Controlling NO_x Emissions from High Temperature Fluidized Bed Incinerators Meeting MACT LLLL Emission Limits

NJWEA 111th Annual Conference and Exposition
Harrah's Atlantic City
Atlantic City, NJ

Levent Takmaz, Veolia Water Technologies

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Agenda

1. Introduction
2. NO_x Emission Limits
3. Primary & Secondary NO_x Control Techniques
4. Process Flow Diagrams with NO_x Control Equipment
5. NO_x Stack Emission Test Results
6. Conclusions

Introduction

INTRODUCTION

High Temperature Fluid Bed Municipal Sludge Incinerators typically operate at freeboard temperatures between 1500°F and 1600°F, which results in the generation of nitrogen oxides (NO_x) through several mechanisms:

- Fuel NO_x: High-temperature oxidation of chemically bound nitrogen within the sludge and auxiliary fuels (e.g., fuel oil or natural gas).
- Thermal NO_x: Atmospheric nitrogen and oxygen reaction during high temperature combustion.

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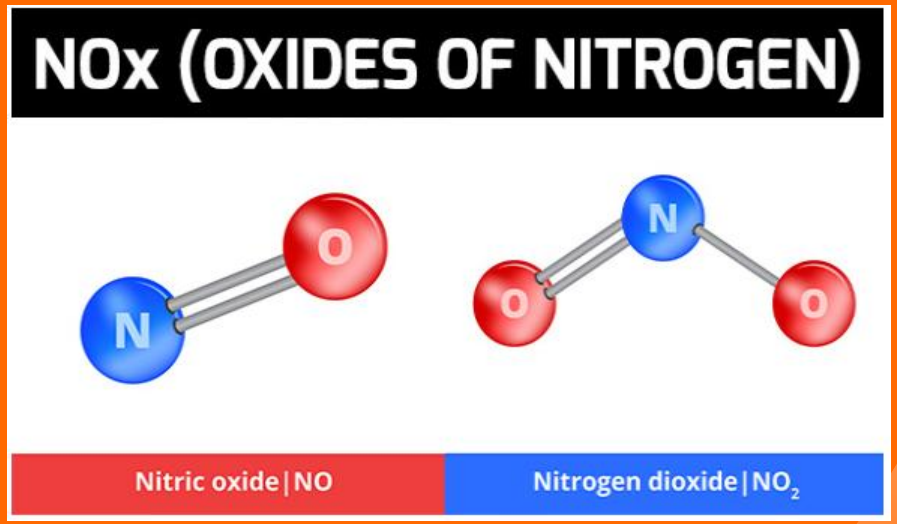
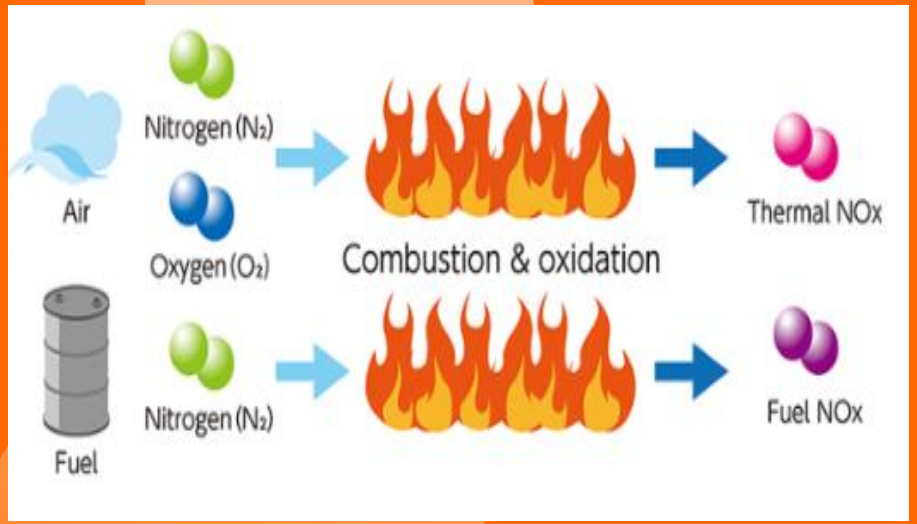
NO vs NO_2 Emissions



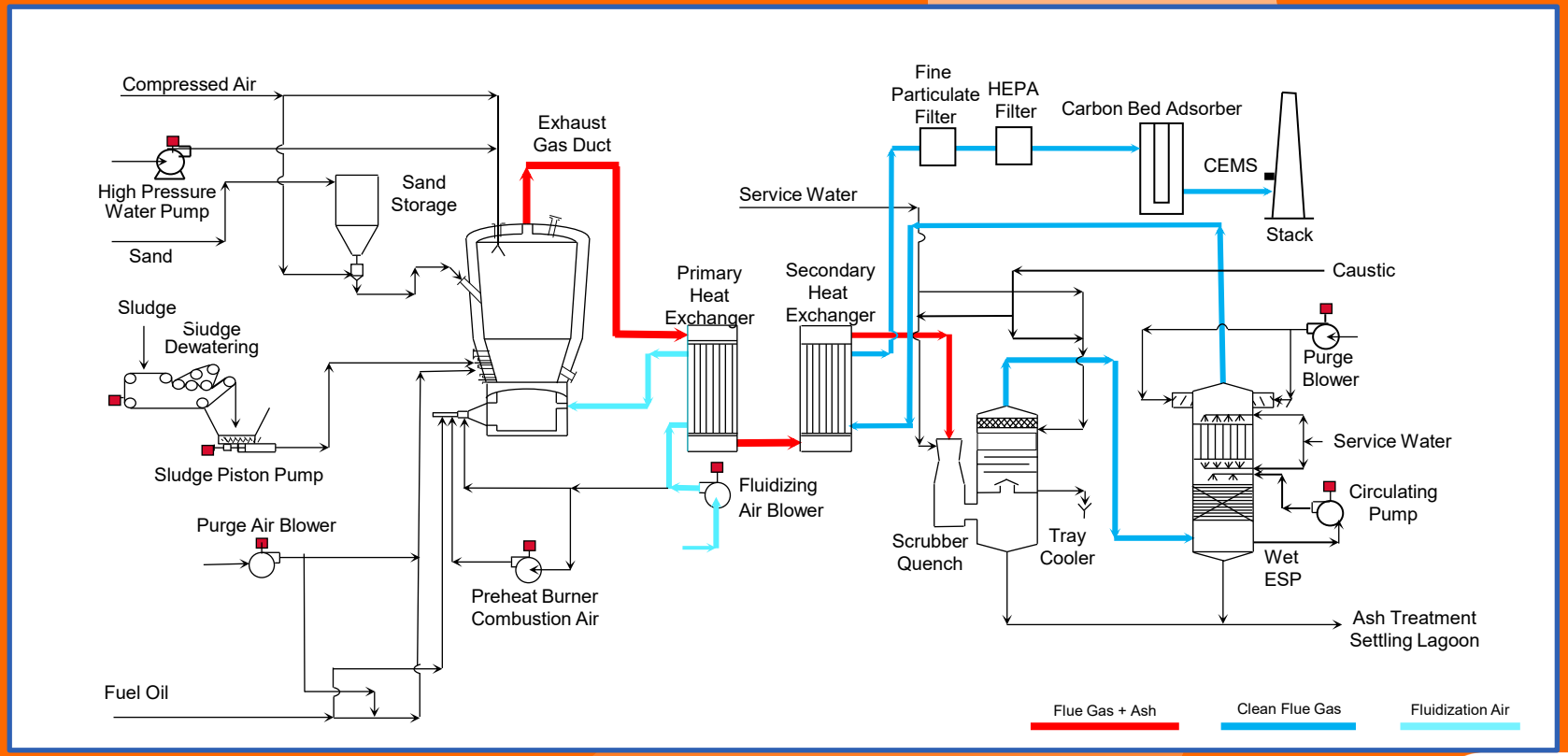
https://www.ametek-land.com/pressreleases/blog/2022/february/nox-and-sox



