

ATTACHMENT X

El Paso Natural Gas Company, LLC**Williams Compressor Station Cost Estimate 8/23/2021**

Turbine Cost Analysis	Interest Rate:	3.25%
All Units	Period (yrs):	20

Cost Effectiveness Summary using Permit Limits

Control Equipment	Unit	Total Capital Investment Cost	Total Annual Cost*	Emission Reduction	Cost Effectiveness
		(\$)	(\$)	(tpy)	(\$/ton)
Selective Catalytic Reduction (SCR)	C-01	11,087,478	1,430,703	216.0	6,623

* Total Annual Cost includes the annualized capital cost as well as the direct and indirect annual operating costs.

EI Paso Natural Gas Company, LLC **Williams Compressor Station Cost Estimate 8/23/2021**

GE Frame 5 Turbine		Interest Rate:	3.25%	-- EPA Default Interest Rate
C-01		Period (yrs):	20	-- EPA Air Pollution Control Cost Manual
Base Case				
NO _x lb/hr:	109.07 lb/hr	-- Average of 2016, 2017, 2018 Emission Test Results		
NO _x tpy:	270.01 tpy	-- Emissions based on projected 2028 annual operating hours and average 2016, 2017, 2018 emission test results		
Projected annual operating hours:	4951 hours	-- Projected 2028 annual operating hours		
SCR				
NO _x Reduction:	80%	-- Based on ADEQ assumption in 8/10/21 email		
NO _x tpy:	54.00 tpy	-- Expected annually NO _x emissions (ton/yr) after SCR		
Turbine Housing Reconfiguration	\$ -	-- Estimated Installation cost included in the total capital investment		
New Transformer	\$ 650,000	--\$2,600,000 new transformer divided by 4 based on ADEQ's 8/10/21 email		
SCR Capital Investment	10,437,478.0	-- KM 8/19/21 Cost Estimate, sized for 42 ppm NO _x outlet		
Total Capital Investment	\$ 11,087,478	-- Includes SCR Vendor quote and KM Cost Estimate		
Annualized TCI:	\$ 762,584	-- Based on interest rate, year and TCI		
Annual O&M Costs:	\$ 668,118	-- EPA Cost Control Spreadsheet		
Total Annual Costs:	\$ 1,430,703			
Emissions Reduction:	216.0 tpy	-- NO _x Reduction based on 4,951 hr/yr		
Cost Effectiveness:	\$ 6,623.35	\$/ton		

Williams Compressor Station Unit C-01: Cost Estimate 8/23/2021

Total Capital Investment (TCI) =	\$ 11,087,478
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Annual Costs

Total Annual Cost (TAC)

TAC = Direct Annual Costs + Indirect Annual Costs

Direct Annual Costs (DAC) =	\$664,825
Indirect Annual Costs (IDAC) =	\$765,878
Total annual costs (TAC) = DAC + IDAC	\$1,430,703

Direct Annual Costs (DAC)

DAC = (Annual Maintenance Cost) + (Annual Reagent Cost) + (Annual Electricity Cost) + (Annual Catalyst Cost)

Annual Maintenance Cost =	0.005 x TCI	\$55,437
Annual Operating Labor Cost =	Operator Labor Rate x Operator Hours/Day x Operating Days/Year =	\$87,600
Annual Reagent Cost =	Reagent Consumption Rate/Hour x Cost of R _{reagent} x Operating Hours/Year =	\$333,361
Annual Electricity Cost =	Electricity Consumption Rate x Cost of E _{electricity} x Operating Hours/Year =	\$108,427
Annual Catalyst Replacement Cost =		\$80,000
Direct Annual Cost =		\$664,825

Indirect Annual Cost (IDAC)

IDAC = Administrative Charges + Capital Recovery Costs

Administrative Charges (AC) =	0.03 x (Operator Cost + 0.4 x Annual Maintenance Cost) =	\$3,293
Capital Recovery Costs (CR)=	CRF x TCI =	\$762,584
Indirect Annual Cost (IDAC) =	AC + CR =	\$765,878

Cost Effectiveness

Cost Effectiveness = Total Annual Cost/ NOx Removed/year

Total Annual Cost (TAC) =	\$1,430,703 Per Year
NOx Removed =	216.0 tons/year
Cost Effectiveness =	\$6,623.35 Per Ton NOx Removed

