

# Air Emissions Control in Spray Finishing Applications

C A T A L Y T I C  
C O M B U S T I O N

The logo consists of a central globe with a horizontal line passing through its center. Two large, black, curved swooshes extend from the globe, one above and one below, creating a sense of motion or a stylized 'S' shape. The text 'CATALYTIC' is positioned above the globe and 'COMBUSTION' is positioned below it, both in a bold, sans-serif font with a slight shadow effect.

- Compare the economic and performance characteristics of applying the Best Available Control Technologies to prevent air pollution from spray finishing operations.

- Regenerative Thermal Oxidizers (RTOs)
- VOC Concentrators
- Booth Ventilation Recirculation

**Dilution  
is NOT the  
Solution**

# Example Scenario

## Booth Parameters

Height	20 ft
Width	100 ft
Length	200 ft
Booth Volume	400,000 ft <sup>3</sup>
<b>Total Flow</b>	<b>200,000 SCFM</b>

## Paint Solvent Composition

Acetone (g/L)	180
Methyl Ethyl Ketone (g/L)	120
Toluene (g/L)	60
<b>Total VOC (g/L)</b>	<b>360</b>

## Spraying Parameters

Spray Rate / Gun (gpm)	0.05
Number of Guns	10

- Operational Schedule
  - Two 8-hour shifts, 5 days/wk, 50 wk/yr
  - 4200 hr/yr Operating
  - 4200 hr/yr Idle/Standby
  - 360 hr/yr Shutdown and Maintenance
- Utility Rates
  - Natural Gas: \$9.00 /MMBTU
  - Electricity: \$0.10 /kWh

- **Spray Rates**

- Shift Average: 16.375 gph
- Maximum: 30 gph

- **Solvent Emissions**

	Avg.	Max.
● Acetone (lb/hr):	24.6	45.0
● MEK (lb/hr):	16.4	30.0
● Toluene (lb/hr):	8.2	15.0
● Total (lb/hr):	49.1	90.0

- Although the solvent concentrations are low in the high volume booth exhaust, the overall mass of solvent is a significant pollution source:
  - Average Solvent Concentration: 24 ppmv
  - Maximum Solvent Concentration: 44 ppmv
  - Yearly Solvent Emissions: 98.25 tpy
  - Yearly VOC Emissions (- Acetone): 49.125 tpy

- Regenerative Thermal Oxidizers (RTOs)
  - Destroy VOCs with high temperature oxidation with DRE's of 95-99%
  - Utilize reversing flow regenerative heat exchange to achieve heat transfer efficiencies near 95%



## RTOs

- Specifications
  - Design Flow: 200,000 SCFM
  - Design DRE: 98%
- Equipment Costs
  - \$3,300,000

