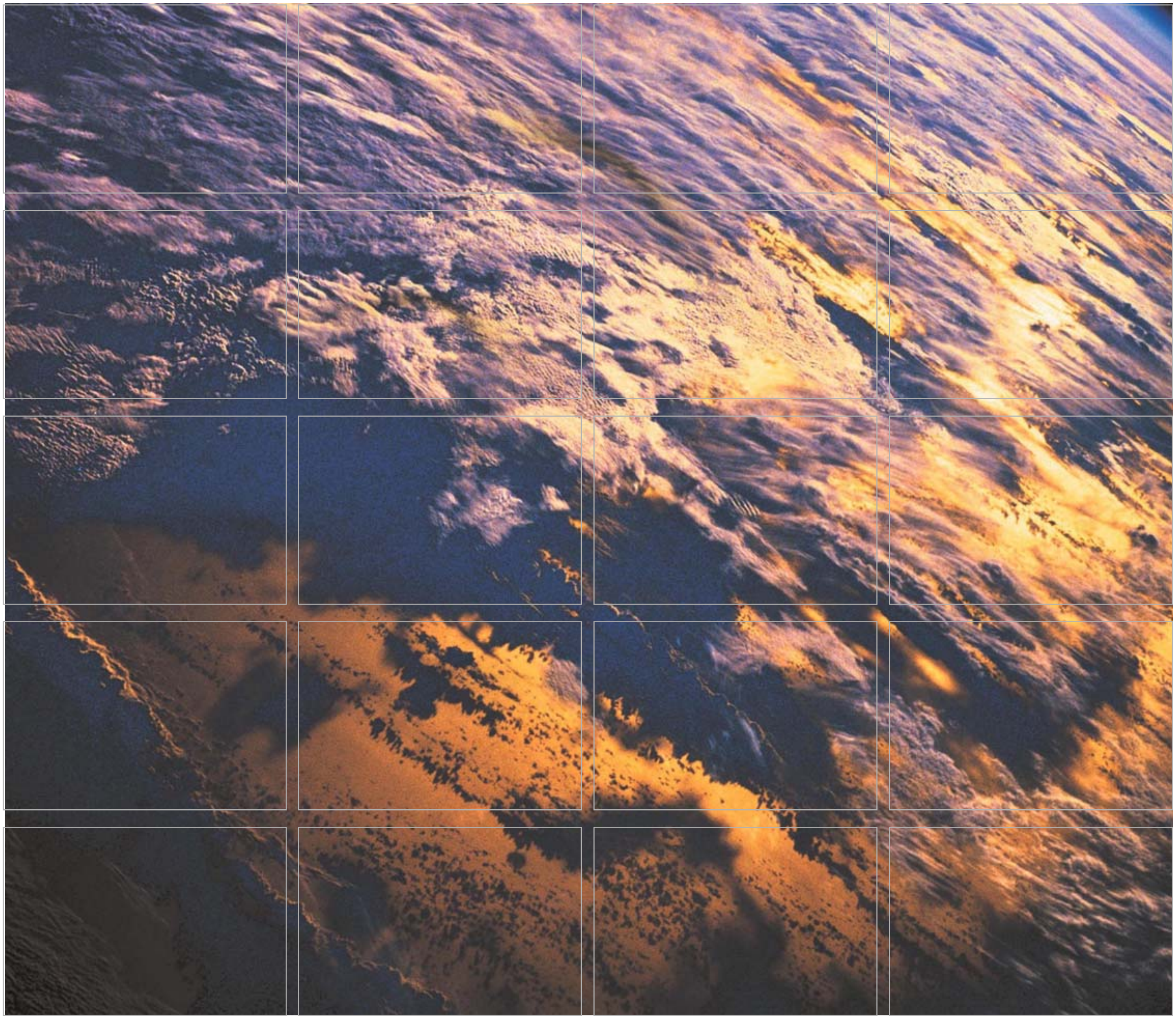

Philadelphia Energy Solutions Refining and Marketing LLC

RACT Update

Philadelphia, Pennsylvania

April 2014 – Original
June 2014 – Revision A
September 2014 – Revision B
June 2015 – Revision C
July 2015 – Revision D
July 2015 – Revision E

Environmental Resources Management
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1.0 INTRODUCTION

Philadelphia Energy Solutions Refining and Marketing, LLC (PES) owns and operates the Philadelphia Refining Complex (Complex) – including the Point Breeze Refinery, Girard Point Refinery, and the Schuylkill River Tank Farm. The Complex is located within the five-county Pennsylvania portion of the Philadelphia consolidated metropolitan statistical area (CMSA) classified as an ozone nonattainment area and emits greater than 25 tons per year (TPY) of volatile organic compounds (VOC) and oxides of nitrogen (NO_x). The Complex is subject to reasonably available control technology (RACT) requirements as promulgated in Pennsylvania Code, Title 25, Chapters 121 and 129. In accordance with the guidance provided by the US Environmental Protection Agency (USEPA), the Pennsylvania Department of Environmental Protection (PADEP) must provide an updated analysis for all sources subject to the 8-hour ozone National Ambient Air Quality Standard (NAAQS) promulgated in 2008. In support of this effort, Philadelphia Air Management Services (AMS) has requested that PES submit an updated RACT analysis and compliance plan for all NO_x and VOC emission sources at the Complex. This RACT analysis and compliance plan complies with the specific requirements listed in 25 PA Code §129.91 through §129.94.

A RACT proposal was last updated in November 1999 when the Complex was owned by Sunoco, Inc. (R&M).

The current 1-hour and 8-hour Case-by-Case NO_x RACT requirements are provided in **Table 1-1** below.

Table 1-1 Approved 1-hour and Proposed 8-hour Case-by-Case NO_x RACT Requirements

Source	Permitted Capacity (MMBtu/ hr unless noted)	Approved 1-hour RACT		Proposed 8-hour RACT		8-hour RACT Approval
		RACT Control	NO_x Emission Limit	RACT Control	NO_x Emission Limit	
Unit 210C-Heater 13H1	235.4	Combustion tuning	0.104 lb/MMBTU for gas and 0.4 lb/MMBTU for oil	Combustion tuning	0.104 lb/MMBTU for gas	RACT Plan Approval
Reformer 860-Heater 2H2	69.8	Combustion Tuning	0.350 lb/MMBTU for gas and 0.4 lb/MMBTU for oil	Combustion Tuning	0.350 lb/MMBTU for gas	RACT Plan Approval
Reformer 860-Heater 2H3	174.7	Combustion Tuning	0.163 lb/MMBTU for gas and 0.4 lb/MMBTU for oil	Combustion Tuning	0.163 lb/MMBTU for gas	RACT Plan Approval
Reformer 860-Heater 2H4	99.4	Combustion Tuning	0.270 lb/MMBTU for gas and 0.4 lb/MMBTU for oil	Combustion Tuning	0.270 lb/MMBTU for gas	RACT Plan Approval

Source	Permitted Capacity (MMBtu/ hr unless noted)	Approved 1-hour RACT		Proposed 8-hour RACT		8-hour RACT Approval
		RACT Control	NO_x Emission Limit	RACT Control	NO_x Emission Limit	
Reformer 860-Heater 2H5	155	Combustion Tuning	0.163 lb/MMBTU for gas and 0.4 lb/MMBTU for oil	Combustion Tuning	0.163 lb/MMBTU for gas	RACT Plan Approval
Reformer 860-Heater 2H7	59	Combustion Tuning	0.157 lb/MMBTU for gas and 0.4 lb/MMBTU for oil	Combustion Tuning	0.157 lb/MMBTU for gas	RACT Plan Approval
Reformer 864-Heater PH1	80	Combustion Tuning	0.167 lb/MMBTU for gas and 0.4 lb/MMBTU for oil	Combustion Tuning	0.167 lb/MMBTU for gas	RACT Plan Approval
Reformer 864-Heater PH11	74	Combustion Tuning	0.145 lb/MMBTU for gas and 0.4 lb/MMBTU for oil	Combustion Tuning	0.145 lb/MMBTU for gas	RACT Plan Approval
Reformer 864-Heater PH12	85.1	Combustion Tuning	0.119 lb/MMBTU for gas and 0.4 lb/MMBTU for oil	Combustion Tuning	0.119 lb/MMBTU for gas	RACT Plan Approval
Unit 870-Heater H01	97	N/A	N/A	ULNB[1]	0.035 lb/MMBTU	AMS Plan Approval 02184
Unit 870-Heater H02	53	N/A	N/A	ULNB[1]	0.035 lb/MMBTU	AMS Plan Approval 02184
Unit 859-Heater 1H1	98	N/A	N/A	ULNB[1]	0.02 lb/MMBTU	AMS Plan Approval 06144
Unit 137 Heater F-1	415	Combustion Tuning	0.230 lb/MMBTU on a 30-day rolling average	Combustion Tuning	0.230 lb/MMBTU on a 30-day rolling average	RACT Plan Approval
Unit 137 Heater F-2	155	Combustion Tuning	0.257 lb/MMBTU for gas and 0.4 lb/MMBTU for oil	Combustion Tuning	0.257 lb/MMBTU for gas	RACT Plan Approval
Unit 137 Heater F-3	60	Combustion Tuning	0.4 lb/MMBTU for oil	ULNB[1]	0.060 lb/MMBTU for gas	AMS Plan Approval 07163
Unit 1332 Heater H-2	60	Combustion Tuning	0.300 lb/MMBTU for gas	ULNB[1]	0.040 lb/MMBTU	AMS Plan Approval 05124
Unit 1332 Heater H-400	186	Combustion Tuning	0.156 lb/MMBTU for gas	SCR[1]	0.06 lb/MMBTU on a rolling 365-day basis	AMS Plan Approval 09040
Unit 1332 Heater H-401	233	Combustion Tuning	0.156 lb/MMBTU for gas	SCR[1]	0.06 lb/MMBTU on a rolling 365-day basis	AMS Plan Approval 09040
Unit 433 - Heater H-1	260	ULNB and Combustion Tuning	0.060 lb/MMBTU for gas	ULNB and Combustion Tuning	0.035 lb/MMBTU for gas	AMS Plan Approval 06050
Unit 1232 FCCU	100,000 BPD feed rate	N/A	N/A	SCR	10 ppmvd on 365-day average (208.28 TPY)	AMS Plan Approval 11353

Source	Permitted Capacity (MMBtu/hr unless noted)	Approved 1-hour RACT		Proposed 8-hour RACT		8-hour RACT Approval
		RACT Control	NO_x Emission Limit	RACT Control	NO_x Emission Limit	
Unit 1232 - Heater B-104	70	ULNB and Combustion Tuning	0.177 lb/MMBTU for gas	ULNB and Combustion Tuning	0.177 lb/MMBTU for gas	RACT Plan Approval
#3 Boiler House Boiler #37	495	ULNB and Combustion Tuning	0.330 lb/MMBTU on a 30-day rolling average	ULNB + FGR[1]	0.040 lb/MMBTU on a rolling 365-day basis	AMS Plan Approval 08080
#3 Boiler House Boiler #39	495	ULNB and Combustion Tuning	0.330 lb/MMBTU on a 30-day rolling average	ULNB + FGR[1]	0.040 lb/MMBTU on a rolling 365-day basis	AMS Plan Approval 08080
#3 Boiler House Boiler #40	660	ULNB and Combustion Tuning	0.330 lb/MMBTU on a 30-day rolling average	ULNB + FGR[1]	0.040 lb/MMBTU on a rolling 365-day basis	AMS Plan Approval 08080
Unit 868 FCCU	50,000 BPD feed rate	Good combustion practices	569 TPY on a 365-day rolling average basis	Low NO_x CO Combustion Promoter	50 ppmvd on 365-day average (130.2 TPY)	Proposed limit based on Consent Decree Low NO_x CO Combustion Promoter Study

[1] Controls were installed after the 1-hour RACT determination, thus are not approved as RACT.

This submittal incorporates the following changes at the Complex since the 1999 RACT analysis:

- Cessation of oil firing at the Refineries;
- Updates to combustion source inventory including shutdowns and new sources as well as added controls;
- Revisions to refinery fuel gas emission rates based on facility air permitting actions; and
- Updates to pollution control costs using refinery project information.

This updated RACT analysis provides a list of each source subject to the RACT requirements, identifying information, the RACT category (exempt, presumptive, or case-by-case) for each source, estimates of actual and potential NO_x and VOC emissions, a RACT analysis and implementation schedule (where applicable), and testing, monitoring, recordkeeping and reporting procedures.

1.1 SITE DESCRIPTION

PES owns and operates a petroleum refining complex in Philadelphia, Pennsylvania. The Philadelphia Refining Complex (Complex) includes the Girard Point (GP) Refinery near the Platt Bridge, the Point Breeze (PB) Refinery located near the Passyunk Avenue Bridge, and the Schuylkill River Tank Farm (SRTF). Each Refinery is made up of a number of processing units that are employed in the overall process of converting crude petroleum and other hydrocarbon feed stocks into finished hydrocarbon products and petrochemicals. Products include gasoline, home heating oil, diesel fuel and others. Simplified process flow diagrams of the Refineries are shown in **Attachment A**.

The person responsible for daily operations is Nithia Thaver, Girard Point Vice President and General Manager, (215) 339-7414, and Mark Brandon, Point Breeze Vice President and General Manager, (215) 339-7414, both at 3144 Passyunk Avenue, Philadelphia, Pennsylvania 19145.

1.2 NO_X RACT ANALYSIS

The NO_x potential to emit and baseline emissions are based on historical fuel firing rates, USEPA AP-42 emission factors, current RACT emission rates, stack test results, or continuous emissions monitor (CEM) data. The potential to emit and baseline NO_x emissions reported herein were calculated using historical firing rates and emission factors (pounds of NO_x per million British Thermal Units [MMBtu] fuel input) in the following manner:

- For units with a rated heat input of greater than 250 MMBtu/hr, the emission factor is derived from CEM measurements;
- For units with a rated heat input of greater than 50 MMBtu/hr and less than 250 MMBtu/hr the emission factor is derived from source testing, if available, otherwise the emission factor is derived from AP-42 or the current RACT emission rate;
- For units with a rated heat input of less than 50 MMBtu/hr the emission factor is derived from AP-42.

The Pennsylvania RACT analysis process includes both presumptive and case-by-case RACT emission limitations. All affected NO_x sources at the Complex greater than 50 MMBtu/hr are subject to case-by-case RACT requirements, while NO_x sources equal to or greater than 20 MMBtu/hr and less than 50 MMBtu/hr are subject to presumptive RACT requirements. Section 3 provides a listing of each of the NO_x sources applicable to case-by-case or presumptive RACT requirements. The sources listed in the presumptive RACT source categories may comply with the presumptive RACT emission limitations of 25 PA Code §129.93 as an alternative to developing and implementing a RACT emission limitation on a case-by case basis. Each of the remaining sources is subject to a case-by-case RACT analysis that includes four basic steps:

- A ranking and identification of all available control options;
- An evaluation of the technical feasibility of each control option;
- A ranking of the technically feasible control options; and
- An evaluation of the cost effectiveness of each control option.

1.3 NO_X RACT ANALYSIS UPDATE SUMMARY

The case-by-case RACT analysis utilized USEPA's "Alternative Control Techniques (ACT) Document - NO_x Emissions from Process Heaters (Revised)" – EPA-453/R-93-034 and "ACT Document – NO_x Emissions from Utility Boilers" – EPA-453/R-94-023, to evaluate the cost effectiveness of all available control options. The technical feasibility of each control option was evaluated specifically for each affected source. Detailed costs estimates were then developed for the technically feasible control options based on input from operations personnel and information from previous engineering projects involving NO_x controls.

Table 1-2 presents a summary of the updates to the 1999 NO_x RACT analysis after this case-by-case RACT analysis for each source. The NO_x RACT analysis summary presents the case-by-case emission sources, the current NO_x RACT control, NO_x control technologies that are currently installed on each source, and the NO_x RACT control technology determined through this update.

Table 1-2 NO_x RACT Update Summary

Location	Source Name	Current NO_x RACT Control	Currently Installed NO_x Control[1]	NO_x RACT Control Update[2]
Point Breeze	Unit 210-13H1 Heater	CT	CT	CT
Point Breeze	Unit 860-2H2 Heater	CT	CT	CT
Point Breeze	Unit 860-2H3 Heater	CT	CT	CT
Point Breeze	Unit 860-2H4 Heater	CT	CT	CT
Point Breeze	Unit 860-2H5 Heater	CT	CT	CT
Point Breeze	Unit 860-2H7 Heater	CT	CT	CT
Point Breeze	Unit 864-PH1 Heater	CT	CT	CT
Point Breeze	Unit 864-PH11 Heater	CT	CT	CT
Point Breeze	Unit 864-PH12 Heater	CT	CT	CT
Point Breeze	Unit 868 FCCU	Good Combustion	Low NO_x CO Combustion Promoter	Low NO_x CO Combustion Promoter
Point Breeze	Unit 870-H01 Heater	N/A[3]	ULNB	ULNB
Point Breeze	Unit 870-H02 Heater	N/A[3]	ULNB	ULNB
Point Breeze	Unit 859-1H1 Heater	N/A[3]	ULNB	ULNB
Girard Point	Unit 137 F-1 Heater	CT	CT	CT
Girard Point	Unit 137 F-2 Heater	CT	CT	CT
Girard Point	Unit 137 F-3 Heater	CT	ULNB	ULNB
Girard Point	Unit 1332 H-2 Heater	CT	ULNB	ULNB
Girard Point	Unit 1332 H-400 Heater	CT	SCR	SCR
Girard Point	Unit 1332 H-401 Heater	CT	SCR	SCR
Girard Point	Unit 433 H-1 Heater	ULNB	ULNB	ULNB
Girard Point	Unit 1232 B-104 Heater	ULNB	ULNB	ULNB
Girard Point	Unit 1232 FCCU	N/A	SCR	SCR
Girard Point	#3 Boilerhouse Boiler #37	ULNB	ULNB & FGR	ULNB & FGR
Girard Point	#3 Boilerhouse Boiler #39	ULNB	ULNB & FGR	ULNB & FGR
Girard Point	#3 Boilerhouse Boiler #40	ULNB	ULNB & FGR	ULNB & FGR
Point Breeze/Girard Point	Diesel-Fired RICE IC-002	N/A	N/A	Good Combustion
Point Breeze/Girard Point	Diesel-Fired RICE IC-005	N/A	N/A	Good Combustion
Point Breeze/Girard Point	Diesel-Fired RICE IC-006	N/A	N/A	Good Combustion
Point Breeze/Girard Point	Diesel-Fired RICE IC-007	N/A	N/A	Good Combustion
Point Breeze/Girard Point	Diesel-Fired RICE IC-008	N/A	N/A	Good Combustion

1 CT = Combustion Tuning, ULNB = Ultra-low NO_x burners, SCR = Selective Catalytic Reduction, and FGR = Flue Gas Recirculation.

2 In conjunction with Plan Approval 12195 issued (February 19, 2014), the RACT cost effectiveness of NO_x controls for seven heaters was evaluated including Unit 231-B101, Unit 865-11H1, Unit 865-11H2, Unit 210-H101, Unit 210-H201A/B, Unit 866-12H1, and Unit 868-8H101. These sources are not re-evaluated in this RACT Update.

3 Note that new combustion sources installed after 1999 are now included in this RACT Update. These sources are the Unit 870-H01 Heater, Unit 870-H02 Heater, and Unit 859-1H1 Heater.

1.4 VOC RACT ANALYSIS UPDATE SUMMARY

The VOC emission sources at the Complex that are in compliance with the requirements of 25 PA Code §129.51 through §129.72, §129.81, or §129.82, were considered exempt from a VOC RACT analysis.

The following sources are not specifically exempted from a case-by-case VOC RACT determination:

- Combustion units;
- Cooling towers;
- Point Breeze and Girard Point marine loading operations;
- Diesel-fired reciprocating internal combustion engines (RICE); and
- Fluid Catalytic Cracking Units (FCCUs).

As part of the VOC RACT analysis process, these case-by-case emission sources were further evaluated to determine the appropriate control strategy to comply with VOC RACT requirements.

1.5 REPORT ORGANIZATION

The following sections provide a summary of the NO_x and VOC RACT analyses. Section 2 provides a physical description of each source subject to RACT as well as an estimate of potential and baseline emissions. The detailed RACT analysis for the Complex is contained in Section 3. Section 4 presents the implementation schedule and Section 5.0 contains the proposed testing, monitoring, recordkeeping and reporting procedures. Additional related information is provided in the attachments as follows:

- Process Flow Diagrams (Attachment A);
- Case-by-Case RACT Cost Effectiveness Analysis (Attachment B); and
- Vendor Quotations for ULNB Installations at Unit 137 and Unit 864 (Attachment C).

2.0 SOURCE IDENTIFICATION AND EMISSIONS INFORMATION

A listing and physical description of each affected NO_x and VOC source located at the Complex are provided in the sections below.

2.1 SHUTDOWN SOURCES

The following units were subject to case-by-case requirements under the 1-hour RACT determination, but have since been shut down:

- #3 Boiler House Boiler #38;
- 22 Boiler House Boiler #1;
- 22 Boiler House Boiler #2;
- 22 Boiler House Boiler #3;
- 859-1H1 Heater (76 MMBtu/hr) – Replaced in 2009 with the 98 MMBtu/hr 859-1H1 heater listed in **Table 2-1** below;
- 859-1H2 Heater;
- 859-1H3 Heater;
- 864-PH3 Heater;
- 864-PH4 Heater;
- 864-PH5 Heater;
- 861-3H1S Heater;
- 861-3H1N Heater;
- 860-2H9 Heater;

The following units were subject to presumptive RACT requirements under the 1-hour RACT determination, but have since been shut down:

- 860-2H1 Heater;

- 860-2H6 Heater;
- 864-PH2 Heater;
- 1332 H-600 Heater;
- Asphalt Heaters H1, H2, H3, and H5;
- Hydrocracker 859-1H4 Heater;
- Scot Heater Incinerator;
- 3 Yard Flares;
- 2 Emergency Turbines (50 MW each); and
- Girard Point Blowdown System.

2.2 *NO_X SOURCES*

This section provides a listing and physical description of each NO_x source and a baseline assessment of the combustion sources[1,2] at the Complex, which must be evaluated, for the potential to reduce NO_x emissions. This requirement has been established by the air quality regulations in Pennsylvania that requires the installation of RACT to reduce NO_x emissions from combustion sources. The following information relative to the combustion sources being evaluated in the RACT analysis is presented to meet this requirement.

Table 2-1 at the end of this section presents the sources, their maximum heat release, NO_x RACT category and field observations for each.

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[1] Note that new combustion sources installed after 1999 are now included in this RACT Update. These sources are the Unit 870-H01 Heater, Unit 870-H02 Heater, and Unit 859-1H1 Heater.

[2] In conjunction with Plan Approval 12195 issued (February 19, 2014), the RACT cost effectiveness of NO_x controls for seven heaters was evaluated including Unit 231-B101, Unit 865-11H1, Unit 865-11H2, Unit 210-H101, Unit 210-H201A/B, Unit 866-12H1, and Unit 868-8H101. These sources are not re-evaluated in this RACT Update.

2.3 VOC SOURCES

As discussed in Section 1.4, the following sources are not exempt from a case-by-case RACT determination: combustion units, cooling towers, marine loading operations, diesel-fired RICE, and the FCCUs. The combustion units and the FCCUs are described in **Table 2-1 below**. **Table 2-3** at the end of this section provides information on the capacity or throughput for each of the cooling towers as well as the Point Breeze and Girard Point marine loading operations.

2.4 ESTIMATE OF POTENTIAL AND ACTUAL EMISSIONS

As required by 25 PA Code §129.92(a)(4), **Tables 2-2** and **2-3** provide the estimated potential and actual NO_x and VOC emissions at both Refineries, respectively. The potential and baseline actual NO_x and VOC emission estimates are based on historical operating data, unit capacities, throughputs and emission factors derived from CEM data, source testing, and other accepted sources such as AP-42 emission factors.

2.4.1 NO_x Sources – Potential and Actual Emissions

The potential and baseline actual NO_x emissions from combustion sources such as industrial boilers and process heaters presented in **Table 2-2** are calculated by examining the fuel firing rates from 2010 through 2013. The baseline year has been established as the year in which the most refinery fuel gas firing occurred, resulting in the highest baseline emissions. The baseline year for the majority of combustion sources was 2013 with the exception of the Unit 1232 B-104 Heater, for which 2011 was used because this heater did not operate consistently in 2013. The baseline emissions (tons per year [TPY]) are established by multiplying the baseline firing rate and an emission factor derived from CEM data, source testing or AP-42 factors[3]. The baseline emissions are used in the case-by-case RACT analysis and for purposes of this submittal are defined as the actual emissions required to be reported under 25 PA Code §129.92(a)(4). The estimate of potential to emit NO_x emission rate (TPY) is based on each source's potential firing rate, the appropriate emission factors as described previously, and 8760 hours of operation per year. The potential firing rate is defined as the source's permitted firing rate.

[3] Following 25 PA Code §129.92(b)(4)(iii), the baseline emissions were calculated using an approved emission factor and historical operating data.

The NO_x baseline actual emissions from the FCCUs are as reported from the Unit 868 FCCU and Unit 1232 FCCU CEM data. The baseline NO_x emissions from the FCCUs are the permitted NO_x emission rates. Potential emissions from the Unit 868 FCCU were calculated by scaling the 2013 actual emissions and throughput to the permitted 365-day average throughput (47.5 thousand barrels per day [MBPD]) and adjusting for the flue gas concentration proposed[4] to comply with the Second Amendment to Civil Action No. 05-02866. See **Attachment B** for the calculation of potential emissions for the Unit 868 FCCU.

2.4.2 *VOC Sources – Potential and Actual Emissions*

The VOC potential and actual emissions from combustion sources such as industrial boilers and process heaters presented in **Table 2-3** are calculated by examining the fuel firing rates from 2010 through 2013. The baseline year has been established as the year in which the most refinery fuel gas firing occurred, resulting in the highest baseline emissions. The baseline year for the majority of combustion sources was 2013 with the exception of the Unit 1232 B-104 Heater, for which 2011 was used because this heater did not operate consistently in 2013. The baseline emissions (TPY) for combustion units are established by multiplying the baseline firing rate and an AP-42 emission factor. The estimate of potential to emit VOC emission rate (TPY) is based on each source's potential firing rate, the AP-42 emission factor, and 8760 hours of operation per year. The potential firing rate is defined as the source's permitted firing rate.

The VOC potential and baseline actual emissions from cooling towers presented in **Table 2-3** below are calculated using the cooling water throughput and an AP-42 emission factor.

The VOC potential and baseline actual emissions from the 1232 FCCU presented in **Table 2-3** below are calculated using the Unit 1232 carbon monoxide (CO) waste heat boiler fuel firing rates from 2013 and an AP-42 emission factor.

The VOC potential and baseline actual emissions from the 868 FCCU presented in **Table 2-3** below are calculated using the Unit 868 stack test results from 2013 and the allowable emission rate from the Title V Operating Permit V06-016, respectively.

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[4] A concentration of 50 parts per million by volume, dry at 0% oxygen was proposed by PES in the February 2013 "868 Low NO_x CO Combustion Promoter Study".

The baseline actual emissions from the Point Breeze and Girard Point marine loading operations are based on the 2013 actual material throughputs and material vapor pressures. The VOC potential emissions from the Point Breeze marine loading operation, which is not authorized to load gasoline[5], are based on the maximum expected non-gasoline material throughput, maximum expected vapor pressures of loaded materials, and USEPA AP-42 Section 5.2 emissions calculations.

The VOC potential emissions from the Girard Point marine loading operation are based on the maximum expected material throughput (both gasoline and non-gasoline materials), maximum expected vapor pressures of loaded materials, USEPA AP-42 Section 5.2 emissions calculations, and the control efficiency of the marine vapor recovery system (greater than 99% control efficiency when loading gasoline).

The VOC potential emissions from the diesel-fired RICE presented in **Table 2-3** below are calculated using the Tier certifications of Nonroad Compression-Ignition Engines requirements codified in 40 Code of Federal Regulations (CFR) Parts 89 and 1039 for each diesel-fired RICE and referenced in the facility's Title V Operating Permit V06-016. If no certification was available, PES conservatively used USEPA AP-42 emission factors to develop potential emissions. Note that other emergency and fire pump RICE meet the presumptive RACT requirements of 25 Pa Code §129.93.

See **Attachment B** for detailed calculations for the VOC potential emissions for the combustion sources, cooling towers, 1232 FCCU CO Boiler, marine loading operations, and the diesel-fired RICE.

Other VOC sources that meet requirements in 25 PA Code §§ 129.58 through 129.63, including fugitive equipment leaks, wastewater treatment plant oil/water separators, storage tanks, stormwater tanks, and degreasers, are discussed in **Table 3-7** below.

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[5] Gasoline is defined in 25 PA Code §121.1 as a petroleum distillate having a Reid vapor pressure of 4 pounds per square inch or greater and which is a liquid at standard temperature and pressure.

Table 2-1 NO_x RACT Source Detail

Location	Source	Permitted Capacity (MMBtu/hr)	NO_x RACT Category	Fuel	Total Number of Burners	Combustion Device Type
Point Breeze	Unit 210-13H1	235.4	Case-by-case	Fuel gas	24	Vertical-cylindrical process heater
Point Breeze	Unit 860-2H2	69.8	Case-by-case	Fuel gas	4	Vertical-cylindrical process heater
Point Breeze	Unit 860-2H3	174.7	Case-by-case	Fuel gas	4	Vertical-cylindrical process heater
Point Breeze	Unit 860-2H4	99.4	Case-by-case	Fuel gas	3	Vertical-cylindrical process heater
Point Breeze	Unit 860-2H5	155	Case-by-case	Fuel gas	4	Vertical-cylindrical process heater
Point Breeze	Unit 860-2H7	59	Case-by-case	Fuel gas	4	Vertical-cylindrical process heater
Point Breeze	Unit 860-2H8	49.6	Presumptive	Fuel gas	4	Vertical-cylindrical process heater
Point Breeze	Unit 864-PH1	80	Case-by-case	Fuel gas	4	Vertical-cylindrical process heater
Point Breeze	Unit 864-PH7	45.5	Presumptive	Fuel gas	4	Vertical-cylindrical process heater
Point Breeze	Unit 864-PH11	74	Case-by-case	Fuel gas	8	Vertical-cylindrical process heater
Point Breeze	Unit 864-PH12	85.1	Case-by-case	Fuel gas	12	Vertical-cylindrical process heater
Point Breeze	Unit 868 FCCU	50 MBPD (maximum daily)	Case-by-case	Fuel gas	N/A	Full-burn FCCU
Point Breeze	Unit 870-H01	97	Case-by-case	Fuel gas	8	Vertical-cylindrical process heater
Point Breeze	Unit 870-H02	53	Case-by-case	Fuel gas	4	Vertical-cylindrical process heater
Point Breeze	Unit 859-1H1	98	Case-by-case	Fuel gas	8	Vertical-cylindrical process heater
Girard Point	Unit 137 F-1	415	Case-by-case	Fuel gas	32	Vertical-cylindrical process heater
Girard Point	Unit 137 F-2	155	Case-by-case	Fuel gas	16	Vertical-cylindrical process heater
Girard Point	Unit 137 F-3	60	Case-by-case	Fuel gas	6	Vertical-cylindrical process heater
Girard Point	Unit 1332 H-1	45	Presumptive	Fuel gas	- - -	Vertical-cylindrical process heater
Girard Point	Unit 1332 H-2	60	Case-by-case	Fuel gas	8	Vertical-cylindrical process heater
Girard Point	Unit 1332 H-3	43	Presumptive	Fuel gas	- - -	Vertical-cylindrical process heater
Girard Point	Unit 1332 H-400	186	Case-by-case	Fuel gas	36	Vertical-cylindrical process heater
Girard Point	Unit 1332 H-401	233	Case-by-case	Fuel gas	36	Vertical-cylindrical process heater
Girard Point	Unit 1332 H-601	48	Presumptive	Fuel gas	- - -	Vertical-cylindrical process heater

Location	Source	Permitted Capacity (MMBtu/hr)	NO_x RACT Category	Fuel	Total Number of Burners	Combustion Device Type
Girard Point	Unit 1332 H-602	49	Presumptive	Fuel gas	- - -	Vertical-cylindrical process heater
Girard Point	Unit 433 H-1	260	Case-by-case	Fuel gas	18	Vertical-cylindrical process heater
Girard Point	Unit 1232 B-104	70	Case-by-case	Fuel gas	12	Vertical-cylindrical process heater
Girard Point	Unit 1232 FCCU	100 MBPD (maximum daily)	Case-by-case	Fuel gas	N/A	Partial-burn FCCU
Girard Point	#3 Boilerhouse Boiler #37	495	Case-by-case	Fuel gas	8	Steam boiler
Girard Point	#3 Boilerhouse Boiler #39	495	Case-by-case	Fuel gas	8	Steam boiler
Girard Point	#3 Boilerhouse Boiler #40	660	Case-by-case	Fuel gas	10	Steam boiler
Point Breeze/Girard Point	Diesel-Fired Emergency and Fire Pump RICE	Varies	Presumptive	Diesel	N/A	Emergency Diesel-Fired RICE
Point Breeze/Girard Point	Diesel-Fired RICE IC-002	1.4	Case-by-case	Diesel	N/A	Non-emergency Diesel-Fired RICE
Point Breeze/Girard Point	Diesel-Fired RICE IC-005	0.2	Case-by-case	Diesel	N/A	Non-emergency Diesel-Fired RICE
Point Breeze/Girard Point	Diesel-Fired RICE IC-006	0.8	Case-by-case	Diesel	N/A	Non-emergency Diesel-Fired RICE
Point Breeze/Girard Point	Diesel-Fired RICE IC-007	0.7	Case-by-case	Diesel	N/A	Non-emergency Diesel-Fired RICE
Point Breeze/Girard Point	Diesel-Fired RICE IC-008	1.5	Case-by-case	Diesel	N/A	Non-emergency Diesel-Fired RICE

Table 2-2 Baseline Actual and Potential NO_x Emissions

Location	Source	NO_x Emission Rate (lb/MMBtu)	Reference	Baseline Year	Baseline Firing Rates (MMBtu/hr)	Baseline Actual NO_x Emissions (TPY)	Permitted Capacity (MMBtu/hr)	Potential NO_x Emissions (TPY)[1]
Point Breeze	Unit 210-13H1	0.104	Current RACT	2013	170.2	77.5	235.4	107.2
Point Breeze	Unit 860-2H2	0.350	Current RACT	2013	28.4	43.5	69.8	107.0
Point Breeze	Unit 860-2H3	0.163	Current RACT	2013	106.0	75.6	174.7	124.7
Point Breeze	Unit 860-2H4	0.270	Current RACT	2013	55.9	66.1	99.4	117.6
Point Breeze	Unit 860-2H5	0.163	Current RACT	2013	113.2	80.8	155	110.7
Point Breeze	Unit 860-2H7	0.157	Current RACT	2013	37.1	25.5	59	40.6
Point Breeze	Unit 864-PH1	0.167	Current RACT	2013	30.7	22.5	80	58.5
Point Breeze	Unit 864-PH11	0.145	Current RACT	2013	42.5	27.0	74	47.0
Point Breeze	Unit 864-PH12	0.119	Current RACT	2013	53.4	27.9	85.1	44.4
Point Breeze	Unit 868 FCCU	50 ppmvd[2] @ 0% oxygen	Low NO_x CO Combustion Promoter	2013	N/A	96.1	50 MBPD feed rate	130.2
Point Breeze	Unit 870-H01	0.035	Stack Test	2013	33.8	5.2	97	14.9
Point Breeze	Unit 870-H02	0.035	Stack Test	2013	31.8	4.9	53	8.1
Point Breeze	Unit 859-1H1	0.02	Stack Test	2013	74.6	6.5	98	8.6
Girard Point	Unit 137 F-1	0.23	Current RACT	2013	312.4	314.7	415	418.1
Girard Point	Unit 137 F-2	0.257	Current RACT	2013	116.5	131.1	155	174.5
Girard Point	Unit 137 F-3	0.06	ULNB	2013	46.2	12.1	60	15.8
Girard Point	Unit 1332 H-2	0.04	ULNB	2013	29.9	5.2	60	10.5
Girard Point	Unit 1332 H-400	0.06	SCR	2013	102.4	26.9	186	48.9
Girard Point	Unit 1332 H-401	0.06	SCR	2013	130.3	34.2	233	61.2
Girard Point	Unit 433 H-1	0.035	ULNB	2013	147.6	22.6	260	39.9
Girard Point	Unit 1232 B-104	0.177	AP-42	2011	4.7	3.7	70	54.3
Girard Point	Unit 1232 FCCU	10 ppmvd @ 0% oxygen	SCR	2013	N/A	45.2	100 MBPD feed rate	208.3
Girard Point	#3 Boilerhouse Boiler #37	0.04	ULNB & FGR	2013	302.9	53.1	495	86.7

Location	Source	NO_x Emission Rate (lb/MMBtu)	Reference	Baseline Year	Baseline Firing Rates (MMBtu/hr)	Baseline Actual NO_x Emissions (TPY)	Permitted Capacity (MMBtu/hr)	Potential NO_x Emissions (TPY)[1]
Girard Point	#3 Boilerhouse Boiler #39	0.04	ULNB & FGR	2013	278.8	48.8	495	86.7
Girard Point	#3 Boilerhouse Boiler #40	0.04	ULNB & FGR	2013	371.4	65.1	660	115.6
Point Breeze/ Girard Point	Diesel-Fired RICE IC-002	4.4	AP-42	N/A[3]	1.4	1.4	1.4	1.4
Point Breeze/ Girard Point	Diesel-Fired RICE IC-005	4.4	AP-42	N/A[3]	0.2	1.0	0.2	1.0
Point Breeze/ Girard Point	Diesel-Fired RICE IC-006	2.2	Tier 1	N/A[3]	0.8	1.0	0.8	1.0
Point Breeze/ Girard Point	Diesel-Fired RICE IC-007	0.7	Tier 3	N/A[3]	0.7	0.7	0.7	0.7
Point Breeze/ Girard Point	Diesel-Fired RICE IC-008	1.1	Tier 2	N/A[3]	1.5	0.3	1.5	0.3

1 Potential NO_x emissions for the FCCUs are the permitted emission rates found in the Title V Operating Permit V06-016.
2 ppmvd = parts per million by volume dry.
3 Diesel-fired RICE potential emissions were treated as actual emissions due to operational variability from year to year.

Table 2-3 Baseline Actual and Potential VOC Emissions

Location	Source Name	VOC Emissions Factor	Reference	Baseline Year	Capacity	Baseline Capacity	Baseline Actual VOC Emissions (TPY)	Potential Capacity	Potential VOC Emissions (TPY)
Point Breeze/Girard Point	Combustion Units (all sources listed in Tables 2-1 and 2-2)	0.0054 lb/MMBtu	AP-42, Chapter 1.4	2013	Firing Rate	Varies (see Table 2-2)	79.3	Varies (see Table 2-2)	109.8
Point Breeze/Girard Point	Cooling Towers: 210 Crude 868 Complex 864 137 433 490 1232	0.7 lb/MMgal	AP-42, Chapter 5.1	2013	Cooling Throughput	29,600 gpm 19,700 gpm 35,000 gpm 18,000 gpm 33,469 gpm 32,609 gpm 48,324 gpm 56,162 gpm 305,900 total	50.2	29,600 gpm 19,700 gpm 35,000 gpm 18,000 gpm 36,300 gpm 35,300 gpm 75,000 gpm 57,000 gpm 305,900 total	5.4 3.6 6.4 3.3 6.7 6.5 13.8 10.5 56.3 total
Point Breeze	868 FCCU (Full-burn)	1.1 lb/hr	Stack Test	2013	Material Throughput	44.1 MBPD average feed rate	5.0	50 MBPD feed rate	23.0[1]
Girard Point	1232 FCCU (Partial-burn)	0.0054 lb/MMBtu	AP-42, Chapter 1.4	2013	CO Boiler Fire Rating	96.4 MMBtu/hr average	2.3	580 MMBtu/hr	13.7
Girard Point	Loading Operations (Wharf) - Gasoline and Non-gasoline	Varies based on material loaded (See Attachment B)	AP-42, Chapter 5.2	2013	Materials Throughput	17,522,420 bbl/yr	4.8	17,902,000 bbl/yr	15.2[2]
Point Breeze	Loading Operations (Wharf) - Non-gasoline	Varies based on material loaded (See Attachment B)	AP-42, Chapter 5.2	2013	Materials Throughput	2,031,994 bbl/yr	34.9	1,482,000 bbl/yr	26.0
Point Breeze/Girard Point	Diesel-Fired RICE IC-002	0.00251 lb/hp-hr	AP-42, Chapter 3.3	N/A[3]	Hours of Operation	458 hr/yr	N/A[3]	1.4 MMBtu/hr	0.12

Location	Source Name	VOC Emissions Factor	Reference	Baseline Year	Capacity	Baseline Capacity	Baseline Actual VOC Emissions (TPY)	Potential Capacity	Potential VOC Emissions (TPY)
Point Breeze/Girard Point	Diesel-Fired RICE IC-005	0.00251 lb/hp-hr	AP-42, Chapter 3.3	N/A[3]	Hours of Operation	2,300 hr/yr	N/A[3]	0.2 MMBtu/hr	0.08
Point Breeze/Girard Point	Diesel-Fired RICE IC-006	0.00251 lb/hp-hr	AP-42, Chapter 3.3	N/A[3]	Hours of Operation	1,150 hr/yr	N/A[3]	0.8 MMBtu/hr	0.17
Point Breeze/Girard Point	Diesel-Fired RICE IC-007	0.00251 lb/hp-hr	AP-42, Chapter 3.3	N/A[3]	Hours of Operation	3,050 hr/yr	N/A[3]	0.7 MMBtu/hr	0.39
Point Breeze/Girard Point	Diesel-Fired RICE IC-008	0.00251 lb/hp-hr	AP-42, Chapter 3.3	N/A[3]	Hours of Operation	360 hr/yr	N/A[3]	1.5 MMBtu/hr	0.10

[1] This is the potential limit for the 868 FCCU in the facility's Title V Operating Permit No. V06-016 that was determined when then unit was originally permitted.
[2] This potential to emit represents 1.4 TPY VOC from gasoline materials loaded that are controlled by the marine vapor recovery system with a thermal oxidizer and 13.9 TPY VOC from non-gasoline materials that are uncontrolled for a total of 15.2 TPY VOC of all materials combined.
[3] Diesel-fired RICE potential emissions were treated as actual emissions due to operational variability from year to year.