KINDER MORGAN									
PROJECT NAME		EPNG Williams Install of SCR on GE Frame 5 Unit							
COMPANY NAME		El Paso Natural Gas Company		COMPANY NO.		██████████			
REQUESTED BY		██████████		PREPARED BY		██████████			
ESTIMATE NO.		██████████		ORIGINAL EST. DATE		08/19/21			
REVISION NO.		-		CONSTRUCTION CONTINGENCY		5%			
REVISION DATE				OVERHEAD		0.00%			
PROJECT MANAGER		██████████		████████████████████		██████████		██████████	
STATE		Arizona		TAX GROSS UP		0.00%			
COUNTY				PROJECT TYPE		Sustaining Capital			
				IN-SERVICE		Nov-22			
				ESTIMATE ACCURACY LEVEL		Class 3			
Unit 1 Emission Controls (CWIP) SCOPE:		Install SCR Emissions control system provided by ██████████. New expansion joints (3 per unit) will be installed on ducting between new regen and new SCR. Install a new Aux building for a new air system and other SCR controls. A new transformer is NOT included in estimate.							
ASSET CAPABILITIES: Vol @ ### psi									
Minimum		MMCFD		Minimum		Pressure			
Maximum		MMCFD		MAOP		psig			
				Normal Operating		psig			
				Delivery Pressure		psig			
ESTIMATE SUMMARY			Unit 1 Emission Controls (CWIP)						TOTAL
MATERIAL (INCL SALES TAX)		\$	6,623,800					\$	6,623,800
COMPANY LABOR COST		\$	37,100					\$	37,100
PM, ENG, LAND, ENVIRO - EXPENSE		\$	3,100					\$	3,100
PRIMARY CONSTRUCTION CONTRACTOR		\$	2,452,600					\$	2,452,600
SECONDARY CONTRACTOR		\$	345,500					\$	345,500
PROFESSIONAL ENGINEERING		\$	49,900					\$	49,900
INSPECTION SERVICES		\$	153,000					\$	153,000
RADIOGRAPHY SERVICES		\$	900					\$	900
ENVIRONMENTAL CONTRACTOR		\$	16,200					\$	16,200
ELECTRICAL & INSTRUMENTATION		\$	-					\$	-
RIGHT OF WAY CONTRACTOR		\$	-					\$	-
SURVEY CONTRACTOR		\$	-					\$	-
OUTSIDE LEGAL SERVICES		\$	-					\$	-
ROW & DAMAGES		\$	-					\$	-
PERMIT FEES		\$	-					\$	-
GAS LOSS		\$	-					\$	-
SUBTOTAL		\$	9,682,100					\$	9,682,100
CONSTRUCTION CONTINGENCY		\$	484,105					\$	484,105
AFUDC		\$	271,273					\$	271,273
SUBTOTAL		\$	10,437,478					\$	10,437,478
CAPITALIZED OVERHEAD (BURDEN)		\$	-					\$	-
TAX GROSS-UP		\$	-					\$	-
ESCALATION		\$	-					\$	-
RISK INSURANCE		\$	-					\$	-
ESTIMATED TOTAL COST		\$	10,437,478					\$	10,437,478
Price/Ton:									
(If Applicable) Escalated Price/Ton:									
Contingency:		5%	5%	5%	5%	5%			
In-Service Date:		Nov-22	Nov-22	Nov-22	Nov-22	Nov-22			
ASSUMPTIONS									
Include (Yes/No)	Assumptions								
Yes	See Assumptions Tab	** Estimate shelf life is 6 months from published date.							
Revision	Date	Notes	Approval		Name	Date			
			Project Manager						
			Project Manager Director						
			Project Controls						
			Vice President						
AUTHORITY LEVELS:							Escalation Rates FV=PV(1+i) ⁿ		
< \$25,000,000 PM, PM Director, Project Controls							Material:	0.0%	
> \$25,000,000 PM, PM Director, Project Controls, VP							Other:	0.0%	
Estimate Form Revision 10.3-Small 05/26/21									



Kinder Morgan

Proposal Title: Williams, AZ - GE Frame 5

Proposal Number: [REDACTED]

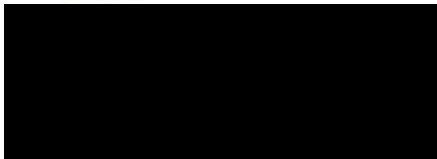
Proposal Description: [REDACTED] Emission Control System to Reduce Emissions from (1)
GE Frame 5 Turbine

Submitted by: [REDACTED]

[REDACTED] Contact: [REDACTED]

Date Submitted: August 17, 2021





August 17, 2021

Kinder Morgan
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]

Proposal #:	[REDACTED]
Project Name:	Williams, AZ - GE Frame 5

[REDACTED]

We are pleased to submit this **REVISED BUDGETARY** proposal for an [REDACTED] designed to reduce emissions for a GE Frame 5 Turbine.

- Rev 1 – Update emissions table and changed to 30,000 USG NH3 tank
- Rev 2 – 80% NOx reduction

The [REDACTED] offered for this project is based on engine and emissions data provided by Kinder Morgan. The enclosed proposal details the price, scope of supply, warranty, commissioning and terms and conditions necessary to achieve the required emissions limits and long-term compliance.

Should you have any questions or comments, please do not hesitate to contact me.

