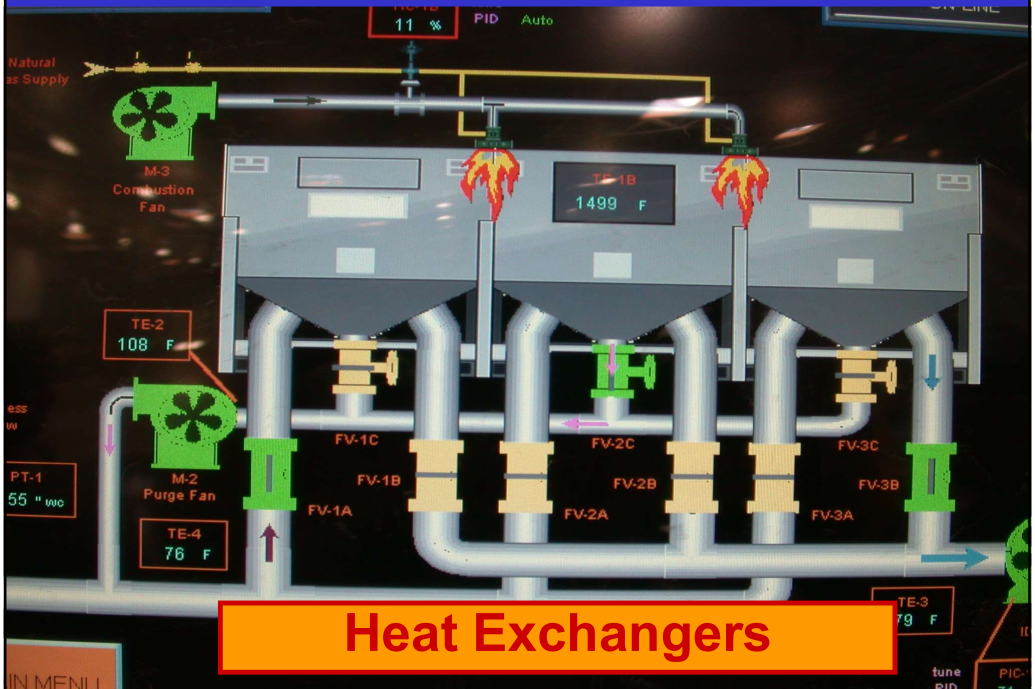
- Scouring
- Thermal burnout
- Thermal aging
- Masking
- Catalyst fouling and poisoning

