OXIDATION TECHNOLOGIES

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FOR A BETTER ENVIRONMENT

**A Presentation Prepared For:**

SOUTH TEXAS SECTION OF THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

# PROCESS COMBUSTION CORPORATION

# Introductions

- Mike Foggia - Business Development / Marketing Manager
- Son Nguyen – Business Development Manger – Gulf Coast

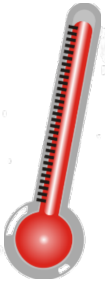
# Program Objectives

- ✓ Technology Description and Basic Design Parameters
  - Thermal Oxidizers
  - Regenerative Thermal Oxidizers
  - Flameless Thermal Oxidation
- ✓ Typical Application's and resulting Control capabilities
  - Selection of the "appropriate" technology is critical to overall compliance
- ✓ Case Study –
- ✓ Q&A

# “APC” Equipment Selection Process

What distinguishes one technology from another is the ***temperature*** at which the air pollutant is destroyed and the ***methods used to generate the heat*** used in the process. The basic design concept of a thermal oxidizer is configured such that it promotes a chemical reaction of the air pollutant with oxygen, at an elevated temperature. This subsequent reaction destroys the pollutant in the air stream by converting it to carbon dioxide, water, and heat. The rate of reaction is controlled by three interdependent and critical factors:

- ✓ Time
- ✓ Temperature
- ✓ Turbulence



# “APC” Equipment Selection Process

***Selecting the right oxidation technology depends on many factors & often times is not an easy decision…….***

- ✓ Detailed description of the production process that is generating the waste gas or liquid.
- ✓ Hours of process operation per day, per month, per year
- ✓ Detailed listing of different emission points to be combined and controlled
- ✓ Waste gas flow rates and temperatures associated with each emission point
- ✓ Compound Composition and volumes of all Waste Gas to be treated
- ✓ Required Compliance needs – Removal Efficiency
- ✓ Need for Waste Heat Recovery – If required, in what form
- ✓ Utility Requirements/Costs
- ✓ Others needs specific to the site, i.e. footprint, location etc.

20,000 CFM TO
Textile Manufacturing Facility

# Common “APC” Technologies

Most Common APC Technologies/Equipment

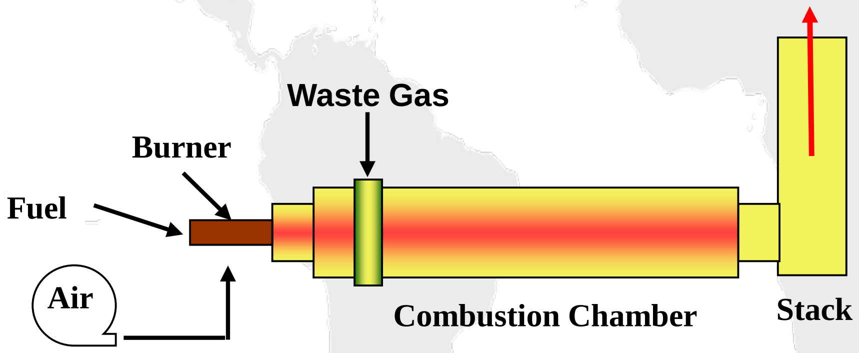
- ✓ Direct Fired/Recuperative Thermal Oxidizers
- ✓ Regenerative Thermal Oxidizers
- ✓ Flameless Thermal Oxidizers
- ✓ Flares – Tip, Ground, Enclosed Ground

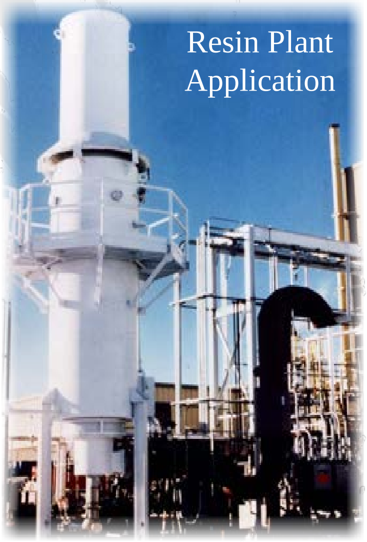
Waste Water Incinerator System
Acrylonitrile Application - China

# Technology Overview

## Direct Fired/Recuperative Thermal Oxidizers

***A Direct Fired Thermal Oxidizer*** is a "thermal reactor" where pollutants, in a waste stream are heated in the presence of oxygen to a temperature sufficient to convert the pollutants to harmless compounds (usually carbon dioxide, water vapor, nitrogen, and oxygen)".

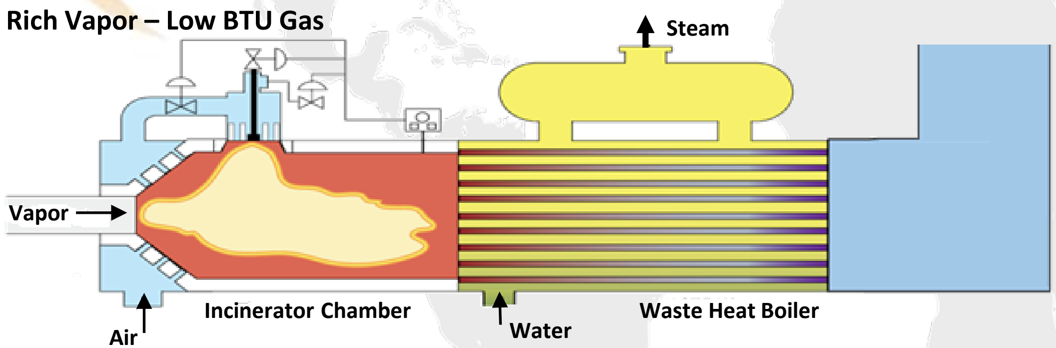


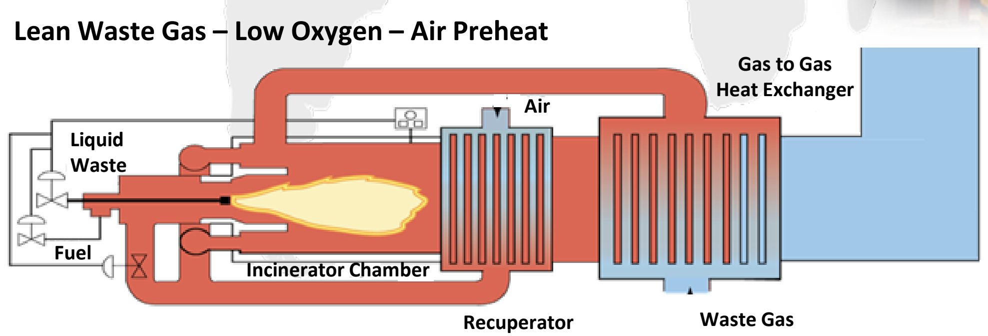




A simple thermal oxidizer system consists of a refractory lined cylinder, into which waste, air and fuel are introduced.