Sincerely,
[REDACTED]



THE [REDACTED] [REDACTED]: COMPLIANCE AT A COMPETITIVE COST

[REDACTED] is an environmental engineering company supplying reliable exhaust after-treatment based emissions control systems to the North American market. Our strength is helping customers comply with federal and local emission regulations targeting process machines, marine vessels, offshore rigs, stationary diesel and natural gas engines and turbines. We specialize in reducing NOx using a comprehensive systems approach based on Selective Catalytic Reduction (SCR). Our SCR systems are then combined with oxidation catalysts or particulate filter technologies to reduce other regulated pollutant emissions, such as carbon monoxide (CO), hydrocarbons (HC), volatile organic compounds (VOC) and particulate matter (PM). We also offer an array of supporting component options, from urea storage tanks to air compressors to silencers, with the goal of providing everything necessary for a successful and near-turnkey installation.

Based in [REDACTED] [REDACTED] [REDACTED]. [REDACTED] leverages more than five decades of experience in environmental compliance, and draws upon the knowledge of over 1000 successful SCR systems in a wide variety of markets such as marine, power generation, oil and gas development, industrial and chemical processes.

Our structured engineering approach begins by comparing your project’s emissions profile to the regulations, or to the project’s unique requirements. We then design an emission control system tailored to your application. Our product manufacturing process is governed by exacting quality standards, and our systems are commissioned with the [REDACTED]. To ensure compliance over the long-term, we provide support after the sale through extensive operator training, spare parts, and on-site maintenance.

[REDACTED] [REDACTED] [REDACTED]
[REDACTED]

- [REDACTED]
- [REDACTED]
- [REDACTED]

[REDACTED] [REDACTED] [REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]

[REDACTED]
[REDACTED]
[REDACTED]

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[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]

I. QUOTATION

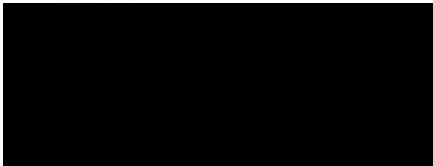
PROPOSAL #:

PROJECT: Williams, AZ - GE Frame 5

DESCRIPTION: to reduce emissions from a GE Frame 5 Natural-Gas Fired Turbine

1. SCOPE OF SUPPLY

ITEM	DESCRIPTION	EXT. PRICE (\$)
001	EMISSIONS CONTROL SYSTEM (1 x Frame 5) 1 x Ducting / SCR Housing / Silencer - Expansion Joint at Regen outlet - Ducting from Regen to inlet of SCR Ducting - Ammonia Injection Grid - SCR Catalyst - Ducting from SCR to Tailpipe - Silencer / Tailpipe with Test Ports 1 x Recycle Gas Skid, each including: 1 x Two-Phase Injection Lance for ammonia/air 1 x Static mixer 1 x Ventilator fan 1 x SCR Control System with Touch-screen and PLC - With NO/O2 analyzer (dual channel, single O2 measurement) 2 x Sample Probes and Heated Sample Lines (Per Unit) 1 x Ammonia/Air Dosing Panel 1 x Reagent Pump Station 1 x Reagent Storage Tank - Engineering, Operation & Maintenance Documentation (Thumb Drive Only)	\$5,100,000



Not included in the scope of supply:

- Load signal from the engine (4-20 mA)
- Fuel flow signal from the engine (4-20mA)
- Fuel composition (TCP/IP)
- Engine running signal (digital dry contact, closed when engine is running)
- Internet connection for remote PLC access and service support
- Structural and civil work necessary to complete the installation
- Catalyst element lift / crane (available as an option)
- Aqueous Ammonia Solution
- Unloading valve/pump skid and controller (available as an option)
- Platforms and other support structures not listed herein
- Compressed Air, per ISO 1.3.4 requirements
- Heat tracing of Ammonia tank or Ammonia lines (available as an option)
- Provision for electricity and connection of the power supply to the enclosure
- System integration (design and engineering) with the building structure
- Unloading of material at customer location
- Any 3rd party emission certification of stack test

[REDACTED]

[REDACTED]	[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]	[REDACTED]



2. PRICE

The given prices for the SCR Emissions Control System are net prices, DDP to customer location in AZ, according to [REDACTED]. All prices are in US dollars. Not included are taxes. Shipping based on standard ground, sea vessel and non-expedited shipping.

3. PAYMENT

[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]

All payments are to be paid within 30 days after each date of invoice, net.

4. SCHEDULING & DELIVERY

Delivery of the drawings and technical documents is approximately 20 weeks after receipt of a purchase order. Delivery of the hardware is approximately 32 weeks after approval of all technical details. Total estimated schedule is 42 weeks (8 weeks for customer review) for receipt of material at the station.

- Preliminary Engineering Drawings – Approximately 20 weeks after receipt of a purchase order
- Customer Review/Approval – 6 Weeks from Receipt of Preliminary
- Release IFC's – 4 Weeks From Receipt of Customer Comments
- Manufacturing – Approximately 6 months From Customer Approval
- Shipping – 4 Weeks

5. QUALITY STANDARD

All drawings will be in both metric and English units. We reserve the right to adapt the technical design of the emission control system based on the results of the final engineering work, provided this does not impact the affect the guaranteed performance characteristics and is approved by the customer before production begins.