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

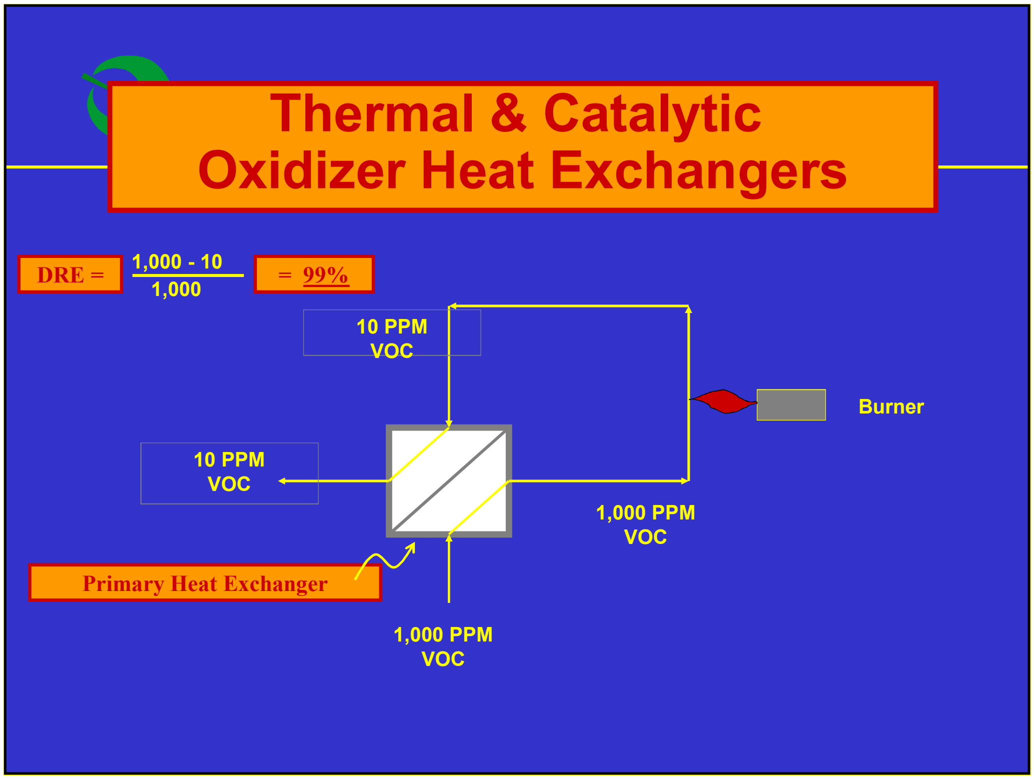


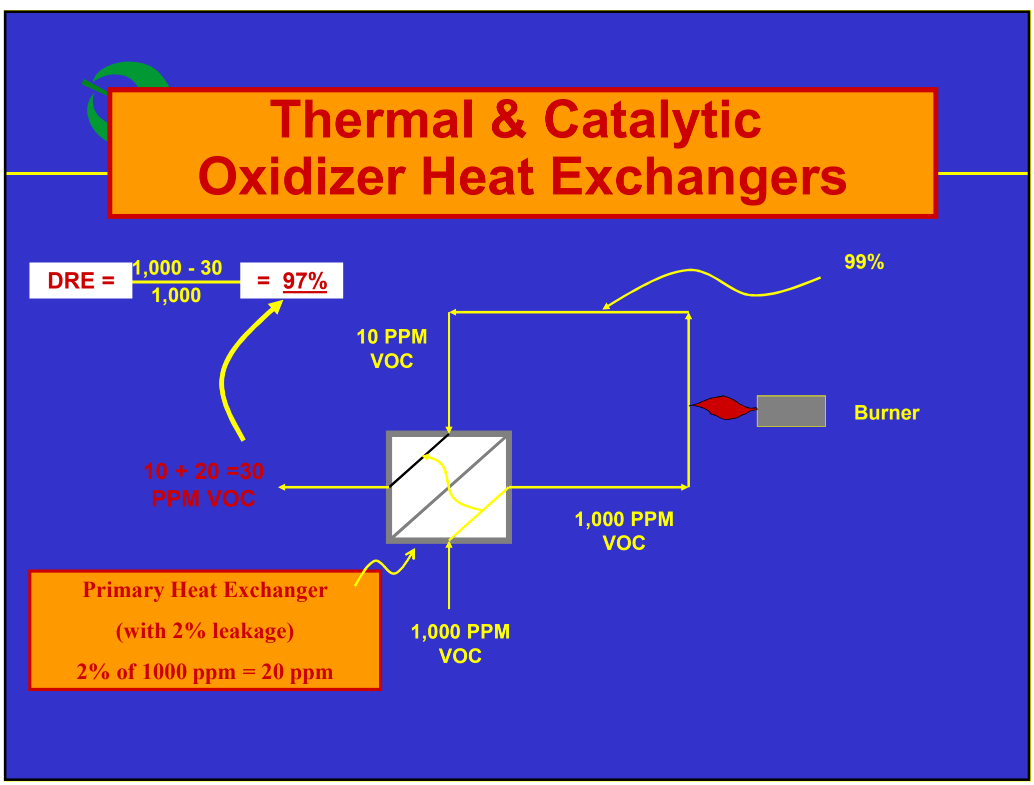
Heat Exchangers

Thermal & Catalytic Oxidizer Heat Exchangers

There are two basic types of heat exchangers used for thermal or catalytic oxidizers

