SJVAPCD Rule Changes

SCR Technologies

AJ Feliz

Director of Engineering

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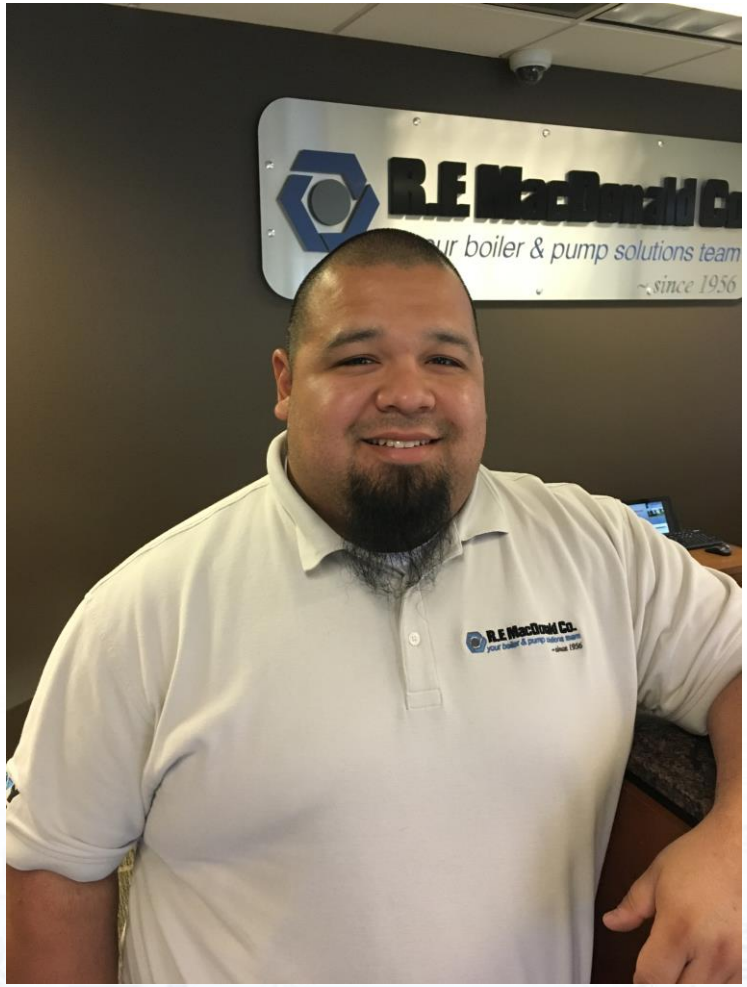
Introduction



- AJ Feliz
- Director of Engineering
- ME degree out of Cal Poly Pomona
- With R.F. MacDonald Co. for 18 years
- Specializing in custom emission control systems utilizing SCR

Applicability

San Joaquin Valley
AIR POLLUTION CONTROL DISTRICT

- Central Valley Counties
- Applies to:
  - Boilers
  - Steam Generators
  - Process Heaters
- Sizes >5 MMBtu/hr
- Approximately 1,273 units effected
- First deadline is May 1, 2022
- Compliance with both rules 4306 and 4320 is required

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Agenda

San Joaquin Valley
AIR POLLUTION CONTROL DISTRICT

- Overview of Boiler NOx Formation
- NOx Reduction Strategies
- SCR Applications
- Ammonia Sources
- Q&A