## RTOs

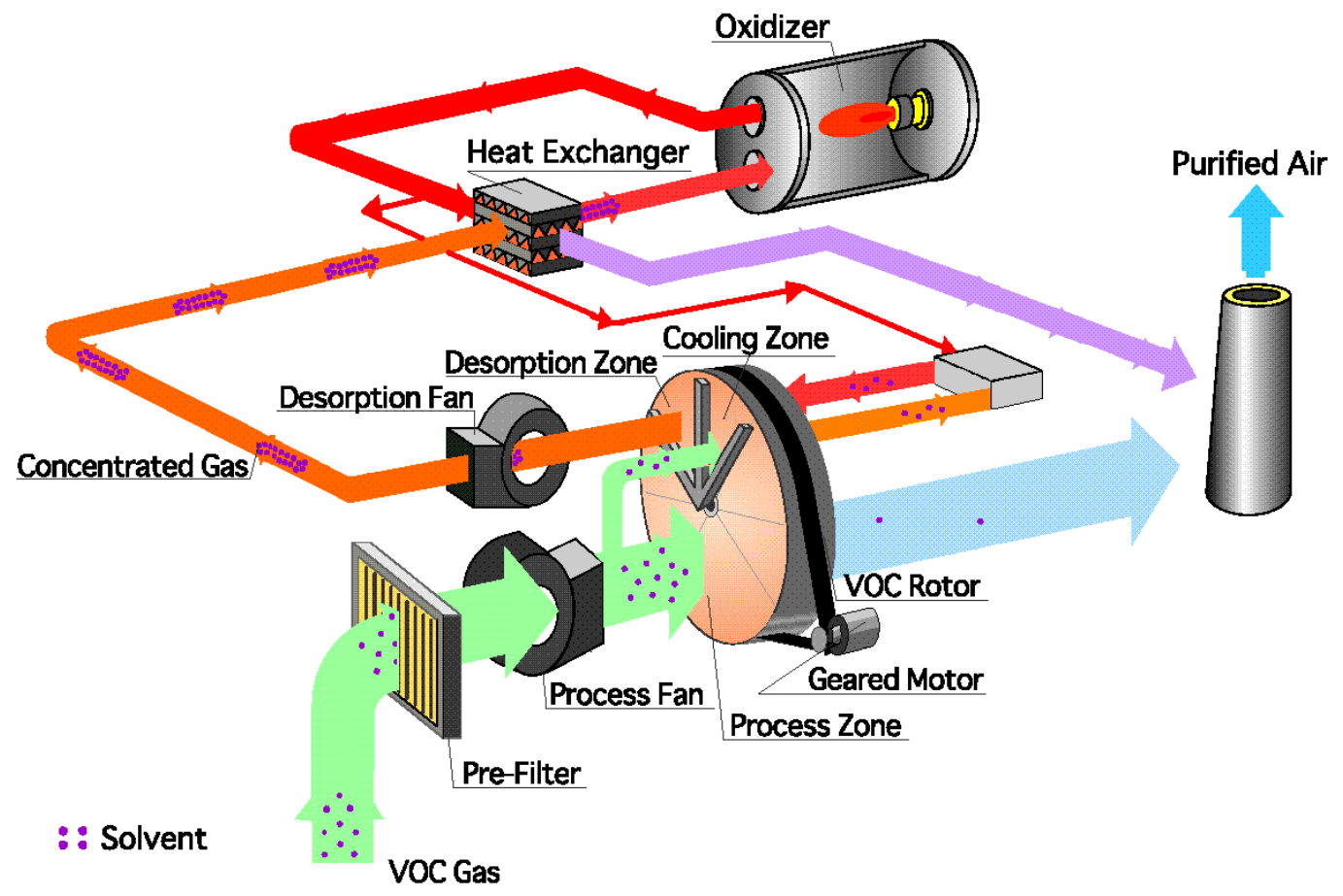
- Utility Usage
  - Natural Gas: 17.2 MMBTU/hr
  - Electricity: 591 kW
- Annual Operating Cost
  - \$1,050,000

## RTOs

- Technically sound solution
  - Robust, proven, and effective solution to prevent VOC emissions
- Economically poor solution
  - Utilize a significant amount of resources for the gain in air pollution prevention.

- VOC Concentrators
  - Concentrate VOCs using a temperature swing adsorption (TSA) process.
  - Concentrated exhaust stream is sent to a smaller oxidizer system
  - Overall DREs typically 95%





## VOC Concentrators w/ RTO

- Specifications
  - Design Flow: 200,000 SCFM
    - RTO Design Flow: 12,000 SCFM
  - Design DRE: 95%
- Equipment Costs
  - \$2,500,000

## VOC Concentrators w/ RTO

- Utility Usage
  - Natural Gas: 3.9 MMBTU/hr
  - Electricity: 332 kW
- Annual Operating Cost
  - \$300,000

- The economics of utilizing concentrators on low concentration streams is evident, but the technology is not as universally applicable as direct oxidation.
  - High temperature streams downgrade adsorption
  - High humidity streams downgrade adsorption
  - Typical capture of 96-98% yields overall DREs closer to 95%
  - Low Boiling Point compound adsorb poorly
  - High Boiling Point Compounds desorb poorly
  - Reactive monomers and oligomers can polymerize
- Typical spray finish exhaust parameters fall within the applicable range which concentrator technology is extremely effective.

