

REINHOLD ENVIRONMENTAL Ltd.



**2012 Coal to Gas Conversion Round Table
& Expo Presentation**

October 23, 2012, Chattanooga, TN / Sponsored by TVA

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The Chemical Company

Reinhold Environmental 2012 Coal-to-Gas Round Table

Hosted by TVA

The Chattanooga Marriott Hotel

Chattanooga, TN

October 23-24, 2012

Presented by

Nancy Stephenson, Cormetech, Inc.

Catalytic Emission Control Coal-to-Gas Boiler Systems



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The Chemical Company

BASF is the leading supplier of *oxidation* catalyst technology

- > 20 Years Experience
- > 750 CO-VOC Catalyst Applications, GT Power

CORMETECH, Inc. is the leading supplier of *reduction* catalyst technology

- > 20 years Experience
- > 1,200 NOx Catalyst Applications, Power/Process Systems
- > 35 Utility Gas Boiler SCRs

Together, have only Gas Fired Utility Boiler Experience with integrated NOx and CO controls, 95% Efficiency

Coal-to-Gas Conversion

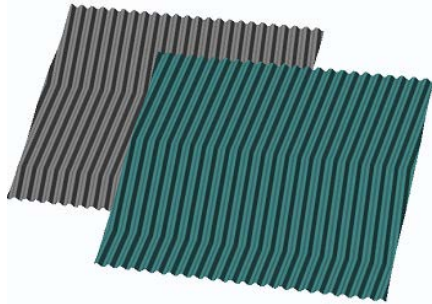
CO & VOC Focus



- EPA Emission Factors: Consider Rates on Gas, Permitting
- Background on CO-VOC Catalysts
- Range of Applicability: Co-Firing, Switching, NG Only
- Example Plant
 - No Catalytic Controls in Place Now
 - 200-250 MW
 - CO conversion 90%
 - VOC conversion (? tbd)
 - Bed Location Importance
- Balance of Plant Impact, incl NO_x/SCR Controls
- Practical Considerations

CO-VOC Catalysts

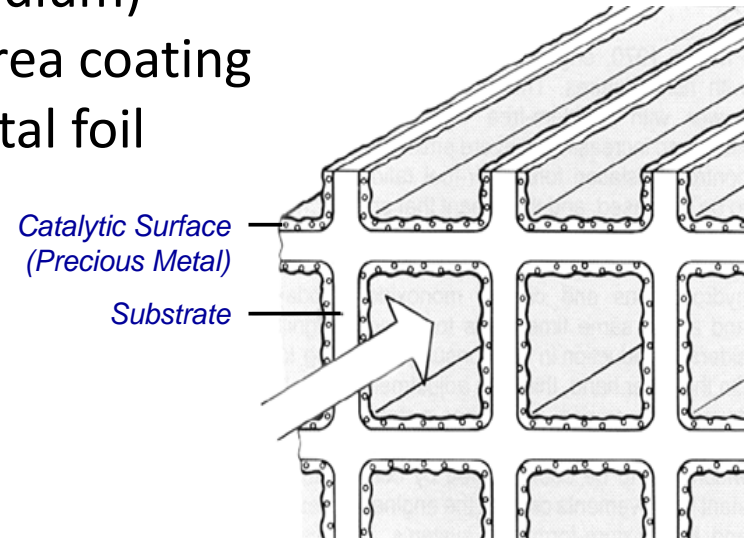
Precious metal (e.g. platinum, palladium)
Dispersed through a high surface area coating
Substrates are ceramic block or metal foil



Herringbone Foil



Ceramic



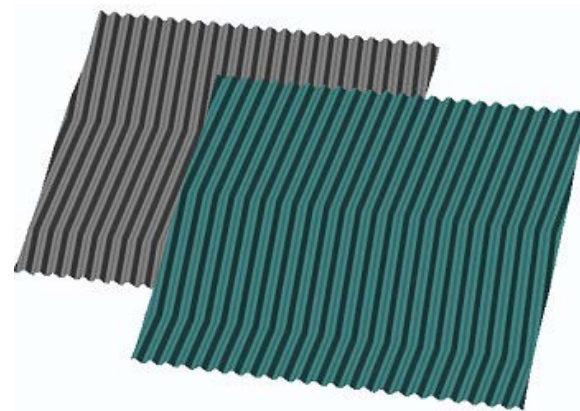
Schematic of honeycomb oxidation catalyst

Oxidation Catalyst is a Surface Coated Technology

Characteristics

- Low Pressure Drop, typ 1"
- Customized to Duct
- Ceramic Can be Washed to Extend Life
- Ceramic Resistant to Acid Gas Environments
- No Reagents Needed
- Requires Low-No Sulfur
- Requires Low-No Dust in Flue Gas