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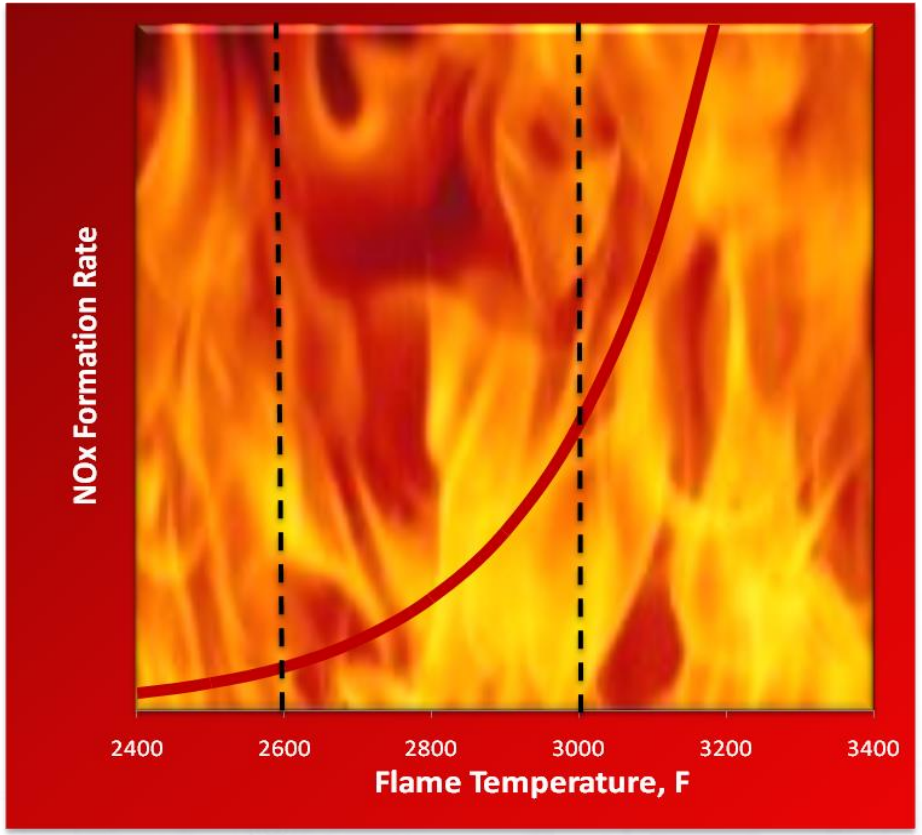
Overview of NOx Formation

- Boilers have burners which use combustion to produce heat to make hot water or steam
    - NOx is a by-product of combustion
- NOx is a pollutant contributing to:
    - Ozone, Particulate Matter, Acid Rain
- 3 Types of NOx Formation:
    - Thermal NOx
    - Prompt NOx
    - Fuel Bound NOx (not a concern if PUC gas)

Overview of NOx Formation

- Thermal NOx is the largest contributor to the overall total NOx
- Combustion: Fuel + Air(O_2+N_2) + Ignition
  - Ideal Combustion:
  - CH_4 +O_2+N_2 =>CO_2 +H_2O+N_2+O_2 +Heat
- Under high temperatures of combustion (> 2600F), Thermal NOx is formed:
  - N_2 + O_2 + Heat => NOx
- Thermal NOx is an exponential function of flame temperature



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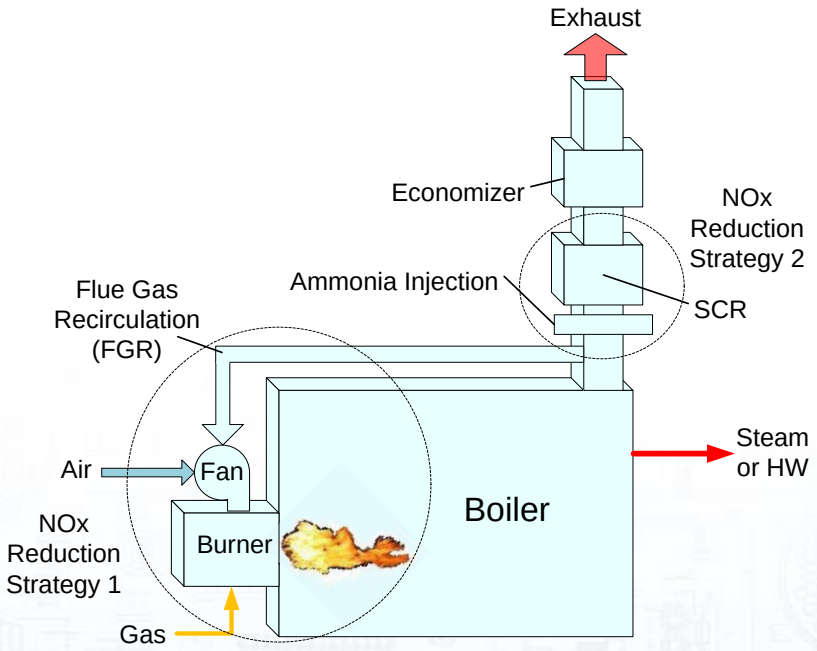
NOx Reduction Strategies 1 and 2

- (1) Burner Modifications or New Burner:
  - Available down to 5 ppm NOx
  - Less expensive than exhaust treatment solutions like SCR
  - Cost effective on boilers < 20 MM Btu
  - Can decrease efficiency depending on the NOx level & burner type, without additional upgrades
- (2) Exhaust Treatment (SCR):
  - Selective catalytic reduction (SCR) equipment added to treat the NOx after combustion
  - NOx reduction less than 2.5 ppm
  - To date, installed on water-tube boilers >8 MMBtu
  - More initial cost and continued maintenance than burner options
  - Less impact on efficiency