# Technology Overview

***Recuperative Thermal Oxidizer*** systems incorporate the use of heat exchangers and / or waste heat boilers which utilize the available heat contained in the thermal oxidizer hot products of combustion to reduce the system energy costs, to produce steam, to heat a process air stream, etc…




# Technology – Selection Criteria

| Selection Criteria | Direct Fired TO | Recuperative TO |
|---|---|---|
| Waste Gas | Exothermic | Endothermic/Exothermic |
| Aux. Fuel Requirement | Minimal Need | Minimal Need |
| Fuel Cost | Not a Concern | Major Concern |
| Heat Recovery Requirement | None | Steam, Hot Oil, Hot Air, Hot Asphalt |
| MOC Concerns, Dirty/Corrosive waste Streams | Minimal Concern | Major design criteria - Must be Evaluated |
| | | |

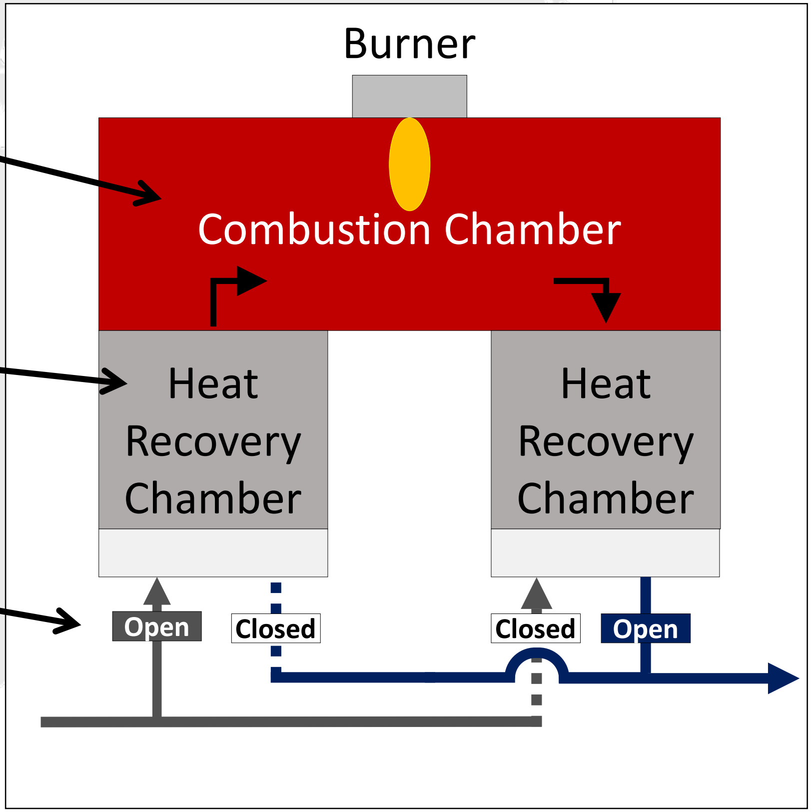
# Regenerative Thermal Oxidizer (RTO)

A regenerative thermal oxidizer (RTO) is a 95% thermally efficient device used to control VOC emissions on *high volume* waste gas streams that contain low VOC concentrations.

2 Chamber RTO

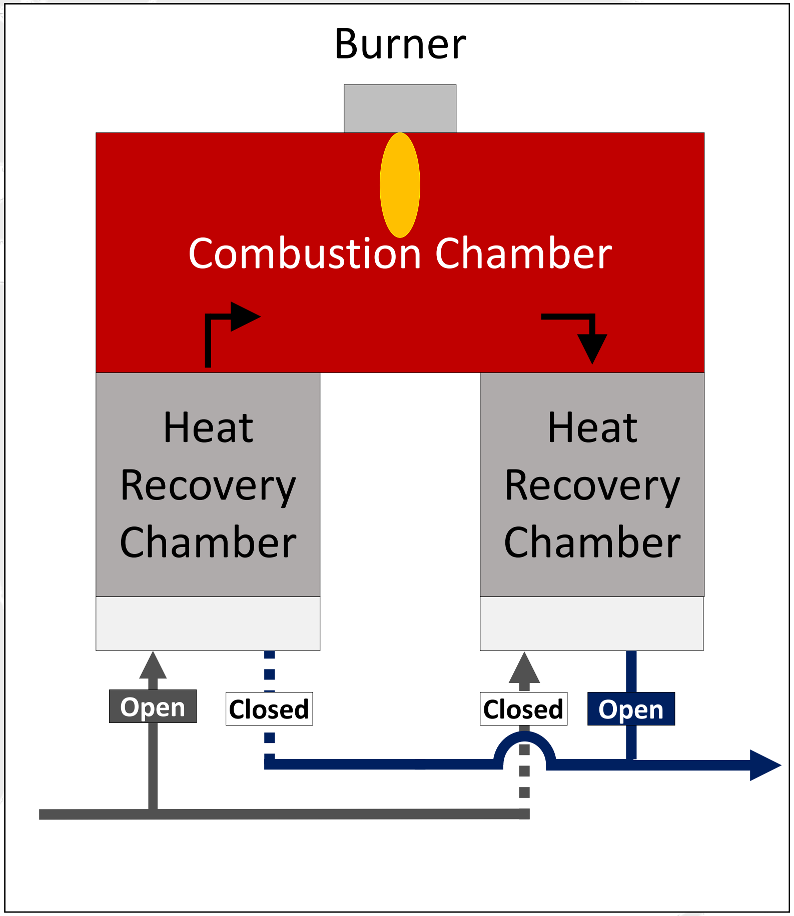
# Regenerative Thermal Oxidizer (RTO)

