Your Presenters:

Scott Bayon / Director of Sales
Anguil Environmental Systems

Brian Kunkle / Director of Systems Sales
Verantis Environmental Solutions Group.
PDH Overview

• Today’s Webinar Value = 1 PDH/CH.
• Must Be Present for at least 50 Minutes.
• Must Complete and Pass Test (8 out of 10).
• Available for 32 states.
• Keep a Record Log.
• Verantis will Keep Records for Six Years.
• Contact Mary Rusnak @ Verantis with Questions.
Agenda

Air Pollution Abatement Technology Overview

Emission & Application Overview
Thermal & Catalytic Oxidizers
Wet Scrubbers
Question & Answer
Quiz for PDH Credits (Optional)

Topics covered throughout:

- Applicable Industries
- Airflow & Concentration Ranges
- Equipment Options & Selection
- Unique Airstreams
- Removal Efficiencies
- Operating Costs
Thermal & Catalytic Oxidizer Types

- Regenerative Thermal Oxidizer (RTO)
- Thermal Recuperative Oxidizer
- Catalytic Recuperative Oxidizer
- Emission Concentrator
- Enclosed Flare - Vapor Combustor
- Direct-Fired Thermal Oxidizer (DFTO)
What is Oxidation?

\[ C_nH_{2m} + (n + m/2) \text{O}_2 \Rightarrow n \text{CO}_2 + m\text{H}_2\text{O} + \text{heat} \]

Three “T”s: Time, Temperature & Turbulence

Target Pollutants:

- VOCs (Volatile Organic Compounds)
- HAPs (Hazardous Air Pollutants)
- NOx (Nitrogen Oxides)

Plus Odors!
Regenerative Thermal Oxidizer (RTO)

Broad Range of Applications: Coating, Printing, Laminating, Painting, Finishing

- Air Flow Range:
  - 1,000-80,000 scfm / Single Unit
  - >80,000 / Multiple Units

- Concentration Range:
  - 0-25% LEL (Lower Explosive Limit)

- Energy-Efficient Operation:
  - 95-97%+ TER (Thermal Energy Recovery)

- High Destruction Rate Efficiency (DRE):
  - Two Chamber RTOs: 99%+
  - Multi-Chamber RTOs: 99.7%+
RTOs maximize heat recovery from combustion to pre-heat incoming solvent laden air and reduce fuel consumption.
RTO Ceramic Media Options

Random Packing
- Typically 1” or 1½”
- ½” – 3” Available

Extruded Honeycomb Monolith
- Variety of cell sizes and wall widths
- Typical block size: 150 x 150 x 300

Multi-Layered Media
- Style and Size Options

Advances in Ceramic Media Now Allow for 97% Thermal Energy Recovery!
Additional RTO Options

- **Hot Side Bypass**
  *Allows the system to handle high loading.*

- **Bake-Out Feature**
  *Recommended for streams with particulate and condensables.*

- **Supplemental Fuel Injection (SFI)**
  *Reduces combustion air needs and NO$_x$ emissions.*

- **Puff / Purge Chamber**
  *Used for visible emissions, odors or higher DRE*

- **Induced Fan Arrangement**
  *Used on corrosive applications or airstreams with particulate.*
Catalytic Oxidizer

- Typical Air Flow Range: 100-100,000 SCFM
- Concentration Range: 0-25% LEL (Lower Explosive Limit)
- Destruction Rate Efficiency (DRE): 99%+
- Thermal Energy Recovery: 50-70%

Generally used on applications with low process volume or weight and space limitations.

Catalysts lower the oxidation temperature which:
- Decreases fuel usage
- Lowers cost of construction materials
- Reduces thermal cycling
- Lowers carbon monoxide & NO$_x$ emissions
Thermal Recuperative Oxidizer

- Typical Air Flow Range: 100-30,000 scfm
- Concentration Range: 0-50% LEL (Lower Explosive Limit)
- Destruction Rate Efficiency (DRE): 99%+
- Thermal Energy Recovery: 50-70%

Generally used on applications with:
- High emission concentrations
- Capital cost limitations
- Process heating needs
- Silica dusts in the airstream
Direct Fired Thermal Oxidizer (DFTO)