3.0 RACT ANALYSIS

The sections below provides the detailed RACT analysis for the affected NO_x and VOC sources that are neither exempt nor allowed to establish presumptive RACT limits.

3.1 NO_X RACT ANALYSIS

Each NO_x emitting source was identified and evaluated for NO_x RACT except for the previously mentioned 7 heaters that were recently evaluated as part of the AMS Plan Approval 12195. The NO_x RACT analysis utilized the following steps:

- Identify the presumptive NO_x RACT sources (Section 3.1.1);
- Identify the case-by-case NO_x RACT sources (Section 3.1.2); and
- Establish baseline emission rate from historical firing rates and appropriate emission factor (Section 2.4.1).

As required by 25 PA Code §§129.92(a)(5) and (b), for case-by-case sources:

- Rank the available control options for each source (Section 3.1.4);
- Evaluate the technical feasibility of the available control options (Section 3.1.5);
- Rank the technically feasible control options for each source (Section 3.1.5);
- Estimate the emission reductions after application of the control option (Section 3.1.5); and
- Calculate the cost effectiveness of each control option for each source (Section 3.1.6).

3.1.1 Presumptive NO_x RACT Sources

Presumptive NO_x RACT combustion sources are considered to be sources with a capacity sources equal to or greater than 20 MMBtu/hr and less than 50 MMBtu/hr. Presumptive NO_x RACT combustion engine sources are emergency standby engines operating less than 500 hours in a consecutive

12-month period. **Table 3-1** below presents a list of these sources at the Complex.

Table 3-1 Presumptive NO_x RACT Sources

Location	Source Name	Permitted Capacity (MMBtu/hr)
Point Breeze	Unit 860-2H8 Heater	49.6
Point Breeze	Unit 864-PH7 Heater	45.5
Point Breeze	Unit 867 SRU Incinerator[1]	- - -
Point Breeze	North Flare[1]	- - -
Point Breeze	South Flare[1]	- - -
Point Breeze	Acid Gas Flare[1]	- - -
Point Breeze	SWS Flare[1]	- - -
Point Breeze	LPG Flare[1]	- - -
Girard Point	Unit 1332 H-1 Heater	45
Girard Point	Unit 1332 H-3 Heater	43
Girard Point	Unit 1332 H-601 Heater	48
Girard Point	Unit 1332 H-602 Heater	49
Girard Point	Marine Vapor Recovery[1]	40
Girard Point	1231/1232 Flare[1]	- - -
Girard Point	433 Flare[1]	- - -
Girard Point	Unit 1232 FCCU CO Boiler[1]	580
Point Breeze/Girard Point	Diesel-Fired Emergency and Fire Pump RICE	- - -

[1] Per 25 PA Code §129.93(c)(4), for incinerators or thermal/catalytic oxidizers used primarily for air pollution control, presumptive RACT emissions limitations are the installation, maintenance and operation of the source in accordance with manufacturers specifications.

3.1.2 Case-By-Case NO_x RACT Sources

A case-by-case RACT analysis must be performed for all NO_x sources that are not Presumptive NO_x RACT sources. **Table 3-2** below presents a list of the case-by-case sources at the Complex.

Table 3-2 Case-by-Case NO_x RACT Sources

Location	Source Name	Permitted Capacity (MMBtu/hr)
Point Breeze	Unit 210-13H1 Heater	235.4
Point Breeze	Unit 860-2H2 Heater	69.8

Location	Source Name	Permitted Capacity (MMBtu/hr)
Point Breeze	Unit 860-2H3 Heater	174.7
Point Breeze	Unit 860-2H4 Heater	99.4
Point Breeze	Unit 860-2H5 Heater	155
Point Breeze	Unit 860-2H7 Heater	59
Point Breeze	Unit 864-PH1 Heater	80
Point Breeze	Unit 864-PH11 Heater	74
Point Breeze	Unit 864-PH12 Heater	85.1
Point Breeze	Unit 868 FCCU	50 MBPD[1] (maximum daily)
Point Breeze	Unit 870-H01 Heater	97
Point Breeze	Unit 870-H02 Heater	53
Point Breeze	Unit 859-1H1 Heater	98
Girard Point	Unit 137 F-1 Heater	415
Girard Point	Unit 137 F-2 Heater	155
Girard Point	Unit 137 F-3 Heater	60
Girard Point	Unit 1332 H-2 Heater	60
Girard Point	Unit 1332 H-400 Heater	186
Girard Point	Unit 1332 H-401 Heater	233
Girard Point	Unit 433 H-1 Heater	260
Girard Point	Unit 1232 B-104 Heater	70
Girard Point	Unit 1232 FCCU	100 MBPD (maximum daily)
Girard Point	#3 Boilerhouse Boiler #37	495
Girard Point	#3 Boilerhouse Boiler #39	495
Girard Point	#3 Boilerhouse Boiler #40	660
Point Breeze/Girard Point	Diesel-Fired RICE IC-002 (200 HP[2])	1.4
Point Breeze/Girard Point	Diesel-Fired RICE IC-005 (28 HP)	0.2
Point Breeze/Girard Point	Diesel-Fired RICE IC-006 (115 HP)	0.8
Point Breeze/Girard Point	Diesel-Fired RICE IC-007 (102 HP)	0.7
Point Breeze/Girard Point	Diesel-Fired RICE IC-008 (214 HP)	1.5

1 MBPD = thousand barrels per day
2 HP = horsepower

3.1.3 *Combustion Sources - Available NO_x Control Options*

The sections below provide an overview of the technologies available for control of NO_x emissions for combustion sources located at the Refineries. The technologies selected for consideration are listed below and are based on USEPA's ACT Documents for Process Heaters and Utility Boilers (EPA-453/R-93-034 and EPA-453/R-94-023, respectively). The selected technologies are:

- Combustion Tuning and Maintenance (CT);
- Selective Non-Catalytic Reduction (SNCR);
- Flue Gas Recirculation (FGR);
- Low NO_x Burners (LNB);
- Ultra-low NO_x Burners (ULNB); and
- Selective Catalytic Reduction (SCR).

3.1.3.1 Combustion Tuning and Maintenance

In many units, reductions in NO_x emissions may be obtained by adjustments and relatively minor upgrades to the existing combustion system. Problems may exist in burner to burner air/fuel balance, burner adjustments, measurement calibrations, control systems, fuel feed systems, and excess air level, among others. A systematic program of combustion system adjustments combined with boiler/heater performance monitoring can frequently reduce NO_x levels while also reducing carbon loss and CO emissions. Changes include burner setting adjustments, upgrade of selected components, addition of burner components, and other operational modifications like:

- *Burner Out of Service (BOOS) Operation*: This can also be referred to as Air Staging. It is achieved by operating with selected burners out of service. The fuel from the out of service burner(s) (idle) is redirected to the remaining in-service burners to maintain the same firing rate. Operating in this manner provides staged, low NO_x conditions similar to those achieved with overfire air ports.

- *Fuel Biasing:* This operation method involves maintaining all burners in service and is less severe, in terms of stoichiometry modification, than BOOS firing (air staging). Using this technique, fuel flow to certain burners is reduced while the flow to others is increased. This creates fuel-rich and fuel-lean regions which are conducive to reducing NO_x emissions.

- *Air Biasing*: Creates stoichiometry variations similar to air staging but the amount of variation is less severe. Air biasing can be accomplished by throttling certain dampers/registers and opening others.

Note that PES currently implements quarterly combustion tuning and maintenance using a portable NO_x analyzer on the majority of combustion sources at the Complex as required in the facility's existing RACT Plan Approval. Therefore, the cost effectiveness for this control option was excluded from the economic analysis as it is already assumed to be occurring.

3.1.3.2 Selective Non-Catalytic Reduction

SNCR is based on the chemical reduction of NO_x into molecular nitrogen and water vapor. A nitrogen reducing agent (reagent), such as ammonia or urea, is injected into the post combustion flue gas. The reduction reaction with NO_x is favored over other chemical reaction processes at temperatures ranging between 1600°F and 2100°F; therefore, it is considered a selective chemical process.

In the SNCR process, the combustion unit acts as the reaction chamber. The reagent is generally injected where the injection system can promote mixing of the reagent with the flue gas within the desired temperature range. Certain applications are more suited for SNCR due to combustion unit design. Units with furnace exit temperatures of 1550°F to 1950°F, residence times of greater than one second, and high levels of uncontrolled NO_x are good candidates.

NO_x reduction levels using SNCR range from 30 to 50%[6]. This analysis assumes 40% NO_x reduction from application of SNCR alone.

3.1.3.3 Flue Gas Recirculation

Flue gas recirculation (FGR) involves the recycling of a portion of the flue gas and mixing it with the combustion air upstream of the burners. The circulated flue gas acts as a diluent in the primary combustion zone to reduce peak temperatures. Lowering the combustion temperature reduces thermal NO_x formation. Since the majority of NO_x emissions from gaseous fuel firing are thermal NO_x, FGR is effective, especially when used in conjunction with LNB.

Burners can be used with modifications to accept the increased gas flow to utilize FGR. However, it would not be feasible to modify existing burners on

[6] Heater stack temperatures below 700°F results in low NO_x removal efficiency (USEPA Air Pollution Control Technology Fact Sheet - EPA-452/F-03-031).

process heaters to allow the use of the FGR without a major redesign of the burner. Furthermore, the expected NO_x reductions increase by 25% when FGR is coupled with LNB.

In general, one of the disadvantages of retrofitting an existing source with FGR is that it requires the installation of ducts and fans. Additionally, FGR has operational and efficiency limitations such as the potential erosion of convective tube sections and fan blades, increased maintenance, lost steam production or throughput at constant heat transfer rates, and the increased auxiliary power consumption to drive the fans.

See Section 3.1.3.4 for a discussion of the expected NO_x reductions from the implementation of FGR.

3.1.3.4 Low NO_x and Ultra-low NO_x Burners

Burners have a dramatic effect on NO_x emissions since they affect the rate of initial heat release and the residence time at peak combustion temperatures by controlling the initial fuel/air mixing and the conditions in the primary ignition zone.

The basic principle behind lowering NO_x emissions is the staging of fuel and air supply to create at first a sub-stoichiometric combustion condition which reduces the formation of thermal NO_x. The burners control the combustion staging at and within the burner rather than in the firebox. This control is achieved through design features which regulate the aerodynamic distribution and mixing of the fuel and air.

Both ULNB and LNB use staged air combustion to control NO_x emissions and while both are technically feasible, ULNB are generally implemented more by the industry today because of availability of burners and desire to maximize benefit given the high cost associated with retrofits. PES generally considers ULNB in existing sources as burners that have a NO_x emission rate of less than 0.06 lb/MMBtu. However, this analysis assumed that new ULNB could achieve NO_x emission rates of approximately 0.03 lb/MMBtu to reflect current technology capabilities for most refinery sources. Based on current emission rates, the installation of new ULNB would result in NO_x reductions ranging from 50 to 86% depending upon which heater ULNB were installed (See **Table 3-3**). PES has also utilized recent vendor quotations for estimated ULNB performance based on proposed installations at the Unit 137 F-1, Unit 137 F-2, Unit 864-PH1, Unit 864-PH11, and Unit 864-PH12 heaters. These vendor quotations are provided in **Attachment C**.

Some heaters in the analysis (Unit 137 F-3, Unit 1332 H-2, and Unit 433 H-1) show NO_x emission rates greater than 0.03 lb/MMBtu but this is due to the definition of ULNB capabilities at the time of burner installation. Also, heaters with higher combustion temperatures, such as those servicing reformer units (Units 860 and 1332), will have emission rates greater than 0.03 lb/MMBtu when utilizing ULNBs[7]. For these reasons, actual emission reductions could be lower than assumed in this analysis, which results in potentially biased low cost effectiveness.

This analysis assumed that LNB and FGR or LNB and SNCR could be employed together achieving NO_x reductions of approximately 55% and 70%, respectively.

ULNBs typically incorporate internal or self-recirculating flue gas as part of the design of the burner, which eliminates the need for a separate FGR system to be installed on the process heater. Therefore, PES has not considered ULNB coupled with FGR technically feasible.

Further, the effectiveness of the SNCR system would be significantly reduced when coupled with ULNB because of the relatively low level of NO_x emissions generated by ULNB alone. As stated in USEPA's guidance[8]:

> "Selective noncatalytic reduction efficiency is dependent on the NO_x concentration in the flue gas. Therefore, it is expected that SNCR used on a heater with relatively high uncontrolled NO_x emissions will have a higher reduction efficiency than an SNCR used on a heater with relatively low uncontrolled NO_x emissions. This also indicates that for any particular heater the performance of SNCR used in combination with LNB may have a lower reduction efficiency than if SNCR was used alone."

Therefore, PES has not considered ULNB coupled with SNCR technically feasible.

3.1.3.5 *Selective Catalytic Reduction*

The SCR process chemically reduces NO_x into molecular nitrogen and water vapor. A nitrogen-based reagent such as ammonia or urea is injected into

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[7] USEPA's "Alternative Control Techniques (ACT) Document - NO_x Emissions from Process Heaters (Revised)" – EPA-453/R-93-034, Table 2-2 Reduction Efficiencies For Control Techniques Applied to Natural Gas- and Refinery Fuel Gas-Fired Process Heaters and Pyrolysis Furnaces, page 2-8.
[8] USEPA's "Alternative Control Techniques (ACT) Document - NO_x Emissions from Process Heaters (Revised)" – EPA-453/R-93-034, page 5-103.

the ductwork, downstream of the combustion unit. The waste gas mixes with the reagent and enters a reactor module containing catalyst. The hot flue gas and reagent diffuse through the catalyst. The reagent reacts selectively with the NO_x within a specific temperature range and in the presence of the catalyst and oxygen. Optimum temperature range depends on the type of catalyst used and the flue gas composition but generally vary from 480°F and 800°F.

Temperature, the amount of reducing agent, injection grid design, and catalyst activity are the main factors that determine the actual removal efficiency. The use of catalyst results in two primary advantages of the SCR process over the SNCR: higher NO_x control efficiency and reactions within a lower and broader temperature range. The benefits are accompanied by a significant increase in capital and operating costs as the catalyst is comprised of active metals or ceramics. Another major disadvantage of SCR is the large amount of space required for the installation of new equipment.

NO_x reduction levels using SCR range from 70 to 90%. This analysis assumes 85% NO_x reduction from SCR alone. This analysis assumed that ULNB and SCR could be employed together achieving NO_x reductions of approximately 96%.

3.1.4 Combustion Sources - Technical Feasibility

Each of the available control options listed in Section 3.1.3 above, were evaluated for each affected source that required a case-by-case RACT analysis. **Attachment B** identifies the NO_x control options found to not be technically feasible for each affected source as well as the economic analysis of each technology.

3.1.5 Combustion Sources - Ranking of NO_x Control Options

Table 3-3 provides a ranking of the NO_x control options that were described in Section 3.1.3. The control options are listed in descending order of control effectiveness.

Table 3-3 Combustion Sources - Ranking of NO_x Control Options

Control Option	Control Efficiency
Ultra-low NO_x burners and Selective Catalytic Reduction	96%
Selective Catalytic Reduction	85%
Ultra-low NO_x burners[1,2,3]	50% to 86%

Control Option	Control Efficiency
Low NO_x burners and Selective Non-Catalytic Reduction	70%
Low NO_x burners and Flue Gas Recirculation	55%
Selective Non-Catalytic Reduction	40%

1 Ultra-low NO_x burner control efficiency based on vendor experience at 0.03 lb/MMBtu.
2 Heaters with higher combustion temperatures such as those servicing reformer units are only expected to achieve 50% control efficiency using ULNB (Alternative Control Techniques Document - NO_x Emissions from Process Heaters (Revised) - EPA-453/R-93-034, Table 2-2 Reduction Efficiencies For Control Techniques Applied to Natural Gas- and Refinery Fuel Gas-Fired Process Heaters and Pyrolysis Furnaces, page 2-8).
3 86% control efficiency is based on the expected reduction from the Unit 137 F-2 heater which has a current NO_x emission rate of 0.257 lb/MMBtu to the estimated NO_x emission rate for ULNBs from the vendor quotation of 0.035 lb/MMBtu.

Installation of ULNB, LNB, and FGR require internal combustion modifications to the process heater to be implemented, while SCR and SNCR are post-combustion controls technologies that can be implemented without affecting combustion characteristics. Where NO_x control technologies are already installed, PES first evaluated if more effective internal combustion modifications (e.g., ULNB replacing LNB) could be implemented for additional NO_x reductions. If a more effective internal combustion modification was not available or infeasible, no cost effectiveness calculation was performed. Post-combustion controls were always evaluated where feasible unless SCR is already installed, as it is the most effective post-combustion NO_x control technology.

3.1.6 *FCCUs - Available NO_x Control Options*

The Unit 868 (Point Breeze) and Unit 1232 (Girard Point) FCCUs are operated differently due to unit design and based on the processing needs of each refinery. The Unit 868 FCCU is operated as a “full-burn” unit where the catalyst is regenerated with excess oxygen in the FCCU regenerator. The excess oxygen provides complete combustion of all flue gases coming from the FCCU regenerator. The Unit 1232 FCCU is operated as a “partial-burn” unit where the catalyst is regenerated with limited oxygen in the FCCU regenerator. Because of limited oxygen, incomplete combustion occurs in the FCCU regenerator and significant amounts of carbon monoxide (CO) are produced. To mitigate the carbon monoxide emissions from the Unit 1232 FCCU, a CO Boiler is used to complete the combustion of flue gases.

As part of Global Air Consent Decree and Amendments with Civil Action No: 05-02866 with the USEPA, the Refinery was required to perform a pilot study of Low NO_x CO Combustion Promoter for Unit 868 FCCU, while the Refinery was required to install SCR for NO_x control for Unit 1232 FCCU. These NO_x reduction technologies were chosen based on the underlying unit designs (i.e., "full-burn" versus "partial-burn"). These NO_x control technologies were not implemented to satisfy RACT requirements.

As described in the facility's Title V Operating Permit No. V06-016, the Unit 868 FCCU is a full-burn unit that is required to operate utilizing a Low NO_x CO Combustion Promoter. As part of the Consent Decree, PES has proposed[9] the following NO_x emission limits: 100 ppmvd corrected to 0% oxygen on a rolling 7-day average and 50 ppmvd corrected to 0% oxygen on a rolling 365-day average. Further, it is noted that the Consent Decree requires that PES immediately operate in accordance with these proposed limits unless and until alternate limits are required by USEPA.

The Unit 1232 FCCU is a partial-burn unit equipped with a CO waste heat boiler and is required to operate a SCR for NO_x control. The Unit 1232 FCCU operates with the following NO_x emission limits: 30 ppmvd corrected to 0% oxygen on a rolling 7-day average and 10 ppmvd corrected to 0% oxygen on a rolling 365-day average.

The sections below provide an overview of the technologies available for control of NO_x emissions for FCCUs located at the Refineries. The technologies selected for consideration are listed below:

- Good Combustion Practices;
- Partial-Burn Operation;
- SCR;
- SNCR; and
- LoTOx™.

3.1.6.1 *Good Combustion Practices*

Controlling the level of excess oxygen in the regenerator will control the amount of afterburn above the dense catalyst bed inside the regenerator. Operating in this manner will control CO emissions and provide a moderate reduction in NO_x emissions. However, due to the numerous variables that produce NO_x from an FCCU regenerator, the level of achievable NO_x reductions cannot be estimated.

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[9] Proposed by PES in the February 2013 "868 Low NO_x CO Combustion Promoter Study".

3.1.6.2 Partial-Burn Operation

Converting an FCCU from full-burn to partial-burn operation to create a CO rich environment would prevent the formation of NO_x in the regenerator. However, as noted above, a CO Boiler would be required to control CO emissions. Since additional combustion occurs in the CO Boiler, NO_x emissions are generated as part of reducing CO emissions. Due to the numerous variables that produce NO_x from an FCCU regenerator, PES cannot determine if reductions or increases of NO_x emissions would occur with the conversion. However, any NO_x emissions reductions achieved by conversion to partial-burn operation may be diminished by NO_x emissions increases from the installation of a CO Boiler.

3.1.6.3 FCCU Post-Combustion Controls

PES evaluated SCR, SNCR, and LoTOx™ systems as available NO_x control technologies for FCCUs. The SCR and SNCR technologies operate in similar manner as described in Sections 3.1.3.5 and 3.1.3.2 above. When applied to FCCUs, SCR and SNCR are expected to achieve NO_x reductions of approximately 90% and 40%, respectively.

The LoTOx™ process uses ozone to oxidize NO_x to nitric pentoxide and other higher order nitrogen oxides which are water soluble and can be removed from the exhaust gas via a wet scrubber. The process is optimized for temperatures below 300°F and therefore is typically installed between the scrubber inlet quench nozzles and before the first level of scrubbing nozzles of a wet gas scrubbing system in order to ensure operation in the optimum range. NO_x reductions for this analysis assume that the LoTOx™ system will achieve NO_x reductions of approximately 90%.

3.1.7 FCCUs - Technical Feasibility

For both FCCUs, the use of Good Combustion Practices is considered a feasible NO_x control methodology; however, the achievable NO_x reductions cannot be estimated. PES already implements Good Combustion Practices by monitoring the flue gas to ensure safe and efficient operation of the FCCUs. For this reason, PES has not performed a cost effectiveness analysis for Good Combustion Practices for the FCCUs.

The Unit 868 FCCU currently operates utilizing a Low NO_x CO Combustion Promoter for NO_x control. For this FCCU, the conversion of the unit from full-burn to partial-burn would require the installation of a CO Boiler along with substantial engineering and redesign of the unit. For these reasons, partial-burn operation is considered infeasible for the Unit 868 FCCU. The use of a Low NO_x CO Combustion Promoter is considered the minimum NO_x RACT control technology. PES evaluated SCR, SNCR, and LoTOx™ systems on the Unit 868 FCCU and **Attachment B** contains the economic analysis of each technology.

The Unit 1232 FCCU is a partial-burn unit equipped with SCR for NO_x control. As shown in **Table 3-4** below, a more effective NO_x control technology beyond SCR is not available. PES has not identified any additional NO_x control technologies beyond those evaluated or installed previously for the Unit 1232 FCCU. Therefore, no cost effectiveness analyses were performed for the Unit 1232 FCCU.

3.1.8 FCCUs - Ranking of NO_x Control Options

Table 3-4 provides a ranking of the NO_x control options that were described in Section 3.1.6. The control options are listed in descending order of control effectiveness.

Table 3-4 FCCUs - Ranking of NO_x Control Options

Control Option	Control Efficiency[1]
Selective Catalytic Reduction	90%
LoTOx™	90%
Selective Non-Catalytic Reduction	40%

[1] The control efficiencies listed above are based on achievable reductions when installed on FCCUs with relatively high uncontrolled NO_x emissions. The control efficiencies listed above are considered conservatively high because the Unit 868 FCCU is already controlled to 50 ppmvd corrected to 0% oxygen on a rolling 365-day average using the aforementioned Low NO_x CO Combustion Promoter.

3.1.9 Economic Analysis

The methodologies for the economic analysis of both the combustion sources and the FCCUs are discussed in the sections below.

3.1.9.1 Combustion Sources - Economic Analysis

PES conducted an economic analysis for each affected combustion source at the Complex. The overall methodology used in performing this analysis follows the guidelines provided in 25 PA Code §§129.92(b)(3) and (b)(4). The following steps were undertaken in conducting this analysis:

1) To be conservative, PES evaluated the cost effectiveness using potential NO_x emissions, which were determined from permitted fuel firing rates and source-specific emission factors;

2) Each control option was assigned a control efficiency for NO_x removal. A single number was used, usually a mid-point in generally-agreed upon range of control efficiencies. The range of efficiencies were determined from a collection of data obtained from previous experience, from vendor claims of the technology performance and most predominantly, from published literature;

3) For each control option, post-control emissions were calculated.

4) Cost effectiveness was calculated for each control option using the methodology in the regulations and in the "OAQPS Control Cost Manual" (EPA/452/B-02-001). Total annual costs are the sum of operating and maintenance (O&M) costs and capital recovery costs. The capital recovery costs assume the equipment will be amortized over a 10-year time frame at 20 percent interest, the rate PES uses for evaluating capital projects[10]. Total capital required to implement the various control options and operating and maintenance costs were estimated using the previously-mentioned ACT Documents for Process Heaters and Utility Boilers, design analysis, and PES operating experience[11].

5) Capital and O&M Costs were scaled up to 2013 dollar amounts using *Chemical Engineering* cost indices.

6) The control options are listed in descending order of control efficiencies in an array.

Table 3-5, located below, summarizes the cost effectiveness of each NO_x control technology for each of the case-by-case NO_x RACT sources. **Attachment B** includes details for each affected source including an evaluation of technical infeasibilities, the baseline NO_x emissions

[10] In conjunction with Plan Approval 12195, the RACT cost effectiveness of NO_x controls for seven heaters (Unit 231-B101, Unit 865-11H1, Unit 865-11H2, Unit 210-H101, Unit 210-H201A/B, Unit 866-12H1, and Unit 868-8H101) was evaluated using a 21.83 percent interest rate, which was the cost of borrowing capital for PES at that time. Furthermore, SCR/SNCR equipment is amortized on 20-year time frame.

[11] PES has utilized recent vendor quotations for ULNB equipment costs based on proposed installations at the Unit 137 F-1, Unit 137 F-2, Unit 864-PH1, Unit 864-PH11, and Unit 864-PH12 heaters. The equipment costs have been incorporated into the cost effectiveness calculations in **Attachment B** and the vendor quotations are included in **Attachment C**.

("pre-control"), emission reduction potentials, and estimated emissions after the application of each control option ("post-control emissions"). The information for each affected source is presented in an individual table. The cost evaluations are presented for each control option, and the controls are listed in descending order of control efficiency. Also, for each control option, capital costs, shutdown costs (if applicable), O&M costs, total annual cost, cost effectiveness are presented. Example equations and calculations used for each control technology associated with process heaters and boilers are shown in the Unit 137 F-1 Heater and Boiler #37 cost effectiveness calculations in **Attachment B**. All other heaters and boilers utilize these same formulas, but for brevity the example equations are not duplicated for every source.

As described in Section 2.5.4.2 of the *Air Pollution Control Cost Manual Sixth Edition* EPA/452/B-02-001 - January 2002, a "lost production" retrofit cost, which is described as "the net revenue (i.e., gross revenue minus the direct costs of generating it) lost during this unanticipated shutdown period" is considered by USEPA as a bonafide retrofit expense. PES has determined that retrofits involving burner replacements for NO_x control on the Unit 137 F-1 and Unit 137 F-2 heaters may require additional time beyond a normal turnaround period because of the necessary retrofit piping and equipment changes that would be required. However, significant engineering has not been completed on the installation to fully evaluate the time needed to install replacement burners.

PES evaluated the lost production impacts of the shutdown of the Unit 137 crude distillation unit and affected downstream units that rely upon feedstreams generated by the crude distillation unit including the fluid catalytic cracking unit, reformer unit, and hydrodesulfurization units. Based on actual refinery crude margins and data from past Unit 137 outages, PES conservatively estimated the net revenue lost per day at approximately $1,000,000 per day for outages lasting longer than a normal unit turnaround. However, at this time, PES has not included a "lost production" retrofit cost in this analysis.

3.1.9.2 FCCUs - Economic Analysis

PES conducted an economic analysis for the Unit 868 FCCU. The overall methodology used in performing this analysis follows the guidelines provided in 25 PA Code §§129.92(b)(3) and (b)(4). The following steps were undertaken in conducting this analysis:

1) To be conservative, PES evaluated the cost effectiveness using potential NO_x emissions, which were determined from the Unit 868 stack flow,

unit throughput, and the 50 ppmvd corrected to 0% oxygen on a rolling 365-day average NO_x emission limit (See **Attachment B** for detailed calculations);

2) Each control option was assigned a control efficiency for NO_x removal based on published literature;

3) For each control option, post-control emissions were calculated.

4) Cost effectiveness was calculated for each control option using the methodology in the regulations and in the "OAQPS Control Cost Manual" (EPA/452/B-02-001). Total annual costs are the sum of operating and maintenance (O&M) costs and capital recovery costs. The capital recovery costs assume the equipment will be amortized over a 10-year time frame at 20 percent interest, the rate PES uses for evaluating capital projects. Total capital required to implement the various control options and operating and maintenance costs were estimated using the previously-mentioned ACT Document for Process Heaters, USEPA's "Documentation of NO_x Control Cost Estimates" – EPA-HQ-OAR-2007-0011-0089, design analysis, and PES operating experience.

5) Capital and O&M Costs were scaled up to 2013 dollar amounts using *Chemical Engineering* cost indices.

Table 3-5, located below, summarizes the cost effectiveness of each NO_x control technology for the Unit 868 FCCU. **Attachment B** includes details for the source including the baseline NO_x emissions ("pre-control"), emission reduction potentials, and estimated emissions after the application of each control option ("post-control emissions"). The cost evaluations are presented for each control option, and the controls are listed in descending order of control efficiency. Also, for each control option, capital costs, O&M costs, total annual cost, cost effectiveness are presented.

PES found that SCR, SNCR, and LoTOx™ NO_x controls were not cost effective for Unit 868 FCCU. It is noted that this analysis disregarded the cost for a wet gas scrubbing system, which was presumed to be present in the cost basis for the LoTOx™ system.

Therefore, PES proposes that for the Unit 868 FCCU the use of Low NO_x CO Combustion Promoter and the associated NO_x emission limit satisfy RACT.

PES has not evaluated the cost effectiveness of SCR control for the Unit 1232 FCCU since an SCR unit was recently installed and reflected in the unit's baseline emissions. The control effectiveness and associated NO_x emission rate due to the presence of SCR satisfy RACT.

Table 3-5 Case-by-Case NO_x RACT Cost Effectiveness based on Potential Emissions

Cost Effectiveness ($/Ton)	Control Option						
	ULNB & SCR	**SCR**	**ULNB**	**LNB & SNCR**	**LNB & FGR**	**SNCR**	**LoTOx™**
Unit 210-13H1	Infeasible	Infeasible	3,151	9,998	Infeasible	13,921	- - -
Unit 860-2H2	Infeasible	Infeasible	Infeasible	Infeasible	Infeasible	5,631	- - -
Unit 860-2H3	Infeasible	Infeasible	Infeasible	Infeasible	Infeasible	9,552	- - -
Unit 860-2H4	Infeasible	Infeasible	2,999	16,808	Infeasible	6,641	- - -
Unit 860-2H5	Infeasible	Infeasible	Infeasible	Infeasible	Infeasible	9,786	- - -
Unit 860-2H7	Infeasible	Infeasible	Infeasible	Infeasible	Infeasible	12,605	- - -
Unit 864-PH1	Infeasible	Infeasible	9,528	7,796	Infeasible	11,045	- - -
Unit 864-PH11	Infeasible	Infeasible	12,967	9,070	Infeasible	12,898	- - -
Unit 864-PH12	Infeasible	Infeasible	17,680	11,561	Infeasible	15,135	- - -
Unit 868 FCCU	Infeasible	30,794	Infeasible	Infeasible	Infeasible	10,679	13,328
Unit 870-H01	ULNB installed	73,298	ULNB installed	ULNB installed	ULNB installed	49,070	- - -
Unit 870-H02	ULNB installed	92,541	ULNB installed	ULNB installed	ULNB installed	56,784	- - -
Unit 859-1H1	ULNB installed	127,640	ULNB installed	ULNB installed	ULNB installed	85,399	- - -
Unit 137 F-1	9,648	6,578	4,331	8,232	7,224	5,883	- - -
Unit 137 F-2	14,897	8,492	8,203	13,023	13,228	6,340	- - -
Unit 137 F-3	ULNB installed	51,523	ULNB installed	ULNB installed	ULNB installed	32,261	- - -
Unit 1332 H-2	ULNB installed	77,200	ULNB installed	ULNB installed	ULNB installed	48,210	- - -
Unit 1332 H-400	SCR installed	SCR installed	11,337	SCR installed	SCR installed	SCR installed	- - -
Unit 1332 H-401	SCR installed	SCR installed	9,051	SCR installed	SCR installed	SCR installed	- - -
Unit 433 H-1	ULNB installed	50,368	ULNB installed	ULNB installed	ULNB installed	39,879	- - -
Unit 1232 B-104	ULNB installed	16,570	ULNB installed	ULNB installed	ULNB installed	10,772	- - -
#3 Boilerhouse Boiler #37	ULNB & FGR installed	32,829	ULNB & FGR installed	ULNB & FGR installed	ULNB & FGR installed	13,221	- - -
#3 Boilerhouse Boiler #39	ULNB & FGR installed	32,829	ULNB & FGR installed	ULNB & FGR installed	ULNB & FGR installed	13,221	- - -

Cost Effectiveness ($/Ton)	Control Option						
	ULNB & SCR	SCR	ULNB	LNB & SNCR	LNB & FGR	SNCR	LoTOx™
#3 Boilerhouse Boiler #40	ULNB & FGR installed	30,139	ULNB & FGR installed	ULNB & FGR installed	ULNB & FGR installed	11,823	- - -
Diesel-Fired RICE IC-002	Infeasible	8,294	Infeasible	Infeasible	Infeasible	Infeasible	- - -
Diesel-Fired RICE IC-005	Infeasible	6,395	Infeasible	Infeasible	Infeasible	Infeasible	- - -
Diesel-Fired RICE IC-006	Infeasible	5,959	Infeasible	Infeasible	Infeasible	Infeasible	- - -
Diesel-Fired RICE IC-007	Infeasible	7,950	Infeasible	Infeasible	Infeasible	Infeasible	- - -
Diesel-Fired RICE IC-008	Infeasible	19,716	Infeasible	Infeasible	Infeasible	Infeasible	- - -

As shown in **Table 3-5** above based on potential emissions, there were no new, additional NO_x controls that were found to be cost effective for any of the affected case-by-case NO_x RACT sources.

Table 3-6 below presents the current NO_x RACT control (based on the 1999 NO_x RACT analysis), NO_x control technologies that are currently installed on each source, and the proposed NO_x RACT control technology based on this update.

Table 3-6 NOx RACT Summary with Proposed Updated Controls

Location	Source Name	Currently permitted NO_x RACT Control	Currently Installed NO_x Control	2014 RACT Control Update
Point Breeze	Unit 210-13H1 Heater	CT	CT	CT
Point Breeze	Unit 860-2H2 Heater	CT	CT	CT
Point Breeze	Unit 860-2H3 Heater	CT	CT	CT
Point Breeze	Unit 860-2H4 Heater	CT	CT	CT
Point Breeze	Unit 860-2H5 Heater	CT	CT	CT
Point Breeze	Unit 860-2H7 Heater	CT	CT	CT
Point Breeze	Unit 864-PH1 Heater	CT	CT	CT
Point Breeze	Unit 864-PH11 Heater	CT	CT	CT
Point Breeze	Unit 864-PH12 Heater	CT	CT	CT
Point Breeze	Unit 868 FCCU	Good Combustion	Low NO_x CO Combustion Promoter	Low NO_x CO Combustion Promoter[2]
Point Breeze	Unit 870-H01 Heater	N/A[1]	ULNB	ULNB[2]
Point Breeze	Unit 870-H02 Heater	N/A[1]	ULNB	ULNB[2]
Point Breeze	Unit 859-1H1 Heater	N/A[1]	ULNB	ULNB[2]
Girard Point	Unit 137 F-1 Heater	CT	CT	CT
Girard Point	Unit 137 F-2 Heater	CT	CT	CT
Girard Point	Unit 137 F-3 Heater	CT	ULNB	ULNB[2]
Girard Point	Unit 1332 H-2 Heater	CT	ULNB	ULNB[2]
Girard Point	Unit 1332 H-400 Heater	CT	SCR	SCR[2]
Girard Point	Unit 1332 H-401 Heater	CT	SCR	SCR[2]
Girard Point	Unit 433 H-1 Heater	ULNB	ULNB	ULNB
Girard Point	Unit 1232 B-104 Heater	ULNB	ULNB	ULNB
Girard Point	Unit 1232 FCCU	N/A	SCR	SCR[2]
Girard Point	#3 Boilerhouse Boiler #37	ULNB	ULNB & FGR	ULNB & FGR[2]
Girard Point	#3 Boilerhouse Boiler #39	ULNB	ULNB & FGR	ULNB & FGR[2]
Girard Point	#3 Boilerhouse Boiler #40	ULNB	ULNB & FGR	ULNB & FGR[2]
Point Breeze/Girard Point	Diesel-Fired RICE IC-002	N/A	N/A	Good Combustion
Point Breeze/Girard Point	Diesel-Fired RICE IC-005	N/A	N/A	Good Combustion
Point Breeze/Girard Point	Diesel-Fired RICE IC-006	N/A	N/A	Good Combustion
Point Breeze/Girard Point	Diesel-Fired RICE IC-007	N/A	N/A	Good Combustion
Point Breeze/Girard Point	Diesel-Fired RICE IC-008	N/A	N/A	Good Combustion

1 Heaters installed after the 1999 NO_x RACT analysis.
2 The currently installed NO_x control technology was not found to be cost effective but the control effectiveness and associated NO_x emission rate satisfy RACT.

3.2 VOC RACT ANALYSIS

Each VOC emitting source was identified and evaluated for VOC RACT. **Table 3-7** below provides the VOC RACT affected sources and a summary of VOC RACT requirements.

Table 3-7 VOC RACT Sources

Location	Source Name	VOC RACT Summary
Point Breeze/Girard Point	Combustion Units (all sources listed in Tables 2-1 and 2-2)	No RACT option for controlling VOC emissions
Point Breeze/Girard Point	Cooling Towers	MACT inspections are RACT 210 Crude - 29,600 gpm 868 - 19,700 gpm Complex - 35,000 gpm 864 - 18,000 gpm 137 – 36,300 gpm 433 – 35,300 gpm 490 – 75,000 gpm 1232 – 57,000 gpm
Point Breeze	868 Fluid Catalytic Cracking Unit	Full-burn unit, no RACT proposed
Girard Point	1232 Fluid Catalytic Cracking Unit	Partial-burn unit, good combustion practices proposed
Point Breeze/Girard Point/Schuylkill River Tank Farm	Equipment Leaks	Exempt - meets PA Code §129.58
Point Breeze/Girard Point/ Schuylkill River Tank Farm	Wastewater Treatment Plant Oil/Water separators (Carbon canisters)	Exempt - meets PA Code §129.55
Point Breeze/Girard Point/ Schuylkill River Tank Farm	Storage Tanks	Exempt - meets PA Code §§129.56 and 129.57
Point Breeze	Stormwater Tank 7308, 7300	Exempt - meets PA Code §§129.56 and 129.57
Girard Point	Degreasers	Exempt - meets PA Code §129.63
Point Breeze	Loading Operations (Wharf)[1]	Case-by-case RACT applies. No gasoline loading. No cost effective control for loading of lower vapor pressure materials.
Girard Point	Loading Operations (Wharf)[1]	Case-by-case RACT applies. No cost effective control for loading of non-gasoline materials. Currently installed marine vapor control system proposed as RACT for gasoline loading.
Girard Point/ Schuylkill River Tank Farm	Loading Operations (Truck Rack)	Exempt - Meets AMR V, Section V
Point Breeze/Girard Point	Diesel-Fired Emergency and Fire Pump RICE	Exempt - meets PA Code §129.93
Point Breeze/Girard Point	Non-emergency Diesel-Fired RICE	Good combustion practices

[1] Note that the Point Breeze and Girard Point marine loading operations are not subject to the RACT requirements of 40 CFR Subpart Y - National Emission Standards for Marine Tank Vessel Loading Operations in §63.562(c) because neither loading operation exceeds the aggregate loading applicability requirements of 10 million barrels or more of

gasoline on a 24-month annual average basis or of 200 million barrels or more of crude oil on a 24-month annual average basis. See **Attachment B** - Case-by-Case RACT Cost Effectiveness Analysis for additional details.