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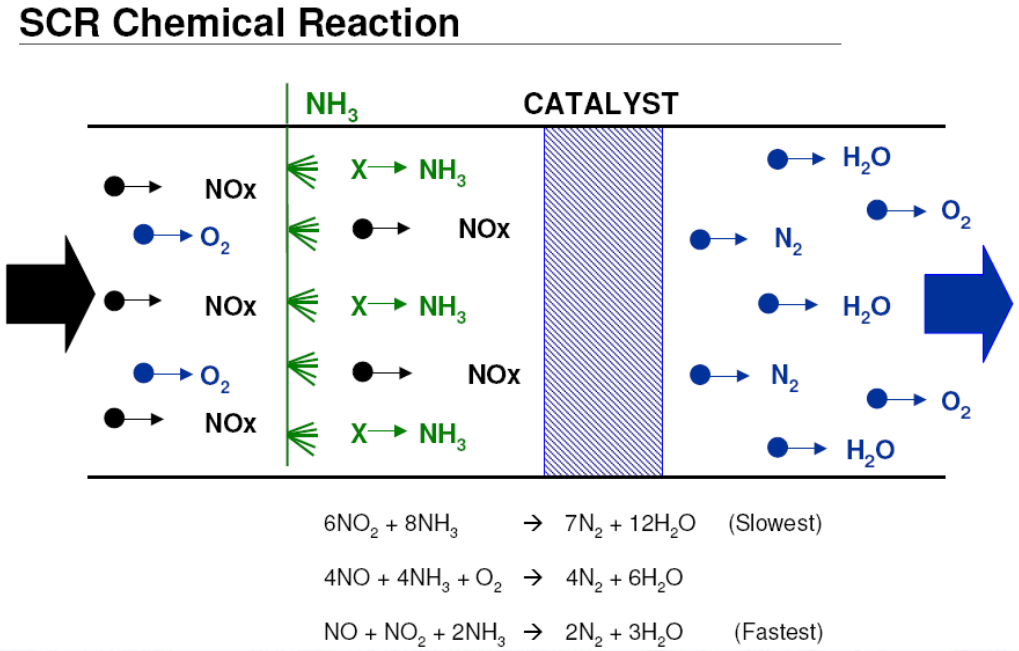
SCR Applications

- SCR can be applied to most Boilers, Steam Generators and Process Heaters
- SCR is proven technology
- Can meet Air District NOx Regulations <2.5 PPM with existing 30PPM burners
- Can achieve Ammonia Slip limit <5 PPM
- SCR more efficient than ULN burners
  - Up to 30% reduction in FD fan hp.
  - Can achieve lower burner turndown for better load matching and reduce cycling
  - Reduced FGR rates from 25% to 10%.
  - Reduced excess air from 25% to 10%.
  - Fuel-to-Steam efficiency gains of ½-1.0%

SCR Process

- The DeNOx process is a Selective Catalytic Reduction of nitrogen oxide (NOx)
- We convert NOx in a combustion flue gas, into harmless nitrogen (N_2) and water (H_2O) without forming any secondary pollutants.
- Ammonia (NH3) is mixed thoroughly with the flue gas by means of an injection grid (AIG), with or without static mixers, prior to the catalyst.



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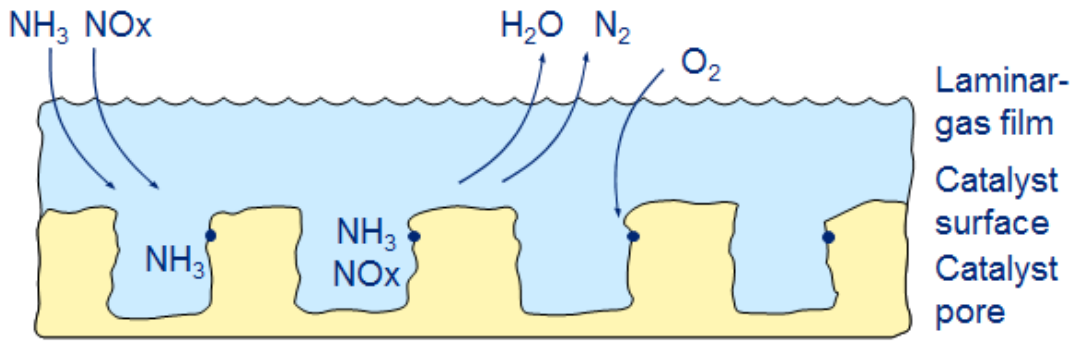
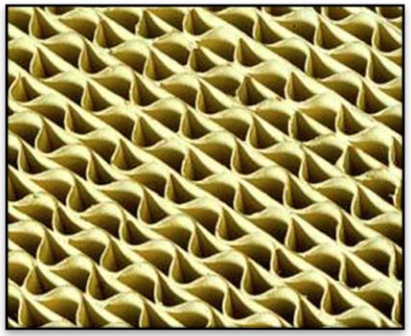
SCR Catalyst