6. OFFER VALIDITY

This offer is valid 90 days from date on proposal.

[REDACTED]

1. EXHAUST GAS DATA & EMISSION REQUIREMENTS

Parameter = 100% Load	Unit	GE Frame 5*
Fuel	-	CQNG
Power	bhp	22,150
Exhaust Gas Flow Rate (wet)	lb/hr	~725,000
Exhaust Gas Moisture Content (actual, wet)	Vol. %	3.9
Oxygen Content (actual, wet)	Vol. %	17.8
Exhaust Temperature	°F	420-550**

****Regen Outlet**

Parameter	Unit	Frame 5
Aqueous Ammonia Solution	%	19
Aqueous NH3 Solution Consumption Rate (at 100% engine load) approximately, per engine	gph	~37.2
Total Estimated Backpressure Contribution	inH2O	~11.0
Air Consumption, per engine (Based on 87 psi nominal, max 160 psi)	scfm	25**

****Type Z purge for control panel and dosing panel are not included in this air consumption**

[REDACTED]		
[REDACTED]	[REDACTED]	[REDACTED]
[REDACTED] [REDACTED] [REDACTED] [REDACTED] [REDACTED] [REDACTED]	[REDACTED]	[REDACTED]



2. EMISSIONS GUARANTEE & WARRANTY

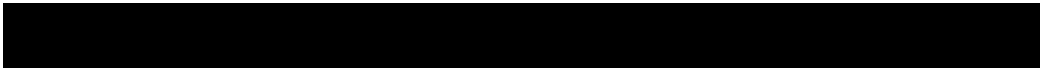
Constituent	Current Engine Out	Required Stack Out**
NOx as NO ₂ *	210 ppmvd @15% O ₂	42 ppmvd @15% O ₂

** Based on 1 hour averaging with the engine operating at 100% load. Minimum temperature for SCR performance is 450F.*

***Based on a minimum 420F SCR outlet temperature with 19% NH3 and Maximum SCR inlet temperature of 700F*

Provided the engine is operating under stable operating conditions,  guarantees the stack emissions (Based on % reduction) for a period of 24,000 hours of operation or 36 months after the initial SCR commissioning, or 42 months after delivery, whichever comes first. All values are per EPA-approved measurement methods, with one-hour averaging while the engine is operating at 100% load. The mechanical warranty is 12 months after commissioning or 18 months after delivery, whichever comes first.

This guarantee is subject certain maintenance practices and engine operating conditions,  . The guarantee is also based on the emissions data provided to  at the time of this quotation and defined in Section 1 of the Technical Description.  reserves the right to modify Items 001 in the Scope of Supply and associated price once more accurate and complete emissions data are obtained in order to ensure the emission limits can be maintained as required.



3. SCOPE OF SUPPLY

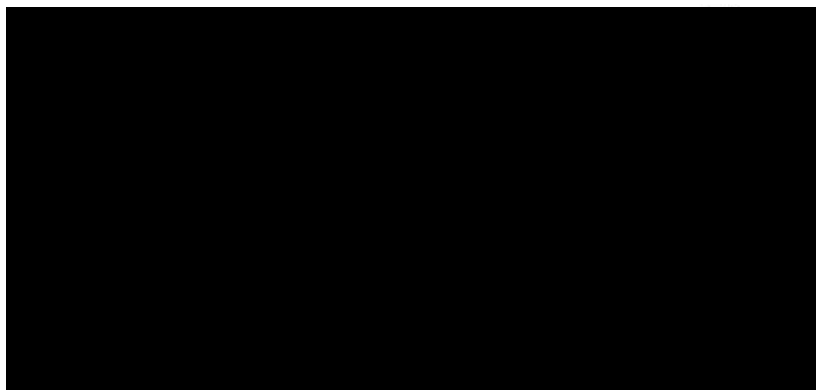
A. Engineering (Per Site)

- [REDACTED]
 - [REDACTED]
 - [REDACTED]
 - [REDACTED]
- [REDACTED]
- Drawings
 - [REDACTED]
 - [REDACTED]
 - [REDACTED]
 - [REDACTED]
- System flow diagram
 - [REDACTED]
 - [REDACTED]
- Control of the SCR system
 - [REDACTED]
 - [REDACTED]
 - [REDACTED]
- Documentation
 - [REDACTED]
 - [REDACTED]
 - [REDACTED]
- Supporting Analyses
 - [REDACTED]
 - [REDACTED]
 - [REDACTED]

B. Ammonia Injection Grid (Per Unit)

Includes one ammonia injection grid (AIG). The ammonia gas will be re-injected in the main exhaust gas duct with an ammonia injection grid. [REDACTED]

[REDACTED]



[REDACTED]

[REDACTED]