A case-by-case VOC RACT analysis was conducted in the sections below for all non-exempt VOC emission sources at the Complex including combustion units, cooling towers, FCCUs, Diesel-Fired RICE, and Girard Point and Point Breeze marine loading operations.

3.2.1 Case-by-Case VOC RACT Sources

A case-by-case VOC RACT analysis was conducted in the sections below for combustion units, cooling towers, FCCUs, Diesel-Fired RICE, and Girard Point and Point Breeze marine loading operations.

3.2.1.1 Combustion Units

No RACT option is available for controlling VOC emissions from process heaters and boilers at the Complex. Emissions from these units are very low and occur due to the incomplete combustion of refinery fuel gas used in the heaters and boilers. Combustion tuning, proposed as NO_x RACT, in conjunction with good operating procedures and combustion practices will minimize VOC emissions from these sources. It would not be practical or technically feasible to vent combustion gases from these units to other combustion units, such as flares, to control the relatively small amount of VOCs emitted from the heaters and boilers. Furthermore, oxidation catalysts have not been demonstrated at refineries because the sulfur compounds found in refinery fuel gas irreversibly poison the catalysts. For these reasons, no VOC RACT is being proposed for the Complex combustion units.

3.2.1.2 Cooling Towers

Emissions from cooling towers can occur due to leaks in refinery heat exchangers, which allow VOCs to enter cooling water streams. These VOCs are volatilized from the cooling water as the water passes through the towers. As required by the RACT Plan Approval, PES utilizes an inspection and maintenance/monitoring program for VOC fugitive emissions from cooling towers by performing daily visual inspections of water basins for presence of hydrocarbon. PES currently implements an equipment monitoring program for heat exchange systems in accordance with the regulations codified in 40 CFR Part 63 Subpart CC – National Emissions Standards for Hazardous Air Pollutants (NESHAP) from Petroleum Refineries. PES proposes that these monitoring programs required by the

RACT Plan Approval remain as VOC RACT for cooling tower emissions at the Philadelphia Complex.

3.2.1.3 FCCUs

The Unit 1232 FCCU at the GP Refinery is a partial-burn unit that uses a CO waste heat boiler to reduce VOC emissions to negligible amounts. Good combustion practices are being proposed as VOC RACT for this source.

The Unit 868 FCCU at the PB Refinery is operation as a full-burn unit, where minimal VOC and CO emissions are emitted in the exhaust gas after thermal regeneration of the catalyst. Because a CO boiler is not applicable, and no other control options are available, no VOC RACT is being proposed for this emission source.

3.2.1.4 Diesel-Fired RICE

Diesel-fired RICE at the facility include three categories; emergency, fire pump, and general. Both emergency and fire pump engines operation are limited to less than 500 hours per year and therefore meet the presumptive RACT outlined in 25 PA Code §129.93 as shown below in **Table 3-8**. Additionally, PES has evaluated oxidation catalyst add-on controls for each diesel-fired RICE and it was not found to be cost effective in any case as demonstrated by the cost effectiveness calculations provided in **Attachment B**. PES proposes that good combustion practices be considered the VOC RACT for diesel-fired RICE.

Table 3-8 Diesel-Fired RICE VOC RACT Sources

Location	Source Name	VOC RACT Category
Point Breeze/Girard Point	EM-001 - Caterpillar (model 3412DITTA) Emergency Generator	Presumptive RACT – Limited to less than 500 hours per year in Title V Operating Permit V06-016 Condition 30(b)(2)
Point Breeze/Girard Point	FP-010 - 24PEN4 Fire Pump #4	Presumptive RACT – Limited to less than 500 hours per year in Title V Operating Permit V06-016 Condition 30(b)(6)
Point Breeze/Girard Point	FP-011 - 24P1 Fire Engine (Haenn's Wharf)	Presumptive RACT – Limited to less than 500 hours per year in Title V Operating Permit V06-016 Condition 30(b)(6)
Point Breeze/Girard Point	FP-012 - Fire Pump (1st and Wharf #8)	Presumptive RACT – Limited to less than 500 hours per year in Title V Operating Permit V06-016 Condition 30(b)(6)
Point Breeze/Girard Point	FP-013 - 24P2 North Fire Pump (Haenn's Wharf)	Presumptive RACT – Limited to less than 500 hours per year in Title V Operating Permit V06-016 Condition 30(b)(6)

Location	Source Name	VOC RACT Category
Point Breeze/Girard Point	FP-014 - 24P3 South Fire Pump (Short Pier)	Presumptive RACT – Limited to less than 500 hours per year in Title V Operating Permit V06-016 Condition 30(b)(6)
Point Breeze/Girard Point	FP-015 - 24PEN5 Fire Pump (North Yard)	Presumptive RACT – Limited to less than 500 hours per year in Title V Operating Permit V06-016 Condition 30(b)(6)
Point Breeze/Girard Point	FP-016 - 24PEN6 Fire Pump (North Yard Wharf)	Presumptive RACT – Limited to less than 500 hours per year in Title V Operating Permit V06-016 Condition 30(b)(6)
Point Breeze/Girard Point	FP-017 - 28P-1150A HF Mitigation Water Pump FP-12#1 (Unit 433)	Presumptive RACT – Limited to less than 500 hours per year in Title V Operating Permit V06-016 Condition 30(b)(6)
Point Breeze/Girard Point	FP-018 - 28P-1150B HF Mitigation Water Pump FP+12 #2 (Unit 433)	Presumptive RACT – Limited to less than 500 hours per year in Title V Operating Permit V06-016 Condition 30(b)(6)
Point Breeze/Girard Point	FP-019 - Belmont Firehouse Williams Pump (fire pump) affixed to a trailer	Presumptive RACT – Limited to less than 500 hours per year in Title V Operating Permit V06-016 Condition 30(b)(17)
Point Breeze/Girard Point	Diesel-Fired RICE IC-002	Case-by-Case RACT
Point Breeze/Girard Point	Diesel-Fired RICE IC-005	Case-by-Case RACT
Point Breeze/Girard Point	Diesel-Fired RICE IC-006	Case-by-Case RACT
Point Breeze/Girard Point	Diesel-Fired RICE IC-007	Case-by-Case RACT
Point Breeze/Girard Point	Diesel-Fired RICE IC-008	Case-by-Case RACT

3.2.1.5 Marine Loading Operations

The case-by-case VOC RACT analysis for the Girard Point marine loading operations are discussed in **Sections 3.2.2 through 3.2.6** below.

The case-by-case VOC RACT analysis for the Point Breeze marine loading operations are discussed in **Sections 3.2.7 through 3.2.12** below.

3.2.2 Girard Point Marine Loading Operation

The Girard Point marine loading operation is capable of loading materials at a nominal rate of 10,000 barrels per hour (bbl/hr). The VOC emissions from loading gasoline (as defined in 25 PA Code §121.1) at the Girard Point marine loading facilities are controlled using a vapor recovery system and a thermal oxidizer (source CD-011 in the current Title V permit) to comply with 25 PA Code §129.81.

3.2.2.1 *Girard Point Marine Gasoline Loading Operations*

PES evaluated the Girard Point marine loading operations assuming the existing marine vapor control system is utilized when loading gasoline materials (i.e., Reid vapor pressures [RVP] over 4.0 pounds per square inch absolute [psia]). As noted in **Section 3.2.3** and **Table 3-9** below, there are additional controls options that were evaluated for the Girard Point marine loading operation when loading non-gasoline materials. The analysis below identifies a thermal incinerator, flare, condenser, and adsorption as available controls options for gasoline loading. Note that the existing marine vapor recovery system and thermal oxidizer currently installed at the Girard Point marine loading facility for gasoline loading has the highest control effectiveness identified.

Table 3-9 Girard Point Marine Gasoline Loading Operation - VOC Control Options

Control Option	Control Efficiency
Thermal Incinerator	98%
Flare	98%
Adsorption	98%
Condenser	90%

PES proposes utilization of the existing marine vapor recovery system and thermal oxidizer be considered the VOC RACT for the Girard Point marine loading operation for gasoline material loading.

3.2.2.2 *Girard Point Marine Non-Gasoline Loading Operations*

The existing marine vapor control system was designed and is only used when loading materials with a RVP over 4.0 psia. For completeness, PES evaluated both the cost effectiveness of controlling non-gasoline loading with the existing marine vapor controls system, and also the cost effectiveness of installing an entirely new VOC control technology for non-gasoline loading. See **Sections 3.2.3 through 3.2.6** for the cost effectiveness for control of VOC loading vapors from non-gasoline loading assuming that the existing marine vapor control system would not be utilized.

Alternatively, utilizing the existing marine vapor control system to control heavier, non-gasoline materials (i.e., RVP less than 4.0 psia) would:

- Require additional operating costs including enrichment fuel;

- Require additional engineering and retrofitting of equipment to allow for control of heaver materials; and

- Create additional pollution from fuel combustion.

The Girard Point marine loading thermal oxidizer is designed to operate at 21% hydrocarbon in the system, which ensures proper combustion of loading vapors. Loading of materials with vapor pressures lower than RVP 4.0 psia does not generate high VOC concentrations in the controlled loading vapors. Therefore, for this analysis, it can be assumed that the loading vapors from non-gasoline materials do not contribute to the necessary 21% hydrocarbon concentration required by the marine loading thermal oxidizer. In this case, the enrichment fuel provides all hydrocarbon needed for proper combustion of VOCs from non-gasoline loading.

Design documentation for the marine loading thermal oxidizer indicates that the maximum enrichment fuel flow is approximately 311 standard cubic feet per minute. Assuming that propane is used as the enrichment fuel, 2,000 loading hours per year, and a cost of $1.46 per gallon of propane, the annual operating costs for enrichment fuel alone are calculated at more than $1,500,000 per year. As noted in **Table 2-3** above, the potential to emit for this operation when loading non-gasoline materials is 13.9 TPY of VOC (See **Attachment B** - Case-by-Case RACT Cost Effectiveness Analysis for details). For the Girard Point marine loading operation for non-gasoline material, the enrichment fuel costs alone represents a cost effectiveness of more than $110,000 per ton of VOC reduced. Note that this cost effectiveness does not include any engineering or capital cost to retrofit the system (hoses, valves, piping, instrumentation, etc.) to control the loading of non-gasoline materials.

Furthermore, as shown in **Table 3-10** below, the combustion of additional enrichment fuel (propane) to control non-gasoline material loading using the existing thermal oxidizer, will cause increases in other pollutant emissions including NO_x, particulate matter (PM), CO, and greenhouses gases in the form of carbon dioxide equivalents (CO_2e).

Table 3-10 Girard Point Marine Non-Gasoline Loading Operation – Pollutant Emissions from Additional Enrichment Fuel Firing

Pollutant	Potential to Emit (TPY)
NO_x	5.67
PM	0.07
CO	0.33
CO_2e	6,642

Based on the cost effectiveness and additional pollutant emissions generated from additional enrichment fuel firing, the use of the existing Girard Point vapor control system is not a cost-effective control option for the loading of non-gasoline material.

3.2.3 Girard Point Marine Non-Gasoline Loading Operation – Available VOC Control Options

The sections below provide an overview of the technologies available for control of VOC emissions from non-gasoline loading for the Girard Point marine loading operations (assuming that the existing marine vapor control system would not be utilized). The technologies selected for consideration are listed below and are based on USEPA's *Air Pollution Control Cost Manual Sixth Edition* EPA/452/B-02-001 - January 2002. The technologies are:

- Thermal Incinerator;
- Flare;
- Condenser; and
- Adsorption.

3.2.3.1 Thermal Incinerator

Incineration, or thermal oxidation, is the process of oxidizing combustible materials by raising the temperature of the material above its auto-ignition point in the presence of oxygen, and maintaining it at high temperature for sufficient time to complete combustion to carbon dioxide and water. Most thermal units are designed to provide no more than 1 second of residence time to the waste gas with typical temperatures of 1,200 to 2,000°F.

VOC reduction levels using thermal incinerators range up to 98% and beyond.

3.2.3.2 *Flare*

Flaring is a VOC combustion control process in which the VOC containing stream is piped to a remote, usually elevated, location and burned in an open flame in the open air using a specially designed burner tip, auxiliary fuel, and steam or air to promote mixing for nearly complete VOC destruction.

VOC reduction levels using flares range up to 98%.

3.2.3.3 *Condenser*

Condensation is a separation technique in which one or more volatile components of a vapor mixture are separated from the remaining vapors through saturation followed by a phase change. The phase change from gas to liquid can be achieved in two ways: (a) the system pressure can be increased at a given temperature, or (b) the temperature may be lowered at a constant pressure. In a two-component system where one of the components is non-condensible (e.g., air), condensation occurs at dew point (saturation) when the partial pressure of the volatile compound is equal to its vapor pressure. Refrigeration is often employed to obtain the low temperatures required for acceptable removal efficiencies. The basic equipment required for a refrigerated condenser system includes a VOC condenser, a refrigeration unit(s), and auxiliary equipment (e.g., precooler, recovery/storage tank, pump/blower, and piping).

VOC reduction levels using condensers range up to 90%. Note that for the Girard Point marine loading operation, based on the composition of the VOC being captured, it was determined that VOC condensation would not occur; therefore, making the condenser technically infeasible for this source (See **Attachment B** - Case-by-Case RACT Cost Effectiveness Analysis for details).

3.2.3.4 *Adsorption*

Adsorption is a phenomenon where VOC gas molecules passing through a bed of solid particles (in this case activated carbon) are selectively held there by attractive forces which are weaker and less specific than those of chemical bonds. During adsorption, a VOC gas molecule migrates from the gas stream to the surface of the carbon where it is held by physical attraction. Most gases ("adsorbates") can be removed ("desorbed") from the carbon adsorbent by heating to a sufficiently high temperature, usually via steam or hot combustion gases, or by reducing the pressure to a sufficiently low value (vacuum desorption).

Fixed-bed adsorbers may be operated in either intermittent or continuous modes. In intermittent operation, the adsorber removes VOC for a specified time (the "adsorption time"), which corresponds to the time during which the controlled source is emitting VOC. After the adsorber and the source are shut down, the unit begins the desorption cycle during which the captured VOC is removed from the carbon. This cycle, in turn, consists of three steps: (1) regeneration of the carbon by heating, generally by blowing steam through the bed in the direction opposite to the gas flow; (2) drying of the bed, with compressed air or a fan; and (3) cooling the bed to its operating temperature via a fan.

VOC reduction levels using adsorption range from 95 to 98%[12].

3.2.4 *Girard Point Marine Non-Gasoline Loading Operation – Technical Feasibility*

For control of VOC loading vapors from the Girard Point marine loading operation of non-gasoline materials, the thermal incinerator, flare, and adsorption technologies were found to be technically feasible. Due to the composition of the VOC being captured, it was determined that VOC condensation would not occur; therefore, making the condenser infeasible for this source.

3.2.5 *Girard Point Marine Non-Gasoline Loading Operation – Ranking of VOC Control Options*

Table 3-11 provides a ranking of the remaining VOC control options for the Girard Point marine loading operation for non-gasoline loading (assuming that the existing marine vapor control system would not be utilized). The control options are listed in descending order of control effectiveness.

[12] US EPA Technical Bulletin, *Choosing An Adsorption System for VOC: Carbon, Zeolite, or Polymers*, EPA 456/F-99-004, May 1999.

Table 3-11 Girard Point Marine Non-Gasoline Loading Operation - Ranking of VOC Control Options

Control Option	Control Efficiency
Thermal Incinerator	98%
Flare	98%
Adsorption	98%

3.2.6 Girard Point Marine Non-Gasoline Loading Operation – Economic Analysis

PES conducted an economic analysis for the Girard Point marine loading operation with the assumption that the existing marine vapor control system would not be utilized for non-gasoline loading. The methodology used in performing this analysis follows the guidelines provided in 25 PA Code §§129.92(b)(3) and (b)(4). The following steps were undertaken in conducting this analysis:

1) To be conservative, PES evaluated the cost effectiveness using potential VOC emissions, which were determined from the maximum expected non-gasoline material throughput, maximum expected vapor pressures of loaded materials, and USEPA AP-42 Section 5.2 emissions calculations (See **Attachment B** - Case-by-Case RACT Cost Effectiveness Analysis for details);

2) Each control option was assigned a control efficiency for VOC removal. A single number was used, usually a mid-point in generally-accepted ranges of control efficiencies. The ranges of efficiencies were determined from a collection of data obtained from previous experience, design analysis and most predominantly, from published literature;

3) For each control option, post-control emissions were calculated;

4) Cost effectiveness was calculated for each control option using the methodology in the regulations and in the "OAQPS Control Cost Manual" (EPA/452/B-02-001). Total annual costs are the sum of operating and maintenance (O&M) costs and capital recovery costs. The capital recovery costs assume the equipment will be amortized over a 10-year time frame at 20 percent interest, the rate PES uses for evaluating

capital projects[13]. Total capital required to implement the various control options and operating and maintenance costs were estimated using USEPA's *Vapor Controls for Barge Loading of Gasoline* (USEPA 903R83004) – December 1983, design analysis, and PES operating experience.

5) Capital and O&M Costs were scaled up to 2013 dollar amounts using *Chemical Engineering* cost indices.

6) The control options are listed in descending order of control efficiencies in an array.

Table 3-12, located below, summarizes the cost effectiveness of each VOC control technology for the Girard Point marine loading operation. **Attachment B** includes details for this source including an evaluation of the baseline VOC emissions ("pre-control"), emission reduction potentials, and estimated emissions after the application of each control option ("post-control emissions"). The cost evaluations are presented for each control option, and the controls are listed in descending order of control efficiency. Also, for each control option, capital costs, O&M costs, total annual cost, cost effectiveness are presented.

Table 3-12 Girard Point Marine Non-Gasoline Loading Operation - VOC Control Cost Effectiveness

Control Option	VOC Cost Effectiveness ($/Ton)
Thermal Incinerator	116,267
Flare	62,828
Adsorption	59,489

As shown in **Table 3-12** above based on potential emissions, there were no new, additional VOC controls that were found to be cost effective for the Girard Point marine loading operation for non-gasoline loading (assuming that the existing marine vapor control system would not be utilized).

[13] In conjunction with Plan Approval 12195, the RACT cost effectiveness of NO_x controls for seven heaters (Unit 231-B101, Unit 865-11H1, Unit 865-11H2, Unit 210-H101, Unit 210-H201A/B, Unit 866-12H1, and Unit 868-8H101) was evaluated using a 21.83 percent interest rate, which was the cost of borrowing capital for PES at that time.

3.2.7 Point Breeze Marine Loading Operation

The Point Breeze marine loading operation is capable of loading materials at a nominal rate of 2,000 bbl/hr. This marine loading operation is only used to load materials with RVP of 4.0 psia or lower. As described in **Sections 3.2.8 through 3.2.11** below, PES evaluated add-on control options for control of VOC loading vapors from non-gasoline loading associated with this source.

3.2.8 Point Breeze Marine Loading Operation – Available VOC Control Options

The sections below provide an overview of the technologies available for control of VOC emissions for marine loading operations located at the Refineries. The technologies selected for consideration are listed below and are based on USEPA's *Air Pollution Control Cost Manual Sixth Edition* EPA/452/B-02-001 - January 2002. The technologies are:

- Thermal Incinerator;
- Flare;
- Condenser; and
- Adsorption.

3.2.8.1 Thermal Incinerator

Incineration, or thermal oxidation, is the process of oxidizing combustible materials by raising the temperature of the material above its auto-ignition point in the presence of oxygen, and maintaining it at high temperature for sufficient time to complete combustion to carbon dioxide and water. Most thermal units are designed to provide no more than 1 second of residence time to the waste gas with typical temperatures of 1,200 to 2,000°F.

VOC reduction levels using thermal incinerators range up to 98% and beyond.

3.2.8.2 Flare

Flaring is a VOC combustion control process in which the VOC containing stream is piped to a remote, usually elevated, location and burned in an open flame in the open air using a specially designed burner tip, auxiliary fuel, and steam or air to promote mixing for nearly complete VOC destruction.

VOC reduction levels using flares range up to 98%.

3.2.8.3 *Condenser*

Condensation is a separation technique in which one or more volatile components of a vapor mixture are separated from the remaining vapors through saturation followed by a phase change. The phase change from gas to liquid can be achieved in two ways: (a) the system pressure can be increased at a given temperature, or (b) the temperature may be lowered at a constant pressure. In a two-component system where one of the components is non-condensible (e.g., air), condensation occurs at dew point (saturation) when the partial pressure of the volatile compound is equal to its vapor pressure. Refrigeration is often employed to obtain the low temperatures required for acceptable removal efficiencies. The basic equipment required for a refrigerated condenser system includes a VOC condenser, a refrigeration unit(s), and auxiliary equipment (e.g., precooler, recovery/storage tank, pump/blower, and piping).

VOC reduction levels using condensers range up to 90%. Note that for the Point Breeze marine loading operation, based on the composition of the VOC being captured, the maximum VOC reduction achievable is 61% (See **Attachment B** - Case-by-Case RACT Cost Effectiveness Analysis for details).

3.2.8.4 *Adsorption*

Adsorption is a phenomenon where VOC gas molecules passing through a bed of solid particles (in this case activated carbon) are selectively held there by attractive forces which are weaker and less specific than those of chemical bonds. During adsorption, a VOC gas molecule migrates from the gas stream to the surface of the carbon where it is held by physical attraction. Most gases ("adsorbates") can be removed ("desorbed") from the carbon adsorbent by heating to a sufficiently high temperature, usually via steam or hot combustion gases, or by reducing the pressure to a sufficiently low value (vacuum desorption).

Fixed-bed adsorbers may be operated in either intermittent or continuous modes. In intermittent operation, the adsorber removes VOC for a specified time (the "adsorption time"), which corresponds to the time during which the controlled source is emitting VOC. After the adsorber and the source are shut down, the unit begins the desorption cycle during which the captured VOC is removed from the carbon. This cycle, in turn, consists of three steps: (1) regeneration of the carbon by heating, generally by blowing steam through the bed in the direction opposite to the gas flow; (2) drying of the bed, with compressed air or a fan; and (3) cooling the bed to its operating temperature via a fan.

VOC reduction levels using adsorption range from 95 to 98%[14].

3.2.9 *Point Breeze Marine Loading Operation – Technical Feasibility*

All identified VOC control technologies for the Point Breeze marine loading operation were found to be technically feasible.

3.2.10 *Point Breeze Marine Loading Operation – Ranking of VOC Control Options*

Table 3-13 provides a ranking of the VOC control options for the Point Breeze marine loading operation. The control options are listed in descending order of control effectiveness.

Table 3-13 Point Breeze Marine Loading Operation - Ranking of VOC Control Options

Control Option	Control Efficiency
Thermal Incinerator	98%
Flare	98%
Adsorption	98%
Condenser	61%

3.2.11 *Point Breeze Marine Loading Operation – Economic Analysis*

PES conducted an economic analysis for the Point Breeze marine loading operation with the assumption that no gasoline materials are loaded or plan to be loaded at this source. The methodology used in performing this analysis follows the guidelines provided in 25 PA Code §§129.92(b)(3) and (b)(4). The following steps were undertaken in conducting this analysis:

1) To be conservative, PES evaluated the cost effectiveness using potential VOC emissions, which were determined from the maximum expected non-gasoline material throughput, maximum expected vapor pressures of loaded materials, and USEPA AP-42 Section 5.2 emissions calculations (See **Attachment B** - Case-by-Case RACT Cost Effectiveness Analysis for details);

2) Each control option was assigned a control efficiency for VOC removal. A single number was used, usually a mid-point in generally-accepted

[14] US EPA Technical Bulletin, *Choosing An Adsorption System for VOC: Carbon, Zeolite, or Polymers*, EPA 456/F-99-004, May 1999.

ranges of control efficiencies. The ranges of efficiencies were determined from a collection of data obtained from previous experience, design analysis and most predominantly, from published literature;

3) For each control option, post-control emissions were calculated;

4) Cost effectiveness was calculated for each control option using the methodology in the regulations and in the "OAQPS Control Cost Manual" (EPA/452/B-02-001). Total annual costs are the sum of operating and maintenance (O&M) costs and capital recovery costs. The capital recovery costs assume the equipment will be amortized over a 10-year time frame at 20 percent interest, the rate PES uses for evaluating capital projects[15]. Total capital required to implement the various control options and operating and maintenance costs were estimated using USEPA's *Vapor Controls for Barge Loading of Gasoline* (USEPA 903R83004) – December 1983, design analysis, and PES operating experience.

5) Capital and O&M Costs were scaled up to 2013 dollar amounts using *Chemical Engineering* cost indices.

6) The control options are listed in descending order of control efficiencies in an array.

Table 3-14, located below, summarizes the cost effectiveness of each VOC control technology for the Point Breeze marine loading operation. **Attachment B** includes details for this source including an evaluation of the baseline VOC emissions ("pre-control"), emission reduction potentials, and estimated emissions after the application of each control option ("post-control emissions"). The cost evaluations are presented for each control option, and the controls are listed in descending order of control efficiency. Also, for each control option, capital costs, O&M costs, total annual cost, cost effectiveness are presented.

[15] In conjunction with Plan Approval 12195, the RACT cost effectiveness of NO_x controls for seven heaters (Unit 231-B101, Unit 865-11H1, Unit 865-11H2, Unit 210-H101, Unit 210-H201A/B, Unit 866-12H1, and Unit 868-8H101) was evaluated using a 21.83 percent interest rate, which was the cost of borrowing capital for PES at that time.

Table 3-14 Point Breeze Marine Loading Operation - VOC Control Cost Effectiveness

Control Option	VOC Cost Effectiveness ($/Ton)
Thermal Incinerator	23,365
Flare	19,254
Adsorption	14,798
Condenser	41,525

As shown in **Table 3-14** above based on potential emissions, there were no new, additional VOC controls that were found to be cost effective for the Point Breeze marine loading operation.

For the combustion type control devices (thermal incinerator and flare) evaluated for the Point Breeze marine loading operation, additional enrichment and pilot fuel would be required, which may not be available at this source currently. This analysis for the Point Breeze marine loading operation does not account for the engineering or material costs to add the enrichment and pilot fuel for the control devices.

3.2.12 VOC RACT Summary

Table 3-15 below provides the VOC RACT affected sources and a summary of VOC RACT requirements.

Table 3-15 VOC RACT Summary

Location	Source Name	VOC RACT Summary
Point Breeze/Girard Point	Combustion Units (all sources listed in Tables 2-1 and 2-2)	No RACT option for controlling VOC emissions
Point Breeze/Girard Point	Cooling Towers	MACT inspections are RACT 210 Crude - 29,600 gpm 868 - 19,700 gpm Complex - 35,000 gpm 864 - 18,000 gpm 137 – 36,300 gpm 433 – 35,300 gpm 490 – 75,000 gpm 1232 – 57,000 gpm
Point Breeze	868 Fluid Catalytic Cracking Unit	Full-burn unit, no RACT proposed
Girard Point	1232 Fluid Catalytic Cracking Unit	Case-by case RACT applies. Partial-burn unit, good combustion practices proposed

Location	Source Name	VOC RACT Summary
Point Breeze/Girard Point/Schuylkill River Tank Farm	Equipment Leaks	Exempt - meets PA Code §129.58
Point Breeze/Girard Point/ Schuylkill River Tank Farm	Wastewater Treatment Plant Oil/Water separators (Carbon canisters)	Exempt - meets PA Code §129.55
Point Breeze/Girard Point/ Schuylkill River Tank Farm	Storage Tanks	Exempt - meets PA Code §§129.56 and 129.57
Point Breeze	Stormwater Tank 7308, 7300	Exempt - meets PA Code §§129.56 and 129.57
Girard Point	Degreasers	Exempt - meets PA Code §129.63
Point Breeze	Loading Operations (Wharf)	Case-by-case RACT applies. No gasoline loading. No cost effective control for loading of lower vapor pressure materials.
Girard Point	Loading Operations (Wharf)	Case-by-case RACT applies. No cost effective control for loading of non-gasoline materials. Currently installed marine vapor control system proposed as RACT for gasoline loading.
Girard Point/ Schuylkill River Tank Farm	Loading Operations (Truck Rack)	Exempt - Meets AMR V, Section V
Point Breeze/Girard Point	Diesel-Fired Emergency and Fire Pump RICE	Exempt - meets PA Code §129.93
Point Breeze/Girard Point	Non-emergency Diesel-Fired RICE	Case-by case RACT applies. Good combustion practices

4.0 RACT IMPLEMENTATION AND SCHEDULE

This section provides details about PES' RACT implementation plan and schedule as required by 25 PA Code §129.92(a)(6). The NO_x and VOC sources are discussed in Sections 4.1 and 4.2, respectively.

4.1 NO_X RACT SOURCES

This updated RACT analysis found there are some changes that appear appropriate to update the 1999 NO_x RACT analysis for several NO_x RACT affected sources.

As **Table 4-1** below shows, the current RACT Plan Approval is proposed to be updated to include sources that have been modified through AMS Plan Approvals, modified to comply with the Consent Decree, and newly installed sources since the 1999 NO_x RACT analysis.

Table 4-1 Updates to NO_x RACT Sources

Location	Source Name	Change from 1999 NO_x RACT	Reason for Change
Point Breeze	Unit 868 FCCU	Reduced NO_x emission rate[1]	Compliance with Consent Decree
Point Breeze	Unit 870-H01 Heater	New Source	New Source
Point Breeze	Unit 870-H02 Heater	New Source	New Source
Point Breeze	Unit 859-1H1 Heater	New Source	New Source
Girard Point	Unit 137 F-3 Heater	Reduced NO_x emission rate[1]	Compliance with Consent Decree
Girard Point	Unit 1332 H-2 Heater	Reduced NO_x emission rate[1]	Modified Source
Girard Point	Unit 1332 H-400 Heater	Reduced NO_x emission rate[1]	Compliance with Consent Decree
Girard Point	Unit 1332 H-401 Heater	Reduced NO_x emission rate[1]	Compliance with Consent Decree
Girard Point	Unit 433 H-1 Heater	Increased permitted capacity and reduced NO_x emission rate[1]	Modified Source
Girard Point	Unit 1232 FCCU	Reduced NO_x emission rate[1]	Compliance with Consent Decree
Girard Point	#3 Boilerhouse Boiler #37	Reduced NO_x emission rate[1]	Compliance with Consent Decree

Location	Source Name	Change from 1999 NO_x RACT	Reason for Change
Girard Point	#3 Boilerhouse Boiler #39	Reduced NO_x emission rate[1]	Compliance with Consent Decree
Girard Point	#3 Boilerhouse Boiler #40	Reduced NO_x emission rate[1]	Compliance with Consent Decree
Point Breeze/ Girard Point	Diesel-Fired RICE IC-002	Additional Identified Affected Source[2]	Additional Identified Affected Source[2]
Point Breeze/ Girard Point	Diesel-Fired RICE IC-005	Additional Identified Affected Source[2]	Additional Identified Affected Source[2]
Point Breeze/ Girard Point	Diesel-Fired RICE IC-006	Additional Identified Affected Source[2]	Additional Identified Affected Source[2]
Point Breeze/ Girard Point	Diesel-Fired RICE IC-007	Additional Identified Affected Source[2]	Additional Identified Affected Source[2]
Point Breeze/ Girard Point	Diesel-Fired RICE IC-008	Additional Identified Affected Source[2]	Additional Identified Affected Source[2]

1 For all sources that have been modified through an AMS Plan Approval, there has been no increase to emissions both on a short-term (pounds per hour [lb/hr]) or long-term (TPY) basis.

2 These sources are not found in the 1999 RACT Plan Approval. PES has conservatively included these sources in this update. In parallel, PES is assessing if each RICE meets the Presumptive RACT limitations for RICE less than 500 HP (gross) which are set and maintaining 4° retarded relative to standard timing as described in 25 PA Code §129.93(c)(3).

The updates outlined in **Table 4-1** above are proposed to ensure consistency with the Title V permit and limitations established by the Consent Decree. However, none of these updates require changes to the RACT Implementation Schedule in the current RACT Plan Approval amended on January 9, 2015. PES proposes that on-going compliance with the Implementation Schedule in the RACT Plan Approval amended January 9, 2015 satisfies NO_x RACT.

4.2 *VOC RACT SOURCES*

This updated RACT analysis found there are some changes that appear appropriate to update the 1999 VOC RACT analysis for several VOC RACT affected sources.

As **Table 4-2** below shows, the RACT Plan Approval amended January 9, 2015 is proposed to be updated to include sources that have new case-by-case analyses.

Table 4-2 Case-By-Case VOC RACT Sources

Location	Source Name
Girard Point	Unit 1232 FCCU
Girard Point	Loading Operations (Wharf)
Point Breeze	Loading Operations (Wharf)
Point Breeze/ Girard Point	Diesel-Fired RICE IC-002
Point Breeze/ Girard Point	Diesel-Fired RICE IC-005
Point Breeze/ Girard Point	Diesel-Fired RICE IC-006
Point Breeze/ Girard Point	Diesel-Fired RICE IC-007
Point Breeze/ Girard Point	Diesel-Fired RICE IC-008

The updates outlined in **Table 4-2** above are proposed to incorporate additional VOC RACT sources. However, none of these updates require changes to the RACT Implementation Schedule in the current RACT Plan Approval amended on January 9, 2015. PES proposes that on-going compliance with the Implementation Schedule in the RACT Plan Approval amended January 9, 2015 satisfies VOC RACT.

5.0 *PROPOSED TESTING, MONITORING, RECORDKEEPING, AND REPORTING PROCEDURES TO DEMONSTRATE RACT*

This section provides details about PES' RACT proposal for testing, monitoring, recordkeeping, and reporting procedures to demonstrate compliance with the RACT applications as required by 25 PA Code §129.92(a)(7). The NO_x and VOC sources are discussed in Sections 5.1 and 5.2, respectively.

5.1 *NO_X RACT SOURCES*

This updated RACT analysis found there are some changes needed to update the 1999 NO_x RACT analysis for several NO_x RACT affected sources. **Table 5-1** below shows the updated NO_x emission rates for certain sources that will update the table in Section 4.C. Testing Requirements and Stack Emission Limitations of the RACT Plan Approval.

Table 5-1 Updates to NO_x RACT Emission Rates

Location	Source Name	Gas Limitation (lb NO_x/MMBtu)
Point Breeze	Unit 859-1H1 Heater	0.02
Girard Point	Unit 137 F-3 Heater	0.06
Girard Point	Unit 1332 H-2 Heater	0.04
Girard Point	Unit 1332 H-400 Heater	0.06
Girard Point	Unit 1332 H-401 Heater	0.06
Girard Point	Unit 433 H-1 Heater	0.035

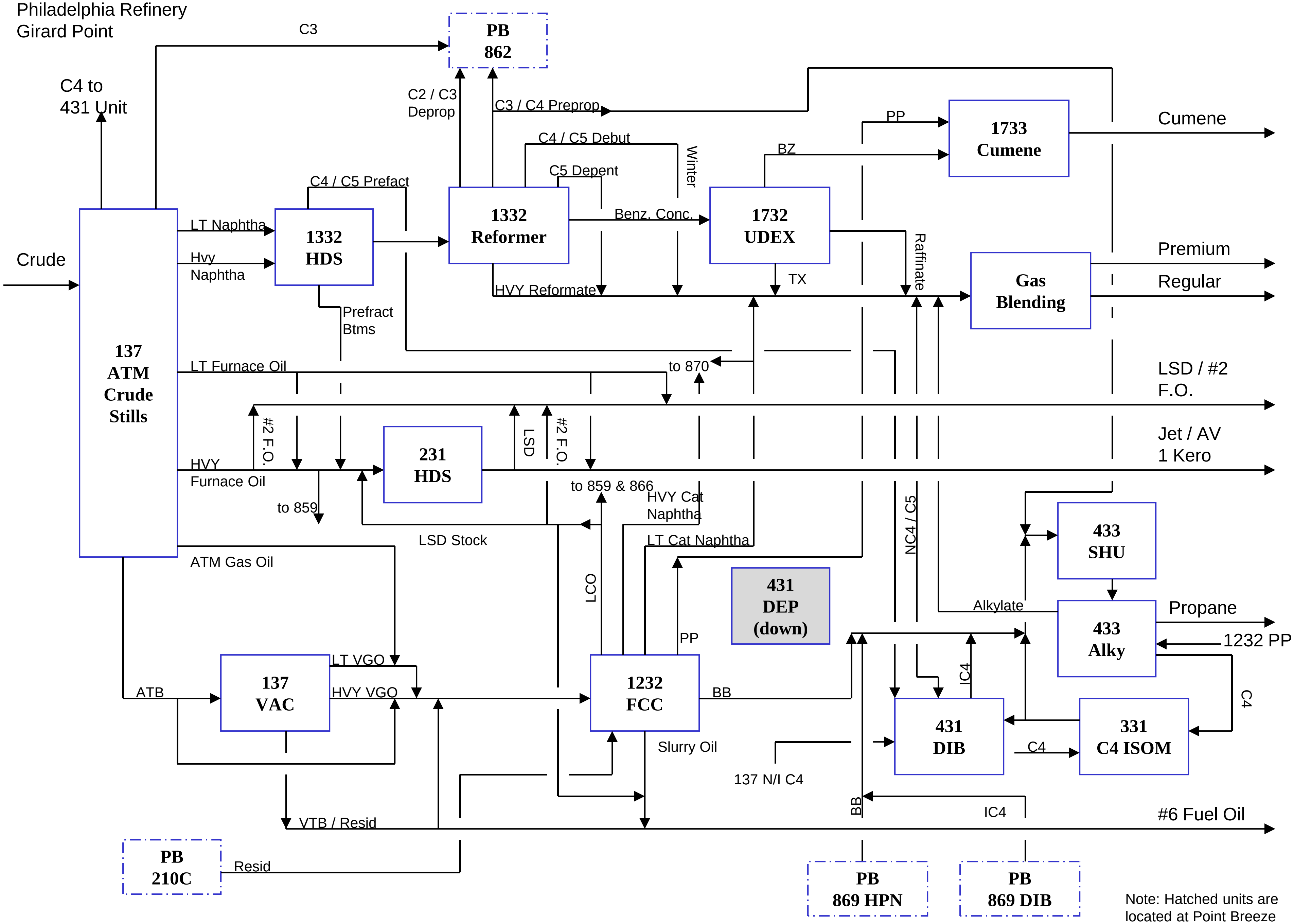
Other than the updates noted in **Table 5-1** above, PES proposes that on-going compliance with the testing, monitoring, recordkeeping, and reporting procedures in the RACT Plan Approval amended January 9, 2015 satisfies NO_x RACT.

5.2 *VOC RACT SOURCES*

The RACT Plan Approval amended January 9, 2015 does not address VOC RACT monitoring, recordkeeping, and reporting procedures for the VOC RACT affected sources in **Table 4-2** above. PES proposes that the RACT Plan Approval amended January 9, 2015 include the appropriate monitoring, recordkeeping, and reporting procedures from the Title V Operating Permit V06-016 for these sources.