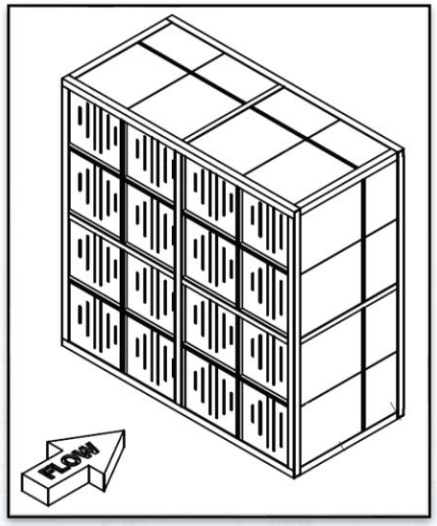
- Catalyst composition varies but typically includes some of these precious metals:
  - Titanium, Rhodium, Vanadium, Molybdenum
- Various technologies available but the ideal catalyst will be durable, have a low pressure drop and a large surface area.



SCR Catalyst



Umicore (corrugated)
Formerly Haldor-Topsoe



- Umicore is a market leader
- The catalyst we use is typically in stock
- Corrugated design is strong with a low pressure drop and compact (high surface area per unit of volume)
- Available as individual cassettes or prefabricated modules for easy loading
- Available for use with exhaust gases from 350^{o}F to 800^{o}F

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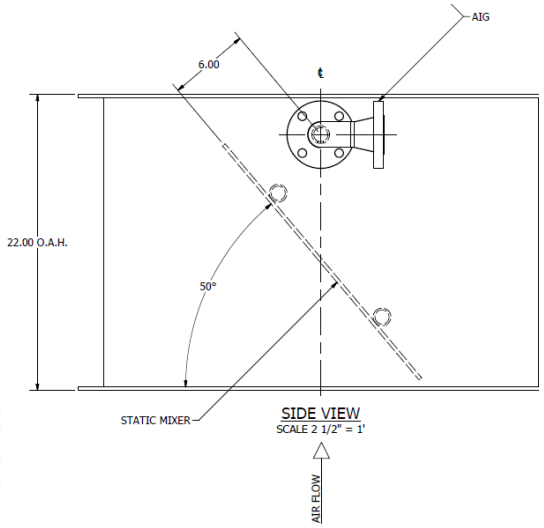
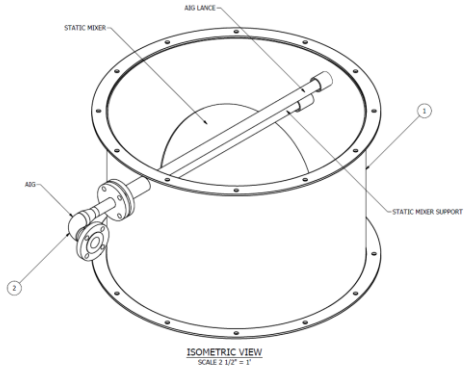
Ammonia Injection

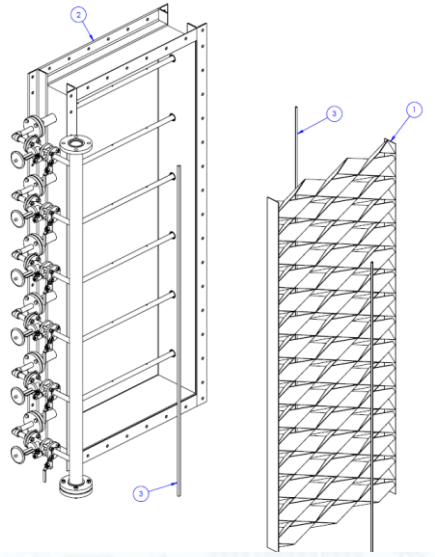
- Injection system must provide a uniform distribution of ammonia in the gas stream to assure all catalyst is utilized.