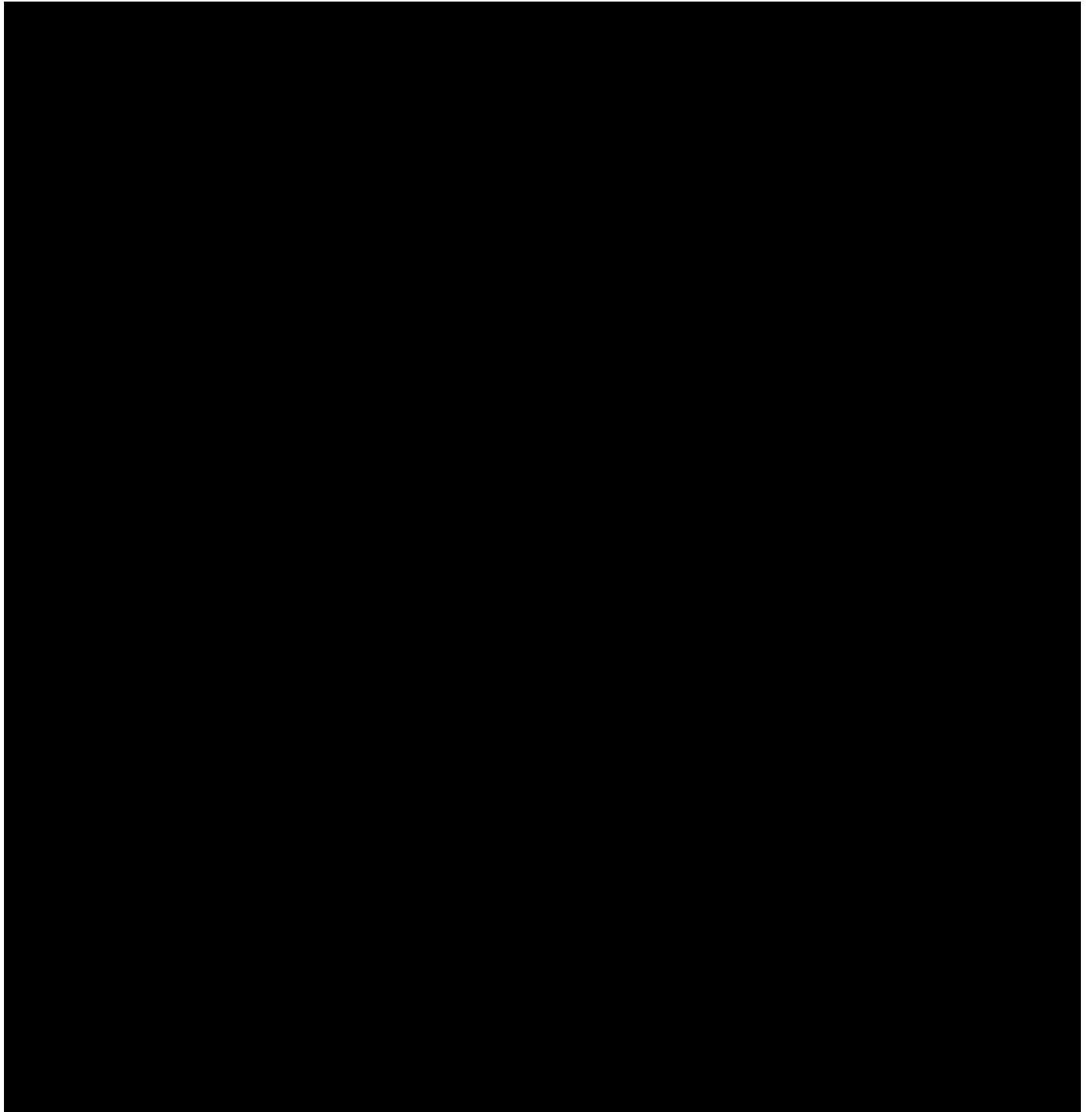
- [REDACTED]
- [REDACTED]
- [REDACTED]

[REDACTED]

- [REDACTED]
- [REDACTED]

Ducting/structure consists of the following major components:

- _____



D. SCR Catalyst (Per Unit)

The SCR catalyst is a corrugated monolith catalyst. The elements will be designed for installation within the framework of the ducting. Individually loaded in the SCR housing.

[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]

Note the SCR catalyst impurity tolerance specification in Section IV and SCR manufacturer data sheet.

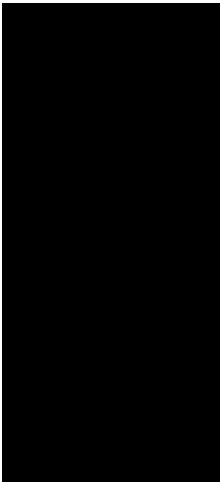
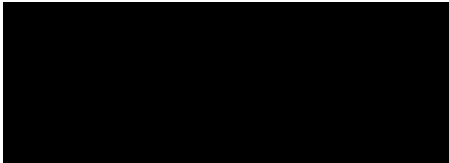
E. Recycle Gas Skid (Per Unit)