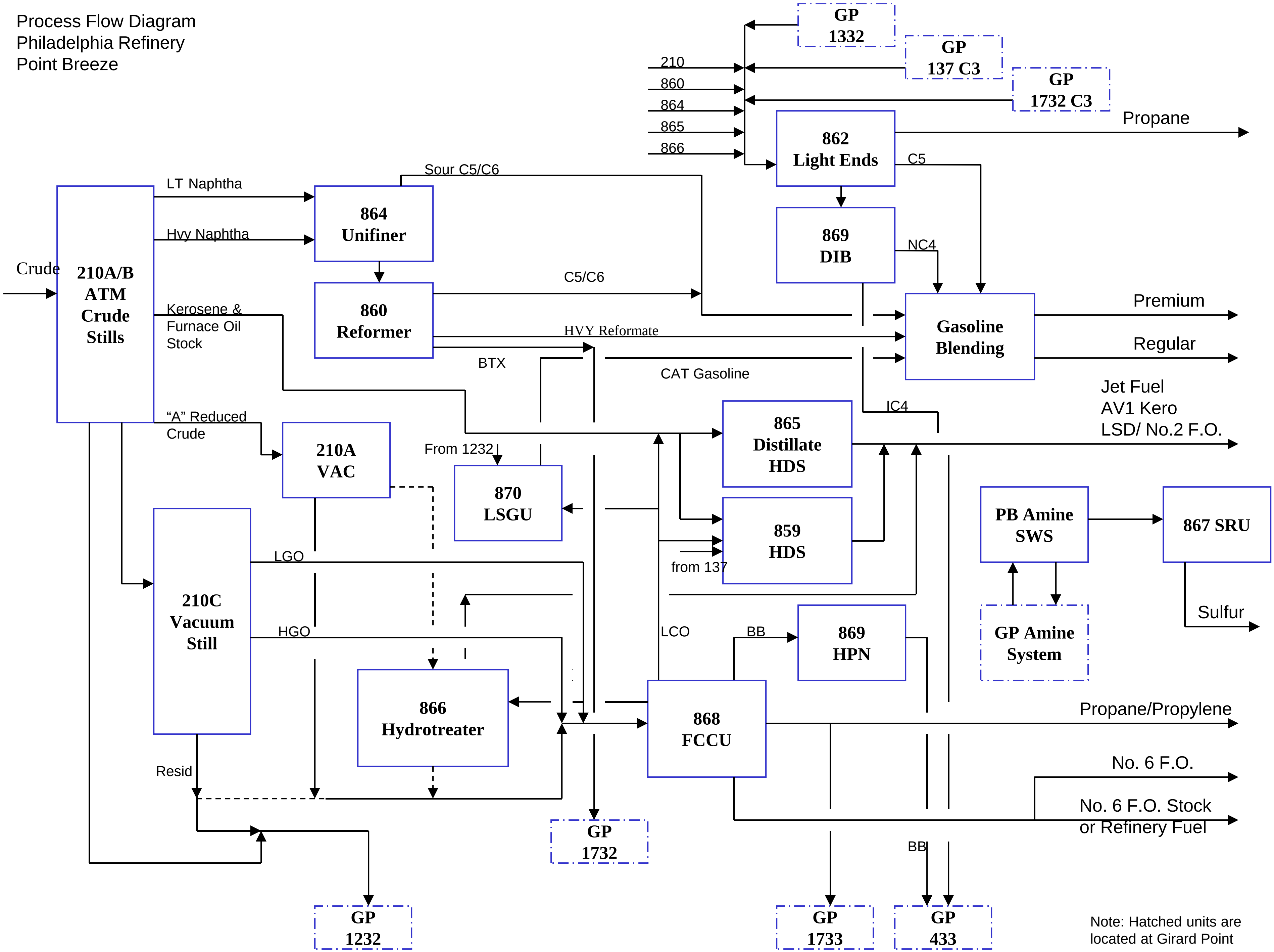
Attachment A Simplified Process Flow Diagrams

Process Flow Diagram
Philadelphia Refinery
Girard Point



Note: Hatched units are located at Point Breeze

Process Flow Diagram
Philadelphia Refinery
Point Breeze



Note: Hatched units are located at Girard Point

Attachment B
Case-by-Case RACT Cost Effectiveness Analysis

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NOx RACT Control Cost Effectiveness

Cost Effectiveness ($/Ton)	**NOx Control Option**						
	ULNB & SCR	SCR	ULNB	LNB & SNCR	LNB & FGR	SNCR	LoTOx
Unit 210-13H1	Infeasible	Infeasible	3,151	9,998	Infeasible	13,921	Infeasible
Unit 860-2H2	Infeasible	Infeasible	Infeasible	Infeasible	Infeasible	5,631	Infeasible
Unit 860-2H3	Infeasible	Infeasible	Infeasible	Infeasible	Infeasible	9,552	Infeasible
Unit 860-2H4	Infeasible	Infeasible	2,999	16,808	Infeasible	6,641	Infeasible
Unit 860-2H5	Infeasible	Infeasible	Infeasible	Infeasible	Infeasible	9,786	Infeasible
Unit 860-2H7	Infeasible	Infeasible	Infeasible	Infeasible	Infeasible	12,605	Infeasible
Unit 864-PH1	Infeasible	Infeasible	9,528	7,796	Infeasible	11,045	Infeasible
Unit 864-PH11	Infeasible	Infeasible	12,967	9,070	Infeasible	12,898	Infeasible
Unit 864-PH12	Infeasible	Infeasible	17,680	11,561	Infeasible	15,135	Infeasible
Unit 870-H01	ULNB installed	73,298	ULNB installed	ULNB installed	ULNB installed	49,070	Infeasible
Unit 870-H02	ULNB installed	92,541	ULNB installed	ULNB installed	ULNB installed	56,784	Infeasible
Unit 859-1H1	ULNB installed	127,640	ULNB installed	ULNB installed	ULNB installed	85,399	Infeasible
Unit 137 F-1	9,648	6,578	4,331	8,232	7,224	5,883	Infeasible
Unit 137 F-2	14,897	8,492	8,203	13,023	13,228	6,340	Infeasible
Unit 137 F-3	ULNB installed	51,523	ULNB installed	ULNB installed	ULNB installed	32,261	Infeasible
Unit 1332 H-2	ULNB installed	77,200	ULNB installed	ULNB installed	ULNB installed	48,210	Infeasible
Unit 1332 H-400	SCR installed	SCR installed	11,337	SCR installed	SCR installed	SCR installed	Infeasible
Unit 1332 H-401	SCR installed	SCR installed	9,051	SCR installed	SCR installed	SCR installed	Infeasible
Unit 433 H-1	ULNB installed	50,368	ULNB installed	ULNB installed	ULNB installed	39,879	Infeasible
Unit 1232 B-104	ULNB installed	16,570	ULNB installed	ULNB installed	ULNB installed	10,772	Infeasible
#3 Boilerhouse Boiler #37	ULNB & FGR installed	32,829	ULNB & FGR installed	ULNB & FGR installed	ULNB & FGR installed	13,221	Infeasible
#3 Boilerhouse Boiler #39	ULNB & FGR installed	32,829	ULNB & FGR installed	ULNB & FGR installed	ULNB & FGR installed	13,221	Infeasible
#3 Boilerhouse Boiler #40	ULNB & FGR installed	30,139	ULNB & FGR installed	ULNB & FGR installed	ULNB & FGR installed	11,823	Infeasible
Unit 868 FCCU	Infeasible	30,794	Infeasible	Infeasible	Infeasible	10,679	13,328
Diesel-Fired RICE IC-002	Infeasible	8,294	Infeasible	Infeasible	Infeasible	Infeasible	Infeasible
Diesel-Fired RICE IC-005	Infeasible	6,395	Infeasible	Infeasible	Infeasible	Infeasible	Infeasible
Diesel-Fired RICE IC-006	Infeasible	5,959	Infeasible	Infeasible	Infeasible	Infeasible	Infeasible
Diesel-Fired RICE IC-007	Infeasible	7,950	Infeasible	Infeasible	Infeasible	Infeasible	Infeasible
Diesel-Fired RICE IC-008	Infeasible	19,716	Infeasible	Infeasible	Infeasible	Infeasible	Infeasible

Cost Effectiveness ($/Ton)	**VOC Control Option**			
	Thermal Incinerator	Flare	Adsorption	Condenser
Girard Point Wharf Loading	116,267	62,828	59,489	- - -
Point Breeze Wharf Loading	23,365	19,254	14,798	41,525

Assumptions for all equipment:

Number of Years (n)	10
Number of Years (n) - SCR/SNCR	20
Interest Rate, % (i)	20
Annualized Cost Factor (ACF)	0.239

$$ACF = \frac{i(1+i)^n}{(1+i)^n - 1}$$

EPA Air Pollution Control Cost Manual, Sixth Edition, EPA/452/B-02-001 - Equation 2.8a

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NOx RACT Control Cost Effectiveness

Year	*Chemical Engineering* Cost Index
1982	314
1986	318.4
1988	342.5
1990	357.6
1991	361
1994	368.1
1998	389.5
1999	390.6
2000	394.1
2002	395.6
2013	567.3
Cost Escalation Factor for SCR[1]	1.78
Cost Escalation Factor for LNB, SNCR, and FGR[2]	1.57
Cost Escalation Factor for Girard Point Lost Production costs	1.45

[1] Cost data from *Alternative Control Techniques Document - NO_x Emissions from Process Heaters (Revised)* - EPA-453/R-93-034 scaled from 1986 to 2012 costs using the Cost Escalation Factor.

[2] Cost data from *Alternative Control Techniques Document - NO_x Emissions from Process Heaters (Revised)* - EPA-453/R-93-034 scaled from 1991 to 2012 costs using the Cost Escalation Factor.

Source		**Heater/Boiler Control Efficiency**	**Comment**
Ultra-low NO_x burners and Selective Catalytic Reduction	ULNB & SCR	96%	Combining both removal efficiencies of ULNB and SCR.
Selective Catalytic Reduction	SCR	85%	Based on Unit 1332 performance.
Ultra-low NO_x burners	ULNB	50% to 86%	Based on vendor experience at 0.03 lb/MMBtu.
Low NO_x burners and Selective Non-Catalytic Reduction	LNB & SNCR	70%	Combining both removal efficiencies. Assumes 50% control efficiency for LNB and 40% control efficiency for SNCR. *Alternative Control Techniques Document - NO_x Emissions from Process Heaters (Revised)* - EPA-453/R-93-034.
Low NO_x burners and Flue Gas Recirculation	LNB & FGR	55%	*Alternative Control Techniques Document - NO_x Emissions from Process Heaters (Revised)* - EPA-453/R-93-034.
Selective Non-Catalytic Reduction	SNCR	40%	Heater stack temperatures below 700°F results in low NO_x removal efficiency. EPA Air Pollution Control Technology Fact Sheet - EPA-452/F-03-031.

Source Name	Permitted Capacity (MMBtu/hr)	Permitted Capacity Source	Baseline Firing Rates (MMBtu/hr)	Baseline Year	NO_x Emission Rate (lb/MMBtu)	Permitted Emission Rate Source	Number of Burners	Summary of Technical Infeasibilities for NO_x Control
Unit 210-13H1	235.4	Case-by-Case RACT	170.2	2013	0.104	Case-by-Case RACT	24	SCR would not physically fit the plot space; therefore, SCR is infeasible. FGR would not physically fit the plot space; therefore, it is infeasible.
Unit 860-2H2	69.8	Case-by-Case RACT	28.4	2013	0.350	Case-by-Case RACT	3	SCR would not physically fit the plot space and there is not adequate pressure to overcome the SCR pressure drop; therefore, SCR is infeasible. With normal burners this heater has experienced flame impingement. LNB and ULNB flames are longer and are not suitable for this heater. Also, the floor of the heater is too low to physically allow the installation of LNB or ULNB. FGR installation would require the installation of mechanical draft burners, which is a major re-design of the unit; therefore FGR is infeasible.
Unit 860-2H3	174.7	Case-by-Case RACT	106.0	2013	0.163	Case-by-Case RACT	4	SCR would not physically fit the plot space and there is not adequate pressure to overcome the SCR pressure drop; therefore, SCR is infeasible. With normal burners this heater has experienced flame impingement. LNB and ULNB flames are longer and are not suitable for this heater. Also, the floor of the heater is too low to physically allow the installation of LNB or ULNB. FGR installation would require the installation of mechanical draft burners, which is a major re-design of the unit; therefore FGR is infeasible.
Unit 860-2H4	99.4	Case-by-Case RACT	55.9	2013	0.270	Case-by-Case RACT	3	SCR would not physically fit the plot space and there is not adequate pressure to overcome the SCR pressure drop; therefore, SCR is infeasible. FGR installation would require the installation of mechanical draft burners, which is a major re-design of the unit; therefore FGR is infeasible.
Unit 860-2H5	155.0	Case-by-Case RACT	113.2	2013	0.163	Case-by-Case RACT	4	SCR would not physically fit the plot space and there is not adequate pressure to overcome the SCR pressure drop; therefore, SCR is infeasible. With normal burners this heater has experienced flame impingement. LNB and ULNB flames are longer and are not suitable for this heater. Also, the floor of the heater is too low to physically allow the installation of LNB or ULNB. FGR installation would require the installation of mechanical draft burners, which is a major re-design of the unit; therefore FGR is infeasible.
Unit 860-2H7	59.0	Case-by-Case RACT	37.1	2013	0.157	Case-by-Case RACT	4	SCR would not physically fit the plot space and there is not adequate pressure to overcome the SCR pressure drop; therefore, SCR is infeasible. With normal burners this heater has experienced flame impingement. LNB and ULNB flames are longer and are not suitable for this heater. Also, the floor of the heater is too low to physically allow the installation of LNB or ULNB. FGR installation would require the installation of mechanical draft burners, which is a major re-design of the unit; therefore FGR is infeasible.
Unit 864-PH1	80.0	Case-by-Case RACT	30.7	2013	0.167	Case-by-Case RACT	8	SCR would not physically fit the plot space and there is not adequate pressure to overcome the SCR pressure drop; therefore, SCR is infeasible. FGR installation would require the installation of mechanical draft burners, which is a major re-design of the unit; therefore FGR is infeasible.
Unit 864-PH11	74.0	Case-by-Case RACT	42.5	2013	0.145	Case-by-Case RACT	8	SCR would not physically fit the plot space and there is not adequate pressure to overcome the SCR pressure drop; therefore, SCR is infeasible. FGR installation would require the installation of mechanical draft burners, which is a major re-design of the unit; therefore FGR is infeasible.
Unit 864-PH12	85.1	Case-by-Case RACT	53.4	2013	0.119	Case-by-Case RACT	12	SCR would not physically fit the plot space and there is not adequate pressure to overcome the SCR pressure drop; therefore, SCR is infeasible. FGR installation would require the installation of mechanical draft burners, which is a major re-design of the unit; therefore FGR is infeasible.
Unit 868 FCCU	50 MBPD feed rate	AMS Plan Approval 00184	N/A	2013	50 ppmvd on 365-day average (130.2 TPY)	Proposed limit based on Consent Decree Low NO_x Combustion Promoter Study	N/A	None.
Unit 870-H01	97.0	AMS Plan Approval 02184	33.8	2013	0.035	AMS Plan Approval 02184	8	None.
Unit 870-H02	53.0	AMS Plan Approval 02184	31.8	2013	0.035	AMS Plan Approval 02184	4	None.
Unit 859-1H1	98.0	AMS Plan Approval 06144	74.6	2013	0.020	AMS Plan Approval 06144	8	None.
Unit 137 F-1	415.0	Case-by-Case RACT	312.4	2013	0.230	Case-by-Case RACT	32	None.
Unit 137 F-2	155.0	Case-by-Case RACT	116.5	2013	0.257	Case-by-Case RACT	16	None.
Unit 137 F-3	60.0	Case-by-Case RACT	46.2	2013	0.060	AMS Plan Approval 07163	6	None.
Unit 1332 H-2	60.0	Case-by-Case RACT	29.9	2013	0.040	AMS Plan Approval 05124	8	None.

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NOx RACT Control Cost Effectiveness

Source Name	Permitted Capacity (MMBtu/hr)	Permitted Capacity Source	Baseline Firing Rates (MMBtu/hr)	Baseline Year	NO_x Emission Rate (lb/MMBtu)	Permitted Emission Rate Source	Number of Burners	Summary of Technical Infeasibilities for NO_x Control
Unit 1332 H-400	186.0	Case-by-Case RACT	102.4	2013	0.060	AMS Plan Approval 09040	36	None.
Unit 1332 H-401	233.0	Case-by-Case RACT	130.3	2013	0.060	AMS Plan Approval 09040	36	None.
Unit 433 H-1	260.0	AMS Plan Approval 06050	147.6	2013	0.035	AMS Plan Approval 06050	18	None.
Unit 1232 B-104	70.0	Case-by-Case RACT	4.7	2011	0.177	Case-by-Case RACT	12	None.
Unit 1232 FCCU	100 MBPD feed rate	AMS Plan Approval 04322	N/A	2013	10 ppmvd on 365-day average (208.28 TPY)	AMS Plan Approval 11353	N/A	None.
#3 Boilerhouse Boiler #37	495.0	Case-by-Case RACT	302.9	2013	0.040	Consent Decree, AMS Plan Approval 08080	8	None.
#3 Boilerhouse Boiler #39	495.0	Case-by-Case RACT	278.8	2013	0.040	Consent Decree, AMS Plan Approval 08080	8	None.
#3 Boilerhouse Boiler #40	660.0	Case-by-Case RACT	371.4	2013	0.040	Consent Decree, AMS Plan Approval 08080	10	None.
Diesel-Fired RICE IC-002	1.4	AMS Installation Permit 11345, 11362-74	1.4	N/A	4.4	AP-42 Section 3.3	N/A	SNCR requires exhaust temperatures >1700°F for effective control and therefore is considered technically infeasible.
Diesel-Fired RICE IC-005	0.2	AMS Installation Permit 11345, 11362-74	0.2	N/A	4.4	AP-42 Section 3.3	N/A	SNCR requires exhaust temperatures >1700°F for effective control and therefore is considered technically infeasible.
Diesel-Fired RICE IC-006	0.8	AMS Installation Permit 11345, 11362-74	0.8	N/A	2.2	40 CFR §89 (Tier 1)	N/A	SNCR requires exhaust temperatures >1700°F for effective control and therefore is considered technically infeasible.
Diesel-Fired RICE IC-007	0.7	AMS Installation Permit 11345, 11362-74	0.7	N/A	0.7	40 CFR §89 (Tier 3)	N/A	SNCR requires exhaust temperatures >1700°F for effective control and therefore is considered technically infeasible.
Diesel-Fired RICE IC-008	1.5	AMS Installation Permit 11345, 11362-74	1.5	N/A	1.1	40 CFR §89 (Tier 2)	N/A	SNCR requires exhaust temperatures >1700°F for effective control and therefore is considered technically infeasible.

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034
All costs are scaled to 2013 U.S. dollars using the appropriate Cost Escalation Factor.

Capital Cost of Low NO_x Burners (page 6-4 and 6-5):

$$TCI = 30{,}000 + HQ[5{,}230 - (622 \times BQ) + (26.1 \times BQ^2)]$$

Where:
TCI = Total Capital Investment
HQ = heater capacity (GJ/hr)
BQ = burner heat release rate (GJ/hr)
BQ = HQ/NB x (1.158 + 8/HQ)
NB = number of burners

Capital Cost of Ultra-low NO_x Burners:
See the "Vendor Quotation ULNB Costs" tab for capital cost details for Ultra-low NO_x Burners

Capital Cost of Selective Non-Catalytic Reduction (page 6-7):

$$TCI = 31{,}850(HQ)^{0.6}$$

HQ = heater capacity (GJ/hr)

Operating Cost of Selective Non-Catalytic Reduction (page 6-8):

$$NH_3\ cost\ = Q\ \times\ (lb/MMBtu) \times \left(\frac{1\ mole\ NO_x}{46\ lb\ NO_x}\right) \times \left(\frac{17\ lb\ NH_3}{1\ mole\ NH_3}\right) \times \left(\frac{1\ mole\ NH_3}{1\ mole\ NO_x}\right) \times \left(\frac{\$0.125}{lb\ NH_3}\right) \times \left(8{,}760\,\frac{hours}{year}\right)$$

Where:
Q = heater capacity, MMBtu/hr

$$Electricty\ cost = \left(\frac{0.3\ kWh}{ton\ NH_3}\right) \times \left(\frac{ton\ NH_3}{year}\right) \times \left(\frac{\$0.06}{kWh}\right)$$

Where:

$$\frac{ton\ NH_3}{year} = Q\ \times\ (lb\ NO_x/MMBtu) \times \left(\frac{1\ mole\ NO_x}{46\ lb\ NO_x}\right) \times \left(\frac{17\ lb\ NH_3}{1\ mole\ NH_3}\right) \times \left(\frac{1\ mole\ NH_3}{1\ mole\ NO_x}\right) \times \left(\frac{ton}{2000\ lb}\right) \times \left(8{,}760\,\frac{hours}{year}\right)$$

Capital Cost of Selective Catalytic Reduction (page 6-8):

$$TCI = 1{,}373{,}000 \times \left(\frac{Q}{48.5}\right)^{0.6} + 49{,}000 \times \left(\frac{Q}{485}\right)$$

Where:
Q = heater capacity, MMBtu/hr

Operating Cost of Selective Catalytic Reduction (page 6-9):

$$NH_3\ cost = Q\ \times\ (lb/MMBtu) \times \left(\frac{1\ mole\ NO_x}{46\ lb\ NO_x}\right) \times \left(\frac{17\ lb\ NH_3}{1\ mole\ NH_3}\right) \times \left(\frac{1\ mole\ NH_3}{1\ mole\ NO_x}\right) \times \left(\frac{\$0.125}{lb\ NH_3}\right) \times \left(\frac{8{,}760\ hours}{year}\right)$$

Where:
Q = heater capacity, MMBtu/hr
Note the capacity factor has been assumed to be equal to 1; therefore, the capacity factor term has been omitted.

$$Catalyst\ Replacement\ Cost = 49{,}000 \times \frac{Q}{48.5}/5\ years$$

$$Electricty\ cost = \left(\frac{0.3\ kWh}{ton\ NH_3}\right) \times \left(\frac{ton\ NH_3}{year}\right) \times \left(\frac{\$0.06}{kWh}\right)$$

Where:

$$\frac{ton\ NH_3}{year} = Q\ \times\ (lb\ NO_x/MMBtu) \times \left(\frac{1\ mole\ NO_x}{46\ lb\ NO_x}\right) \times \left(\frac{17\ lb\ NH_3}{1\ mole\ NH_3}\right) \times \left(\frac{1\ mole\ NH_3}{1\ mole\ NO_x}\right) \times \left(\frac{ton}{2000\ lb}\right) \times \left(8{,}760\,\frac{hours}{year}\right)$$

Capital Cost of Flue Gas Recirculation (page 6-9):

$$TCI = 12{,}800(HQ)^{0.6}$$

Where:
HQ = heater capacity (GJ/hr)

Operating Cost of Flue Gas Recirculation (page 6-10):

$$Electricty\ cost =\ (motor\ hp) \times \left(\frac{0.75\ kW}{hp}\right) \times \left(\frac{8{,}760\ hours}{year}\right) \times \left(\frac{\$0.06}{kWh}\right)$$

Where:
motor hp = FGR fan motor horsepower, (1/5) x (Q)
Q = heater capacity, MMBtu/hr

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Unit 868 FCCU
NO_x Potential Emissions

Unit 868 FCCU - 2013 Actual Emissions

2013 Month	Days	Actual Emissions (lb)	Stackflow (mmscf)	Stackflow (avg mmscf/day)	Throughput (MBbl)	Throughput (avg mbpd)	lb/bbl	lb/mmscf stack flow
Jan	31	15400.15	3832.58	123.63	1361.88	43.93	11.31	4.02
Feb	28	9640.32	3561.57	127.20	1269.34	45.33	7.59	2.71
Mar	31	17447.28	4092.11	132.00	1427.51	46.05	12.22	4.26
Apr	30	17110.93	4142.23	138.07	1454.82	48.49	11.76	4.13
May	31	20667.49	4216.34	136.01	1539.83	49.67	13.42	4.90
Jun	30	23313.70	4180.77	139.36	1413.44	47.11	16.49	5.58
Jul	31	17100.15	4310.67	139.05	1457.55	47.02	11.73	3.97
Aug	31	15227.37	4310.85	139.06	1478.94	47.71	10.30	3.53
Sep	30	13070.94	4068.59	135.62	1387.26	46.24	9.42	3.21
Oct	31	15748.85	4085.76	131.80	1169.85	37.74	13.46	3.85
Nov	30	12804.30	3677.10	122.57	1071.48	35.72	11.95	3.48
Dec	31	14648.74	3886.06	125.36	1052.64	33.96	13.92	3.77
Total	365	96.09						
					Max:		16.49	5.58
					Avg:	44.08	12.00	3.96

Stackflow

Average Stackflow (mmscf/day)	132.51
Average Throughput (mbpd)	44.07
(mmscf/mbbl)	3.01

Projected Stack flow @ 47.5mbpd

142.83 mmscf/day @ conditions (wet, with O_2)
52,132 mmscf/yr

Concentration @ 0% O_2 dry

Measured flow 50 ppmvd (@ 0% O_2)

Concentration Adjusted to Reflect Average Oxygen and Water

$$50\ ppmvd\ @\ 0\%\ O_2 * \left(\frac{20.9 - 1.5\%\ O_2}{20.9}\right) * \left(\frac{100 - 10\%\ H_2O}{100}\right) = 41.77\ ppmv, wet\ with\ 1.5\%\ O_2$$

$$142.83\ \frac{MMSCF}{day} * \frac{day}{24\ hours} * \frac{hour}{60\ mins} * \frac{10^6 SCF}{MMSCF} = 99{,}186\ scfm, wet\ with\ 1.5\%\ O_2$$

Projected Emissions

$$\frac{41.77\ ppmv, wet\ with\ 1.5\%\ O_2}{1{,}000{,}000} * \frac{99{,}186\ scf, wet\ with\ 1.5\%\ O_2}{min} * \frac{lbmol}{385\ scf} * \frac{46.01\ lb\ NO_x}{lbmol} * \frac{60\ min}{hour} * \frac{8{,}760\ hours}{year} * \frac{ton}{2{,}000\ lb} = 130.2\ tons\ NO_x\ per\ year$$

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VOC Potential Emissions

Combustion Sources VOC Potential Emissions

Location	Source	Permitted Capacity (MMBtu/hr)	AP-42 Chapter 1.4, Table 1.4-2 VOC Emission Factor (lb/MMBtu)[1]	VOC Potential Emissions (TPY)[2]
Point Breeze	Unit 210-13H1	235.4	0.0054	5.6
Point Breeze	Unit 860-2H2	69.8	0.0054	1.6
Point Breeze	Unit 860-2H3	174.7	0.0054	4.1
Point Breeze	Unit 860-2H4	99.4	0.0054	2.3
Point Breeze	Unit 860-2H5	155	0.0054	3.7
Point Breeze	Unit 860-2H7	59	0.0054	1.4
Point Breeze	Unit 860-2H8	49.6	0.0054	1.2
Point Breeze	Unit 864-PH1	80	0.0054	1.9
Point Breeze	Unit 864-PH7	45.5	0.0054	1.1
Point Breeze	Unit 864-PH11	74	0.0054	1.7
Point Breeze	Unit 864-PH12	85.1	0.0054	2.0
Point Breeze	Unit 870-H01	97	0.0054	2.3
Point Breeze	Unit 870-H02	53	0.0054	1.3
Point Breeze	Unit 859-1H1	98	0.0054	2.3
Girard Point	Unit 137 F-1	415	0.0054	9.8
Girard Point	Unit 137 F-2	155	0.0054	3.7
Girard Point	Unit 137 F-3	60	0.0054	1.4
Girard Point	Unit 1332 H-1	45	0.0054	1.1
Girard Point	Unit 1332 H-2	60	0.0054	1.4
Girard Point	Unit 1332 H-3	43	0.0054	1.0
Girard Point	Unit 1332 H-400	186	0.0054	4.4
Girard Point	Unit 1332 H-401	233	0.0054	5.5
Girard Point	Unit 1332 H-601	48	0.0054	1.1
Girard Point	Unit 1332 H-602	49	0.0054	1.2
Girard Point	Unit 433 H-1	260	0.0054	6.1
Girard Point	Unit 1232 B-104	70	0.0054	1.7
Girard Point	#3 Boilerhouse Boiler #37	495	0.0054	11.7
Girard Point	#3 Boilerhouse Boiler #39	495	0.0054	11.7
Girard Point	#3 Boilerhouse Boiler #40	660	0.0054	15.6
Total for all combustion sources				**109.8**

[1] Higher heating value of refinery fuel gas assumed to be similar to natural gas at 1,020 Btu/scf.
[2] Formula for calculation provided below:

$$\frac{MMBtu}{hr} \times \frac{lb}{MMBtu} \times \frac{8{,}760\ hr}{year} \times \frac{ton}{2{,}000\ lb} = \frac{ton}{year}$$

1232 FCCU CO Boiler VOC Potential Emissions

Location	Source	Permitted Capacity (MMBtu/hr)	AP-42 Chapter 1.4, Table 1.4-2 VOC Emission Factor (lb/MMBtu)[1]	VOC Potential Emissions (TPY)[2]
1232 FCCU	CO Boiler	580	0.0054	13.7

[1] Higher heating value of refinery fuel gas assumed to be similar to natural gas at 1,020 Btu/scf.
[2] Formula for calculation provided below:

$$\frac{MMBtu}{hr} \times \frac{lb}{MMBtu} \times \frac{8{,}760\ hr}{year} \times \frac{ton}{2{,}000\ lb} = \frac{ton}{year}$$

Cooling Tower VOC Potential Emissions

Cooling Tower	Permitted Recirculation Rate (gallons per minute)	AP-42 Chapter 5.1, Table 5.1-3, VOC Controlled Emission Factor (lb/MMgal)	VOC Potential Emissions (TPY)[1]
210 Crude	29,600	0.7	5.4
868	19,700	0.7	3.6
Complex	35,000	0.7	6.4
864	18,000	0.7	3.3
137	36,300	0.7	6.7
433	35,300	0.7	6.5
490	75,000	0.7	13.8
1232	57,000	0.7	10.5
Total for all cooling towers			**56.3**

[1] Formula for calculation provided below:

$$\frac{gal}{min} \times \frac{60\ min}{hr} \times \frac{8{,}760\ hr}{year} \times \frac{MMgal}{1{,}000{,}000\ gal} \times \frac{0.7\ lb}{MMgal} \times \frac{ton}{2{,}000\ lb} = \frac{ton}{year}$$

Diesel-Fired RICE VOC Potential Emissions

Cooling Tower	Permitted Capacity (MMBtu/hr)	Permitted Operation (hr/year)	AP-42 Chapter 3.3, Table 3.3-1, VOC Emission Factor (lb/hp-hr)[1]	VOC Potential Emissions (TPY)[2]
Diesel-Fired RICE IC-002	1.4	458	0.00251	0.12
Diesel-Fired RICE IC-005	0.2	2,300	0.00251	0.08
Diesel-Fired RICE IC-006	0.8	1,150	0.00251	0.17
Diesel-Fired RICE IC-007	0.7	3,050	0.00251	0.39
Diesel-Fired RICE IC-008	1.5	360	0.00251	0.10
Total for all Diesel-Fired RICE				**0.85**

[1] TOC emission factors for exhaust and crankcase are added together to get 0.00251 lb/hp-hr.
[1] Formula for calculation provided below:

$$\frac{MMBtu}{hr} \times \frac{2.51 * 10^{-3}\ lb}{hp-hr} \times \frac{hp-hr}{7{,}000\ Btu} \times \frac{1{,}000{,}000\ BTU}{MMBtu} \times \frac{hr}{year} \times \frac{ton}{2{,}000\ lb} = \frac{ton}{year}$$

Maximum True Vapor Pressure Calculations for Reformate

Parameter	Abbreviation	Value	Comment
Reid vapor pressure (psia)	RVP[1]	2.5	Facility Data - Maximum RVP
Maximum liquid surface temp. - daily avg. (°R)	T_{LA}	515.6	Average T_{LA} for Philadelphia Area (from AP-42 Ch. 7.1 Eq. 1-26 See Page 10)
Vapor pressure equation constant "A"	A	12.15	From AP-42 Figure 7.1-15 (See Below)
Vapor pressure equation constant "B"	B	6261	From AP-42 Figure 7.1-15 (See Below)
Stock ASTM-D86 distillation slope	SLOPE	3	From AP-42, Table 7.1-4 (Motor Gasoline)
Maximum true vapor pressure of liquid (psia)	TVP	1.01	From AP-42, Section 7.1-3 Equation 1-24 (See Below)

Reformate Loading Emissions

Parameter	Abbreviation	Value	Comment
Saturation Factor	S	0.5	From AP-42, Table 5.2-1 (Submerged Loading of a Clean Cargo Tank)
TVP	P	1.01	Calculated above
Vapor Molecular Weight	M	68	From AP-42, Table 7.1-2 (assumed MW of Heaviest Gasolines for conservatism)
Temperature of bulk liquid loaded (°R)	T	515.6	Assumed equal to T_{LA} for Philadelphia Area because the liquid is not heated
Loading loss (lb/Mgal)	L_L	0.826	From AP-42, Section 5.2-4
Estimated Barge Loading	bbls	1,311,000	
Estimated Barge Loading	Mgal	55,062	1 Mgal = 23.81 bbls
Reformate Loading Emissions (TPY)	PTE	22.74	PTE = L_L * Estimated Reformate Throughput (Mgal/yr) * (1 ton/2000 lb)

Maximum True Vapor Pressure Calculations for Heavy Naphtha

Parameter	Abbreviation	Value	Comment
Reid vapor pressure (psia)	RVP[1]	3.0	Facility Data - Maximum RVP
Maximum liquid surface temp. - daily avg. (°R)	T_{LA}	515.6	Average T_{LA} for Philadelphia Area
Vapor pressure equation constant "A"	A	12.32	From AP-42 Figure 7.1-15 (See Below)
Vapor pressure equation constant "B"	B	6254	From AP-42 Figure 7.1-15 (See Below)
Stock ASTM-D86 distillation slope	SLOPE	2.5	From AP-42, Table 7.1-4 (Naphtha)
Maximum true vapor pressure of liquid (psia)	TVP	1.21	From AP-42, Section 7.1-3 Equation 1-24 (below)

Heavy Naptha Loading Emissions

Parameter	Abbreviation	Value	Comment
Saturation Factor	S	0.5	From AP-42, Table 5.2-1 (Submerged Loading of a Clean Cargo Tank)
TVP	P	1.21	Calculated above
Vapor Molecular Weight	M	62	From AP-42, Table 7.1-2 (assumed same MW as Gasoline RVP 13 for conservatism)
Temperature of bulk liquid loaded (°R)	T	515.6	Assumed equal to T_{LA} for Philadelphia Area because the liquid is not heated
Loading loss (lb/Mgal)	L_L	0.905	From AP-42, Section 5.2-4 Equation 1 (below)
Estimated Barge Loading	bbls	171,000	
Estimated Barge Loading	Mgal	7,182	1 Mgal = 23.81 bbls
Naphtha Loading Emissions (TPY)	PTE	3.25	PTE = L_L * Estimated Naphtha Throughput (Mgal/yr) * (1 ton/2000 lb)

Total PB Wharf Potential to Emit	**PTE**	**25.99**	**Reformate - 1,311,000 bbls/year and Naphtha - 171,000 bbls/year**

[1] The RVP for materials loaded does vary and this analysis assumes the worst case RVP for each material to be conservative.

$$P_{VA} = \exp\left[A - \left(\frac{B}{T_{LA}}\right)\right] \quad (1\text{-}24)$$

where:

exp = exponential function
A = constant in the vapor pressure equation, dimensionless
B = constant in the vapor pressure equation, °R
T_{LA} = daily average liquid surface temperature, °R
P_{VA} = true vapor pressure, psia

For selected petroleum liquid stocks, physical property data are presented in Table 7.1-2. For refined petroleum stocks, the constants A and B can be calculated from the equations presented in Figure 7.1-15 and the distillation slopes presented in Table 7.1-4. For crude oil stocks, the constants A and B can be calculated from the equations presented in Figure 7.1-16. Note that in Equation 1-24, T_{LA} is determined in degrees Rankine instead of degrees Fahrenheit.

$A = 15.64 - 1.854\ S^{0.5} - (0.8742 - 0.3280\ S^{0.5})\ln(RVP)$
$B = 8{,}742 - 1{,}042\ S^{0.5} - (1{,}049 - 179.4\ S^{0.5})\ln(RVP)$

where:

RVP = stock Reid vapor pressure, in pounds per square inch
ln = natural logarithm function
S = stock ASTM-D86 distillation slope at 10 volume percent evaporation (°F/vol %)

Figure 7.1-15. Equations to determine vapor pressure constants A and B for refined petroleum stocks.[8]

8. *Evaporative Loss From Fixed Roof Tanks*, Second Edition, Bulletin No. 2518, American Petroleum Institute, Washington, D.C., October 1991.

$$L_L = 12.46\ \frac{SPM}{T} \quad (1)$$

where:

L_L = loading loss, pounds per 1000 gallons (lb/10^3 gal) of liquid loaded

S = a saturation factor (see Table 5.2-1)
P = true vapor pressure of liquid loaded, pounds per square inch absolute (psia) (see Section 7.1, "Organic Liquid Storage Tanks")
M = molecular weight of vapors, pounds per pound-mole (lb/lb-mole) (see Section 7.1, "Organic Liquid Storage Tanks")
T = temperature of bulk liquid loaded, °R (°F + 460)

MET Data for Philadelphia Area

Month	T_{AX}	T_{AX}	T_{AN}	T_{AN}	T_{AA}	T_{AA}	T_B	I	T_{LA}
	Maximum Ambient Temperature	**Maximum Ambient Temperature**	**Minimum Ambient Temperature**	**Minimum Ambient Temperature**	**Daily Average Ambient Temperature**	**Daily Average Ambient Temperature**	**Liquid Bulk Temperature**	**Daily Total Solar Insolation Factor**	**Daily Average Liquid Surface Temperature**
	°F	**°R**	**°F**	**°R**	**°F**	**°R**	**°R**	**Btu/ft^2*d**	**°R**
	EPA TANKS 4.09D (AP-42 Table 7.1-7)	Conversion	EPA TANKS 4.09D (AP-42 Table 7.1-7)	Conversion	AP-42 Ch. 7.1 Eq. 1-27 (Below)	Conversion	AP-42 Ch. 7.1 Eq. 1-28 (Below)	EPA TANKS 4.09D (AP-42 Table 7.1-7)	AP-42 Ch. 7.1 Eq. 1-26
Jan	37.9	497.5	22.8	482.4	30.4	489.95	489.97	623.8	490.8
Feb	41	500.6	24.8	484.4	32.9	492.5	492.52	877.9	493.7
Mar	51.6	511.2	33.2	492.8	42.4	502	502.02	1202.5	503.6
Apr	62.6	522.2	42.1	501.7	52.4	511.95	511.97	1527.0	514.0
May	73.1	532.7	52.7	512.3	62.9	522.5	522.52	1759.9	524.9
Jun	81.7	541.3	61.8	521.4	71.8	531.35	531.37	1943.3	534.0
Jul	86.1	545.7	67.2	526.8	76.7	536.25	536.27	1896.3	538.8
Aug	84.6	544.2	66.3	525.9	75.5	535.05	535.07	1711.4	537.4
Sep	77.6	537.2	58.7	518.3	68.2	527.75	527.77	1381.7	529.6
Oct	66.3	525.9	46.4	506	56.4	515.95	515.97	1021.3	517.3
Nov	55.1	514.7	37.6	497.2	46.4	505.95	505.97	677.7	506.9
Dec	43.4	503	28.1	487.7	35.8	495.35	495.37	536.5	496.1
Annual Average	63.4	523.0	45.1	504.7	54.3	513.9	513.9	1263.3	515.6

3. If the daily average liquid surface temperature, T_{LA}, is unknown, it is calculated using the following equation:

$$T_{LA} = 0.44T_{AA} + 0.56T_B + 0.0079\ \alpha\ I \qquad (1\text{-}26)$$

where:

T_{LA} = daily average liquid surface temperature, °R
T_{AA} = daily average ambient temperature, °R; see Note 4
T_B = liquid bulk temperature, °R; see Note 5
α = tank paint solar absorptance, dimensionless; see Table 7.1-6
I = daily total solar insolation factor, Btu/(ft^2 day); see Table 7.1-7

If T_{LA} is used to calculate P_{VA} from Figures 7.1-13a, 7.1-13b, 7.1-14a, or 7.1-14b, T_{LA} must be converted from degrees Rankine to degrees Fahrenheit (°F = °R - 460). If T_{LA} is used to calculate P_{VA} from Equation 1-25, T_{LA} must be converted from degrees Rankine to degrees Celsius (°C = [°R - 492]/1.8). Equation 1-26 should not be used to estimate liquid surface temperature from insulated tanks. In the case of insulated tanks, the average liquid surface temperature should be based on liquid surface temperature measurements from the tank.

4. The daily average ambient temperature, T_{AA}, is calculated using the following equation:

$$T_{AA} = \left(\frac{T_{AX} + T_{AN}}{2}\right) \qquad (1\text{-}27)$$

where:

T_{AA} = daily average ambient temperature, °R
T_{AX} = daily maximum ambient temperature, °R
T_{AN} = daily minimum ambient temperature, °R

Table 7.1-7 gives values of T_{AX} and T_{AN} for selected U.S. cities.