- ✓ Thermal Oxidizer
- ✓ Heat Exchangers
- ✓ Switching Valves



# How do RTO's Work?

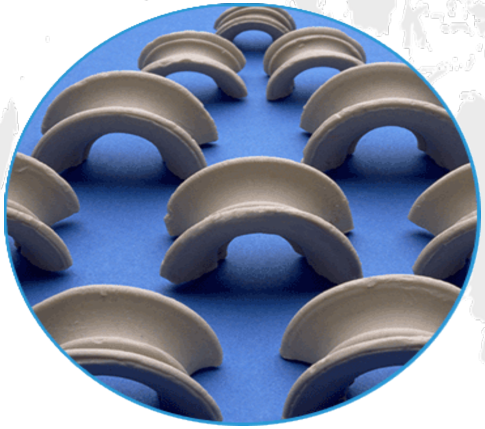
- ✓ Valves divert flow
- ✓ Preheat
- ✓ Combust VOCs
- ✓ Exchange heat
- ✓ Vent to Stack
- ✓ Valves switch again



# RTO MEDIA BED EXAMPLES

Structured Packing Ceramic Example

Random Packing Ceramic Saddles Examples

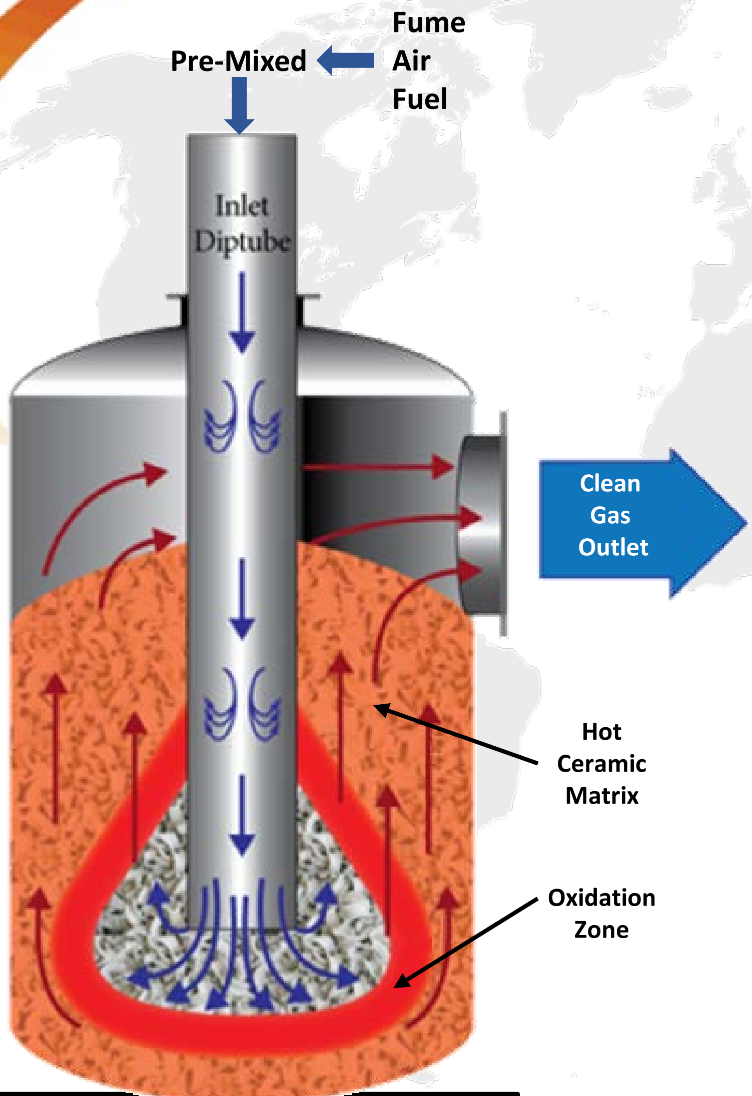


# Regenerative Thermal Oxidizer (RTO)

**TYPICAL APPLICATION FITS:**

- ✓ High Volume & Low VOC Concentration Streams
- ✓ Clean Waste Streams (minimal/ no particulate)
- ✓ Non- Corrosive Waste Streams
- ✓ Steady State Waste Stream Operating Ranges

# Flameless Thermal Oxidation (FTO)




## What is FTO?

- A refractory lined vessel filled with ceramic media

## How Does it Work?

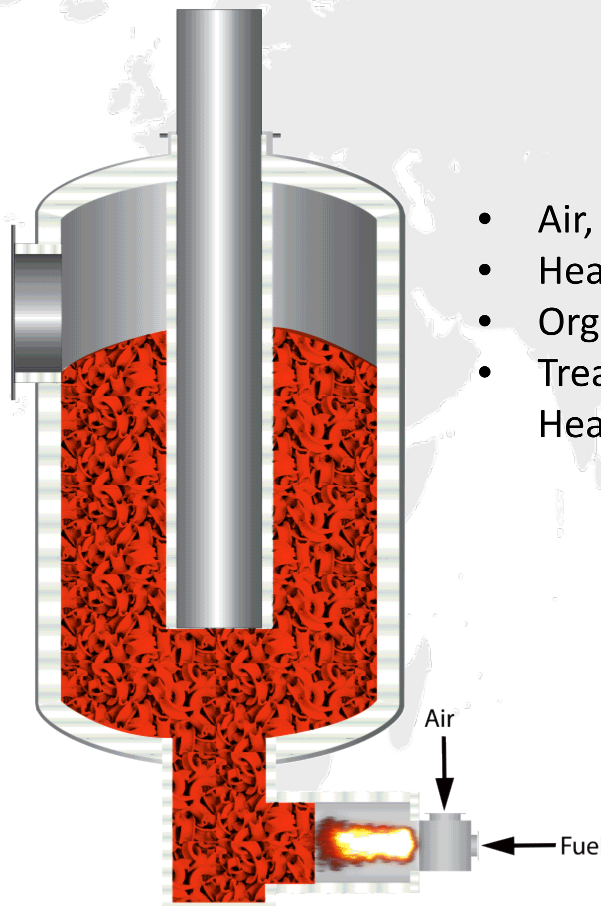
- Bed is preheated to initiate oxidation reactions (Bottom Mounted Preheat Burner)
- Premix Waste Gas, Ambient Air, and Natural Gas
- Gas mixture **below** flammable range (Below LEL)
- Oxidizing; Not Combusting
- Maximum Temperature **1800-1900°F**

**Pre-Heater – Start-Up Only**

# FTO Start-Up & Run Sequence

**Start-Up Mode**

- Bed Initially in Cold State
- Burner used for Preheat
- Burner only used during start-up




