Toelichting onderbouwing van garantiewaarden SCR

Het rookgas van het proces fornuis (unit 360) wordt gereinigd door middel van een selectieve katalytische reductie (SCR) voor de reductie van de NO_x emissie. Door een combinatie van toepassing van een 'low-NO_x burner' (LNB), en optimalisatie in het ontwerp en bediening van de SCR, wordt een zeer lage NO_x-emissie en ammoniak restemissie bereikt. In deze notitie wordt de onderbouwing van de garantiewaarden verder toegelicht.

Omdat AMA als uitgangspunt heeft genomen om geen of minimale stikstof depositie te hebben is de leverancier gevraagd een configuratie te ontwerpen waarbij NO_x en NH_3 emissies zo ver mogelijk geminimaliseerd worden. Omdat andere installaties niet dit uitganspunt hebben genomen is het momenteel nog niet gebruikelijk om vergelijkbare configuratie toe te passen.

De primaire technologie die toegepast zijn om zo laag mogelijke NO_x waarden te behalen zijn weergegeven in de afbeelding hieronder:

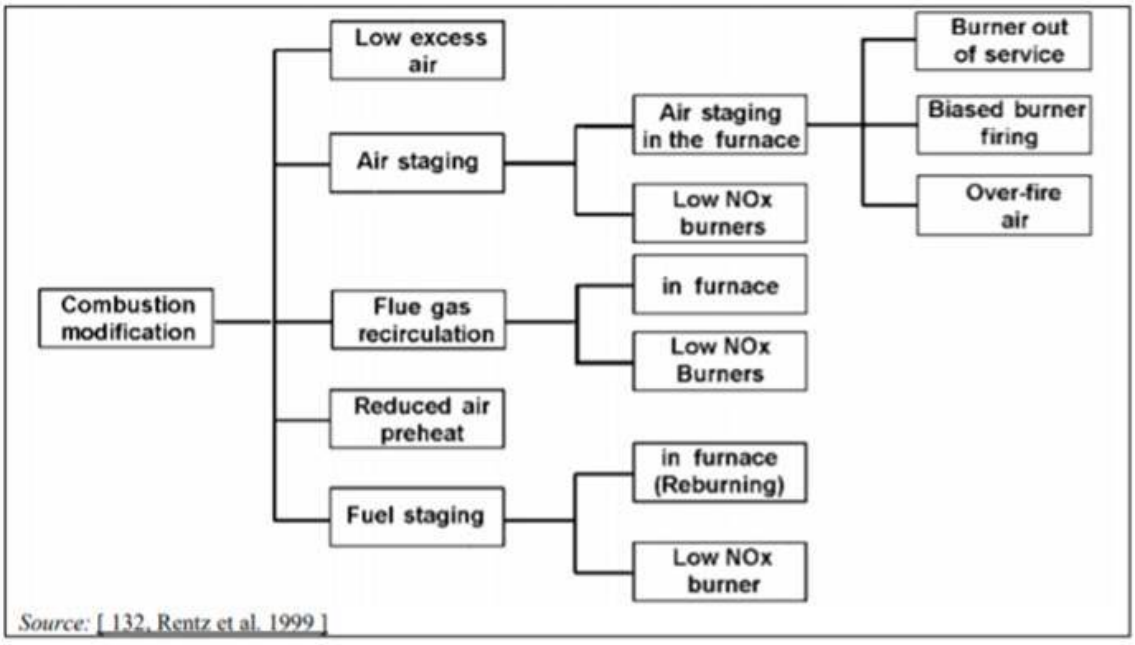

Figure 3.3: Overview of combustion modifications for reducing nitrogen oxide emissions

Deze primaire technieken worden toegepast om ervoor te zorgen dat een zo laag mogelijk vlam temperatuur wordt bereikt en als gevolg de productie van NO_x wordt geminimaliseerd. Dit is ook in lijn met het BREF Document 'Production of Large Volume Organic Chemicals' paragraaf 2.4.2.1. [1].

Door het toepassen van een LNB kan een garantiewaarde door de leverancier gegeven worden voor de NO_x uitlaat concentratie van de brander van 70 mg/Nm^3 (gelijk aan 35 ppmv @ 3%O_2 droog). Er kan

van worden uitgegaan dat de te verwachten waarden lager liggen. Dit wordt ook bevestigd door de waarden die gerapporteerd zijn voor 'low-NOx burners' in de BREF [2]:

Table 4.17: BAT-associated emission level (BAT-AEL) for channelled NO_X emissions to air from process furnaces/heaters

Parameter	BAT-AEL (mg/Nm^3) (Daily average or average over the sampling period)	Mass flow threshold (g/h)
Nitrogen oxides (NO_X)	50-150 (1)	1 000
(1) The upper end of the range may be up to 400 mg/Nm^3 if the combustion temperature is higher than 1 200 °C.		

Daarnaast hebben we gegevens uit de prestatie test toegevoegd van deze 'low-NOx burners', zie bijlage I voor de onderbouwing in SCR tabel 4.3.1.1 en de referenties van leverancier waarin de referenties staan voor installaties waarbij de garantiewaarden van <70 mg/Nm^3 worden behaald in bijlage II.

Om de NO_x emissie verder te verlagen kan gebruik gemaakt worden van secondaire NO_x reductie technologie. De secondaire NO_x reductie technologie die wordt toegepast door AMA is 'Selective Catalytic Reduction' (SCR). In een SCR wordt NO_x emissie gereduceerd door een reactie met NH_3 of ureum over een katalysator. Hierbij wordt NO_x omgezet tot N_2 en H_2O. De resterende emissie van NO_x is afhankelijk van de ingaande NO_x concentratie in het rookgas en de conversie die bereikt wordt over de katalysator.

In de BREF [2] wordt gesproken over verwijderingsefficiëntie tussen de 50% en 99%. De omzetting is hierbij sterk afhankelijk van de voedingsconcentratie en de emissie limieten die behaald moeten worden. De leverancier gaat uit van een verwijdering efficiëntie van 97.1% om tot de garantie waarde van 2,1 mg/Nm^3 (1 ppmv) NO_x te komen. Dat deze verwijderingsefficiëntie behaald worden is te zien uit de referentie lijst van de SCR leverancier UMICORE in bijlage III.

Een 'Cross-media' effect van het gebruik van een SCR is het gebruik van NH_3 of Ureum. Het gebruik wordt minimaal gehouden door ervoor te zorgen dat er een zo laag mogelijke concentratie NO_x in het rookgas aanwezig is voor het de SCR binnen komt. Een ander 'cross media' effect is de emissie van de niet gereageerde NH_3 (NH_3 slip). Ook voor de emissie van NH_3 is door AMA gevraagd deze te minimaliseren. Omdat de reactie tussen NO_x en NH_3 niet perfect is blijft er altijd een kleine hoeveelheid NH_3 over. Deze overmaat resulteert in de NH_3 slip. De eerste stap in het minimaliseren van deze slip is wederom ervoor te zorgen dat er een lage concentratie NO_x de SCR in komt.

Door het toepassen van de juiste monitoring kan de dosering van NH_3 gestuurd worden en wordt de NH_3 slip minimaal gehouden. Doordat de brander en de SCR bij dezelfde leverancier zijn aangevraagd kunnen de systemen op elkaar inspelen, waardoor er een goede controle blijft. De leverancier geeft aan dat met deze maatregelen de NH_3 slip van 0,2 ppmv gegarandeerd kan worden.

Ook in de BREF [2] wordt bevestigd dat door middel van optimalisatie deze waarden haalbaar zijn:

BAT 17. In order to reduce channelled emissions to air of ammonia from the use of selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR) for the abatement of NO_X emissions, BAT is to optimise the design and/or operation of SCR or SNCR (e.g. optimised reagent to NO_X ratio, homogeneous reagent distribution and optimum size of the reagent drops).

Table 4.5: BAT-associated emission level (BAT-AEL) for channelled emissions to air of ammonia from the use of SCR or SNCR

Substance/Parameter	BAT-AEL (mg/Nm^3) (Average over the sampling period)
Ammonia (NH_3) from SCR/SNCR	< 0.5-8 ([1])
([1]) The upper end of the range may be up to 30 mg/Nm^3 in the case of: • thermal or catalytic oxidation of waste gases containing high levels of NO_X precursors; or • if the waste gases contain high levels of NO_X prior to treatment with SCR or SNCR.	

Naast de hierboven aangegeven maatregelen kan ook het toepassen van een additionele NH_3 oxidatie katalysator in de SCR de NH_3 slip verder reduceren. Deze katalysator is hetzelfde als de katalysator die wordt toegepast bij diesel motoren om NH_3 emissies te verlagen. Deze katalysator wordt ook toegepast in de industrie. Referenties met garanties over deze katalysator zijn gegeven in de bijlage IV.

Het uitganspunt van AMA is om de NO_x en NH_3 emissies zo ver mogelijk te minimaliseren, waar bij andere installaties het uitgangspunt slechts het behalen van de emissie grenswaarden is. Het is daarom niet vreemd dat er op dit moment nog geen voorbeelden zijn waarin dezelfde (lage) emissiewaarden worden behaald. Door de combinatie van de verschillende best beschikbare technieken kunnen deze lage emissiewaarden bereikt worden. Individueel hebben deze technieken de resultaten die gebruikt zijn om tot de lage emissie waarden van AMA te komen allemaal bewezen.

Referenties:

[1] Best Available Techniques (BAT) Reference Document for the Production of Large Volume Organic Chemicals (2017)
[2] Best Available Techniques (BAT) Reference Document for Common Waste Gas Management and Treatment Systems in the Chemical Sector. Draft 1 (November 2019)

Bijlagen:

Bijlage I	Onderbouwing SCR Casale
Bijlage II	Referenties Zeeco
Bijlage III	Referenties UMICORE
Bijlage IV	Referenties NH_3 oxidatie

FIRED HEATER EMISSION REPORT

CONFIDENTIAL

Form TDT01-rev02

REV.	DATE	DESCRIPTION	PREPARED	CHECKED	APPROVED

CASALE ADVANCED METHANOL AMSTERDAM	**Advanced Methanol Amsterdam B.V.** New 260 MTPD Methanol Plant Amsterdam, The Netherlands	**Proj. No.:** A09480 **Doc. No.:** A09480M-E-PRH-3602 **Rev.:** 00 **Sheet No.:** 2 of 13 **Client Proj. No.:** 1 **Client Doc. No.:**

REVISION INDEX SHEET

REV. / PAGE	00	01	02	03	04	05	REV. / PAGE	00	01	02	03	04	05	REV. / PAGE	00	01	02	03	04	05
1	X																			
2	X																			
3	X																			
4	X																			
5	X																			
6	X																			
7	X																			
8	X																			
9	X																			
10	X																			
11	X																			
12	X																			
13	X																			

CONTENTS

1 INTRODUCTION

G.I. Dynamics B.V. (GID) is developing a Gasification to Bio-Methanol Plant for and on behalf of Advanced Methanol Amsterdam B.V. (AMA).

The facility will be located in Amsterdam, and is based on HTW Gasification technology from GIDARA Energy B.V.

This plant will produce Advanced Methanol from Refuse Derived Fuel (RDF) and Waste Wood (WW).

Since the plant will be located close to a protected area, the local authorities require more stringent limits both in term of NO_x emissions and NH_3 slip.

In particular, zero dispersion of ammonia is allowed at ground level.

G.I. Dynamics B.V. (GID) has requested to CASALE SA to provide a report in order to describe the NO_x Control Technologies selected for the AMA Project.

2 SCOPE

The purpose of this report is to give evidence about the maximum achievable emission reduction level with the technologies selected for the AMA Project.

3 NO_X CONTROL STRATEGIES EXECUTIVE SUMMARY

Based on the current best available technologies, different strategies have been adopted in order to achieve the required emission level imposed by local regulations.

The system has been properly designed with the following features:

- Burners design has been selected as Low-NO_x type achieving the minimum achievable emission level without excessively affecting the combustion efficiency.
- The fired heater has been designed adopting a configuration able to burn all the available plant waste gas (the lower emission producer), minimizing the make-up fuel gas consumption (higher emission producer).
- SCR System has been foreseen in combination with the Low-NO_x Burners in order to achieve the required both the NO_x and NH_3 target values. Selective Catalytic Reduction (SCR) is recognized worldwide as the most effective NO_x control technology when substantial NO_x reduction of 50% up to 99% is required.
- The ammonia slip has been reduced as much as possible both with a proper design for injection/mixing distribution system and a proper fine control system for the ammonia dosing unit. The design been optimized as much as possible to achieve the target value.

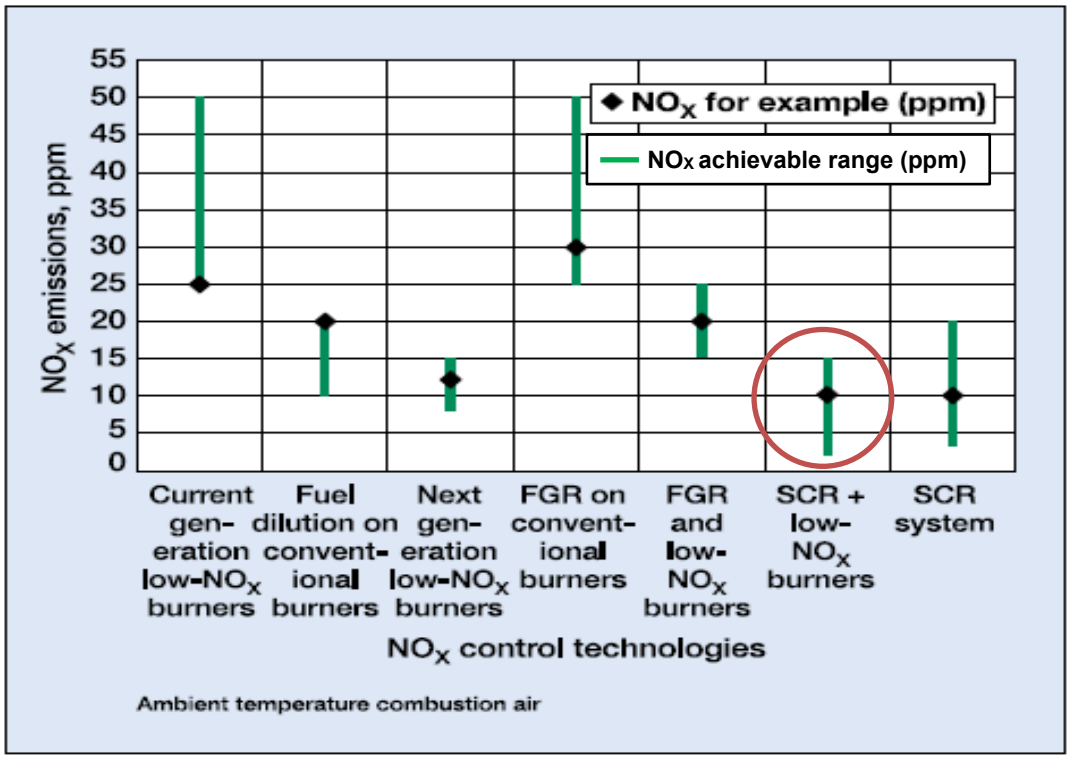

Fig. 3.1 NO_x control technology - Achievable NO_x emission range

The achievable NO_x emission range using the combination of the Low-NO_x Burners and the SCR System is 2 ÷ 15 ppmv @3%O_2 dry basis depending on the installed catalyst volume. (**Fig**.3.1).

4 NO_X CONTROL SELECTED TECHNOLOGIES FOR AMA PROJECT

4.1 LOW-NO_X BURNERS

Combustion control techniques reduce the amount of NO_x emission by limiting the amount of NO_x formation during the combustion process.

In particular, LNB burners can use air staging, fuel staging or internal furnace gas recirculation to lower peak flame temperatures and directly reduce NO_x emissions from combustion.

4.1.1 LNB REQUIRED PERFORMANCES

For this specific project, LNB Burners have been foreseen in order to achieve a maximum NO_x content of 35 ppmv @3%O_2 dry (70 mg/Nm^3), as a guaranteed figure, in the flue gas from the combustion zone.

This value is in compliance with the maximum NO_x emission levels allowed by the EU regulation and it can be guaranteed by all Top Class Burner Vendors (i.e. ZEECO, John Zink, Callidus, etc).

4.2 SCR SYSTEM

SCR process is based on the chemical reduction of the NO_x molecule through the ammonia injected upstream in presence of a metal-based catalyst with activated sites to increase the rate of the reduction reaction.

The reagent reacts selectively with the flue gas NO_x within a specific temperature range and in the presence of the catalyst and oxygen to reduce the NO_x into molecular nitrogen (N_2) and water vapor (H_2O).

Selective catalytic reduction can be utilized where exhaust gases are between 250°C and 650°C, depending on the catalyst used.

Theoretically, SCR systems can be designed for NOx removal efficiencies up close to 100 percent. In practice, commercial fuel gas fired SCR systems are often designed to meet control targets of over 95 percent. Properly designed SCR systems, which operate close to the theoretical stoichiometry and supply adequate catalyst volume, maintain low ammonia slip levels, approximately less than 2 ppm [1].

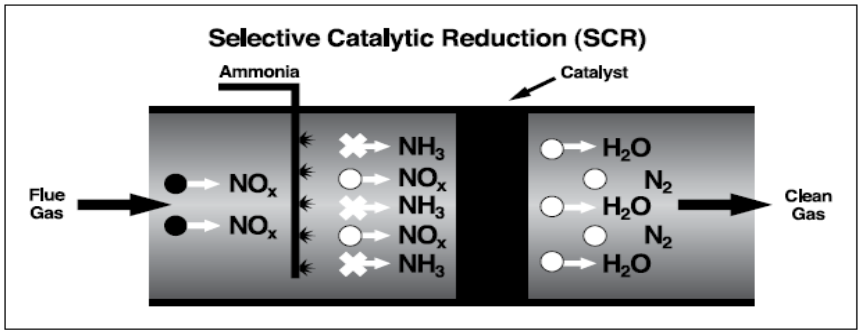

Fig. 4.2.1 SCR System Operation Scheme

4.2.1 SCR REQUIRED PERFOMANCES

Due to the AMA complex location constrains, an extremely low emission levels are allowed in order to be in compliance with the local law requirements.

In particular, the results of the dispersion study require that the SCR System performances shall be the following:

- max 1 ppmv @ 3%O_2 dry of NO_X
- max 0.2 ppmv @ 3%O_2 dry of NH_3

4.3 SCR VENDOR DATA

In the next paragraph are shown the expected and guaranteed performances of three different SCR Catalyst Vendors.

4.3.1 DESIGN BASIS

FLUE GAS OPERATING CONDITION					
OPERATING CASE:		**EOR DESIGN CASE**	**SOR CASE**	**MOR MINIMUM REACTIVITY CASE**	**MOR MAXIMUM REACTIVITY CASE**
Flowrate	kg/h	6609	6560	6678	4253
Temperature	°C	333	333	333	333
Inlet Pressure	mmWCg	-145	-145	-147	-122
MW		28.1	28.1	27.8	28.3
Composition:	%v				-
O_2		2.3	2.3	2.3	2.3
N_2		66.3	66.3	69.2	65.8
Ar		0.9	0.9	1	0.9
CO_2		11.4	11.4	9	12.2
H_2O		19.1	19.1	18.5	18.8
SO_2	ppmv	N/A	N/A	N/A	N/A
NO_X	ppmv	35 max	35 max	35 max	35 max
Maximum Allowable NO_X @ SCR SYSTEM OUTLET			ppmv @3% O_2 dry		**≤ 1**
Maximum Allowable NH_3 Slip @ SCR SYSTEM OUTLET			ppmv @3% O_2 dry		**≤ 0.2**

Tab. 4.3.1.1. SCR System Performances Design Basis

4.3.1.1 ZEECO SCR PERFORMANCES

ZEECO provided a technical offer both Burner and SCR so that can be considered responsible for the overall NO_x and NH_3 stack emissions.

in the table below are shown the guaranteed performances both for the Radiant Chamber Burners and the SCR System:

Burner	Unit	Guaranteed
NOx	mg/Nm3	70(*)
CO	ppmvd	50
UHC	ppmvd	4
Particulates	ppmvd	100
Stack Emission	**Unit**	**Guaranteed**
NOx	ppm	< 1,0
Ammonia slip	ppm	< 0,2
Pressure drop	mmWC	< 90 (**)

(*) Zeeco will be responsible to guarantee the NOx stack emissions since we are offering both Burners and SCR system.
(**) The above pressure drop doesn't take in account the pressure drop of the static mixer that might be necessary after CFD analysis to be installed downstream the ammonia atomizing gun to ensure that the necessary distribution NH3/NOx is reached. In case static mixer will be necessary, the pressure drop of the system will be 200mmWC.

These values are understood to apply only when the system is operated in accordance with the operating conditions stipulated in the design summary and for the waste(s) stipulated in the design basis sections of this proposal. VOC is defined as non-methane and non-ethane hydrocarbons.

Tab. 4.3.1.1.1 ZEECO SCR System Performances

For details refer to the Attachment 1.