5. The liquid bulk temperature, T_B, is calculated using the following equation:

$$T_B = T_{AA} + 6\alpha - 1 \qquad (1\text{-}28)$$

where:

T_B = liquid bulk temperature, °R
T_{AA} = daily average ambient temperature, °R, as calculated in Note 4
α = tank paint solar absorptance, dimensionless; see Table 7.1-6.

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Point Breeze Wharf RACT Cost Effectiveness Summary - Non-gasoline Loading

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Throughput (bbl/yr)[1]	Current Emission Rate (lb VOC/Mbbl)[2]	VOC Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control VOC Emissions (TPY)	Potential VOC Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[3] ($)	2013 Cost Effectiveness ($/Ton)
Thermal Incinerator	1,482,000	35.08	25.99	98%	0.5	25.5	943,994	370,019	595,183	23,365
Flare	1,482,000	35.08	25.99	98%	0.5	25.5	820,511	294,749	490,459	19,254
Adsorption	1,482,000	35.08	25.99	98%	0.5	25.5	618,791	229,340	376,936	14,798
Condenser	1,482,000	35.08	25.99	61%	10.2	15.8	1,161,700	377,069	654,161	41,525
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Notes:
[1] Potential Throughput (bbl/yr) = 1,311,000 bbls/yr of Reformate + 171,000 bbls/yr of Naphtha
[2] Current Emission Rate (lb VOC/Mbbl) = (25.99 tons/yr * 2,000 lb/ton) / (1,482,000 bbls/yr *(1 Mbbl/1,000 bbls))
[3] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).

Table 2 from *Vapor Controls for Barge Loading of Gasoline* (EPA 903R83004)

Capital Investment Costs for Vapor Control Systems For Gasoline Barge Loading (September 1982 dollars)				
Barge Terminal loading Rate	Number of barge berths	Type of vapor control system		
barrels/hour		Refrigeration	Incineration	Adsorption
1,400	1	$517,000	$422,000	$320,000
3,000	2	$853,000	$690,000	$380,000
6,000	2	$1,170,000	$898,000	$485,000
Scaled to 2013 dollars				
2,000	1	$1,161,700	$943,994	$618,791
10,000	1	$3,523,041	$2,704,010	$1,460,406

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VOC RACT Control Cost Effectiveness

Source	**Point Breeze Wharf Loading Rack**	
Control	**Thermal Incinerator (VOC Control)**	
Maximum Throughput	**1,482,000**	**bbl/yr**
Baseline Actual Emissions	**25.99**	**tpy**
Current Emission Rate	**35.08**	**lb/Mbbl**
Hours per year	**741.0**	**Hours**
Exhaust Flow Rate	**5,000**	**scfm**
Control Efficiency	**98%**	

Evaluated at 2013 Cost and Efficiencies
Costs derived from *EPA Air Pollution Control Cost Manual, Sixth Edition, EPA/452/B-02-001*

COST COMPONENT:	COST ($)	Equation
DIRECT COSTS		
Purchased Equipment Costs		
Equipment Cost (EC)	943,994	*Vapor Controls for Barge Loading of Gasoline (EPA 903R83004)*
Instrumentation (10%)	- - -	
Sales taxes (3%)	- - -	
Freight (5%)	- - -	
Subtotal - Purchased Equipment Costs (PEC)	**943,994**	
Direct Installation Costs		
Foundations & Supports (8% of PEC)	- - -	
Handling & Erection (14% of PEC)	- - -	
Electrical (4% of PEC)	- - -	
Piping (2% of PEC)	- - -	
Insulation for ductwork (1% of PEC)	- - -	
Painting (1% of PEC)	- - -	
Site Preparation / Buildings- Included above	- - -	
Subtotal - Direct Installation Costs (DIC)	**0**	
TOTAL DIRECT COSTS (TDC)	**943,994**	
INDIRECT INSTALLATION COSTS		
Engineering Costs (10% of PEC)	- - -	
Construct. & Field Expenses (5% of PEC)	- - -	
Contractor Fees (10% of PEC)	- - -	
Start-up (2% of PEC)	- - -	
Performance Test (3% of PEC)	- - -	
Contingency (3% of PEC)	- - -	
TOTAL INDIRECT COSTS, IC	**0**	
TOTAL CAPITAL INVESTMENT (TCI)	**943,994**	

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VOC RACT Control Cost Effectiveness

Source	**Point Breeze Wharf Loading Rack**	
Control	**Thermal Incinerator (VOC Control)**	
Maximum Throughput	**1,482,000**	**bbl/yr**
Baseline Actual Emissions	**25.99**	**tpy**
Current Emission Rate	**35.08**	**lb/Mbbl**
Hours per year	**741.0**	**Hours**
Exhaust Flow Rate	**5,000**	**scfm**
Control Efficiency	**98%**	

COST COMPONENT:	COST ($)	Equation
ANNUAL DIRECT COSTS		
Operation and Maintenance Labor		
Operator (0.5 hr/shift @ $19/hr, 500 hours/year)	9,500	$Operator\ (\$) = \$19/hour \times 500\ hours/year$
Supervisor (15% of operator)	1,425	$Supervisor\ (\$) = 15\% \times Operator\ (\$)$
Labor (0.5 hr/shift @ $22/hr, 500 hours/year)	11,000	$Labor\ (\$) = \$22/hour \times 500\ hours/year$
Material (100% of maintenance labor)	11,000	$Material\ (\$) = 100\% \times Labor\ (\$)$
	32,925	
Utilities		
Natural Gas Cost (250 scfm and $4.88/Mscf)	54,241	$Natural\ Gas\ (\$) = 250\ scfm \times 741\ \frac{hours}{year} \times 60\ \frac{minutes}{hour} \times \$4.88/Mscf \times \frac{Mscf}{1{,}000\ scf}$
Electricity Cost ($0.06/kWh) - OAQPS Equation 2.42 and Table 2.11	173.4	$Electricity\ (\$) = \frac{1.17 \times 10^{-4} \times 5{,}000\ scfm \times 4\ inches\ water}{0.6} \times \frac{\$0.06}{kWh} \times 741\ \frac{hours}{year}$
	54,415	
ANNUAL INDIRECT COSTS		
Overhead (60% of Operation and Maintenance Labor)	19,755	$Overhead(\$) = 60\% \times Operation\ and\ Maintenance\ Labor\ (\$)$
Administrative Charges (2% of TCI)	18,880	$Administrative(\$) = 2\% \times TCI\ (\$)$
Property Taxes (1% of TCI)	9,440	$Property\ Tax(\$) = 1\% \times TCI\ (\$)$
Insurance (1% of TCI)	9,440	$Insurance(\$) = 1\% \times TCI\ (\$)$
Capital Recovery Factor (Annualized Cost Factor * TCI)	225,164	$Capital\ Recovery\ Factor(\$) = ACF \times TCI\ (\$)$
	282,679	
TOTAL ANNUAL COSTS	**370,019**	

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VOC RACT Control Cost Effectiveness

Source	**Point Breeze Wharf Loading Rack**	
Control	**Thermal Incinerator (VOC Control)**	
Maximum Throughput	**1,482,000**	**bbl/yr**
Baseline Actual Emissions	**25.99**	**tpy**
Current Emission Rate	**35.08**	**lb/Mbbl**
Hours per year	**741.0**	**Hours**
Exhaust Flow Rate	**5,000**	**scfm**
Control Efficiency	**98%**	

COST COMPONENT:	COST ($)	Equation
TOTAL ANNUAL O&M COSTS	**370,019**	
Annualized Cost Factor		
Equipment Life (years) = 10		
Interest Rate (%) = 20		
Annualized Cost Factor	0.24	$ACF = \frac{i(1+i)^n}{(1+i)^n - 1}$
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT	943,994	
TOTAL ANNUAL CAPITAL REQUIREMENT	**225,164**	$Total\ Annual\ Capital\ Requirement\ (\$) = TCI\ (\$) * ACF$
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***	**595,183**	$Total\ Annualized\ Cost\ (\$) = Total\ Annual\ Capital\ Requirement + Total\ O\&M\ Costs\ (\$)$

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Source	**Point Breeze Wharf Loading Rack**		
Control	**Flare (VOC Control)**		
Maximum Throughput	**1,482,000**	**bbl/yr**	
Baseline Actual Emissions	**25.99**	**tpy**	
Current Emission Rate	**35.08**	**lb/Mbbl**	
Hours per year	**741.0**	**Hours**	
Exhaust Flow Rate	**194**	**scfm**	***Q***
Control Efficiency	**98%**		
Exit Velocity	**38.67**	**ft/sec**	***Vmax***
Fuel Requirement	**44.74**	**scfm**	***F***
Vent Heating Value	**138**	**btu/scf**	***Bv***
Flare Tip Diameter	**5.00**	**in**	***Dmin***
Flare Height	**129.87**	**ft^2**	L^2
Flare Height	**50**	**ft**	***L***
Heat Release	**4,294,812**	**Btu/hr**	***R***
Knock Out Pot Parameters			
Dropout Velocity	**1.82**	**ft/sec**	***U***
Min Cross Sectional Area	**2.19**	**ft^2**	***A***
Vessel Diameter	**6.00**	**in**	***dmin***
Vessel Height	**18.00**	**in**	***h***
Vessel Thickness	**0.25**	**in**	***t***

Evaluated at 2013 Cost and Efficiencies
Costs derived from *EPA Air Pollution Control Cost Manual, Sixth Edition, EPA/452/B-02-001*

	COST COMPONENT:	COST ($)	Equation
DIRECT COSTS			
	Purchased Equipment Costs		
	Flare Cost (C_F) - OAQPS Equation 1.16	37,382	$C_F(\$) = (78.0 + 9.14D + 0.749L)^2 * Cost\ Escalation\ Factor$
	Knock Out Pot Cost (C_K) - OAQPS Equation 1.21	277	$C_K(\$) = 14.2\ [dmin \times t(h + 0.812dmin)]^{0.737} * Cost\ Escalation\ Factor$
	Pipe Cost (C_P) - OAQPS Equation 1.19	1,282	$C_P(\$) = 127\ D^{1.21} * Cost\ Escalation\ Factor$
	Equipment Cost (EC)	38,941	$EC(\$) = Flare\ Cost\ (\$) + Knock\ Out\ Pot\ Cost\ (\$) + Pipe\ Cost\ (\$)$
	Instrumentation (Approximate Cost of NSPS Ja Instrumentation, based on recent quotes)	200,000	
	Sales taxes (3%)	1,168	$Sales\ Tax(\$) = 3\% \times EC\ (\$)$
	Freight (5%)	1,947	$Freight(\$) = 5\% \times EC\ (\$)$
	Subtotal - Purchased Equipment Costs (PEC)	**280,997**	
	Direct Installation Costs		
	Foundations & Supports (12% of PEC)	33,720	$Foundations\ \&\ Supports(\$) = 12\% \times PEC\ (\$)$
	Handling & Erection (40% of PEC)	112,399	$Handling\ \&\ Erection(\$) = 40\% \times PEC\ (\$)$

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Source	**Point Breeze Wharf Loading Rack**		
Control	**Flare (VOC Control)**		
Maximum Throughput	**1,482,000**	**bbl/yr**	
Baseline Actual Emissions	**25.99**	**tpy**	
Current Emission Rate	**35.08**	**lb/Mbbl**	
Hours per year	**741.0**	**Hours**	
Exhaust Flow Rate	**194**	**scfm**	***Q***
Control Efficiency	**98%**		
Exit Velocity	**38.67**	**ft/sec**	***Vmax***
Fuel Requirement	**44.74**	**scfm**	***F***
Vent Heating Value	**138**	**btu/scf**	***Bv***
Flare Tip Diameter	**5.00**	**in**	***Dmin***
Flare Height	**129.87**	**ft^2**	L^2
Flare Height	**50**	**ft**	***L***
Heat Release	**4,294,812**	**Btu/hr**	***R***
Knock Out Pot Parameters			
Dropout Velocity	**1.82**	**ft/sec**	***U***
Min Cross Sectional Area	**2.19**	**ft^2**	***A***
Vessel Diameter	**6.00**	**in**	***dmin***
Vessel Height	**18.00**	**in**	***h***
Vessel Thickness	**0.25**	**in**	***t***

	Electrical (1% of PEC)	2,810	$Electrical(\$) = 1\% \times PEC\ (\$)$
	Piping (2% of PEC)	5,620	$Piping(\$) = 2\% \times PEC\ (\$)$
	Insulation (1% of PEC)	2,810	$Insulation(\$) = 1\% \times PEC\ (\$)$
	Painting (1% of PEC)	2,810	$Painting(\$) = 1\% \times PEC\ (\$)$
	Site Preparation / Buildings- Included above	- - -	
	Subtotal - Direct Installation Costs	**160,168**	
TOTAL DIRECT COSTS (TDC)		**441,165**	
INDIRECT INSTALLATION COSTS			
	Engineering Costs (10% of PEC)	28,100	$Engineering\ Costs(\$) = 10\% \times PEC\ (\$)$
	Construct. & Field Expenses (10% of PEC)	28,100	$Construct.\&\ Field\ Expenses(\$) = 10\% \times PEC\ (\$)$
	Contractor Fees (10% of PEC)	28,100	$Contractor\ Fees(\$) = 10\% \times PEC\ (\$)$
	Start-up (1% of PEC)	2,810	$Start{-}up(\$) = 1\% \times PEC\ (\$)$
	Performance Test (1% of PEC)	2,810	$Performance\ Test(\$) = 1\% \times PEC\ (\$)$
	Contingency (3% of PEC)	8,430	$Contingency(\$) = 3\% \times PEC\ (\$)$
TOTAL INDIRECT COSTS, IC		**98,349**	
TOTAL CAPITAL INVESTMENT (TCI)		**820,511**	

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VOC RACT Control Cost Effectiveness

Source	**Point Breeze Wharf Loading Rack**		
Control	**Flare (VOC Control)**		
Maximum Throughput	**1,482,000**	**bbl/yr**	
Baseline Actual Emissions	**25.99**	**tpy**	
Current Emission Rate	**35.08**	**lb/Mbbl**	
Hours per year	**741.0**	**Hours**	
Exhaust Flow Rate	**194**	**scfm**	***Q***
Control Efficiency	**98%**		
Exit Velocity	**38.67**	**ft/sec**	***Vmax***
Fuel Requirement	**44.74**	**scfm**	***F***
Vent Heating Value	**138**	**btu/scf**	***Bv***
Flare Tip Diameter	**5.00**	**in**	***Dmin***
Flare Height	**129.87**	**ft^2**	L^2
Flare Height	**50**	**ft**	***L***
Heat Release	**4,294,812**	**Btu/hr**	***R***
Knock Out Pot Parameters			
Dropout Velocity	**1.82**	**ft/sec**	***U***
Min Cross Sectional Area	**2.19**	**ft^2**	***A***
Vessel Diameter	**6.00**	**in**	***dmin***
Vessel Height	**18.00**	**in**	***h***
Vessel Thickness	**0.25**	**in**	***t***

COST COMPONENT:	COST ($)	Equation
ANNUAL DIRECT COSTS		
Operation and Maintenance Labor		
Operator (0.5 hr/shift @ $19/hr, 500 hours/year)	9,500	$Operator\ (\$) = \$19/hour \times 500\ hours/year$
Supervisor (15% of operator)	1,425	$Supervisor\ (\$) = 15\% \times Operator\ (\$)$
Labor (0.5 hr/shift @ $22/hr, 500 hours/year)	11,000	$Labor\ (\$) = \$22/hour \times 500\ hours/year$
Material (100% of maintenance labor)	11,000	$Material\ (\$) = 100\% \times Labor\ (\$)$
	32,925	
Utilities		
Auxiliary Fuel	9,707	$Auxiliary\ Fuel\ (\$) = F \times 741\ \frac{hours}{year} \times 60 \frac{minutes}{hour} \times \$4.88/Mscf \times \frac{Mscf}{1,000\ scf}$
Natural Gas Cost for Purging - OAQPS Eq. 1.8	839	$Purge(\$) = 6.88D^2 \times \$4.88/Mscf$
Pilot Natural Gas Cost - OAQPS Eq. 1.9	2,991	$Pilot(\$) = 613 \frac{scf}{year} \times 1\ Pilot\ Burner \times \$4.88/Mscf$
	13,538	
ANNUAL INDIRECT COSTS		
Overhead (60% of Operation and Maintenance Labor)	19,755	$Overhead(\$) = 60\% \times Operation\ and\ Maintenance\ Labor\ (\$)$
Administrative Charges (2% of TCI)	16,410	$Administrative(\$) = 2\% \times TCI\ (\$)$
Property Taxes (1% of TCI)	8,205	$Property\ Tax(\$) = 1\% \times TCI\ (\$)$
Insurance (1% of TCI)	8,205	$Insurance(\$) = 1\% \times TCI\ (\$)$
Capital Recovery Factor (Annualized Cost Factor * TCI)	195,710	$Capital\ Recovery\ Factor(\$) = ACF \times TCI\ (\$)$
	248,286	
TOTAL ANNUAL COSTS	**294,749**	

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VOC RACT Control Cost Effectiveness

Source	**Point Breeze Wharf Loading Rack**		
Control	**Flare (VOC Control)**		
Maximum Throughput	**1,482,000**	**bbl/yr**	
Baseline Actual Emissions	**25.99**	**tpy**	
Current Emission Rate	**35.08**	**lb/Mbbl**	
Hours per year	**741.0**	**Hours**	
Exhaust Flow Rate	**194**	**scfm**	***Q***
Control Efficiency	**98%**		
Exit Velocity	**38.67**	**ft/sec**	***Vmax***
Fuel Requirement	**44.74**	**scfm**	***F***
Vent Heating Value	**138**	**btu/scf**	***Bv***
Flare Tip Diameter	**5.00**	**in**	***Dmin***
Flare Height	**129.87**	**ft^2**	***L^2***
Flare Height	**50**	**ft**	***L***
Heat Release	**4,294,812**	**Btu/hr**	***R***
Knock Out Pot Parameters			
Dropout Velocity	**1.82**	**ft/sec**	***U***
Min Cross Sectional Area	**2.19**	**ft^2**	***A***
Vessel Diameter	**6.00**	**in**	***dmin***
Vessel Height	**18.00**	**in**	***h***
Vessel Thickness	**0.25**	**in**	***t***

COST COMPONENT:			COST ($)	Equation
TOTAL ANNUAL O&M COSTS			**294,749**	
Annualized Cost Factor				
	Equipment Life (years) =	10		
	Interest Rate (%) =	20		
	Annualized Cost Factor		0.24	$ACF = \frac{i(1+i)^n}{(1+i)^n - 1}$
CAPITAL RECOVERY COSTS				
	TOTAL CAPITAL REQUIREMENT		820,511	
	TOTAL ANNUAL CAPITAL REQUIREMENT		**195,710**	$Total\ Annual\ Capital\ Requirement\ (\$) = TCI\ (\$) * ACF$
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***			**490,459**	$Total\ Annualized\ Cost\ (\$) = Total\ Annual\ Capital\ Requirement + Total\ O\&M\ Costs\ (\$)$

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VOC RACT Control Cost Effectiveness

Source	**Point Breeze Wharf Loading Rack**		
Control	**Adsorption (VOC Control)**		
Maximum Throughput	**1,482,000**	**bbl/yr**	
Baseline Actual Emissions	**25.99**	**tpy**	
Current Emission Rate	**35.08**	**lb/Mbbl**	
VOC inlet loading	**70.16**	**lb/hr**	m_{VOC}
Hours per year	**741.0**	**Hours**	
Exhaust Flow Rate	**5,000**	**scfm**	
Control Efficiency	**98%**		

Evaluated at 2013 Cost and Efficiencies

Costs derived from Technical Bulletin - Choosing an adsorption system for VOC: Carbon, Zeolite, or Polymers? *(EPA-456/F-99-004)*

COST COMPONENT:	**COST ($)**	**Equation**
DIRECT COSTS		
Purchased Equipment Costs		
Equipment Cost (EC)	618,791	*Vapor Controls for Barge Loading of Gasoline (EPA 903R83004)*
Instrumentation (10%)	- - -	
Sales taxes (3%)	- - -	
Freight (5%)	- - -	
Subtotal - Purchased Equipment Costs (PEC)	**618,791**	
Direct Installation Costs		
Foundations & Supports (8% of PEC)	- - -	
Handling & Erection (14% of PEC)	- - -	
Electrical (4% of PEC)	- - -	
Piping (2% of PEC)	- - -	
Insulation for ductwork (1% of PEC)	- - -	
Painting (1% of PEC)	- - -	
Site Preparation / Buildings- Included above	- - -	
Subtotal - Direct Installation Costs	**0**	
TOTAL DIRECT COSTS (TDC)	**618,791**	
INDIRECT INSTALLATION COSTS		
Engineering Costs (10% of PEC)	- - -	
Construct. & Field Expenses (5% of PEC)	- - -	
Contractor Fees (10% of PEC)	- - -	
Start-up (2% of PEC)	- - -	
Performance Test (1% of PEC)	- - -	
Contingency (3% of PEC)	- - -	
TOTAL INDIRECT COSTS, IC	**0**	
TOTAL CAPITAL INVESTMENT (TCI)	**618,791**	

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RACT Update 2015

VOC RACT Control Cost Effectiveness

Source	**Point Breeze Wharf Loading Rack**		
Control	**Adsorption (VOC Control)**		
Maximum Throughput	**1,482,000**	**bbl/yr**	
Baseline Actual Emissions	**25.99**	**tpy**	
Current Emission Rate	**35.08**	**lb/Mbbl**	
VOC inlet loading	**70.16**	**lb/hr**	m_{VOC}
Hours per year	**741.0**	**Hours**	
Exhaust Flow Rate	**5,000**	**scfm**	
Control Efficiency	**98%**		

COST COMPONENT:	**COST ($)**	**Equation**
ANNUAL DIRECT COSTS		
Operation and Maintenance Labor		
Operator (0.5 hr/shift @ $19/hr, 500 hours/year)	9,500	$Operator\ (\$) = \$19/hour \times 500\ hours/year$
Supervisor (15% of operator)	1,425	$Supervisor\ (\$) = 15\% \times Operator\ (\$)$
Labor (0.5 hr/shift @ $22/hr, 500 hours/year)	11,000	$Labor\ (\$) = \$22/hour \times 500\ hours/year$
Material (100% of maintenance labor)	11,000	$Material\ (\$) = 100\% \times Labor\ (\$)$
	32,925	
Replacement Parts, Carbon		
Replacement Labor ($0.073/lb carbon)	282	$Replacement\ Labor\ (\$) = \frac{\$0.073}{lb\ carbon} \times M_C \times ACF$
Replacement Life (years) = 5		
Interest Rate (%) = 20		
Annualized Cost Factor	0.33	$ACF = \frac{i(1+i)^n}{(1+i)^n - 1}$
Carbon cost	8,365	
	8,648	
Utilities		
Steam - OAQPS Equation 1.28	1,065	$Steam\ (\$) = 3.50 \times 10^{-3} \times m_{VOC} \times 741 \frac{hours}{year} \times \left(1.2 \times \frac{\$4.88}{Mscf} of\ Natural\ Gas\right)$
Cooling Water - OAQPS Equation 1.29	187	$Cooling\ Water(\$) = 3.43 \times \left(\frac{Steam(\$)}{1.2 \times \frac{\$4.88}{Mscf} of\ Natural\ Gas}\right) \times \frac{\$0.3}{thousand\ gallons}$
Electricity Cost ($0.06/kWh) - OAQPS Equation 1.30	581	$Electricity(\$) = (System\ Fan\ (kWh) + Cooling\ Fan\ (kWh) + Cooling\ Water\ (kWh)) \times \$0.06/kWh$
	1,833	
ANNUAL INDIRECT COSTS		
Overhead (60% of Operation and Maintenance Labor)	19,755	$Overhead(\$) = 60\% \times Operation\ and\ Maintenance\ Labor\ (\$)$
Administrative Charges (2% of TCI)	12,376	$Administrative(\$) = 2\% \times TCI\ (\$)$
Property Taxes (1% of TCI)	6,188	$Property\ Tax(\$) = 1\% \times TCI\ (\$)$
Insurance (1% of TCI)	6,188	$Insurance(\$) = 1\% \times TCI\ (\$)$
Capital Recovery Factor = ACF * (TCI - (Carbon Cost))	141,427	$Capital\ Recovery\ Factor(\$) = ACF \times (TCI(\$) - Carbon\ Cost)$
	185,934	
TOTAL ANNUAL DIRECT COSTS	**229,340**	

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VOC RACT Control Cost Effectiveness

Source	**Point Breeze Wharf Loading Rack**		
Control	**Adsorption (VOC Control)**		
Maximum Throughput	**1,482,000**	**bbl/yr**	
Baseline Actual Emissions	**25.99**	**tpy**	
Current Emission Rate	**35.08**	**lb/Mbbl**	
VOC inlet loading	**70.16**	**lb/hr**	m_{VOC}
Hours per year	**741.0**	**Hours**	
Exhaust Flow Rate	**5,000**	**scfm**	
Control Efficiency	**98%**		

COST COMPONENT:	**COST ($)**	**Equation**
TOTAL ANNUAL O&M COSTS	**229,340**	
Annualized Cost Factor		
Equipment Life (years) = 10		
Interest Rate (%) = 20		
Annualized Cost Factor	0.24	$ACF = \frac{i(1+i)^n}{(1+i)^n - 1}$
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT	618,791	
TOTAL ANNUAL CAPITAL REQUIREMENT	**147,596**	$Total\ Annual\ Capital\ Requirement\ (\$) = TCI\ (\$) * ACF$
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***	**376,936**	$Total\ Annualized\ Cost\ (\$) = Total\ Annual\ Capital\ Requirement + Total\ O\&M\ Costs\ (\$)$

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VOC RACT Control Cost Effectiveness

Source	**Point Breeze Wharf Loading Rack**		
Control	**Condenser (VOC Control)**		
Maximum Throughput	**1,482,000**	**bbl/yr**	
Baseline Actual Emissions	**25.99**	**tpy**	
Current Emission Rate	**35.08**	**lb/Mbbl**	
Hours per year	**741.0**	**Hours**	
Exhaust Flow Rate	**194**	**scfm**	***Qin***
Control Efficiency	**61%**		
Target Temperature	**32.00**	**F**	***Tcon***
Refrigeration Capacity	**3.17**	**tons**	***R***
VOCs @ inlet	**1.02**	**lb-mol/hr**	***Mvoc in***
VOCs @ outlet	**0.40**	**lb-mol**	***Mvoc out***
VOCs condensed	**0.62**	**lb-mol**	***Mcon***

Evaluated at 2013 Cost and Efficiencies
Costs derived from Technical Bulletin - Refrigerated Condensers for Control of Corganic Air Emissions *(EPA-456/R-01-004)*

COST COMPONENT:	COST ($)	Equation
DIRECT COSTS		
Purchased Equipment Costs		
Equipment Cost (EC)	1,161,700	*Vapor Controls for Barge Loading of Gasoline* (*EPA* 903R83004)
Instrumentation (10%)	- - -	
Sales taxes (3%)	- - -	
Freight (5%)	- - -	
Subtotal - Purchased Equipment Costs (PEC)	**1,161,700**	
Direct Installation Costs		
Foundations & Supports (14% of PEC)	- - -	
Handling & Erection (8% of PEC)	- - -	
Electrical (8% of PEC)	- - -	
Piping (2% of PEC)	- - -	
Insulation (10% of PEC)	- - -	
Painting (1% of PEC)	- - -	
Site Preparation / Buildings- Included above	- - -	
Subtotal - Direct Installation Costs	**0**	
TOTAL DIRECT COSTS (TDC)	**1,161,700**	
INDIRECT INSTALLATION COSTS		
Engineering Costs (10% of PEC)	- - -	
Construct. & Field Expenses (5% of PEC)	- - -	
Contractor Fees (10% of PEC)	- - -	
Start-up (2% of PEC)	- - -	
Performance Test (1% of PEC)	- - -	
Contingency (3% of PEC)	- - -	
TOTAL INDIRECT COSTS, IC	**0**	
TOTAL CAPITAL INVESTMENT (TCI)	**1,161,700**	

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VOC RACT Control Cost Effectiveness

Source	**Point Breeze Wharf Loading Rack**		
Control	**Condenser (VOC Control)**		
Maximum Throughput	**1,482,000**	**bbl/yr**	
Baseline Actual Emissions	**25.99**	**tpy**	
Current Emission Rate	**35.08**	**lb/Mbbl**	
Hours per year	**741.0**	**Hours**	
Exhaust Flow Rate	**194**	**scfm**	***Qin***
Control Efficiency	**61%**		
Target Temperature	**32.00**	**F**	***Tcon***
Refrigeration Capacity	**3.17**	**tons**	***R***
VOCs @ inlet	**1.02**	**lb-mol/hr**	***Mvoc in***
VOCs @ outlet	**0.40**	**lb-mol**	***Mvoc out***
VOCs condensed	**0.62**	**lb-mol**	***Mcon***

COST COMPONENT:	**COST ($)**	**Equation**
ANNUAL DIRECT COSTS		
Operation and Maintenance Labor		
Operator (0.5 hr/shift @ $19/hr, 500 hours/year)	9,500	$Operator\ (\$) = \$19/hour \times 500\ hours/year$
Supervisor (15% of operator)	1,425	$Supervisor\ (\$) = 15\% \times Operator\ (\$)$
Labor (0.5 hr/shift @ $22/hr, 500 hours/year)	11,000	$Labor\ (\$) = \$22/hour \times 500\ hours/year$
Material (100% of maintenance labor)	11,000	$Material\ (\$) = 100\% \times Labor\ (\$)$
	32,925	
Utilities		
Electricity Cost ($0.06/kWh) - OAQPS Equation 2.37 and Table 2.4	829	$Electricity(\$) = \left(\frac{R, tons}{\eta\ (0.85)}\right) \times 5.0 \frac{kW}{ton} \times 741 \frac{hours}{year} \times \$0.06/\text{kWh}$
	829	
ANNUAL INDIRECT COSTS		
Overhead (60% of Operation and Maintenance Labor)	19,755	$Overhead(\$) = 60\% \times Operation\ and\ Maintenance\ Labor\ (\$)$
Administrative Charges (2% of TCI)	23,234	$Administrative(\$) = 2\% \times TCI\ (\$)$
Property Taxes (1% of TCI)	11,617	$Property\ Tax(\$) = 1\% \times TCI\ (\$)$
Insurance (1% of TCI)	11,617	$Insurance(\$) = 1\% \times TCI\ (\$)$
Capital Recovery Factor (Annualized Cost Factor * TCI)	277,092	$Capital\ Recovery\ Factor(\$) = ACF \times TCI\ (\$)$
	343,315	
TOTAL ANNUAL DIRECT COSTS	**377,069**	

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RACT Update 2015
VOC RACT Control Cost Effectiveness

Source	**Point Breeze Wharf Loading Rack**		
Control	**Condenser (VOC Control)**		
Maximum Throughput	**1,482,000**	**bbl/yr**	
Baseline Actual Emissions	**25.99**	**tpy**	
Current Emission Rate	**35.08**	**lb/Mbbl**	
Hours per year	**741.0**	**Hours**	
Exhaust Flow Rate	**194**	**scfm**	***Qin***
Control Efficiency	**61%**		
Target Temperature	**32.00**	**F**	***Tcon***
Refrigeration Capacity	**3.17**	**tons**	***R***
VOCs @ inlet	**1.02**	**lb-mol/hr**	***Mvoc in***
VOCs @ outlet	**0.40**	**lb-mol**	***Mvoc out***
VOCs condensed	**0.62**	**lb-mol**	***Mcon***

COST COMPONENT:		COST ($)	Equation
TOTAL ANNUAL O&M COSTS		**377,069**	
Annualized Cost Factor			
Equipment Life (years) =	10		
Interest Rate (%) =	20		
Annualized Cost Factor		0.24	$ACF = \frac{i(1+i)^n}{(1+i)^n - 1}$
CAPITAL RECOVERY COSTS			
TOTAL CAPITAL REQUIREMENT		1,161,700	
TOTAL ANNUAL CAPITAL REQUIREMENT		**277,092**	$Total\ Annual\ Capital\ Requirement\ (\$) = TCI\ (\$) * ACF$
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**654,161**	$Total\ Annualized\ Cost\ (\$) = Total\ Annual\ Capital\ Requirement + Total\ O\&M\ Costs\ (\$)$

RACT Update 2015
VOC RACT Control Cost Effectiveness
Point Breeze Wharf Loading Rack

Condensor Exit Temperature Evaluation
Evaluated using Rachford-Rice Method
Methods for Estimating Air Emissions from Chemical Manufacturing Sources - Chapter 16, Section 4

Efficiency	60.61%			
Outlet temperature	0 °C	32 °F	492 °R	T2
Inlet temperature	30 °C	86 °F	546 °R	T1
Inlet Pressure	1 atm			

Step 1: Establish characteristics of the inlet feed stream. 16.4-17

Vent stream Press. 760 mm Hg
System is assumed to be idea because pressure ≤ 1 atm

Compound	F_i lb/hr	MWt	Fi lb-moles/hr	z_i mole frac.	Pure VP_i (mm Hg) 30°C	Pure VPi (mm Hg) 0°C	Partial pressure p_i mm Hg	Tc (°R)	delta H VOC	Hcond (Btu/lb-mol)	Cp VOC (Btu/lb-mol*F)	delta H cond	delta H uncond	delta H noncond	MWvoc
Condensable															
Benzene + C3 Benzenes	0.67	78.11	0.0086	0.017	119.24	26.26	12.96	1,012	13,793	13,230	19.52	4,554			49%
Toluene	0.24	92.14	0.0026	0.005	36.64	6.75	3.96	1,065	14,817	14,270	24.77	1,513			15%
Ethyl Benzene	0.26	106.17	0.0025	0.005	12.58	1.88	3.73	1,111	15,840	15,300	30.69	1,545			14%
Xylenes	0.39	106.16	0.0037	0.007	11.75	1.78	5.60	1,111	16,192	15,640	30.49	2,362			21%
				0.035			26.25					9,974			90.194711
Noncondensable							-								
Air	13.12	28.01	0.47	0.931		414,687.14	707.51						390	27,691	
Totals	14.68		0.49	1.000											

H load 38,055 Btu/hr

Antoine Equation

$$\log_{10}(P) = A - (B / (T + C))$$

P = vapor pressure (bar)
T = temperature (K)

@ inlet temp 30 (°C)

Compound	Range for Coeff	A	B	C	T (K)	P (bar)	P (mm Hg)
Benzene + C3 Benzenes	287.70 - 354.07	4.01814	1203.835	-53.226	303.15	0.16	119.24
Toluene	273. - 323.	4.14157	1377.578	-50.507	303.15	0.05	36.64
Ethyl Benzene	329.74 - 410.27	4.07488	1419.315	-60.539	303.15	0.02	12.58
Xylenes	286.43 - 452.38	4.14553	1474.403	-55.377	303.15	0.02	11.75
Nitrogen					303.15	1.00	-

Source: http://webbook.nist.gov/chemistry/

@ outlet temp (0°C)

Compound	Range for Coeff	A	B	C	T (K)	P (bar)	P (mm Hg)
Benzene + C3 Benzenes	287.70 - 354.07	4.02	1,203.84	-53.23	273.15	0.04	26.26
Toluene	273. - 323.	4.14	1,377.58	-50.51	273.15	0.01	6.75
Ethyl Benzene	329.74 - 410.27	4.07	1,419.32	-60.54	273.15	0.00	1.88
Xylenes	286.43 - 452.38	4.15	1,474.40	-55.38	273.15	0.00	1.78
Nitrogen	63.14 - 126	3.74	264.65	-6.79	273.15	552.87	414,687.14

Source: *Lange's Handbook of Chemistry,* Table 5.9

1 bar = 750.061683 mm Hg

Step 2. Check to confirm whether condensation will occur

$$x_i = \frac{p_i^{30°C}}{\gamma_i P_i^{2°C}} = \frac{p_i^{30°C}}{P_i^{2°C}} \qquad \text{Eq. 4-26}$$

where P_i is the pure component vapor pressure at 2°C,
p_i is the component partial pressure at the condenser inlet conditions (30°C), and
γ_i is 1.0 for the ideal mixture.

Compound	Inlet Partial Pres. (mm Hg)	Pi @0°C	x_i Estimated
Condensable			
Benzene + C3 Benzenes	12.96	26.26	0.49
Toluene	3.96	6.75	0.59
Ethyl Benzene	3.73	1.88	1.98
Xylenes	5.60	1.78	3.15
Noncondensable			
Air	707.51	414687.14	0.00
		Σx_i =	6.21

Σx_i is greater than 1 so condensation occurs

Step 3. Calculate Values to use in the Modified Rachford-Rice Equation

Compound	Fi lb-moles/hr	z_i mole frac.	Pi (mm Hg) 0°C	$K_i = P_i/P_{sys}$
Benzene + C3 Benzenes	0.01	0.02	26.26	0.03
Toluene	0.00	0.01	6.75	0.01
Ethyl Benzene	0.00	0.00	1.88	0.00
Xylenes	0.00	0.01	1.78	0.00
Air	0.47	0.93	414687.14	545.64

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VOC RACT Control Cost Effectiveness
Point Breeze Wharf Loading Rack

Condensor Exit Temperature Evaluation

Step 4. Add known values to the modified Rachford-Rice equation.

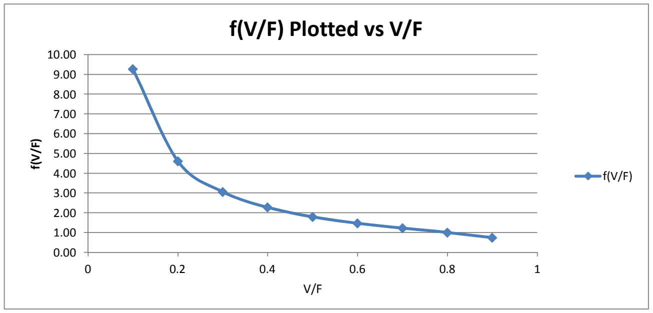
modified Rachford-Rice equation

$$f\left(\frac{V}{F}\right)=\sum_{i=1}^{C_c}\frac{z_i}{1/(K_i-1)+V/F}+\sum_{j=1}^{C_{nc}}\frac{z_j}{V/F}$$

Set f(V/F) = 0

f(V/F) term for Benzene + C3 Benzenes =	-0.2928
f(V/F) term for Toluene =	-0.1658
f(V/F) term for Ethyl Benzene =	-0.1969
f(V/F) term for Xylenes =	-0.2969
f(V/F) term for Air =	0.9523
f(V/F) =	0.000000
V/F =	0.98

V/F	Benzene + C3 Benzenes	Toluene	Ethyl Benzene	Xylenes	Air	f(V/F)
0.01	-1.66E-02	-5.21E-03	-4.95E-03	-7.42E-03		-0.03
0.1	-1.82E-02	-5.73E-03	-5.44E-03	-8.16E-03	9.31E+00	9.27
0.2	-2.04E-02	-6.44E-03	-6.12E-03	-9.18E-03	4.65E+00	4.61
0.3	-2.32E-02	-7.35E-03	-6.99E-03	-1.05E-02	3.10E+00	3.06
0.4	-2.68E-02	-8.55E-03	-8.15E-03	-1.22E-02	2.33E+00	2.27
0.5	-3.18E-02	-1.02E-02	-9.77E-03	-1.47E-02	1.86E+00	1.80
0.6	-3.91E-02	-1.27E-02	-1.22E-02	-1.83E-02	1.55E+00	1.47
0.7	-5.08E-02	-1.69E-02	-1.62E-02	-2.44E-02	1.33E+00	1.22
0.8	-7.23E-02	-2.49E-02	-2.42E-02	-3.64E-02	1.16E+00	1.01
0.9	-1.26E-01	-4.78E-02	-4.79E-02	-7.19E-02	1.03E+00	0.74
0.99	-3.72E-01	-2.75E-01	-3.93E-01	-5.96E-01	9.40E-01	-0.70



Step 5. Replaced use of newton's method with Excel's solver function
Set f(V/F) to 0 by varying V/F

Determine Molar Flow Rates

$$V=F\,(V/F) \qquad L=F-V$$

Compound	Fi lb-moles/hr	V	L
Total	0.49	0.47	0.01

Compound	Fi lb-moles/hr	z_i	K_i	Li lb-moles/hr	Xi	Vi lb-moles/hr	Yi	Vi (lb/hr)
Condensable								
Benzene + C3 Benzenes	0.01	0.02	3.46E-02	0.00	0.30	0.00	0.010	0.389
Toluene	0.00	0.01	8.88E-03	0.00	0.17	0.00	0.001	0.065
Ethyl Benzene	0.00	0.00	2.47E-03	0.00	0.20	0.00	0.000	0.025
Xylenes	0.00	0.01	2.34E-03	0.00	0.30	0.00	0.001	0.035
Noncondensable	0.47	0.93	5.46E+02	0.00	0.00	0.47	0.987	13.124

					Antoine from NIST Webbook			
Component	ppm	%	MW	mol % in gas	Range (K)	A	B	C
Benzene + C3 Benzenes	850.00	0.085%	78.11	1.71%	287.70 - 354.07	4.01814	1203.835	-53.226
Toluene	220.00	0.022%	92.14	0.52%	273. - 323.	4.14157	1377.578	-50.507
Ethyl Benzene	180.00	0.018%	106.17	0.49%	329.74 - 410.27	4.07488	1419.315	-60.539
Xylenes	270.00	0.027%	106.16	0.74%	286.43 - 452.38	4.14553	1474.403	-55.377
Air	998,480	99.848%	28.01	96.55%				

Girard Point Wharf Loading

Emissions Calculations for Materials Loaded

MVRS Parameters	
Control Efficiency	**99.86%**
% Operation	**100.0%**

Material	Saturation Factor[1]	RVP (psia)[2]	TVP (psia)[3,4,5]	Vapor (MW)[5]	Temp (°R)[6]	Potential Volume (bbls/yr)	EF (lb/Mgal)[7]	VOC (lb/yr)[8,9]	VOC (tons/yr)[10]
DIESEL/NO.2 FUEL OIL	0.5	0.009	0.009	130	515.6	1,710,000	0.01	1,015.33	0.51
GASO COMP - REFORMATE	0.5	2.5	1.01	68	515.6	171,000	0.83	5,932.94	2.97
GASOLINE	0.5	15.0	7.56	68	515.6	7,200,000	6.21	2,628.99	1.31
CUMENE	0.5	0.0552	0.0552	120	515.6	2,304,000	0.08	7,745.10	3.87
LT NAPHTHA	0.5	10.0	4.87	62	515.6	342,000	3.65	73.35	0.04
ALKYLATE	0.5	6.0	2.69	68	515.6	60,000	2.21	7.81	0.00
NAPHTHA	0.5	3.0	1.21	62	515.6	342,000	0.90	12,996.23	6.50
RESIDUAL OIL(# 6 oil)	0.5	0.00006	0.00006	190	515.6	12,775,000	0.00	73.91	0.04
VACUUM GAS OIL	0.5	0.00006	0.00006	190	515.6	360,000	0.00	2.08	0.00
CAT FEED	0.5	0.00006	0.00006	190	515.6	240,000	0.00	1.39	0.00
Total									**15.2**

[1] From AP-42, Table 5.2-1 (Submerged Loading of a Clean Cargo Tank).