**Run Mode**

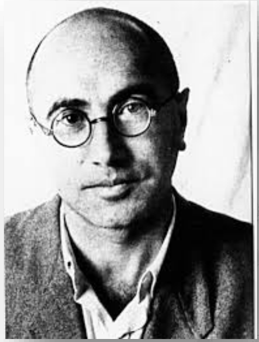
- Air, Fuel, & Fume Premixed
- Heat Transfers to total gas flow
- Organics Oxidize Releasing heat
- Treated Gases Discharged in Headspace of the System

# Flameless Thermal Oxidation (FTO)


**Design Benefits:**

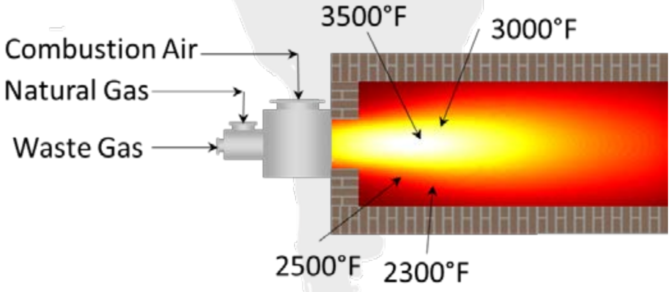
- ✓ High DRE……… **99.9999%**
- ✓ Low Thermal NOx….. **< 1 ppmv**
- ✓ Low Temperatures Throughout
- ✓ Feed Forward Control to account for changing waste conditions
- ✓ Emission Reduction Credits (ERCs)

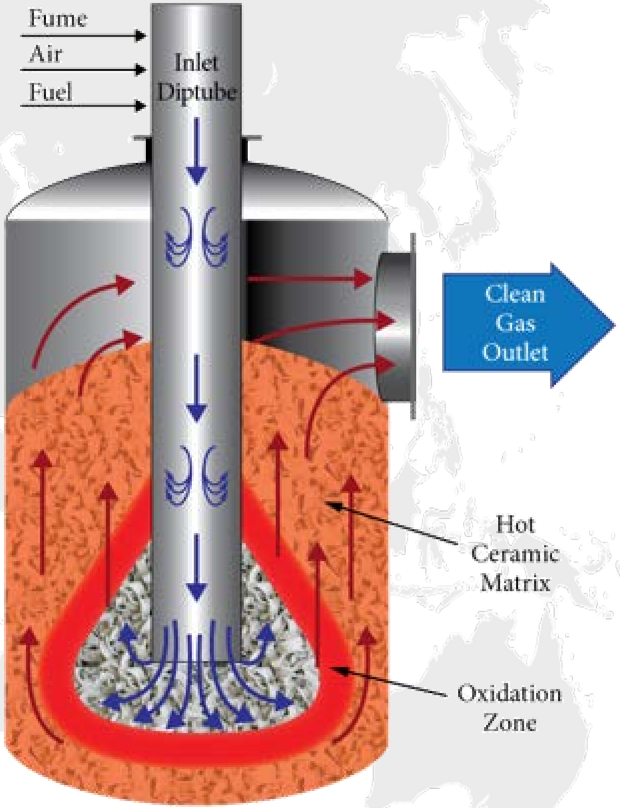
# How do we achieve NOX emissions < 1 ppm?



**Yakov Zel'dovich**
Determined the correlation between temperature and NOx formation in a combustion system. Temperatures >2300F cause an exponential growth rate in NOx generation.

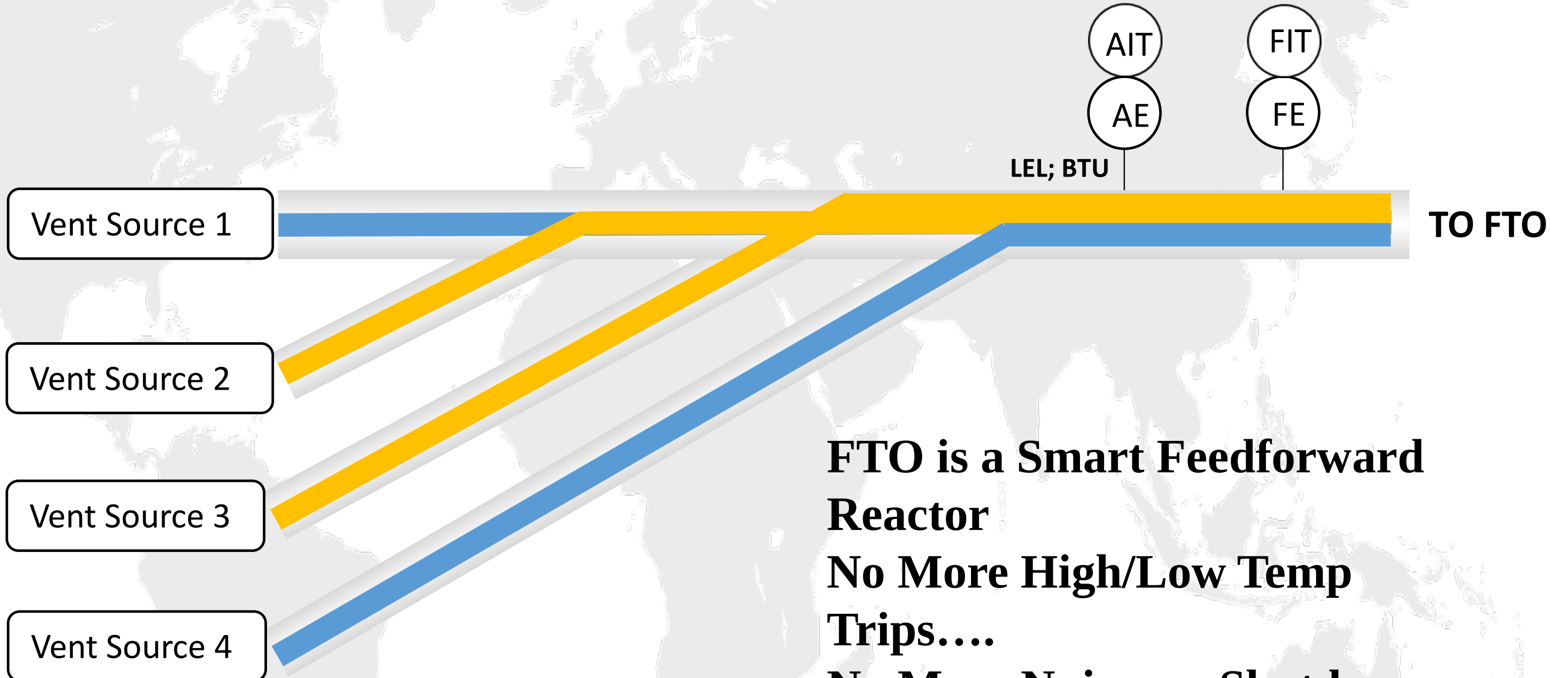
**Thermal Oxidizer Flame Temperature Profile**