4.3.1.1.1 ZEECO REFERENCES

Refer to Attachment 2.

4.3.1.2 FUEL TECH SCR PERFORMANCES

5.0 SCR NO_x DESIGN BASIS

Parameter	Units	EOR	SOR	MOR minimum reactivity	MOR maximum reactivity
Flue gas flow	kg/h wet	6609	6560	6678	4253
Flue gas flow	Nm^3/h wet	5266	5227	5381	3370
Temperature	°C	338	334	337	330
Duct Inlet pressure	mmwg	-45	-45	-47	-22
Inlet NO_x	**ppm @3% O_2 dry**	**35**	**35**	**35**	**35**
NOx present as NO_2	%	20	20	20	20
Inlet CO	mg/Nm^3 @ 3% O_2 dry	n.a.	n.a.	n.a.	n.a.
O_2, volume	% wet	2.3	2.3	2.3	2.3
H_2O, volume	% wet	19.1	19.1	18.5	18.8
CO_2, volume	% wet	11.4	11.4	9	12.2
SO_2	ppm @ op. O_2 wet	<1	<1	<1	<1
SO_3	ppm @ op. O_2 wet	n.a.	n.a.	n.a.	n.a.
Particulate <10µ	mg/Nm^3 wet	< 130	<130	<130	<130

5.1 SCR Performance

Parameter	Units	EOR	SOR	MOR minimum reactivity	MOR maximum reactivity
NOx outlet **guaranteed**	**ppm @3% O_2 dry**	**1.0**	**1.0**	**1.0**	**1.0**
NH_3 slip **guaranteed**	**ppm @3% O_2 dry**	**0.2**	**0.2**	**0.2**	**0.2**
Estimated Reagent	kg/h @ 24.5% NH_4OH	0.45	0.45	0.49	0.29
Pressure drop guaranteed *(within battery limits)*	mmH_2O @ 4°C	100	100	100	100
Expected NH_3 slip w/ new catalyst vs. EoL catalyst		-		None	
Ammonia inj. rate w/ new catalyst vs. EoL catalyst		-		None*	

** There might be other dust with the ability to oxidize NH3 in the flue gas which can deposit on catalyst: this might cause NH3 consumption to increase.*

Tab. 4.3.1.2.1 Fuel Tech SCR System Performances

For details refer to the Attachment 3.

4.3.1.2.1 FUEL TECH REFERENCES

Refer to Attachment 4.

4.3.1.3 CECO PEERLEES SCR PERFORMANCES

A, DESIGN CONDITIONS: The proposed SCR System design is based on the following design conditions; the data is for one (1) unit. Should the actual gas conditions be different from the design data, the performance shall be re-evaluated, based on the corrected design data.

PROCESS DATA							
Design Case				Case 1	Case 2	Case 3	Case 4
Customer Design Case				EOR Design	SOR Design	MOR Min Reactivity	MOR Max Reactivity
Percent Load			Percent	100%	100%	100%	100%
Fuel Case				Gas	Gas	Gas	Gas
Exhaust Gas Mass Flowrate, Wet			kg/h	7269,0	6560,0	6678,0	4253,0
Exhaust Gas Volumetric Flowrate, Wet			Nm3/h	5786	5221	5374	3366
Exhaust Gas Temperature			degrees C	338,0	334,0	337,0	330,0
Exhaust Gas Composition							
Component	*MW*						
O2	31,999		vol% (wet)	2,30	2,30	2,30	2,30
H2O	18,015		vol% (wet)	19,10	19,10	18,50	18,80
N2	28,013		vol% (wet)	66,30	66,30	69,20	65,80
CO2	44,010		vol% (wet)	11,40	11,40	9,00	12,20
Ar	39,948		vol% (wet)	0,90	0,90	1,00	0,90
				100,00	100,00	100,00	100,00
Emissions from the Source		@ %O2	3				
Nox as NO2			ppmvd	35,00	35,00	35,00	35,00
Nox as NO2			kg/h	0,34	0,31	0,32	0,20
SO2			ppmvw	1,00	1,00	1,00	1,00
SO2			kg/h	0,02	0,01	0,02	0,01
Particulates			mg/Nm3 (dry)	130,00	130,00	130,00	130,00
Amount of Nox as NO2			Percent	20,00	20,00	20,00	20,00
Nox Reduction			Percent	97,14	97,14	97,14	97,14
Aqueous Ammonia Requirement			kg/h	0,619	0,614	0,638	0,398
Aqueous Ammonia Requirement			m3/month	1,000	0,492	0,511	0,319
Performance Warranties		@ %O2	3				
Nox as NO2			ppmvd	1,0	1,0	1,0	1,0
Nox as NO2			kg/h	0,010	0,009	0,009	0,006
NH3 Slip			ppmvd	1,00	1,00	1,00	1,00
NH3 Slip			kg/h	0,004	0,003	0,003	0,002

Tab. 4.3.1.3.1 CECO Peerless SCR System Performances

For details refer to the Attachment 4.

4.3.1.3.1 CECO PEERLEES REFERENCES

Refer to the Attachment 6.

4.4 CASALE REFERENCES

Casale confirms that in some Acid Nitric Plant licensed by Casale and provided with an SCR Unit, the following parameters have been achieved:

Performance guarantee for 100% load	Guarantee value	Measured figure (without tolerance)	Evaluated figure (with tolerance)	Result
NOx (as NO2) in any vented stream	≤ 30 ppmv	10,68	9,68	OK
NH3 in any vented stream	≤ 2 ppmv	0,000 Note a	0,000 Note a	OK

Note:

a. Not detectable

Tab. 4.4.1. SCR System Performances - Casale Ammonia Nitric Plant

Casale can not disclose Client name due to confidentiality issue.

In any case the above data (**Tab**. 4.4.1) is an evident proof that the “zero” ammonia slip is industrially achievable with an SCR Unit.

5 REFERENCES

[1]. Institute of Clean Air Companies (ICAC). White Paper. Selective Catalytic Reduction (SCR) Control of NO_x Emissions From Fossil Fuel-Fired Electric Power Plants. May 2009.

6 ATTACHMENTS

- ATTACHMENT 1: ZEECO SCR PERFORMANCES
- ATTACHMENT 2: ZEECO REFERENCE LIST
- ATTACHMENT 3: FUEL TECH SCR PERFORMANCES
- ATTACHMENT 4: FUEL TECH REFERENCE LIST
- ATTACHMENT 5: CECO PEERLESS SCR PERFORMANCES
- ATTACHMENT 6: CECO PEERLESS REFERENCE LIST

TABLE OF CONTENTS

1.0 INTRODUCTION

Zeeco has been designing and manufacturing burners, flares, incinerators, air pre-heaters, and combustion systems for world wide use since 1980.

Zeeco's Engineering Staff offers over 1,000 years of experience in the development, design, and testing of Combustion Systems. Zeeco has the proven skills and innovative abilities to design a practical and environmentally friendly combustion system to thermally treat virtually any industrial waste. This learned "art" gained by research and design efforts which are refined by testing and field experience has been implemented in the process plants of numerous industries throughout the world.

From project planning through design, procurement, manufacturing, installation, and even start-up, Zeeco will provide project management and support as deemed necessary. It is our world class HANDS ON type design skills, quality products, experienced staff, and especially our responsiveness to our customers needs that truly set Zeeco apart from our competition.

Quality: Our customers expect it. We demand it!

4.0 DESIGN BASIS

4.1 Site Conditions

Seismic Zone	Later
Design Wind Velocity	Later
Minimum Barometric Pressure, mbar	Later
Temperature, °C (Min/Max/Avg)	Later
Design Relative Humidity	Later

4.2 Exhaust Summary from burner and SCR

Refer to the datasheets in the attachment X.

4.3 Utilities

Electrical Power 460V / 3 Phase / 50 Hz	< 5 kW
Instrument Air, Nm3/hr	Later
Ammonia Solution 19% kg/hr	Refer to the datasheets attachment X

Above data are preliminary and will be confirmed during job stage.

4.4 System Performances

Burner	Unit	Guaranteed
NOx	mg/Nm3	70(*)
CO	ppmvd	50
UHC	ppmvd	4
Particulates	ppmvd	100
Stack Emission	**Unit**	**Guaranteed**
NOx	ppm	< 1.0
Ammonia slip	ppm	< 0.2
Pressure drop	mmWC	< 90 (**)

(*) Zeeco will be responsible to guarantee the NOx stack emissions since we are offering both Burners and SCR system.
(**) The above pressure drop doesn't take in account the pressure drop of the static mixer that might be necessary after CFD analysis to be installed downstream the ammonia atomizing gun to ensure that the necessary distribution NH3/NOx is reached. In case static mixer will be necessary, the pressure drop of the system will be 200mmWC.

These values are understood to apply only when the system is operated in accordance with the operating conditions stipulated in the design summary and for the waste(s) stipulated in the design basis sections of this proposal. VOC is defined as non-methane and non-ethane hydrocarbons.

5.0 COMMERCIAL

Attachment E
Burners datasheets

22151 East 91st Street
Broken Arrow,
Oklahoma 74014 USA
Phone: (918)258-8551
Fax: (918)251-5519
Email:sales@zeeco.com

ZEECO BURNER DATA SHEET

PURCHASER:	Casale SA	PURCHASER REF.:	A09480
OWNER:	UNKNOWN - WITHIN EUROPE	ZEECO QUOTE REF.:	2020-09279PR-01
JOBSITE:	UNKNOWN - WITHIN EUROPE	ZEECO JOB REF.:	
FURNACE TAG:	TBA	**SHEET 1 OF 5**	

GENERAL INFORMATION

REV

PURCHASER NAME:	Casale SA
CUSTOMER CONTACT:	FRANCESCO GALMARINI
ADDRESS:	Via G. Pocobelli
LINE 2:	6 6900 Lugano
LINE 3:	Switzerland
LINE 4:	
LINE 5:	
TELEPHONE:	+41 91641 9327
FAX:	
EMAIL:	f.galmarini@casale.ch
PURCHASER REFERENCE:	A09480
ZEECO QUOTE REFERENCE:	2020-09279PR-01
ZEECO JOB REFERENCE:	
OWNER / END USER:	UNKNOWN - WITHIN EUROPE
ADDRESS OF JOBSITE:	
LINE 2:	
LINE 3:	
LINE 4:	
LINE 5:	
FURNACE TAG:	TBA
FURNACE TYPE:	Double Vertical Cylidrical
LOCATION OF JOBSITE:	UNKNOWN - WITHIN EUROPE

REV. DATE	NAME	DESCRIPTION OF REVISION	REVISION TABLE ISSUE	REV.
10/8/2020	Matt Roush	First Issue	1	0

22151 East 91st Street
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Oklahoma 74014 USA
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Email:sales@zeeco.com

ZEECO BURNER DATA SHEET

CUSTOMER:	Casale SA	PURCHASER REF.:	A09480
OWNER:	UNKNOWN - WITHIN EUROPE	ZEECO QUOTE REF.:	2020-09279PR-01
JOBSITE:	UNKNOWN - WITHIN EUROPE	ZEECO JOB REF.:	
FURNACE TAG:	TBA	**SHEET 2 OF 5**	

HEATER GENERAL DATA

			REV
FURNACE EQUIPMENT TAG NUMBER		**TBA**	
FURNACE SERVICE		TBA	
FURNACE MANUFACTURER		Casale	
TYPE OF FURNACE		Double Vertical Cylidrical	
SETTING REFRACTORY THICKNESS	millimeters	TBA	
HEATER CASING THICKNESS	millimeters	6	
FIREBOX INTERIOR HEIGHT (*Floor to Convection Section*)	meters	6	
FIREBOX INTERIOR LENGTH from WALL TO WALL	meters	N/A	
FIREBOX WIDTH between TUBES CENTERLINE TO CENTERLINE	meters	N/A	
TUBE CIRCLE DIAMETER [VERTICAL CYLINDRICAL/HELICAL COIL HEATERS]	meters	2.33 / 2.55	
COMBUSTION AIR PLENUM		Individual Plenum	

BURNER DATA

TYPE OF BURNER		Low NO_x emissions technology	
BURNER MODEL		GLSF (Round Flame, "Free Jet")	
BURNER PROJECT CLASSIFICATION		New furnace application	
BURNER FLAME SHAPE		Round Flame	
TYPE OF FUEL(S)		Gas Only	
BURNER MODEL NUMBER		9	
QUANTITY OF BURNERS REQUIRED		3 per cell - 6 total	
FIRING DIRECTION		Vertically upfired	
BURNER MOUNTING LOCATION		Floor	
BURNER CENTERLINE TO TUBE CENTERLINE	millimeters	712	
BURNER CENTERLINE TO ADJACENT BURNER CENTERLINE	millimeters	N/A	
BURNER CENTERLINE TO UNSHIELDED REFRACTORY	millimeters	-	
BURNER CIRCLE DIAMETER [VERTICAL CYLINDRICAL HEATER]	meters	0.905	
HEATER STEEL TO GRADE	millimeters	TBA	
PILOT REQUIRED		Required	
PILOT MODEL		JM-1S-F	
PILOT IGNITION METHOD		Manual Ignition	
FLAME ROD		Kanthal A1	
PILOT FUEL		Natural Gas / RFG	
FUEL PRESSURE at PILOT	barg	0.7	
PILOT HEAT RELEASE	W	26,370	

OPERATING DATA

BURNER FUEL TYPE			Gas Fired			
DESIGN HEAT RELEASE per BURNER	* **[LHV]**	MW	1.010			
NORMAL HEAT RELEASE per BURNER	* **[LHV]**	MW	0.670			
MINIMUM HEAT RELEASE per BURNER	* **[LHV]**	MW	0.200			
OTHER CONDITION:		MW				
OTHER CONDITION:		MW				
HEAT RELEASE TURNDOWN REQUIRED			5.1			
EXCESS AIR at DESIGN HEAT RELEASE		%	15%			
HEATER DRAFT TYPE			Natural			
COMBUSTION AIR SOURCE			Fresh Air			
COMBUSTION AIR TEMPERATURE at BURNER		°C	29.5	Design	-6.6 Min	11.5 Max
COMBUSTION AIR RELATIVE HUMIDITY		%	77.8	@ 11.5 °C		
MAXIMUM AVAILABLE PRESSURE DROP THRU BURNER		mm W.C.	10.5			
BURNER AIR PRESSURE DROP at DESIGN HEAT RELEASE		mm W.C.	9.72			
HEATER ELEVATION ABOVE SEA LEVEL		meters	1			
AMBIENT AIR TEMPERATURE		°C	29.5	Design	-6.6 Min	11.5 Max
FLAME LENGTH at DESIGN HEAT RELEASE		meters				
FLAME WIDTH or DIAMETER at DESIGN HEAT RELEASE		meters				
ADDITIONAL OPERATION CASE (FOR FORCED DRAFT TYPE)			NO			

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ZEECO BURNER DATA SHEET

CUSTOMER:	Casale SA	PURCHASER REF.:	A09480
OWNER:	UNKNOWN - WITHIN EUROPE	ZEECO QUOTE REF.:	2020-09279PR-01
JOBSITE:	UNKNOWN - WITHIN EUROPE	ZEECO JOB REF.:	
FURNACE TAG:	TBA	**SHEET 3 OF 5**	

GAS FUEL CHARACTERISTICS

REV

		Design		MOR Min Reactivity		MOR Max Reactivity	
FUEL GAS DESIGNATION		Make-up	Waste	Make-up	Waste	Make-up	Waste
HEATING VALUE * [LHV]	kJ/kg	25,638	14,780	25,768	21,199	24,950	15,315
SPECIFIC GRAVITY [AIR = 1.0]		0.40	0.88	0.41	0.70	0.40	0.92
MOLECULAR WEIGHT		11.54	25.63	11.78	20.23	11.47	26.74
FUEL TEMPERATURE at BURNER	°C	122.1	122.1	122.9	122.9		
FUEL PRESSURE AVAILABLE at BURNER	barg	2.5	2.5	2.5	2.5		
FUEL GAS COMPOSITION		Volume%	Volume%	Volume%	Volume%	Volume%	Volume%
	CH_4 (METHANE)	9.46%	31.16%	11.70%	41.79%	7.30%	37.11%
	C_2H_6 (ETHANE)						
	C_3H_8 (PROPANE)						
	C_4H_{10} (BUTANE)						
	C_5H_{12} (PENTANE)						
	C_6H_{14} (HEXANE)						
	C_5H_{10} (CYCLOPENTANE)						
	C_6H_{12} (CYCLOHEXANE)						
	C_2H_4 (ETHENE)						
	C_3H_6 (PROPENE)						
	C_4H_8 (BUTENE)						
	CH3OH (METHANOL)		16.03%		7.27%		14.72%
	C_6H_6 (BENZENE)						
	C_5H_8 (ISOPRENE)						
	CO_2 (CARBON DIOXIDE)	3.39%	22.65%	3.85%	8.23%	3.00%	29.83%
	H_2O (WATER)		6.89%		2.57%		7.57%
	O_2 (OXYGEN)						
	N_2 (NITROGEN)	0.42%	11.16%	1.50%	19.54%	0.10%	2.75%
	SO_2 (SULFUR DIOXIDE)						
	H_2S (HYDROGEN SULFIDE)						
	CO (CARBON MONOXIDE)	25.58%	1.44%	23.40%	2.43%	27.47%	1.20%
	NH_3 (AMMONIA)						
	H_2 (HYDROGEN)	61.12%	9.25%	59.45%	16.62%	62.11%	5.95%
	AR (ARGON)	0.04%	1.42%	0.10%	1.55%	0.02%	0.88%
TOTAL (%)		100.0%	100.0%	100.0%	100.00%	100.00%	100.01%

GAS FUEL CHARACTERISTICS (CONTINUED)

FUEL GAS DESIGNATION		Natural Gas
HEATING VALUE * [LHV]	kJ/kg	45,768
SPECIFIC GRAVITY [AIR = 1.0]		0.62
MOLECULAR WEIGHT		18.03
FUEL TEMPERATURE at BURNER	°C	30
FUEL PRESSURE AVAILABLE at BURNER	barg	2.50
FUEL GAS COMPOSITION		Volume%
CH_4 (METHANE)		89.00%
C_2H_6 (ETHANE)		5.30%
C_3H_8 (PROPANE)		1.30%
C_4H_{10} (BUTANE)		0.30%
C_5H_{12} (PENTANE)		
C_6H_{14} (HEXANE)		
C_5H_{10} (CYCLOPENTANE)		
C_6H_{12} (CYCLOHEXANE)		
C_2H_4 (ETHENE)		
C_3H_6 (PROPENE)		
C_4H_8 (BUTENE)		
CH3OH (METHANOL)		
C_6H_6 (BENZENE)		
C_5H_8 (ISOPRENE)		
CO_2 (CARBON DIOXIDE)		1.61%
H_2O (WATER)		
O_2 (OXYGEN)		
N_2 (NITROGEN)		2.30%
SO_2 (SULFUR DIOXIDE)		
H_2S (HYDROGEN SULFIDE)		
CO (CARBON MONOXIDE)		0.19%
NH_3 (AMMONIA)		
H_2 (HYDROGEN)		
AR (ARGON)		
TOTAL (%)		100.00%

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FURNACE TAG:	TBA	**SHEET 4 OF 5**	

EMISSION REQUIREMENTS

REV

FIREBOX BRIDGEWALL TEMPERATURE	°C	782	
EXCESS AIR at DESIGN HEAT RELEASE	%	15%	
O_2 CORRECTION BASIS (%)	%	3	
COMBUSTION AIR TEMPERATURE at BURNER	°C	29.5	
COMBUSTION AIR RELATIVE HUMIDITY	°C	77.8	
NOISE SPECIFICATION (SINGLE BURNER)	dBa @ 1 meter	85	Sound Pressure Level
HEAT RELEASE RANGE FOR EMISSIONS GUARANTEE	MW	1.01	0.67
STEAM INJECTION REQUIREMENT (SEE NOTE)		Not Required	

Emissions:	Predicted	Guaranteed
NOx (mg/Nm3)	53	70
CO (ppmvd)	5	50
UHC (ppmvd)	2	4
Particulates (ppmvd)	5	100

Estimated SOx emissions is <1 ppmvd

EMISSIONS NOTES AND CLARIFICATIONS

4-1	The above listed UHC (Unburned Hydrocarbon) emissions are based upon UHC being defined as free "methane" as the result of incomplete combustion due to the supplied combustion equipment as stated in these data sheets.
4-2	The above listed Particulate emissions are based upon Particulate being defined as free "ethane" as the result of incomplete combustion due to the supplied combustion equipment as stated in these data sheets. This excludes ash, sand and heavy metals in the fuel oil.
4-3	NO_X guarantees are based on the furnace temperature, combustion air temperature, excess combustion air and the fuel gas compositions as specified on the Zeeco Burner Data Sheets.
4-4	The emissions guarantees above are for operation between maximum and normal heat release unless otherwise listed.
4-5	The emissions guarantees as stated above are based upon operation with the % excess air, temperature, furnace temperature, and fuel temperatures as stated in these data sheets.
4-6	Zeeco takes exception to any SO_X guarantees since SO_X production is based upon the amount of Sulfur in the fuel stream and the equilibrium conditions in the furnace.
4-7	All ppmv and/or mg/Nm^3 guarantees are corrected to 3% O_2 dry basis.