## VOC Concentrators w/ RTO

- Technically sound solution
  - Ambient Temperature and Humidity
  - Upstream PM removal systems in place
  - All compatible VOC solvents to allow 95% DRE
    - Liquid solvents that vaporize in near ambient conditions in spray finishing are typically good for TSA process.
    - No reactive monomers or oligomers present.
- Economically practical solution

- Recirculation Booth w/ VOC Concentrator
  - The exhaust of the spray booth is decreased by recirculation of a portion of the required booth flow.
    - This reduces the exhaust requiring treatment even prior to concentrating.
  - Assume for the example scenario an 80% recirculation to 20% exhaust ratio:
    - Booth Flow: 200,000 SCFM
    - Booth Exhaust: 40,000 SCFM

## Recirculation Booth w/ VOC Concentrator

- Specifications

- Design Flow: 200,000 SCFM

- Concentrator Flow: 40,000 SCFM

- Oxidizer Flow: 3,000 SCFM

- Design DRE: 95%

- Equipment Costs

- \$820,000

## Recirculation Booth w/ VOC Concentrator

- Utility Usage
  - Natural Gas: 300 MBTU/hr
  - Electricity: 70 kW
- Annual Operating Cost
  - \$42,000

## Recirculation Booth w/ VOC Concentrator

- Technically sound solution
  - Emission control equipment of VOC concentrators is equivalently applicable, but at a smaller scale when utilizing recirculation.
  - The alterations in booth conditions must be evaluated to ensure no undesirable internal environments are allowed.
- Economically the Ultimate Solution

# Economic Summary

	<b>RTOs</b>	<b>Concentrators/ RTO</b>	<b>Recirculation/ Concentrator/ Oxidizer</b>
<b>Emission Control System Costs</b>	<b>\$ 3,300,000</b>	<b>\$ 2,500,000</b>	<b>\$ 820,000</b>
<b>Annual Operating Costs</b>	<b>\$ 1,050,000</b>	<b>\$ 300,000</b>	<b>\$ 42,000</b>
<b>10 year Total Costs</b>	<b>\$ 13,800,000</b>	<b>\$ 5,500,000</b>	<b>\$ 1,240,000</b>
<b>Cost of Control \$/ton Solvent NOT emitted</b>	<b>\$ 14,332</b>	<b>\$ 5,893</b>	<b>\$ 1,329</b>

	<b>Concentrators/ RTO</b>	<b>Recirculation/ Concentrator/ Oxidizer</b>
<b>Emission Control System Costs</b>	<b>\$ 2,500,000</b>	<b>\$ 900,000*</b>
<b>Annual Operating Costs</b>	<b>\$ 300,000</b>	<b>\$ 42,000</b>
<b>10 year Total Costs</b>	<b>\$ 5,500,000</b>	<b>\$ 1,320,000</b>

\* Adding in costs for additional equipment and instrumentation required for recirculation booth design and additional process engineering with related safety controls

- **Decreased ventilation half-life**
  - The ventilation half life increases with the lower amount of fresh make-up air and there are fewer air changes in the booth per period of time.
- **Increased equilibrium contaminant levels**
  - Exhausting less and bringing less fresh make up in increases equilibrium contaminant levels
- **Increased booth temperatures**

- Only dependent on the booth (or room) size and the exhaust rate:
  - $t_{1/2}$  = Ventilation Half-life
  - $V$  = Booth Volume
  - $R$  = Exhaust Volumetric Flow Rate
- For Example Scenario = 6.93 minutes

$$t_{1/2} = \frac{\ln(2) \cdot V}{R}$$

- Level of build up of recirculated substances:
  - $C_{eq}$  = Equilibrium Concentration
  - $S$  = Introduction Rate
  - $R$  = Exhaust Volumetric Flow Rate
  - $V_b$  = Booth Volumetric Flow Rate