Single Point Injection





Multi-Zone Injection



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SCR Installation

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Ammonia Sources

- Common reacting agents (reagents)
  - Anhydrous Ammonia

- Preferred is grade 4: (refrigerant grade)
- Specification: 99.995% pure NH_3, 33ppm water maximum
- OSHA Permissible Exposure Limit (PEL) is 25ppm (CA only). Immediately Dangerous to Life and Health (IDLH) @300ppm

Health Hazard	
4	Very short exposure could cause death or serious residual injury even though prompt medical attention was given.
3	Short exposure could cause serious temporary or residual injury even though prompt medical attention was given.
2	Intense or continued exposure could cause temporary incapacitation or possible residual injury unless prompt medical attention is given.
1	Exposure could cause irritation but only minor residual injury even if no treatment is given.
0	Exposure under fire conditions would offer no hazard beyond that of ordinary combustible materials.

Flammability	
4	Will rapidly or completely vaporize at normal pressure and temperature, or is readily dispersed in air and will burn readily.
3	Liquids and solids that can be ignited under almost all ambient conditions.
2	Must be moderately heated or exposed to relatively high temperature before ignition can occur.
1	Must be preheated before ignition can occur.
0	Materials that will not burn.

Instability[1]	
4	Readily capable of detonation or of explosive decomposition or reaction at normal temperatures and pressures.
3	Capable of detonation or explosive reaction, but requires a strong initiating source or must be heated under confinement before initiation, or reacts explosively with water.
2	Normally unstable and readily undergo violent decomposition but do not detonate. Also: may react violently with water or may form potentially explosive mixtures with water.
1	Normally stable, but can become unstable at elevated temperatures and pressures or may react with water with some release of energy, but not violently.
0	Normally stable, even under fire exposure conditions, and are not reactive with water.

Anhydrous Ammonia Storage

- Safety and consumption rate influences storage selection
- 500# Cal-ARP limit ➡ 3ea 150# cylinders
- Bulk tanks for safety, cost and larger users

Anhydrous Ammonia Safety Features

- Ambient ammonia-leak detectors
- Relief valve discharge line pressure switches/gauges
- Air tight ammonia cylinder cabinets with purge air fans to minimize exposure.
- Alarm horn and beacons
- Water capture tank for vents & relief valves

Ammonia Sources

- Common reacting agents (reagents)
  - Aqueous Ammonia

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- Aqueous ammonia is a solution of water and NH_3.
- Lower risk and regulatory issues than anhydrous.
- Strong base solution with a pH above 11.

Aqueous Ammonia

- Safer to handle & easier to contain leaks than anhydrous ammonia
- Aqueous Ammonia storage tanks sized by demand, often 2,000 to 10,000 gallons

Aqueous Ammonia Safety Features

- Ammonia leak detectors
- Alarm horn and beacons
- Bulk tank filled by aqueous ammonia supplier
- Storage incorporates secondary containment

Ammonia Sources

- Common reacting agents (reagents)
  - Urea

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4	Very short exposure could cause death or serious residual injury even though prompt medical attention was given.
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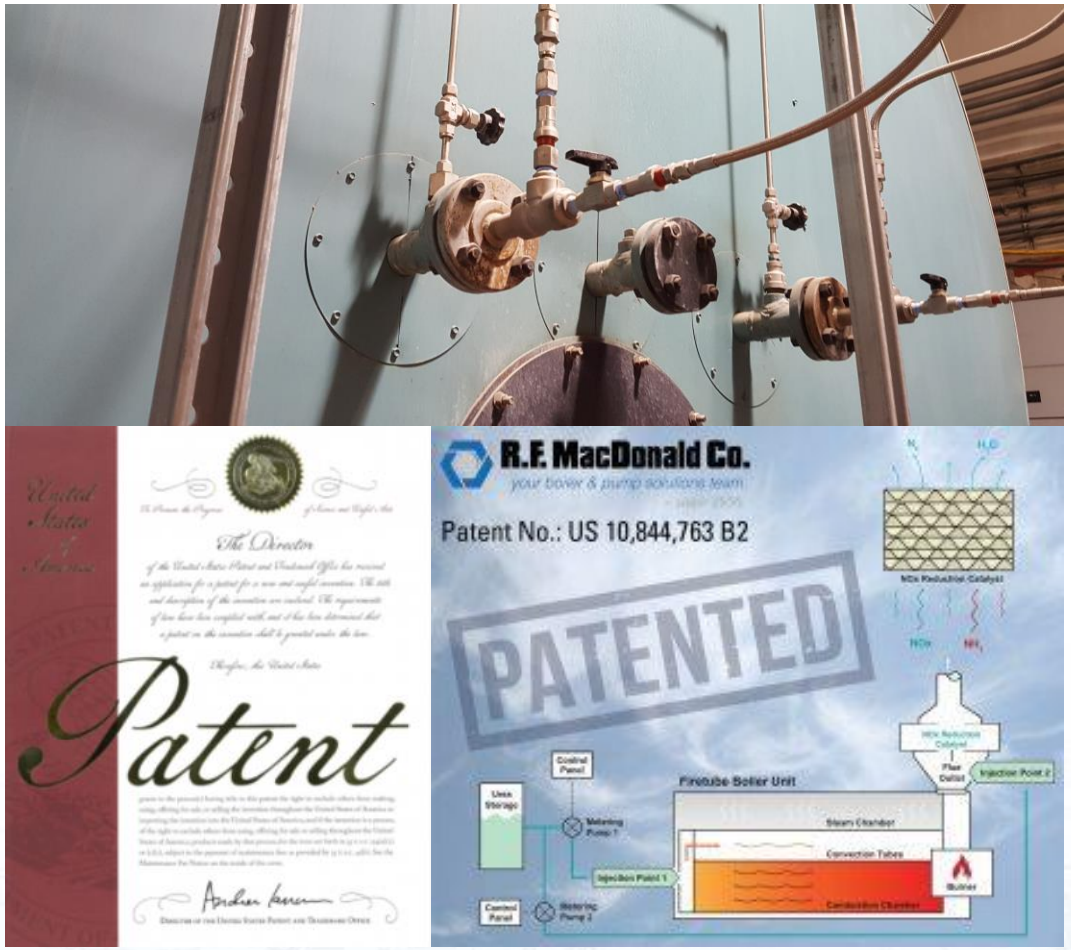
- Classified as non-hazardous – ammonia is not present until solution is treated and converted to ammonia on demand
- Similar to what is used in motor vehicles as diesel exhaust fluid (**DEF**)
- 32.5% high-purity urea and 67.5% deionized water is common