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FURNACE TAG:	TBA	**SHEET 5 OF 5**	

SPECIFICATION OPTIONS

		REV
BURNER PLENUM		
COMMON / INTEGRAL	Individual Plenum	
PLENUM SHAPE	Round	
MATERIAL	A-36 Carbon Steel	
PLATE THICKNESS	10 gauge (3 mm) material	
INTERNAL INSULATION / THICKNESS	Mineral Wool, 1" (25 mm) thick	
METHOD OF CONSTRUCTION	Seal Welded	
INLET AIR CONTROL	Individual air control required with burner	
MODE OF OPERATION	Manually Operated c/w self-locking handle & position indicator	
SEAL STRIP CONSTRUCTION REQUIRED	Required	
LEAKAGE %	3% leakage when damper is in the full closed position	
BEARINGS REQUIRED FOR DAMPERS?	Required - Grease Bearings	
BURNER TILE	Included with burner	
REGEN TILE COMPOSITION	Not Required	
TILE COMPOSITION	60% Al_2O_3	
NEEDLE CONSTRUCTION REQUIRED	Not Required	
RATED SERVICE TEMP., °F	3000 °F (1650 °C)	
TEMP. OF PRE-FIRING, °F	500 °F (260 °C)	
ATTENUATION METHOD	Muffler & Insulated Plenum for natural draft applications	
FUEL DELIVERY SYSTEM		
TYPE OF MANIFOLD	Manufactured Pipe Manifold	
METHOD OF CONSTRUCTION	Seal Welded	
MANIFOLD MATERIAL	ASTM A106B Pipe	
GAS TIP MATERIAL	310 Stainless Steel or ASTM-297 HK	
GAS RISER MATERIAL	Schedule 40 type 310 Stainless Steel	
WASTE GAS / PSA LANCE MATERIAL	Not Required	
WASTE GAS / PSA LANCE TIP MATERIAL	Not Required	
OIL TIP / ATOMIZER MATERIAL	Not Required	
FUEL GAS CONNECTION	RFSW 150#, Carbon Steel Flange	
PILOT GAS CONNECTION	RFSW 150#, Carbon Steel Flange	
WASTE GAS / PSA GAS CONNECTION	Not Required	
OIL & STEAM CONNECTIONS	Not Required	
PAINTING REQUIREMENTS	Zeeco Standard	
CARBON STEEL SURFACE PREPARATION	SSPC-SP-10 // NACE 2 // SA 2 1/2 - Near-White Blast	
PRIMER	Inorganic Zinc Primer	
PRIMER THICKNESS	2-3 mils dft or 55-75 microns dft	
1ST PAINT COAT	Silicone Acrylic	
1ST PAINT COAT THICKNESS	1-1.5 mils dft	
2ND PAINT COAT	-	
2ND PAINT COAT THICKNESS	-	
BURNER TILE MOUNTING PLATE	Required	
MOUNTING TEMPLATE REQUIRED	Not Required	
LIFTING LUGS	Not Required	
PRESSURE TAP ON WINDBOX	Required - 1/2" NPT c/w plug	
SCANNER CONNECTIONS	(1) - 1" NPT Swivel Scanner Mount	
IGNITION PORTS	(1) - 2"(50.8mm) Ignition Port c/w Swing Door	
SIGHT PORTS	(1) - 2"(50.8mm) Sight Port c/w Swing Door	
PILOT CONDUIT TYPE	Not Applicable	
COMBUSTION TEST REQUIRED	Required	
HEAT FLUX REQUIREMENT	Not Required	
AIRSIDE PRESSURE DROP REQUIREMENT	Required - 90% of Total Pressure with 80% across the Throat	

ADDITIONAL NOTES

Attachment F
SCR Datasheets

Flue Gas Data:

Case: EOR DESIGN

Design Pressure	1013	mbar	Flue Gas Flow Rate	5375	Nm^3/h, wet, actual O2
Design Temperature	338	°C		12030	m^3/h, wet, actual O2
Oxygen	2,3	Vol.-% wet		4951	Nm^3/h, dry, ref. O2
Reference Oxygen	3	Vol.-%		4833	Nm^3/h, dry, actual O2
Water	10,1	Vol.-%, wet			
NOx in	35	ppmV i. N., dry, ref. O2			
NOx out	1	ppmV i. N., dry, ref. O2			
NOx reduction	97,1	%			
NO2 fraction	10	%			

Catalyst and Reactor Data:

Layer	Sublayer	Cell Type	Spec. surface m^2/m^3	Pitch mm	open cross section %	cat. height mm	layer height mm	layer volume m^3	layer weight to.	Face hardening mm

Guarantee Values:

Slip-NH3 (end of guarantee period)	0,2	ppmV i. N., dry, ref. O2
Guarantee Period	32000	h
Flue gas velocity (@ operation conditions, before catalyst)	3,1	m/s
Pressure drop over catalyst layers (initial)	≤ 7,6	mbar
NH_3 consumption	≤ 0,2	kg/h
NH_4OH 25%	≤ 0,7	kg/h

Please Note:

Flue Gas Data:

Case: MOR MAXIMUM

Design Pressure	1013	mbar	Flue Gas Flow Rate	3569	Nm^3/h, wet, actual O2
Design Temperature	330	°C		7883	m^3/h, wet, actual O2
Oxygen	2,3	Vol.-% wet		2925	Nm^3/h, dry, ref. O2
Reference Oxygen	3	Vol.-%		2898	Nm^3/h, dry, actual O2
Water	18,8	Vol.-%, wet			
NOx in	35	ppmV i. N., dry, ref. O2			
NOx out	1	ppmV i. N., dry, ref. O2			
NOx reduction	97,1	%			
NO2 fraction	10	%			

Catalyst and Reactor Data:

Layer	Sublayer	Cell Type	Spec. surface m^2/m^3	Pitch mm	open cross section %	cat. height mm	layer height mm	layer volume m^3	layer weight to.	Face hardening mm

Guarantee Values:

Slip-NH3 (end of guarantee period)	0,2	ppmV i. N., dry, ref. O2
Guarantee Period	32000	h
Flue gas velocity (@ operation conditions, before catalyst)	2,0	m/s
Pressure drop over catalyst layers (initial)	≤ 4,7	mbar
NH_3 consumption	≤ 0,1	kg/h
NH_4OH 25%	≤ 0,5	kg/h

Please Note:

Flue Gas Data:

Case: MOR MINIMUM

Design Pressure	1013	mbar	Flue Gas Flow Rate	5598	Nm^3/h, wet, actual O2
Design Temperature	337	°C		12507	m^3/h, wet, actual O2
Oxygen	2,3	Vol.-% wet		4607	Nm^3/h, dry, ref. O2
Reference Oxygen	3	Vol.-%		4562	Nm^3/h, dry, actual O2
Water	18,5	Vol.-%, wet			
NOx in	35	ppmV i. N., dry, ref. O2			
NOx out	1	ppmV i. N., dry, ref. O2			
NOx reduction	97,1	%			
NO2 fraction	10	%			

Catalyst and Reactor Data:

Layer	Sublayer	Cell Type	Spec. surface m^2/m^3	Pitch mm	open cross section %	cat. height mm	layer height mm	layer volume m^3	layer weight to.	Face hardening mm

Guarantee Values:

Slip-NH3 (end of guarantee period)	0,2	ppmV i. N., dry, ref. O2
Guarantee Period	32000	h
Flue gas velocity (@ operation conditions, before catalyst)	3,2	m/s
Pressure drop over catalyst layers (initial)	≤ 7,7	mbar
NH_3 consumption	≤ 0,2	kg/h
NH_4OH 25%	≤ 0,7	kg/h

Please Note:

Flue Gas Data:

Case: SOR DESIGN

Design Pressure	1013	mbar	Flue Gas Flow Rate	5511	Nm^3/h, wet, actual O2
Design Temperature	334	°C		12252	m^3/h, wet, actual O2
Oxygen	2,3	Vol.-% wet		4497	Nm^3/h, dry, ref. O2
Reference Oxygen	3	Vol.-%		4458	Nm^3/h, dry, actual O2
Water	19,1	Vol.-%, wet			
NOx in	35	ppmV i. N., dry, ref. O2			
NOx out	1	ppmV i. N., dry, ref. O2			
NOx reduction	97,1	%			
NO2 fraction	10	%			

Catalyst and Reactor Data:

Layer	Sublayer	Cell Type	Spec. surface m^2/m^3	Pitch mm	open cross section %	cat. height mm	layer height mm	layer volume m^3	layer weight to.	Face hardening mm

Guarantee Values:

Slip-NH3 (end of guarantee period)	0,2	ppmV i. N., dry, ref. O2
Guarantee Period	32000	h
Flue gas velocity (@ operation conditions, before catalyst)	3,2	m/s
Pressure drop over catalyst layers (initial)	≤ 7,5	mbar
NH_3 consumption	≤ 0,2	kg/h
NH_4OH 25%	≤ 0,7	kg/h

Please Note:

Zeeco, Inc.
GLSF Free Jet Burner 5 Year Reference List Guaranteed Emission NOx < 70mg/Nm3

SO Number	Award Year	Product Group	Equipment Type	Equipment Type Description	Customer Name	End User Name / Facility / City	End User State	End User Country
50310	2021	Process Burners	Process Burner	24 GLSF-11 "Free-Jet" Flat Flame Burner Assembly 48 GLSF-7 "Free-Jet" Flat Flame Burner Assembly 1 Combustion Testing GLSF-11 1 Combustion Testing GLSF-7 1 100% PMI of Alloy Material	Great Southern Technologies, LLC	Flint Hills Resources, LP / Houston Propylene Plant / Houston	TX	United States
50192	2021	Retrofit	Process Burner	F-5601 (4) GLSF-12 Free Jet Gas Burner Assembly Includes JM-1S Manual Pilot	Parkland Refining (B.C.) Ltd.	Parkland Fuel Corporation / Burnaby Refinery / Burnaby	BC	Canada
49838	2021	Process Burners	Process Burner	4 GLSF-19 Free Jet Ultra Low NOx Burner	Bantrel Co.	Cenovus Energy, Inc. / Lloydminster Upgrader / Lloydminster	SK	Canada
49510	2021	Process Burners	Process Burner	30 GLSF-7 Free-Jet Downfired 78% Burner 75 GLSF-8 Free-Jet Downfired 100% Burner 2 Portable Ignitor 1 Burner performance test -ea. Burner type 1 Set erection spare parts *Zeeco China Fabrication	Air Liquide Global E&C Solutions	Sarawak Shell Berhad / Sarawak Shell Berhad / Lutong		Malaysia
48700	2021	Retrofit	Process Burner	(6) GLSF-12 "Free-Jet" Burner Assembly (4) GLSF-12 "Free-Jet" Burner Assembly (2) GLSF-13 "Free-Jet" Burner Assembly (2) CLSF-15 "Free-Jet" Burner Assembly (1) Construction for both heaters (1) On site engineer site construction (14) Ignition transformer (14) Fireye 85 UVF1-1QD w/ 20 meter cable (2) Emission check by authorized company (1) Negotiation	Taekwang Industrial Co., Ltd	Taekwang Industrial Company Ltd. / Petrochemical Plant #1 / Ulsan		Korea
47951	2020	Retrofit	Process Burner	6 GLSF-12 "Free-Jet" Ultra Low NOx Burner 6 SM-1S-HEI Pilot Assembly 6 SM-1S-HEI Pilot Assembly 6 SM-1S-HEI Pilot Assembly 6 Export Crating & FCA Containerization 1 Bespoke pilot panel modification kit	LBL Trading	Oil Refineries Limited - ORL / Bazan Refinery / Haifa		Israel
47816	2020	Process Burners	Process Burner	GLSF-11 RF FJ Burners GLSF-7 FF EJ Burners	Formosa Plastics	Formosa Plastics (Ningbo) Co., Ltd. / PDH Plant / Ningbo		China
47256	2020	Process Burners	Process Burner	12 GLSF-10 "Free-Jet" Burner Assembly 1 GLSF-10 Combustion Test 1 Domestic Packing 1 Dye Pen and Radiography Testing	Great Southern Technologies, LLC	Countrymark Cooperative, LLP / Mount Vernon Refinery / Mount Vernon	IN	United States
47093	2020	Retrofit	Process Burner	4 GLSF Free Jet G2 Retrofit Kit. Including: (4) Primary Tips per Kit with 3/32" Firing Orifice (4) Drains per Kit (19) Secondary Tips per Kit with Larger Firing Orifice Diameter (1) Fuel Gas Manifolds with 1/4" Gas Risers (1) Front Plate with (1) Sight Port and (1) Scanner Connection (1) JM-1S Pilot Domestic Packaging	Phillips 66	Phillips 66 Company / Los Angeles Refinery - Wilmington / Wilmington	CA	United States
46442	2020	Process Burners	Process Burner	192 GLSF-4 Free-Jet Ultra Low NOx Burners 192 Adapter Plate 20 Burner Front Plate Blanking Plate 14 Lighting Torch 192 All Fuel Gas Piping 316L SS 192 PMI of alloy metal 192 Dye-pen 25% of alloy socket-welds	Jacobs Engineering	Chevron Corporation / El Segundo Refinery / El Segundo	CA	United States
46324	2020	Retrofit	Process Burner	(16) GLSF-13 "Free-Jet" Gas Burner assembly Burner combustion test per heater (1) CFD per heater (1) Spare parts for construction / commissioning	GS Caltex	GS Caltex Corporation / Yeosu Complex / Yeosu		Korea
46251	2020	Process Burners	Process Burner	12 GLSF-14 "Free-Jet" Burner Assembly 12 Smitsvonk Type 54 Pilot Burner 12 Smitsvonk Ignition Control Unit 24 Durag D-LE 603 Scanner 1 Combustion Performance Testing 1 Scanner control unit panel for installation in control room 1 CFD Study - Base Case 1 Additional Testing with 85% Hydrogen fuel	BOUSTEAD INTERNATIONAL HEATERS LTD	Essar Oil UK / Stanlow Refinery / South Wirral		United Kingdom
46025	2020	Process Burners	Process Burner	24 GLSF-11 "Free-Jet" Flat Flame Burner Assembly 48 GLSF-7 "Free-Jet" Flat Flame Burner Assembly 1 Inner Burner Combustion Test 1 Inner Burner Combustion Test 72 International Crating	Great Southern Technologies, LLC	Flint Hills Resources, LP / Houston Propylene Plant / Houston	TX	United States
45502	2020	Retrofit	Process Burner	7 CLSF-15 DT Combination Free-Jet Burner Including JM-1S-EF Pilot 6 GLSF-14 Free-Jet Burner Including JM-1S-EF Pilot	Great Orient Chemical (Taicang) Co., Ltd	Great Orient Chemical (TaiCang) Co., Ltd. - GOC / LAB (Linear Alkyl Benzene) Factory / Taicang		China
45307	2020	Retrofit	Process Burner	32 GLSF-11 Free Jet Flat flame Burner 1 CFD 1 GLSF Combustion Testing 4 Spare Tip Sets	Wison	CNOOC Limited / Huizhou 21-1B Platform / Hong Kong		China

SO Number	Award Year	Product Group	Equipment Type	Equipment Type Description	Customer Name	End User Name / Facility / City	End User State	End User Country
43992	2020	Process Burners	Process Burner	24 GLSF-14 "Free-Jet" Gas Burner Assembly 3 GLSF-8 "Free-Jet" Gas Burner Assembly 3 GLSF-9 "Free-Jet" Gas Burner Assembly 4 GLSF-9 "Free-Jet" Gas Burner Assembly 1 H-1101 Combustion Testing 1 H-1301 Combustion Testing 1 H-1302 Combustion Testing 3 CFD Simulation of Vertical Cylindrical Furnace 1 CFD Simulation of Cabin Style Furnace (1) Cell 1 Air Flow Modeling of Combustion Air Ducting 1 Domestic Packaging 1 Lot of Commissioning Spare Parts 1 Lot of 2 Years Operational Spares	JNK Heaters	S-Oil Corporation / Ulsan Complex / Ulsan		Korea
43749	2020	Retrofit	Process Burner	3 GLSF Free Jet G2 Retrofit Kits 3 JM-1S-HEI Pilot w/scanner connection 6 Zeeco ProFlame ZPF-120 Flame Scanners 1 Witnessed combustion testing - 1 day	BP Refinery (Kwinana)	BP Australia / Kwinana Refinery / Kwinana		Australia
42663	2019	Process Burners	Process Burner	12 GLSF-16 Free Jet ULNB Round Flame F-10101 8 GLSF-14 Free Jet DT ULNB Round Flame F-10201 4 GLSF-14 Free Jet ULNB Round Flame F-10301 4 GLSF-12 Free Jet ULNB Round Flame F-10501 2 GLSF-16/14 Burner Testing 2 GLSF-14/12 Burner Testing. 1 CFD of 1 cell - firebox 1 CFD of 1 cell - firebox 1 CFD of 1 cell - firebox 1 CFD of 1 cell - firebox 1 CFD of combustion air ducting 1 CFD of combustion air ducting 1 CFD of combustion air ducting 1 CFD of combustion air ducting 1 Lot Export Crating	JNK Heaters Co., Ltd	Thai Oil Public Company Limited / Sri Racha Refinery / Sri Racha		Thailand
42444	2019	Process Burners	Process Burner	1 GLSF-18 Free-Jet Ultra Low NOx Burner 1 Domestic Packing	Tulsa Heaters Midstream LLC	Williams Olefins, LLC / Williams Olefins, LLC / Carville	LA	United States
41461	2019	Process Burners	Process Burner	30 GLSF Free Jet Burner 12 H5201 8 GLSF Free Jet Burner 12 H5601 6 GLSF Free Jet Burner 12 H5602 8 GLSF Free Jet Burner 12 H5001 6 GLSF Free Jet Burner 12 H5002 1 Packing and freight to job site	KTI	SK Energy Company Limited / Naphtha Cracking Plant / Ulsan		Korea
41280	2019	Process Burners	Process Burner	1 GLSF Free Jet Burner Kits	Datek	Fujian Petrochemical Company Limited - FPCL / Fujian Petrochemical Company Limited - FPCL / Quanzhou		China
41224	2019	Process Burners	Process Burner	384GLSF-12 Flat Flame Free-Jet Kit Includes Engineering and Drafting 24GLSF-12 Flat Flame Free-Jet Kit Includes Engineering and Drafting 1Combustion Test (Dual Burner) F-1120 per attached combustion test procedure 1CFD Modeling 1/2 of Firebox F-1110 Design & Decoke Conditions 1CFD Modeling 1/2 of Firebox F-1120 Design & Decoke Conditions 3Lighting Torches Drawing Only	China Huanqiu Contracting Engineering Co. Ltd. Beijing Huanqiu Corporation	Shandong Shouguang Luqing Petrochemical Co., Ltd. / Shandong Shouguang Luqing Petrochemical Co., Ltd. / Shouguang		China
41092	2019	Retrofit	Process Burner	24 GLSF-15 Free-Jet-V Burner Insert Assembly - F3101 6 GLSF-14 Free-Jet Burner Assembly - F660 1 Combustion Testing GLSF-15 - 2 Fuels 1 Combustion Testing GLSF-14 - 2 Fuels 1 Lot Export Packing	ExxonMobil Engineering Europe Limited	ExxonMobil / Sarpom Trecate Novara Refinery / San Martino di Trecate		Italy
40483	2019	Process Burners	Process Burner	6 GLSF-13 Free Jet Ultra Low NOx Burner 1 GLSF Combustion Test 12 ZPF-120 Flame Scanner	OPF Optimized Process Furnaces	Cenovus Energy, Inc. / Superior Refinery / Superior	WI	United States
39861	2019	Process Burners	Process Burner	6 GLSF-14 Freejet Burner 1 Export Crating 1 GLSF combustion test 6 Zeeco ProFlame ZPF-1100	KTI	LG Chem / SM Plant / Yeosu		Korea
39675	2019	Process Burners	Process Burner	2 GLSF-21 Free Jet Dual Fuel Burner F9401 A/B 2 Export Crating	Hydro Chem	Shell SA Refining/BP Southern Africa / Durban Sapref Refinery / Durban		South Africa
39614	2019	Process Burners	Process Burner	1 GLSF-13 Free Jet Ultra Low NOx Burner 1 Palletizing for Domestic Shipment	Tulsa Heaters Midstream	Exterran		United States
39165	2019	Process Burners	Process Burner	280 RWSF-4 Radiant Wall Staged Fuel Burner Kits 280 GLSF-12 FF Flat Flame Free-Jet Burner Kits	Lianyungang Petrochemical Co. (LYPC)	Lianyuangang Petrochemical Co., Ltd. / Lianyungang Petrochemical Complex / Lianyungang		China