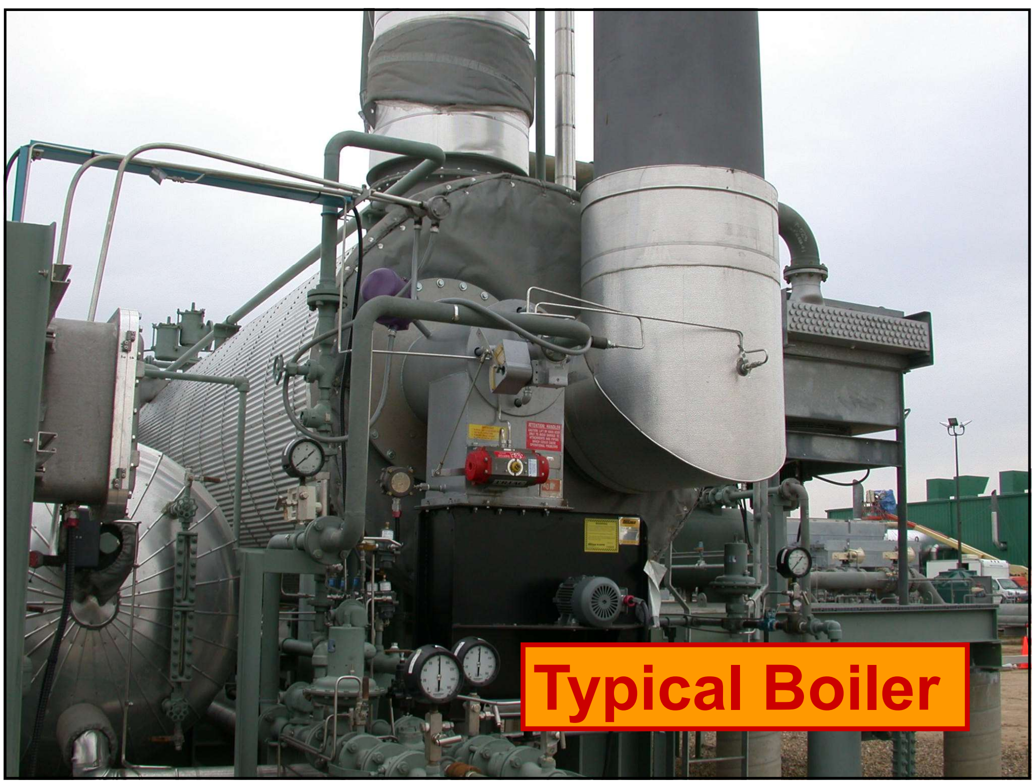
- Metal Heat Exchangers or "recuperative heat exchangers"
- Ceramic Bed Heat Exchangers or "regenerative heat exchangers"


Thermal & Catalytic
Oxidizer Heat Exchangers
DRE =
1,000 - 10
1,000
= 99%
10 PPM
VOC
Burner
10 PPM
VOC
1,000 PPM
VOC
Primary Heat Exchanger
1,000 PPM
VOC

