REINHOLD ENVIRONMENTAL ®

2023 Reinhold/PCUG Round Table Presentation

Cohosted by Duke Energy and Vistra in The Westin Hotel, Cincinnati, OH on June 26-27, 2023

Good Neighbor Compliance:
Adaptable NOx Control

Agenda

- Safety Share
- Introduction to Messer and Good Neighbor
- Ozone Injection Technology
- Case Study

Safety Share - Pennybacker Bridge, Austin

Safety Share - CO In and Around Boats

- Carbon Monoxide is a colorless, odorless gas
- Ranked among Top 5 causes of boating deaths
- Buildup near the swim deck can kill someone in seconds
- Avoid prolonged idling
- Maintain ventilation louvres and exhaust outlets
- Install a cabin CO detector
- Wear life jackets

Messer Americas

Gas Solutions That Unlock Opportunity

Products

Messer manufactures and supplies hydrogen, oxygen, nitrogen, argon, carbon dioxide, helium, specialty gases, and gas technologies so our customers thrive.

Key Markets

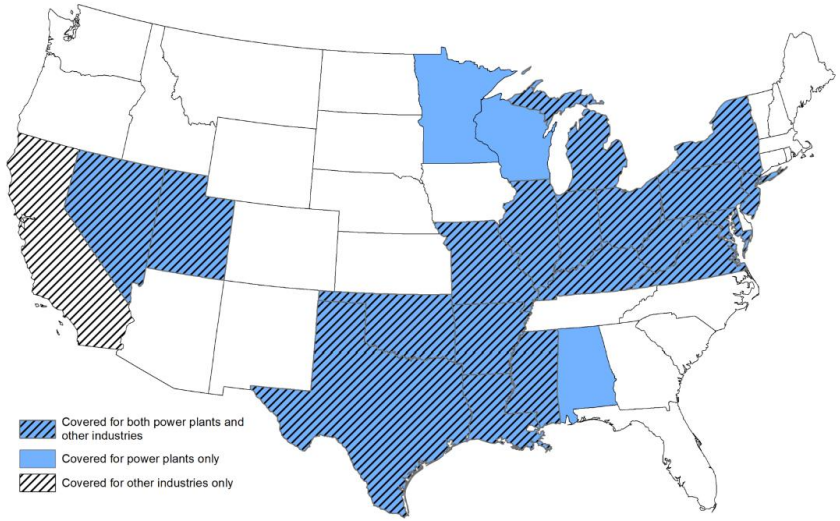
Food and Beverages | Metals | Chemicals and Specialties | Healthcare | Water Treatment | Electronics

Power Plant Applications

- Hydrogen for steam turbine cooling
- Nitrogen pumping services for plant turnarounds
- Oxygen for wastewater treatment and NOx reduction

Good Neighbor Rule History

Map of States Covered by the Final Good Neighbor Plan



- Driven by 2015 reduction of Ozone NAAQS to 70 ppb
- Promulgated March 15, 2023
- Targets EGFs in 22 states with several others at risk
- Latest in a long line of interstate transport rules:
  - 1998 - 1st Interstate Transport Rule
  - 2003 - NOx Budget Trading Program
  - 2009 - Clean Air Interstate Rule (CAIR)
  - 2015 - Cross-State Air Pollution Rule (CSAPR)
  - 2017 - Updated CSAPR
  - 2021 - Revised CSAPR
  - 2023 - Good Neighbor Rule
  - 20xx - ?

EPA's "Good Neighbor" Plan Cuts Ozone Pollution – Overview Fact Sheet (epa.gov)