- Typical Air Flow Range: 100-100,000 SCFM
- Concentration Range: 15-25% LEL (Lower Explosive Limit)
- Destruction Rate Efficiency (DRE): 99.5%+
- Thermal Energy Recovery (TER): None without secondary heat recovery

Generally used on applications with:

- Inert gases
- Low process volume
- Varying process conditions
- High destruction efficiency requirements
Vapor Combustor Unit (VCU)

**Features and Benefits:**

- Handles varying emission flow rates and concentrations
- High destruction rate efficiency (99-99.99%)
- Ideal for intermittent or continuous use
- Turndown capabilities of 10:1 or greater
- Natural draft can eliminate combustion fans
- Low supplemental fuel requirements

---

- Low greenhouse gas emissions
  - Carbon Dioxide (CO₂) & Nitrous Oxide (N₂O)
- No visible emissions as seen with open flaring
- Low noise pollution & no vapor radiation
- Maintenance free combustion technology
Emission Concentrator

Converts high process air volumes with low VOC concentrations into a low volume, higher concentration stream.

Technology Applicability:

- Inlet Temperature < 100ºF (40ºC)
- VOC Concentrations < 500 ppm. Higher concentrations reduce concentration factor making this technology uneconomical.
- Relative Humidity < 90%
- Low boiling point VOCs
How Do Concentrators Work?

Large Flow / Low Concentration Airstream

Small Flow / High Concentration Airstream
Operating Cost Comparison

Design Basis:

- 10,000 SCFM process exhaust flow
- 100°F process exhaust temperature
- 15 lbs./hr. styrene emissions
- $5/MM BTU gas cost
- $0.07/KWH electrical cost

<table>
<thead>
<tr>
<th>Technology</th>
<th>Operating Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>DFTO</td>
<td>$90/hr</td>
</tr>
<tr>
<td>Thermal Recup</td>
<td>$33/hr</td>
</tr>
<tr>
<td>Catox</td>
<td>$15/hr</td>
</tr>
<tr>
<td>RTO</td>
<td>$7.50/hr</td>
</tr>
<tr>
<td>Concentrator</td>
<td>$2.00/hr</td>
</tr>
</tbody>
</table>
Operating Cost Reduction Strategies

1. Know the estimated and actual oxidizer operating costs for gas usage and electrical consumption.

2. Pay attention to percentages.
   • A 1% drop in thermal efficiency for a standard RTO equates to a 20% increase in natural gas consumption.

3. Monitor emission loading. Have process conditions changed since the oxidizer was installed?

4. Determine what type of oxidizer System would be specified today. Technologies and components have advanced.
Operating Cost Reduction Strategies

5. Know what state and federal grant money is available.
   • Database of State Incentives for Renewables & Efficiency: [www.dsireusa.org](http://www.dsireusa.org)

6. Consider an emission concentrator for high volume, low concentration process streams; Permanent Total Enclosures (PTE), floor sweeps, washers, spray machines

7. Focus on Combustion Air
   • Using ambient air for oxidizer burners is like burning money.

   Consider supplying combustion blowers with tempered air from a secondary heat exchanger.

   Also ideal for process heating needs!
Operating Cost Reduction Strategies

8. Improve Primary Heat Recovery

Catalytic & Recuperative: Metal Heat Exchangers
60-80% Efficient

Regenerative Thermal: Ceramic Heat Recovery Media
95-97% Efficient

9. Properly Maintain Existing Systems

Did you know some permits require service documentation?
10. Consider Secondary Heat Recovery

- Recover exhaust stack heat for use in industrial ovens and dryers
- Recover exhaust stack heat for other plant and/or process heating applications
- Upgrade Heat Efficiency of existing VOC control equipment
Halogenated Hydrocarbons & Acid Control

Oxidation Reaction Can Produce Acids:

Halogenated Hydrocarbon + O₂ \Rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{Heat} + \text{Inorganic Acid}

Scrubbers Neutralize Acids:

HCl + NaOH \Rightarrow \text{NaCl} + \text{H}_2\text{O}

_The presence of halogenated hydrocarbons requires an increase in oxidizer residence time and operating temperature._
Wet Scrubber
Introduction to Wet Scrubbers