SO Number	Award Year	Product Group	Equipment Type	Equipment Type Description	Customer Name	End User Name / Facility / City	End User State	End User Country
39120	2019	Process Burners	Process Burner	128GLSF-12 "Free-Jet" Ultra Low NOx Burner 320GLSF-12 "Free-Jet" Ultra Low NOx Burner 128GLSF-9 "Free-Jet" Ultra Low NOx Burner 1GLSF-12 Combustion Test 3 Simulated Fuels, 8 points each per API 535 1GLSF-9 Combustion Test 3 Simulated Fuels, 8 points each per API 535 LOTExport Crating 1CFD Modeling by REI Normal Cracking Operation + Decoke Operation See CFD Datasheets 1CFD Modeling by REI Normal Cracking Operation + Decoke Operation See CFD Datasheets	Shanghai Supezet Engineering Technology Co., Ltd.	Zhejiang Shaoxing Sanjin Petrochemical Co. Ltd. / Shaoxing Polypropylene / Shaoxing		China
38320	2019	Process Burners	Process Burner	5 GLSF-17 Free Jet Ultra Low NOx Burner 5 Export Crating LOT 10% PMI of fuel wetted parts	XRG Technologies	VPR Energy BV / Rotterdam Terminal / Rotterdam		Netherlands
38294	2019	Process Burners	Process Burner	1 GLSF-6 Free Jet Gas Burner	Scelerin Heaters LLC	DCP Midstream / Okarche Gas Plant / Okarche	OK	United States
38281	2019	Process Burners	Process Burner	1 GLSF-12 Free Jet Gas Burner 1 Domestic Crating	Scelerin Heaters LLC	DCP Midstream / Okarche Gas Plant / Okarche	OK	United States
38165	2019	Process Burners	Process Burner	4 GLSF-12 FreeJet Next Generation Ultra Low NOx Burner 4 Optional Upgrade to SM-1S-HEI Pilots 4 Optional Unispark Ignition system for SM Pilots 1 Optional Engineering Services for controls narrative 4 Zeeco ZPF-120 Flame Scanner 1 Lot Overland freight to US Methanol Plant	US Methanol LLC	Liberty One Methanol, LLC / Methanol Plant / Institute	WV	United States
37977	2019	Retrofit	Process Burner	(4) GLSF-15 Free-Jet Gas Burner Assembly (4) Adapter Plate for GLSF-15 Free-Jet Burner	Sinclair Wyoming Refinery Company	Sinclair Oil Corporation / Sinclair Wyoming Refining Company / Sinclair	WY	United States
37760	2018	Process Burners	Process Burner	1 GLSF-18 Free Jet Ultra Low NOx Burner 1 Domestic Packing	Tulsa Heaters Midstream LLC	Williams Olefins, LLC / Williams Olefins, LLC / Carville	LA	United States
37666	2018	Process Burners	Process Burner	1 GLSF-14 Free Jet Ultra Low NOx Burner 1 Domestic Packing	Tulsa Heaters, Inc.	Targa Resources, Inc. / Galena Park Terminal / Galena Park	TX	United States
37367	2018	Process Burners	Process Burner	1 GLSF-7 Free Jet Ultra Low NOx Burner 1 Fuel Skid 1 BMS 1 Domestic packing	Thermal Engineering International (TEI)	Ascend Performance Materials Operations, LLC / Pensacola Plant / Gonzalez	FL	United States
37180	2018	Process Burners	Process Burner	1 GLSF Free Jet Round Flame Burner Kit 2 GLSF Free Jet Combustion Test 3 HEI 4 CFD Simulation	China HuanQiu Contracting & Engineering Corp. (HQC)	PetroChina Company Ltd. / Dushanzi Refinery / Karamay		China
37160	2018	Process Burners	Process Burner	8 GLSF-15 Free-Jet Ultra Low NOx Burner H-001 8 Export Crating 8 GLSF-15 Free-Jet Ultra Low NOx Burner H-002 8 Export Crating	Chiyoda Corp.	Cosmo Oil Company Ltd. / Sakai Refinery / Sakai		Japan
37027	2018	Process Burners	Process Burner	2 GLSF-15 Free Jet Ultra Low NOx Burner 2 Palletizing for domestic shipment	Scelerin Heaters LLC	Scelerin Heaters		United States
37007	2018	Process Burners	Process Burner	1 GLSF-8 Free Jet Gas Burner 1 Domestic Packing	Scelerin	Sherwood Midstream LLC / Exterran Corp.		United States
36371	2018	Process Burners	Process Burner	1 GLSF-15 Free Jet Gas Burner 1 Expedited Drawings	Scelerin	Sunoco / Orbit		United States
36117	2018	Process Burners	Process Burner	1 GLSF-13 Free Jet Ultra Low NOx Burner 1 Palletizing for Domestic Shipment	Tulsa Heaters Midstream	Exterran		United States
35989	2018	Process Burners	Process Burner	128 GLSF-6 Free Jet Flat Flame Burner 64 Export Crating 1 385 Ignition Cable & 2560m detection cable 128 Flame Relays	Wood PLC	Esso Nederland BV / Rotterdam Refinery / Rotterdam		Netherlands
35963	2018	Process Burners	Process Burner	2 GLSF-13 Free Jet Ultra Low NOx Burner 2 Palletizing for domestic Shipment	Tulsa Heaters Midstream	Exterran		United States
35812	2018	Process Burners	Process Burner	1 GLSF-20 Free Jet Gas Burner	Hydro-Chem / Linde	Hansol Chemical		Korea
35774	2018	Process Burners	Process Burner	1 GLSF-16 Free Jet Burner Assembly 1 Domestic Shipping Prep H-701 1 GLSF-19 Free Jet Burner Assembly 1 Domestic shipping Prep H-768 1 GLSF_15 Free Jet Burner Assembly 1 Domestic Shipping Prep H-771	Tulsa Heaters Midstream	SEEPCO		Nigeria

SO Number	Award Year	Product Group	Equipment Type	Equipment Type Description	Customer Name	End User Name / Facility / City	End User State	End User Country
35751	2018	Process Burners	Process Burner	56 GLSF-6 Free-Jet Burner 56 GLSF-6 Free-Jet Burner 112 Extended Damper Handle (1850mm grade) 112 Bilingual Nameplates, Burners & Enclosures 1 GLSF Burner Combustion Test 112 Fireye 85UVF-1CEX Flame Scanner 24 Local Panel for Pilot Ignition/Detection 2 Portable Battery Operated Torch 16 Local Panel for Flame Scanners LOT Tile Mortar (if necessary) 2 Burner Mounting Template LOT Burner Mounting Gasket LOT Tile Supports, Gaskets, Nuts, & Bolts LOT Spare Parts for Commissioning & Start-Up LOT Spare Parts for 4 Years Operation 112 Export Crating 6 Shipping FOB Port of Export LOT Technical Passports & Translation 112 ADDER for 200mm Extended Damper Box	Lummus Technology Heat Transfer	LUKOIL OAO / Perm Refinery / Perm		Russia
35637	2018	Process Burners	Process Burner	2 GLSF-15 Free-Jet Burner Assembly 2 Palletizing for Domestic Shipment	Tulsa Heaters Midstream	XTO Energy, Inc. / Cordona Lake Gas Plant / Crane	TX	United States
35301	2018	Process Burners	Process Burner	1 GLSF-13 "Free-Jet" Ultra Low NOx Burner 1 Palletizing for Domestic Shipment	Tulsa Heaters Midstream	Exterran		United States
35061	2018	Process Burners	Process Burner	2 GLSF-15 Free-Jet Ultra Low NOx Burner 2 Domestic Packing 2 Zeeco ProFlame ZPF-120 UV Scanner	Greyrock Services, LLC			United States
34692	2018	Process Burners	Process Burner	8 GLSF-11 Free Jet DT Burners for B-3901 8 GLSF-11 Free Jet DT Burners for B-3902 6 GLSF-11 Free Jet DT Burners for B-3903 4 GLSF-11 Free Jet DT Burners for B-3904 1 GLSF-11 Free Jet Combustion Test for B-3901 1 CFD Modeling - Radiant Section - Three Cases	Tulsa Heaters Inc	LyondellBasell North America, Inc. / Bayport Propylene Glycol Plant / Pasadena	TX	United States
34534	2018	Process Burners	Process Burner	1 GLSF-19 Free Jet Burner Assembly D3-H-768 1 Domestic Shipping Prep 1 GLSF-7 Free Jet Burner Assembly 1 Domestic Free Jet Burner Assembly D2-H-775 1 Domestic Shipping Prep	Tulsa Heaters Midstream LLC	MarkWest Energy Partners, LP / Sherwood Processing Facility / West Union	WV	United States
34263	2018	Process Burners	Process Burner	1 GLSF-13 Free Jet Ultra Low NOx Burner 1 Palletizing for domestic shipment	Tulsa Heaters Midstream LLC	Exterran		United States
33795	2018	Process Burners	Process Burner	8 GLSF-14 Free Jet Burner w/ JM-1S-EF Pilot 8 Export crating	Sinopec Engineering, Incorporated (SEI)	PetroChina Company Ltd. / Sichuan Petrochemical Complex / Chengdu City		China
33633	2017	Process Burners	Process Burner	1 GLSF-13 Free Jet Ultra Low NOx Burner 1 GLSF-13 Free Jet Ultra Low NOx Burner	Tulsa Heaters Midstream			United States
33442	2017	Process Burners	Process Burner	6 GLSF-14 Free Jet Burner Assembly H-4701 6 Burner Damper Actuator Assembly 1 Witnessed combustion test 6 domestic packaging 6 Adder 1 Engineering and drafting for GLSF-14 Free Jet	OPF Optimized Process Furnaces	Delek US Holdings, Inc. / Krotz Springs Refinery & Terminal / Krotz Springs	LA	United States
33054	2017	Process Burners	Process Burner	72 GLSF-4 Free Jet Flat Flame Burner 1 Packaging per Burner 1 Comb. Test (10 pts) 1 CFD 1/4 Furnace (1 Run) for existing burners 1 CFD 1/4 Furnace (1 Run) for new burners 72 Strainers , Wye Type, one per Burners 4 Jackshaft with actuator to control	Jacobs Engineering, Inc	Chevron Corporation / El Segundo Refinery / El Segundo	CA	United States
32942	2017	Process Burners	Process Burner	1 GLSF-10 Free Jet Ultra Low Now Burner 1 Palletizing for domestic shipmen	Tulsa Heaters Midstream	MarkWest Energy Partners, LP / Sherwood Processing Facility / West Union	WV	United States
32773	2017	Process Burners	Process Burner	4 GLSF-13 Free Jet Ultra Low NOx Burner 4 Palletizing for Domestic Shipment	Tulsa Heaters Midstream			United States
32416	2017	Process Burners	Process Burner	1 GLSF-7 Free Jet Ultra Low NOx Burner 1 Domestic Shipping Prep	Tulsa Heaters Midstream	Puget Sound Energy / Tacoma LNG Facility / Tacoma	WA	United States
32319	2017	Process Burners	Process Burner	1 GLSF-8 Free Jet Burner Assembly H-2775 1 Domestic Shipping Prep 1 GLSF-10 Free Jet Burner Assembly H-10711 1 Domestic Shipping Prep 1 GLSF-19 Continuous Ring Free Jet Burner H-2768	Tulsa Heaters Midstream LLC	MarkWest Energy Partners, LP / Sherwood Processing Facility / West Union	WV	United States
32235	2017	Process Burners	Process Burner	1 GLSF-18 Free Jet Burner Assembly H-1768 1 Domestic Shipping Prep	Scelerin Heaters	MarkWest Energy Partners, LP / Bluestone Gas Plant / Evans City	PA	United States
32234	2017	Process Burners	Process Burner	1 GLSF-18 Free Jet Burner Assembly H-1767 1 domestic shipping prep	Scelerin Heaters LLC	MarkWest Energy Partners, LP / Bluestone Gas Plant / Evans City	PA	United States
32228	2017	Process Burners	Process Burner	75 GLSF-8 Free-Jet Downfired 100% Burner 30 GLSF-7 Free-Jet Downfired 78% Burner 1 Lot Commissioning Spares 1 Capital Spares 2 Hand Held Ignitors 1 Lot gas connection nuts, bolts, gaskets 1 Lot gaskets and bolts to fix burner to furn	Air Liquide Global	Yuhuang Chemical, Inc. / Yuhuang Chemical, Inc. / St. James	LA	United States
32181	2017	Process Burners	Process Burner	1 GLSF-10 Free Jet Burner Assembly H-1769 1 Domestic Shipping Prep 1 GLSF-10 Free Jet Burner Assembly H-1769 1 Domestic Shipping Prep 1 GLSF-8 Free Jet Burner Assembly H-1775 1 Domestic Shipping Prep	Tulsa Heaters Midstream, LLC	MarkWest Energy Partners, LP / Harmon Creek Plant / Washington County	PA	United States

SO Number	Award Year	Product Group	Equipment Type	Equipment Type Description	Customer Name	End User Name / Facility / City	End User State	End User Country
31978	2017	Retrofit	Process Burner	12 GLSF-17 Free Jet Ultra Low NOx Burner Kits 110-F-101 20 GLSF-12 Free Jet Ultra Low NOX Burner kits 110-F-102 LOT Export Crating 1 GLSF-17 Combustion Test 1 GLSF-12 Combustion Test 1 CFD Modeling 2 HEI Portable Igniter	PetroChina Sichuan Petrochemical	PetroChina Company Ltd. / Sichuan Petrochemical Complex / Chengdu City		China
31885	2017	Process Burners	Process Burner	1 GLSF-15 Free Jet Burner assembly 1 Domestic Shipping Prep	OPF Optimized Process Furnaces	Boardwalk Louisiana Midstream, LLC / Moss Lake Fractionation Plant / Lake Charles	LA	United States
31866	2017	Process Burners	Process Burner	16 GLSF-12 Free Jet Flat Flame Burner Kit F-103 48 RWSF-4 Radiant Wall Burner Kit 16 JM-1S Pilot Kit 16 Export Crating GLSF-12 Kits 48 Export Crating RWSF-4 Kits 16 Export Crating JM-1S Kits 1 Single RWSF-4 Combustion Test 1 Single GLSF-6 Combustion Test 1 Two GLSF-12, six RWSF-4 Combustion Test 1 CFD Modeling	Datek	PetroChina Company Ltd. / Dushanzi Refinery / Karamay		China
31616	2017	Process Burners	Process Burner	2 GLSF-10 Free Jet Burner Assembly 2 Domestic Shipping Prep	Tulsa Heaters Midstream			Mexico
31491	2017	Process Burners	Process Burner	4 GLSF-13 Free Jet Ultra Low NOx Burner 1 GLSF-15 Free Jet Ultra Low NOx Burner 5 Palletizing for domestic shipment	Tulsa Heaters Midstream			United States
31335	2017	Process Burners	Process Burner	1 GLSF-17 Free Jet Burner Assembly 1 Domestic Shipping Prep	Tulsa Heaters Midstream	Sendero Midstream Partners, LP / Carlsbad Gas Plant / Carlsbad	NM	United States
31193	2017	Process Burners	Process Burner	2 GLSF-16 FJ Burner 2 Actuators for air control of GLSF Burners 6 Honeywell Flame Scanner Assemblies 2 3" diameter x 3ft long flex hose for main gas 2 1" diameter x 3ft long flex hose for pilot gas 2 Adapter plate assembly 2 ignition/detection panel 2 upgrade to SM-1S-HEI-F Pilot 1 Palletization for domestic shipment 1 FCA Jobsite Shipment (Donaldsonville, LA)	CF Industries	CF Industries Holdings, Inc. / Donaldsonville Nitrogen Complex / Donaldsonville	LA	United States
31134	2017	Process Burners	Process Burner	3 GLSF-13 Free Jet Ultra Low NOx Burner 3 Palletizing for Domestic Shipment	Tulsa Heater's Midstream	Woodford Express, LLC / Grady Cryogenic Gas Plant / Lindsay	OK	United States
31133	2017	Process Burners	Process Burner	1 GLSF-18 Free Jet Burner Assembly 1 Domestic Shipping Prep	Tulsa Heaters Midstream	Woodford Express, LLC / Grady Cryogenic Gas Plant / Lindsay	OK	United States
31055	2017	Process Burners	Process Burner	1 GLSF-8 Free Jet Ultra Low NOx Burner 1 Shipping Prep	Scelerin Heaters LLC	Exterran Energy Solutions L.P.		United States
31004	2017	Process Burners	Process Burner	10 GLSF-15 Free Jet Burner Assembly 10 Shipping Prep for domestic shipment	Tulsa Heaters, Inc.	Occidental Permian Ltd. - OPL / Denver Unit CO2 Recovery Plant / Denver City	TX	United States
30827	2017	Process Burners	Process Burner	1 GLSF-13 Free Jet Ultra Low NOx Burner 1 Palletizing for Domestic Shipment	Tulsa Heaters Midstream	Woodford Express, LLC / Grady Cryogenic Gas Plant / Lindsay	OK	United States
30517	2016	Process Burners	Process Burner	8 GLSF-12 Round Flame Free Jet Burner 8 HEI Ignition / Detection Enclosure 8 Export Crating	Delta Engineering sp. z o.o	PKN Orlen SA / Plock Refinery / Plock		Poland
30453	2016	Process Burners	Process Burner	1 GLSF-7 Free Jet Ultra Low NOx burner 1 Palletizing for domestic shipment	Tulsa Heaters Midstream	MarkWest Energy Partners, LP / Sherwood Processing Facility / West Union	WV	United States
30312	2016	Process Burners	Process Burner	1 GLSF-14 Free Jet Ultra Low NOx Burner 1 304 SS Flex Hose Pilot Connection Ex Works - Point of Fabrication	G.C. Broach Company	TopSail Energy		United States
30149	2016	Retrofit	Process Burner	(4) RB-743 GLSF-12 Round Flame "Free Jet" Gas Burner Assembly	Lauren Engineers & Constructors, Inc	Marathon Petroleum Corporation / St. Paul Park Refinery / Saint Paul Park	MN	United States
29994	2016	Process Burners	Process Burner	2 GLSF-15 Free Jet Ultra Low NOx Burner 3 GLSF-20 DT Free Jet Ultra Low NOx Burner	BSS (Beijing) Environmental Equipment Co., Ltd.			China
29834	2016	Process Burners	Process Burner	26 GLSF Free Jet Burners 90 RWSF Wall Burners	ENI SpA	Versalis SpA / Priolo Plant / Priolo		Italy
29811	2016	Process Burners	Process Burner	6 GLSF-13 Free jet Ultra Low NOx Burner 1 CFD Modeling , Base Case Only 1 Combustion Test Performance Test Option 2	OPF Optimized Process Furnaces	Monroe Energy, LLC / Trainer Refinery / Trainer	PA	United States
29804	2016	Process Burners	Process Burner	4 GLSF-14 "Free-Jet" Ultra Low NOx Burner 4 Domestic Shipping Prep LOT PMI of fuel wetted stainless steel components	Tulsa Heaters Inc	Sinclair Oil Corporation / Sinclair Wyoming Refining Company / Sinclair	WY	United States
29791	2016	Process Burners	Process Burner	48 GLSF-15 Free Jet Round Flame Burner Kit (46 Gas Tips) 1 GLSF-15 Free Jet Combustion Test 1 Freight GLSF-15 Kits CIF China 1 Startup supervision from headquarters, 1 week 16 GLSF-15 Free Jet Round Flame Burner Kit (46 Gas Tips) 48 RWSF-4 Radiant Wall Burner Kit	Datek / PetroChina DuShanZi	PetroChina Company Ltd. / Dushanzi Refinery / Karamay		China
29719	2016	Process Burners	Process Burner	1 GLSF-10 Free Jet Ultra Low NOx Burner 1 GLSF-11 Free Jet Ultra Low NOx Burner 2 Palletizing for Domestic Shipment	Tulsa Heaters Midstream LLC	Exterran / Oman Office		Oman
29669	2016	Process Burners	Process Burner	1 GLSF-21 Free Jet GR-DT Special 1 BMS 1 Damper Actuator 1 Burner Shipping Prep 1 Skid Shipping Prep LOT start Up Assistance Ex Works	Interstate Treating	Energy Transfer Midland		United States
29650	2016	Process Burners	Process Burner	3 GLSF-13 Free Jet Burner Assembly 3 Palletizing & Shrinkwrap for burners 3 crating for burner tiles	THI - Tulsa Heaters			United States
29314	2016	Process Burners	Process Burner	10 GLSF-14 Free Jet Ultra Low NOx Burner (F-4246) 1 Combustion Testing - 2 Fuels w/CO Probing (F-4246)	BOUSTEAD INTERNATIONAL HEATERS LTD	Shell Oil Products US / Norco Refinery & Chemical Plant / Norco	LA	United States