Plugging, Erosion



CO-VOC Emissions Profiles

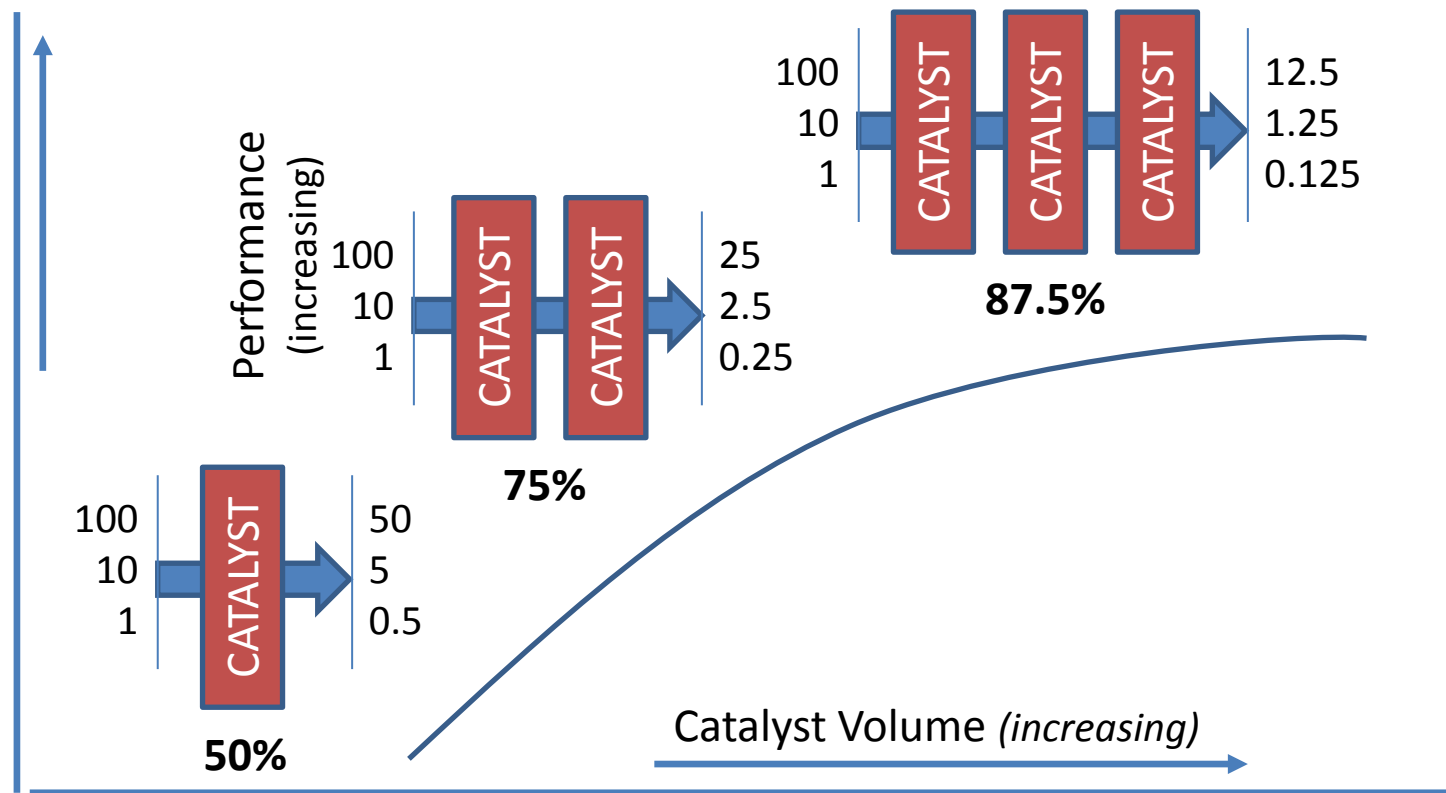


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- Natural gas boiler combustion may not yield the same CO-VOC profile as natural gas turbine combustion
- Predictive Modeling lacks Reliable Database
- CO-VOC levels need to be defined at all loads and operating conditions (temperature, flow)

Catalyst Volume Impacted by Required Conversion Rate



Oxidation catalyst is a “constant conversion” device – performance is independent of inlet concentration

VOC – Catalyst Perspective



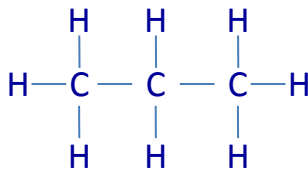
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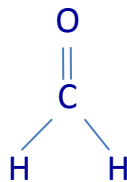
“VOC” represents a class of compounds

- EPA CFR 51.100(s) Definition – Volatile organic compounds (VOC): “...any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric photochemical reactions.”
- EPA CFR 51.100(s)(1) “[VOC includes] ...any such compound other than the following, which have been determined to have negligible photochemical reactivity: methane, ethane,...”