1. Types and classifications of air pollutants.

2. Basic wet scrubber types for different pollutants, with focus on most relevant for thermal oxidation applications.
Air Pollutants
Types and Classification

- Gases (including HAPs)
- Airborne Particles (aerosols)
  - Liquids: Entrainment, Mist, Fog
  - Solids: Dust, Fumes
- Visible Emissions (Opacity)
- Nuisance Odors
Air Pollutants
Types and Classification

• Gases (including HAPs)
• Airborne Particles (aerosols)
  – Liquids: Entrainment, Mist, Fog
  – Solids: Dust, Fumes
• Visible Emissions (Opacity)
• Nuisance Odors
Typical Gaseous Pollutants

- Halogen Acids – HF, HCl, HBr
- Sulfur Dioxide - SO$_2$
- Chlorine - Cl$_2$
- Ammonia - NH$_3$
- Nitrogen Oxides – NO$_x$
- Volatile Organic Compounds (VOC’s) - Toluene
Typical Gaseous Pollutants

- Halogen Acids – HF, HCl, HBr
- Sulfur Dioxide - SO\textsubscript{2}
- Chlorine - Cl\textsubscript{2}
- Ammonia - NH\textsubscript{3}
- Nitrogen Oxides – NO\textsubscript{x}
- Volatile Organic Compounds (VOC’s) - Toluene
Important Properties of Pollutant Gases for Wet Scrubbing

Solubility - The capability of a substance to dissolve in water.

Volutility - The tendency of a substance to vaporize.

Reactivity - The capability of a substance to undergo a chemical reaction with another substance.
Gas Scrubbing Chemistry

- $\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$ (HBr, HF, etc.)

- $\text{SO}_2 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_3 + \text{H}_2\text{O}$

- $\text{Cl}_2 + 2\text{NaOH} \rightarrow \text{NaCl} + \text{NaOCl} + \text{H}_2\text{O}$

Note that some low vapor pressure compound like HCl and HF can also be scrubbed into water only if preferred, depending on efficiency requirements and process conditions.
Wet Scrubber Definition

A device that provides intimate contact between a contaminated air stream and a liquid stream to allow for transfer of gases, liquid, or solid contaminants from the air to the liquid.

Scrubber types are typically selected based upon achieving the highest contaminant removal while consuming the least amount of energy.
Reasons to use a Wet Scrubber

1. Soluble and/or reactive gases are present.
2. The pollutant cannot be easily removed in dry form.
3. Liquid droplets or mists are present.
4. Soluble or wettable particulates are present.
5. The pollutant will undergo some subsequent wet process (such as neutralization).
6. The pollutants are more safely handled wet than dry (potential explosiveness).
Wet Scrubbing Process

Wet Scrubbing is a two-step process.

1. Capture of the gas and/or particulate in the liquid.

2. Separation of the scrubbing liquid droplets (entrainment) from the gas stream before leaving the scrubber.
Basic Types Of Wet Scrubbers

- Spray Tower
- Countercurrent Packed Tower
- Crossflow Packed Bed
- Tray Scrubber
- Venturi
Basic Types Of Wet Scrubbers

- Spray Tower
- Countercurrent Packed Tower
- Crossflow Packed Bed
- Tray Scrubber
- Venturi
Countercurrent Packed Scrubber

Dirty Gas In

Clean Gas Out

Liquid In

Liquid Out

Dirty Gas In

Liquid Out
Countercurrent Packed Scrubber

- Top Gas Outlet
- Entrainment Separator
- Liquid Distributor
- Random Packing
- Packing Support
- Side Gas Inlet
- Integral Liquid Sump
Countercurrent Packed Scrubber

- Top Gas Outlet
- Entrainment Separator
- Liquid Distributor
- Random Packing
- Packing Support
- Side Gas Inlet
- Integral Liquid Sump
- Spray Nozzle Liquid Distribution
Countercurrent Packed Scrubber

- Top Gas Outlet
- Entrainment Separator
- Liquid Distributor
- Random Packing
- Packing Support
- Side Gas Inlet
- Integral Liquid Sump
- Chevron Entrainment Separator
Countercurrent Packed Tower