Good Neighbor Rule Summary

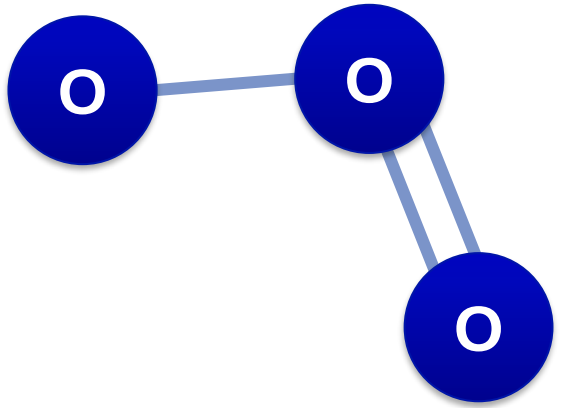
- 2023 reductions due to operation of existing equipment
- 2024-26 phased implementation of controls
- CSAPR Group 2 units rolled into Revised Group 3 Trading Program
- Dynamic budgets and annual recalibration
- Designed for NOx budgets to decline over time
- 3:1 allowance surrender over 50 TPY threshold
- Backstop emission limits
- Projected 14 GW of retirements and 8 GW of new SCR

EPA's "Good Neighbor" Plan Cuts Ozone Pollution – Overview Fact Sheet (epa.gov)

Ozone Injection from Messer

High-Performance NOx Removal Technology

- Patented technology uses ozone to oxidize insoluble NOx to higher oxides that are then captured in a wet or dry scrubber
- Rapid rate of reaction at typical scrubber inlet temperatures
- Short reaction zone minimizes need for duct modifications
- Stable and constant NOx control - regardless of load or concentration



Reaction Chemistry

Low-temperature oxidation process, operating below 350°F

1. **Converts insoluble NOx to highly soluble form (N_2O_5).**

$$NO + O_3 \rightarrow NO_2 + O_2$$

$$2NO_2 + O_3 \rightarrow N_2O_5 + O_2$$

2. **Very slow to oxidize SO_2.**

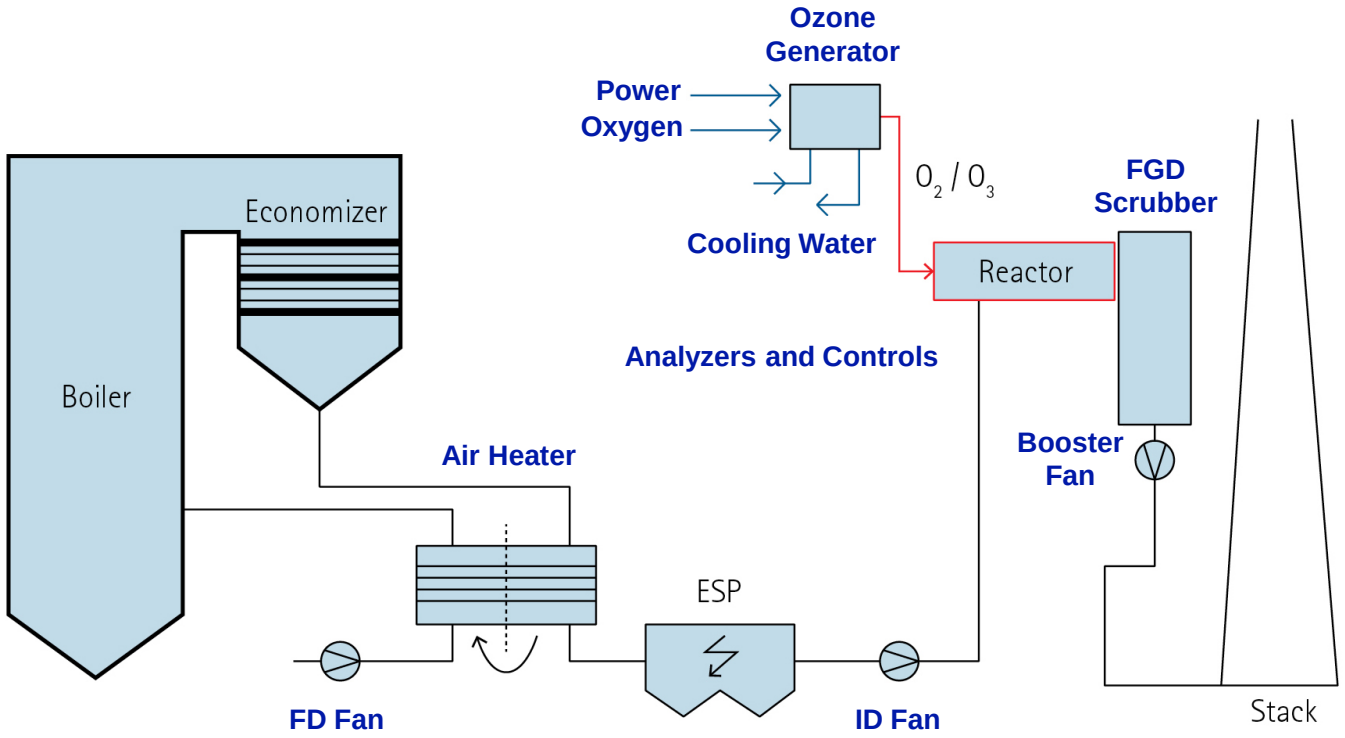
$$SO_2 + O_3 \rightarrow SO_3 + O_2 \quad \text{(Slow)}$$