Urea Storage

- Storage tank system required. Sizes ranging from 500 to 6,500 gallon plastic tanks.
- Temperature dependent to keep in solution.
  - Salt-out temperature of 12 °F for 32.5% urea
  - Salt-out temperature of 33 °F for 40% urea

Direct Injection

- Direct injection of urea or aqueous ammonia into flue gas stream.
- Simplifies use of urea by eliminating external conversion of urea to ammonia.
- May require multiple injection points to optimize the urea consumption.
- Constant flow nozzles with DI water and urea added on demand.
- RF MacDonald holds a patent for this technology on boiler applications.



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Reagent Distribution

- Liquid or Gas injection controlled by PLC based controls
- Liquid systems included pump and injection control
- System can be integrated into existing systems to allow for remote monitoring

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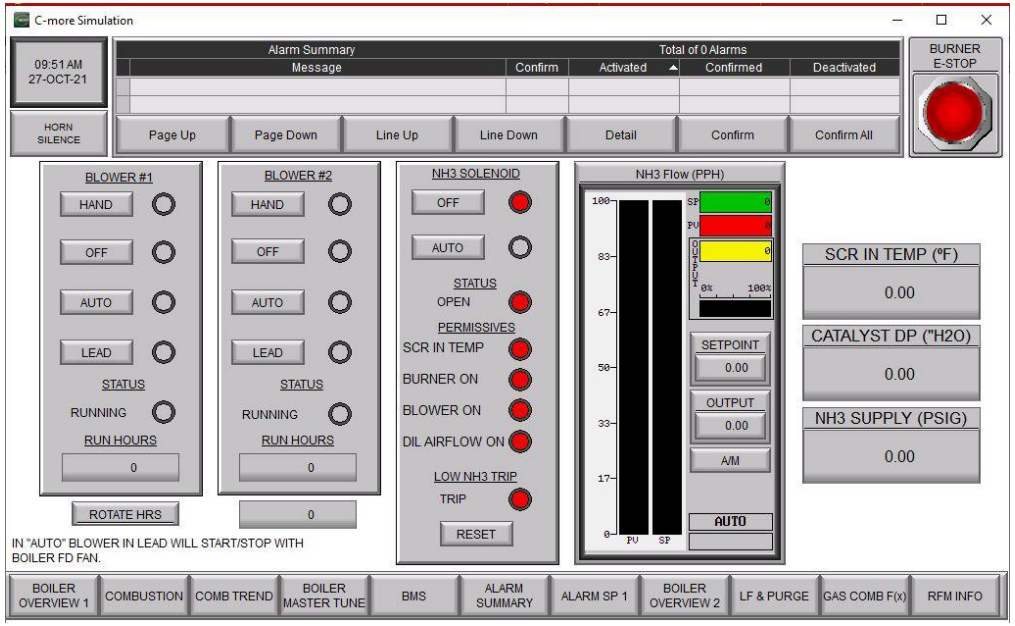
SCR & Boiler Controls