A small part of the exhaust gas will be taken out from the main exhaust gas duct downstream of the SCR reactor housing and sent to the recycle gas skid, where aqueous ammonia solution will be injected, evaporated and re-injected in the main exhaust gas duct via the ammonia injection grid. [REDACTED]

- [illegible]

F. SCR Control (Per Unit)

The SCR unit is controlled by a single control system housed in a control cabinet. Includes an Allen-Bradley ControlLogix Programmable Logic Controller and an A-B 15in touch screen with menu-guided parameter inputs (without any program change); password protection; error message and clear readable display. Includes an Ethernet communication between the PLC and the customer's control system. [REDACTED]



- [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]
 - [REDACTED]
 - [REDACTED]
- [REDACTED]

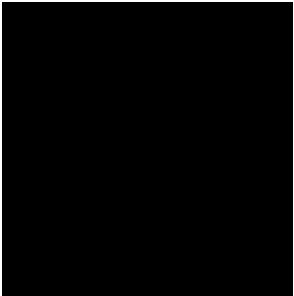
[REDACTED]
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[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]

G. Reagent Dosing Panel (Per Unit)

All components for aqueous ammonia dosing are mounted on a steel back panel; includes steel dosing valve, magnetic valves and shut-off valves. (Pressure indicators related to reagent solution supply to the dosing panel are the customer’s scope.) [REDACTED]

[REDACTED]

[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]



[REDACTED]
[REDACTED]
[REDACTED]

H. Ammonia Pump Station (Per Site)

Pump station complete with auxiliary valves, filters; ships fully assembled and pretested from our factory. The pump station has been designed for 19% aqueous NH₃ for simultaneous operation of all units at the facility. The pump station also comes with one 100% backup pump. [REDACTED]

I. Ammonia Tank and End Devices (Per Site)

Includes (1) horizontal, 30,000 USG, single-wall stainless-steel tank. 126in D x 44ft tangent to tangent length, made of 304 stainless steel, built to ASME Section VIII Division 1 Code, Design Parameters: 30 psig, 125°F with 1/16 in corrosion allowance. Tank includes:

- [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]

- (1) Ultrasonic level transmitter
- (1) Temperature transmitter
- (1) Pressure transmitter
- (1) Relief and Vacuum Valve
- (1) NH₃ leak detection sensor
- (1) Control panel for indication of level, pressure and temperature

III. OPERATING PRINCIPLE

Selective Catalytic Reduction Principle

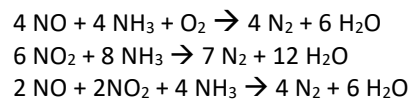
NO_x is a general term referring to Nitrogen Oxide (NO) and Nitrogen Dioxide (NO₂) gases. NO_x forms at the high temperatures of a combustion process, typical of internal combustion engines. NO_x is a precursor to smog and adversely affects health and the environment. As such, NO_x is increasingly regulated by both the US Environmental Protection Agency and by local authorities.

NO_x emissions are most efficiently removed from the exhaust by Selective Catalytic Reduction, often referred to as SCR. SCR works by promoting a chemical reaction between the NO_x and ammonia gas (NH₃), which is introduced upstream of the SCR catalysts. The ammonia can come from a variety of sources, including directly as a gas (known as anhydrous ammonia), or as an aqueous ammonia solution. It is more common to use aqueous urea solution. Urea is a widespread component of fertilizer, and water-based solutions made from urea are easier to handle than ammonia compounds. Moreover, aqueous urea solutions are readily available in different storage capacities and concentrations.

Commercially, aqueous urea solutions come in two concentrations, either 32.5% or 40%. The lower concentration, 32.5%, has the lowest freezing point of 12°F (-11°C), and is therefore used in colder climates where ambient temperatures can reach this point. The 40% concentration has a higher freezing temperature of 35°F (2°C), but requires less volume of solution to achieve the same degree of NO_x reduction. In either case, freezing is to be avoided since injection becomes problematic. When low temperatures are encountered in the application, it is customary to install an immersion heater in the urea storage tank, as well as heat-tracing the urea supply lines to the SCR System. This is true for both concentrations of urea solution.

When the engine is running and the catalyst has warmed up to its normal operating temperature, urea solution is injected into exhaust stream ahead of the SCR catalyst, in combination with high-pressure air, to assist in atomizing the spray. (The air also cools the urea injection nozzle and purges the injector when the engine is no longer running.) Chemically, the heat of the exhaust first vaporizes the water in the urea solution, resulting in the formation of small urea crystals. These crystals further breakdown in the exhaust stream into ammonia and carbon dioxide. Once ammonia is present, the chemical reactions shown below take place over the SCR catalyst, reducing NO_x to harmless nitrogen gas and water vapor.