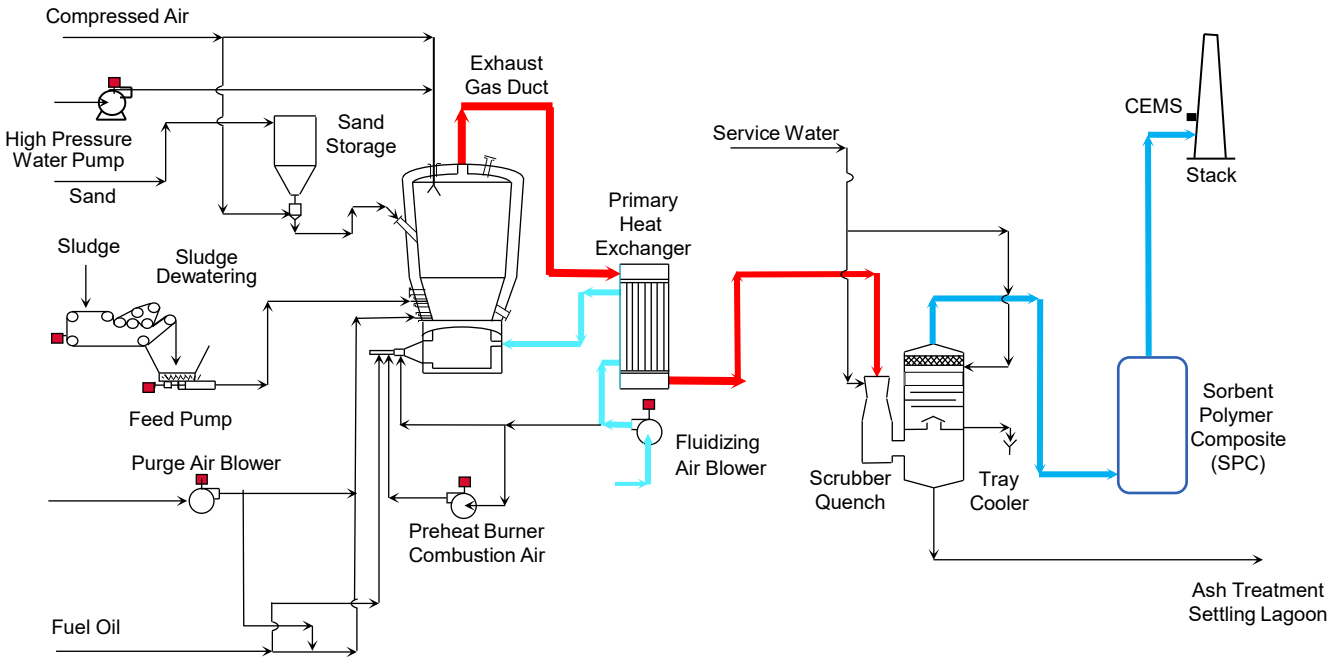
https://www.kanadevia.com/english/business/field/marine/denitration.html

NO (~95%), NO_2 (~5%)

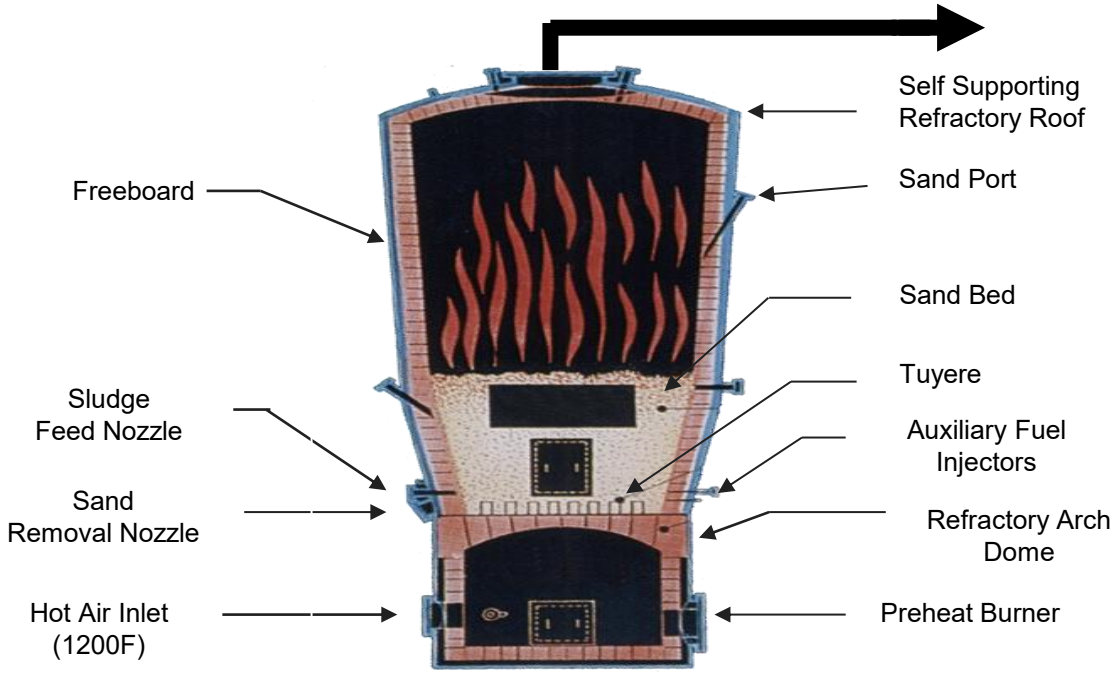
New High Temperature Fluid Bed Incineration System – MACT LLLL



Existing High Temperature Fluid Bed Incineration System – MACT MMMM



Fluid Bed Reactor



Fluid Bed Plant

NO_x Emission Limits

NO_x Emission Limits

- MACT LLLL and MMMM emission limits have been released in 2011.
- New incineration plants had to meet the MACT LLLL emission limits.
- Existing incineration plants had to meet the MACT MMMM emission limits by 2016.
- Veolia designed and implemented NO_x removal systems for new incineration plants to meet the NO_x emission limit per MACT LLLL.
- Veolia's existing incineration plants were able to meet the new NO_x emission limit per MACT MMMM without additional equipment.

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NO_x EMISSION LIMITS

US EPA MACT Air Emission Requirements (2016)

Pollutant	Units	Existing Fluid Bed Municipal Incinerators (MMMM) (@ 7% O_2)	New Fluid Bed Municipal Sludge Incinerators (LLLL) (@ 7% O_2)
Cd	mg/dscm	0.0016	0.0011
CO	ppmvd	64	27
HCl	ppmvd	0.51	0.24
Hg	mg/dscm	0.037	0.0010
NO_x	ppmvd	150	30
Pb	mg/dscm	0.0074	0.00062
PCDD/PCDF,TEQ	ng/dscm	0.1	0.0044
PCDD/PCDF,TMB	ng/dscm	1.2	0.013
PM	mg/dscm	18	9.6
SO_2	ppmvd	15	5.3

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Primary & Secondary NO_x Control Techniques

Primary NO_x Control Techniques

- Freeboard Temperature: 1500°F to 1600°F
- Oxygen Levels: 3.5% to 4% (Wet)
- Feed Rates: Accurate control of scum, skim, and FOG feed rates
- Volatile Solids: Monitor sludge volatile (Daily Tests)
- Heat Value: Monitor sludge heat value (Weekly or Monthly Tests)

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Primary NO_x Control Techniques

- Bed Temperature: Minimum Set Point: 1250°F. Operate around 1300°F to 1325°F
- Excess Air: 40% (Operate at design point)
- Total Solids: Monitor sludge total solids (Daily Tests)
- Merchant Plant: Test imported sludge properties

Secondary NO_x Control Techniques

- Selective Non-Catalytic Reduction (SNCR)
- Selective Catalytic Reduction (SCR)
- Hybrid (SNCR & SCR)

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Secondary NO_x Control Techniques - SNCR

- Selective Non-Catalytic Reduction (SNCR) is a cost-effective technique for reducing NO_x emissions in high-temperature fluid bed municipal sludge incinerators.
- Reduction Efficiency: Typical NO_x reduction ranges between 30% and 50%.
- Installation: Ammonia or urea injection nozzles are installed on the fluid bed reactor, the hot gas duct, or both.
- Reaction Temperature: The flue gas temperature is maintained above 1500°F to minimize the slip ratio.
- Implementation: SNCR is already designed and installed by Veolia on new fluid bed projects in the US.

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Secondary NO_x Control Techniques - SCR

- Selective Catalytic Reduction (SCR) provides higher NO_x removal efficiencies, however this approach involves higher capital costs due to additional equipment, including catalysts, heat exchangers, urea, or ammonia systems.
- Reduction Efficiency: Typical NO_x reduction ranges between 70% and 90%.
- Installation: The SCR system is installed before the stack.
- Reaction Temperature: Flue gas temperature is maintained above 500°F.
- Implementation: Currently, the SCR approach is not required for new fluid bed projects in the US.