Typical "Maximum"
Bed Temperature = 1,800°F

# Proactive, Feed Forward Control to Manage Change




**FTO is a Smart Feedforward Reactor**
**No More High/Low Temp Trips….**
**No More Nuisance Shutdowns….**

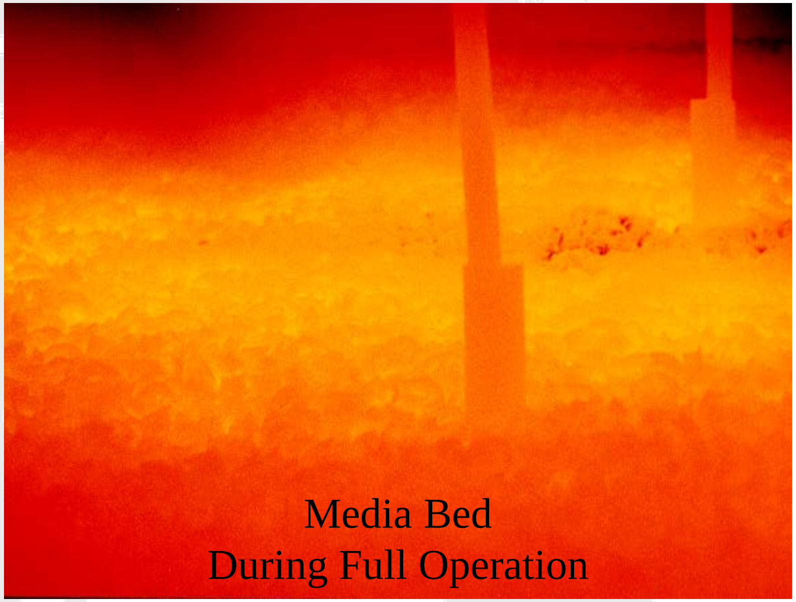
**Great for Sold Out Products!**
**Maximize Production Time!**

# Example FTO Installation

System Burner (Start-up Only)

Dip Tube


Refractory Condition:
15 Years in Operation at Pfizer
1CAM501U 11 Apr, 2016 13:43:38


Media Bed
During Full Operation

# Elevated or Tip Flares

Flares can be used to control almost any VOC stream, and can typically handle large fluctuations in VOC concentration, flow rate, heating value, and inert species content. Used for continuous, batch, and variable flow vent stream applications. The primary use is to control a large volume of pollutant resulting from upset conditions.

Flares find their primary application in the petroleum and petrochemical industries. The majority of chemical plants and refineries have existing flare systems designed to relieve emergency process upsets that require release of large volumes of gas. They can also be used to control vent streams from various process operations. Typical flared waste streams are low molecular weight and have high heating values.

Disadvantages of Elevated/Tip flares include:

- ✓ Can produce undesirable noise, smoke, heat radiation, and light
- ✓ Can be a source of $SO_x$, $NO_x$, and CO
- ✓ Cannot be used to treat waste streams with halogenated compounds
- ✓ Released heat from combustion is lost.

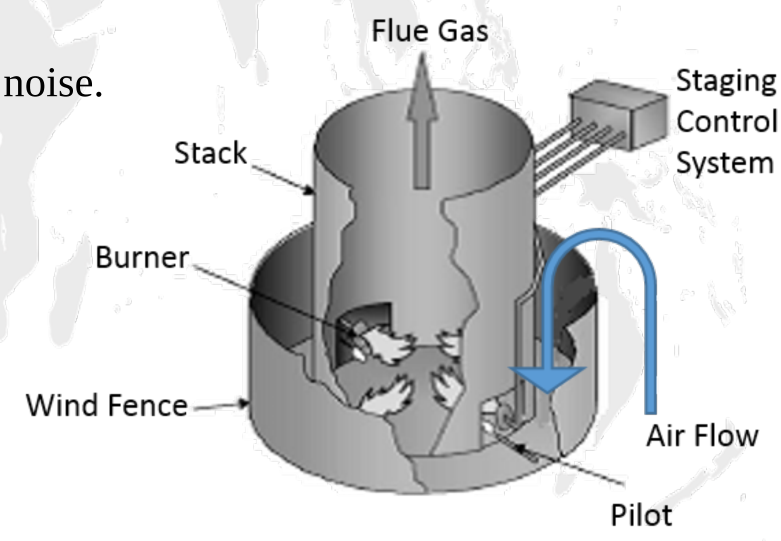
# Enclosed Ground Flare

Enclosed ground flares are used when heat, light, and noise must be controlled and safety is an issue. Open ground flares are useful when these are not concerns.

Advantages:

- ✓ Closer to ground, making repairs and cleaning easier.
- ✓ Lower operating costs than elevated flares.
- ✓ Enclosed flares block radiation, luminescence and noise.
- ✓ Almost fully smokeless.
- ✓ Very cost-effective and simple
- ✓ Natural draft with high excess air
- ✓ Great for consistent exothermic waste streams
- ✓ 98% DRE is common