SO Number	Award Year	Product Group	Equipment Type	Equipment Type Description	Customer Name	End User Name / Facility / City	End User State	End User Country
29114	2016	Process Burners	Process Burner	F2151 6 GB-15 Single Jet Ultra Low Emissions Burners 6 Heater Adapter Plates 6 Adder for insulation retention 2 Natural Draft Plenum for 3 Burners w/actuator 6 ICEL J250E Torch and Control Unit 1 CFD Model of Common Air Ducting 1 CFD Model of Firebox to simulate Combustion 1 GB-15 Combustion Test F2300 (New Burner) 8 GLSF-12 Free Jet Burner 4 GLSF-12 Free Jet Burner 2 GLSF-1 Free Jet Burner 14 3 C.S. Patches per Burner for Welding Support 14 Adder for Insulation Retention 1 CFD Model of Common Air Ducting 1 CFD Model of Firebox to simulate combustion 1 GLSF Free Jet Combustion test for F2301 14 combustion air expansion joint 14 Heater steel adaptor plate 14 ICEL J250E Torch and Control Unit LOT Delivery and Export Crating	ExxonMobile in France (Fos-Sur-Mer)	Esso SAF / Raffinerie de Fos-sur-Mer / Fos-sur-Mer		France
29012	2016	Process Burners	Process Burner	6 GLSF-12 Free Jet Next Generation Ultra Low 6 Export Crating 1 FOB - Port of Altamira	Atepisa	Compania Espanola de Petroleos SA - CEPSA / La Rabida Refinery / Huelva		Spain
28586	2016	Process Burners	Process Burner	1 GLSF-21 Free Jet GR- DT Special 1 Burner Management System 1 Damper Actuator LOT Start-Up Assistance	RAMA Interstate Treating Co	RAMA Interstate Treating Co		United States
28515	2016	Retrofit	Process Burner	5 GLSF-15 Free Jet Ultra Low NOx Burner w/ JM-1s-EF Manual Pilot Assembly 1 CFD analysis base case 2 CFD additional case 2 CFD additional case 1 GLSF-15 Free Jet Burner combustion test 345 PMI 100% Bulk Material Alloy & Welds 1 LOT Spare Parts Start-up & Commissioning 5 T-Connection 5 NDE - 5% Radiography of Welds	Jacobs	Philadelphia Energy Solutions - PES / Philadelphia Refining Complex / Philadelphia	PA	United States
28458	2016	Process Burners	Process Burner	1 GLSF-19 Continuous Ring "Free-Jet" Burner 1 Palletizing for Domestic Shipment	Tulsa Heaters Midstream LLC	MarkWest		United States
28439	2016	Process Burners	Process Burner	1 GLSF-7 Free Jet Ultra Low NOx Burner 1 Palletizing for Domestic Shipment	Tulsa Heaters Midstream	MarkWest Energy Partners, LP / Cibus Ranch Compressor Station / Washington	PA	United States

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Offer Request no. 0000009334-5-6
Unknown plant – The Netherlands

NOx SCR System
Direct Injection

FT Proposal I-20-B-050, Rev.03

05th October 2020

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5.0 SCR NO_x DESIGN BASIS

Parameter	Units	EOR	SOR	MOR minimum reactivity	MOR maximum reactivity
Flue gas flow	kg/h wet	6609	6560	6678	4253
Flue gas flow	Nm^3/h wet	5266	5227	5381	3370
Temperature	°C	338	334	337	330
Duct Inlet pressure	mmwg	-45	-45	-47	-22
Inlet NO_x	**ppm @3% O_2 dry**	**35**	**35**	**35**	**35**
NOx present as NO_2	%	20	20	20	20
Inlet CO	mg/Nm^3 @ 3% O_2 dry	n.a.	n.a.	n.a.	n.a.
O_2, volume	% wet	2.3	2.3	2.3	2.3
H_2O, volume	% wet	19.1	19.1	18.5	18.8
CO_2, volume	% wet	11.4	11.4	9	12.2
SO_2	ppm @ op. O_2 wet	<1	<1	<1	<1
SO_3	ppm @ op. O_2 wet	n.a.	n.a.	n.a.	n.a.
Particulate <10µ	mg/Nm^3 wet	< 130	<130	<130	<130

5.1 SCR Performance

Parameter	Units	EOR	SOR	MOR minimum reactivity	MOR maximum reactivity
NOx outlet **guaranteed**	**ppm @3% O_2 dry**	**1.0**	**1.0**	**1.0**	**1.0**
NH_3 slip **guaranteed**	**ppm @3% O_2 dry**	**0.2**	**0.2**	**0.2**	**0.2**
Estimated Reagent	kg/h @ 24.5% NH_4OH	0.45	0.45	0.49	0.29
Pressure drop guaranteed *(within battery limits)*	mmH_2O @ 4°C	100	100	100	100

5.2 Catalyst data

Parameter	Units	
Max catalyst temp. peaks	°C for 100h total	540
Expected catalyst life	hours	37700

** Sizes are approximate, subject to the approval of the final drawings*

5.3 Preconditions & Assumptions

Parameter		Units
Expected NH_3 slip w/ new catalyst vs. EoL catalyst	-	None
Ammonia inj. rate w/ new catalyst vs. EoL catalyst	-	None*

** There might be other dust with the ability to oxidize NH3 in the flue gas which can deposit on catalyst: this might cause NH3 consumption to increase.*

REV.	DATE	DESCRIPTION	PREPARED BY	CHECKED BY	APPROVED BY
1	17/09/2020	2nd EDITION	LC	LC	LC
0	14/12/2015	FIRST EDITION	AL	GC	PdH

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SCR/SNCR - Selective (Non) Catalytic Reduction

CLIENT

xxx

SITE

xxx

ORDER NO.

xxx

VENDOR LIST / SUBSUPPLIER LIST

JOB NUMBER	DOCUMENT NUMBER	REVISION	SCALE
xxx		0	N.A
			SCOPE

FILE IDENTIFICATION

INSTRUMENTATION					
Category	**Output**	**Sensor Type**	**Supplier**	**Country**	**Related Medium/Equipment**
Pressure	Analog	DP Cell (Transmitter)	**ENDRESS+HAUSER / ROSEMOUNT**	**Worldwide / ITALY**	UREA SOLUTION, NH3 SOLUTION, WATER, AIR
	Digital	Pressure switch	**BARKSDALE / TELEMECANIQUE / NORGREN / CELLA /TRAFAG**	**Worldwide / ITALY**	UREA SOLUTION, NH3 SOLUTION, WATER, AIR
	-----	Local Gauge	**NUOVA FIMA / WIKA / CELLA**	**Worldwide / ITALY**	UREA SOLUTION, NH3 SOLUTION, WATER, AIR
Temperature	Analog	PT100	**ENDRESS+HAUSER**	**Worldwide / ITALY**	Urea solution, NH3 solution
	-----	Local Gauge	**ASHCROFT (DRESSER) / NUOVA FIMA**	**Worldwide / ITALY**	Urea solution, NH3 solution
	ACOUSTIC		**BONNENBERG&DRESCHER**	**Worldwide / GERMANY**	Flue Gas
Flow	Analog	Magnetic flow meter	**ENDRESS+HAUSER / KROHNE / BÜRKERT / iFM**	**Worldwide / ITALY**	Urea solution, NH3 solution
	Analog	Variable area	**KROHNE / ROTA-YOKOGAWA / iFM**	**Worldwide / ITALY**	Urea solution, NH3 solution, Water, Air
	-----	Variable area	**KROHNE / ROTA-YOKOGAWA / iFM**	**Worldwide / ITALY**	Urea solution, NH3 solution, Water, Air
	Analog	Turbine flow meter	**BÜRKERT**	**Worldwide / ITALY**	Water
Level	Analog	Radar / Ultra Sonic	**ENDRESS+HAUSER / KROHNE / VEGA**	**Worldwide / ITALY**	Urea solution, NH3 solution
	Analog	DP Cell (Transmitter)	**ENDRESS+HAUSER / ROSEMOUNT**	**Worldwide / ITALY**	Urea solution
	Digital	Levelswitch (Vibration)	**ENDRESS+HAUSER / OFFICINE OROBICHE**	**Worldwide / ITALY**	Urea solution, NH3 solution, Urea prill
Analyzer			**ABB / ENDRESS & HAUSER / YOGOKAWA / SICK/UNISEARCH-Associates**	**Worldwide / ITALY**	NOx / NH3 / O2 / H2O

VALVES					
Category	**Output**	**Sensor Type**	**Supplier**	**Country**	**Related Medium/Equipment**
Control valves	Analog	Globe valve	**ROSEMOUNT EMERSON / FOXBORO / MASONEILAN**	**Worldwide / ITALY**	Urea solution, NH3 solution
	Analog	Globe valve	**BÜRKERT / SPIRAX SARCO**	**Worldwide / ITALY**	Water
ON-OFF valves		Body Valve	**ADLER / BÜRKERT**	**Worldwide / ITALY**	Urea solution, NH3 solution,Water
Pressure relief valves	-----	Self Actuated	**STUBBE**	**Worldwide / ITALY**	Urea solution, NH3 solution,Water
Pressure reduction valves	-----	Self Actuated	**SMC / BOSCH-REXROTH**	**Worldwide / ITALY**	AIR
Solenoid valves	-----	Direct Action	**ASCO JOUMATIC / BÜRKERT / NADI**	**Worldwide / ITALY**	Urea solution, NH3 solution,Water

PUMPS				
Category	**Type**	**Supplier**	**Country**	**Related Medium/Equipment**
Dosing pumps	Piston diaphragm dosing pump	**GRUNDFOS / PROMINENT**	**Worldwide / ITALY**	Urea solution, NH3 solution
Pompe Centrifughe	Multistadio	**GRUNDFOS / KSB**	**Worldwide / ITALY**	Urea solution, NH3 solution,Water

FANS				
Category	**Type**	**Supplier**	**Country**	**Related Medium/Equipment**
Centrifugal fans	Centrifugal fan	**ACOVENT / MORO / FLAKTWOODS**	**Worldwide / ITALY**	Air, Flue gas

ELECTRICAL HEATER				
Category	**Type**	**Supplier**	**Country**	**Related Medium/Equipment**
Heaters	Battery heaters	**FATI / MC RESISTORI / AMARC / CRC / Others**	**ITALY**	Air / Urea Solution / Flue Gas
Heaters	Elements for Heater	**FATI / MC-RESISTORI / Others**	**ITALY**	Urea Solution

ELECTRICAL EQUIPMENT				
Category	**Type**	**Supplier**	**Country**	**Related Medium/Equipment**
Control system	PLC, AI-AO-DI-DO Cards, Control Panel	**ABB / SIEMENS**	**Worldwide / ITALY**	Automation & Control
Electrical Equipment	CCM and auxiliaries	**ABB / SIEMENS**	**Worldwide / ITALY**	Automation & Control & Feeding

HEAT EXCHANGER				
Category	**Type**	**Supplier**	**Country**	**Related Medium/Equipment**
HeatSink	Dry	**TEMPCO / ALFA LAVAL**	**Worldwide / ITALY**	PROCESS / MECHANICAL / ELECTRICAL
	Wet	**TEMPCO**	**ITALY**	PROCESS / MECHANICAL / ELECTRICAL

TANK				
Category	**Type**	**Supplier**	**Country**	**Related Medium/Equipment**
Storage	Carbon Steel / AISI 316	**DIZIO INOXA / ABL / Others**	**ITALY**	Urea/Ammonia storage
	GRFP (Glass Reinforced Fiber Plastic)	**SELIP / FANTONI SERBATOI**	**ITALY**	Urea/Ammonia storage

INJECTORS				
Category	**Type**	**Supplier**	**Country**	**Related Medium/Equipment**
Lances	Injectors (Retarct or Wall)	**Assembled by Fuel Tech Inc. / Manufactured by Lechler**	**USA**	MECHANICAL / PROCESS
	Retract System	**Assembled by Fuel Tech Inc. / Manufactured by AmeriChem System**	**USA**	MECHANICAL / ELECTRICAL
	Multi Nozzles Lances (with Mechanical Retract System)	**Assembled by Fuel Tech Inc./ Assembled by Diamond Power**	**USA**	MECHANICAL / ELECTRICAL

ASSEMBLY				
Category	**Type**	**Supplier**	**Country**	**Related Medium/Equipment**
Skid	SKID	**MONTECO / G&G / Others**	**ITALY**	MECHANICAL / ELECTRICAL / I&C

PIPES				
Category	**Type**	**Supplier**	**Country**	**Related Medium/Equipment**
Piping	AISI	**MARKET AVAILABLE**	**WORLDWIDE / ITALY**	MECHANICAL / ELECTRICAL / I&C

SITE ACTIVITIES				
Category	**Type**	**Supplier**	**Country**	**Related Medium/Equipment**
Site activities	Supervision on site	**Fuel Tech**	**ITALY / USA**	MECHANICAL / ELECTRICAL / I&C

NOx REDUCTION SYSTEMS REFERENCE LIST - SCR only

INDUSTRY	PRODUCT TYPE	COUNTRY	OWNER	# of UNITS	UNIT SIZE (EACH)	UNITS	FUEL TYPE (PRIMARY)
IPP/Co-Gen	SCR - Ammonia	USA	KGT for Confidential Client	20	6	MW	Gas - Natural
Industrial	SCR - Ammonia	USA	Shell Chemical Apalachia	3	41	MW	Gas - Natural
Utility	SCR - with ULTRA®	China	China Light and Power	1	550	MW	Gas - Natural
Steel	SCR - Ammonia	USA	Pro-Tec Coatings (US Steel)	1	46241	kg/hr	Gas - Waste
Steel	SCR - Ammonia	USA	Pro-Tec Coatings (US Steel)	1	44857	kg/hr	Gas - Waste
Refinery	SCR - with ULTRA®	Italy	Eni Power	1	144263	kg/hr	Gas - Natural
IPP/Co-Gen	SCR - Ammonia	USA	Greenidge Generation LLC	1	106	MW	Gas - Natural
Industrial	SCR - Ammonia	USA	Dupont AMEC FW	2	316000	lbs steam/hr	Gas - Natural
Industrial	SCR - Ammonia	USA	Technimont - KT	1	443000	lb/hr	Gas - Natural
Refinery	SCR - Ammonia	China	Cabot Carbon Corporation Hebei Province	1	167000	Nm3/hr	Tail Gas
Industrial	SCR - Ammonia	USA	OXEA Corp.	1	250.000	lbs steam/hr	Gas - Natural
Industrial	SCR - NOxOUT®	USA	PQ Corporation	1	5.000	lb/hr	Gas - Natural
Utility	SCR - Ammonia	USA	Gainesville Renewable Energy Center	1	100	MW	Biomass - Wood/Bark
Steel	SCR - with ULTRA®	Mexico	Ternium Mexico S.A de C.V.	1	74.000	lb/hr	Gas - Natural
MWC	SCR - Ammonia	China	NEM	1	634000	Nm3/hr	Gas - Waste
MWC	SCR - Ammonia	China	NEM	1	1174000	Nm3/hr	Gas - Waste
Steel	SCR - NOxOUT®	USA	Pro-Tec Coatings (US Steel)	1	90	MMBtu/hr	Gas - Natural
Chemical	SCR - NOxOUT®	China	Cabot Risun Chemical Corp.	1	20	MW	Other - Alternative

NOx REDUCTION SYSTEMS REFERENCE LIST - SCR only

INDUSTRY	PRODUCT TYPE	COUNTRY	OWNER	# of UNITS	UNIT SIZE (EACH)	UNITS	FUEL TYPE (PRIMARY)
MWC	SCR - Ammonia	Spain	Conzorzio di Maresme	1	8.6	t/hr	Biomass - MSW
MWC	SCR - Ammonia	Spain	Conzorzio di Maresme	1	8.6	t/hr	Biomass - MSW
Glass	SCR - NOxOUT®	China	Jiangsu Wujiang Nanbo Glass Co., Ltd.	1	600	tpd	Gas - Natural
Glass	SCR - NOxOUT®	China	Jiangsu Wujiang Nanbo Glass Co., Ltd.	1	900	tpd	Gas - Natural
Glass	SCR - Ammonia	USA	AGC Flat Glass	1	10525	Nm3/hr	Gas - Natural
Glass	SCR - Ammonia	USA	AGC Flat Glass	1	2900	Nm3/hr	Gas - Natural
Steel	SCR - NOxOUT®	USA	Nucor Steel	1	98.7	MMBtu/hr	Gas - Natural
MWC	SCR - Ammonia	Italy	Hamon Research Cottrell Italia	1	93000	Nm3/hr	Other - Industrial Waste
MWC	SCR - Ammonia	Italy	C.C.T.	1	95000	Nm3/hr	Biomass
IPP/Co-Gen	SCR - NOxOUT®	Turkey	Hamon Research Cottrell Italia	7	*CONFIDENTIAL*	*CONFIDENTIAL*	*CONFIDENTIAL*
Steel	SCR - NOxOUT®	USA	Nucor Steel	1	20	MMBtu/hr	Gas - Natural
Steel	SCR - NOxOUT®	USA	US Steel	1	117	MMBtu/hr	Gas - Natural
Steel	SCR - NOxOUT®	USA	Pro-Tec Coatings (US Steel)	1	76.8	MMBtu/hr	Gas - Natural
Steel	SCR - NOxOUT®	USA	Pro-Tec Coatings (US Steel)	1	99	MMBtu/hr	Gas - Natural
Industrial	SCR - NOxOUT®	Taiwan	Shinkong Synthetic Fiber	3	6	MW	Oil - #6
				63			

CECO ENVIRONMENTAL

Peerless

TECHNICAL & COMMERCIAL PROPOSAL

Date:	19-October-2020
Client:	Casale SA
Project:	A09480 – SCR System for Fired Heater Convection Section
Quotation No.:	Q-204133
Revision No.:	1

V. DESIGN CRITERIA

A. DESIGN CONDITIONS: The proposed SCR System design is based on the following design conditions; the data is for one (1) unit. Should the actual gas conditions be different from the design data, the performance shall be re-evaluated, based on the corrected design data.

PROCESS DATA							
Design Case				Case 1	Case 2	Case 3	Case 4
Customer Design Case				EOR Design	SOR Design	MOR Min Reactivity	MOR Max Reactivity
Percent Load			Percent	100%	100%	100%	100%
Fuel Case				Gas	Gas	Gas	Gas
Exhaust Gas Mass Flowrate, Wet			kg/h	7269.0	6560.0	6678.0	4253.0
Exhaust Gas Volumetric Flowrate, Wet			Nm3/h	5786	5221	5374	3366
Exhaust Gas Temperature			degrees C	338.0	334.0	337.0	330.0
Exhaust Gas Composition							
Component	*MW*						
O2	31.999		vol% (wet)	2.30	2.30	2.30	2.30
H2O	18.015		vol% (wet)	19.10	19.10	18.50	18.80
N2	28.013		vol% (wet)	66.30	66.30	69.20	65.80
CO2	44.010		vol% (wet)	11.40	11.40	9.00	12.20
Ar	39.948		vol% (wet)	0.90	0.90	1.00	0.90
				100.00	100.00	100.00	100.00
Emissions from the Source		@ %O2	3				
Nox as NO2			ppmvd	35.00	35.00	35.00	35.00
Nox as NO2			kg/h	0.34	0.31	0.32	0.20
SO2			ppmvw	1.00	1.00	1.00	1.00
SO2			kg/h	0.02	0.01	0.02	0.01
Particulates			mg/Nm3 (dry)	130.00	130.00	130.00	130.00
Amount of Nox as NO2			Percent	20.00	20.00	20.00	20.00
Nox Reduction			Percent	97.14	97.14	97.14	97.14
Aqueous Ammonia Requirement			kg/h	0.619	0.614	0.638	0.398
Aqueous Ammonia Requirement			m3/month	1.000	0.492	0.511	0.319
Performance Warranties		@ %O2	3				
Nox as NO2			ppmvd	1.0	1.0	1.0	1.0
Nox as NO2			kg/h	0.010	0.009	0.009	0.006
NH3 Slip			ppmvd	1.00	1.00	1.00	1.00
NH3 Slip			kg/h	0.004	0.003	0.003	0.002

B. CATALYST DESIGN DETAILS:

SCR CATALYST	
Maximum Catalyst Exposure Temp for Short Term Duration	475 deg C (limited to 100 hours or less)
Maximum Catalyst Exposure Temp for Continuous Duration	425 deg C

C. UTILITY CONSUMPTION (AQUEOUS AMMONIA FLOW CONTROL UNIT):

DESCRIPTION	QUANTITY	UNITS
Design Flow Rate **Aqueous Ammonia** (19% by Weight)	1	kg/hr
Ammonia Supply Pressure	80	PSIG
Ammonia Inlet Temperature	Ambient	C Minimum for NH_3
Instrument Air (-40 C Dew Point or Better)		
Supply Pressure	80 - 125	PSIG
Maximum Steady State Air Consumption	1	SCFM
Maximum Instantaneous Air Supply Demand	5	SCFM
Maximum Continuous Air Supply Demand for Atomization	80	SCFM

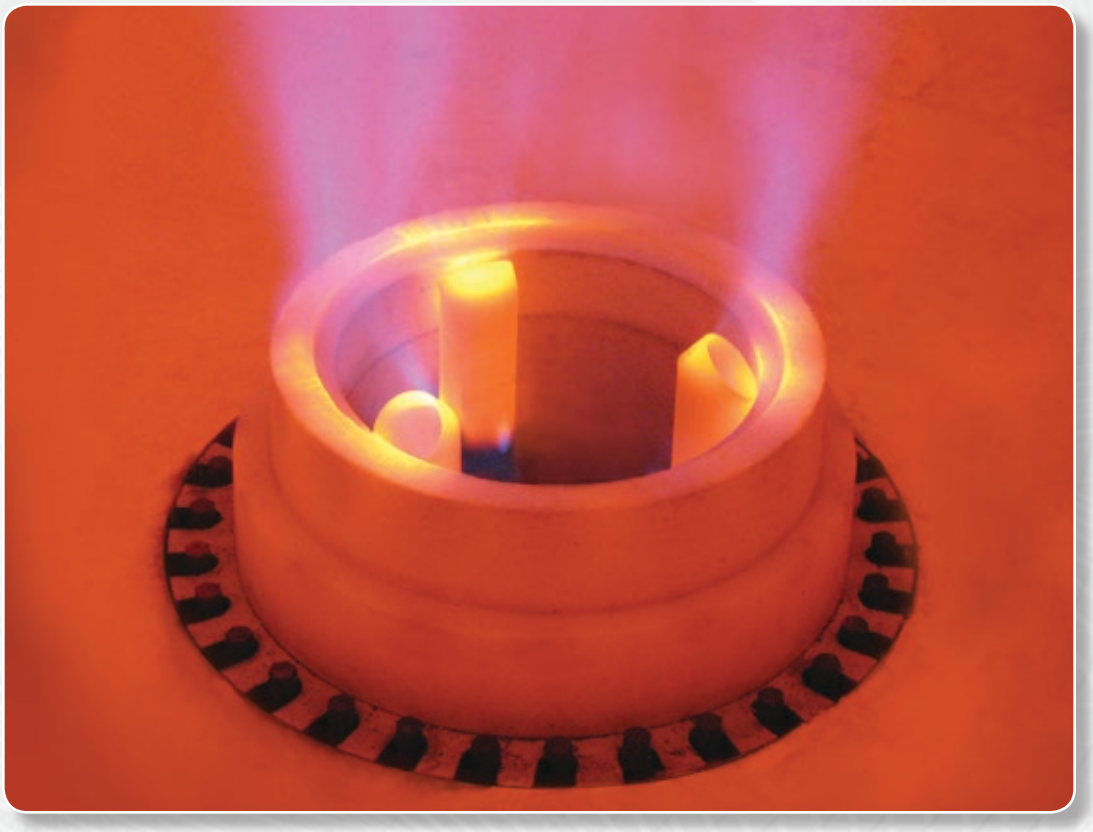
PEERLESS Mfg. Co.
MAKING ENERGY SAFE, EFFICIENT, AND CLEAN.