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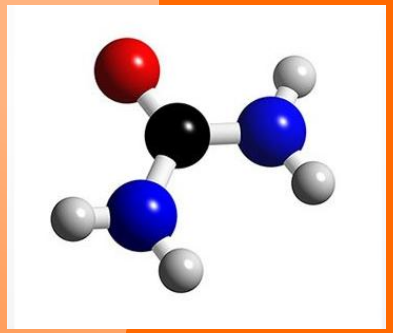
Secondary NO_x Control Techniques - SCR

Exhaust	Containing NO_x (NO and NO_2)
AdBlue	Containing urea ($(NH_2)_2CO$)
Thermolysis	$(NH_2)_2CO \rightarrow NH_3 + HNCO$
Hydrolysis	$HNCO + H_2O \rightarrow NH_3 + CO_2$
SCR	$4\ NO + 4\ NH_3 + O_2 \rightarrow 4\ N_2 + 6\ H_2O$ $NO + NO_2 + 2\ NH_3 \rightarrow 2\ N_2 + 3\ H_2O$ $6\ NO_2 + 8\ NH_3 \rightarrow 7\ N_2 + 12\ H_2O$
Output	$N_2 + H_2O$

Figure 2. *Chemicals and reactions involved in the NO_x reduction in diesel vehicles. NO_x is ultimately converted to nitrogen gas (N_2) and water (H_2O) by reactions involving urea ($(NH_2)_2CO$). Image Credit: Mettler-Toledo Ltd*

https://www.azom.com/article.aspx?ArticleID=20173

UREA MOLECULE



https://condorchem.com/en/blog/removal-nox-nitrogen-oxides/

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Secondary NO_x Control Techniques - Hybrid

The Hybrid Approach includes SNCR followed by SCR. SNCR handles the initial reduction, while the SCR provides final polishing.

- Performance: Typical reduction is higher than 90%.
- Cost: This approach requires more equipment, resulting in higher capital costs.
- Implementation: For new fluid bed projects in the US, the hybrid approach is currently not required.

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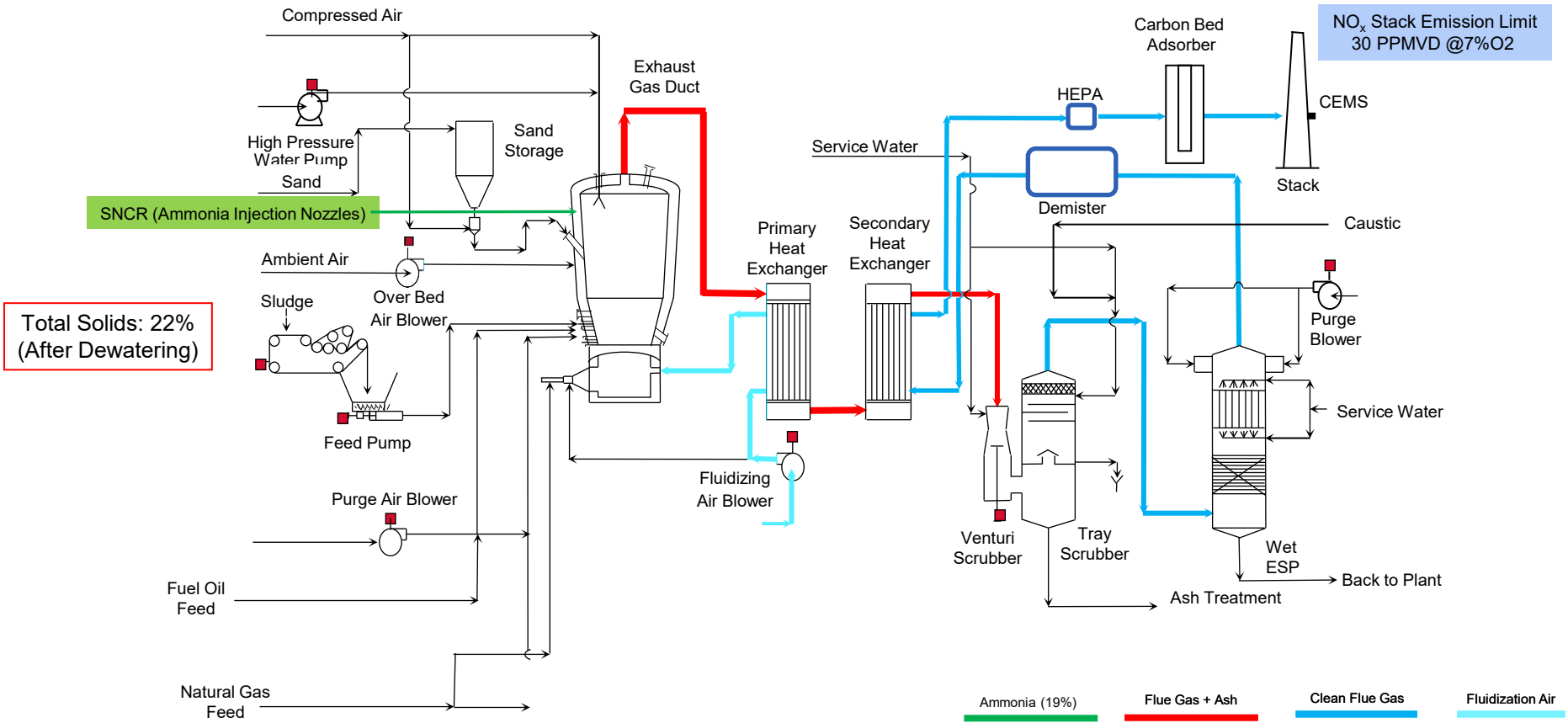
Process Flow Diagrams with NO_x Control Equipment

PFD Incineration Train with SNCR (MACT LLLL)