- All SCR systems can operate with stand alone PLC based controls
- If controls upgrades are desired on an existing boiler this control can be designed to include advanced parallel positioning or multi-element control with the SCR control integrated to minimize hardware and maintenance costs



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RFM Install List

Industry	Boiler	Size	Catalyst	Year	Reagent	Inlet NOx	Outlet NOx	NH3 Slip
Food and Beverage	NBC IWT	120kpph	Hitachi H-T	2006 2013	Anhydrous Ammonia	80ppm	<7 ppm	<10ppm
Food and Beverage	NBC IWT	120kpph	Hitachi	2006	Anhydrous Ammonia	80ppm	<7 ppm	<10ppm
Food and Beverage	CB IWT	75kpph	Hitachi	2007	Anhydrous Ammonia	70ppm	<9ppm	<10ppm
Food and Beverage	NBC IWT	130kpph	Hitachi	2007	Anhydrous Ammonia	70ppm	<9ppm	<10ppm
Food and Beverage	NBC IWT	112kpph	Hitachi	2007	Anhydrous Ammonia	70ppm	<9ppm	<10ppm
Food and Beverage	NBC IWT	125kpph	H-T	2008	Anhydrous Ammonia	90ppm	<5ppm	<10ppm
Food and Beverage	NBC IWT	125kpph	H-T	2008	Anhydrous Ammonia	90ppm	<5ppm	<10ppm
Food and Beverage	CB FT	1200BHP	H-T	2009	Anhydrous Ammonia	30ppm	<7ppm	<10ppm
Food and Beverage	CB FT	1500BHP	H-T	2009	Anhydrous Ammonia	50ppm	<5ppm	<10ppm
Chemical	NBC IWT	50kpph	H-T	2009	Anhydrous Ammonia	30ppm	<5ppm	<10ppm
Power & Energy	Indeck IWT	225kpph	BASF (CO)	2009	NA	10ppm	<1ppm	NA
Food and Beverage	NBC IWT	50kpph	H-T	2009	Anhydrous Ammonia	40ppm	<5ppm	<10ppm
Pharma/Biotech	NBC IWT	50kpph	H-T	2010	19% aq ammonia	40ppm	<4ppm	<10ppm
Food and Beverage	(2) CB FT	350BHP	H-T	2010	Anhydrous Ammonia	30ppm	<6ppm	<10ppm
Oil/Gas	CT	4.7 MW	H-T	2011	Anhydrous Ammonia	35ppm	<5ppm	<10ppm
Food and Beverage	CT	3.5 MW	H-T	2011	Anhydrous Ammonia	37ppm	<5ppm	<5ppm
Water Treament	(2) CT	3.5 MW	H-T	2011	Anhydrous Ammonia	26ppm	<5ppm	<10ppm
Food and Beverage	CT	3.5 MW	H-T	2011	Anhydrous Ammonia	31ppm	<5ppm	<10ppm
Pulp/Paper	NBC IWT	70kpph	H-T	2011	Anhydrous Ammonia	40ppm	<5ppm	<10ppm
Correctional Facility	(2) CT	2.6 MW	H-T	2012	32.5% Urea	35ppm	<5ppm	<10ppm
Food and Beverage	(2) CB IWT	100kpph	H-T	2012	Anhydrous Ammonia	40ppm	<5 ppm	<10ppm
Food and Beverage	CB IWT	75kpph	H-T	2012	Anhydrous Ammonia	40ppm	<5ppm	<10ppm
Food and Beverage	NBC IWT	70kpph	H-T	2012	Anhydrous Ammonia	40 ppm	<5ppm	<10ppm
Food and Beverage	NBC IWT	50kpph	H-T	2012	Anhydrous Ammonia	40 ppm	<5ppm	<10ppm
Food and Beverage	NBC IWT	15kpph	H-T	2012	Anhydrous Ammonia	40ppm	<5ppm	<10ppm
Agriculture	IWT	50kpph	H-T	2012	Anhydrous Ammonia	40ppm	<5ppm	<10ppm