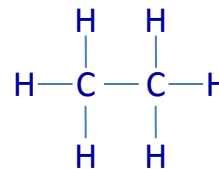
There is no one compound that may characterize the reaction of all VOCs across a given oxidation catalyst technology



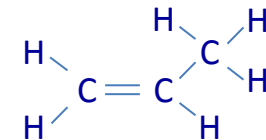
Propane
VOC & Saturated HC



Formaldehyde
VOC but not a HC



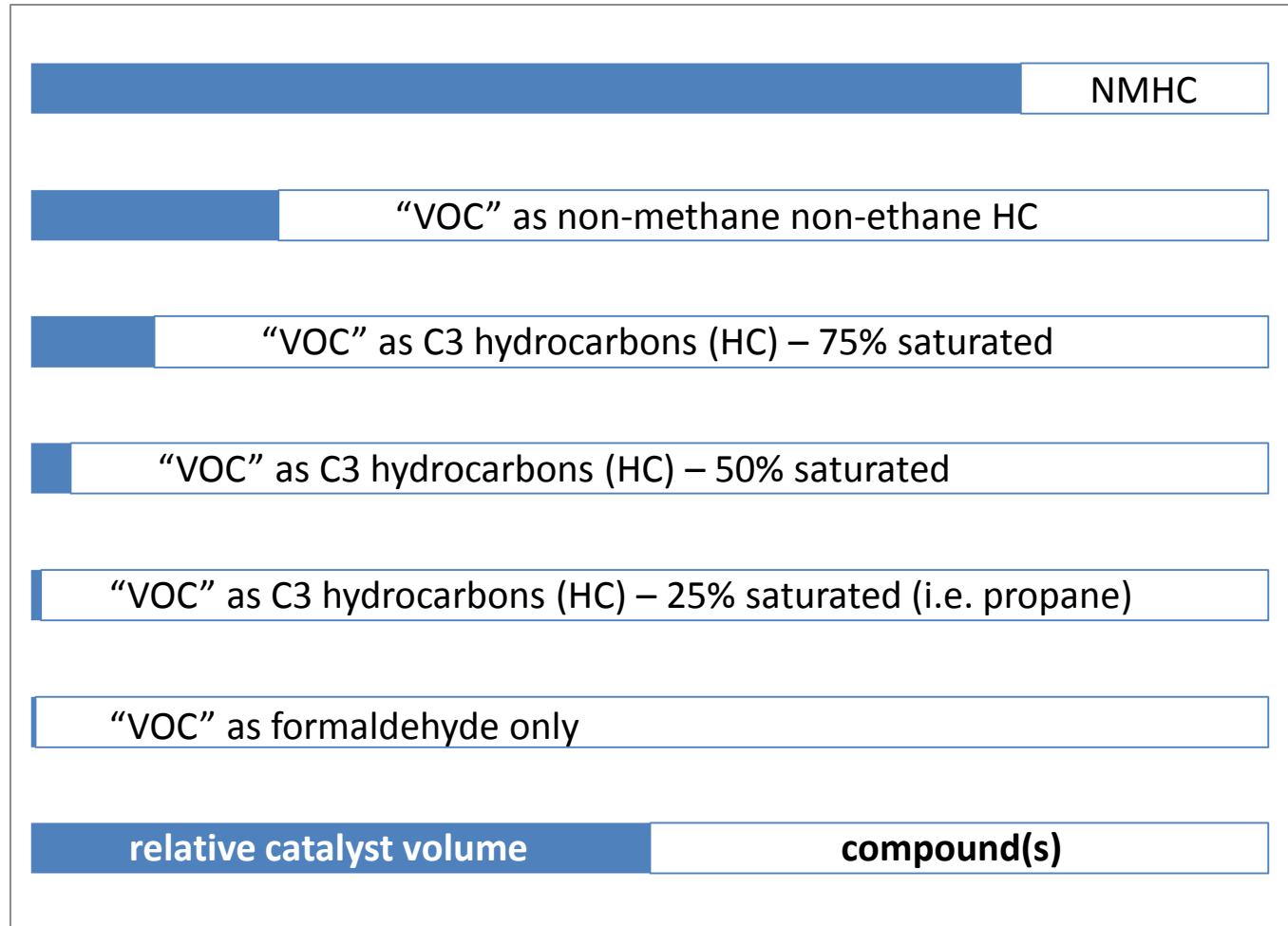
Ethane
HC but not a VOC



Propylene
VOC & Unsaturated HC

"VOC" Definition Criticality

Example: 50% VOC Oxidation Design