Once ammonia gas is present, the chemical reactions shown below take place over the SCR catalyst, reducing NO_x to harmless nitrogen gas and water vapor:



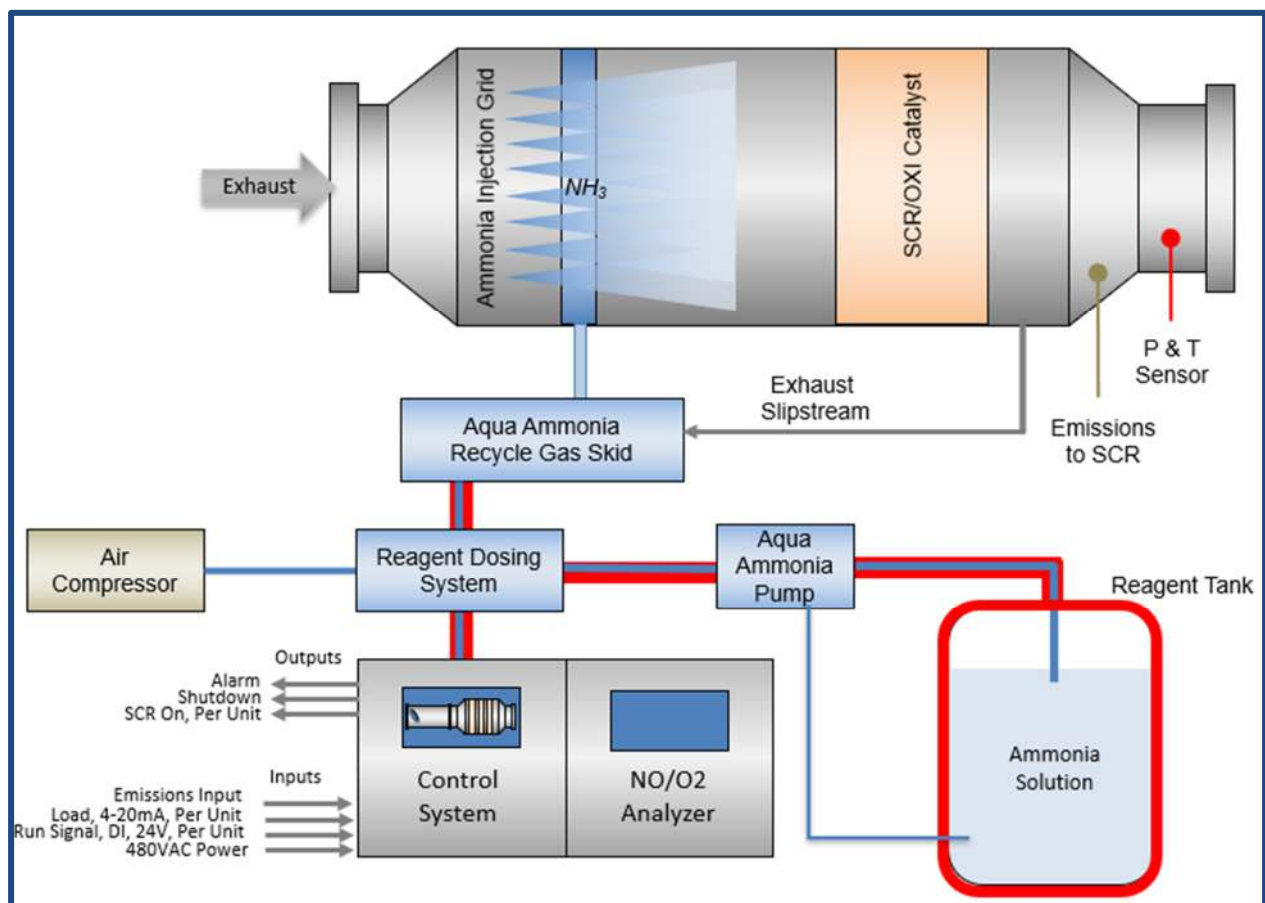
The SCR Catalyst Technology:

SCR catalysts generally fall into two categories, a vanadia-based catalyst embedded in an extruded ceramic substrate, or a zeolite-based technology coated onto the surface of a ceramic substrate. In the former, the catalyst is actually incorporated into the ceramic structure, and as a result the catalyst is generally more robust to thermal variation. In addition, vanadia-based technologies operate over a wide temperature range, and when combined with its strength advantages and lower cost, are used in many

industrial applications such as large-scale power plants and boiler systems. Vanadia-based catalysts have demonstrated NO_x reduction capability of up to 98%, and can operate continuously to temperatures of 510°C (950°F).

Zeolite systems are ideal for higher temperature applications, for example above 510°C, and as such have found wide use in mobile diesel applications such as on-highway trucks. These systems have also demonstrated a capability for high NO_x reduction.

The size of the SCR catalyst elements and how they are configured in a catalyst housing (e.g., number of catalyst layers) is determined by factors such as the required NO_x reduction, allowable back pressure of the engine, and ammonia slip limits. High levels of NO_x reduction (>80%) generally require 2-4 layers of catalyst.



Schematic of a representative [REDACTED].

Urea Injection Strategy:

Reducing NO_x to N₂ with high levels of chemical conversion efficiency without introducing excess ammonia into the exhaust (known as “ammonia slip”) requires precise control of the urea or ammonia injection process. The strategy for urea or ammonia injection depends on the degree of NO_x reduction, and the required ammonia slip limits.