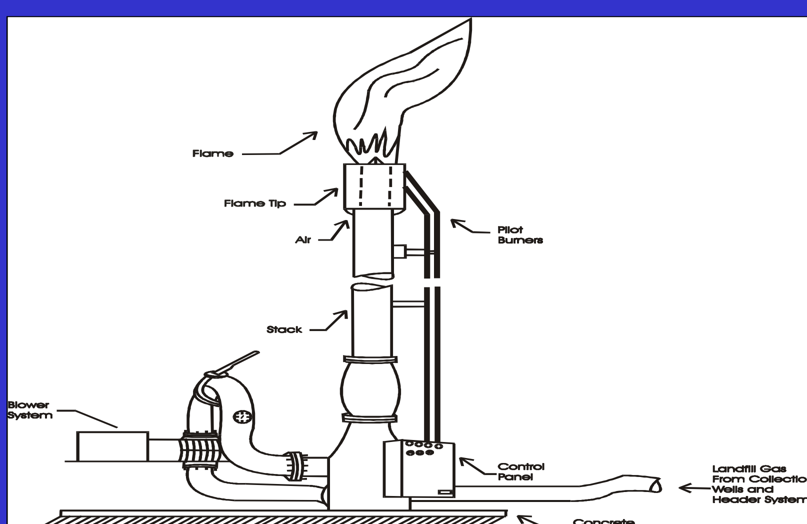

Thermal & Catalytic
Oxidizer Heat Exchangers
DRE =
1,000 - 30
1,000
= 97%
99%
10 PPM
VOC
Burner
10 + 20 =30
PPM VOC
1,000 PPM
VOC
Primary Heat Exchanger
(with 2% leakage)
2% of 1000 ppm = 20 ppm
1,000 PPM
VOC

Boilers, Process Heaters & Flares

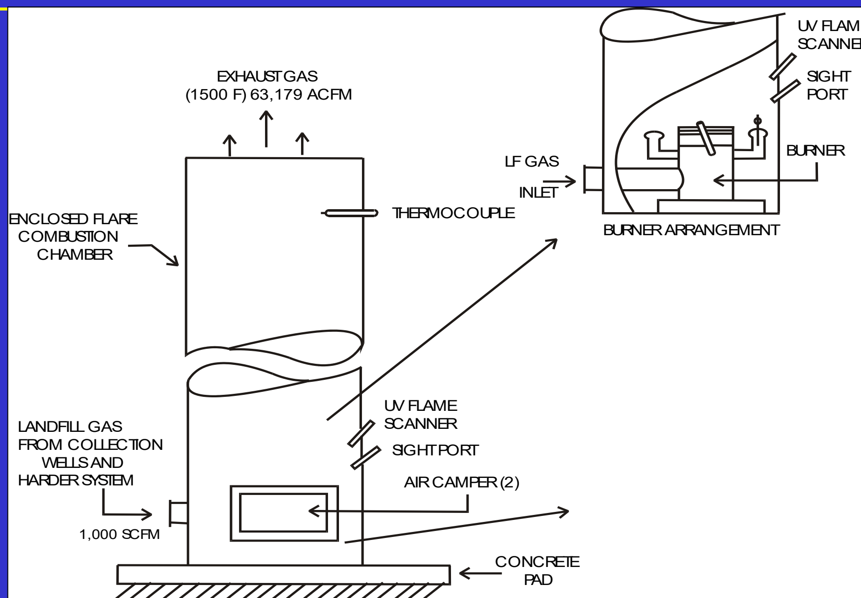
- Boilers make steam
- Process heaters add heat to material
- Flares are thermal incinerators without a combustion chamber