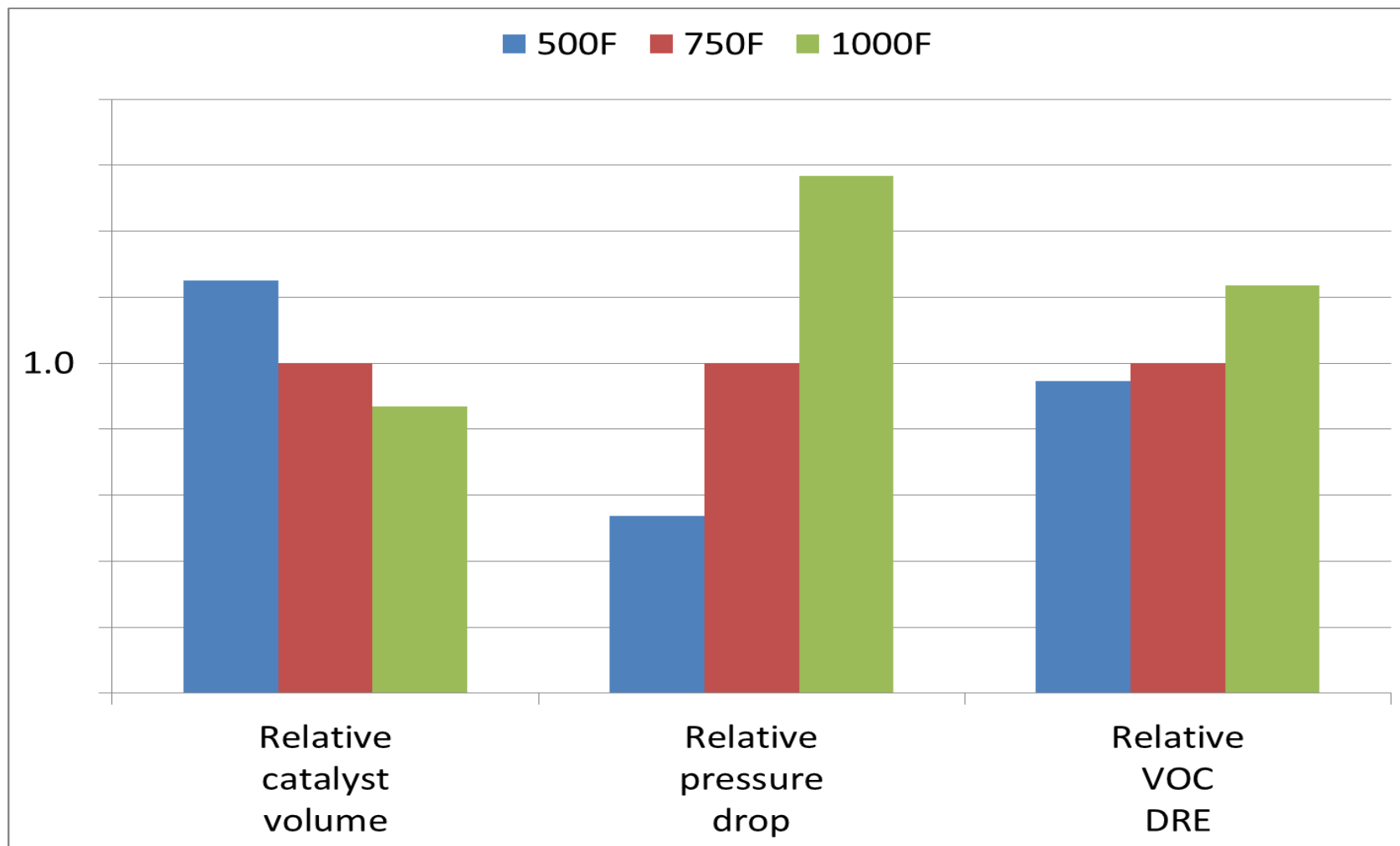
VOC Definition : Gas Turbines



- Has evolved to jointly mesh the technology of catalysts with clarity needs of regulators
- VOC performance requirements on GTs typically set as “what comes along” with CO performance
- Natural Gas Boilers do not mimic the combustion characteristics of natural gas turbines and, therefore, should be characterized without penalty until well understood