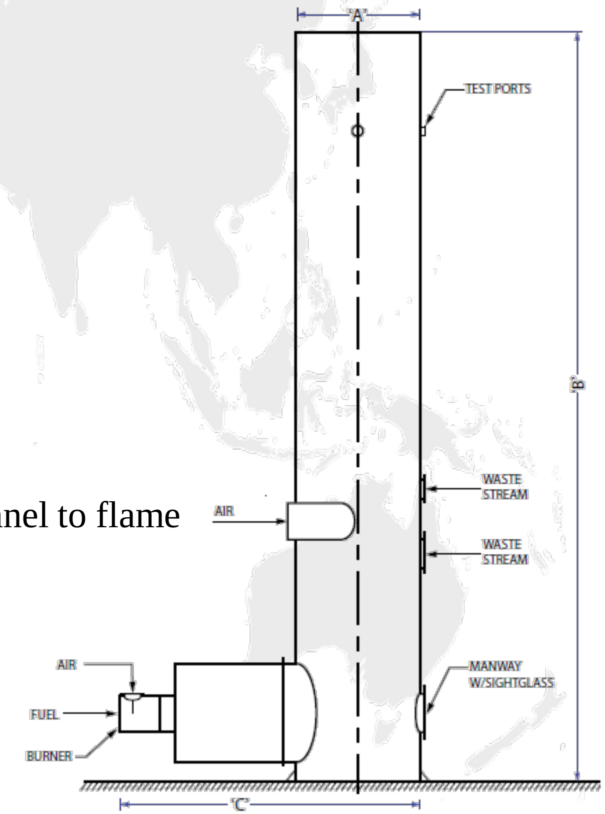
Internal Configuration – Typical Design



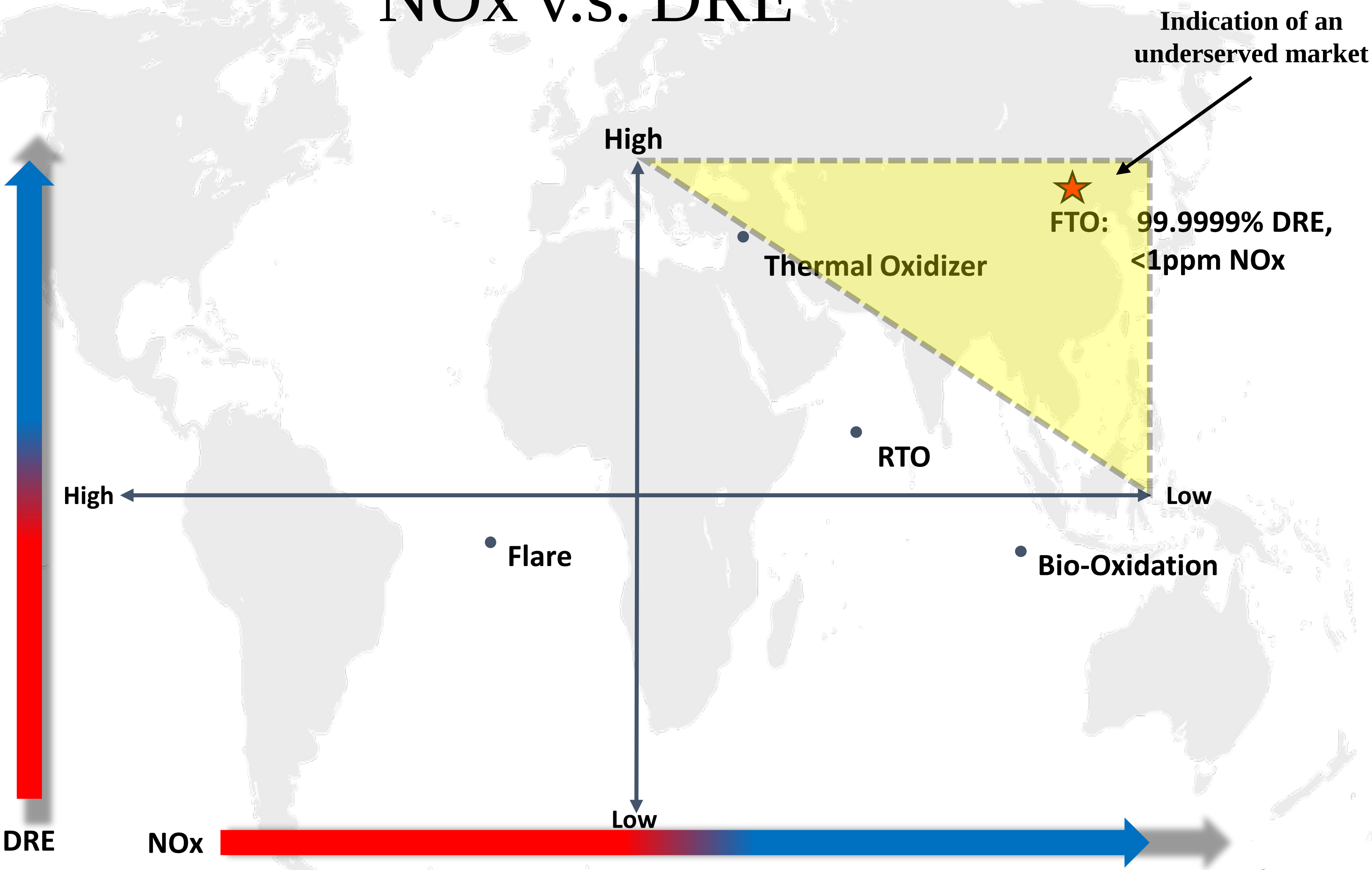
# Forced Draft – Ground Flare

Some applications require a reasonable but effective alternative to a thermal oxidizer or an enclosed ground flare.  A Forced Draft Flare incorporates the best features of both to produce a cost-effective, fuel-efficient, combustion-based pollution control device. A modular design also allows for simple and quick modifications to increase residence time or incorporate heat recovery in the future.

- ✓ Improved management of combustion air for performance benefits
- ✓ Significantly less fuel consumption vs. EGFs
- ✓ Burner access at grade
- ✓ Not draft dependent
- ✓ Adaptable to varying operating cases
- ✓ Minimum 0.5 seconds residence time
- ✓ Operating temperature 1400°F to 1800°F
- ✓ 98%+ Destruction Removal Efficiency (DRE)
- ✓ Greater turndown
- ✓ No open dampers at grade that could expose errant fumes and personnel to flame
- ✓ Flame detection, block valves, and purge
- ✓ Not impacted by wind
- ✓ Skid mounting
- ✓ Heat recovery