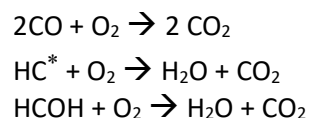
The simplest injection strategy links the engine to the SCR system through the engine load. NO_x emissions are measured as a function of engine load, creating a “NO_x vs. Engine Load” map. From this map, an injection algorithm determines the amount of urea or aqua ammonia necessary to reach the required NO_x level, and sends this signal to the dosing control system. Because the amount of urea or ammonia injected is based on the engine load and not on a direct measurement of NO_x, such an engine mapping strategy is often referred to as an “open-loop” control strategy. Such an injection strategy has been used successfully when NO_x reduction requirements are generally less than 90%. Moreover, the strategy has demonstrated that ammonia slip is minimal, generally far less than typical 10ppm regulatory requirements.

When higher levels of NO_x reduction are necessary, it is customary to add a NO_x analyzer to the SCR System to directly measure NO_x after the SCR catalyst. The signal from the analyzer is then sent to the SCR dosing control system, which then “trims” the injection volume up or down to ensure the required NO_x reduction level is reached, without overdosing that could lead to an increase in ammonia slip. As the NO_x is measured directly with the NO_x analyzer, and the signal is used to control the reagent dosing volume, this strategy is referred to as “closed-loop” control. This strategy has demonstrated up to 98% NO_x reduction, with very low levels of ammonia slip (as low as 5ppm in some applications).

Role of the Oxidation Catalyst:

By incorporating an oxidation catalyst into the system, it is possible to reduce carbon monoxide (CO), many hydrocarbon species (HC), volatile organic compounds (VOC) such as formaldehyde, and particulate matter. Placement of the oxidation catalyst depends on the application requirements, such as degree of CO reduction, but also on parameters such as the degree of NO_x reduction and maximum levels of ammonia slip. In many cases, the oxidation catalyst can be incorporated directly into the SCR catalyst housing, saving both space and the cost of a separate housing.

Oxidation catalysts are generally precious metals-based systems composed of platinum, or mixtures of platinum, palladium and other precious group metals (PGM). PGM catalysts are highly effective at utilizing the excess oxygen in the exhaust stream of lean-burning engines to convert CO, HC and formaldehyde to water vapor and carbon dioxide, as shown below:



Oxidation catalysts can be engineered to operate at temperatures similar to SCR catalysts, allowing for reduction of several pollutant emissions within the same system. Moreover, oxidation catalysts are highly effective, reducing emissions as much as 95%.

* The specific reaction depends on HC species, such as CH₄, C₂H₆ etc.

IV. SCR CATALYST IMPURITY TOLERANCE SPECIFICATION

To maintain the warranty for the SCR quoted in this engineering document, the following impurities and impurity concentrations must be strictly adhered to. Any unexpected performance degradation of the SCR and/or Oxidation catalyst system will result in a chemical analysis of the catalyst system to determine if these impurity tolerances were exceeded.

SCR CATALYST:

Impurity	Max. Concentration Limit
HCl	<20 mg/m ³ (wet) in fuel gas
HBr	<10 mg/m ³ (wet) in fuel gas
HF	<1 mg/m ³ (wet) in fuel gas
Na ₂ O + K ₂ O + alkali metals	0.05wt%
CaO + MgO + BaO + Other Alkaline Earth Metals	0.1wt%
H ₂ O	0.1wt%
PbO	0.1wt%
As ₂ O ₃	0.1wt%
ZnO	0.1wt%
P ₂ O ₅	0.1wt%
SiO ₂	0.1wt%
MnO ₂	0.1wt%
NiO	0.1wt%
CuO	0.1wt%
Sb ₂ O ₃	0.1wt%
SnO ₂	0.1wt%
Fe ₂ O ₃	0.1wt%
CrO ₂	0.1wt%
CdO	0.1wt%
TOTAL AMOUNT, AS QUANTITATIVELY ANALYZED ON THE CATALYST, OF ALL THE LISTED CONTAMINANTS IN THE TABLE NOT TO EXCEED	400 g/m ³ (0.1wt%)

OXIDATION CATALYST:

Impurity	Max. Concentration Limit
Lube Oil Specification: Sulfated Ash Zinc Phosphorus	<0.6% wt% (50 g per liter of catalyst element (1400 g/ft ³) <900 ppm <400 ppm
Sulfur	<100 ppm
Chlorinated Compounds	<10 ppm
Siloxane Compounds	<40 ppb
Poisons (As a fraction of washcoat): Sulfur Calcium Phosphorus Zinc Iron Sulfur, Calcium, Phosphorus, Zinc, Iron Lead, Mercury, Arsenic, Antimony, Copper, Tin, Nickel, Chromium	<1% <1% <1% 0.5% <1% <2% (Collectively) <200 ppm (Collectively)

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