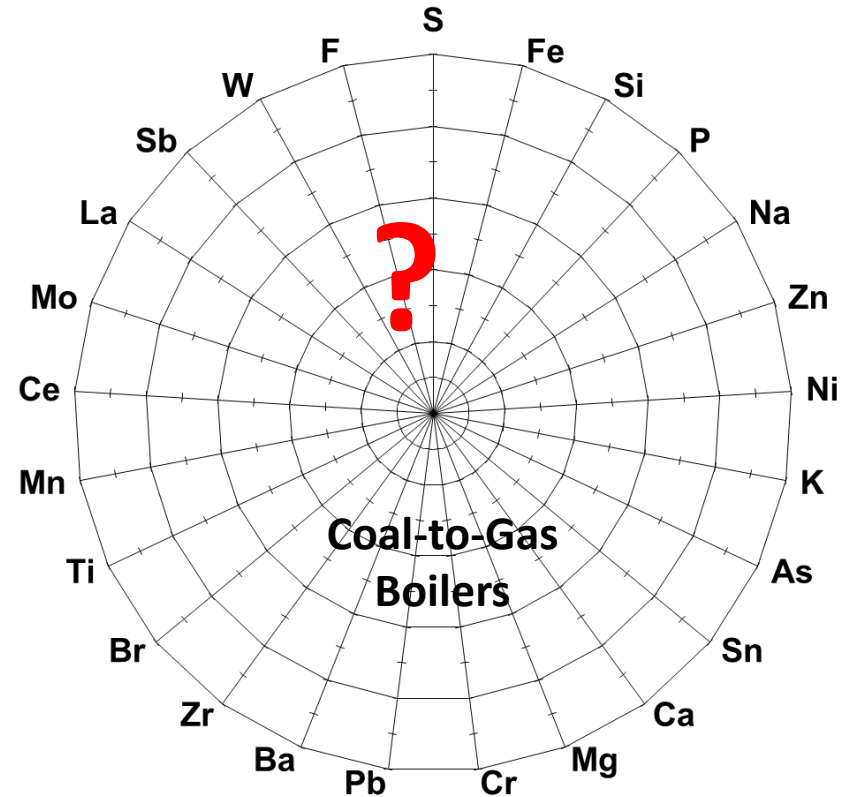
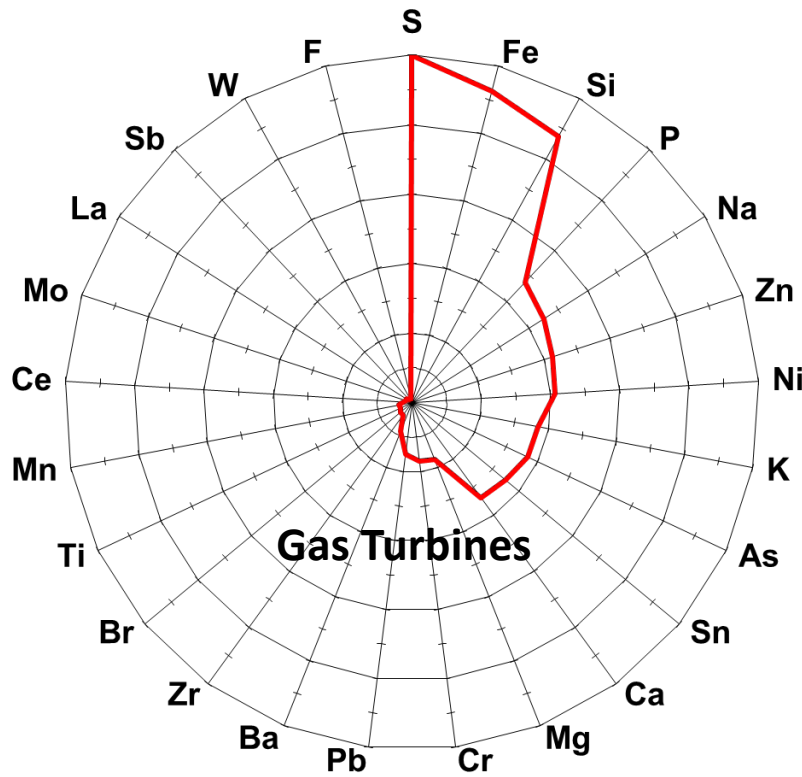
VOC Gas turbine \neq VOC Coal-to-Gas Boiler