# Competing Control Technologies
# NOx v.s. DRE

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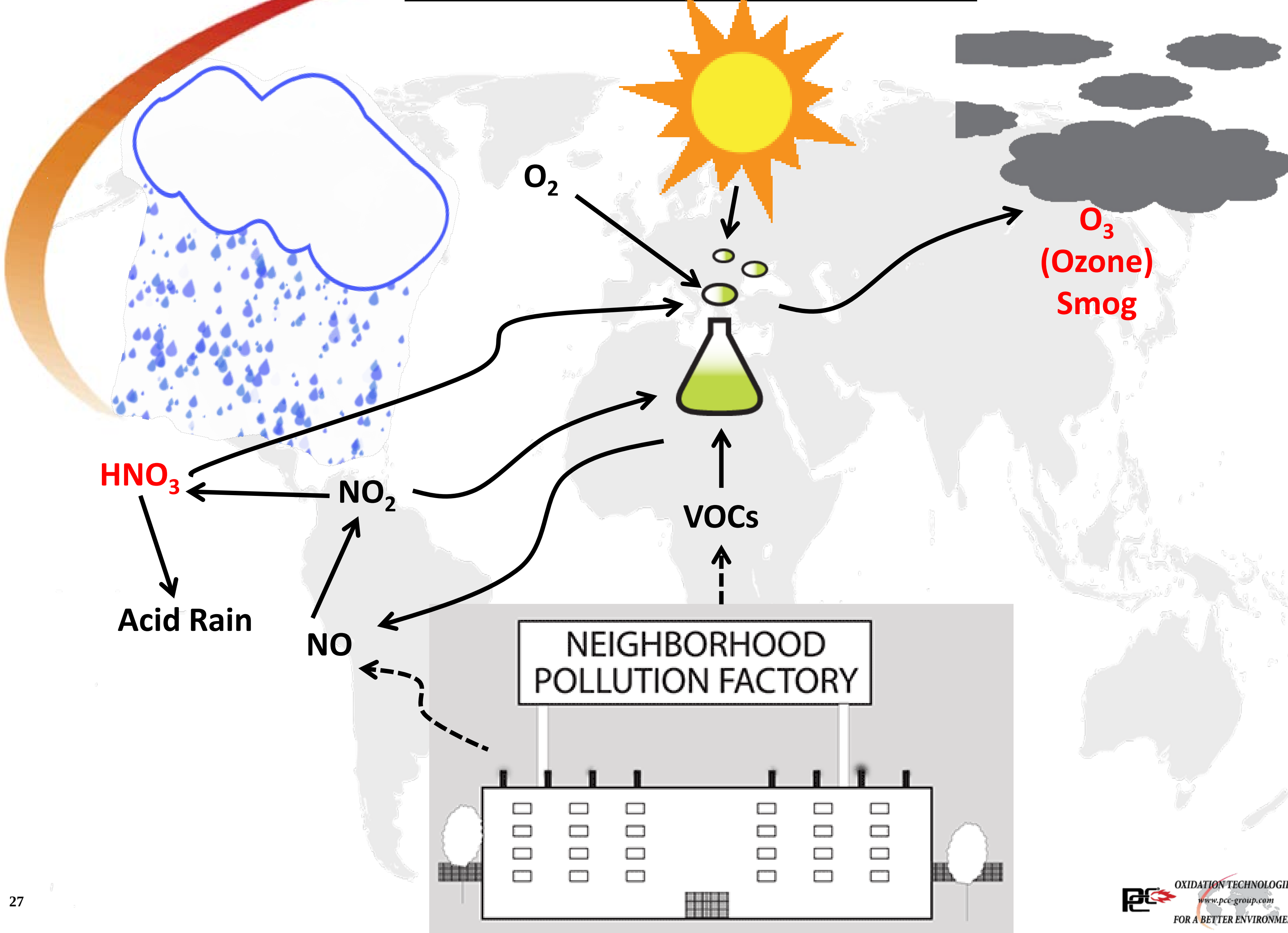
# Technology vs Application Fit

| Project Parameter | Thermal Oxidizer | Regenerative Thermal Oxidizer (RTO) | Flameless Thermal Oxidizer | Flare Systems |
|---|---|---|---|---|
| High Concentration | X | | X | X |
| Low Concentration | X | X | X | |
| High Waste Stream Volume | X | X | X | X |
| Halogenated Service, Cl, Fl, Br | X | | X | |
| Sulfur, Mercaptans, thiols, etc. | X | | X | X |
| DRE 99.99%+ | X | | X | |
| Continuous Process | X | X | X | Pressure Relief,<br>Low DRE VOC<br>Emergency<br>By -Pass |
| Batch Process | X | X | X | |
| Thermal NOx < 1ppmv | | | X | |

# Chemical Reactions In Air



# What is NOx?

- Nitrogen Oxides are one of six chemical species classified as a criteria pollutants under the National Ambient Air Quality Standards (NAAQS)

- NOx in combination with volatile organic compounds (VOC) present in the atmosphere can combine in the presence of sunlight to form ozone which has been found to be damaging to human health.

- Major precursor of photochemical smog

  ( NOx + VOC + SUN LIGHT = O3 + Smog )