Confidential Experience List
Refinery and Process Applications
4/14/2016

Project/Facility	Units	Site State	Start-Up	Application	Unit Type	Customer	Owner/EPC
Valero Refinery	1	Houston	2016	Crude Heater	Fired Heater	Tulsa Heaters Inc	Valero Refinery
Shintech	7	Louisiana		Heater	Fired Heater	Lummus Technology	Shintech Inc.
Pine Bend		Minnesota	2016	Simple Cycle	Fired Heater	Great Southern	Flint Hills Resources
Flint Hills		Minnesota	2016	Simple Cycle	Fired Heater	Tulsa Heaters Inc	Flint Hills Resources
Valero	1	Corpus Christi	2015	Crude Heater	Fired Heater	Tulsa Heaters Inc	Valero Refinery
Westlake	1	Louisiana	2015	Crude Heater	Fired Heater	Lummus Technology	Westlake Chemical
Occidental	5	Texas	2016	Heater	Fired Heater	CB & I Lummus	CBI
Valero	2	Louisiana	2015	Heater	Fired Heater	Tulsa Heaters Inc	Valero Refinery
Westlake	1	Louisiana	2016	Heater	Crude Heater	Lummus Technology	Westlake Chemical
Lone Star NGL - Mont Belview	1	Texas		Fired Heater	Fired Heater	Tulsa Heaters	
Lummus	1		2013	Fired heater	Fired Heater	Lummus	
Mont Belvieu	1	Texas	2013	Fired Heater	Fired Heater	Tulsa Heaters	
CB&I - BP Cherry Point	1	Washington	2012	Reformer	Fired Heater	CB&I	BP
MAP	1	Illinois	2011	Fired Heater	Reformer	MAP	
MAP - Detroit Heavy Oil Upgrade	1	Michigan	2011	Coker FCC	Fired Htr	Onquest	
MAP	1	Illinois	2010	Fired Heater	Fired Htr	Onquest	
Bayway Refinery	1	New Jersey	2011	Fired Heater	Fired Htr	Conoco Philips	
Valero	1	California	2011	Reformer	Fired Htr	CBI Howe Baker	
Lemont	1	Illinois	2011	Reformer	Reformer	Selas	
PL Propylene - Selas	1	Texas	2010	Propane Superheater	Fired Htr	Selas	
OXY Elk Hills	2	California	2010	Fired Heater	Fired Htr	OXY	**Elk Hills Power**
Citgo - Mark West	1	Texas	2011	Fired Heater	Fired Htr	Selas	
B P Whiting	1	Indiana	2010	Fired Heater	Fired Heater	Selas	**Whiting Clean Energy**
Navajo Refining	1	New Mexico	2010	Fired Heater	Reformer	CBI Howe Baker	
MAP Garyville Coker	1	Louisiana	2009	Coker	Fired Htr	OnQuest	
GoldenPass LNG Expansion	8	Texas	2009	LNG Heaters	Fired Htr	Tulsa Heaters	
Toyo Linde SCD	2	Qatar	2008/9	Heater	Fired Htr	Linde	**Pearl GTL**
Toyo Linde HTF	2	Qatar	2008	Heater	Fired Htr	Linde	**Pearl GTL**
MAP Garyville Vacuum	1	Louisiana	2009	Heater	Fired Htr	Tulsa Heaters	
MAP Garyville Crude	1	Louisiana	2009	Heater	Fired Htr	Tulsa Heaters	
Big West-THI	1	California	2009	Heater	Fired Htr	Tulsa Heaters	
ConocoPhillips-THI	1	California	2009	Heater	Fired Htr	Tulsa Heaters	
Air Liquide Rodeo	1	California	2007	H Reformer	Reformer	Howe-Baker Engineers	Air Liquide
BASF - Freeport	1	Texas	2005	Incinerator	Process	BASF	BASF
GE EER Delaware City	2	Delaware	2005	SNCR	Process	GE EER	Premcor
Baytown II	1	Texas	2005	Aqua Storage and Handling	Process	Air Products	ExxonMobil
CB&I - Howe-Baker	1	Texas	2005	Fired Heaters	Fired Htr	CB&I - Howe-Baker	
Inergy Gas Services	1	California	2005	Process Heater	Process	Aqua-Chem, Inc.	Inergy
Motiva Norco Refinery	1	Louisiana	2005	SNCR	Fired Htr	GE-EER Division	Motiva
Air Liquide	1	California	2004	Hydrogen Reformer	Reformer	Howe Baker Engineers	Air Liquide
BASF - Freeport	1	Texas	2005	Incinerator	Process	BASF	BASF
NOx Reduction Project 4	1	Texas	2004	Retrofit Hydrogen Reformer	Reformer	Fluor Daniel	ExxonMobil
Motiva Refinery	1	Delaware	2005	Fired Heater	Fired Htr	GE - EER	Motiva
Marathon Ashland	1	Illinois	2003	Fired Heater	Fired Htr	Jacobs Engineering	Marathon Ashland
THI - Dow Freeport	1	Texas	2003	Fired Heater	Fired Htr	Tulsa Heaters	Dow Chemical
THI - Ultramar	1	California	2003	Fired Heater	Fired Htr	Tulsa Heaters	Ultramar Diamond Shamrock
Praxair Project	1	Canada	2002	Reformer	Reformer	Selas Fluid Processing	
Ultramar Golden Eagle Refinery	3	California	2002	Fired Heaters	Fired Htr	Technip USA Corp	UDS
Tosco Rodeo Phase 2	4	California	2001	Heater (NH3 to NH4OH Conversion	Fired Htr	Jacobs Engineering	TOSCO
Chevron F201A Heater	1	California	2000	F201 A Vacuum Heater	Fired Htr	Chevron	
Tosco Rodeo Refinery	1	California	2000	Process Heater	Fired Htr	Tulsa Heaters	Tosco Rodeo Refinery
Hydro-Chem	1	Alabama	1998	Boiler/Reformer	Reformer	Carbonyl	
Hydro-Chem II	1		1999	Steam Reformer	Reformer	Hydro-Chem/Pro-Quip Corp.	Hydro-Chem
UOP	1	Alabama	1998	Retrofit Process Unit	Process	UOP	Herzog-Hart Corp.
Alcoa	1	Louisiana	1998	Process Unit	Process	Alcoa Alumina & Chemicals	Alcoa Alumina & Chemicals
BASF Tradewinds	2	Texas	1999	Fired Heaters	Fired Htr	ABB Lummus Heat Transfer	
Hydro-Chem	1	Alabama	1999	Process unit	Process	Carbonyl	Hydrochem
Formosa Petro-Chem	1	Taiwan	1998	Fired Heater	Fired Htr	Tulsa Heaters	Formosa
Air Liquide	1	Texas	N/A	Hydrogen Reformer	Reformer	Howe-Baker Engineers, Inc.	Howe-Baker
Air Liquide	1	Texas	1998	Hydro Reformer	Reformer	Howe-Baker Engineers, Inc.	Air Liquide
Grace Division	1	Louisiana	1998	Process Unit	Process	W. R. Grace	SSOE
Curtis Bay Unit 63603	1	Maryland	1996	Process Unit	Process	W. R. Grace	SSOE
Lockheed Pit 9	1	Indiana	1996	Waste Incinerator	Process	Lockheed Martin	Merrick Engineers
Liquid Carbonic	1	Louisiana	1996	Hydro Reformer	Reformer	Selas Fluid Processing	Liquid Carbonic
Exxon - Benicia	1	California	1995	Fired Heater	Fired Htr	Petro-Chem	Exxon / Ralph M. Parsons
UNOCAL Corporation	1	California	1995	Hydrogen Reformer 35mm SCFD	Reformer	Howe-Baker Engineers, Inc.	UNOCAL
Apache Nitrogen	1	Arizona	1994	De-Nitrification Process	Process	Jacobs Engineering	Jacobs Engineering
UNOCAL Corporation San Fransisc	1	California	1995	Hydrogen Reformer	Reformer	Howe-Baker Engineers, Inc.	UNOCAL
Conoco	1	Montana	N/A	Hydrogen Reformer	Reformer	Howe-Baker Engineers, Inc.	Conoco
Maalaea Power Plant	1	Hawaii	1994	Pilot Plant SCR	Process	Stone & Webster Engineering	Hawaii Electric
Chevron USA, Inc.	1	California	1993	Fired Heater	Fired Htr	KTI Corporation	Fluor Daniel, Inc.
Ashland Petroleum Company	1	Minnesota	1993	Fired Heater	Fired Htr	Howe-Baker Engineers, Inc.	Marathon Ashland
ARCO Refining	1	California	1991	Hydrogen Reformer	Reformer	Peerless Mfg. Co.	ARCO Refining
Texaco Refining	1	California	1991	Fired Heaters	Fired Htr	Born Environmental	E&L Engineering
Texaco Refining	1	California	1991	Fired Heaters	Fired Htr	Born Environmental	E&L Engineering
Texaco Refining	1	California	1991	Fired Heaters	Fired Htr	Born Environmental	E&L Engineering
Texaco Refining	1	California	1991	Fired Heaters	Fired Htr	Born Environmental	E&L Engineering
Texaco Refining	1	California	1991	Fired Heaters	Fired Htr	Born Environmental	E&L Engineering
Texaco Refining	2	California	1991	Fired Heaters	Fired Htr	ENTEC	E&L Engineering

FREE-JET NEXT GENERATION ULTRA-LOW NOx BURNER

GLSF Series



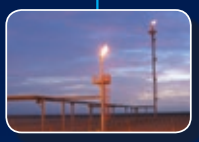
Description

The ZEECO® GLSF Free-Jet burner is a next generation ultra-low emissions round flame burner.

Technology

The photo above shows a GLSF Free-Jet round flame burner in operation. This patented burner design uses the free jet method of mixing the fuel gas ejected from the gas tips with the surrounding inert products of combustion which dramatically lowers thermal NOx production. In addition to superior NOx reduction performance, the free jet design offers a superior turndown, typically 10:1 or greater. Each tip only has one large firing port.


BURNERS


FLARES


INCINERATORS


PARTS & SERVICE

Free-Jet Next Gen Ultra-Low NOx Burner

Design Features

- Stable flame over a wide range of conditions
- High turndown of 10:1 or greater for most cases
- No stabilization metal used in the burner throat
- Tips have only a single firing port and do not require a small ignition port
- Low maintenance cost since tip mass is small and exposed into firebox less than 1" (25 mm)
- Low maintenance cost since the tips do not have small ignition ports which are prone to plug
- Compact design makes this burner an ideal choice for retrofit applications
- Low probability of flame interaction since the burners are smaller and gas is not swirled
- Superior heat flux profile
- Great value
- Combustion air is controlled by gear driven dampers for precise control
- Bearings are used for the combustion air dampers for smooth, precise operation
- Configurations available: plenum mounted or individual windbox
- 304 stainless steel fuel gas risers
- 310 stainless steel (type HK) gas tips

Design Information

Burner Model: ..... GLSF Free-Jet Burner
Fuels: ..... Gas Only
Description: ..... Round Flame Next Generation Ultra-Low Emissions
NO_x Reduction Method: ..... Internal Flue Gas Recirculation by Free Jet Mixing
Predicted NO_x Emissions Range (Natural Draft): ..... 6 to 20 ppmv
Predicted NO_x Emissions Range (600° F Air Preheat): ..... 10 to 25 ppmv
Combustion Air Induction: ..... Natural, Forced, Induced and Balanced Draft
Mounting Options: ..... Upfired, Downfired and Sidefired
Natural Draft Heat Release Range: ..... 1 to 20 MMBtu/hr [0.293 to 5.86 MW]
Forced Draft Heat Release Range: ..... 1 to 350 MMBtu/hr [0.293 to 102.6 MW]
Turndown: 10:1
Typical Excess Air Range: ..... 10 to 25%

ZEECO® combustion solutions are designed and manufactured to comply with applicable local and international standards as defined by our customers.

NSF
REGISTERED
ISO 9001: 2008

CERTIFICATION APPLIES TO ZEECO HEADQUARTERS ONLY.

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Zeeco, Inc.
GLSF Free Jet Burner 5 Year Reference List Guaranteed Emission NOx < 70mg/Nm3

SO Number	Award Year	Product Group	Equipment Type	Equipment Type Description	Customer Name	End User Name / Facility / City	End User State	End User Country
50310	2021	Process Burners	Process Burner	24 GLSF-11 "Free-Jet" Flat Flame Burner Assembly 48 GLSF-7 "Free-Jet" Flat Flame Burner Assembly 1 Combustion Testing GLSF-11 1 Combustion Testing GLSF-7 1 100% PMI of Alloy Material	Great Southern Technologies, LLC	Flint Hills Resources, LP / Houston Propylene Plant / Houston	TX	United States
50192	2021	Retrofit	Process Burner	F-5601 (4) GLSF-12 Free Jet Gas Burner Assembly Includes JM-1S Manual Pilot	Parkland Refining (B.C.) Ltd.	Parkland Fuel Corporation / Burnaby Refinery / Burnaby	BC	Canada
49838	2021	Process Burners	Process Burner	4 GLSF-19 Free Jet Ultra Low NOx Burner	Bantrel Co.	Cenovus Energy, Inc. / Lloydminster Upgrader / Lloydminster	SK	Canada
49510	2021	Process Burners	Process Burner	30 GLSF-7 Free-Jet Downfired 78% Burner 75 GLSF-8 Free-Jet Downfired 100% Burner 2 Portable Ignitor 1 Burner performance test -ea. Burner type 1 Set erection spare parts *Zeeco China Fabrication	Air Liquide Global E&C Solutions	Sarawak Shell Berhad / Sarawak Shell Berhad / Lutong		Malaysia
48700	2021	Retrofit	Process Burner	(6) GLSF-12 "Free-Jet" Burner Assembly (4) GLSF-12 "Free-Jet" Burner Assembly (2) GLSF-13 "Free-Jet" Burner Assembly (2) CLSF-15 "Free-Jet" Burner Assembly (1) Construction for both heaters (1) On site engineer site construction (14) Ignition transformer (14) Fireye 85 UVF1-1QD w/ 20 meter cable (2) Emission check by authorized company (1) Negotiation	Taekwang Industrial Co., Ltd	Taekwang Industrial Company Ltd. / Petrochemical Plant #1 / Ulsan		Korea
47951	2020	Retrofit	Process Burner	6 GLSF-12 "Free-Jet" Ultra Low NOx Burner 6 SM-1S-HEI Pilot Assembly 6 SM-1S-HEI Pilot Assembly 6 SM-1S-HEI Pilot Assembly 6 Export Crating & FCA Containerization 1 Bespoke pilot panel modification kit	LBL Trading	Oil Refineries Limited - ORL / Bazan Refinery / Haifa		Israel
47816	2020	Process Burners	Process Burner	GLSF-11 RF FJ Burners GLSF-7 FF EJ Burners	Formosa Plastics	Formosa Plastics (Ningbo) Co., Ltd. / PDH Plant / Ningbo		China
47256	2020	Process Burners	Process Burner	12 GLSF-10 "Free-Jet" Burner Assembly 1 GLSF-10 Combustion Test 1 Domestic Packing 1 Dye Pen and Radiography Testing	Great Southern Technologies, LLC	Countrymark Cooperative, LLP / Mount Vernon Refinery / Mount Vernon	IN	United States
47093	2020	Retrofit	Process Burner	4 GLSF Free Jet G2 Retrofit Kit. Including: (4) Primary Tips per Kit with 3/32" Firing Orifice (4) Drains per Kit (19) Secondary Tips per Kit with Larger Firing Orifice Diameter (1) Fuel Gas Manifolds with 1/4" Gas Risers (1) Front Plate with (1) Sight Port and (1) Scanner Connection (1) JM-1S Pilot Domestic Packaging	Phillips 66	Phillips 66 Company / Los Angeles Refinery - Wilmington / Wilmington	CA	United States
46442	2020	Process Burners	Process Burner	192 GLSF-4 Free-Jet Ultra Low NOx Burners 192 Adapter Plate 20 Burner Front Plate Blanking Plate 14 Lighting Torch 192 All Fuel Gas Piping 316L SS 192 PMI of alloy metal 192 Dye-pen 25% of alloy socket-welds	Jacobs Engineering	Chevron Corporation / El Segundo Refinery / El Segundo	CA	United States
46324	2020	Retrofit	Process Burner	(16) GLSF-13 "Free-Jet" Gas Burner assembly Burner combustion test per heater (1) CFD per heater (1) Spare parts for construction / commissioning	GS Caltex	GS Caltex Corporation / Yeosu Complex / Yeosu		Korea
46251	2020	Process Burners	Process Burner	12 GLSF-14 "Free-Jet" Burner Assembly 12 Smitsvonk Type 54 Pilot Burner 12 Smitsvonk Ignition Control Unit 24 Durag D-LE 603 Scanner 1 Combustion Performance Testing 1 Scanner control unit panel for installation in control room 1 CFD Study - Base Case 1 Additional Testing with 85% Hydrogen fuel	BOUSTEAD INTERNATIONAL HEATERS LTD	Essar Oil UK / Stanlow Refinery / South Wirral		United Kingdom
46025	2020	Process Burners	Process Burner	24 GLSF-11 "Free-Jet" Flat Flame Burner Assembly 48 GLSF-7 "Free-Jet" Flat Flame Burner Assembly 1 Inner Burner Combustion Test 1 Inner Burner Combustion Test 72 International Crating	Great Southern Technologies, LLC	Flint Hills Resources, LP / Houston Propylene Plant / Houston	TX	United States
45502	2020	Retrofit	Process Burner	7 CLSF-15 DT Combination Free-Jet Burner Including JM-1S-EF Pilot 6 GLSF-14 Free-Jet Burner Including JM-1S-EF Pilot	Great Orient Chemical (Taicang) Co., Ltd	Great Orient Chemical (TaiCang) Co., Ltd. - GOC / LAB (Linear Alkyl Benzene) Factory / Taicang		China
45307	2020	Retrofit	Process Burner	32 GLSF-11 Free Jet Flat flame Burner 1 CFD 1 GLSF Combustion Testing 4 Spare Tip Sets	Wison	CNOOC Limited / Huizhou 21-1B Platform / Hong Kong		China