$$C_{eq} = \frac{S}{R} \left( 1 - \frac{R}{V_b} \right)$$

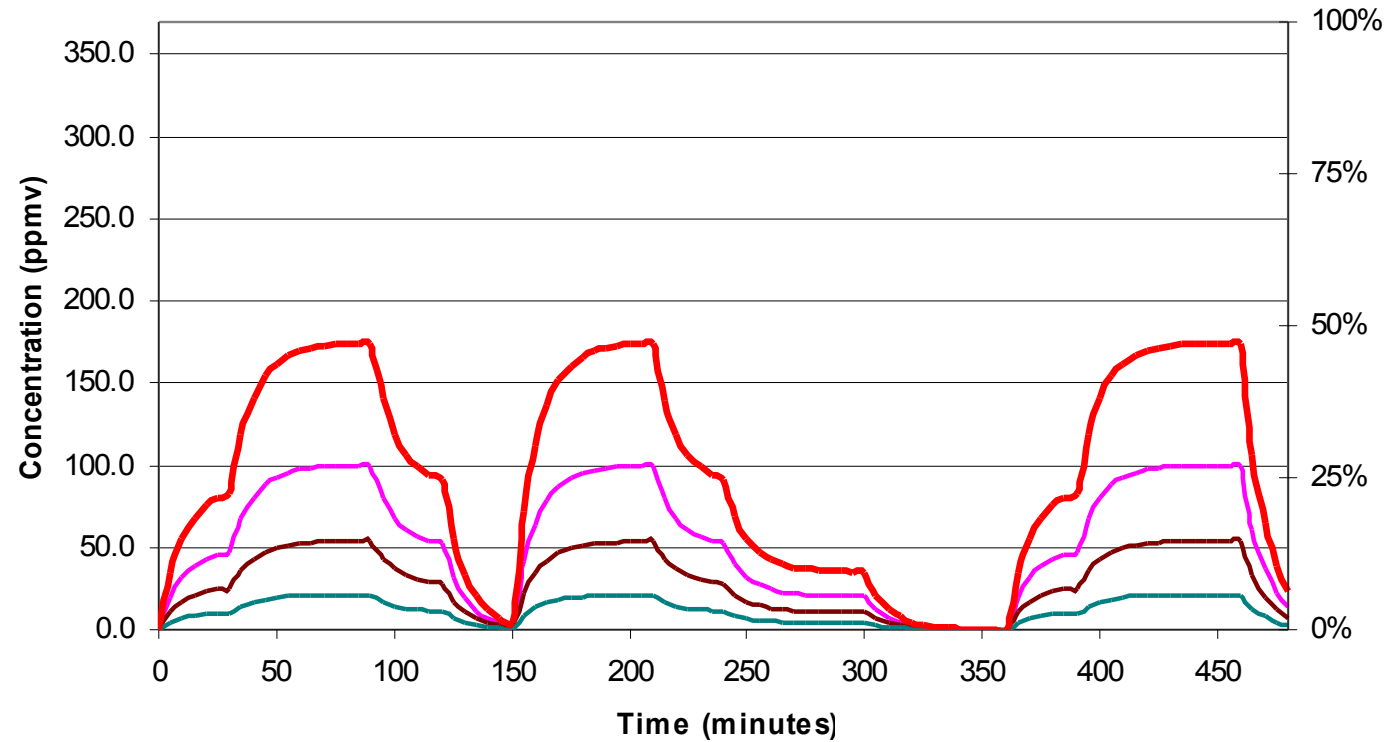
# Filtration Consequences

- Utilize Dry Filtration to prevent undesirable high equilibrium humidity levels
- Utilize more efficient or an additional stage of particulate matter (PM) filtration to prevent a noticeable increase in booth PM levels.

- Solvent equilibriums for the example scenario at the maximum possible application rates (ppmv):

	Exhaust	Booth
● Acetone:	125	100
● MEK:	67	54
● Toluene:	26	21
● Total:	218	175

Booth VOC Concentrations over 8 hour shift



Acetone    MEK    Toluene    Total VOC    Spray Flow

- Lower Explosive Limit (LEL) comparison:

	LEL* (ppmv)	Max. % LEL
● Acetone:	26000	0.5%
● MEK:	18000	0.4%
● Toluene:	14000	0.2%
● <b>Total:</b>	<b>21000</b>	<b>1.0%</b>

\*per Table G-11 OSHA 1910.94(c)(6)(ii)

- 8 hour Time Weighted Average (TWA) Permissible Exposure Level (PEL) comparison:

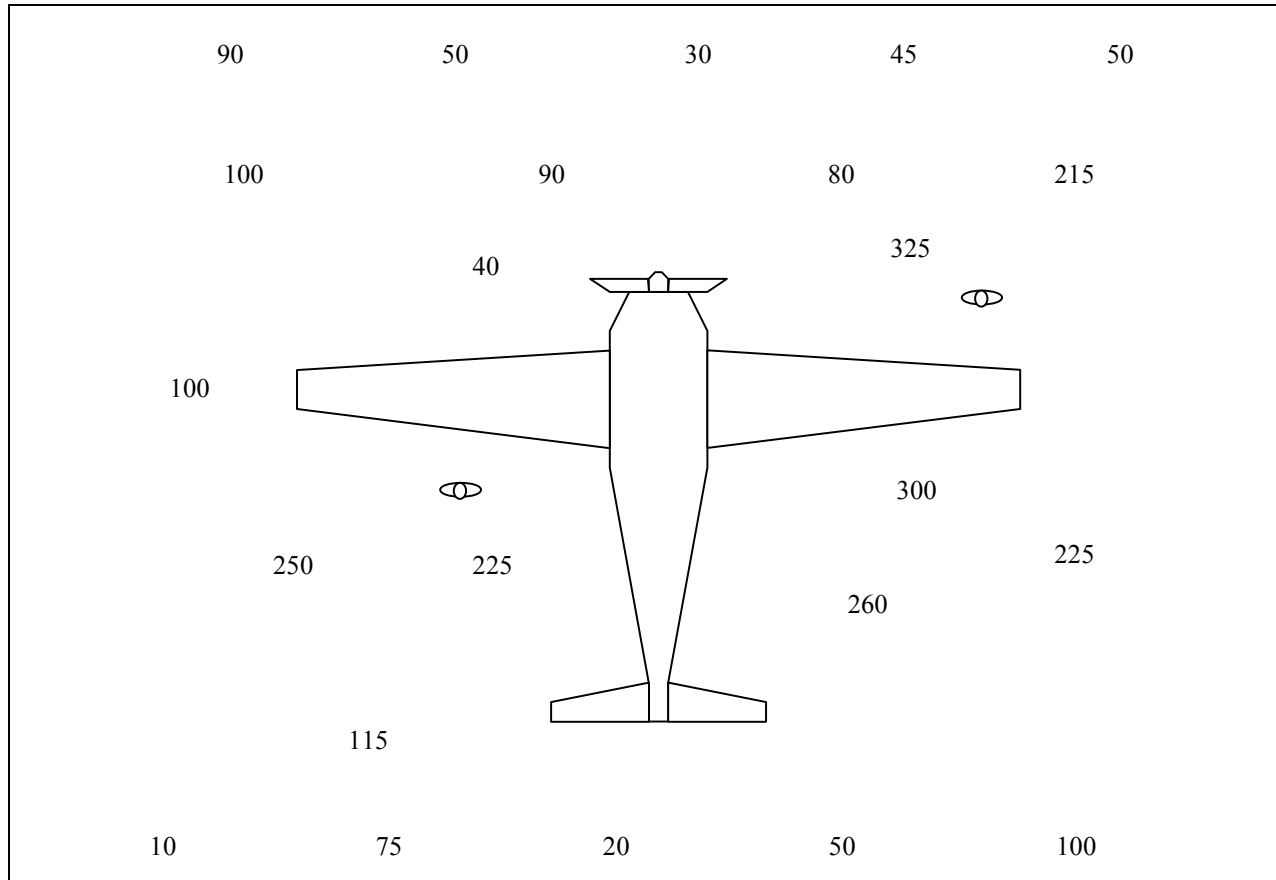
	PEL* (ppmv)	Max. % PEL
● Acetone:	1000	10%
● MEK:	200	27%
● Toluene:	200	11%
● <b>Total:</b>	<b>369</b>	<b>47%</b>

\*per OSHA 1910.1000

- Using the 8 hour TWA the equivalent exposure **w/o PPE** would be 25.7% PEL

- The above simplistic theoretical equations accurately show overall average solvent level increases, but do not model the booth concentration gradients due to finite dispersion rates.
- Near spray sources, local solvent concentration levels of once through booths can be higher than the equilibrium levels generated due to recirculation.

# Booth Survey



Standard manual once through spray booth VOC survey

- Recirculation leads to slightly higher booth temperatures due to heat and energy losses warming the recirculating air stream.
  - Fans, Lights, People, etc.
- Assuming in the example scenario there is 246,000 BTU/hr of heat losses due to recirculation fan air movement, lights, personnel and equipment.
  - Leads to a 4.5°F increase in booth temperature

- The lower make-up air flow rates make heating and cooling a recirculation booth more economical
- Heating cost savings for the example booth would be approximately \$18,000/yr (in an area requiring about 10000°F·hr of annual heating)
- Cooling cost savings for the example booth would be approximately \$13,000/yr (in an area requiring about 10000°F·hr of annual cooling)
- Also capital equipment savings available utilizing smaller HVAC systems

- Isn't "Thou shall not recirculate" written on some stone tablets?
  - Only considering internal environments, it makes complete sense to exhaust as much as possible to make the contaminants the rest of the world's problem.
  - Although regulations and standards evolve slower than technology, there is more consideration for the balance between internal and external environmental impact.