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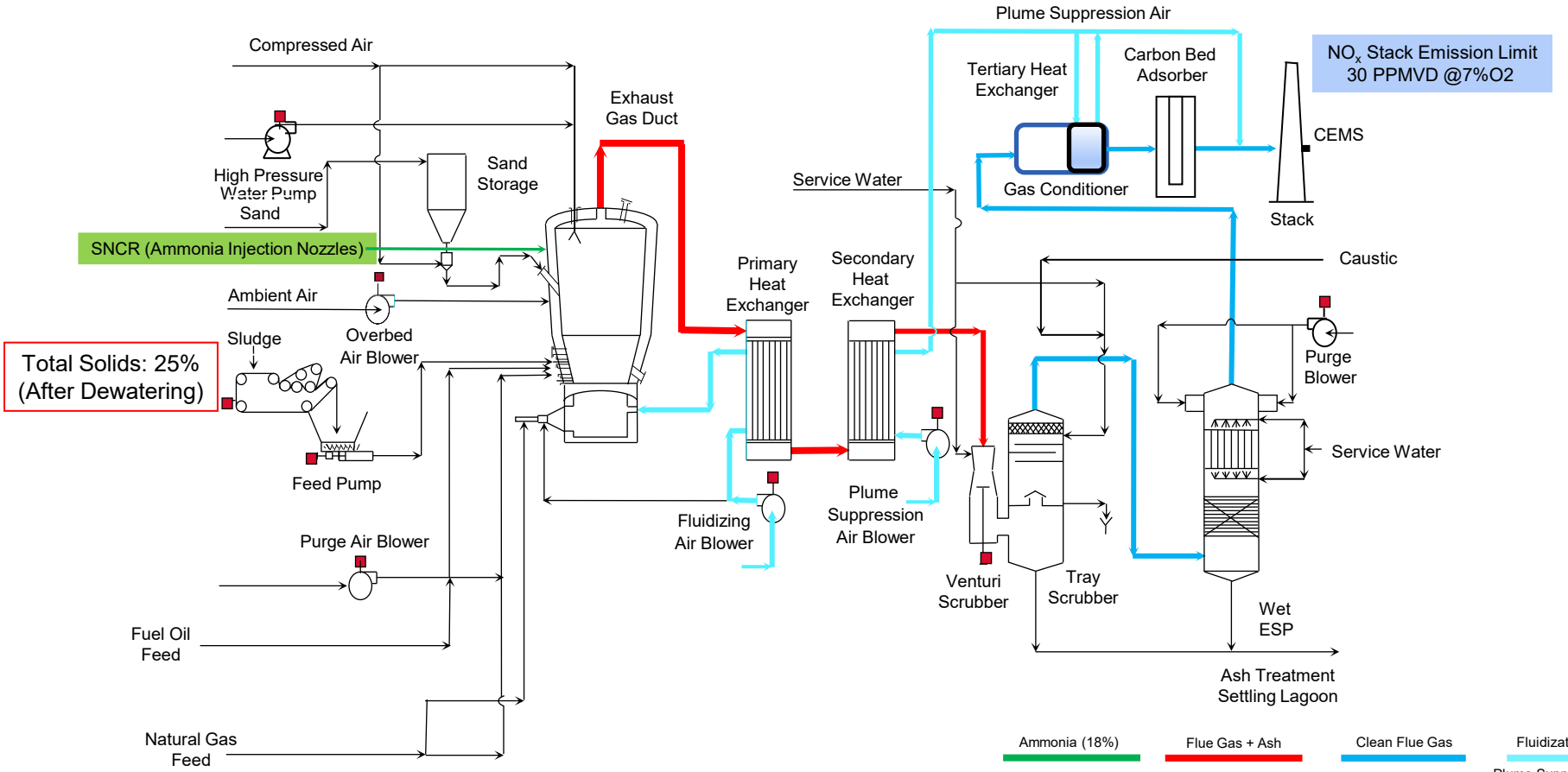
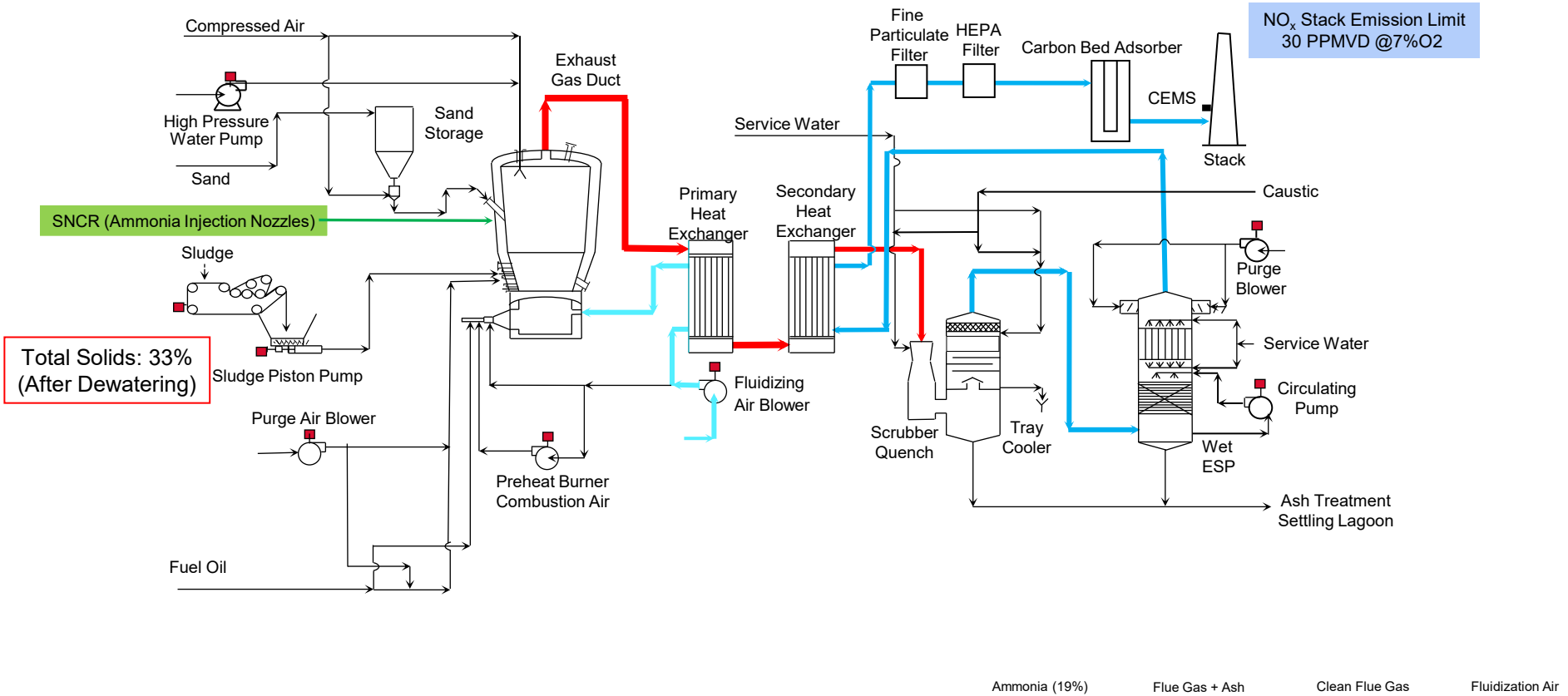
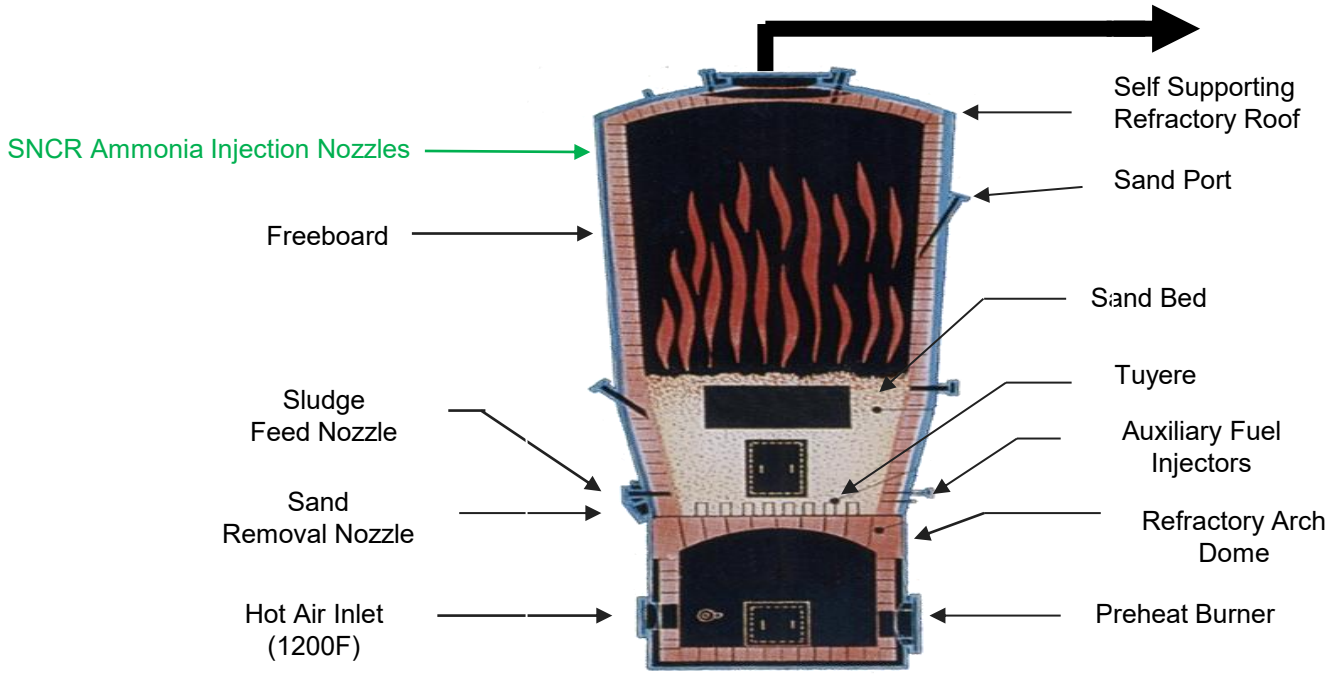


PFD Incineration Train with SNCR (MACT LLLL)



Fluid Bed Reactor – Ammonia Injection



SNCR Ammonia Injection Nozzle

SNCR – 19% AMMONIUM HYDROXIDE - SDS

SECTION 1: IDENTIFICATION

1.1. Product Identifier

Product Name: Aqua Ammonia 19%

CAS No: 1336-21-6

Synonyms: Ammonia water, Aqueous ammonia, Household ammonia, Ammonium hydrate, Ammonium hydroxide

Freezing Point	:	-38 °C (-36 °F)
Boiling Point	:	37.4 °C (99.3°F) (25% NH_3)

~50°C (122F) for 19% NH3

SECTION 4: FIRST AID MEASURES

4.1. Description of First Aid Measures

General: Never give anything by mouth to an unconscious person. Seek medical attention immediately. Show label if possible.

Inhalation: When symptoms occur: go into open air and ventilate suspected area. Immediately call a POISON CENTER or doctor/physician.

Skin Contact: Immediately flush skin with plenty of water for at least 60 minutes. Remove/Take off immediately all contaminated clothing. Immediately call a POISON CENTER or doctor/physician. Wash contaminated clothing before reuse.

Eye Contact: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing for at least 60 minutes. Immediately call a POISON CENTER or doctor/physician.

Ingestion: Rinse mouth. Do NOT induce vomiting. Immediately call a POISON CENTER or doctor/physician.

4.2. Most Important Symptoms and Effects Both Acute and Delayed

General: Harmful if swallowed. Corrosive to eyes, respiratory system and skin. Harmful if inhaled.

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SNCR – 19% AMMONIUM HYDROXIDE - SDS

SECTION 7: HANDLING AND STORAGE

7.1. Precautions for Safe Handling

Additional Hazards When Processed: Do NOT enter (storage areas, confined spaces) unless adequately ventilated. Emits ammonia vapors. Flammable gas. Ammonium hydroxide reacts with many heavy metals and their salts forming explosive compounds. It may attack metals forming flammable/explosive gas. The solution in water is a strong base, it reacts violently with acids.