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43992	2020	Process Burners	Process Burner	24 GLSF-14 "Free-Jet" Gas Burner Assembly 3 GLSF-8 "Free-Jet" Gas Burner Assembly 3 GLSF-9 "Free-Jet" Gas Burner Assembly 4 GLSF-9 "Free-Jet" Gas Burner Assembly 1 H-1101 Combustion Testing 1 H-1301 Combustion Testing 1 H-1302 Combustion Testing 3 CFD Simulation of Vertical Cylindrical Furnace 1 CFD Simulation of Cabin Style Furnace (1) Cell 1 Air Flow Modeling of Combustion Air Ducting 1 Domestic Packaging 1 Lot of Commissioning Spare Parts 1 Lot of 2 Years Operational Spares	JNK Heaters	S-Oil Corporation / Ulsan Complex / Ulsan		Korea
43749	2020	Retrofit	Process Burner	3 GLSF Free Jet G2 Retrofit Kits 3 JM-1S-HEI Pilot w/scanner connection 6 Zeeco ProFlame ZPF-120 Flame Scanners 1 Witnessed combustion testing - 1 day	BP Refinery (Kwinana)	BP Australia / Kwinana Refinery / Kwinana		Australia
42663	2019	Process Burners	Process Burner	12 GLSF-16 Free Jet ULNB Round Flame F-10101 8 GLSF-14 Free Jet DT ULNB Round Flame F-10201 4 GLSF-14 Free Jet ULNB Round Flame F-10301 4 GLSF-12 Free Jet ULNB Round Flame F-10501 2 GLSF-16/14 Burner Testing 2 GLSF-14/12 Burner Testing. 1 CFD of 1 cell - firebox 1 CFD of 1 cell - firebox 1 CFD of 1 cell - firebox 1 CFD of 1 cell - firebox 1 CFD of combustion air ducting 1 CFD of combustion air ducting 1 CFD of combustion air ducting 1 CFD of combustion air ducting 1 Lot Export Crating	JNK Heaters Co., Ltd	Thai Oil Public Company Limited / Sri Racha Refinery / Sri Racha		Thailand
42444	2019	Process Burners	Process Burner	1 GLSF-18 Free-Jet Ultra Low NOx Burner 1 Domestic Packing	Tulsa Heaters Midstream LLC	Williams Olefins, LLC / Williams Olefins, LLC / Carville	LA	United States
41461	2019	Process Burners	Process Burner	30 GLSF Free Jet Burner 12 H5201 8 GLSF Free Jet Burner 12 H5601 6 GLSF Free Jet Burner 12 H5602 8 GLSF Free Jet Burner 12 H5001 6 GLSF Free Jet Burner 12 H5002 1 Packing and freight to job site	KTI	SK Energy Company Limited / Naphtha Cracking Plant / Ulsan		Korea
41280	2019	Process Burners	Process Burner	1 GLSF Free Jet Burner Kits	Datek	Fujian Petrochemical Company Limited - FPCL / Fujian Petrochemical Company Limited - FPCL / Quanzhou		China
41224	2019	Process Burners	Process Burner	384GLSF-12 Flat Flame Free-Jet Kit Includes Engineering and Drafting 24GLSF-12 Flat Flame Free-Jet Kit Includes Engineering and Drafting 1Combustion Test (Dual Burner) F-1120 per attached combustion test procedure 1CFD Modeling 1/2 of Firebox F-1110 Design & Decoke Conditions 1CFD Modeling 1/2 of Firebox F-1120 Design & Decoke Conditions 3Lighting Torches Drawing Only	China Huanqiu Contracting Engineering Co. Ltd. Beijing Huanqiu Corporation	Shandong Shouguang Luqing Petrochemical Co., Ltd. / Shandong Shouguang Luqing Petrochemical Co., Ltd. / Shouguang		China
41092	2019	Retrofit	Process Burner	24 GLSF-15 Free-Jet-V Burner Insert Assembly - F3101 6 GLSF-14 Free-Jet Burner Assembly - F660 1 Combustion Testing GLSF-15 - 2 Fuels 1 Combustion Testing GLSF-14 - 2 Fuels 1 Lot Export Packing	ExxonMobil Engineering Europe Limited	ExxonMobil / Sarpom Trecate Novara Refinery / San Martino di Trecate		Italy
40483	2019	Process Burners	Process Burner	6 GLSF-13 Free Jet Ultra Low NOx Burner 1 GLSF Combustion Test 12 ZPF-120 Flame Scanner	OPF Optimized Process Furnaces	Cenovus Energy, Inc. / Superior Refinery / Superior	WI	United States
39861	2019	Process Burners	Process Burner	6 GLSF-14 Freejet Burner 1 Export Crating 1 GLSF combustion test 6 Zeeco ProFlame ZPF-1100	KTI	LG Chem / SM Plant / Yeosu		Korea
39675	2019	Process Burners	Process Burner	2 GLSF-21 Free Jet Dual Fuel Burner F9401 A/B 2 Export Crating	Hydro Chem	Shell SA Refining/BP Southern Africa / Durban Sapref Refinery / Durban		South Africa
39614	2019	Process Burners	Process Burner	1 GLSF-13 Free Jet Ultra Low NOx Burner 1 Palletizing for Domestic Shipment	Tulsa Heaters Midstream	Exterran		United States
39165	2019	Process Burners	Process Burner	280 RWSF-4 Radiant Wall Staged Fuel Burner Kits 280 GLSF-12 FF Flat Flame Free-Jet Burner Kits	Lianyungang Petrochemical Co. (LYPC)	Lianyuangang Petrochemical Co., Ltd. / Lianyungang Petrochemical Complex / Lianyungang		China

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39120	2019	Process Burners	Process Burner	128GLSF-12 "Free-Jet" Ultra Low NOx Burner 320GLSF-12 "Free-Jet" Ultra Low NOx Burner 128GLSF-9 "Free-Jet" Ultra Low NOx Burner 1GLSF-12 Combustion Test 3 Simulated Fuels, 8 points each per API 535 1GLSF-9 Combustion Test 3 Simulated Fuels, 8 points each per API 535 LOTExport Crating 1CFD Modeling by REI Normal Cracking Operation + Decoke Operation See CFD Datasheets 1CFD Modeling by REI Normal Cracking Operation + Decoke Operation See CFD Datasheets	Shanghai Supezet Engineering Technology Co., Ltd.	Zhejiang Shaoxing Sanjin Petrochemical Co. Ltd. / Shaoxing Polypropylene / Shaoxing		China
38320	2019	Process Burners	Process Burner	5 GLSF-17 Free Jet Ultra Low NOx Burner 5 Export Crating LOT 10% PMI of fuel wetted parts	XRG Technologies	VPR Energy BV / Rotterdam Terminal / Rotterdam		Netherlands
38294	2019	Process Burners	Process Burner	1 GLSF-6 Free Jet Gas Burner	Scelerin Heaters LLC	DCP Midstream / Okarche Gas Plant / Okarche	OK	United States
38281	2019	Process Burners	Process Burner	1 GLSF-12 Free Jet Gas Burner 1 Domestic Crating	Scelerin Heaters LLC	DCP Midstream / Okarche Gas Plant / Okarche	OK	United States
38165	2019	Process Burners	Process Burner	4 GLSF-12 FreeJet Next Generation Ultra Low NOx Burner 4 Optional Upgrade to SM-1S-HEI Pilots 4 Optional Unispark Ignition system for SM Pilots 1 Optional Engineering Services for controls narrative 4 Zeeco ZPF-120 Flame Scanner 1 Lot Overland freight to US Methanol Plant	US Methanol LLC	Liberty One Methanol, LLC / Methanol Plant / Institute	WV	United States
37977	2019	Retrofit	Process Burner	(4) GLSF-15 Free-Jet Gas Burner Assembly (4) Adapter Plate for GLSF-15 Free-Jet Burner	Sinclair Wyoming Refinery Company	Sinclair Oil Corporation / Sinclair Wyoming Refining Company / Sinclair	WY	United States
37760	2018	Process Burners	Process Burner	1 GLSF-18 Free Jet Ultra Low NOx Burner 1 Domestic Packing	Tulsa Heaters Midstream LLC	Williams Olefins, LLC / Williams Olefins, LLC / Carville	LA	United States
37666	2018	Process Burners	Process Burner	1 GLSF-14 Free Jet Ultra Low NOx Burner 1 Domestic Packing	Tulsa Heaters, Inc.	Targa Resources, Inc. / Galena Park Terminal / Galena Park	TX	United States
37367	2018	Process Burners	Process Burner	1 GLSF-7 Free Jet Ultra Low NOx Burner 1 Fuel Skid 1 BMS 1 Domestic packing	Thermal Engineering International (TEI)	Ascend Performance Materials Operations, LLC / Pensacola Plant / Gonzalez	FL	United States
37180	2018	Process Burners	Process Burner	1 GLSF Free Jet Round Flame Burner Kit 2 GLSF Free Jet Combustion Test 3 HEI 4 CFD Simulation	China HuanQiu Contracting & Engineering Corp. (HQC)	PetroChina Company Ltd. / Dushanzi Refinery / Karamay		China
37160	2018	Process Burners	Process Burner	8 GLSF-15 Free-Jet Ultra Low NOx Burner H-001 8 Export Crating 8 GLSF-15 Free-Jet Ultra Low NOx Burner H-002 8 Export Crating	Chiyoda Corp.	Cosmo Oil Company Ltd. / Sakai Refinery / Sakai		Japan
37027	2018	Process Burners	Process Burner	2 GLSF-15 Free Jet Ultra Low NOx Burner 2 Palletizing for domestic shipment	Scelerin Heaters LLC	Scelerin Heaters		United States
37007	2018	Process Burners	Process Burner	1 GLSF-8 Free Jet Gas Burner 1 Domestic Packing	Scelerin	Sherwood Midstream LLC / Exterran Corp.		United States
36371	2018	Process Burners	Process Burner	1 GLSF-15 Free Jet Gas Burner 1 Expedited Drawings	Scelerin	Sunoco / Orbit		United States
36117	2018	Process Burners	Process Burner	1 GLSF-13 Free Jet Ultra Low NOx Burner 1 Palletizing for Domestic Shipment	Tulsa Heaters Midstream	Exterran		United States
35989	2018	Process Burners	Process Burner	128 GLSF-6 Free Jet Flat Flame Burner 64 Export Crating 1 385 Ignition Cable & 2560m detection cable 128 Flame Relays	Wood PLC	Esso Nederland BV / Rotterdam Refinery / Rotterdam		Netherlands
35963	2018	Process Burners	Process Burner	2 GLSF-13 Free Jet Ultra Low NOx Burner 2 Palletizing for domestic Shipment	Tulsa Heaters Midstream	Exterran		United States
35812	2018	Process Burners	Process Burner	1 GLSF-20 Free Jet Gas Burner	Hydro-Chem / Linde	Hansol Chemical		Korea
35774	2018	Process Burners	Process Burner	1 GLSF-16 Free Jet Burner Assembly 1 Domestic Shipping Prep H-701 1 GLSF-19 Free Jet Burner Assembly 1 Domestic shipping Prep H-768 1 GLSF_15 Free Jet Burner Assembly 1 Domestic Shipping Prep H-771	Tulsa Heaters Midstream	SEEPCO		Nigeria

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35751	2018	Process Burners	Process Burner	56 GLSF-6 Free-Jet Burner 56 GLSF-6 Free-Jet Burner 112 Extended Damper Handle (1850mm grade) 112 Bilingual Nameplates, Burners & Enclosures 1 GLSF Burner Combustion Test 112 Fireye 85UVF-1CEX Flame Scanner 24 Local Panel for Pilot Ignition/Detection 2 Portable Battery Operated Torch 16 Local Panel for Flame Scanners LOT Tile Mortar (if necessary) 2 Burner Mounting Template LOT Burner Mounting Gasket LOT Tile Supports, Gaskets, Nuts, & Bolts LOT Spare Parts for Commissioning & Start-Up LOT Spare Parts for 4 Years Operation 112 Export Crating 6 Shipping FOB Port of Export LOT Technical Passports & Translation 112 ADDER for 200mm Extended Damper Box	Lummus Technology Heat Transfer	LUKOIL OAO / Perm Refinery / Perm		Russia
35637	2018	Process Burners	Process Burner	2 GLSF-15 Free-Jet Burner Assembly 2 Palletizing for Domestic Shipment	Tulsa Heaters Midstream	XTO Energy, Inc. / Cordona Lake Gas Plant / Crane	TX	United States
35301	2018	Process Burners	Process Burner	1 GLSF-13 "Free-Jet" Ultra Low NOx Burner 1 Palletizing for Domestic Shipment	Tulsa Heaters Midstream	Exterran		United States
35061	2018	Process Burners	Process Burner	2 GLSF-15 Free-Jet Ultra Low NOx Burner 2 Domestic Packing 2 Zeeco ProFlame ZPF-120 UV Scanner	Greyrock Services, LLC			United States
34692	2018	Process Burners	Process Burner	8 GLSF-11 Free Jet DT Burners for B-3901 8 GLSF-11 Free Jet DT Burners for B-3902 6 GLSF-11 Free Jet DT Burners for B-3903 4 GLSF-11 Free Jet DT Burners for B-3904 1 GLSF-11 Free Jet Combustion Test for B-3901 1 CFD Modeling - Radiant Section - Three Cases	Tulsa Heaters Inc	LyondellBasell North America, Inc. / Bayport Propylene Glycol Plant / Pasadena	TX	United States
34534	2018	Process Burners	Process Burner	1 GLSF-19 Free Jet Burner Assembly D3-H-768 1 Domestic Shipping Prep 1 GLSF-7 Free Jet Burner Assembly 1 Domestic Free Jet Burner Assembly D2-H-775 1 Domestic Shipping Prep	Tulsa Heaters Midstream LLC	MarkWest Energy Partners, LP / Sherwood Processing Facility / West Union	WV	United States
34263	2018	Process Burners	Process Burner	1 GLSF-13 Free Jet Ultra Low NOx Burner 1 Palletizing for domestic shipment	Tulsa Heaters Midstream LLC	Exterran		United States
33795	2018	Process Burners	Process Burner	8 GLSF-14 Free Jet Burner w/ JM-1S-EF Pilot 8 Export crating	Sinopec Engineering, Incorporated (SEI)	PetroChina Company Ltd. / Sichuan Petrochemical Complex / Chengdu City		China
33633	2017	Process Burners	Process Burner	1 GLSF-13 Free Jet Ultra Low NOx Burner 1 GLSF-13 Free Jet Ultra Low NOx Burner	Tulsa Heaters Midstream			United States
33442	2017	Process Burners	Process Burner	6 GLSF-14 Free Jet Burner Assembly H-4701 6 Burner Damper Actuator Assembly 1 Witnessed combustion test 6 domestic packaging 6 Adder 1 Engineering and drafting for GLSF-14 Free Jet	OPF Optimized Process Furnaces	Delek US Holdings, Inc. / Krotz Springs Refinery & Terminal / Krotz Springs	LA	United States
33054	2017	Process Burners	Process Burner	72 GLSF-4 Free Jet Flat Flame Burner 1 Packaging per Burner 1 Comb. Test (10 pts) 1 CFD 1/4 Furnace (1 Run) for existing burners 1 CFD 1/4 Furnace (1 Run) for new burners 72 Strainers , Wye Type, one per Burners 4 Jackshaft with actuator to control	Jacobs Engineering, Inc	Chevron Corporation / El Segundo Refinery / El Segundo	CA	United States
32942	2017	Process Burners	Process Burner	1 GLSF-10 Free Jet Ultra Low Now Burner 1 Palletizing for domestic shipmen	Tulsa Heaters Midstream	MarkWest Energy Partners, LP / Sherwood Processing Facility / West Union	WV	United States
32773	2017	Process Burners	Process Burner	4 GLSF-13 Free Jet Ultra Low NOx Burner 4 Palletizing for Domestic Shipment	Tulsa Heaters Midstream			United States
32416	2017	Process Burners	Process Burner	1 GLSF-7 Free Jet Ultra Low NOx Burner 1 Domestic Shipping Prep	Tulsa Heaters Midstream	Puget Sound Energy / Tacoma LNG Facility / Tacoma	WA	United States
32319	2017	Process Burners	Process Burner	1 GLSF-8 Free Jet Burner Assembly H-2775 1 Domestic Shipping Prep 1 GLSF-10 Free Jet Burner Assembly H-10711 1 Domestic Shipping Prep 1 GLSF-19 Continuous Ring Free Jet Burner H-2768	Tulsa Heaters Midstream LLC	MarkWest Energy Partners, LP / Sherwood Processing Facility / West Union	WV	United States
32235	2017	Process Burners	Process Burner	1 GLSF-18 Free Jet Burner Assembly H-1768 1 Domestic Shipping Prep	Scelerin Heaters	MarkWest Energy Partners, LP / Bluestone Gas Plant / Evans City	PA	United States
32234	2017	Process Burners	Process Burner	1 GLSF-18 Free Jet Burner Assembly H-1767 1 domestic shipping prep	Scelerin Heaters LLC	MarkWest Energy Partners, LP / Bluestone Gas Plant / Evans City	PA	United States
32228	2017	Process Burners	Process Burner	75 GLSF-8 Free-Jet Downfired 100% Burner 30 GLSF-7 Free-Jet Downfired 78% Burner 1 Lot Commissioning Spares 1 Capital Spares 2 Hand Held Ignitors 1 Lot gas connection nuts, bolts, gaskets 1 Lot gaskets and bolts to fix burner to furn	Air Liquide Global	Yuhuang Chemical, Inc. / Yuhuang Chemical, Inc. / St. James	LA	United States
32181	2017	Process Burners	Process Burner	1 GLSF-10 Free Jet Burner Assembly H-1769 1 Domestic Shipping Prep 1 GLSF-10 Free Jet Burner Assembly H-1769 1 Domestic Shipping Prep 1 GLSF-8 Free Jet Burner Assembly H-1775 1 Domestic Shipping Prep	Tulsa Heaters Midstream, LLC	MarkWest Energy Partners, LP / Harmon Creek Plant / Washington County	PA	United States