[2] Represents worst cast RVP based on facility data.

[3] TVPs for Refomate, Gasoline, Lt Naphtha, Alkylate, and Naphtha were calculated using AP-42, Section 7.1-3 Equation 1-24 (See Pages 9 and 29).

[4] TVPs for Diesel/No.2 Fuel Oil, Cumene, Residual Oil (#6 oil), Vacuum Gas Oil, and Cat Feed, were set equal to RVP for conservatism.

[5] MWs for petroleum liquids were conservatively selected using the range of MWs provided in AP-42 Table 7.1-2. The MW for Cumene is based on its molecular formula (C_6H_{12}). The RVP, TVP, and MW for Vacuum Gas and Cat Feed were set equal to the values listed for Residual Oil (# 6 oil) for conservatism.

[6] Temperature was set equal to T_{LA} for Philadelphia Area because the material is not heated (See Pages 9 and 10).

[7] EF was caculated from AP-42, Section 5.2-4 Equation 1 (See Page 9).

[8] VOC (lb/yr) from Distillates = Potential Volume (bbl/yr) * 42 gal/bbl * (1 Mgal/1,000 gal) * EF (lb/Mgal).

[9] VOC (lb/yr) from Gasolines = Potential Volume (bbl/yr) * 42 gal/bbl * (1 Mgal/1,000 gal) * EF (lb/Mgal) * [(1 - Control Efficiency%)+(1-%Operation)].

[10] VOC tons/yr = VOC (lb/yr) / 2,000 (lbs/ton).

Vapor Pressure Range	VOC PTE (TPY)
Distillate (RVP <4)	13.9
Gasoline (RVP >4)	1.4
Total	**15.2**

Loading Type	Potential Volume Loaded (bbls)	2012 Actual Volume Loaded (bbls)	2013 Actual Volume Loaded (bbls)	2014 Actual Volume Loaded (bbls)
Distillates	17,902,000	12,869,652	14,214,889	13,176,123
Gasoline	7,602,000	4,898,630	3,307,531	1,783,013

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Girard Point Wharf Loading

Maximum True Vapor Pressure Calculations for Materials Loaded

Parameter	Abbreviation	Material					Comment
		Light Naphtha	Heavy Naphtha	Finished Gasoline	Reformate	Alkylate	
		Value	Value	Value	Value	Value	
Reid vapor pressure (psia)	RVP[1]	10.0	3.0	15.0	2.50	6.0	Facility Data - Maximum RVP
Maximum liquid surface temp. - daily avg. (°R)	T_{LA}	515.6	515.6	515.6	515.6	515.6	Average T_{LA} for Philadelphia Area (from AP-42 Ch. 7.1 Eq. 1-26 See Page 10)
Vapor pressure equation constant "A"	A	11.57	12.32	11.60	12.15	11.88	From AP-42 Figure 7.1-15 (See Page 9)
Vapor pressure equation constant "B"	B	5150	6254	4938	6261	5614	From AP-42 Figure 7.1-15 (See Page 9)
Stock ASTM-D86 distillation slope	SLOPE	3.5	2.5	3	3	3	From AP-42, Table 7.1-4 (Motor Gasoline, Heavy and Light Naphtha)
Maximum true vapor pressure of liquid (psia)	TVP	4.87	1.21	7.56	1.01	2.69	From AP-42, Section 7.1-3 Equation 1-24 (See Page 9)

[1] The RVP for materials loaded does vary and this analysis assumes the worst case RVP for each material to be conservative.

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Girard Point Wharf Loading - MVRS Costs for Non-gasoline Loading

Girard Point Wharf Loading - VOC Potential to Emit (PTE)

Parameter	Non-gasoline materials (RVP <4) VOC (TPY)	Gasoline materials (RVP >4) VOC (TPY)[1]	Total VOC (TPY) - All Vapor Pressures
Potential to emit	13.9	1.4	15.2

[1] Marine vapor recovery system and thermal oxidizer are used to control loading.

Girard Point Wharf Loading - Additional Enrichment Fuel Cost for Control of Non-gasoline Loading

Parameter	Value	Units	Description
Maximum enrichment fuel	311.0	scfm	Design Basis
Hours of operation	2,000	hours/year	Potential Operation
Propane Cost	$1.46	$/gallon	EIA 2014 Average Wholesale Propane
Density of propane	35.67	scf/gallon	Conversion
Propane Usage	37,314,864	scf/year	
Propane Usage	1,046,113	gallon/year	
Propane Annual Cost	$1,527,326	$/year	

Girard Point Wharf Loading - Non-gasoline Loading Control Cost Effectiveness

Parameter	Value	Units	Description
Propane Annual Cost	$1,527,326	$/year	
Maximum VOC reductions from non-gasoline materials	13.9	TPY VOC	Conservatively assumed to be the potential emissions from non-gasoline loading
Cost Effectiveness	$110,010	$/ton reduced	

Girard Point Wharf Loading - Pollutant Emissions from Additional Enrichment Fuel Firing

Parameter	Value	Units	Description
Maximum enrichment fuel	311.0	scfm	Design Basis
Propane Higher Heating Value	2,516	Btu/scf	Design Basis
Maximum heat release	46.9	MMBtu/hr	Design Basis
Hours of operation	2,000	hours/year	Potential Operation
NO_x	5.67	lb/hr	Stack Test
PM	0.07	lb/hr	Stack Test
CO	0.33	lb/hr	Stack Test
SO_2	0	lb/hr	Stack Test
VOC	0	lb/hr	Stack Test
CO_2	135.89	lb/MMBtu	40 CFR Part 98
CH_4	0.066	lb/MMBtu	40 CFR Part 98
N_2O	0.013	lb/MMBtu	40 CFR Part 98
NO_x	0.121	lb/MMBtu	
PM	0.002	lb/MMBtu	
CO	0.007	lb/MMBtu	
SO_2	0.0	lb/MMBtu	
VOC	0.0	lb/MMBtu	
CO_2e	141.5	lb/MMBtu	
NO_x	5.67	TPY	
PM	0.07	TPY	
CO	0.33	TPY	
SO_2	0	TPY	
VOC	0	TPY	
CO_2e	6,642	TPY	

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Girard Point Wharf RACT Cost Effectiveness Summary - Non-gasoline Loading

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Throughput (bbl/yr)[1]	Current Emission Rate (lb VOC/Mbbl)[2]	VOC Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control VOC Emissions (TPY)	Potential VOC Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[3] ($)	2013 Cost Effectiveness ($/Ton)
Thermal Incinerator	17,902,000	1.55	13.88	98%	0.3	13.6	2,704,010	936,935	1,581,902	116,267
Flare	17,902,000	1.55	13.88	98%	0.3	13.6	1,130,737	585,116	854,823	62,828
Adsorption	17,902,000	1.55	13.88	98%	0.3	13.6	1,460,406	461,063	809,403	59,489
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Notes:
[1] Potential Throughput (bbl/yr) of distillate material.
[2] Current Emission Rate (lb VOC/Mbbl) = (13.88 tons/yr * 2,000 lb/ton) / (17,902,000 bbls/yr *(1 Mbbl/1,000 bbls))
[3] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).

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VOC RACT Control Cost Effectiveness

Source	**Girard Point Wharf Loading Rack - Non-gasoline Loading**	
Control	**Thermal Incinerator (VOC Control)**	
Maximum Throughput	**17,902,000**	**bbl/yr**
Baseline Actual Emissions	**13.88**	**tpy**
Current Emission Rate	**1.55**	**lb/Mbbl**
Hours per year	**1790.2**	**Hours**
Exhaust Flow Rate	**1,000**	**scfm**
Control Efficiency	**98%**	

Evaluated at 2013 Cost and Efficiencies
Costs derived from *EPA Air Pollution Control Cost Manual, Sixth Edition, EPA/452/B-02-001*

COST COMPONENT:	COST ($)	Equation
DIRECT COSTS		
Purchased Equipment Costs		
Equipment Cost (EC)	2,704,010	*Vapor Controls for Barge Loading of Gasoline (EPA 903R83004)*
Instrumentation (10%)	- - -	
Sales taxes (3%)	- - -	
Freight (5%)	- - -	
Subtotal - Purchased Equipment Costs (PEC)	**2,704,010**	
Direct Installation Costs		
Foundations & Supports (8% of PEC)	- - -	
Handling & Erection (14% of PEC)	- - -	
Electrical (4% of PEC)	- - -	
Piping (2% of PEC)	- - -	
Insulation for ductwork (1% of PEC)	- - -	
Painting (1% of PEC)	- - -	
Site Preparation / Buildings- Included above	- - -	
Subtotal - Direct Installation Costs (DIC)	**0**	
TOTAL DIRECT COSTS (TDC)	**2,704,010**	
INDIRECT INSTALLATION COSTS		
Engineering Costs (10% of PEC)	- - -	
Construct. & Field Expenses (5% of PEC)	- - -	
Contractor Fees (10% of PEC)	- - -	
Start-up (2% of PEC)	- - -	
Performance Test (3% of PEC)	- - -	
Contingency (3% of PEC)	- - -	
TOTAL INDIRECT COSTS, IC	**0**	
TOTAL CAPITAL INVESTMENT (TCI)	**2,704,010**	

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VOC RACT Control Cost Effectiveness

Source	**Girard Point Wharf Loading Rack - Non-gasoline Loading**	
Control	**Thermal Incinerator (VOC Control)**	
Maximum Throughput	**17,902,000**	**bbl/yr**
Baseline Actual Emissions	**13.88**	**tpy**
Current Emission Rate	**1.55**	**lb/Mbbl**
Hours per year	**1790.2**	**Hours**
Exhaust Flow Rate	**1,000**	**scfm**
Control Efficiency	**98%**	

COST COMPONENT:	**COST ($)**	**Equation**
ANNUAL DIRECT COSTS		
Operation and Maintenance Labor		
Operator (0.5 hr/shift @ $19/hr, 500 hours/year)	9,500	$Operator\ (\$) = \$19/hour \times 500\ hours/year$
Supervisor (15% of operator)	1,425	$Supervisor\ (\$) = 15\% \times Operator\ (\$)$
Labor (0.5 hr/shift @ $22/hr, 500 hours/year)	11,000	$Labor\ (\$) = \$22/hour \times 500\ hours/year$
Material (100% of maintenance labor)	11,000	$Material\ (\$) = 100\% \times Labor\ (\$)$
	32,925	
Utilities		
Natural Gas Cost (250 scfm and $4.88/Mscf)	131,043	$Natural\ Gas\ (\$) = 250\ scfm \times 741\ \frac{hours}{year} \times 60\ \frac{minutes}{hour} \times \$4.88/Mscf \times \frac{Mscf}{1{,}000\ scf}$
Electricity Cost ($0.06/kWh) - OAQPS Equation 2.42 and Table 2.11	83.8	$Electricity\ (\$) = \frac{1.17 \times 10^{-4} \times 1{,}000\ scfm \times 4\ inches\ water}{0.6} \times \frac{\$0.06}{kWh} \times 1{,}790\ \frac{hours}{year}$
	131,126	
ANNUAL INDIRECT COSTS		
Overhead (60% of Operation and Maintenance Labor)	19,755	$Overhead(\$) = 60\% \times Operation\ and\ Maintenance\ Labor\ (\$)$
Administrative Charges (2% of TCI)	54,080	$Administrative(\$) = 2\% \times TCI\ (\$)$
Property Taxes (1% of TCI)	27,040	$Property\ Tax(\$) = 1\% \times TCI\ (\$)$
Insurance (1% of TCI)	27,040	$Insurance(\$) = 1\% \times TCI\ (\$)$
Capital Recovery Factor (Annualized Cost Factor * TCI)	644,968	$Capital\ Recovery\ Factor(\$) = ACF \times TCI\ (\$)$
	772,883	
TOTAL ANNUAL COSTS	**936,935**	

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VOC RACT Control Cost Effectiveness

Source	**Girard Point Wharf Loading Rack - Non-gasoline Loading**	
Control	**Thermal Incinerator (VOC Control)**	
Maximum Throughput	**17,902,000**	**bbl/yr**
Baseline Actual Emissions	**13.88**	**tpy**
Current Emission Rate	**1.55**	**lb/Mbbl**
Hours per year	**1790.2**	**Hours**
Exhaust Flow Rate	**1,000**	**scfm**
Control Efficiency	**98%**	

COST COMPONENT:	COST ($)	Equation
TOTAL ANNUAL O&M COSTS	**936,935**	
Annualized Cost Factor		
Equipment Life (years) = 10		
Interest Rate (%) = 20		
Annualized Cost Factor	0.24	$ACF = \frac{i(1+i)^n}{(1+i)^n - 1}$
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT	2,704,010	
TOTAL ANNUAL CAPITAL REQUIREMENT	**644,968**	$Total\ Annual\ Capital\ Requirement\ (\$) = TCI\ (\$) * ACF$
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***	**1,581,902**	$Total\ Annualized\ Cost\ (\$) = Total\ Annual\ Capital\ Requirement + Total\ O\&M\ Costs\ (\$)$

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VOC RACT Control Cost Effectiveness

Source	**Girard Point Wharf Loading Rack - Non-gasoline Loading**		
Control	**Flare (VOC Control)**		
Maximum Throughput	**17,902,000**	**bbl/yr**	
Baseline Actual Emissions	**13.88**	**tpy**	
Current Emission Rate	**1.55**	**lb/Mbbl**	
Hours per year	**1790.2**	**Hours**	
Exhaust Flow Rate	**936**	**scfm**	***Q***
Control Efficiency	**98%**		
Exit Velocity	**26.85**	**ft/sec**	***Vmax***
Fuel Requirement	**396.68**	**scfm**	***F***
Vent Heating Value	**3**	**btu/scf**	***Bv***
Flare Tip Diameter	**14.00**	**in**	***Dmin***
Flare Height	**725.61**	**ft^2**	L^2
Flare Height	**50**	**ft**	***L***
Heat Release	**23,995,615**	**Btu/hr**	***R***
Knock Out Pot Parameters			
Dropout Velocity	**1.82**	**ft/sec**	***U***
Min Cross Sectional Area	**12.23**	**ft^2**	***A***
Vessel Diameter	**6.00**	**in**	***dmin***
Vessel Height	**18.00**	**in**	***h***
Vessel Thickness	**0.25**	**in**	***t***

Evaluated at 2013 Cost and Efficiencies
Costs derived from *EPA Air Pollution Control Cost Manual, Sixth Edition, EPA/452/B-02-001*

	COST COMPONENT:	COST ($)	Equation
DIRECT COSTS			
	Purchased Equipment Costs		
	Flare Cost (C_F) - OAQPS Equation 1.16	85,287	$C_F(\$) = (78.0 + 9.14D + 0.749L)^2 * Cost\ Escalation\ Factor$
	Knock Out Pot Cost (C_K) - OAQPS Equation 1.21	277	$C_K(\$) = 14.2\,[dmin \times t(h + 0.812dmin)]^{0.737} * Cost\ Escalation\ Factor$
	Pipe Cost (C_P) - OAQPS Equation 1.19	4,455	$C_P(\$) = 127\ D^{1.21} * Cost\ Escalation\ Factor$
	Equipment Cost (EC)	90,019	$EC(\$) = Flare\ Cost\ (\$) + Knock\ Out\ Pot\ Cost\ (\$) + Pipe\ Cost\ (\$)$
	Instrumentation (Approximate Cost of NSPS Ja Instrumentation, based on recent quotes)	200,000	
	Sales taxes (3%)	2,701	$Sales\ Tax(\$) = 3\% \times EC\ (\$)$
	Freight (5%)	4,501	$Freight(\$) = 5\% \times EC\ (\$)$
	Subtotal - Purchased Equipment Costs (PEC)	**387,239**	
	Direct Installation Costs		
	Foundations & Supports (12% of PEC)	46,469	$Foundations\ \&\ Supports(\$) = 12\% \times PEC\ (\$)$
	Handling & Erection (40% of PEC)	154,895	$Handling\ \&\ Erection(\$) = 40\% \times PEC\ (\$)$

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VOC RACT Control Cost Effectiveness

Source	**Girard Point Wharf Loading Rack - Non-gasoline Loading**		
Control	**Flare (VOC Control)**		
Maximum Throughput	**17,902,000**	**bbl/yr**	
Baseline Actual Emissions	**13.88**	**tpy**	
Current Emission Rate	**1.55**	**lb/Mbbl**	
Hours per year	**1790.2**	**Hours**	
Exhaust Flow Rate	**936**	**scfm**	***Q***
Control Efficiency	**98%**		
Exit Velocity	**26.85**	**ft/sec**	***Vmax***
Fuel Requirement	**396.68**	**scfm**	***F***
Vent Heating Value	**3**	**btu/scf**	***Bv***
Flare Tip Diameter	**14.00**	**in**	***Dmin***
Flare Height	**725.61**	**ft^2**	L^2
Flare Height	**50**	**ft**	***L***
Heat Release	**23,995,615**	**Btu/hr**	***R***
Knock Out Pot Parameters			
Dropout Velocity	**1.82**	**ft/sec**	***U***
Min Cross Sectional Area	**12.23**	**ft^2**	***A***
Vessel Diameter	**6.00**	**in**	***dmin***
Vessel Height	**18.00**	**in**	***h***
Vessel Thickness	**0.25**	**in**	***t***

	Electrical (1% of PEC)	3,872	$Electrical(\$) = 1\% \times PEC\ (\$)$
	Piping (2% of PEC)	7,745	$Piping(\$) = 2\% \times PEC\ (\$)$
	Insulation (1% of PEC)	3,872	$Insulation(\$) = 1\% \times PEC\ (\$)$
	Painting (1% of PEC)	3,872	$Painting(\$) = 1\% \times PEC\ (\$)$
	Site Preparation / Buildings- Included above	- - -	
	Subtotal - Direct Installation Costs	**220,726**	
TOTAL DIRECT COSTS (TDC)		**607,965**	
INDIRECT INSTALLATION COSTS			
	Engineering Costs (10% of PEC)	38,724	$Engineering\ Costs(\$) = 10\% \times PEC\ (\$)$
	Construct. & Field Expenses (10% of PEC)	38,724	$Construct.\&\ Field\ Expenses(\$) = 10\% \times PEC\ (\$)$
	Contractor Fees (10% of PEC)	38,724	$Contractor\ Fees(\$) = 10\% \times PEC\ (\$)$
	Start-up (1% of PEC)	3,872	$Start{-}up(\$) = 1\% \times PEC\ (\$)$
	Performance Test (1% of PEC)	3,872	$Performance\ Test(\$) = 1\% \times PEC\ (\$)$
	Contingency (3% of PEC)	11,617	$Contingency(\$) = 3\% \times PEC\ (\$)$
TOTAL INDIRECT COSTS, IC		**135,534**	
TOTAL CAPITAL INVESTMENT (TCI)		**1,130,737**	

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VOC RACT Control Cost Effectiveness

Source	**Girard Point Wharf Loading Rack - Non-gasoline Loading**		
Control	**Flare (VOC Control)**		
Maximum Throughput	**17,902,000**	**bbl/yr**	
Baseline Actual Emissions	**13.88**	**tpy**	
Current Emission Rate	**1.55**	**lb/Mbbl**	
Hours per year	**1790.2**	**Hours**	
Exhaust Flow Rate	**936**	**scfm**	***Q***
Control Efficiency	**98%**		
Exit Velocity	**26.85**	**ft/sec**	***Vmax***
Fuel Requirement	**396.68**	**scfm**	***F***
Vent Heating Value	**3**	**btu/scf**	***Bv***
Flare Tip Diameter	**14.00**	**in**	***Dmin***
Flare Height	**725.61**	**ft^2**	***L^2***
Flare Height	**50**	**ft**	***L***
Heat Release	**23,995,615**	**Btu/hr**	***R***
Knock Out Pot Parameters			
Dropout Velocity	**1.82**	**ft/sec**	***U***
Min Cross Sectional Area	**12.23**	**ft^2**	***A***
Vessel Diameter	**6.00**	**in**	***dmin***
Vessel Height	**18.00**	**in**	***h***
Vessel Thickness	**0.25**	**in**	***t***

COST COMPONENT:	**COST ($)**	**Equation**
ANNUAL DIRECT COSTS		
Operation and Maintenance Labor		
Operator (0.5 hr/shift @ $19/hr, 500 hours/year)	9,500	$Operator\ (\$) = \$19/hour \times 500\ hours/year$
Supervisor (15% of operator)	1,425	$Supervisor\ (\$) = 15\% \times Operator\ (\$)$
Labor (0.5 hr/shift @ $22/hr, 500 hours/year)	11,000	$Labor\ (\$) = \$22/hour \times 500\ hours/year$
Material (100% of maintenance labor)	11,000	$Material\ (\$) = 100\% \times Labor\ (\$)$
	32,925	
Utilities		
Auxiliary Fuel	207,928	$Auxiliary\ Fuel\ (\$) = F \times 1{,}790\frac{hours}{year} \times 60\frac{minutes}{hour} \times \$4.88/Mscf \times \frac{Mscf}{1{,}000\ scf}$
Natural Gas Cost for Purging - OAQPS Eq. 1.8	6,581	$Purge(\$) = 6.88D^2 \times \$4.88/Mscf$
Pilot Natural Gas Cost - OAQPS Eq. 1.9	2,991	$Pilot(\$) = 613\frac{scf}{year} \times 1\ Pilot\ Burner \times \$4.88/Mscf$
	217,500	
ANNUAL INDIRECT COSTS		
Overhead (60% of Operation and Maintenance Labor)	19,755	$Overhead(\$) = 60\% \times Operation\ and\ Maintenance\ Labor\ (\$)$
Administrative Charges (2% of TCI)	22,615	$Administrative(\$) = 2\% \times TCI\ (\$)$
Property Taxes (1% of TCI)	11,307	$Property\ Tax(\$) = 1\% \times TCI\ (\$)$
Insurance (1% of TCI)	11,307	$Insurance(\$) = 1\% \times TCI\ (\$)$
Capital Recovery Factor (Annualized Cost Factor * TCI)	269,706	$Capital\ Recovery\ Factor(\$) = ACF \times TCI\ (\$)$
	334,691	
TOTAL ANNUAL COSTS	**585,116**	

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VOC RACT Control Cost Effectiveness

Source	**Girard Point Wharf Loading Rack - Non-gasoline Loading**		
Control	**Flare (VOC Control)**		
Maximum Throughput	**17,902,000**	**bbl/yr**	
Baseline Actual Emissions	**13.88**	**tpy**	
Current Emission Rate	**1.55**	**lb/Mbbl**	
Hours per year	**1790.2**	**Hours**	
Exhaust Flow Rate	**936**	**scfm**	***Q***
Control Efficiency	**98%**		
Exit Velocity	**26.85**	**ft/sec**	***Vmax***
Fuel Requirement	**396.68**	**scfm**	***F***
Vent Heating Value	**3**	**btu/scf**	***Bv***
Flare Tip Diameter	**14.00**	**in**	***Dmin***
Flare Height	**725.61**	**ft^2**	***L^2***
Flare Height	**50**	**ft**	***L***
Heat Release	**23,995,615**	**Btu/hr**	***R***
Knock Out Pot Parameters			
Dropout Velocity	**1.82**	**ft/sec**	***U***
Min Cross Sectional Area	**12.23**	**ft^2**	***A***
Vessel Diameter	**6.00**	**in**	***dmin***
Vessel Height	**18.00**	**in**	***h***
Vessel Thickness	**0.25**	**in**	***t***

COST COMPONENT:	**COST ($)**	**Equation**
TOTAL ANNUAL O&M COSTS	**585,116**	
Annualized Cost Factor		
Equipment Life (years) = 10		
Interest Rate (%) = 20		
Annualized Cost Factor	0.24	$ACF = \frac{i(1+i)^n}{(1+i)^n - 1}$
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT	1,130,737	
TOTAL ANNUAL CAPITAL REQUIREMENT	**269,706**	$Total\ Annual\ Capital\ Requirement\ (\$) = TCI\ (\$) * ACF$
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***	**854,823**	$Total\ Annualized\ Cost\ (\$) = Total\ Annual\ Capital\ Requirement + Total\ O\&M\ Costs\ (\$)$

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RACT Update 2015
VOC RACT Control Cost Effectiveness

Source	**Girard Point Wharf Loading Rack - Non-gasoline Loading**		
Control	**Adsorption (VOC Control)**		
Maximum Throughput	**17,902,000**	**bbl/yr**	
Baseline Actual Emissions	**13.88**	**tpy**	
Current Emission Rate	**1.55**	**lb/Mbbl**	
VOC inlet loading	**15.51**	**lb/hr**	m_{VOC}
Hours per year	**1790.2**	**Hours**	
Exhaust Flow Rate	**1,000**	**scfm**	
Control Efficiency	**98%**		

Evaluated at 2013 Cost and Efficiencies
Costs derived from Technical Bulletin - Choosing an adsorption system for VOC: Carbon, Zeolite, or Polymers? *(EPA-456/F-99-004)*

COST COMPONENT:	COST ($)	Equation
DIRECT COSTS		
Purchased Equipment Costs		
Equipment Cost (EC)	1,460,406	*Vapor Controls for Barge Loading of Gasoline (EPA 903R83004)*
Instrumentation (10%)	- - -	
Sales taxes (3%)	- - -	
Freight (5%)	- - -	
Subtotal - Purchased Equipment Costs (PEC)	**1,460,406**	
Direct Installation Costs		
Foundations & Supports (8% of PEC)	- - -	
Handling & Erection (14% of PEC)	- - -	
Electrical (4% of PEC)	- - -	
Piping (2% of PEC)	- - -	
Insulation for ductwork (1% of PEC)	- - -	
Painting (1% of PEC)	- - -	
Site Preparation / Buildings- Included above	- - -	
Subtotal - Direct Installation Costs	**0**	
TOTAL DIRECT COSTS (TDC)	**1,460,406**	
INDIRECT INSTALLATION COSTS		
Engineering Costs (10% of PEC)	- - -	
Construct. & Field Expenses (5% of PEC)	- - -	
Contractor Fees (10% of PEC)	- - -	
Start-up (2% of PEC)	- - -	
Performance Test (1% of PEC)	- - -	
Contingency (3% of PEC)	- - -	
TOTAL INDIRECT COSTS, IC	**0**	
TOTAL CAPITAL INVESTMENT (TCI)	**1,460,406**	

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VOC RACT Control Cost Effectiveness

Source	**Girard Point Wharf Loading Rack - Non-gasoline Loading**		
Control	**Adsorption (VOC Control)**		
Maximum Throughput	**17,902,000**	**bbl/yr**	
Baseline Actual Emissions	**13.88**	**tpy**	
Current Emission Rate	**1.55**	**lb/Mbbl**	
VOC inlet loading	**15.51**	**lb/hr**	m_{VOC}
Hours per year	**1790.2**	**Hours**	
Exhaust Flow Rate	**1,000**	**scfm**	
Control Efficiency	**98%**		

COST COMPONENT:	COST ($)	Equation
ANNUAL DIRECT COSTS		
Operation and Maintenance Labor		
Operator (0.5 hr/shift @ $19/hr, 500 hours/year)	9,500	$Operator\ (\$) = \$19/hour \times 500\ hours/year$
Supervisor (15% of operator)	1,425	$Supervisor\ (\$) = 15\% \times Operator\ (\$)$
Labor (0.5 hr/shift @ $22/hr, 500 hours/year)	11,000	$Labor\ (\$) = \$22/hour \times 500\ hours/year$
Material (100% of maintenance labor)	11,000	$Material\ (\$) = 100\% \times Labor\ (\$)$
	32,925	
Replacement Parts, Carbon		
Replacement Labor ($0.073/lb carbon)	69	$Replacement\ Labor\ (\$) = \frac{\$0.073}{lb\ carbon} \times M_C \times ACF$
Replacement Life (years) = 5		
Interest Rate (%) = 20		
Annualized Cost Factor	0.33	$ACF = \frac{i(1+i)^n}{(1+i)^n - 1}$
Carbon cost	2,045	
	2,115	
Utilities		
Steam - OAQPS Equation 1.28	569	$Steam\ (\$) = 3.50 \times 10^{-3} \times m_{VOC} \times 1{,}790\frac{hours}{year} \times \left(1.2 \times \frac{\$4.88}{Mscf} of\ Natural\ Gas\right)$
Cooling Water - OAQPS Equation 1.29	100	$Cooling\ Water(\$) = 3.43 \times \left(\frac{Steam(\$)}{1.2 \times \frac{\$4.88}{Mscf} of\ Natural\ Gas}\right) \times \frac{\$0.3}{thousand\ gallons}$
Electricity Cost ($0.06/kWh) - OAQPS Equation 1.30	351	$Electricity(\$) = (System\ Fan\ (kWh) + Cooling\ Fan\ (kWh) + Cooling\ Water\ (kWh)) \times \$0.06/kWh$
	1,020	
ANNUAL INDIRECT COSTS		
Overhead (60% of Operation and Maintenance Labor)	19,755	$Overhead(\$) = 60\% \times Operation\ and\ Maintenance\ Labor\ (\$)$
Administrative Charges (2% of TCI)	29,208	$Administrative(\$) = 2\% \times TCI\ (\$)$
Property Taxes (1% of TCI)	14,604	$Property\ Tax(\$) = 1\% \times TCI\ (\$)$
Insurance (1% of TCI)	14,604	$Insurance(\$) = 1\% \times TCI\ (\$)$
Capital Recovery Factor = ACF * (TCI - (Carbon Cost))	346,832	$Capital\ Recovery\ Factor(\$) = ACF \times (TCI(\$) - Carbon\ Cost)$
	425,003	
TOTAL ANNUAL DIRECT COSTS	**461,063**	

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VOC RACT Control Cost Effectiveness

Source	**Girard Point Wharf Loading Rack - Non-gasoline Loading**		
Control	**Adsorption (VOC Control)**		
Maximum Throughput	**17,902,000**	**bbl/yr**	
Baseline Actual Emissions	**13.88**	**tpy**	
Current Emission Rate	**1.55**	**lb/Mbbl**	
VOC inlet loading	**15.51**	**lb/hr**	m_{VOC}
Hours per year	**1790.2**	**Hours**	
Exhaust Flow Rate	**1,000**	**scfm**	
Control Efficiency	**98%**		

COST COMPONENT:		**COST ($)**	**Equation**
TOTAL ANNUAL O&M COSTS		**461,063**	
Annualized Cost Factor			
Equipment Life (years) =	10		
Interest Rate (%) =	20		
Annualized Cost Factor		0.24	$ACF = \frac{i(1+i)^n}{(1+i)^n - 1}$
CAPITAL RECOVERY COSTS			
TOTAL CAPITAL REQUIREMENT		1,460,406	
TOTAL ANNUAL CAPITAL REQUIREMENT		**348,340**	$Total\ Annual\ Capital\ Requirement\ (\$) = TCI\ (\$) * ACF$
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**809,403**	$Total\ Annualized\ Cost\ (\$)$ $= Total\ Annual\ Capital\ Requirement + Total\ O\&M\ Costs\ (\$)$

RACT Update 2015
VOC RACT Control Cost Effectiveness
Girard Point Wharf Loading Rack - Non-gasoline Loading

__Condensor Exit Temperature Evaluation__
Evaluated using Rachford-Rice Method
Methods for Estimating Air Emissions from Chemical Manufacturing Sources - Chapter 16, Section 4

Efficiency	0.00%			
Outlet temperature	0 °C	32 °F	492 °R	T2
Inlet temperature	30 °C	86 °F	546 °R	T1
Inlet Pressure	1 atm			

Step 1: Establish characteristics of the inlet feed stream. 16.4-17

Vent stream Press. 760 mm Hg
System is assumed to be idea because pressure ≤ 1 atm

Compound	F_i lb/hr	MWt	Fi lb-moles/hr	z_i mole frac.	Pure VP_i (mm Hg) 30°C	Pure VPi (mm Hg) 0°C	Partial pressure p_i mm Hg	Tc (°R)	delta H VOC	Hcond (Btu/lb-mol)	Cp VOC (Btu/lb-mol*F)	delta H cond	delta H uncond	delta H noncond	MWvoc
Condensable															
Benzene + C3 Benzenes	0.06	78.11	0.0007	0.000	119.24	26.26	0.23	1,012	13,793	13,230	19.52	4,554			49%
Toluene	0.02	92.14	0.0002	0.000	36.64	6.75	0.07	1,065	14,817	14,270	24.77	1,513			15%
Ethyl Benzene	0.02	106.17	0.0002	0.000	12.58	1.88	0.07	1,111	15,840	15,300	30.69	1,545			14%
Xylenes	0.03	106.16	0.0003	0.000	11.75	1.78	0.10	1,111	16,192	15,640	30.49	2,362			21%
				0.001			0.47					9,974			90.194711
Noncondensable							-								
Air	68.02	28.01	2.4282	0.999		414,687.14	759.53						390	27,691	
Totals	68.16		2.43	1.000											

H load 38,055 Btu/hr

__Antoine Equation__

$\log_{10}(P) = A - (B / (T + C))$
P = vapor pressure (bar)
T = temperature (K)

@ inlet temp 30 (°C)

Compound	Range for Coeff	A	B	C	T (K)	P (bar)	P (mm Hg)
Benzene + C3 Benzenes	287.70 - 354.07	4.01814	1203.835	-53.226	303.15	0.16	119.24
Toluene	273. - 323.	4.14157	1377.578	-50.507	303.15	0.05	36.64
Ethyl Benzene	329.74 - 410.27	4.07488	1419.315	-60.539	303.15	0.02	12.58
Xylenes	286.43 - 452.38	4.14553	1474.403	-55.377	303.15	0.02	11.75
Nitrogen					303.15	1.00	-

Source: http://webbook.nist.gov/chemistry/

@ outlet temp (0°C)

Compound	Range for Coeff	A	B	C	T (K)	P (bar)	P (mm Hg)
Benzene + C3 Benzenes	287.70 - 354.07	4.02	1,203.84	-53.23	273.15	0.04	26.26
Toluene	273. - 323.	4.14	1,377.58	-50.51	273.15	0.01	6.75
Ethyl Benzene	329.74 - 410.27	4.07	1,419.32	-60.54	273.15	0.00	1.88
Xylenes	286.43 - 452.38	4.15	1,474.40	-55.38	273.15	0.00	1.78
Nitrogen	63.14 - 126	3.74	264.65	-6.79	273.15	552.87	414,687.14

Source: *Lange's Handbook of Chemistry,* Table 5.9

1 bar = 750.061683 mm Hg

Step 2. Check to confirm whether condensation will occur

Compound	Inlet Partial Pres. (mm Hg)	Pi @0°C	x_i Estimated
Condensable			
Benzene + C3 Benzenes	0.23	26.26	0.01
Toluene	0.07	6.75	0.01
Ethyl Benzene	0.07	1.88	0.04
Xylenes	0.10	1.78	0.06
Noncondensable			
Air	759.53	414687.14	0.00
		$\Sigma x_i =$	0.11

$$x_i = \frac{p_i^{30°C}}{\gamma_i P_i^{2°C}} = \frac{p_i^{30°C}}{P_i^{2°C}} \qquad \text{Eq. 4-26}$$

where P_i is the pure component vapor pressure at 2°C,
p_i is the component partial pressure at the condenser inlet conditions (30°C), and
γ_i is 1.0 for the ideal mixture.

Σx_i is less than 1 so condensation will not occur.

Component	ppmw	%	MW	mol % in gas	Range (K)	A	B	C
					Antoine from NIST Webbook			
Benzene + C3 Benzenes	850.00	0.085%	78.11	0.03%	287.70 - 354.07	4.01814	1203.835	-53.226
Toluene	220.00	0.022%	92.14	0.01%	273. - 323.	4.14157	1377.578	-50.507
Ethyl Benzene	180.00	0.018%	106.17	0.01%	329.74 - 410.27	4.07488	1419.315	-60.539
Xylenes	270.00	0.027%	106.16	0.01%	286.43 - 452.38	4.14553	1474.403	-55.377
Air	998,480	99.848%	28.01	99.94%				

RACT Update 2015
ULNB Vendor Cost Estimates

Vendor Provided Estimates

Heater	Firing Duty (MMBtu/hr)	Number of Burners	Total Equipment Cost ($)	Equipment Cost per burner ($/burner)	Direct Installation Materials ($)	Direct Installation Labor ($)	Direct Labor Hours per burner	Labor Cost ($/hr)	Direct Labor Burner Install ($)	Direct Labor Burner Install ($/burner)	Direct Labor Pipe Mods ($/heater)	Direct Labor Furnace Mods ($/heater)	Direct Labor Demo ($/heater)	Total Labor Hours	Total Direct Costs
864 PH-1	76.5	8	63,756	7,970	36,487	117,895	37.5	95	28,500	3,563	65,669	23,750	5,873	1,071	224,035
864 PH-11	74	8	63,756	7,970	36,487	117,895	37.5	95	28,500	3,563	65,669	23,750	5,873	1,071	224,035
864 PH-12	85.1	12	95,634	7,970	44,745	140,410	37.5	95	42,750	3,563	65,669	23,750	6,390	1,267	278,938
864 Header	- - -	- - -	- - -	- - -	192,882	185,155	- - -	95	- - -	- - -	- - -	- - -	- - -	1,559	378,037
137 F-1	415.0	32	240,000	7,500	344,899	940,250	45	125	180,000	5,625	781,750	158,500	96,277	6,784	1,801,426
137 F-2	155.0	16	120,000	7,500	277,508	731,750	45	125	90,000	5,625	573,250	158,500	47,619	4,782	1,266,877
137 F-1 Header	- - -	- - -	- - -	- - -	316,052	304,665	40	95	- - -	- - -	- - -	- - -	- - -	2,565	620,717
137 F-2 Header				- - -	325,031	356,630	40	95	- - -	- - -	- - -	- - -	- - -	3,003	681,661
Average[1]	**- - -**	**- - -**	**- - -**	**7,782**	**148,025**	**409,640**	**- - -**	**- - -**	**- - -**	**4,388**	**310,401**	**77,650**	**32,406**	**- - -**	**- - -**

[1] Average does not include header costs.