Hygiene Measures: Handle in accordance with good industrial hygiene and safety procedures. Wash hands and other exposed areas with mild soap and water before eating, drinking, or smoking and again when leaving work.

7.2. Conditions for Safe Storage, Including Any Incompatibilities

Technical Measures: Any proposed use of this product in elevated-temperature processes should be thoroughly evaluated to assure that safe operating conditions are established and maintained. Ensure adequate ventilation. Comply with applicable regulations.

Storage Conditions: Store in a dry, cool and well-ventilated place. Detached outside storage is preferable. Keep in fireproof place. Store away from oxidizers, combustible materials, and all ignition sources. Store in corrosive resistant container with a resistant inner liner. Storage containers should have safety relief valves. Store locked up.

Incompatible Materials: Forms explosive compounds with calcium hypochlorite, bleaches, gold, mercury, silver, chlorine and other halogens. Contact with strong oxidizers can result in fires and explosions. Corrosive to copper, brass, silver, zinc and galvanized steel.

Storage Area: Post readily visible warning signs in the storage area listing emergency measures. Water hoses should be readily available to disperse vapors in case of a spill.

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SNCR – 50% UREA SOLUTION - SDS

nexchem
chemical marketing and distribution

SAFETY DATA SHEET
Urea 40%

Page 1
Issued: 18/04/2023
Revision No: 3

1. IDENTIFICATION OF THE SUBSTANCE / PREPARATION AND OF THE COMPANY / UNDERTAKING

Product identifier:
Product name: Urea 40%

Relevant identified uses of the substance or mixture and uses advised against:
Identified uses: Industrial Chemical.

4. FIRST AID MEASURES

Description of first aid measures:

General information: Get medical attention if any discomfort continues. Show this Safety Data Sheet to the medical personnel.

Inhalation: IF INHALED: Move affected person to fresh air at once.

Ingestion: Get medical attention. Do not induce vomiting unless under the direction of medical personnel. Never give anything by mouth to an unconscious person.

Skin contact: Rinse immediately with plenty of water. Get medical attention if irritation persists after washing.

Eye contact: Rinse immediately with plenty of water. Remove any contact lenses and open eyelids wide apart. Continue to rinse for at least 10 minutes. Get medical attention if any discomfort continues.

Protection of first aiders: First aid personnel should wear appropriate protective equipment during any rescue.

Most important symptoms and effects, both acute and delayed:

Inhalation: No specific symptoms known.
Ingestion: No specific symptoms known.
Skin contact: No specific symptoms known.
Eye contact: No specific symptoms known.

10. STABILITY AND REACTIVITY

Reactivity: There are no known reactivity hazards associated with this product.

Chemical stability:
Stability: Stable at normal ambient temperatures and when used as recommended. Stable under the prescribed storage conditions.

Possibility of hazardous reactions: No potentially hazardous reactions known.

Conditions to avoid: There are no known conditions that are likely to result in a hazardous situation.

chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.nexchem.co.uk/wp-content/uploads/2015/10/Urea-40.pdf

TECHNICAL DATA

UREA SOLUTION 32.5%

GUARANTEED ANALYSIS
Total Nitrogen (N) 15.37%

PHYSICAL PROPERTIES
pH 8.37
Specific Gravity ..... 1.10 (68°F)
Density ..... 9.08 lbs/gal
Freezing Point ..... 12°F
Appearance ..... Clear solution

UREA SOLUTION 40%

GUARANTEED ANALYSIS
Total Nitrogen (N) 18.5%

PHYSICAL PROPERTIES
pH ..... 7.20 - 9.20
Specific Gravity 1.112
Density ..... 9.26 lbs/gal
Freezing Point ..... 28°F
Appearance ..... Clear

UREA SOLUTION 50%

GUARANTEED ANALYSIS
Total Nitrogen (N) 23.05%

PHYSICAL PROPERTIES
pH ..... 7.50 - 9.50
Specific Gravity ..... 1.135 - 1.15
Density ..... 9.52 lbs/gal
Freezing Point ..... 61°F
Appearance ..... Clear to slightly turbid

The Andersons

FOR MORE INFORMATION CONTACT TONY PIFER
419-569-4144 | tony_pifer@andersonsinc.com
AndersonsPlantNutrient.com

chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://assets.andersonsplantnutrient.com/pdf/Urea_Solution.pdf

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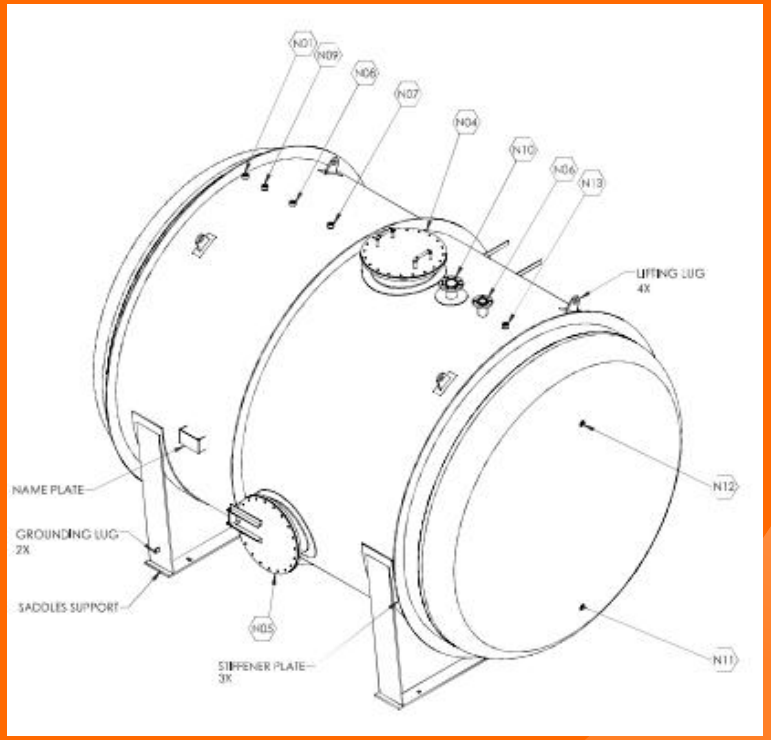
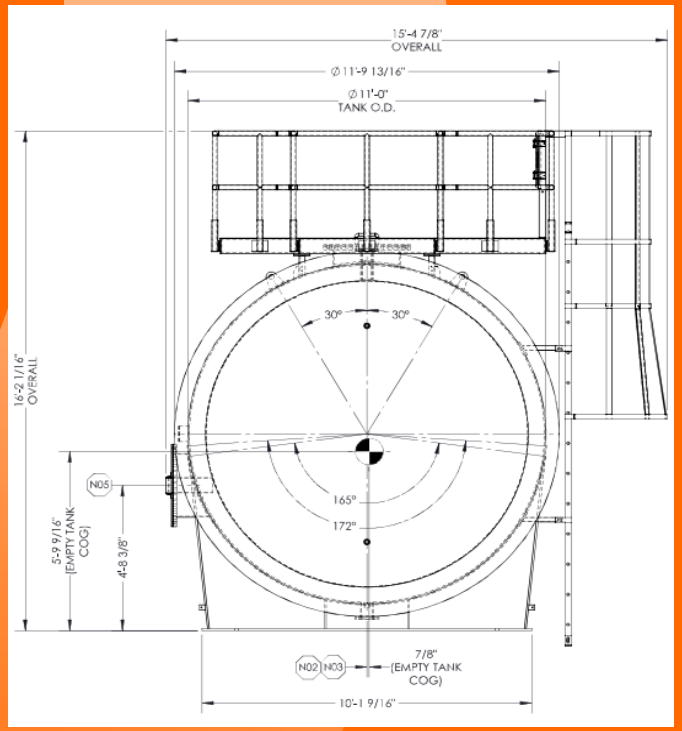
SNCR Ammonia Tank