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

Venturi Scrubbers

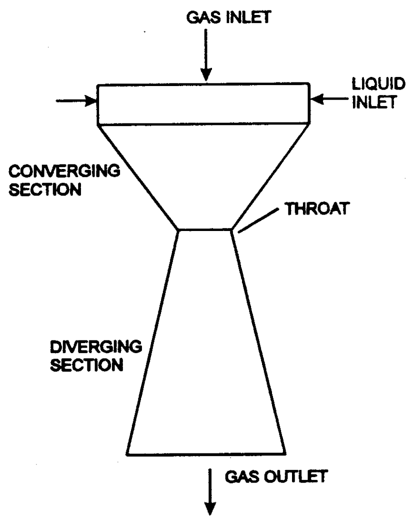


Figure 605.10 Venturi

Venturi Scrubbers

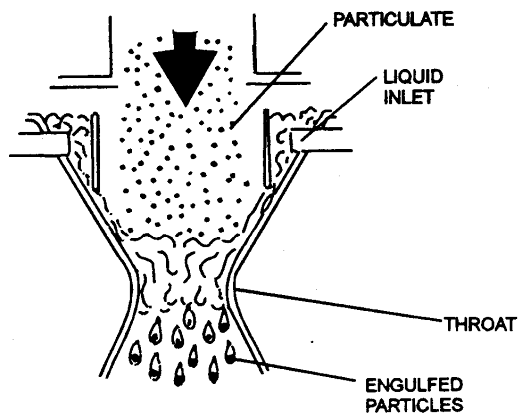
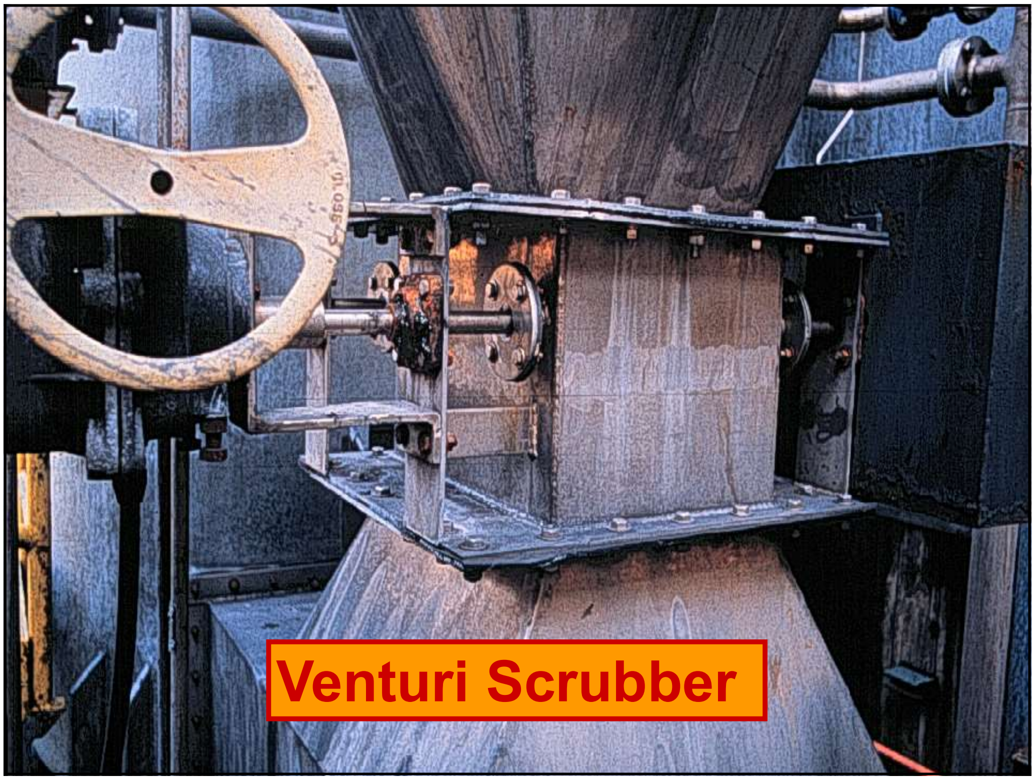


Figure 605.11 Impaction of Particles and Target Droplets In Venturi



Venturi Scrubber Types

- Venturi with weir
- Venturi with jets
- “Dentist sink” venturi
- Rod deck scrubber (with cyclone demister)
- Collision scrubber
- Orifice scrubber
- Ejector venturi scrubber
- Gas ejector scrubber