RFM Install List

Customer	Boiler	Size	Catalyst	Year	Reagent	Inlet NOx	Outlet NOx	NH3 Slip
Hospital	(2) NBC IWT	50kpph	H-T	2012	40% Urea	40ppm	<5ppm	<10ppm
Food and Beverage	NBC IWT	80kpph	H-T	2012	Anhydrous Ammonia	40ppm	<5ppm	<10ppm
Food and Beverage	B&W IWT	150kpph	H-T	2013	Anhydrous Ammonia	70ppm	<7 ppm	<10ppm
Food and Beverage	(2) B&W IWT	20kpph	H-T	2013	Anhydrous Ammonia	80ppm	<5ppm	<10ppm
Food and Beverage	B&WIWT	60kpph	H-T	2013	Anhydrous Ammonia	50ppm	<5ppm	<5ppm
Food and Beverage	B&W IWT	35kpph	H-T	2013	Anhydrous Ammonia	30ppm	<5ppm	<10ppm
Correctional Facility	CT	20.9 MW	H-T	2013	40% Urea	42pppm	<9ppm	<10ppm
Oil/Gas	FT	800BHP	H-T	2013	Anhydrous Ammonia	60ppm	<5ppm	<10ppm
Food and Beverage	(2) IWT	150kpph	H-T	2013	Anhydrous Ammonia	20ppm	<5ppm	<10ppm
Food and Beverage	(1) IWT	150kpph	H-T	2013	Anhydrous Ammonia	40ppm	<5ppm	<10ppm
Food and Beverage	CB FT	1200HP	H-T	2014	Anhydrous Ammonia	40ppm	<5ppm	<5ppm
University	(2) CB FT	1400HP	H-T	2016	40% Urea	30ppm	<5ppm	<5ppm
Food and Beverage	FT	800HP	H-T	2017	Anhydrous Ammonia	40ppm	<5ppm	<5ppm
Oil/Gas	TFH	32MMBTU	Umicore	2018	Anhydrous Ammonia	30ppm	<5ppm	<10ppm
Manufacturing	(1) FT	800HP	Umicore	2019	Anhydrous Ammonia	30ppm	<2.5ppm	<5ppm
Manufacturing	(1) FT	670HP	Umicore	2019	Anhydrous Ammonia	10ppm	<2.5ppm	<5ppm
Pulp/Paper	(1) IWT	80kpph	Umicore	2019	Anhydrous Ammonia	70ppm	<5ppm	<10ppm
Food and Beverage	(2) IWT	125kpph	Umicore	2019	Anhydrous Ammonia	60ppm	<5ppm	<5ppm
Aerospace	(1) IWT	25kpph	Umicore	2020	Anhydrous Ammonia	33ppm	<5ppm	<5ppm
Food and Beverage	(1) IWT	180kpph	Umicore	2020	Anhydrous Ammonia	30ppm	<5ppm	<5ppm
Agriculture	(4) FT	52kpph	Umicore	2021	Anhydrous Ammonia	30ppm	<2.5ppm	<5ppm
Chemical	(1) IWT	5.7kpph	Umicore	2021	Anhydrous Ammonia	40ppm	<6ppm	<5ppm

- More units currently in design for supply in 2022

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SCR Summary

- The selection of the appropriate emission control system requires a detailed evaluation of environmental, technical, safety and economic factors
- Contact your local RFM Representative to help guide you through this process to determine what makes the best sense for your conditions

Efficiency with NOx Upgrades

- SCR solutions are more efficient in comparison to Ultra Low NOx Burners
- There could still be efficiency improvements available to lower your utility costs if this equipment does not currently exist in your plant:
  - Single Stage Economizers
  - 2-Stage Economizers
  - Blowdown Heat Recovery
  - VFD Controlled Blower Motor
- Efficiency gains of 1% to 5% may be available depending on your operational conditions with possible rebates available

Recommendations for Evaluating Boiler NOx Upgrades

- Every customer is different
- RFM can evaluate site specific conditions and propose customized options
- Evaluation will look at costs:
  - Energy
  - Operations
  - 4320 Fee compliance
- Competitive analysis available to make sure you are making the most of your investment

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Rule Change Milestones

May 1, 2022

- 4306 – Non-Deferred Units Submit Emission Control Plan/Authority to Construct
- 4320 – Submit Emission Control Plan/Authority to Construct

Dec 31, 2023

- 4306 – Non-Deferred Units Compliance Date
- 4320 – Compliance Date

Jan 1, 2025

- 4320 – Invoices for those choosing the fee method will be issued for 2024 opearations

May 1, 2028

- 4306 – Deferred Units Submit Emission Control Plan/Authority to Construct

Dec 31, 2029

- 4306 – Deferred Units Compliance Date

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Conclusion

- When navigating the new rule changes, each user will have options to evaluate to see what makes the best sense for them
- Some early adopters have the ability to defer compliance until Dec. 31, 2029
- Regardless of the course of action, all users must have compliance plans submitted to the district by May 1, 2022

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