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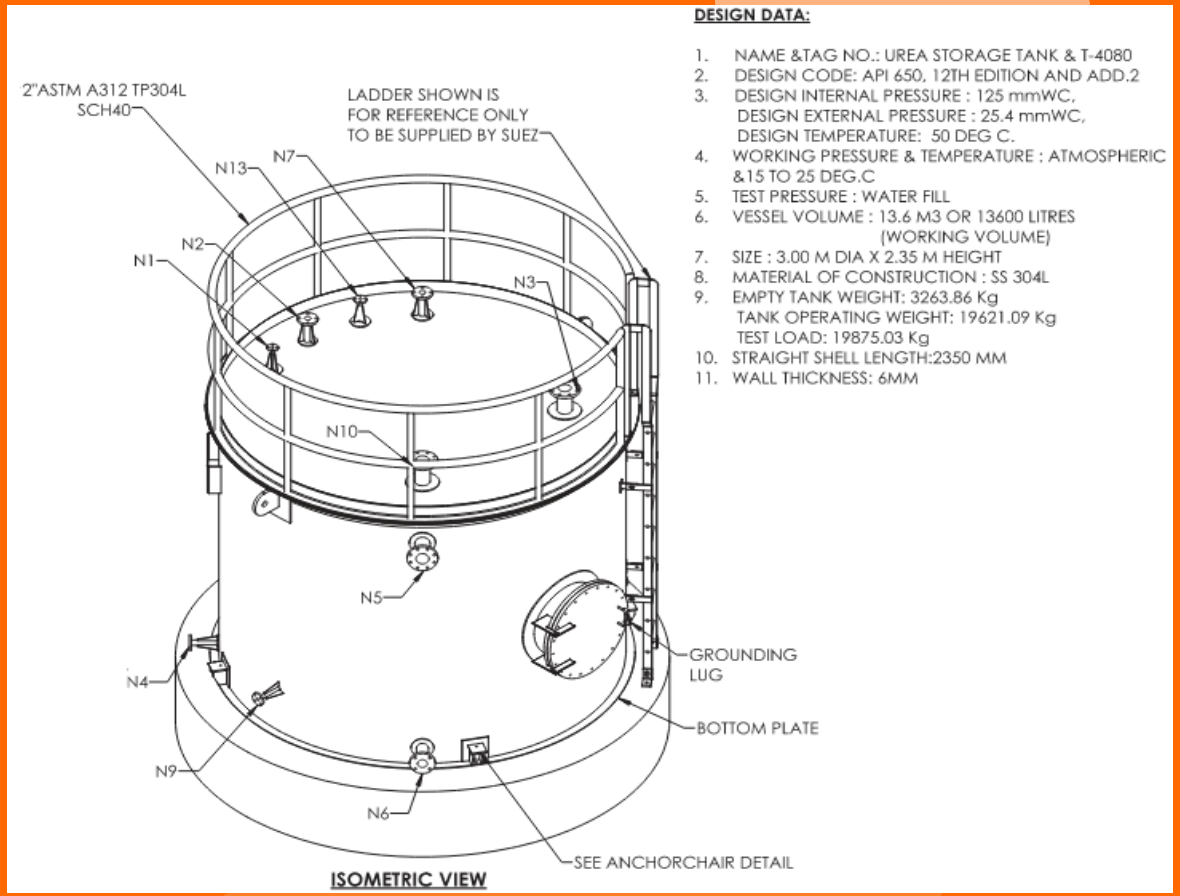
SNCR Ammonia Tank

SNCR Urea Tank

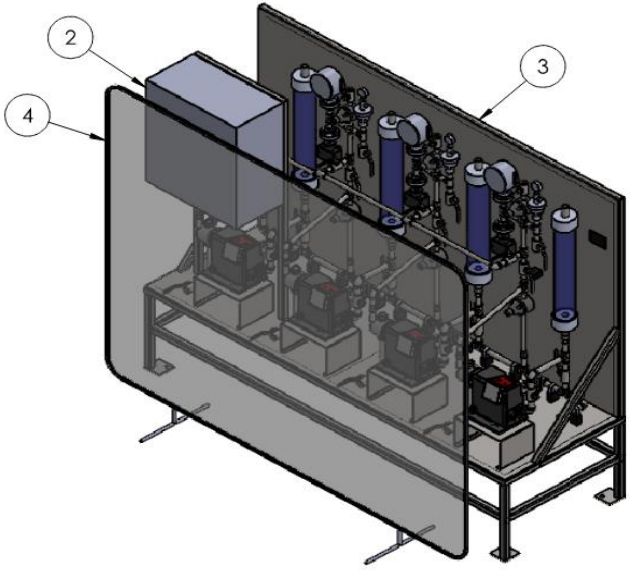


DESIGN DATA:

1. NAME &TAG NO.: UREA STORAGE TANK & T-4080
2. DESIGN CODE: API 650, 12TH EDITION AND ADD.2
3. DESIGN INTERNAL PRESSURE : 125 mmWC,
   DESIGN EXTERNAL PRESSURE : 25.4 mmWC,
   DESIGN TEMPERATURE: 50 DEG C.
4. WORKING PRESSURE & TEMPERATURE : ATMOSPHERIC &15 TO 25 DEG.C
5. TEST PRESSURE : WATER FILL
6. VESSEL VOLUME : 13.6 M3 OR 13600 LITRES (WORKING VOLUME)
7. SIZE : 3.00 M DIA X 2.35 M HEIGHT
8. MATERIAL OF CONSTRUCTION : SS 304L
9. EMPTY TANK WEIGHT: 3263.86 Kg
   TANK OPERATING WEIGHT: 19621.09 Kg
   TEST LOAD: 19875.03 Kg
10. STRAIGHT SHELL LENGTH:2350 MM
11. WALL THICKNESS: 6MM

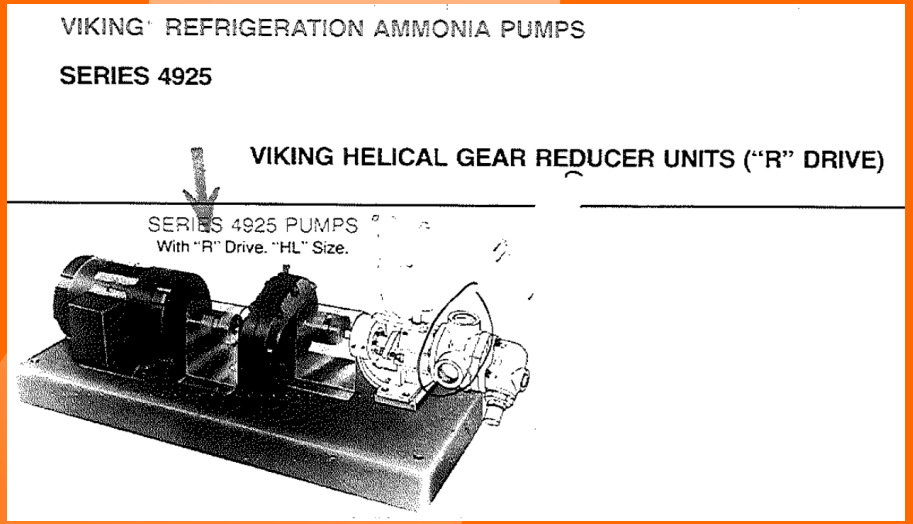
SNCR Ammonia Pump Skid

Hydraulically Actuated Diaphragm Metering Pumps

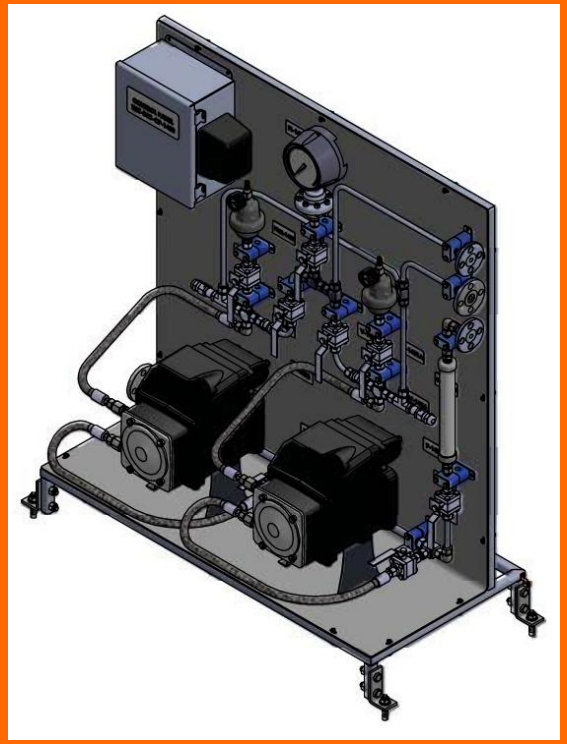


ITEM NO.	PART NUMBER	Vendor	VendorNo	QTY.
1	DDA 60-10 AR-SS-L_T_C-F-31A3A3BG	GRUNDFOS	93280647	4
2	CUSTOM CONTROL PANEL	ALDERON	TBD	1
3	SS FRAME			1
4	SPLASH SCREEN	ULINE	H-6704	1