VOC Control : Three-Way Catalyst


INSPECTIONS
DANGER
STARTS AUTOMATICALLY

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

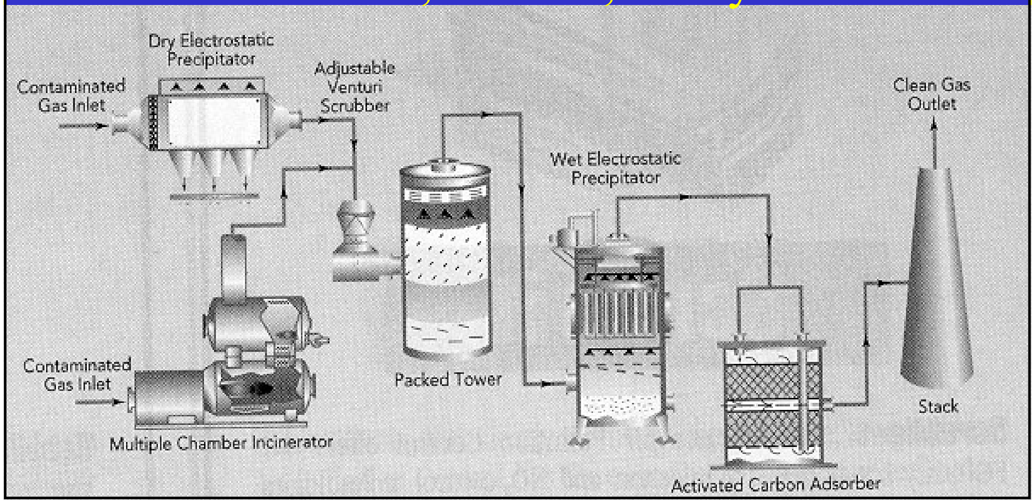
- Description of facility & processes
- Flowchart with equipment location & emission points
- Process diagram (materials handled, flow rates, temperatures, pressures)
- Statement as to compliance or non-compliance
- Enforcement action recommendation

Usage Records

- Review usage records
- Obtain necessary copies

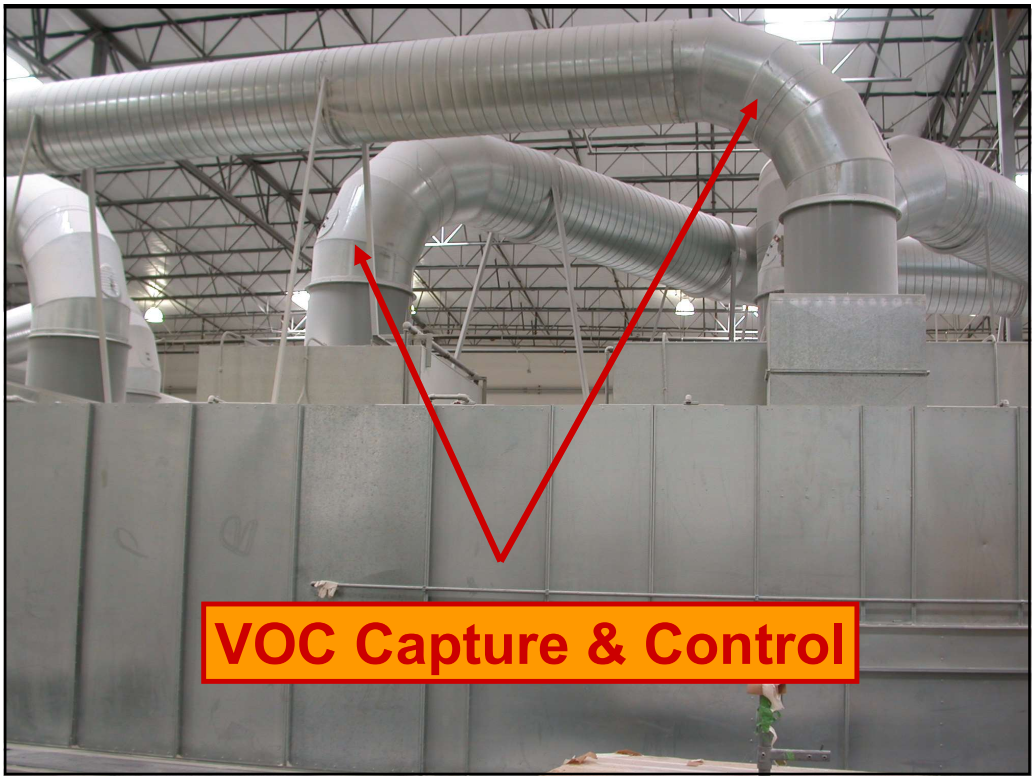
Six points of Inspection

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



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