RACT Update 2015
Unit 137 F-1 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (lb/MMBtu)	Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[1] ($)	2013 Cost Effectiveness ($/Ton)
ULNB & SCR	415.0	0.23	418.1	96%	16.6	401.4	14,983,684	604,532	3,872,940	9,648
ULNB[2]	415.0	0.23	418.1	85%	63.6	354.5	5,771,261	158,710	1,535,287	4,331
SCR	415.0	0.23	418.1	85%	62.7	355.4	9,212,423	445,822	2,337,654	6,578
LNB & SNCR	415.0	0.23	418.1	70%	125.4	292.6	7,081,498	777,232	2,409,177	8,232
LNB & FGR	415.0	0.23	418.1	55%	188.1	229.9	6,050,794	217,813	1,661,065	7,224
SNCR	415.0	0.23	418.1	40%	250.8	167.2	1,723,251	629,880	983,761	5,883
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Notes:
[1] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).
[2] Vendor quotation assumes that with ULNB, the achievable NO_x emission rate is 0.035 lb/MMBtu.

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NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-1**	
Control	**ULNB & SCR**	
Rated Heat Input	**415.0**	**MMBtu/hr**
Number of Burners	**32.0**	**Burners**
Baseline Actual Emissions	**418.07**	**tpy**
Current Emission Rate	**0.230**	**lb/MMBtu**
Control Efficiency	**96%**	
Heater Capacity	**437.8**	**GJ/hr**
Burner Heat Release Rate	**16.1**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from Vendor Quotation and *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

COST COMPONENT:		COST ($)	Equation
DIRECT COSTS - ULNB			
	Purchased Equipment Costs		
	Equipment Cost (EC)	900,951	$EC(\$) = Burner\ Cost\ and\ Direct\ Materials\ from\ Vendor\ Quotation$
	Instrumentation (included in Furnace Modifications)	- - -	
	Sales taxes (added below to all materials and equipment)	- - -	
	Freight (added below to all materials and equipment)	- - -	
	Subtotal - Purchased Equipment Costs (PEC)	**900,951**	$PEC\ (\$) = EC\ (\$)$
	Direct Installation Costs		
	Direct Labor - Header Improvements	304,665	
	Direct Labor - Burner Install	180,000	
	Direct Labor - Piping Modifications	781,750	$All\ Direct\ Installation\ Costs\ from\ Vendor\ Quotation$
	Direct Labor - Furnace Modifications (Instrumentation)	158,500	
	Direct Labor - Demolition	96,277	
	Subtotal - Direct Installation Costs	**1,521,192**	
TOTAL DIRECT COSTS (TDC) - ULNB		**2,422,143**	$TDC\ (\$) = PEC\ (\$) + Direct\ Installation\ Costs$
INDIRECT INSTALLATION COSTS - ULNB			
	Sales Tax and Freight (5% of EC)	45,048	$Sales\ Tax\ and\ Freight\ (\$) = EC\ (\$) * 5\%$
	Temporary Construction (10% of all labor hours @ $75/hour)	70,116	$Temporary\ Construction\ (\$) = Labor\ Hours * 10\% * \$75/hour$
	Construction Equipment (2% of Direct Installation Costs)	30,424	$Construction\ Equipment\ (\$) = Direct\ Installation\ Costs\ (\$) * 2\%$
	Construction Supervision (5% of Direct Installation Costs)	76,060	$Construction\ Supervision(\$) = Direct\ Installation\ Costs\ (\$) * 5\%$
TOTAL INDIRECT COSTS, IC - ULNB		**221,647**	$IC\ (\$) = Sales\ Tax\ and\ Freight\ (\$) + Temporary\ Construction\ (\$) + Construction\ Equipment\ (\$) + Construction\ Supervision\ (\$)$

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NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-1**	
Control	**ULNB & SCR**	
Rated Heat Input	**415.0**	**MMBtu/hr**
Number of Burners	**32.0**	**Burners**
Baseline Actual Emissions	**418.07**	**tpy**
Current Emission Rate	**0.230**	**lb/MMBtu**
Control Efficiency	**96%**	
Heater Capacity	**437.8**	**GJ/hr**
Burner Heat Release Rate	**16.1**	**GJ/hr**

OTHER COSTS - ULNB			
	Detailed Engineering (30% of TDC + IC)	793,137	$Detailed\ Engineering\ (\$) = (TDC(\$) + IC\ (\$)) * 30\%$
	Construction Management (5% of TDC + IC)	132,189	$Construction\ Management\ (\$) = (TDC(\$) + IC\ (\$)) * 5\%$
	Subtotal - Total Prime Contract (TDC + IC + Detailed Engineering + Construction Management)	**3,569,116**	$Total\ Prime\ Contract\ (\$) = (TDC\ (\$) + IC\ (\$) + Detailed\ Engineering\ (\$) + Construction\ Management\ (\$)$
	Escalation (5% of Total Prime Contract)	178,456	$Escalation\ (\$) = Total\ Prime\ Contract\ (\$) * 5\%$
	Contingency (40% of Total Prime Contract + Escalation)	1,499,029	$Contingency\ (\$) = (Total\ Prime\ Contract\ (\$) + Escalation\ (\$)) * 40\%$
	Owner's Cost (10% of Total Prime Contract + Escalation + Contingency)	524,660	$Owner's\ Cost\ (\$) = \begin{pmatrix} Total\ Prime\ Contract\ (\$) + Escalation\ (\$) \\ + Contingency\ (\$) \end{pmatrix} * 10\%$
DIRECT COSTS - SCR			
	Purchased Equipment Costs		
	Equipment Cost (EC)	8,944,100	$EC = \left(1{,}373{,}000 \times \left(\frac{Q}{48.5}\right)^{0.6} + 49{,}000 \times \left(\frac{Q}{485}\right)\right) * Cost\ Escalation\ Factor$
	Instrumentation (Included in above costs)	- - -	
	Sales taxes (Included in above costs)	- - -	
	Freight (Included in above costs)	- - -	
	Subtotal - Purchased Equipment Costs (PEC)	**8,944,100**	
	Direct Installation Costs		
	Foundations & supports; handling & erection; electrical; piping; etc.	0	
	Site Preparation / Buildings- Included above	- - -	
	Subtotal - Direct Installation Costs	**0**	
TOTAL DIRECT COSTS (TDC) - SCR		**8,944,100**	
INDIRECT INSTALLATION COSTS - SCR			
	Engineering Costs (Included in above costs)	- - -	
	Construct. & Field Expenses (Included in above costs)	- - -	
	Contractor Fees (Included in above costs)	- - -	
	Start-up (Included in above costs)	- - -	
	Performance Test (Included in above costs)	- - -	
	Contingency (3% of PEC)	268,323	$Contingency\ (\$) = PEC\ (\$) * 3\%$
TOTAL INDIRECT COSTS, IC - SCR		**268,323**	
TOTAL CAPITAL INVESTMENT (TCI) - ULNB		**5,771,261**	
TOTAL CAPITAL INVESTMENT (TCI) - SCR		**9,212,423**	
TOTAL CAPITAL INVESTMENT (TCI)		**14,983,684**	

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NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-1**	
Control	**ULNB & SCR**	
Rated Heat Input	**415.0**	**MMBtu/hr**
Number of Burners	**32.0**	**Burners**
Baseline Actual Emissions	**418.07**	**tpy**
Current Emission Rate	**0.230**	**lb/MMBtu**
Control Efficiency	**96%**	
Heater Capacity	**437.8**	**GJ/hr**
Burner Heat Release Rate	**16.1**	**GJ/hr**

COST COMPONENT:	COST ($)	Equation
ANNUAL DIRECT COSTS		
Operation and Maintenance Labor		
Maintenance Labor and Material (2.75% of TCI)	412,051	$Maintenance\ Labor\ and\ Material\ (\$) = TCI\ (\$) * 2.75\%$
	412,051	
Utilities		
Ammonia Cost	60,700	$NH_3\ cost\ = (lb/hr) \times \left(\frac{1\ mol\ NO_x}{46\ lb\ NO_x}\right) \times \left(\frac{17\ lb\ NH_3}{1\ mol\ NH_3}\right) \times \left(\frac{1\ mol\ NH_3}{1\ mol\ NO_x}\right) \times \left(\frac{\$0.125}{lb\ NH_3}\right) \times \left(8{,}760 \frac{hr}{yr}\right) \times Cost\ EscalationFactor$
Catalyst Replacement Cost	131,777	$Catalyst\ Replacement\ Cost = \left(49{,}000 \times \frac{Q}{48.5} / 5\ years\right) \times Cost\ Escalation\ Factor$
Electricity Cost	4.4	$Electricty\ cost = \left(\frac{0.3\ kWh}{ton\ NH_3}\right) \times \left(\frac{ton\ NH_3}{year}\right) \times \left(\frac{\$0.06}{kWh}\right) \times Cost\ Escalation\ Factor$
Subtotal - Utilities	**192,481**	
TOTAL ANNUAL DIRECT COSTS	**604,532**	

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NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-1**	
Control	**ULNB & SCR**	
Rated Heat Input	**415.0**	**MMBtu/hr**
Number of Burners	**32.0**	**Burners**
Baseline Actual Emissions	**418.07**	**tpy**
Current Emission Rate	**0.230**	**lb/MMBtu**
Control Efficiency	**96%**	
Heater Capacity	**437.8**	**GJ/hr**
Burner Heat Release Rate	**16.1**	**GJ/hr**

COST COMPONENT:			**COST ($)**	**Equation**
TOTAL ANNUAL O&M COSTS			**604,532**	
Annualized Cost Factor - ULNB				
	Replacement Life, years (n) =	10		
	Interest Rate, % (i) =	20		
	Annualized Cost Factor		0.24	$ACF = \frac{i(1+i)^n}{(1+i)^n - 1}$
Annualized Cost Factor - SCR				
	Replacement Life, years (n) =	20		
	Interest Rate, % (i) =	20		
	Annualized Cost Factor		0.21	
CAPITAL RECOVERY COSTS				
	TOTAL CAPITAL REQUIREMENT		14,983,684	
	TOTAL ANNUAL CAPITAL REQUIREMENT		**3,268,408**	$Total\ Annual\ Capital\ Requirement\ (\$) = TCI\ (\$) * ACF$
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***			**3,872,940**	$Total\ Annualized\ Cost\ (\$) = Total\ Annual\ Capital\ Requirement + Total\ O\&M\ Costs\ (\$)$

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Source	**Unit 137 F-1**	
Control	**ULNB**	
Rated Heat Input	**415.0**	**MMBtu/hr**
Number of Burners	**32.0**	**Burners**
Baseline Actual Emissions	**418.07**	**tpy**
Current Emission Rate	**0.230**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**437.8**	**GJ/hr**
Burner Heat Release Rate	**16.1**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies
Costs derived from Vendor Quotation and *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	COST ($)	Equation
DIRECT COSTS			
	Purchased Equipment Costs		
	Equipment Cost (EC)	900,951	$EC(\$) = Burner\ Cost\ and\ Direct\ Materials\ from\ Vendor\ Quotation$
	Instrumentation (included in Furnace Modifications)	- - -	
	Sales taxes (added below to all materials and equipment)	- - -	
	Freight (added below to all materials and equipment)	- - -	
	Subtotal - Purchased Equipment Costs (PEC)	**900,951**	$PEC\ (\$) = EC\ (\$)$
	Direct Installation Costs		
	Direct Labor - Header Improvements	304,665	
	Direct Labor - Burner Install	180,000	
	Direct Labor - Piping Modifications	781,750	$All\ Direct\ Installation\ Costs\ from\ Vendor\ Quotation$
	Direct Labor - Furnace Modifications (Instrumentation)	158,500	
	Direct Labor - Demolition	96,277	
	Subtotal - Direct Installation Costs	**1,521,192**	
TOTAL DIRECT COSTS (TDC)		**2,422,143**	$TDC\ (\$) = PEC\ (\$) + Direct\ Installation\ Costs$
INDIRECT INSTALLATION COSTS			
	Sales Tax and Freight (5% of EC)	45,048	$Sales\ Tax\ and\ Freight\ (\$) = EC\ (\$) * 5\%$
	Temporary Construction (10% of all labor hours @ $75/hour)	70,116	$Temporary\ Construction\ (\$) = Labor\ Hours * 10\% * \$75/hour$
	Construction Equipment (2% of Direct Installation Costs)	30,424	$Construction\ Equipment\ (\$) = Direct\ Installation\ Costs\ (\$) * 2\%$
	Construction Supervision (5% of Direct Installation Costs)	76,060	$Construction\ Supervision(\$) = Direct\ Installation\ Costs\ (\$) * 5\%$
TOTAL INDIRECT COSTS, IC		**221,647**	$IC\ (\$) = Sales\ Tax\ and\ Freight\ (\$) + Temporary\ Construction\ (\$) + Construction\ Equipment\ (\$) + Construction\ Supervision\ (\$)$
OTHER COSTS			
	Detailed Engineering (30% of TDC + IC)	793,137	$Detailed\ Engineering\ (\$) = (TDC(\$) + IC\ (\$)) * 30\%$
	Construction Management (5% of TDC + IC)	132,189	$Construction\ Management\ (\$) = (TDC(\$) + IC\ (\$)) * 5\%$
	Subtotal - Total Prime Contract (TDC + IC + Detailed Engineering + Construction Management)	**3,569,116**	$Total\ Prime\ Contract\ (\$) = (TDC\ (\$) + IC\ (\$) + Detailed\ Engineering\ (\$) + Construction\ Management\ (\$)$
	Escalation (5% of Total Prime Contract)	178,456	$Escalation\ (\$) = Total\ Prime\ Contract\ (\$) * 5\%$
	Contingency (40% of Total Prime Contract + Escalation)	1,499,029	$Contingency\ (\$) = (Total\ Prime\ Contract\ (\$) + Escalation\ (\$)) * 40\%$
	Owner's Cost (10% of Total Prime Contract + Escalation + Contingency)	524,660	$Owner's\ Cost\ (\$) = \left(Total\ Prime\ Contract\ (\$) + Escalation\ (\$) + Contingency\ (\$)\right) * 10\%$
TOTAL CAPITAL INVESTMENT (TCI)		**5,771,261**	$TCI\ (\$) = Total\ Prime\ Contract\ (\$) + Escalation\ (\$) + Contingency\ (\$) + Owner's\ Cost\ (\$)$

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NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-1**	
Control	**ULNB**	
Rated Heat Input	**415.0**	**MMBtu/hr**
Number of Burners	**32.0**	**Burners**
Baseline Actual Emissions	**418.07**	**tpy**
Current Emission Rate	**0.230**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**437.8**	**GJ/hr**
Burner Heat Release Rate	**16.1**	**GJ/hr**

COST COMPONENT:	COST ($)	Equation
ANNUAL DIRECT COSTS		
Operation and Maintenance Labor		
Maintenance Labor and Material (2.75% of TCI)	158,710	$Maintenance\ Labor\ and\ Material\ (\$) = TCI\ (\$) * 2.75\%$
	158,710	
Utilities		
None		
Subtotal - Utilities	**0.0**	
TOTAL ANNUAL DIRECT COSTS	**158,710**	

COST COMPONENT:	COST ($)	Equation
TOTAL ANNUAL O&M COSTS	**158,710**	
Annualized Cost Factor		
Replacement Life, years (n) = 10		
Interest Rate, % (i) = 20		
Annualized Cost Factor	0.24	$ACF = \frac{i(1+i)^n}{(1+i)^n - 1}$
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT	5,771,261	
TOTAL ANNUAL CAPITAL REQUIREMENT	**1,376,577**	$Total\ Annual\ Capital\ Requirement\ (\$) = TCI\ (\$) * ACF$
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***	**1,535,287**	$Total\ Annualized\ Cost\ (\$) = Total\ Annual\ Capital\ Requirement\ (\$) + Total\ O\&M\ Costs\ (\$)$

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NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-1**	
Control	**SCR**	
Rated Heat Input	**415.0**	**MMBtu/hr**
Number of Burners	**32.0**	**Burners**
Baseline Actual Emissions	**418.07**	**tpy**
Current Emission Rate	**0.230**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**437.8**	**GJ/hr**
Burner Heat Release Rate	**16.1**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	COST ($)	Equation
DIRECT COSTS			
	Purchased Equipment Costs		
	Equipment Cost (EC)	8,944,100	$EC = \left(1{,}373{,}000 \times \left(\frac{Q}{48.5}\right)^{0.6} + 49{,}000 \times \left(\frac{Q}{485}\right)\right) * Cost\ Escalation\ Factor$
	Instrumentation (Included in above costs)	- - -	
	Sales taxes (Included in above costs)	- - -	
	Freight (Included in above costs)	- - -	
	Subtotal - Purchased Equipment Costs (PEC)	**8,944,100**	$PEC\ (\$) = EC\ (\$) + Instrumentation(\$) + Sales\ Tax\ (\$) + Freight(\$)$
	Direct Installation Costs		
	Foundations & supports; handling & erection; electrical; piping; etc.	0	
	Site Preparation / Buildings- Included above	- - -	
	Subtotal - Direct Installation Costs	**0**	
TOTAL DIRECT COSTS (TDC)		**8,944,100**	$TDC(\$) = PEC\ (\$)$
INDIRECT INSTALLATION COSTS			
	Engineering Costs (Included in above costs)	- - -	
	Construct. & Field Expenses (Included in above costs)	- - -	
	Contractor Fees (Included in above costs)	- - -	
	Start-up (Included in above costs)	- - -	
	Performance Test (Included in above costs)	- - -	
	Contingency (3% of PEC)	268,323	$Contingency\ (\$) = PEC\ (\$) * 3\%$
TOTAL INDIRECT COSTS, IC		**268,323**	$IC = Engineering\ Costs + Contractor\ Fees + Startup + Lost\ Production\ Cost + Performance\ Test + Contingency$
TOTAL CAPITAL INVESTMENT (TCI)		**9,212,423**	

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Source	**Unit 137 F-1**	
Control	**SCR**	
Rated Heat Input	**415.0**	**MMBtu/hr**
Number of Burners	**32.0**	**Burners**
Baseline Actual Emissions	**418.07**	**tpy**
Current Emission Rate	**0.230**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**437.8**	**GJ/hr**
Burner Heat Release Rate	**16.1**	**GJ/hr**

COST COMPONENT:	COST ($)	Equation
ANNUAL DIRECT COSTS		
Operation and Maintenance Labor		
Maintenance Labor and Material (2.75% of TCI)	253,342	$Maintenance\ Labor\ and\ Material\ (\$) = TCI\ (\$) * 2.75\%$
	253,342	
Utilities		
Ammonia Cost	60,700	$NH_3\ cost\ = (lb/hr) \times \left(\frac{1\ mol\ NO_x}{46\ lb\ NO_x}\right) \times \left(\frac{17\ lb\ NH_3}{1\ mol\ NH_3}\right) \times \left(\frac{1\ mol\ NH_3}{1\ mol\ NO_x}\right) \times \left(\frac{\$0.125}{lb\ NH_3}\right) \times \left(8{,}760\frac{hr}{yr}\right) \times Cost\ Escalation\ Factor$
Catalyst Replacement Cost	131,777	$Catalyst\ Replacement\ Cost = \left(49{,}000 \times \frac{Q}{48.5}/5\ years\right) \times Cost\ Escalation\ Factor$
Electricity Cost	4.4	$Electricty\ cost = \left(\frac{0.3\ kWh}{ton\ NH_3}\right) \times \left(\frac{ton\ NH_3}{year}\right) \times \left(\frac{\$0.06}{kWh}\right) \times Cost\ Escalation\ Factor$
Subtotal - Utilities	**192,481**	
TOTAL ANNUAL DIRECT COSTS	**445,822**	

COST COMPONENT:	COST ($)	Equation
TOTAL ANNUAL O&M COSTS	**445,822**	
Annualized Cost Factor		
Replacement Life, years (n) = 20		$ACF = \frac{i(1+i)^n}{(1+i)^n - 1}$
Interest Rate, % (i) = 20		
Annualized Cost Factor	0.21	
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT	9,212,423	
TOTAL ANNUAL CAPITAL REQUIREMENT	**1,891,831**	$Total\ Annual\ Capital\ Requirement\ (\$) = TCI\ (\$) * ACF$
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***	**2,337,654**	$Total\ Annualized\ Cost\ (\$) = Total\ Annual\ Capital\ Requirement + Total\ O\&M\ Costs\ (\$)$

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NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-1**	
Control	**LNB & SNCR**	
Rated Heat Input	**415.0**	**MMBtu/hr**
Number of Burners	**32.0**	**Burners**
Baseline Actual Emissions	**418.07**	**tpy**
Current Emission Rate	**0.230**	**lb/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**437.8**	**GJ/hr**
Burner Heat Release Rate	**16.1**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from Vendor Quotation and *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

COST COMPONENT:		COST ($)	Equation
DIRECT COSTS - LNB			
	Purchased Equipment Costs		
	Equipment Cost (EC)	720,761	$EC(\$) = Burner\ Cost\ and\ Direct\ Materials\ from\ Vendor\ Quotation$ $(LNB\ EC\ (\$)\ assumed\ to\ be\ 80\%\ of\ ULNB\ EC\ (\$))$
	Instrumentation (included in Furnace Modifications)	- - -	
	Sales taxes (added below to all materials and equipment)	- - -	
	Freight (added below to all materials and equipment)	- - -	
	Subtotal - Purchased Equipment Costs (PEC)	**720,761**	$PEC\ (\$) = EC\ (\$)$
	Direct Installation Costs		
	Direct Labor - Header Improvements	304,665	
	Direct Labor - Burner Install	180,000	
	Direct Labor - Piping Modifications	781,750	$All\ Direct\ Installation\ Costs\ from\ Vendor\ Quotation$
	Direct Labor - Furnace Modifications (Instrumentation)	158,500	
	Direct Labor - Demolition	96,277	
	Subtotal - Direct Installation Costs	**1,521,192**	
TOTAL DIRECT COSTS (TDC) - LNB		**2,241,953**	$TDC\ (\$) = PEC\ (\$) + Direct\ Installation\ Costs$
INDIRECT INSTALLATION COSTS - LNB			
	Sales Tax and Freight (5% of EC)	36,038	$Sales\ Tax\ and\ Freight\ (\$) = EC\ (\$) * 5\%$
	Temporary Construction (10% of all labor hours @ $75/hour)	70,116	$Temporary\ Construction\ (\$) = Labor\ Hours * 10\% * \$75/hour$
	Construction Equipment (2% of Direct Installation Costs)	30,424	$Construction\ Equipment\ (\$) = Direct\ Installation\ Costs\ (\$) * 2\%$
	Construction Supervision (5% of Direct Installation Costs)	76,060	$Construction\ Supervision(\$) = Direct\ Installation\ Costs\ (\$) * 5\%$
TOTAL INDIRECT COSTS, IC - LNB		**212,637**	$IC\ (\$) = Sales\ Tax\ and\ Freight\ (\$) + Temporary\ Construction\ (\$) + Construction\ Equipment\ (\$) + Construction\ Supervision\ (\$)$

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NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-1**	
Control	**LNB & SNCR**	
Rated Heat Input	**415.0**	**MMBtu/hr**
Number of Burners	**32.0**	**Burners**
Baseline Actual Emissions	**418.07**	**tpy**
Current Emission Rate	**0.230**	**lb/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**437.8**	**GJ/hr**
Burner Heat Release Rate	**16.1**	**GJ/hr**

OTHER COSTS - LNB			
	Detailed Engineering (30% of TDC + IC)	736,377	$Detailed\ Engineering\ (\$) = (TDC(\$) + IC\ (\$)) * 30\%$
	Construction Management (5% of TDC + IC)	122,729	$Construction\ Management\ (\$) = (TDC(\$) + IC\ (\$)) * 5\%$
	Subtotal - Total Prime Contract (TDC + IC + Detailed Engineering + Construction Management)	**3,313,696**	$Total\ Prime\ Contract\ (\$) = (TDC\ (\$) + IC\ (\$) + Detailed\ Engineering\ (\$) + Construction\ Management\ (\$)$
	Escalation (5% of Total Prime Contract)	165,685	$Escalation\ (\$) = Total\ Prime\ Contract\ (\$) * 5\%$
	Contingency (40% of Total Prime Contract + Escalation)	1,391,752	$Contingency\ (\$) = (Total\ Prime\ Contract\ (\$) + Escalation\ (\$)) * 40\%$
	Owner's Cost (10% of Total Prime Contract + Escalation + Contingency)	487,113	$Owner's\ Cost\ (\$) = \left(\begin{matrix}Total\ Prime\ Contract\ (\$) + Escalation\ (\$) \\ + Contingency\ (\$)\end{matrix}\right) * 10\%$
DIRECT COSTS - SNCR			
	Purchased Equipment Costs		
	Equipment Cost (EC)	1,673,059	$EC = 31{,}850(Q)^{0.6} \times \text{Cost Escalation Factor}$
	Instrumentation (Included in above costs)	- - -	
	Sales taxes (Included in above costs)	- - -	
	Freight (Included in above costs)	- - -	
	Subtotal - Purchased Equipment Costs (PEC)	**1,673,059**	
	Direct Installation Costs		
	Foundations & supports; handling & erection; electrical; piping; etc.	0	
	Site Preparation / Buildings- Included above	- - -	
	Subtotal - Direct Installation Costs	**0**	
TOTAL DIRECT COSTS (TDC) - SNCR		**1,673,059**	
INDIRECT INSTALLATION COSTS - SNCR			
	Engineering Costs (Included in above costs)	- - -	
	Construct. & Field Expenses (Included in above costs)	- - -	
	Contractor Fees (Included in above costs)	- - -	
	Start-up (Included in above costs)	- - -	
	Performance Test (Included in above costs)	- - -	
	Contingency (3% of PEC)	50,192	$Contingency\ (\$) = PEC\ (\$) * 3\%$
TOTAL INDIRECT COSTS, IC - SNCR		**50,192**	
TOTAL CAPITAL INVESTMENT (TCI) - LNB		**5,358,247**	
TOTAL CAPITAL INVESTMENT (TCI) - SNCR		**1,723,251**	
TOTAL CAPITAL INVESTMENT (TCI)		**7,081,498**	

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NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-1**	
Control	**LNB & SNCR**	
Rated Heat Input	**415.0**	**MMBtu/hr**
Number of Burners	**32.0**	**Burners**
Baseline Actual Emissions	**418.07**	**tpy**
Current Emission Rate	**0.230**	**lb/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**437.8**	**GJ/hr**
Burner Heat Release Rate	**16.1**	**GJ/hr**

COST COMPONENT:	COST ($)	Equation
ANNUAL DIRECT COSTS		
Operation and Maintenance Labor		
Maintenance Labor and Material (2.75% of TCI)	194,741	$Maintenance\ Labor\ and\ Material\ (\$) = TCI\ (\$) * 2.75\%$
	194,741	
Utilities		
Ammonia Cost	60,700	$NH_3\ cost\ = (lb/hr) \times \left(\frac{1\ mol\ NO_x}{46\ lb\ NO_x}\right) \times \left(\frac{17\ lb\ NH_3}{1\ mol\ NH_3}\right) \times \left(\frac{1\ mol\ NH_3}{1\ mol\ NO_x}\right) \times \left(\frac{\$0.125}{lb\ NH_3}\right) \times \left(8{,}760\frac{hr}{yr}\right) \times Cost\ Escalation\ Factor$
Electricity Cost	4.4	$Electricty\ cost = \left(\frac{0.3\ kWh}{ton\ NH_3}\right) \times \left(\frac{ton\ NH_3}{year}\right) \times \left(\frac{\$0.06}{kWh}\right) \times Cost\ Escalation\ Factor$
Fuel Penalty Cost ($4.88/Mscf)	521,787	$Fuel\ Penalty\ cost = 3\% \times Q \times \left(\frac{8{,}760\ hours}{year}\right) \times \left(\frac{\$4.78}{MMBtu}\right)$
Subtotal - Utilities	**582,491**	
TOTAL ANNUAL DIRECT COSTS	**777,232**	

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NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-1**	
Control	**LNB & SNCR**	
Rated Heat Input	**415.0**	**MMBtu/hr**
Number of Burners	**32.0**	**Burners**
Baseline Actual Emissions	**418.07**	**tpy**
Current Emission Rate	**0.230**	**lb/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**437.8**	**GJ/hr**
Burner Heat Release Rate	**16.1**	**GJ/hr**

COST COMPONENT:			**COST ($)**	**Equation**
TOTAL ANNUAL O&M COSTS			**777,232**	
Annualized Cost Factor - LNB				
	Replacement Life, years (n) =	10		
	Interest Rate, % (i) =	20		
	Annualized Cost Factor		0.24	
Annualized Cost Factor - SNCR				$ACF = \frac{i(1+i)^n}{(1+i)^n - 1}$
	Replacement Life, years (n) =	20		
	Interest Rate, % (i) =	20		
	Annualized Cost Factor		0.21	
CAPITAL RECOVERY COSTS				
	TOTAL CAPITAL REQUIREMENT		7,081,498	
	TOTAL ANNUAL CAPITAL REQUIREMENT		**1,631,945**	$Total\ Annual\ Capital\ Requirement\ (\$) = TCI\ (\$) * ACF$
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***			**2,409,177**	$Total\ Annualized\ Cost\ (\$) = Total\ Annual\ Capital\ Requirement + Total\ O\&M\ Costs\ (\$)$

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NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-1**	
Control	**LNB & FGR**	
Rated Heat Input	**415.0**	**MMBtu/hr**
Number of Burners	**32.0**	**Burners**
Baseline Actual Emissions	**418.07**	**tpy**
Current Emission Rate	**0.230**	**lb/MMBtu**
Control Efficiency	**55%**	
Heater Capacity	**437.8**	**GJ/hr**
Burner Heat Release Rate	**16.1**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from Vendor Quotation and *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	**COST ($)**	**Equation**
DIRECT COSTS - LNB			
	Purchased Equipment Costs		
	Equipment Cost (EC)	720,761	$EC(\$) = Burner\ Cost\ and\ Direct\ Materials\ from\ Vendor\ Quotation$ $(LNB\ EC\ (\$)\ assumed\ to\ be\ 80\%\ of\ ULNB\ EC\ (\$))$
	Instrumentation (included in Furnace Modifications)	- - -	
	Sales taxes (added below to all materials and equipment)	- - -	
	Freight (added below to all materials and equipment)	- - -	
	Subtotal - Purchased Equipment Costs (PEC)	**720,761**	$PEC\ (\$) = EC\ (\$)$
	Direct Installation Costs		
	Direct Labor - Header Improvements	304,665	
	Direct Labor - Burner Install	180,000	
	Direct Labor - Piping Modifications	781,750	$All\ Direct\ Installation\ Costs\ from\ Vendor\ Quotation$
	Direct Labor - Furnace Modifications (Instrumentation)	158,500	
	Direct Labor - Demolition	96,277	
	Subtotal - Direct Installation Costs	**1,521,192**	
TOTAL DIRECT COSTS (TDC) - LNB		**2,241,953**	$TDC\ (\$) = PEC\ (\$) + Direct\ Installation\ Costs$
INDIRECT INSTALLATION COSTS - LNB			
	Sales Tax and Freight (5% of EC)	36,038	$Sales\ Tax\ and\ Freight\ (\$) = EC\ (\$) * 5\%$
	Temporary Construction (10% of all labor hours @ $75/hour)	70,116	$Temporary\ Construction\ (\$) = Labor\ Hours * 10\% * \$75/hour$
	Construction Equipment (2% of Direct Installation Costs)	30,424	$Construction\ Equipment\ (\$) = Direct\ Installation\ Costs\ (\$) * 2\%$
	Construction Supervision (5% of Direct Installation Costs)	76,060	$Construction\ Supervision(\$) = Direct\ Installation\ Costs\ (\$) * 5\%$
TOTAL INDIRECT COSTS, IC - LNB		**212,637**	$IC\ (\$) = Sales\ Tax\ and\ Freight\ (\$) + Temporary\ Construction\ (\$) + Construction\ Equipment\ (\$) + Construction\ Supervision\ (\$)$

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Source	**Unit 137 F-1**	
Control	**LNB & FGR**	
Rated Heat Input	**415.0**	**MMBtu/hr**
Number of Burners	**32.0**	**Burners**
Baseline Actual Emissions	**418.07**	**tpy**
Current Emission Rate	**0.230**	**lb/MMBtu**
Control Efficiency	**55%**	
Heater Capacity	**437.8**	**GJ/hr**
Burner Heat Release Rate	**16.1**	**GJ/hr**

OTHER COSTS - LNB			
	Detailed Engineering (30% of TDC + IC)	736,377	$Detailed\ Engineering\ (\$) = (TDC(\$) + IC\ (\$)) * 30\%$
	Construction Management (5% of TDC + IC)	122,729	$Construction\ Management\ (\$) = (TDC(\$) + IC\ (\$)) * 5\%$
	Subtotal - Total Prime Contract (TDC + IC + Detailed Engineering + Construction Management)	**3,313,696**	$Total\ Prime\ Contract\ (\$) = (TDC\ (\$)\ +\ IC\ (\$) +\ Detailed\ Engineering\ (\$) + Construction\ Management\ (\$)$
	Escalation (5% of Total Prime Contract)	165,685	$Escalation\ (\$) = Total\ Prime\ Contract\ (\$) * 5\%$
	Contingency (40% of Total Prime Contract + Escalation)	1,391,752	$Contingency\ (\$) = \left(Total\ Prime\ Contract\ (\$) + Escalation\ (\$)\right) * 40\%$
	Owner's Cost (10% of Total Prime Contract + Escalation + Contingency)	487,113	$Owner's\ Cost\ (\$) = \begin{pmatrix} Total\ Prime\ Contract\ (\$) + Escalation\ (\$) \\ + Contingency\ (\$) \end{pmatrix} * 10\%$
DIRECT COSTS - FGR			
	Purchased Equipment Costs		
	Equipment Cost (EC)	672,375	$TCI = 12{,}800(HQ)^{0.6}$
	Instrumentation (Included in above costs)	- - -	HQ = heater capacity (GJ/hr)
	Sales taxes (Included in above costs)	- - -	
	Freight (Included in above costs)	- - -	
	Subtotal - Purchased Equipment Costs (PEC)	**672,375**	
	Direct Installation Costs		
	Foundations & supports; handling & erection; electrical; piping; etc.	0	
	Site Preparation / Buildings- Included above	- - -	
	Subtotal - Direct Installation Costs	**0**	
TOTAL DIRECT COSTS (TDC) - FGR		**672,375**	
INDIRECT INSTALLATION COSTS - FGR			
	Engineering Costs (Included in above costs)	- - -	
	Construct. & Field Expenses (Included in above costs)	- - -	
	Contractor Fees (Included in above costs)	- - -	
	Start-up (Included in above costs)	- - -	
	Performance Test (Included in above costs)	- - -	
	Contingency (3% of PEC)	20,171	$Contingency\ (\$) = PEC\ (\$) * 3\%$
TOTAL INDIRECT COSTS, IC - FGR		**20,171**	
TOTAL CAPITAL INVESTMENT (TCI) - LNB		**5,358,247**	
TOTAL CAPITAL INVESTMENT (TCI) - FGR		**692,547**	
TOTAL CAPITAL INVESTMENT (TCI)		**6,050,794**	

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-1**	
Control	**LNB & FGR**	
Rated Heat Input	**415.0**	**MMBtu/hr**
Number of Burners	**32.0**	**Burners**
Baseline Actual Emissions	**418.07**	**tpy**
Current Emission Rate	**0.230**	**lb/MMBtu**
Control Efficiency	**55%**	
Heater Capacity	**437.8**	**GJ/hr**
Burner Heat Release Rate	**16.1**	**GJ/hr**

COST COMPONENT:	**COST ($)**	**Equation**
ANNUAL DIRECT COSTS		
Operation and Maintenance Labor		
Maintenance Labor and Material (2.75% of TCI)	166,397	$Maintenance\ Labor\ and\ Material\ (\$) = TCI\ (\$) * 2.75\%$
	166,397	
Utilities		
Electricity Cost	51,416	$Electricty\ cost = \left(\frac{0.3\ kWh}{ton\ NH_3}\right) \times \left(\frac{ton\ NH_3}{year}\right) \times \left(\frac{\$0.06}{kWh}\right) \times Cost\ Escalation\ Factor$
Subtotal - Utilities	**51,416**	
TOTAL ANNUAL DIRECT COSTS	**217,813**	

COST COMPONENT:	**COST ($)**	**Equation**
TOTAL ANNUAL O&M COSTS	**217,813**	
Annualized Cost Factor		
Replacement Life, years (n) = 10		$ACF = \frac{i(1+i)^n}{(1+i)^n - 1}$
Interest Rate, % (i) = 20		
Annualized Cost Factor	0.24	
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT	6,050,794	
TOTAL ANNUAL CAPITAL REQUIREMENT	**1,443,252**	$Total\ Annual\ Capital\ Requirement\ (\$) = TCI\ (\$) * ACF$
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***	**1,661,065**	$Total\ Annualized\ Cost\ (\$) = Total\ Annual\ Capital\ Requirement + Total\ O\&M\ Costs\ (\$)$

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-1**	
Control	**SNCR**	
Rated Heat Input	**415.0**	**MMBtu/hr**
Number of Burners	**32.0**	**Burners**
Baseline Actual Emissions	**418.07**	**tpy**
Current Emission Rate	**0.230**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**437.8**	**GJ/hr**
Burner Heat Release Rate	**16.1**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

COST COMPONENT:	COST ($)	Equation
DIRECT COSTS		
Purchased Equipment Costs		
Equipment Cost (EC)	1,673,059	$EC = 31{,}850(Q)^{0.6} \times \text{Cost Escalation Factor}$
Instrumentation (Included in above costs)	- - -	
Sales taxes (Included in above costs)	- - -	
Freight (Included in above costs)	- - -	
Subtotal - Purchased Equipment Costs (PEC)	**1,673,059**	$PEC\ (\$) = EC\ (\$)$
Direct Installation Costs		
Foundations & supports; handling & erection; electrical; piping; etc.	0	
Site Preparation / Buildings- Included above	- - -	
Subtotal - Direct Installation Costs	**0**	
TOTAL DIRECT COSTS (TDC)	**1,673,059**	$TDC(\$) = PEC\ (\$)$
INDIRECT INSTALLATION COSTS		
Engineering Costs (Included in above costs)	- - -	
Construct. & Field Expenses (Included in above costs)	- - -	
Contractor Fees (Included in above costs)	- - -	
Start-up (Included in above costs)	- - -	
Performance Test (Included in above costs)	- - -	
Contingency (3% of PEC)	50,192	$Contingency\ (\$) = PEC\ (\$) * 3\%$
TOTAL INDIRECT COSTS, IC	**50,192**	$IC = Engineering\ Costs + Contractor\ Fees + Startup + Lost\ Production\ Cost + Performance\ Test + Contingency$
TOTAL CAPITAL INVESTMENT (TCI)	**1,723,251**	

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NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-1**	
Control	**SNCR**	
Rated Heat Input	**415.0**	**MMBtu/hr**
Number of Burners	**32.0**	**Burners**
Baseline Actual Emissions	**418.07**	**tpy**
Current Emission Rate	**0.230**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**437.8**	**GJ/hr**
Burner Heat Release Rate	**16.1**	**GJ/hr**

COST COMPONENT:	**COST ($)**	**Equation**
ANNUAL DIRECT COSTS		
Operation and Maintenance Labor		
Maintenance Labor and Material (2.75% of TCI)	47,389	$Maintenance\ Labor\ and\ Material\ (\$) = TCI\ (\$) * 2.75\%$
	47,389	
Utilities		
Ammonia Cost	60,700	$NH_3\ cost = (lb/hr) \times \left(\frac{1\ mol\ NO_x}{46\ lb\ NO_x}\right) \times \left(\frac{17\ lb\ NH_3}{1\ mol\ NH_3}\right) \times \left(\frac{1\ mol\ NH_3}{1\ mol\ NO_x}\right) \times \left(\frac{\$0.125}{lb\ NH_3}\right) \times \left(8{,}760\frac{hr}{yr}\right) \times Cost\ Escalation\ Factor$
Electricity Cost	4.4	$Electricty\ cost = \left(\frac{0.3\ kWh}{ton\ NH_3}\right) \times \left(\frac{ton\ NH_3}{year}\right) \times \left(\frac{\$0.06}{kWh}\right) \times Cost\ Escalation\ Factor$
Fuel Penalty Cost ($4.88/Mscf)	521,787	$Fuel\ Penalty\ cost = 3\% \times Q \times \left(\frac{8{,}760\ hours}{year}\right) \times \left(\frac{\$4.78}{MMBtu}\right)$
Subtotal - Utilities	**582,491**	
TOTAL ANNUAL DIRECT COSTS	**629,880**	

COST COMPONENT:		**COST ($)**	
TOTAL ANNUAL O&M COSTS		**629,880**	
Annualized Cost Factor			
Replacement Life, years (n) =	20		$ACF = \frac{i(1+i)^n}{(1+i)^n - 1}$
Interest Rate, % (i) =	20		
Annualized Cost Factor		0.21	
CAPITAL RECOVERY COSTS			
TOTAL CAPITAL REQUIREMENT		1,723,251	
TOTAL ANNUAL CAPITAL REQUIREMENT		**353,881**	$Total\ Annual\ Capital\ Requirement\ (\$) = TCI\ (\$) * ACF$
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**983,761**	$Total\ Annualized\ Cost\ (\$) = Total\ Annual\ Capital\ Requirement + Total\ O\&M\ Costs\ (\$)$