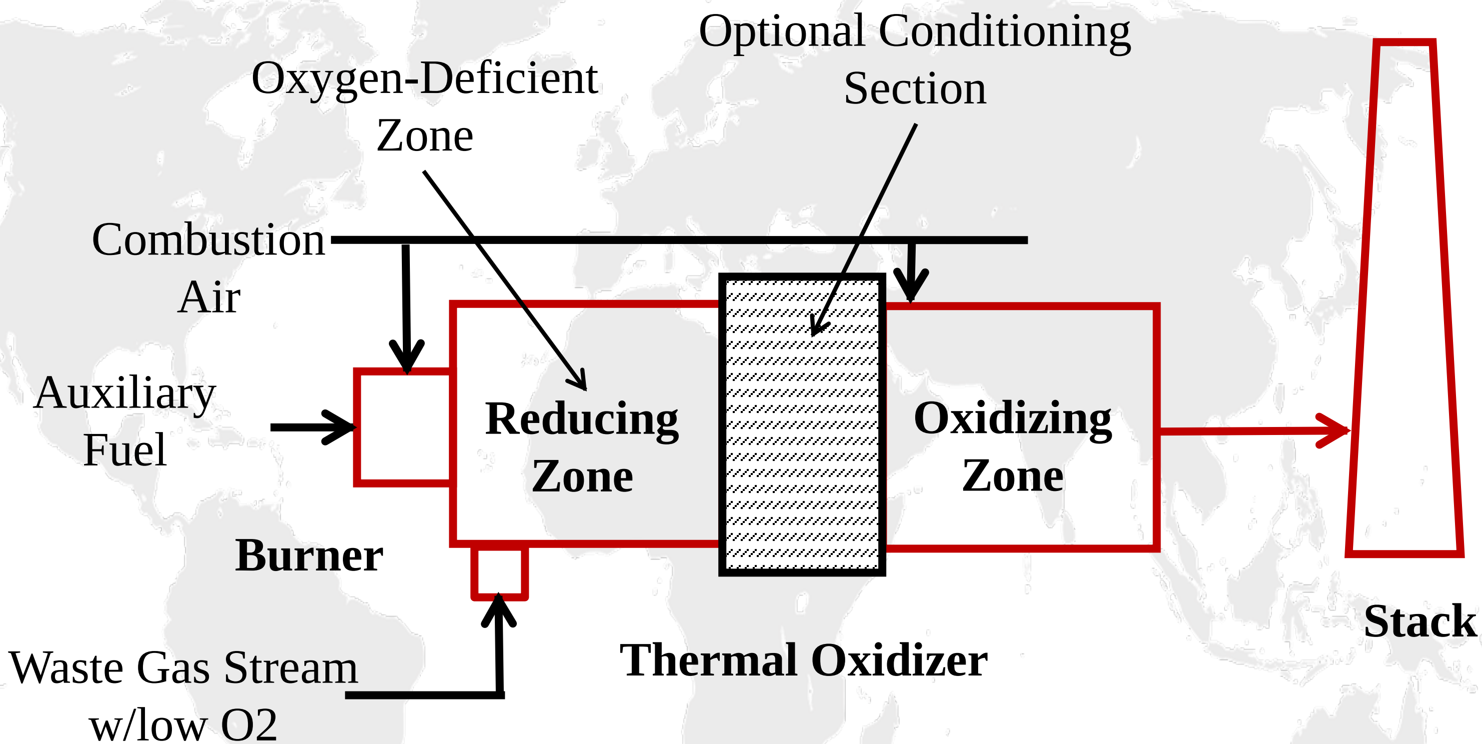
# NOx Control

The objective of combustion NOx control is to minimize the formation of NOx **during the combustion process**.

Chemical NOx control – reducing the formation of NOx by breaking the chemical bonds and then effectively Oxidizing the non-chemically bound compounds.

| **Common Types:** | **Reduces** |
|---|---|
| ❑ Low NOx Burners (LNB) | -(thermal NOx) |
| ❑ Vitiated Air | -(thermal (NOx) |
| ❑ Flue Gas Recirculation (FGR) | -(thermal NOx) |
| ❑ Water / Steam Injection | -(thermal NOx) |
| ❑ Fuel Staging | -(thermal NOx) |
| ❑ **Multi-Stage Combustion** | **-(chemical NOx)** |

# Multi- Stage NOx Control




- **For Chemically Bound Nitrogen:**

  *Reduced oxygen content converts N to $N_2$ - Inter-stage cooling may be required to reduce the temperature prior to entry into the Oxidizing Zone.*

# Case Study

# AOGI – WWI Systems – Acrylonitrile Production Process

**Background Information:**

Process Combustion Corporation was selected by the customer to supply one (1) Absorber Off-Gas Incinerator (AOGI) and one (1) Waste Water Incinerator (WWI) because PCC is the world leader in Low NOx combustion systems for treating waste streams from the Acrylonitrile Production Process.

This project was a joint venture between a major US chemical company, that PCC had work with on previous Acrylonitrile Projects, and a major China chemical company. PCC was selected because of our proven application experience with the US partner of this joint venture.

Two separate incinerator systems were supplied. One incinerator treated a gaseous waste stream and the other incinerator treated multiple liquid waste streams. Both incinerators used a "multi-stage" combustion process to minimize the formation of NOx emissions.

# AOGI - Solution

**Absorber Off-Gas Incinerator (AOGI):**

| | |
|---|---|
| Quantity: | One (1) |
| Orientation: | Horizontal |
| Type: | Two Stage Low NOx Combustion Process |
| Size: | 22'-0" diameter x 80 feet long |
| Auxiliary Fuel: | Propane & Olefin |
| Total System Capacity: | 248 MM Btu/hr |
| Heat Recovery: | Multiple<br>(1)- Primary Combustion Air Preheater<br>(1)- AOG Preheater<br>(1)- Secondary Combustion Air Preheater<br>(1)- Waste Heat Recovery Boiler<br>(1)- BFW Economizer |
| Waste Stream Flow: | 102,000 scfm |

**Equipment Scope:**

**AOGI System:**

- Multi-Stage Incinerator w/ Dual-Fuel Burner
- Primary Air Preheater
- Secondary Air Preheater
- AOG Preheater
- Waste Heat Recovery Boiler
- BFW Economizer
- Primary & Secondary Air Blowers
- Exhaust Stack
- PLC Based Control Panel
- All Instruments & Controls
- All Interconnecting Ducting
- Dual Fuel Train
- Platforms & Ladders

DRE – 99.9% - 99.99% NOx- <100ppmv

# WWI - Solution

**Waste Water Incinerator (WWI):**

| | |
|---|---|
| **Quantity:** | **One (1)** |
| **Orientation:** | **Vertical Down-Fired** |
| **Type:** | **Two Stage Low NOx Combustion Process with SNCR** |
| **Size:** | **12'-0" diameter x 95'-0" long** |
| **Auxiliary Fuel:** | **Propane & Olefin** |
| **Total System Capacity:** | **129 MM Btu/hr** |
| **Heat Recovery:** | **Multiple**<br>**(1)- Waste Heat Recovery Boiler**<br>**(1)- BFW Economizer** |
| **APC Equipment:** | **Bag House** |
| **Liquid Wastes:** | **HCN Liquid, Crude CAN Liquid, and Two Waste Water Streams** |
| **Liquid Waste Flow:** | **70 GPM (normal)** |

**WWI System:**

- **Multi-Stage Incinerator w/ Dual-Fuel Burner**
- **SNCR Section**
- **Conditioning Chamber**
- **Combustion Preheater**
- **Waste Heat Recovery Boiler**
- **BFW Economizer**
- **Bag House**
- **Combustion Air Blower**
- **ID Blower**
- **Recycle Blower**
- **Exhaust Stack**
- **PLC Based Control Panel**
- **All Instruments & Controls**
- **All Interconnecting Ducting**
- **Dual Fuel Train**
- **Platforms & Ladders**
- **Liquid Waste Guns**

DRE – 99.9% - 99.99%     NOx- <70ppmv

# Conclusion

***It is very important that your APC equipment selection be based on a well planned and executed selection process. Many factors must be considered to ensure you install a system that will meet your control requirements in an efficient, economical manner.***

- ✓ ***Oxidation control technology selection is normally driven by the waste stream type, waste stream composition and air permit requirements***

- ✓ ***Every oxidation control technology has benefits & limitations depending on the application & air permit needs***

***Do not base a decision on capital cost alone. Consider operating costs, maintenance costs, up-Time, reliability, supplier service and overall lone term compliance.***


Q&A