- Isn't it black and white in OSHA 1910.107(d)(9)?
  - *Air exhaust.* Air exhaust from spray operations shall not be directed so that it will contaminate makeup air being introduced into the spraying area or other ventilating intakes, nor directed so as to create a nuisance. Air exhausted from spray operations shall not be recirculated.

- The OSHA interpretation letter of September 17, 2001 shows that it is a grey area:
  - ... employers that **fully** comply with NFPA 33-2000, Section 5.5, Recirculation of Exhaust, (including subsections 5.5.1 through 5.5.2), would not be cited under 1910.107(d)(9).

- National Fire Protection Association (NFPA) 33- Standard for Spray Application Using Flammable or Combustible Materials
  - Primary objective of ventilation is to maintain solvent levels below 25% LEL

- Section 5.5.1 exception requirements for unmanned booths:
  - (a) *Solid particulates have been removed from the recirculated air.*
  - (b) *The concentration of vapors in the exhaust airstream do not exceed 25 percent of the lower flammable limit.*
  - (c) *Listed equipment is used to monitor the concentration of vapors in all exhaust airstreams.*
  - (d) *An alarm will sound and the spray operation will automatically shut down if the concentration of any vapor in the exhaust airstream exceeds 25 percent of the lower flammable limit.*
  - (e) *Equipment installed to process and remove contaminants from the air exhausted from spray operations is approved by the authority having jurisdiction.*

- Section **5.5.2** states the provisions of 5.5.1 shall not disallow the use of recirculated air to occupied spaces. However, other requirements addressing the toxicity and the permissible exposure limits shall also apply.
  - Refer to appropriate occupational safety and health and industrial hygiene standards for permissible exposure limits such as ANSI Z9.7, *Recirculation of Air from Industrial Process Exhaust Systems*.

- Example section 4.2 guidelines:
  - Do NOT recirculate 100% of booth air.
  - Perform a documented hazard evaluation as part of the design process.
  - Perform continued contaminant monitoring and work area evaluations when the system is operational.

- NFPA 33-2000: Standard for Spray Application Using Flammable or Combustible Materials
- OSHA 1910.94: Occupational Health and Environment Control- Ventilation
- OSHA 1910.107: Hazardous Materials- Spray finishing using flammable and combustible materials
- OSHA 1910.1000: Toxic and Hazardous Substances- Air contaminants
- ANSI/AIHA Z9-7-2007: Recirculation of Air from Industrial Process Exhaust Systems

- Flammability / Explosion concerns
  - Maximum expected 1% LEL well below the 25% guidelines.
  - SAFE with implementing NFPA section 5.5.1 requirements
- Exposure concerns
  - Maximum expected levels approaching 50% PEL
  - SAFE only with PPE to bring maximum exposures down to at least below 10% PEL values, utilizing LEL monitors accurate at the lower concentrations for exposure monitoring, and conducting periodic booth surveys.

- Is Concentrator technology applicable?
  - Yes
- Can I recirculate?
  - Yes
- Are additional flammability hazards addressed?
  - Yes
- Are additional exposure hazards addressed?
  - Yes
- Do I want to save lots of money?
  - Yes
- I'll take an 80/20% Recirculation Booth with a 40,000 SCFM Concentrator/ 3000 SCFM Oxidizer combo on the side, please.

- Emission Control Technologies
- Economics
- Recirculation Quantitative Effects
- Ventilation Regulations

- VOC Concentrator technology and properly engineered recirculation booth technology provides an economically feasible means to minimize air pollution emissions from applicable spray finishing operations while continuing to maintain a safe working environment.
- With Safety being the overriding principle, each application must be properly evaluated to ensure that the respective technologies can be applied with minimal deviation in risks.

# Air Emissions Control in Spray Finishing Applications

C A T A L Y T I C  
C O M B U S T I O N

A stylized logo for Catalytic Combustion. It features a globe in the center, partially obscured by a thick, black, curved swoosh that arches over the top and under the bottom. The words "CATALYTIC" and "COMBUSTION" are written in a bold, sans-serif font, with a horizontal line separating the two words. The letters are white with a black outline.