3. **Oxidized NOx is very soluble in aqueous media**

Conversion of N_2O_5 into HNO_3 is rapid and irreversible, results in near-complete NOx removal.

$$N_2O_5 + 2\,H_2O \rightarrow 2\,HNO_3$$

Coal Fired Boiler System Schematic



Major Equipment

- O_2 storage tanks
- Vaporizers
- Ozone Generators
- Cooling Water/Chiller
- Ozone Transport/Injection
- Duct Work Modification
- Scrubber (if not existing)
- Electrical Supply
- BOP

Project Delivery

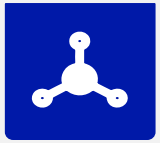
- **Technology, Services and License**
  - Feasibility study and demonstration
  - Process license
  - Basic engineering package, (Process description, control narrative for system integration into DCS, PFD, M&E Balance, P&ID, equipment specs, utilities, etc)
  - Support detailed engineering, (CFD of injection system, review drawings/documents etc)
  - Startup and troubleshooting
  - Process guarantees
- **Gas Supply and Equipment Leasing Options with Limited Term**
- **Complete Turn-key System Available through A&E Partner**

Technology Benefits

Highly Effective, Flexible and Easy to Retrofit

High NOx removal:
NOx removal rates of 95%+ of treated flue gas

Reliable:
Two decades of operating experience on flue gas streams; no catalyst deactivation



Ammonia-free:
No unwanted reactions with SO_3 and no deposition

Easy retrofit:
Post-combustion technology downstream of APH[3]; ozone plant located at grade

Adaptable:
System works across full load range; no MOT; no significant dP

Economic Flexibility:
Operating cost based on tons of NOx removed. Flexible gas supply contract terms