Rotary Positive Displacement Pumps



SNCR Urea Pump Skid



Positive Displacement Peristaltic Hose Type Pumps

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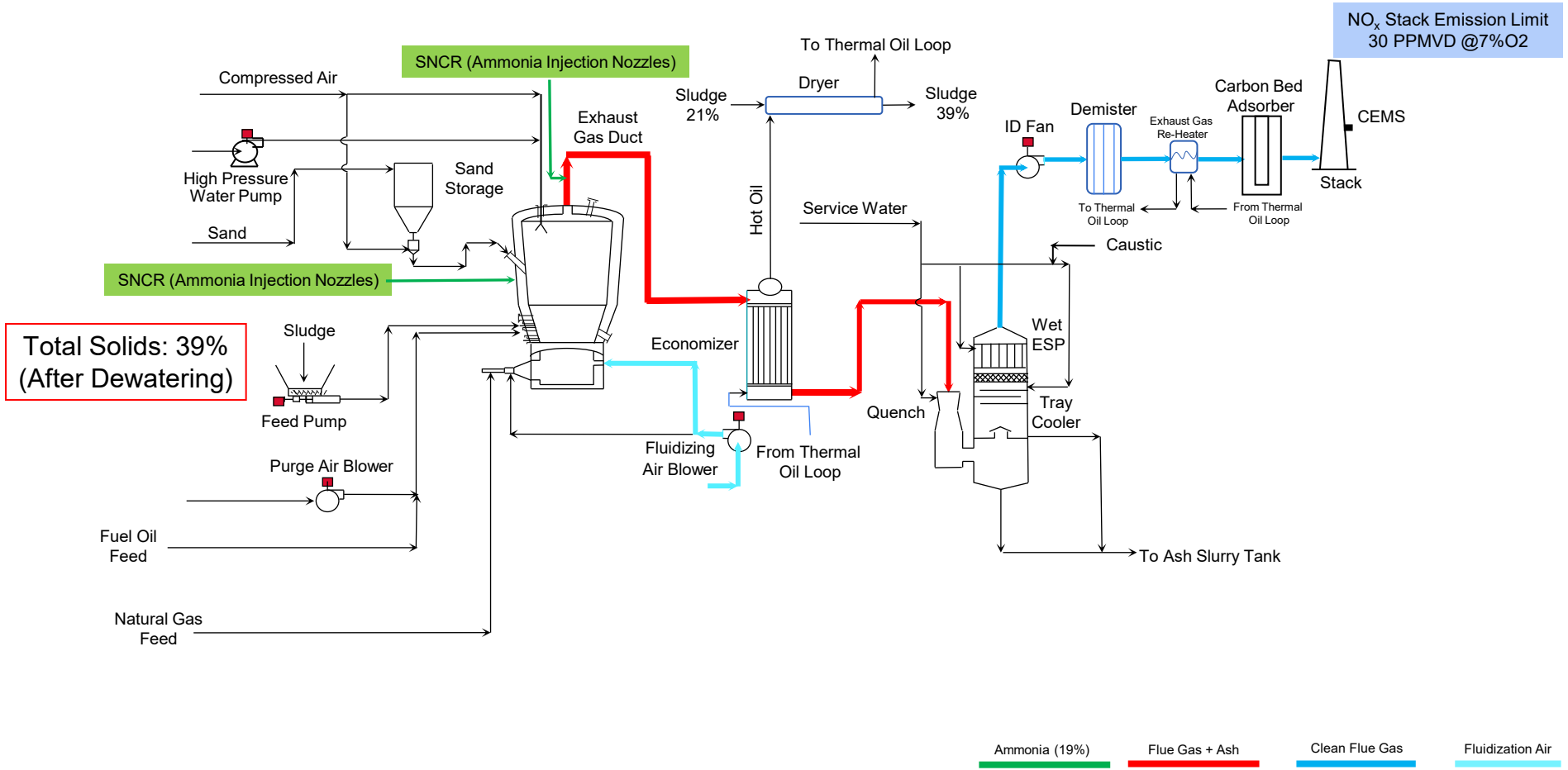
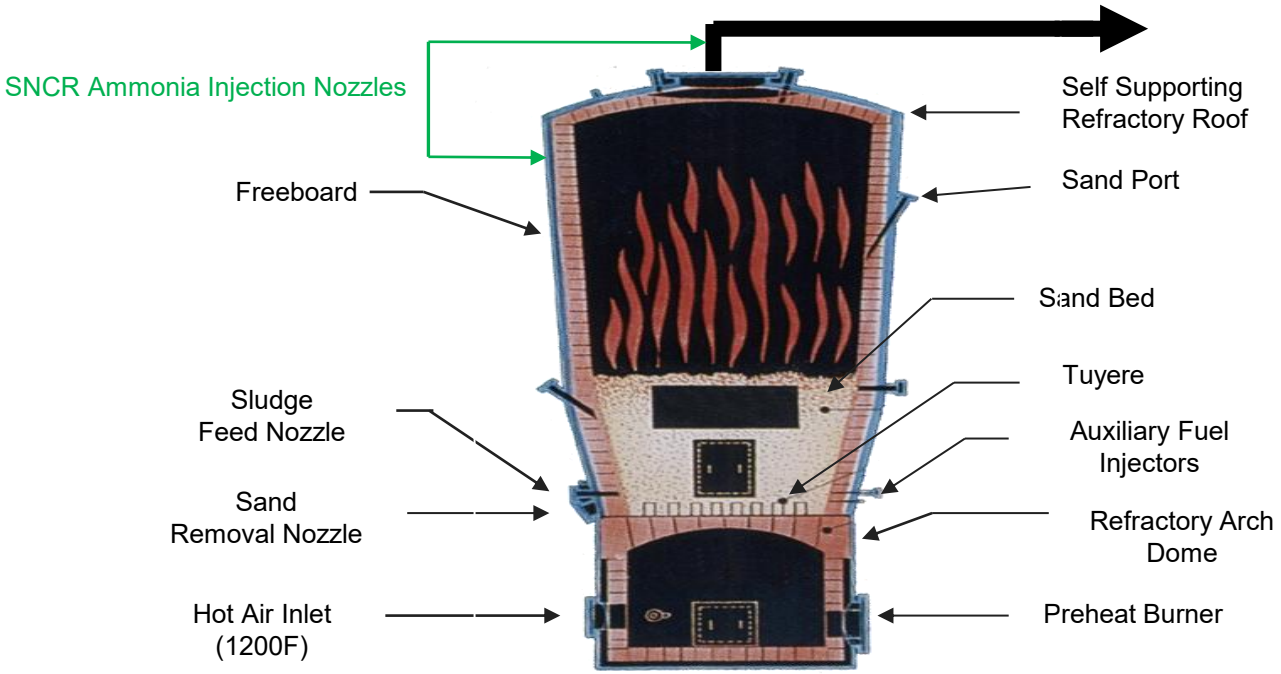
PFD Incineration Train with SNCR (MACT LLLL)



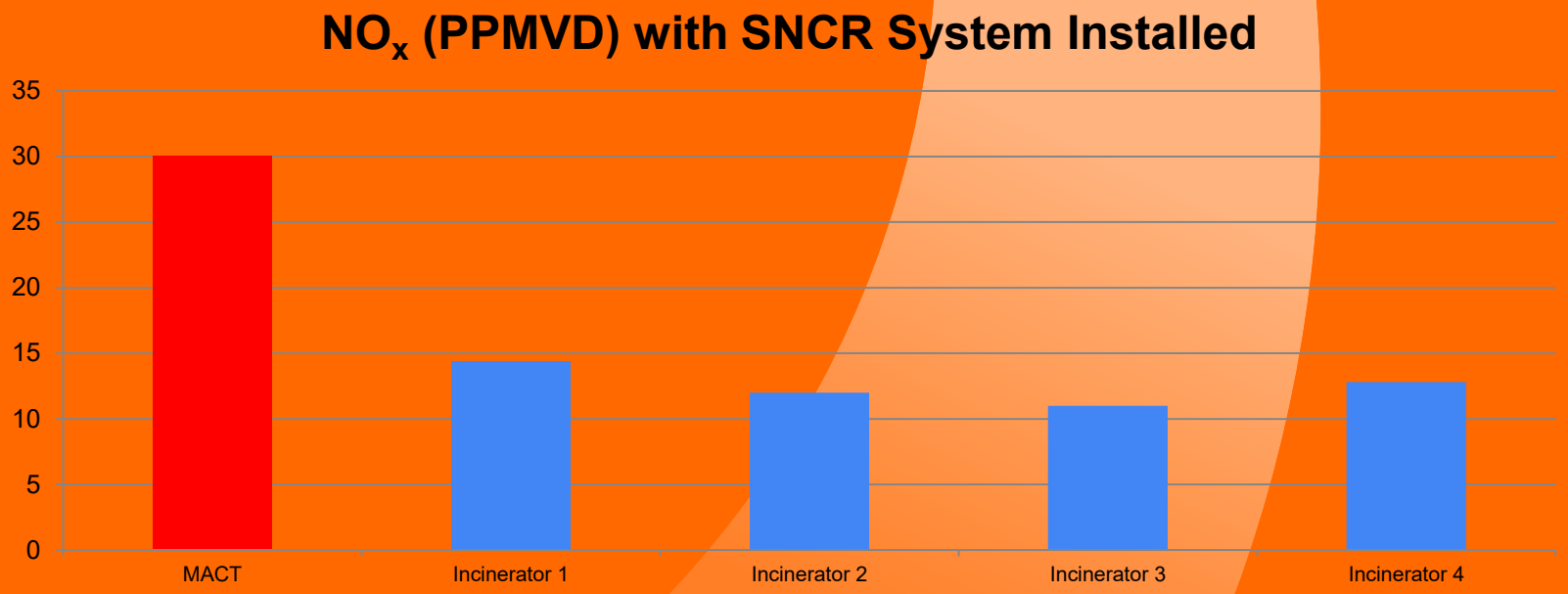
Fluid Bed Reactor



Hot Gas Duct – Ammonia Injection Nozzle

NO_x Stack Emission Test Results

New Incinerator (MACT LLLL)