Importance of Location Temperature Impacts



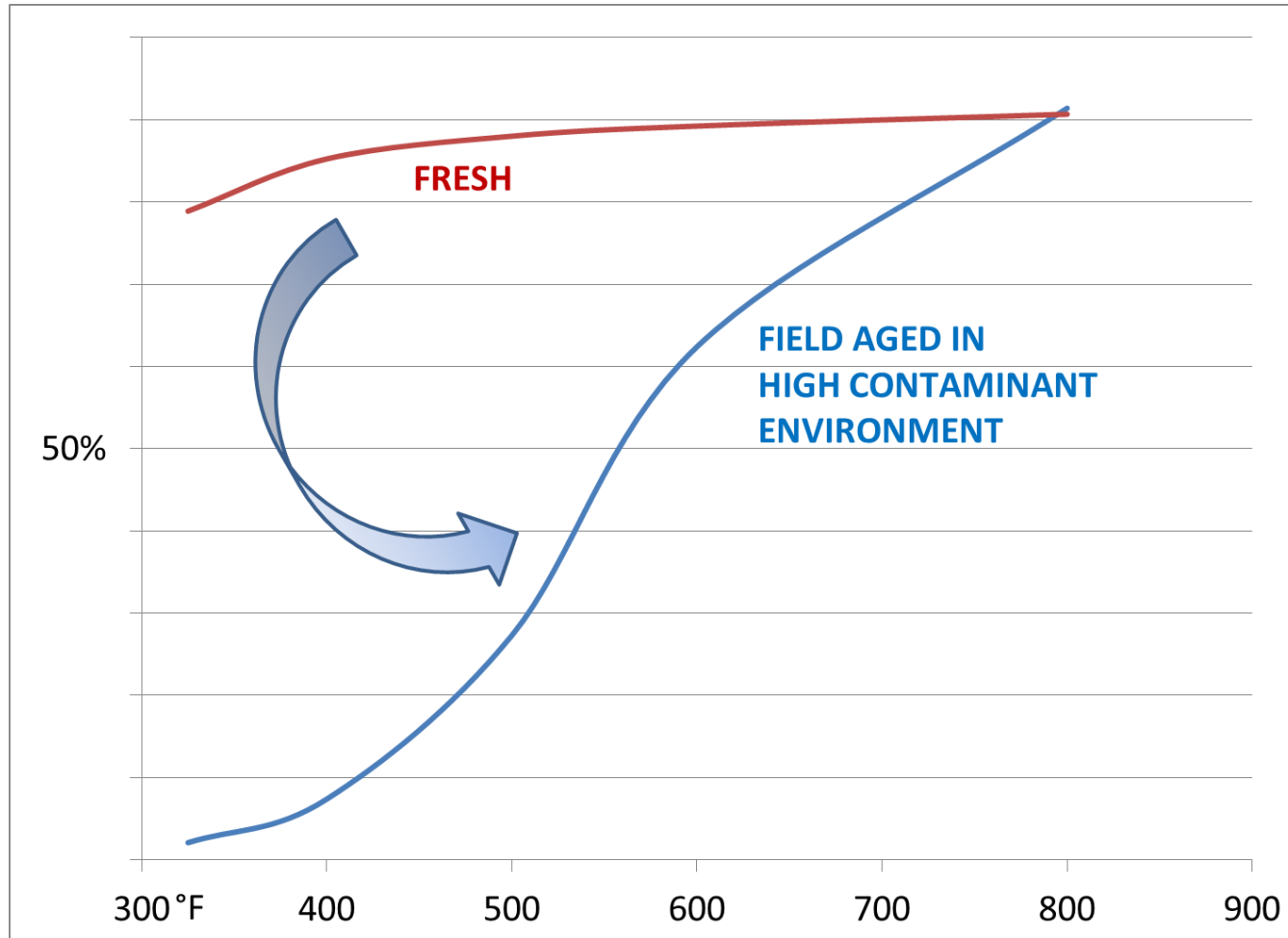
Oxidation Catalyst Contaminants

Element deposition frequency on oxidation catalyst:



Contaminants

Lower Temperature Impacts



Oxidation Catalyst Constraints in Fuel Switching



- Reverse fuel switching, from natural gas back to coal, would necessitate the physical removal of the oxidation catalyst before switch is made to avoid significant premature deactivation due to physical masking and chemical poisoning agents unique to coal (e.g. arsenic).
- Sulfur attacks CO catalyst and oxidizes SO_2 to SO_3
- Ash would erode the catalytic coating
- Upstream ducting needs to be clean; even consider water washing