Commercial Installations

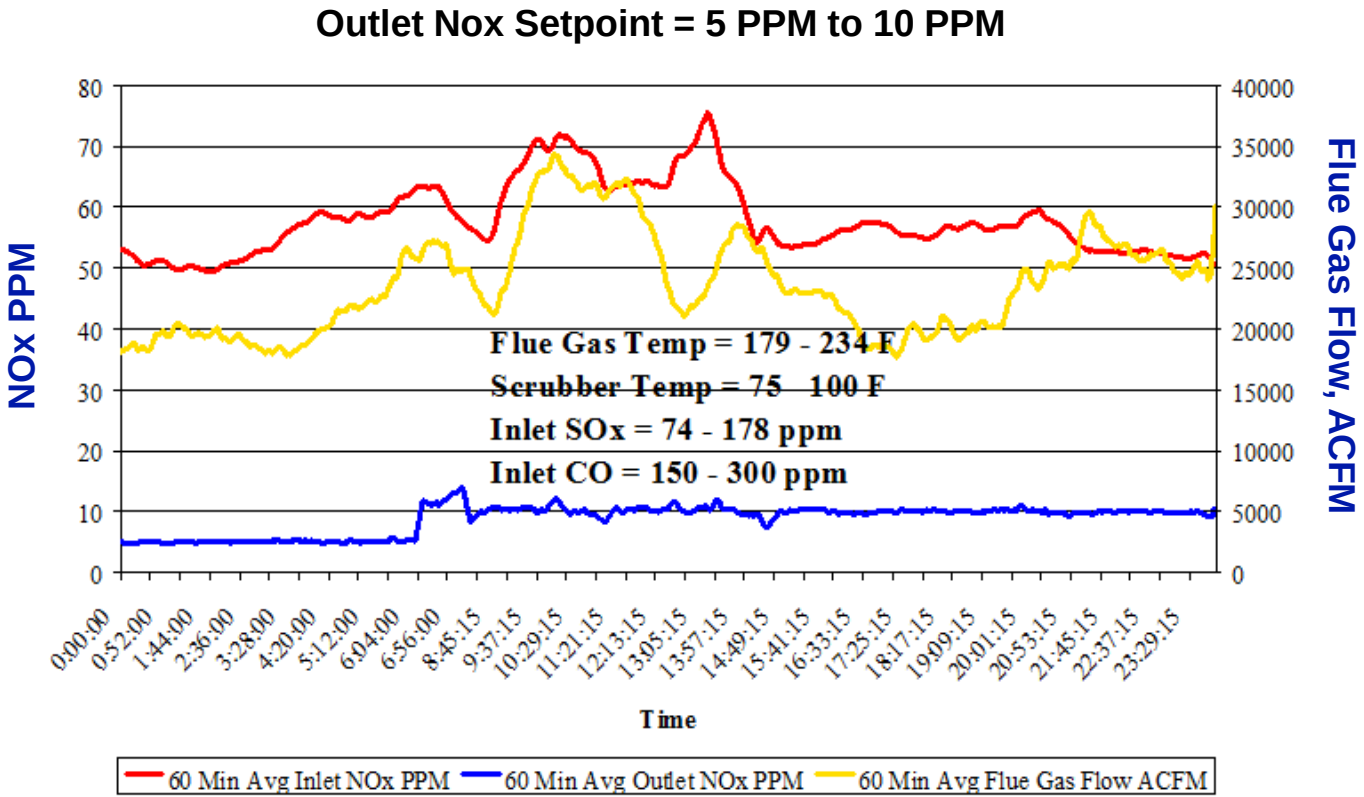
Application	Location	Year
Confidential Customer	USA	2023
Refinery	USA	2018
Refinery	Kazakhstan	2018
Chemical Plant	China	2017
Refinery	China	2016
Refinery	China	2016
Refinery	China	2016
Refinery	China	2016
Refinery	China	2016
Refinery	USA	2015
Refinery	USA	2015
Refinery	China	2015
Refinery	China	2015
Refinery	USA	2014
Refinery	USA	2014
Refinery	China	2014
Refinery	China	2014
Refinery	China	2014
15 Installations	USA	pre-2014
5 Installations	China	pre-2014

- First installation in 1997
- Initial wave of applications in US driven by refinery Consent Decrees
- Gas volumes up to equivalent of 80MW boiler
- 10+ units in the US operating continuously for over a decade

Coal-fired Boiler Experience

- EPRI pilot demonstration on 550 MW coal-fired power plant
  - 90%+ NO_x removal achievable
  - Indication of up to 50% Hg oxidation
- 25 MW coal-fired institutional boiler installation in 2001
- Numerous feasibility studies
- Potential to achieve lower removal rates by treating portion of flue gas

Results on 25 MW Coal Fired Boiler



Case Study: 220 MW Coal-fired Utility Boiler

Economic Comparison of SCR and Ozone Injection

- Affected source under Good Neighbor Rule
- 220MW Coal-fired Boiler
- Baseline NOx - 0.22 lb/MMBtu
- Capacity Factor - 70%
- Ozone Season NOx Controls - May through September

Case Study: 220 MW Coal-fired Utility Boiler

	Ozone Injection	SCR
Capital Cost, $M	29.6	110
Operating Cost, $M/year	1.9	1.6
20-year Cost-Effectiveness, $/ton	8,800	26,900
7-year Cost-Effectiveness, $/ton	13,900	49,600
Total Spend after 7 Years, $M	46.6	125

Questions?

Blake Stapper
Manager,
MC&C Application Development Team
Blake.Stapper@messer-us.com
Mobile +1 512-221-0081

Peter C. Studer
Chemistry, Energy & Environment
Program Manager
Peter.Studer@messer-us.com
Mobile: +1 908-656-0301


MESSER
Gases for Life
6795
12718
MESSER
Gases for Life
Messer LLC
US DOT 117394

Thank You!