SNCR system was not used during the tests

Red Bar: MACT LLLL Emission Limit @7%O2
Blue Bar: Measured Emissions @ 7%O2

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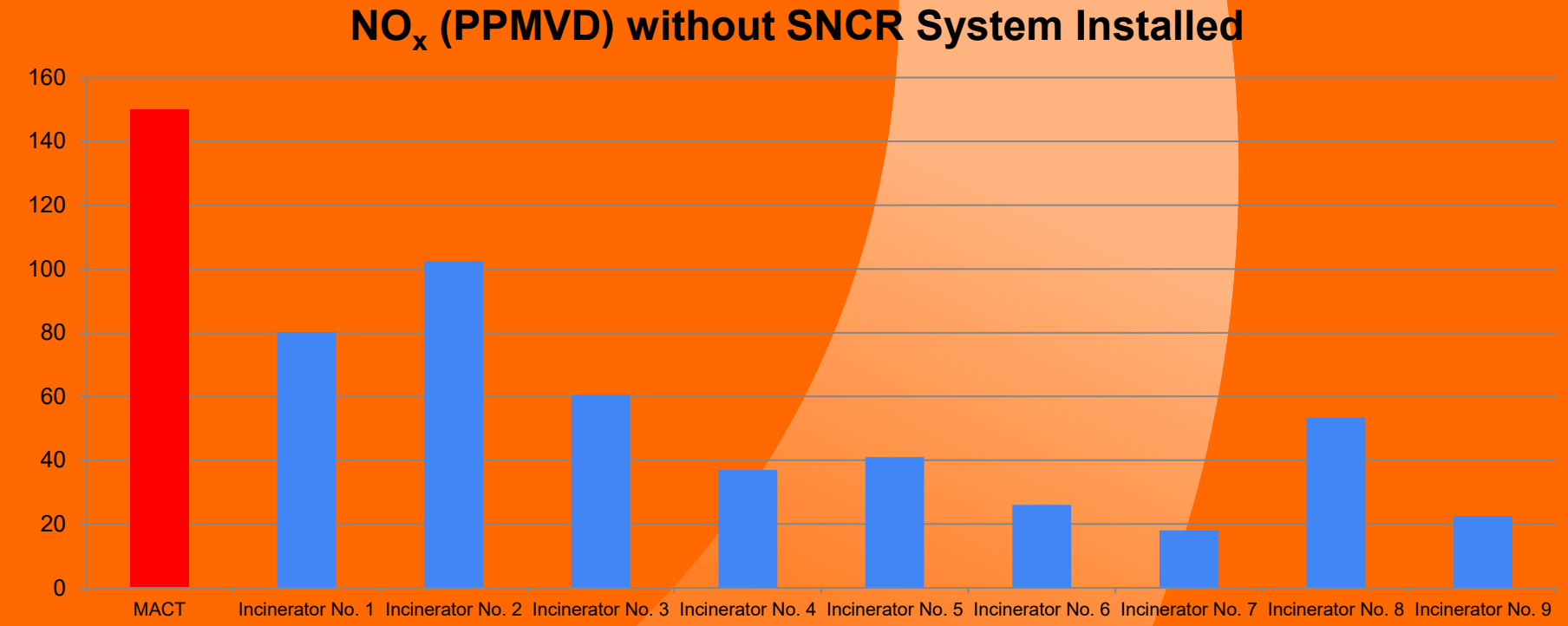
Existing Incinerator (MACT MMMM)



Red Bar: MACT MMMM Emission Limit @7%O2
Blue Bar: Measured Emissions @ 7%O2

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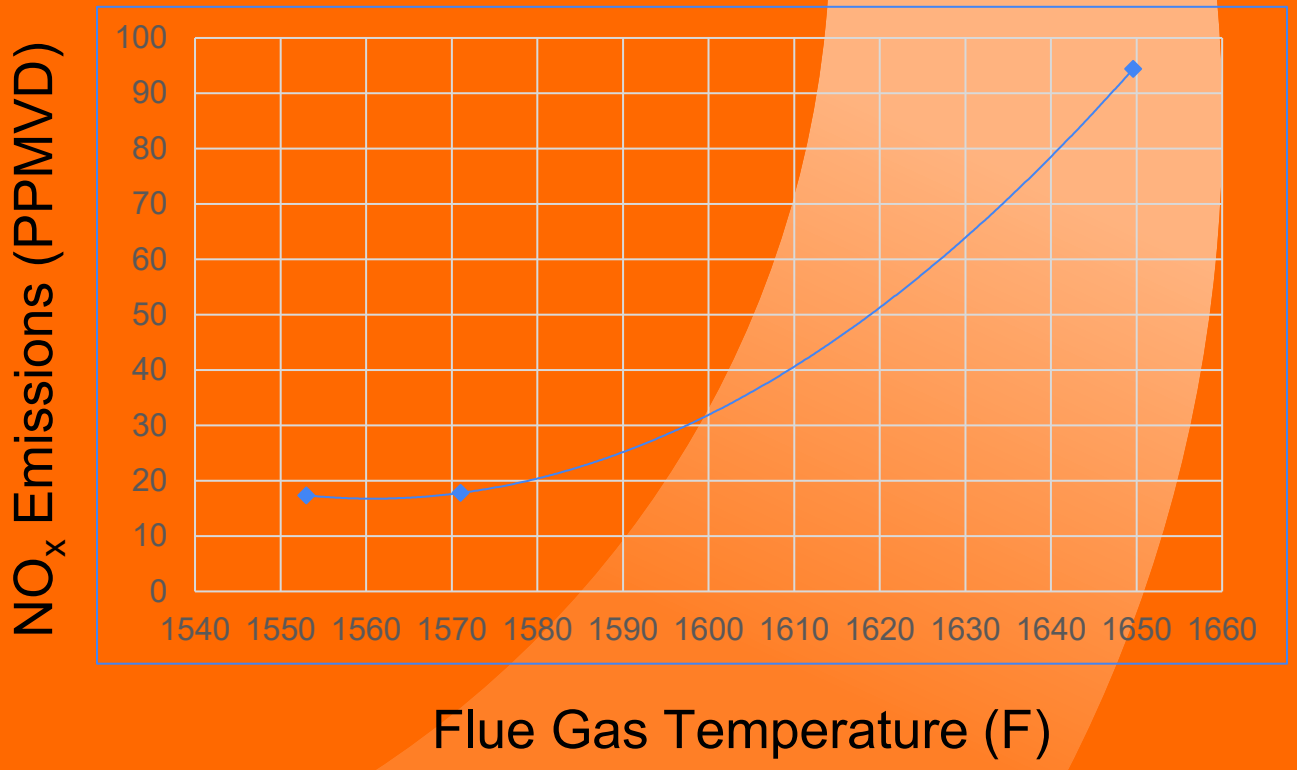
Flue Gas Temperature and NO_x Emissions @ 7% O2



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Conclusions

Conclusions

- Primary control methods have proven to be extremely effective in controlling NO_x emissions for both new and existing fluid bed incinerators in the US.
- While Selective Non-Catalytic Reduction (SNCR) is the most common secondary control technique installed on the new fluid bed units, stack emission test results show that the new fluid bed plants are capable of achieving NO_x emissions lower than 30 PPMVD without using the SNCR.
- Based on stack emission test results, existing fluid bed incinerators in the US are capable of achieving NO_x emissions lower than 150 PPMVD without the installation of an SNCR system.
- It is recommended that all future new fluid bed incinerators be equipped with a temporary SNCR system. If performance results indicate the need for a permanent solution, a permanent SNCR system should then be installed.

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Questions?

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