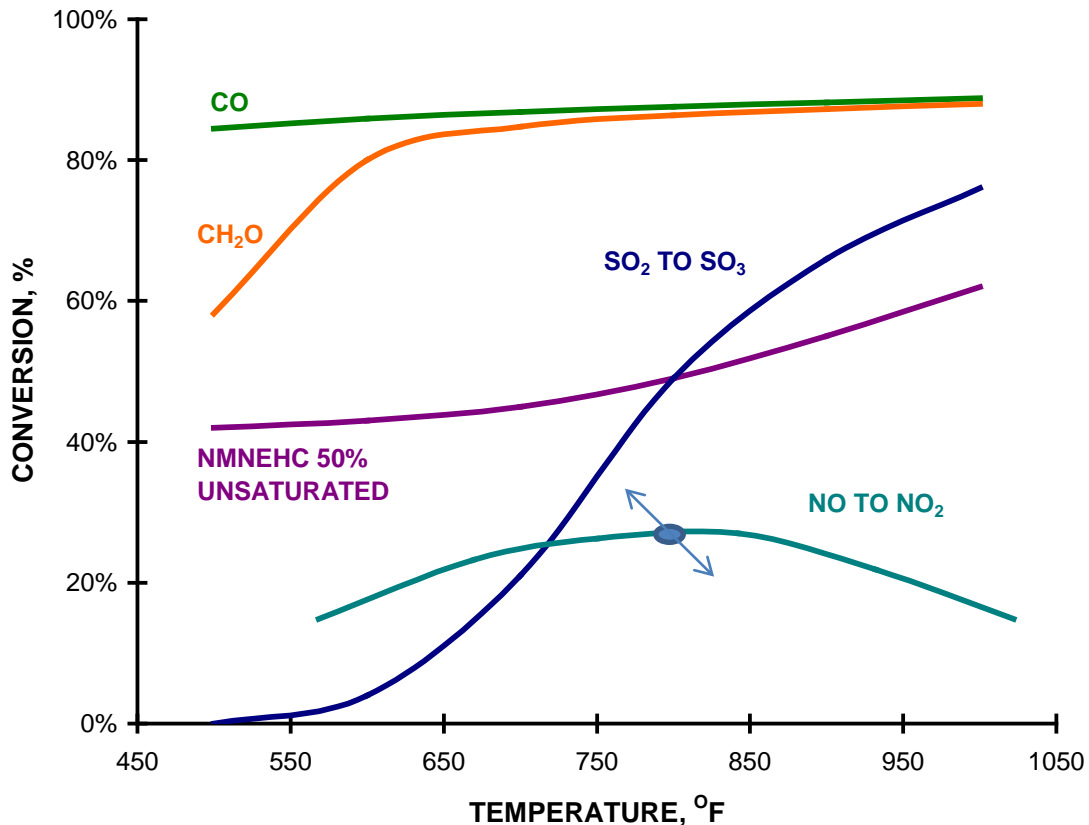
Oxidation Catalyst Impacts

Example: Stationary Engine CO Design Driven by Application & Catalyst Design



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Everything that contacts the catalyst is oxidized, but not necessarily to the same degree (“**activity**”).

Catalyst performance determined by **catalyst surface area** (i.e. residence time) and **temperature**.

Catalyst formulations may be customized to enhance or inhibit certain reaction pathways (“**selectivity**”).

Oxidation catalyst is a “passive” technology –
no active control of performance

Example Plant: Natural Gas Use Only



- 200-250 MW
- No Catalytic Controls in Place Now
(SCR enhances suitability)
- CO conversion 90%
- VOC conversion (? characterize)
- Bed Location Importance

Case Study: Natural Gas Operation



Boiler Load	Full
MWe	225
Fuel Type	NG
Gas Flow – Wet (lb/hr)	1,833,000
Flue Gas Composition:	
CO2 (vol. %, wet)	9.2
H2O (vol. %, wet)	18.9
N2 (vol. %, wet)	70.7
O2 (vol. %, wet)	1.2
SO2 (ppmvd @ actual O2)	negl.
SO3 (ppmvd @ actual O2)	negl.
Inlet Nox to SCR (ppmvd @ actual O2)	108
Nox, lbs/hr as NO2	268
Particulate Loading (gr/dscf)	negl.*
Flue Gas Temperature (F)	730
Velocity Distribution (%RMS)	15
Temperature distribution (± °F)	20

* Particulate does not include residual ash in duct from prior coal combustion

Option #1

Oxidation Catalyst Option - Baseline

20 ft x 48 ft duct cross-section

18 ft x 44.5 ft catalyst bed cross-section

3 inch catalyst depth

105 cells per square inch substrate

200 ft³ +/- 20% total catalyst volume

90% CO DRE

44% VOC DRE - C3 HC 50/50 saturated

29% SO2 to SO3 conversion

12% NO to NO2 conversion

\$275 per 1,000 lb/hour

0.9 in.w.c. dP

108 inlet NOx

Assume 20ppm NO2, 88ppm NO

Outlet 30.6 ppm NO2

Stack tolerance from 120 inches_max to 78 inches_max

Notes:

1. Metal foil substrate design, typ for GT
2. Catalyst refc costs only; frame & installation extra
3. Ceramic substrate options yield higher costs, but are best suited to the operating environment

Case Study:

Locate Downstream, 550F



- ~ 15% increase in catalyst volume
- Significant increase in NO oxidation rate to NO₂
 - May have stack diameter implications for plume generation
 - Equilibrium favors NO₂ formation at lower temperatures

Option #2

Oxidation Catalyst Option @ 550F

20 ft x 48 ft duct cross-section

18 ft x 44.5 ft catalyst bed cross-section

3.5 inch catalyst depth

105 cells per square inch substrate

235 ft³ +/- 20% total catalyst volume

90% CO DRE

42% VOC DRE - C3 HC 50/50 saturated

2% SO₂ to SO₃ conversion

46% NO to NO₂ conversion

\$325 per 1,000 lb/hr

0.7 in.w.c. dP

108 inlet NO_x

Assume 20ppm NO₂, 88ppm NO

Outlet 60.5 ppm NO₂

Stack tolerance from 120 inches_max to 40 inches_max

Notes:

1. Metal foil substrate design, typ for GT
2. Catalyst refc costs only; frame & installation extra
3. Ceramic substrate options yield higher costs, but are best suited to the operating environment

Case Study:

Double Catalyst Volume, 730F



- 200% increase in catalyst volume to evaluate VOC benefit
- Small Benefit in VOC conversion
- Little contribution to VOC conversion from saturated C3 hydrocarbon
- Propane does not ignite across oxidation catalyst at 735F

Option #3

Oxidation Catalyst Option @ 2x Catalyst Volume

20 ft x 48 ft duct cross-section

18 ft x 44.5 ft catalyst bed cross-section

6 inch catalyst depth

105 cells per square inch substrate

400 ft³ +/- 20% total catalyst volume

99% CO DRE

49% VOC DRE - C3 HC 50/50 saturated

49% SO₂ to SO₃ conversion

14% NO to NO₂ conversion

\$550 per 1,000 lb/hr

1.8 in.w.c. dP

108 inlet NO_x

Assume 20ppm NO₂, 88ppm NO

Outlet 32.3 ppm NO₂

Stack tolerance from 120 inches_max to 74 inches_max

Notes:

1. Metal foil substrate design, typ for GT
2. Catalyst refc costs only; frame & installation extra
3. Ceramic substrate options yield higher costs, but are best suited to the operating environment

Example:

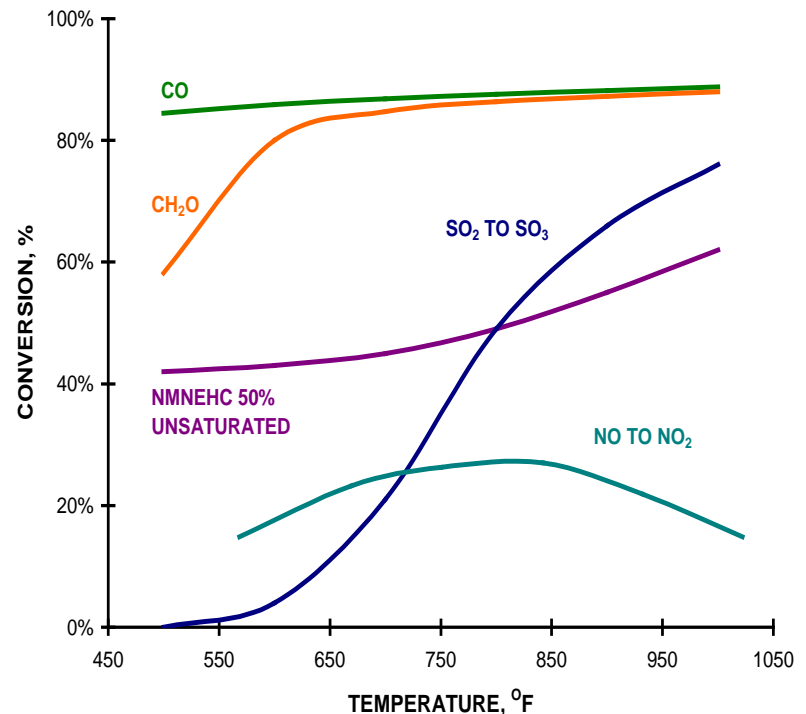
Impact on NO_x and SO_x



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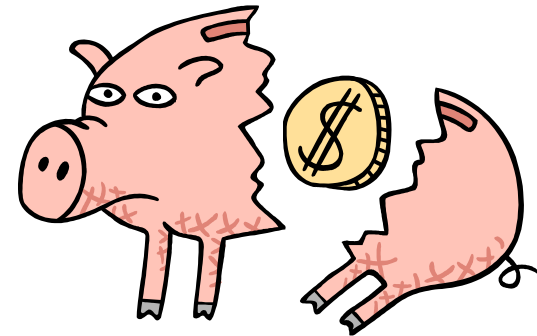
- Oxidation catalyst will convert
 - NO to NO_2 and
 - SO_2 to SO_3
- Increased NO_2 and H_2SO_4
Potential for brown (NO_2) plume generation in existing wide diameter stacks, as catalyst may shift NO/NO_2 ratio and raise the NO_2 concentration at the stack



By the Example: How Can we Assure?

Most Reliable but Costly

- Catalytically Control CO-VOC on Gas-Only and install SCR for NO₂ Mgt



Most Practical if Sufficient

- Manage combustion CO-NO_x balance in favor of CO
- Seek optimal efficiency vs CO emission and run against tonnage limit

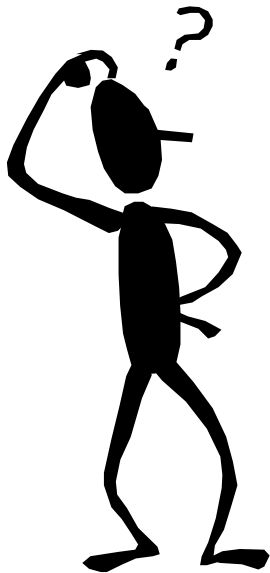


Summary



	NG Only	Coal : Gas Switching
Control CO	Combustion Tuning OR Catalyst	Bypass or Remove CO-VOC Catalyst when on any Coal
Consider/Control VOC	Must Characterize or Accept as Co-Benefit Catalyst Located >750F Zone Better	Co-benefit, characterize when on Gas
Control NOx	Trade-off in Favor of CO Control if possible If CO Catalyst needed, evaluate NO2, SO3 impact Install SCR if NO2 must be mitigated, balanced against emission caps and optimal designs	Run as Permitted on Coal On Gas, minimize NO2 if Catalytic for CO-VOC On Gas, tune for CO if no Catalytic controls
Operating Constraints	Need Flue Gas Distribution Balance w/Catalysts Boiler rust/scale so consider Catalyst Open Area and Ceramic Substrate Evaluate Stack Impact for Visibility	Take Offline and Fully Clean to Switch Fuels Accept Tonnage Cap if Catalyst Solution not a fit

QUESTIONS



Thank you

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