- Vertical configuration with gas flowing upward countercurrent to liquid flow.
- Contains a section of random packing media to provide good mixing and contact of the gas and liquid.
- Used for absorption of soluble and/or reactive gaseous pollutants.
- Also used for impingement of entrained liquids and/or soluble solids (dusts) above 10 micron in size.
Countercurrent Packed Tower Design Considerations

- Commonly employed for gas removal efficiencies in the 90% to 99.99%+ range
- Typical 500-600 ft/min gas velocity range
- Packing selection to minimize packed bed height and pressure drop while maintaining high velocity (and low diameter) equipment – Minimize capital and operating costs
- Gas pressure drop in the typical range of 1 to 6 in-wc, varying based on packing type, entrainment separator type, efficiency requirements
- Typical discharge entrainment separator types include chevron blade assemblies and mesh-pad type separators
Pre-Cooling

• A direct contact adiabatic quench system is typically used to efficiently cool the gas stream to a **temperature appropriate for the downstream equipment**. A specific approach to the saturation temperature is not required.

• Proper quench design requires good mixing and adequate contact time between the gas and liquid phases to achieve maximum evaporation. As with mass transfer, optimum contacting can be achieved using a number of different methods.

• Quench residence time is defined as the time from the initial contact of gas and liquid and the exit of the quench. This is not necessarily a function of the physical length of the quench.

• If design utilizes circulation of any salt solution, care must be taken to avoid creation of sub-micron salt particulate during evaporation.
Quench Arrangements

Horizontal – Low Temp

Vertical – High Temp
Quench / Scrubber Example

- Exhaust Stack
- Packed Tower Scrubber
- Adiabatic Quench
- Exhaust Fan
## General Wet Scrubber Selection Guide

<table>
<thead>
<tr>
<th>Scrubber Type</th>
<th>Gas Absorption</th>
<th>Liquid Aerosols &gt; 10 µm</th>
<th>Liquid Aerosols &lt; 10 µm</th>
<th>Soluble Particulate &gt; 10 µm</th>
<th>Soluble Particulate &lt; 10 µm</th>
<th>Insoluble Particulate &gt; 10 µm</th>
<th>Insoluble Particulate &lt; 10 µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spray Tower</td>
<td>G</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Packed Tower</td>
<td>E</td>
<td>E</td>
<td>NR</td>
<td>E</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Crossflow</td>
<td>G</td>
<td>E</td>
<td>NR</td>
<td>E</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Tray Tower</td>
<td>E</td>
<td>E</td>
<td>NR &lt; 5µm</td>
<td>E</td>
<td>NR &lt; 5µm</td>
<td>E</td>
<td>NR &lt; 5µm</td>
</tr>
<tr>
<td>Venturi</td>
<td>F</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>E</td>
</tr>
</tbody>
</table>

E = Excellent  
G = Good  
F = Fair  
NR = Not Recommended
## General Wet Scrubber Selection Guide

<table>
<thead>
<tr>
<th>Scrubber Type</th>
<th>Gas Absorption</th>
<th>Liquid Aerosols &gt; 10 µm</th>
<th>Liquid Aerosols &lt; 10 µm</th>
<th>Soluble Particulate &gt; 10 µm</th>
<th>Soluble Particulate &lt; 10 µm</th>
<th>Insoluble Particulate &gt; 10 µm</th>
<th>Insoluble Particulate &lt; 10 µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spray Tower</td>
<td>G</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Packed Tower</td>
<td>E</td>
<td>E</td>
<td>NR</td>
<td>E</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Crossflow</td>
<td>G</td>
<td>E</td>
<td>NR</td>
<td>E</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Tray Tower</td>
<td>E</td>
<td>E</td>
<td>NR &lt; 5µm</td>
<td>E</td>
<td>NR &lt; 5µm</td>
<td>E</td>
<td>NR &lt; 5µm</td>
</tr>
<tr>
<td>Venturi</td>
<td>F</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>E</td>
</tr>
</tbody>
</table>

E = Excellent  
G = Good  
F = Fair  
NR = Not Recommended
Questions?

Thank You for Attending!