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31978	2017	Retrofit	Process Burner	12 GLSF-17 Free Jet Ultra Low NOx Burner Kits 110-F-101 20 GLSF-12 Free Jet Ultra Low NOX Burner kits 110-F-102 LOT Export Crating 1 GLSF-17 Combustion Test 1 GLSF-12 Combustion Test 1 CFD Modeling 2 HEI Portable Igniter	PetroChina Sichuan Petrochemical	PetroChina Company Ltd. / Sichuan Petrochemical Complex / Chengdu City		China
31885	2017	Process Burners	Process Burner	1 GLSF-15 Free Jet Burner assembly 1 Domestic Shipping Prep	OPF Optimized Process Furnaces	Boardwalk Louisiana Midstream, LLC / Moss Lake Fractionation Plant / Lake Charles	LA	United States
31866	2017	Process Burners	Process Burner	16 GLSF-12 Free Jet Flat Flame Burner Kit F-103 48 RWSF-4 Radiant Wall Burner Kit 16 JM-1S Pilot Kit 16 Export Crating GLSF-12 Kits 48 Export Crating RWSF-4 Kits 16 Export Crating JM-1S Kits 1 Single RWSF-4 Combustion Test 1 Single GLSF-6 Combustion Test 1 Two GLSF-12, six RWSF-4 Combustion Test 1 CFD Modeling	Datek	PetroChina Company Ltd. / Dushanzi Refinery / Karamay		China
31616	2017	Process Burners	Process Burner	2 GLSF-10 Free Jet Burner Assembly 2 Domestic Shipping Prep	Tulsa Heaters Midstream			Mexico
31491	2017	Process Burners	Process Burner	4 GLSF-13 Free Jet Ultra Low NOx Burner 1 GLSF-15 Free Jet Ultra Low NOx Burner 5 Palletizing for domestic shipment	Tulsa Heaters Midstream			United States
31335	2017	Process Burners	Process Burner	1 GLSF-17 Free Jet Burner Assembly 1 Domestic Shipping Prep	Tulsa Heaters Midstream	Sendero Midstream Partners, LP / Carlsbad Gas Plant / Carlsbad	NM	United States
31193	2017	Process Burners	Process Burner	2 GLSF-16 FJ Burner 2 Actuators for air control of GLSF Burners 6 Honeywell Flame Scanner Assemblies 2 3" diameter x 3ft long flex hose for main gas 2 1" diameter x 3ft long flex hose for pilot gas 2 Adapter plate assembly 2 ignition/detection panel 2 upgrade to SM-1S-HEI-F Pilot 1 Palletization for domestic shipment 1 FCA Jobsite Shipment (Donaldsonville, LA)	CF Industries	CF Industries Holdings, Inc. / Donaldsonville Nitrogen Complex / Donaldsonville	LA	United States
31134	2017	Process Burners	Process Burner	3 GLSF-13 Free Jet Ultra Low NOx Burner 3 Palletizing for Domestic Shipment	Tulsa Heater's Midstream	Woodford Express, LLC / Grady Cryogenic Gas Plant / Lindsay	OK	United States
31133	2017	Process Burners	Process Burner	1 GLSF-18 Free Jet Burner Assembly 1 Domestic Shipping Prep	Tulsa Heaters Midstream	Woodford Express, LLC / Grady Cryogenic Gas Plant / Lindsay	OK	United States
31055	2017	Process Burners	Process Burner	1 GLSF-8 Free Jet Ultra Low NOx Burner 1 Shipping Prep	Scelerin Heaters LLC	Exterran Energy Solutions L.P.		United States
31004	2017	Process Burners	Process Burner	10 GLSF-15 Free Jet Burner Assembly 10 Shipping Prep for domestic shipment	Tulsa Heaters, Inc.	Occidental Permian Ltd. - OPL / Denver Unit CO2 Recovery Plant / Denver City	TX	United States
30827	2017	Process Burners	Process Burner	1 GLSF-13 Free Jet Ultra Low NOx Burner 1 Palletizing for Domestic Shipment	Tulsa Heaters Midstream	Woodford Express, LLC / Grady Cryogenic Gas Plant / Lindsay	OK	United States
30517	2016	Process Burners	Process Burner	8 GLSF-12 Round Flame Free Jet Burner 8 HEI Ignition / Detection Enclosure 8 Export Crating	Delta Engineering sp. z o.o	PKN Orlen SA / Plock Refinery / Plock		Poland
30453	2016	Process Burners	Process Burner	1 GLSF-7 Free Jet Ultra Low NOx burner 1 Palletizing for domestic shipment	Tulsa Heaters Midstream	MarkWest Energy Partners, LP / Sherwood Processing Facility / West Union	WV	United States
30312	2016	Process Burners	Process Burner	1 GLSF-14 Free Jet Ultra Low NOx Burner 1 304 SS Flex Hose Pilot Connection Ex Works - Point of Fabrication	G.C. Broach Company	TopSail Energy		United States
30149	2016	Retrofit	Process Burner	(4) RB-743 GLSF-12 Round Flame "Free Jet" Gas Burner Assembly	Lauren Engineers & Constructors, Inc	Marathon Petroleum Corporation / St. Paul Park Refinery / Saint Paul Park	MN	United States
29994	2016	Process Burners	Process Burner	2 GLSF-15 Free Jet Ultra Low NOx Burner 3 GLSF-20 DT Free Jet Ultra Low NOx Burner	BSS (Beijing) Environmental Equipment Co., Ltd.			China
29834	2016	Process Burners	Process Burner	26 GLSF Free Jet Burners 90 RWSF Wall Burners	ENI SpA	Versalis SpA / Priolo Plant / Priolo		Italy
29811	2016	Process Burners	Process Burner	6 GLSF-13 Free jet Ultra Low NOx Burner 1 CFD Modeling , Base Case Only 1 Combustion Test Performance Test Option 2	OPF Optimized Process Furnaces	Monroe Energy, LLC / Trainer Refinery / Trainer	PA	United States
29804	2016	Process Burners	Process Burner	4 GLSF-14 "Free-Jet" Ultra Low NOx Burner 4 Domestic Shipping Prep LOT PMI of fuel wetted stainless steel components	Tulsa Heaters Inc	Sinclair Oil Corporation / Sinclair Wyoming Refining Company / Sinclair	WY	United States
29791	2016	Process Burners	Process Burner	48 GLSF-15 Free Jet Round Flame Burner Kit (46 Gas Tips) 1 GLSF-15 Free Jet Combustion Test 1 Freight GLSF-15 Kits CIF China 1 Startup supervision from headquarters, 1 week 16 GLSF-15 Free Jet Round Flame Burner Kit (46 Gas Tips) 48 RWSF-4 Radiant Wall Burner Kit	Datek / PetroChina DuShanZi	PetroChina Company Ltd. / Dushanzi Refinery / Karamay		China
29719	2016	Process Burners	Process Burner	1 GLSF-10 Free Jet Ultra Low NOx Burner 1 GLSF-11 Free Jet Ultra Low NOx Burner 2 Palletizing for Domestic Shipment	Tulsa Heaters Midstream LLC	Exterran / Oman Office		Oman
29669	2016	Process Burners	Process Burner	1 GLSF-21 Free Jet GR-DT Special 1 BMS 1 Damper Actuator 1 Burner Shipping Prep 1 Skid Shipping Prep LOT start Up Assistance Ex Works	Interstate Treating	Energy Transfer Midland		United States
29650	2016	Process Burners	Process Burner	3 GLSF-13 Free Jet Burner Assembly 3 Palletizing & Shrinkwrap for burners 3 crating for burner tiles	THI - Tulsa Heaters			United States
29314	2016	Process Burners	Process Burner	10 GLSF-14 Free Jet Ultra Low NOx Burner (F-4246) 1 Combustion Testing - 2 Fuels w/CO Probing (F-4246)	BOUSTEAD INTERNATIONAL HEATERS LTD	Shell Oil Products US / Norco Refinery & Chemical Plant / Norco	LA	United States

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29114	2016	Process Burners	Process Burner	F2151 6 GB-15 Single Jet Ultra Low Emissions Burners 6 Heater Adapter Plates 6 Adder for insulation retention 2 Natural Draft Plenum for 3 Burners w/actuator 6 ICEL J250E Torch and Control Unit 1 CFD Model of Common Air Ducting 1 CFD Model of Firebox to simulate Combustion 1 GB-15 Combustion Test F2300 (New Burner) 8 GLSF-12 Free Jet Burner 4 GLSF-12 Free Jet Burner 2 GLSF-1 Free Jet Burner 14 3 C.S. Patches per Burner for Welding Support 14 Adder for Insulation Retention 1 CFD Model of Common Air Ducting 1 CFD Model of Firebox to simulate combustion 1 GLSF Free Jet Combustion test for F2301 14 combustion air expansion joint 14 Heater steel adaptor plate 14 ICEL J250E Torch and Control Unit LOT Delivery and Export Crating	ExxonMobile in France (Fos-Sur-Mer)	Esso SAF / Raffinerie de Fos-sur-Mer / Fos-sur-Mer		France
29012	2016	Process Burners	Process Burner	6 GLSF-12 Free Jet Next Generation Ultra Low 6 Export Crating 1 FOB - Port of Altamira	Atepisa	Compania Espanola de Petroleos SA - CEPSA / La Rabida Refinery / Huelva		Spain
28586	2016	Process Burners	Process Burner	1 GLSF-21 Free Jet GR- DT Special 1 Burner Management System 1 Damper Actuator LOT Start-Up Assistance	RAMA Interstate Treating Co	RAMA Interstate Treating Co		United States
28515	2016	Retrofit	Process Burner	5 GLSF-15 Free Jet Ultra Low NOx Burner w/ JM-1s-EF Manual Pilot Assembly 1 CFD analysis base case 2 CFD additional case 2 CFD additional case 1 GLSF-15 Free Jet Burner combustion test 345 PMI 100% Bulk Material Alloy & Welds 1 LOT Spare Parts Start-up & Commissioning 5 T-Connection 5 NDE - 5% Radiography of Welds	Jacobs	Philadelphia Energy Solutions - PES / Philadelphia Refining Complex / Philadelphia	PA	United States
28458	2016	Process Burners	Process Burner	1 GLSF-19 Continuous Ring "Free-Jet" Burner 1 Palletizing for Domestic Shipment	Tulsa Heaters Midstream LLC	MarkWest		United States
28439	2016	Process Burners	Process Burner	1 GLSF-7 Free Jet Ultra Low NOx Burner 1 Palletizing for Domestic Shipment	Tulsa Heaters Midstream	MarkWest Energy Partners, LP / Cibus Ranch Compressor Station / Washington	PA	United States

UMICORE REFERENCE LIST– SCR SYSTEM PERFORMANCE DATA (CONVERSION >98% DENOX)

End user data		Plant data	SCR Data	Performance Data		
		Confidential				
End user	Country	Plant type	SCR s/u year	DeNOx %	NH_3 slip	NH_3 unit
CIMO, Industrial Company Monthey S.A.	Switzerland			98	10	mg/Nm3 d,ref
Marathon Petroleum Corp.	USA	Refinery heater	2005	98.7	10	ppmd, ref
Unknown	Germany	Engine, station.	2012	98.3	2	ppmd, ref
CF Industries	USA	Other	2013	98	10	ppmd, ref
Wärtsila Iberica	Spain	Engine, station.	2013	98	5	ppmd, ref
Dyno Nobel	USA	Other	2015	98.46	10	ppmd, ref
Shandong Yuhuang Shengsi	China	Other	2016	99.15	10	ppmw
Shandong Qirun Petrochemical Co.	China	Petrochemical	2017	98	10	ppmw
Undisclosed	USA	Engine, marine	2017	99	5	ppmd, ref
Panjin Haoye Chemical Co.	China	Other	2017	99.82	10	ppmw
Shandong Super Energy Industrial	China	Other	2017	99.27	10	ppmw
Denton Municipal Electric	USA	Engine, station.	2018	98.18	5	ppmd, ref
LLC CNT Real Invest	Russia	Engine, station.	2014	98.6	9	ppm
Liberty Packing Co	USA	Boiler	2018	98.33	10	ppmd, ref
CNT Real Invest - lacks signing of contract	Russia	Engine, station.	2019	98.6	9	ppmw
Expected - Jingbo Zhongcheng	China	Other	2019	98.72	10	ppmw
Indian Oil	India	Other	2019	98.3	10	ppmw
Wanhua Chemical	China	Waste incin.	2019	98.59	3	ppmd
Shandong Jinmei Mingshengda Chemical	China	Other	2019	99.58	10	ppmw
Sentinel Peak Resources	USA	Gas turbine		98.11	10	ppmd, ref
Undisclosed	USA	Other	2020	98.16	10	ppmw

Note 1. Performance data referred to EOR operation.

Design oxidation catalyst

Type of catalyst	EnviCat®2520 CERAMIC		
Substrate	Cordierit/Cordierite Monolith		
Active components	Platin/Platinum		
Cell density			
Matrix LxWxH			
Catalyst temperatures			
Inlet	333	°C	SOR
	333	°C	EOR
Exothermic app.	0,03	°C	
Outlet min	334	°C	
Max Kat Temp / Max catalyst temperature	650	°C	
Pressure	1	bara	
Catalyst dimensions			
Space velocity			
Linear velocity			
Leading area			
Number of monoliths			
Layers	2		
modules (monoliths) per layer			
catalyst volume			
Pressure drop	6,20	mbar	
Customer input			
Exhaust gas mass flow	6560	kg/h	
Exhaust gas flow	5241	Nm^3/h	
Operating pressure	1,0	bar (abs)	
Pollutants raw gas			
NH3 at inlet	3	ppm v	

Expected Emission limit at outlet				
	NH3	≤ 0,03	ppmv	
Conversion rate		≥ 99	%	
Remark:	N_2O formation	ca. 1,2	ppmv	3% O_2
	NOx formation	ca. 0.3	ppmv	3% O_2
Expected life time		4	Years	
Guaranteed Emission limit at outlet				
	NH3	≤ 0,1	ppm	
Conversion rate		≥ 97	%	
Guaranteed life time		3	Years	

The catalyst offered by this quotation contains proprietary precious metals. The standard catalyst sales price stated in this quotation is based on the precious metals' prices applied at the London Metals Exchange at the date of this quotation. If the precious metals' prices at the date of a binding and final supply agreement related to this quotation deviates by +/-5% or more from the precious metals' prices applied at the date of this quotation, the standard price stated in this quotation shall no longer apply, and an appropriate price adjustment may be instituted.

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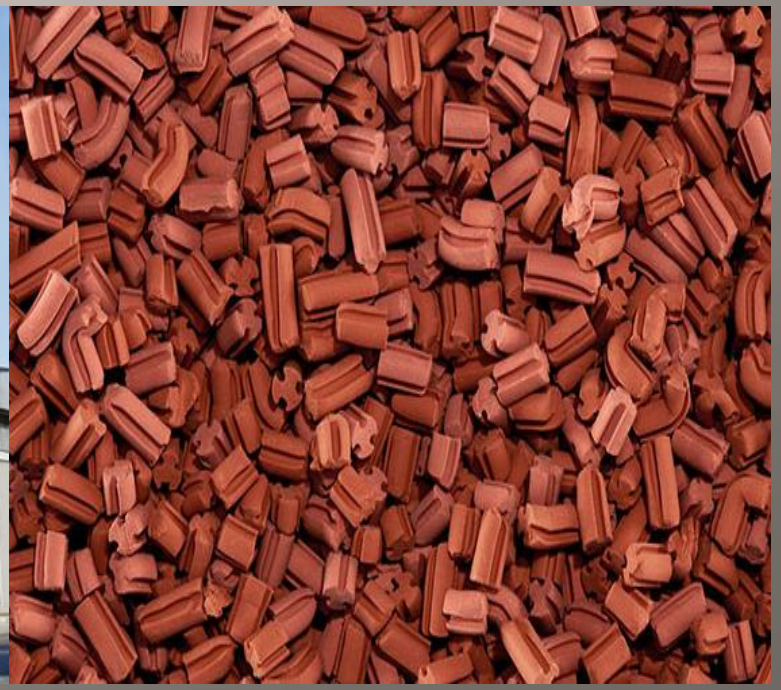
NH3 Oxidation Catalyst
Design Proposa for Casale



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Jovica Zorjanovic
Catalysts

05.03.2021

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Lab Scale Data

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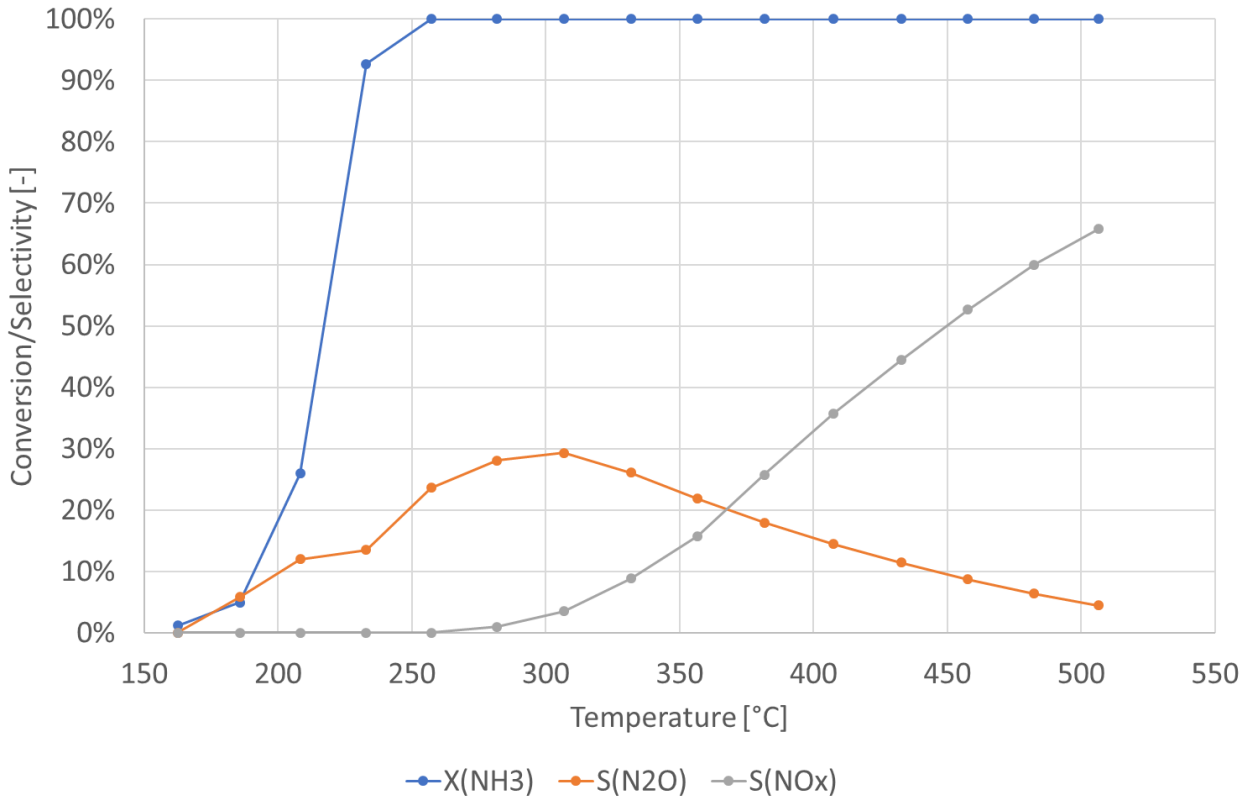
NH_3 oxidation on EnviCat 2520 as “police” catalyst to avoid NH_3 slip

- - High oxidation activity for NH_3, N_2O, N_2 and NO_x are the products
- - Prevents NH_3 slip, but small decrease of NO_x reduction efficiency of the entire system
- - The catalyst converts also CO into CO_2 at a similar temperature range (< 250 °C).



Test conditions:

930 ppmv NH_3, 1800 ppmv H_2O, in air

GHSV = 10000 h^{-1}

200 cpsi honeycomb

Design Proposal

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Catalysts Design

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As per attached file

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Jovica Zorjanovic
BU Catalyst

05.03.2021

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Disclaimer

This presentation contains certain statements that are neither reported financial results nor other historical information.

This presentation also includes forward-looking statements. Because these forward-looking statements are subject to risks and uncertainties, actual future results may differ materially from those expressed in or implied by the statements.

Many of these risks and uncertainties relate to factors that are beyond Clariant's ability to control or estimate precisely, such as future market conditions, currency fluctuations, the behavior of other market participants, the actions of governmental regulators and other risk factors such as: the timing and strength of new product offerings; pricing strategies of competitors; the Company's ability to continue to receive adequate products from its vendors on acceptable terms, or at all, and to continue to obtain sufficient financing to meet its liquidity needs; and changes in the political, social and regulatory framework in which the Company operates or in economic or technological trends or conditions, including currency fluctuations, inflation and consumer confidence, on a global, regional or national basis.

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BASF
The Chemical Company

NOxCat™ AD

Ammonia Destruction Catalysts

NOxCat™ AD Series 300 NH_3 Catalyst

For natural gas turbines and stationary engines

BASF's innovative family of ammonia destruction catalysts includes a new, patented catalyst for ammonia, NO_x and CO emissions.

NOxCAT AD Series 300 Ammonia Destruction Catalyst consistently achieves high levels of ammonia conversion. These catalysts have the potential to reduce ammonia and NOx, and also control CO emissions.

Extend SCR Catalyst Life

NOxCAT AD Series 300 Ammonia Destruction Catalyst, installed at the exit of the SCR catalyst bed, may extend the SCR catalyst working life by curbing the peak ammonia slip emissions that dictate the practical lifespan of an SCR catalyst bed.

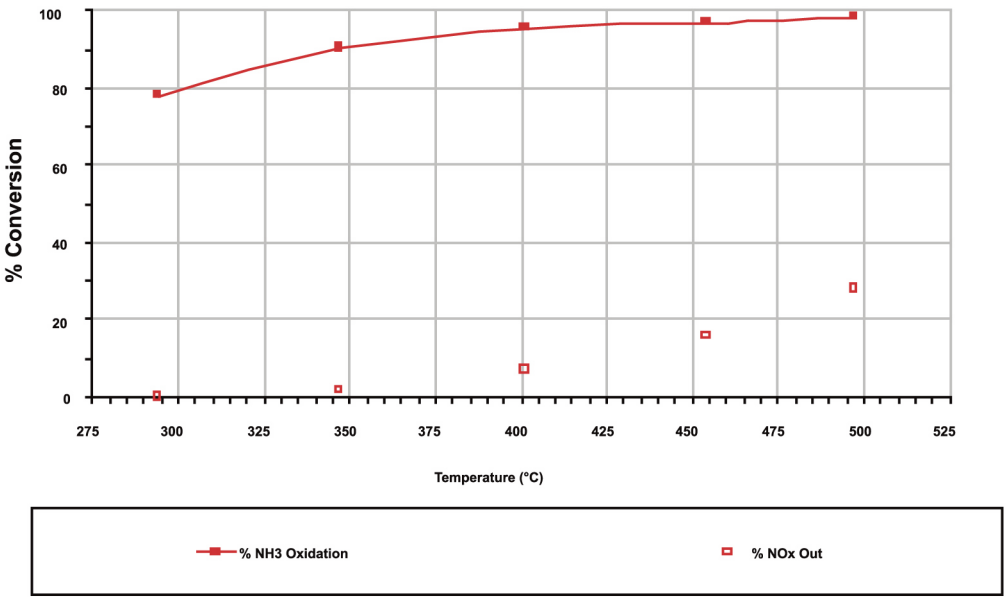
Improve Power Plant Reliability

NOxCAT Series 300 Ammonia Destruction Catalyst lowers the ammonia slip reaching the air preheater, thus reducing the potential for fouling from bisulfate deposits and resulting in improved plant reliability.

Enhance Control over SCR System

Series 300 Ammonia Destruction Catalyst may curb peak ammonia slip emissions associated with reductant overdosing due to sudden and unexpected load changes.

Conversion vs. Temperature



About BASF

BASF Catalysts, the **Global Leader in Catalysis**, is a division of BASF - The Chemical Company. We offer exceptional expertise in the development of technologies that protect the air we breathe, produce the fuels that power our world and ensure the efficient production of a wide variety of chemicals, plastics, adsorbents and other products. By leveraging our industry-leading R&D platforms, passion for innovation and deep knowledge of precious and base metals, BASF Catalysts develop unique, proprietary catalyst solutions that drive customer success.

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BF-9441 Rev. 09/09