RACT Update 2015
NOx RACT Control Cost Effectiveness

Source	**Boiler #37**	
Control	**SCR**	
Rated Heat Input	**495.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**86.72**	**tpy**
Current Emission Rate	**0.040**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**522.3**	**GJ/hr**
Burner Heat Release Rate	**76.6**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies
Costs derived from *Alternative Control Techniques Document - NOx Emissions from Utility Boilers* - EPA-453/R-94-023

	COST COMPONENT:	**COST ($)**	**Equation**
DIRECT COSTS			
	Purchased Equipment Costs		
	Equipment Cost (EC)	7,358,414	$EC = BSC\left(\frac{\$}{kW}\right) \times MW \times \frac{1000\ kW}{MW} \times Cost\ Escalation\ Factor$
	Instrumentation (Included in above costs)	- - -	
	Sales taxes (Included in above costs)	- - -	
	Freight (Included in above costs)	- - -	
	Subtotal - Purchased Equipment Costs (PEC)	**7,358,414**	$PEC = EC$
	Direct Installation Costs		
	Foundations & supports; handling & erection; electrical; piping; etc.	- - -	
	Site Preparation / Buildings- Included above	- - -	
	Subtotal - Direct Installation Costs	**0**	
TOTAL DIRECT COSTS (TDC)		**7,358,414**	$TDC = EC$
TOTAL INDIRECT COSTS, IC	Assumed to be 30% of Direct Costs	**2,207,524**	$IC = 30\% \times TDC$
TOTAL CAPITAL INVESTMENT (TCI)		**9,565,938**	

RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Boiler #37**	
Control	**SCR**	
Rated Heat Input	**495.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**86.72**	**tpy**
Current Emission Rate	**0.040**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**522.3**	**GJ/hr**
Burner Heat Release Rate	**76.6**	**GJ/hr**

COST COMPONENT:	**COST ($)**	**Equation**
ANNUAL DIRECT COSTS		
Operation and Maintenance Labor		
Maintenance Labor and Material (2.75% of TCI)	263,063	$Maintenance\ \&\ Labor = 2.75\% \times TCI$
	263,063	
Utilities		
Ammonia Cost	14,276	$NH_3\ cost = (lb/hr) \times \left(\frac{1\ mol\ NO_x}{46\ lb\ NO_x}\right) \times \left(\frac{17\ lb\ NH_3}{1\ mol\ NH_3}\right) \times \left(\frac{1\ mol\ NH_3}{1\ mol\ NO_x}\right) \times \left(\frac{\$0.125}{lb\ NH_3}\right) \times \left(8{,}760\frac{hr}{yr}\right) \times Cost\ Escalation\ Factor$
Catalyst Replacement Cost	178,209	$Catalyst\ Replacement\ Cost = \left(49{,}000 \times \frac{Q}{48.5}/5\ years\right) \times Cost\ Escalation\ Factor$
Electricity Cost	1.0	$Electricty\ cost = \left(\frac{0.3\ kWh}{ton\ NH_3}\right) \times \left(\frac{ton\ NH_3}{year}\right) \times \left(\frac{\$0.06}{kWh}\right) \times Cost\ Escalation\ Factor$
Subtotal - Utilities	**192,486**	
TOTAL ANNUAL DIRECT COSTS	**455,549**	

RACT Update 2015
NOx RACT Control Cost Effectiveness

Source	**Boiler #37**	
Control	**SCR**	
Rated Heat Input	**495.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**86.72**	**tpy**
Current Emission Rate	**0.040**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**522.3**	**GJ/hr**
Burner Heat Release Rate	**76.6**	**GJ/hr**

COST COMPONENT:			**COST ($)**	**Equation**
TOTAL ANNUAL O&M COSTS			**455,549**	
Annualized Cost Factor				
	Replacement Life, years (n) =	20		$ACF = \frac{i(1+i)^n}{(1+i)^n - 1}$
	Interest Rate, % (i) =	20		
	Annualized Cost Factor		0.21	
CAPITAL RECOVERY COSTS				
	TOTAL CAPITAL REQUIREMENT		9,565,938	
	TOTAL ANNUAL CAPITAL REQUIREMENT		**1,964,428**	$Total\ Annual\ Capital\ Requirement\ (\$) = TCI\ (\$) * ACF$
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***			**2,419,977**	$Total\ Annualized\ Cost\ (\$) = Total\ Annual\ Capital\ Requirement + Total\ O\&M\ Costs\ (\$)$

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Boiler #37**	
Control	**SNCR**	
Rated Heat Input	**495.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**86.72**	**tpy**
Current Emission Rate	**0.040**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**522.3**	**GJ/hr**
Burner Heat Release Rate	**76.6**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

COST COMPONENT:	COST ($)	Equation
DIRECT COSTS		
Purchased Equipment Costs		
Equipment Cost (EC)	1,859,711	$EC = BSC\left(\frac{\$}{kW}\right) \times MW \times \frac{1000\ kW}{MW} \times Cost\ Escalation\ Factor$
Instrumentation (Included in above costs)	- - -	
Sales taxes (Included in above costs)	- - -	
Freight (Included in above costs)	- - -	
Subtotal - Purchased Equipment Costs (PEC)	**1,859,711**	$PEC = EC$
Direct Installation Costs		
Foundations & supports; handling & erection; electrical; piping; etc.	0	
Site Preparation / Buildings- Included above	- - -	
Subtotal - Direct Installation Costs	**0**	
TOTAL DIRECT COSTS (TDC)	**1,859,711**	$TDC = EC$
INDIRECT INSTALLATION COSTS		$IC = 30\% \times TDC$
Engineering Costs (Included in above costs)	- - -	
Construct. & Field Expenses (Included in above costs)	- - -	
Contractor Fees (Included in above costs)	- - -	
Start-up (Included in above costs)	- - -	
Performance Test (Included in above costs)	- - -	
Contingency (3% of PEC)	55,791	
TOTAL INDIRECT COSTS, IC	**55,791**	
TOTAL CAPITAL INVESTMENT (TCI)	**1,915,503**	

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Boiler #37**	
Control	**SNCR**	
Rated Heat Input	**495.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**86.72**	**tpy**
Current Emission Rate	**0.040**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**522.3**	**GJ/hr**
Burner Heat Release Rate	**76.6**	**GJ/hr**

COST COMPONENT:	**COST ($)**	**Equation**
ANNUAL DIRECT COSTS		
Operation and Maintenance Labor		
Maintenance Labor and Material (2.75% of TCI)	52,676	$Maintenance\ \&\ Labor = 2.75\% \times TCI$
	52,676	
Utilities		
Ammonia Cost	12,591	$NH_3\ cost = (lb/hr) \times \left(\frac{1\ mol\ NO_x}{46\ lb\ NO_x}\right) \times \left(\frac{17\ lb\ NH_3}{1\ mol\ NH_3}\right) \times \left(\frac{1\ mol\ NH_3}{1\ mol\ NO_x}\right) \times \left(\frac{\$0.125}{lb\ NH_3}\right) \times \left(8{,}760\frac{hr}{yr}\right) \times Cost\ Escalation\ Factor$
Electricity Cost	0.9	$Electricty\ cost = \left(\frac{0.3\ kWh}{ton\ NH_3}\right) \times \left(\frac{ton\ NH_3}{year}\right) \times \left(\frac{\$0.06}{kWh}\right) \times Cost\ Escalation\ Factor$
Subtotal - Utilities	**12,592**	
TOTAL ANNUAL DIRECT COSTS	**65,269**	

COST COMPONENT:		**COST ($)**	**Equation**
TOTAL ANNUAL O&M COSTS		**65,269**	
Annualized Cost Factor			
Replacement Life, years (n) =	20		
Interest Rate, % (i) =	20		$ACF = \frac{i(1+i)^n}{(1+i)^n - 1}$
Annualized Cost Factor		0.21	
CAPITAL RECOVERY COSTS			
TOTAL CAPITAL REQUIREMENT		1,915,503	
TOTAL ANNUAL CAPITAL REQUIREMENT		**393,361**	$Total\ Annual\ Capital\ Requirement\ (\$) = TCI\ (\$) * ACF$
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**458,630**	$Total\ Annualized\ Cost\ (\$) = Total\ Annual\ Capital\ Requirement + Total\ O\&M\ Costs\ (\$)$

RACT Update 2015
Unit 210-13H1 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (lb/MMBtu)	Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[1] ($)	2013 Cost Effectiveness ($/Ton)
ULNB & SCR	235.4	0.104	107.2	96%	4.3	103.0	NA	NA	NA	Infeasible
SCR	235.4	0.104	107.2	85%	16.1	91.1	NA	NA	NA	Infeasible
ULNB	235.4	0.104	107.2	71%	30.9	76.3	903,784	24,854	240,427	3,151
LNB & SNCR	235.4	0.104	107.2	70%	32.2	75.1	1,802,822	361,120	750,462	9,998
LNB & FGR	235.4	0.104	107.2	55%	48.3	59.0	NA	NA	NA	Infeasible
SNCR	235.4	0.104	107.2	40%	64.3	42.9	1,226,319	345,266	597,099	13,921
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
SCR would not physically fit the plot space; therefore, SCR is infeasible.
FGR would not physically fit the plot space; therefore, it is infeasible.
Notes:
[1] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).

RACT Update 2015
Unit 860-2H2 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (lb/MMBtu)	Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[1] ($)	2013 Cost Effectiveness ($/Ton)
ULNB & SCR	69.8	0.35	107.0	96%	4.3	102.7	NA	NA	NA	Infeasible
SCR	69.8	0.35	107.0	85%	16.1	91.0	NA	NA	NA	Infeasible
LNB & SNCR	69.8	0.35	107.0	70%	32.1	74.9	NA	NA	NA	Infeasible
LNB & FGR	69.8	0.35	107.0	55%	48.2	58.9	NA	NA	NA	Infeasible
ULNB[2]	69.8	0.35	107.0	50%	53.5	53.5	NA	NA	NA	Infeasible
SNCR	69.8	0.35	107.0	40%	64.2	42.8	591,334	119,559	240,994	5,631
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
SCR would not physically fit the plot space and there is not adequate pressure to overcome the SCR pressure drop; therefore, SCR is infeasible.
LNB and ULNB are not suitable for this heater due to their extended flame length causing flame impingement. The avalaible floor space also does not allow for installation
FGR installation would require the installation of mechanical draft burners, which is a major re-design of the unit; therefore FGR is infeasible.
Notes:
[1] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).
[2] Heaters with higher combustion temperatures such as those servicing reformer units are only expected to achieve 50% control efficiency using ULNB (Alternative Control Techniques Document - NO_x Emissions from Process Heaters (Revised) - EPA-453/R-93-034, Table 2-2 Reduction Efficiencies For Control Techniques Applied to Natural Gas- and Refinery Fuel Gas-Fired Process Heaters and Pyrolysis Furnaces, page 2-8).

RACT Update 2015
Unit 860-2H3 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (lb/MMBtu)	Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[1] ($)	2013 Cost Effectiveness ($/Ton)
ULNB & SCR	174.7	0.163	124.7	96%	5.0	119.8	NA	NA	NA	Infeasible
SCR	174.7	0.163	124.7	85%	18.7	106.0	NA	NA	NA	Infeasible
LNB & SNCR	174.7	0.163	124.7	70%	37.4	87.3	NA	NA	NA	Infeasible
LNB & FGR	174.7	0.163	124.7	55%	56.1	68.6	NA	NA	NA	Infeasible
ULNB[2]	174.7	0.163	124.7	50%	62.4	62.4	NA	NA	NA	Infeasible
SNCR	174.7	0.163	124.7	40%	74.8	49.9	1,025,405	265,962	476,536	9,552
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
SCR would not physically fit the plot space and there is not adequate pressure to overcome the SCR pressure drop; therefore, SCR is infeasible.
LNB and ULNB are not suitable for this heater due to their extended flame length causing flame impingement. The avalaible floor space also does not allow for installation
FGR installation would require the installation of mechanical draft burners, which is a major re-design of the unit; therefore FGR is infeasible.
Notes:
[1] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).
[2] Heaters with higher combustion temperatures such as those servicing reformer units are only expected to achieve 50% control efficiency using ULNB (Alternative Control Techniques Document - NO_x Emissions from Process Heaters (Revised) - EPA-453/R-93-034, Table 2-2 Reduction Efficiencies For Control Techniques Applied to Natural Gas- and Refinery Fuel Gas-Fired Process Heaters and Pyrolysis Furnaces, page 2-8).

RACT Update 2015
Unit 860-2H4 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (lb/MMBtu)	Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[1] ($)	2013 Cost Effectiveness ($/Ton)
ULNB & SCR	99.4	0.27	117.6	96%	4.7	112.9	NA	NA	NA	Infeasible
SCR	99.4	0.27	117.6	85%	17.6	99.9	NA	NA	NA	Infeasible
LNB & SNCR	99.4	0.27	117.6	70%	35.3	82.3	4,756,124	272,839	1,383,037	16,808
LNB & FGR	99.4	0.27	117.6	55%	52.9	64.7	NA	NA	NA	Infeasible
ULNB[2]	99.4	0.27	117.6	50%	58.8	58.8	662,583	18,221	176,262	2,999
SNCR	99.4	0.27	117.6	40%	70.5	47.0	731,057	162,150	312,277	6,641
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
SCR would not physically fit the plot space and there is not adequate pressure to overcome the SCR pressure drop; therefore, SCR is infeasible.
FGR installation would require the installation of mechanical draft burners, which is a major re-design of the unit; therefore FGR is infeasible.
Notes:
[1] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).
[2] Heaters with higher combustion temperatures such as those servicing reformer units are only expected to achieve 50% control efficiency using ULNB (Alternative Control Techniques Document - NO_x Emissions from Process Heaters (Revised) - EPA-453/R-93-034, Table 2-2 Reduction Efficiencies For Control Techniques Applied to Natural Gas- and Refinery Fuel Gas-Fired Process Heaters and Pyrolysis Furnaces, page 2-8).

RACT Update 2015
Unit 860-2H5 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (lb/MMBtu)	Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[1] ($)	2013 Cost Effectiveness ($/Ton)
ULNB & SCR	155.0	0.163	110.7	96%	4.4	106.3	NA	NA	NA	Infeasible
SCR	155.0	0.163	110.7	85%	16.6	94.1	NA	NA	NA	Infeasible
LNB & SNCR	155.0	0.163	110.7	70%	33.2	77.5	NA	NA	NA	Infeasible
LNB & FGR	155.0	0.163	110.7	55%	49.8	60.9	NA	NA	NA	Infeasible
ULNB[2]	155.0	0.163	110.7	50%	55.3	55.3	NA	NA	NA	Infeasible
SNCR	155.0	0.163	110.7	40%	66.4	44.3	954,374	237,198	433,184	9,786
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
SCR would not physically fit the plot space and there is not adequate pressure to overcome the SCR pressure drop; therefore, SCR is infeasible.
LNB and ULNB are not suitable for this heater due to their extended flame length causing flame impingement. The avalaible floor space also does not allow for installation
FGR installation would require the installation of mechanical draft burners, which is a major re-design of the unit; therefore FGR is infeasible.
Notes:
[1] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).
[2] Heaters with higher combustion temperatures such as those servicing reformer units are only expected to achieve 50% control efficiency using ULNB (Alternative Control Techniques Document - NO_x Emissions from Process Heaters (Revised) - EPA-453/R-93-034, Table 2-2 Reduction Efficiencies For Control Techniques Applied to Natural Gas- and Refinery Fuel Gas-Fired Process Heaters and Pyrolysis Furnaces, page 2-8).

RACT Update 2015
Unit 860-2H7 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (lb/MMBtu)	Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[1] ($)	2013 Cost Effectiveness ($/Ton)
ULNB & SCR	59.0	0.157	40.6	96%	1.6	39.0	NA	NA	NA	Infeasible
SCR	59.0	0.157	40.6	85%	6.1	34.5	NA	NA	NA	Infeasible
LNB & SNCR	59.0	0.157	40.6	70%	12.2	28.4	NA	NA	NA	Infeasible
LNB & FGR	59.0	0.157	40.6	55%	18.3	22.3	NA	NA	NA	Infeasible
ULNB[2]	59.0	0.157	40.6	50%	20.3	20.3	NA	NA	NA	Infeasible
SNCR	59.0	0.157	40.6	40%	24.3	16.2	534,602	94,774	204,558	12,605
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
SCR would not physically fit the plot space and there is not adequate pressure to overcome the SCR pressure drop; therefore, SCR is infeasible.
LNB and ULNB are not suitable for this heater due to their extended flame length causing flame impingement. The avalaible floor space also does not allow for installation
FGR installation would require the installation of mechanical draft burners, which is a major re-design of the unit; therefore FGR is infeasible.
Notes:
[1] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).
[2] Heaters with higher combustion temperatures such as those servicing reformer units are only expected to achieve 50% control efficiency using ULNB (Alternative Control Techniques Document - NO_x Emissions from Process Heaters (Revised) - EPA-453/R-93-034, Table 2-2 Reduction Efficiencies For Control Techniques Applied to Natural Gas- and Refinery Fuel Gas-Fired Process Heaters and Pyrolysis Furnaces, page 2-8).

RACT Update 2015
Unit 864-PH1 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (lb/MMBtu)	Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[1] ($)	2013 Cost Effectiveness ($/Ton)
ULNB & SCR	80.0	0.167	58.5	96%	2.3	56.2	NA	NA	NA	Infeasible
SCR	80.0	0.167	58.5	85%	8.8	49.7	NA	NA	NA	Infeasible
LNB & SNCR	80.0	0.167	58.5	70%	17.6	41.0	870,315	133,016	319,321	7,796
ULNB[2]	80.0	0.167	58.5	64%	21.0	37.5	1,342,858	36,929	357,231	9,528
LNB & FGR	80.0	0.167	58.5	55%	26.3	32.2	NA	NA	NA	Infeasible
SNCR	80.0	0.167	58.5	40%	35.1	23.4	641,762	126,731	258,520	11,045
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
SCR would not physically fit the plot space and there is not adequate pressure to overcome the SCR pressure drop; therefore, SCR is infeasible.
FGR installation would require the installation of mechanical draft burners, which is a major re-design of the unit; therefore FGR is infeasible.
Notes:
[1] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).
[2] Vendor quotation assumes that with ULNB, the achievable NO_x emission rate is 0.06 lb/MMBtu.

RACT Update 2015
Unit 864-PH11 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (lb/MMBtu)	Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[1] ($)	2013 Cost Effectiveness ($/Ton)
ULNB & SCR	74.0	0.145	47.0	96%	1.9	45.1	NA	NA	NA	Infeasible
SCR	74.0	0.145	47.0	85%	7.0	39.9	NA	NA	NA	Infeasible
LNB & SNCR	74.0	0.145	47.0	70%	14.1	32.9	822,578	122,486	298,378	9,070
ULNB[2]	74.0	0.145	47.0	59%	19.4	27.6	1,342,858	36,929	357,231	12,967
LNB & FGR	74.0	0.145	47.0	55%	21.1	25.8	NA	NA	NA	Infeasible
SNCR	74.0	0.145	47.0	40%	28.2	18.8	612,433	116,707	242,475	12,898
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
SCR would not physically fit the plot space and there is not adequate pressure to overcome the SCR pressure drop; therefore, SCR is infeasible.
FGR installation would require the installation of mechanical draft burners, which is a major re-design of the unit; therefore FGR is infeasible.
Notes:
[1] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).
[2] Vendor quotation assumes that with ULNB, the achievable NO_x emission rate is 0.06 lb/MMBtu.

RACT Update 2015
Unit 864-PH12 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (lb/MMBtu)	Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[1] ($)	2013 Cost Effectiveness ($/Ton)
ULNB & SCR	85.1	0.119	44.4	96%	1.8	42.6	NA	NA	NA	Infeasible
SCR	85.1	0.119	44.4	85%	6.7	37.7	NA	NA	NA	Infeasible
LNB & SNCR	85.1	0.119	44.4	70%	13.3	31.0	922,883	138,818	358,946	11,561
LNB & FGR	85.1	0.119	44.4	55%	20.0	24.4	NA	NA	NA	Infeasible
ULNB[2]	85.1	0.119	44.4	50%	22.4	22.0	1,461,532	40,192	388,801	17,680
SNCR	85.1	0.119	44.4	40%	26.6	17.7	666,005	131,753	268,522	15,135
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
SCR would not physically fit the plot space and there is not adequate pressure to overcome the SCR pressure drop; therefore, SCR is infeasible.
FGR installation would require the installation of mechanical draft burners, which is a major re-design of the unit; therefore FGR is infeasible.
Notes:
[1] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).
[2] Vendor quotation assumes that with ULNB, the achievable NO_x emission rate is 0.06 lb/MMBtu.

RACT Update 2015
Unit 870-H01 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (lb/MMBtu)	Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[1] ($)	2013 Cost Effectiveness ($/Ton)
ULNB & SCR	97.0	0.035	14.9	96%	0.6	14.3	NA	NA	NA	ULNB installed
SCR	97.0	0.035	14.9	85%	2.2	12.6	3,837,124	138,481	926,459	73,298
LNB & SNCR	97.0	0.035	14.9	70%	4.5	10.4	NA	NA	NA	ULNB installed
LNB & FGR	97.0	0.035	14.9	55%	6.7	8.2	NA	NA	NA	ULNB installed
SNCR	97.0	0.035	14.9	40%	8.9	5.9	720,415	143,930	291,872	49,070
ULNB	97.0	0.035	14.9	0%	14.9	0.0	NA	NA	NA	ULNB installed
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
ULNB already installed; therefore, only the installation of post-combustion controls are evaluated.
Notes:
[1] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).

RACT Update 2015
Unit 870-H02 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (lb/MMBtu)	Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[1] ($)	2013 Cost Effectiveness ($/Ton)
ULNB & SCR	53.0	0.035	8.1	96%	0.3	7.8	NA	NA	NA	ULNB installed
SCR	53.0	0.035	8.1	85%	1.2	6.9	2,667,294	91,360	639,106	92,541
LNB & SNCR	53.0	0.035	8.1	70%	2.4	5.7	NA	NA	NA	ULNB installed
LNB & FGR	53.0	0.035	8.1	55%	3.7	4.5	NA	NA	NA	ULNB installed
SNCR	53.0	0.035	8.1	40%	4.9	3.2	501,286	81,603	184,545	56,784
ULNB	53.0	0.035	8.1	0%	8.1	0.0	NA	NA	NA	ULNB installed
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
ULNB already installed; therefore, only the installation of post-combustion controls are evaluated.
Notes:
[1] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).

RACT Update 2015
Unit 859-1H1 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (lb/MMBtu)	Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[1] ($)	2013 Cost Effectiveness ($/Ton)
ULNB & SCR	98.0	0.02	8.6	96%	0.3	8.2	NA	NA	NA	ULNB installed
SCR	98.0	0.02	8.6	85%	1.3	7.3	3,860,884	138,539	931,397	127,640
LNB & SNCR	98.0	0.02	8.6	70%	2.6	6.0	NA	NA	NA	ULNB installed
LNB & FGR	98.0	0.02	8.6	55%	3.9	4.7	NA	NA	NA	ULNB installed
SNCR	98.0	0.02	8.6	40%	5.2	3.4	724,862	144,397	293,252	85,399
ULNB	98.0	0.02	8.6	0%	8.6	0.0	NA	NA	NA	ULNB installed
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
ULNB already installed; therefore, only the installation of post-combustion controls are evaluated.
Notes:
[1] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).

RACT Update 2015
Unit 137 F-2 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (lb/MMBtu)	Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[1] ($)	2013 Cost Effectiveness ($/Ton)
ULNB & SCR	155.0	0.257	174.5	96%	6.9	167.5	9,735,389	342,275	2,495,632	14,897
ULNB[2]	155.0	0.257	174.5	86%	23.8	150.7	4,647,222	127,799	1,236,267	8,203
SCR	155.0	0.257	174.5	85%	26.2	148.3	5,088,167	214,477	1,259,365	8,492
LNB & SNCR	155.0	0.257	174.5	70%	52.3	122.1	5,270,370	365,154	1,590,604	13,023
LNB & FGR	155.0	0.257	174.5	55%	78.5	96.0	4,699,544	148,441	1,269,389	13,228
SNCR	155.0	0.257	174.5	40%	104.7	69.8	954,374	246,464	442,451	6,340
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Notes:
[1] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).
[2] Vendor quotation assumes that with ULNB, the achievable NO_x emission rate is 0.035 lb/MMBtu.

RACT Update 2015
Unit 137 F-3 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (lb/MMBtu)	Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[1] ($)	2013 Cost Effectiveness ($/Ton)
ULNB & SCR	60.0	0.06	15.8	96%	0.6	15.1	NA	NA	NA	ULNB installed
SCR	60.0	0.06	15.8	85%	2.4	13.4	2,873,939	100,375	690,557	51,523
LNB & SNCR	60.0	0.06	15.8	70%	4.7	11.0	NA	NA	NA	ULNB installed
LNB & FGR	60.0	0.06	15.8	55%	7.1	8.7	NA	NA	NA	ULNB installed
SNCR	60.0	0.06	15.8	40%	9.5	6.3	540,021	92,579	203,476	32,261
ULNB	60.0	0.06	15.8	0%	15.8	0.0	NA	NA	NA	ULNB installed
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
ULNB already installed; therefore, only the installation of post-combustion controls are evaluated.
Notes:
[1] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).

RACT Update 2015
Unit 1332 H-2 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (lb/MMBtu)	Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[1] ($)	2013 Cost Effectiveness ($/Ton)
ULNB & SCR	60.0	0.04	10.5	96%	0.4	10.1	NA	NA	NA	ULNB installed
SCR	60.0	0.04	10.5	85%	1.6	8.9	2,873,939	99,612	689,794	77,200
LNB & SNCR	60.0	0.04	10.5	70%	3.2	7.4	NA	NA	NA	ULNB installed
LNB & FGR	60.0	0.04	10.5	55%	4.7	5.8	NA	NA	NA	ULNB installed
SNCR	60.0	0.04	10.5	40%	6.3	4.2	540,021	91,816	202,713	48,210
ULNB	60.0	0.04	10.5	0%	10.5	0.0	NA	NA	NA	ULNB installed
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
ULNB already installed; therefore, only the installation of post-combustion controls are evaluated.
Notes:
[1] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).

RACT Update 2015
Unit 1332 H-400 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (lb/MMBtu)	Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[1] ($)	2013 Cost Effectiveness ($/Ton)
ULNB & SCR	186.0	0.06	48.9	96%	1.9	46.9	NA	NA	NA	SCR installed
SCR	186.0	0.06	48.9	85%	7.3	41.5	NA	NA	NA	SCR installed
LNB & SNCR	186.0	0.06	48.9	70%	14.7	34.2	NA	NA	NA	SCR installed
LNB & FGR	186.0	0.06	48.9	55%	22.0	26.9	NA	NA	NA	SCR installed
ULNB[2]	186.0	0.06	48.9	50%	24.4	24.4	1,041,614	28,644	277,093	11,337
SNCR	186.0	0.06	48.9	40%	29.3	19.6	NA	NA	NA	SCR installed
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
SCR already installed; therefore, the installation of less-effective SNCR and FGR are not evaluated.
Notes:
[1] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).
[2] Heaters with higher combustion temperatures such as reformers achieve 50% control efficiency using ULNB per Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised) - EPA-453/R-93-034

RACT Update 2015
Unit 1332 H-401 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (lb/MMBtu)	Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[1] ($)	2013 Cost Effectiveness ($/Ton)
ULNB & SCR	233.0	0.06	61.2	96%	2.4	58.8	NA	NA	NA	SCR installed
SCR	233.0	0.06	61.2	85%	9.2	52.0	NA	NA	NA	SCR installed
LNB & SNCR	233.0	0.06	61.2	70%	18.4	42.9	NA	NA	NA	SCR installed
LNB & FGR	233.0	0.06	61.2	55%	27.6	33.7	NA	NA	NA	SCR installed
ULNB[2]	233.0	0.06	61.2	50%	30.6	30.6	1,041,614	28,644	277,093	9,051
SNCR	233.0	0.06	61.2	40%	36.7	24.5	NA	NA	NA	SCR installed
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
SCR already installed; therefore, the installation of less-effective SNCR and FGR are not evaluated.
Notes:
[1] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).
[2] Heaters with higher combustion temperatures such as reformers achieve 50% control efficiency using ULNB per Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised) - EPA-453/R-93-034

RACT Update 2015
Unit 433 H-1 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (lb/MMBtu)	Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[1] ($)	2013 Cost Effectiveness ($/Ton)
ULNB & SCR	260.0	0.035	39.9	96%	1.6	38.3	NA	NA	NA	ULNB installed
SCR	260.0	0.035	39.9	85%	6.0	33.9	6,948,800	279,438	1,706,420	50,368
LNB & SNCR	260.0	0.035	39.9	70%	12.0	27.9	NA	NA	NA	ULNB installed
LNB & FGR	260.0	0.035	39.9	55%	17.9	21.9	NA	NA	NA	ULNB installed
SNCR	260.0	0.035	39.9	40%	23.9	15.9	1,301,678	368,486	635,794	39,879
ULNB	260.0	0.035	39.9	0%	39.9	0.0	NA	NA	NA	ULNB installed
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
ULNB already installed; therefore, only the installation of post-combustion controls are evaluated.
Notes:
[1] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).

RACT Update 2015
Unit 1232 B-104 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (lb/MMBtu)	Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[1] ($)	2013 Cost Effectiveness ($/Ton)
ULNB & SCR	70.0	0.177	54.3	96%	2.2	52.1	NA	NA	NA	ULNB installed
SCR	70.0	0.177	54.3	85%	8.1	46.1	3,153,207	116,820	764,352	16,570
LNB & SNCR	70.0	0.177	54.3	70%	16.3	38.0	NA	NA	NA	ULNB installed
LNB & FGR	70.0	0.177	54.3	55%	24.4	29.8	NA	NA	NA	ULNB installed
SNCR	70.0	0.177	54.3	40%	32.6	21.7	592,350	112,182	233,825	10,772
ULNB	70.0	0.177	54.3	0%	54.3	0.0	NA	NA	NA	ULNB installed
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Notes:
[1] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).

RACT Update 2015
Boiler #37 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (lb/MMBtu)	Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[1] ($)	2013 Cost Effectiveness ($/Ton)
ULNB & SCR	495.0	0.04	86.7	96%	3.5	83.3	NA	NA	NA	ULNB & FGR installed
SCR	495.0	0.04	86.7	85%	13.0	73.7	1,964,428	455,549	2,419,977	32,829
LNB & SNCR	495.0	0.04	86.7	70%	26.0	60.7	NA	NA	NA	ULNB & FGR installed
LNB & FGR	495.0	0.04	86.7	55%	39.0	47.7	NA	NA	NA	ULNB & FGR installed
SNCR	495.0	0.04	86.7	40%	52.0	34.7	1,915,503	65,269	458,630	13,221
ULNB	495.0	0.04	86.7	0%	86.7	0.0	NA	NA	NA	ULNB & FGR installed
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
ULNB and FGR already installed; therefore, only the installation of post-combustion controls are evaluated.
Notes:
[1] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).

RACT Update 2015
Boiler #39 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (lb/MMBtu)	Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[1] ($)	2013 Cost Effectiveness ($/Ton)
ULNB & SCR	495.0	0.04	86.7	96%	3.5	83.3	NA	NA	NA	ULNB & FGR installed
SCR	495.0	0.04	86.7	85%	13.0	73.7	1,964,428	455,549	2,419,977	32,829
LNB & SNCR	495.0	0.04	86.7	70%	26.0	60.7	NA	NA	NA	ULNB & FGR installed
LNB & FGR	495.0	0.04	86.7	55%	39.0	47.7	NA	NA	NA	ULNB & FGR installed
SNCR	495.0	0.04	86.7	40%	52.0	34.7	1,915,503	65,269	458,630	13,221
ULNB	495.0	0.04	86.7	0%	86.7	0.0	NA	NA	NA	ULNB & FGR installed
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
ULNB and FGR already installed; therefore, only the installation of post-combustion controls are evaluated.
Notes:
[1] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).

RACT Update 2015
Boiler #40 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (lb/MMBtu)	Potential Emissions (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2013 Total Capital Cost ($)	2013 O&M Cost ($)	2013 Annualized Cost[1] ($)	2013 Cost Effectiveness ($/Ton)
ULNB & SCR	660.0	0.04	115.6	96%	4.6	111.0	NA	NA	NA	ULNB & FGR installed
SCR	660.0	0.04	115.6	85%	17.3	98.3	2,386,133	576,183	2,962,316	30,139
LNB & SNCR	660.0	0.04	115.6	70%	34.7	80.9	NA	NA	NA	ULNB & FGR installed
LNB & FGR	660.0	0.04	115.6	55%	52.0	63.6	NA	NA	NA	ULNB & FGR installed
SNCR	660.0	0.04	115.6	40%	69.4	46.3	2,276,387	79,390	546,861	11,823
ULNB	660.0	0.04	115.6	0%	115.6	0.0	NA	NA	NA	ULNB & FGR installed
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
ULNB and FGR already installed; therefore, only the installation of post-combustion controls are evaluated.
Notes:
[1] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).

RACT Update 2015
FCC 868 RACT Cost Effectiveness Summary

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate (ppmvd @ 0% O_2)	Potential Emissions (TPY)[1]	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2012 Total Capital Cost ($)	2012 O&M Cost ($)	2012 Annualized Cost[2] ($)	2012 Cost Effectiveness ($/Ton)
SCR v1 (EPA)	N/A	50	130.2	90%	13.0	117.2	2,009,414	1,599,089	3,608,503	30,794
LoTox	N/A	50	130.2	90%	13.0	117.2	1,400,367	161,453	1,561,820	13,328
SNCR	N/A	50	130.2	40%	78.1	52.1	477,286	78,902	556,188	10,679
Calculation			= A * B * 8760 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Notes:
[1] Emissions based on 50 ppmvd @ 0% oxygen (concentration established to comply with the Second Amendment to Civil Action No. 05-02866) and projected stack flow for 47.5 MBPD throughput.
[2] See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).
[3] LoTOx cost estimate assumes that there is a wet scrubber already installed on the unit.

RACT Update 2015
IC-002 Diesel-Fired RICE RACT Cost Effectiveness Summary

NOx

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate[2] (lb/MMBtu)	Potential Emissions[3] (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2012 Total Capital Cost ($)	2012 O&M Cost ($)	2012 Annualized Cost[1] ($)	2012 Cost Effectiveness ($/Ton)
SCR (NO_x Control)	1.4	4.41	1.4	70%	0.4	1.0	3,384	4,824	8,209	8,294
Calculation			A * B * 458 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

VOC

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate[2] (lb/MMBtu)	Potential Emissions[3] (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential VOC Reduced (TPY)	2012 Total Capital Cost ($)	2012 O&M Cost ($)	2012 Annualized Cost[1] ($)	2012 Cost Effectiveness ($/Ton)
Oxidation Catalyst (VOC Control)	1.4	0.36	0.12	50%	0.1	0.1	6,032	851	2,290	39,781
Calculation			A * B * / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
SNCR requires exhaust temperatures >1700°F for effective control and therefore is considered technically infeasible.
Notes:
1 - See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).
2 - Potential emissions based on AP-42, Section 3.3 factors
3 - Potential emissions based on TVOP operating hours limit of 458

RACT Update 2015
IC-005 Diesel-Fired RICE RACT Cost Effectiveness Summary

NOx

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate[2] (lb/MMBtu)	Potential Emissions[3] (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2012 Total Capital Cost ($)	2012 O&M Cost ($)	2012 Annualized Cost[1] ($)	2012 Cost Effectiveness ($/Ton)
SCR (NO_x Control)	0.2	4.41	1.0	70%	0.3	0.7	3,384	1,065	4,449	6,395
Calculation			A * B * 2300 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

VOC

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate[2] (lb/MMBtu)	Potential Emissions[3] (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential VOC Reduced (TPY)	2012 Total Capital Cost ($)	2012 O&M Cost ($)	2012 Annualized Cost[1] ($)	2012 Cost Effectiveness ($/Ton)
Oxidation Catalyst (VOC Control)	0.2	0.36	0.08	50%	0.0	0.0	6,032	851	2,290	56,582
Calculation			A * B * / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
SNCR requires exhaust temperatures >1700°F for effective control and therefore is considered technically infeasible.
Notes:
1 - See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).
2 - Potential emissions based on AP-42, Section 3.3 factors
3 - Potential emissions based on TVOP operating hours limit of 2300

RACT Update 2015
IC-006 Diesel-Fired RICE RACT Cost Effectiveness Summary

NOx

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate[2] (lb/MMBtu)	Potential Emissions[3] (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2012 Total Capital Cost ($)	2012 O&M Cost ($)	2012 Annualized Cost[1] ($)	2012 Cost Effectiveness ($/Ton)
SCR (NO_x Control)	0.8	2.16	1.0	70%	0.3	0.7	3,384	785	4,169	5,959
Calculation			A * B * 1150 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

VOC

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate[2] (lb/MMBtu)	Potential Emissions[3] (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential VOC Reduced (TPY)	2012 Total Capital Cost ($)	2012 O&M Cost ($)	2012 Annualized Cost[1] ($)	2012 Cost Effectiveness ($/Ton)
Oxidation Catalyst (VOC Control)	0.8	0.36	0.17	50%	0.1	0.1	6,032	851	2,290	27,553
Calculation			A * B * / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
SNCR requires exhaust temperatures >1700°F for effective control and therefore is considered technically infeasible.
Notes:
1 - See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).
2 - Potential emissions based on AP-42, Section 3.3 factors
3 - Potential emissions based on TVOP operating hours limit of 1150

RACT Update 2015
IC-007 Diesel-Fired RICE RACT Cost Effectiveness Summary

NOx

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate[2] (lb/MMBtu)	Potential Emissions[3] (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2012 Total Capital Cost ($)	2012 O&M Cost ($)	2012 Annualized Cost[1] ($)	2012 Cost Effectiveness ($/Ton)
SCR (NO_x Control)	0.7	0.66	0.7	70%	0.2	0.5	3,384	597	3,982	7,950
Calculation			A * B * 3050 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

VOC

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate[2] (lb/MMBtu)	Potential Emissions[3] (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential VOC Reduced (TPY)	2012 Total Capital Cost ($)	2012 O&M Cost ($)	2012 Annualized Cost[1] ($)	2012 Cost Effectiveness ($/Ton)
Oxidation Catalyst (VOC Control)	0.7	0.36	0.39	50%	0.2	0.2	6,032	851	2,290	11,713
Calculation			A * B * / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
SNCR requires exhaust temperatures >1700°F for effective control and therefore is considered technically infeasible.
Notes:
1 - See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).
2 - Potential emissions based on AP-42, Section 3.3 factors
3 - Potential emissions based on TVOP operating hours limit of 3050

RACT Update 2015
IC-008 Diesel-Fired RICE RACT Cost Effectiveness Summary

NOx

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate[2] (lb/MMBtu)	Potential Emissions[3] (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential NO_x Reduced (TPY)	2012 Total Capital Cost ($)	2012 O&M Cost ($)	2012 Annualized Cost[1] ($)	2012 Cost Effectiveness ($/Ton)
SCR (NO_x Control)	1.5	1.08	0.3	70%	0.1	0.2	3,384	651	4,035	19,716
Calculation			A * B * 360 / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

VOC

	A	B	C	D	E	F	G	H	I	J
Control Option	Potential Firing Rates (MMBtu/hr)	Current Emission Rate[2] (lb/MMBtu)	Potential Emissions[3] (TPY)	Control Efficiency (%)	Maximum Post Control Emissions (TPY)	Potential VOC Reduced (TPY)	2012 Total Capital Cost ($)	2012 O&M Cost ($)	2012 Annualized Cost[1] ($)	2012 Cost Effectiveness ($/Ton)
Oxidation Catalyst (VOC Control)	1.5	0.36	0.10	50%	0.0	0.0	6,032	851	2,290	47,299
Calculation			A * B * / 2000		= C * (1 - D)	= C - E			= (G * ACF) + H	= I / F

Technical Infeasibilities:
SNCR requires exhaust temperatures >1700°F for effective control and therefore is considered technically infeasible.
Notes:
1 - See "RACT Cost Summary" tab for details on the Annualized Cost Factor (ACF).
2 - Potential emissions based on AP-42, Section 3.3 factors
3 - Potential emissions based on TVOP operating hours limit of 360

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 210-13H1**	
Control	**ULNB**	
Rated Heat Input	**235.4**	**MMBtu/hr**
Number of Burners	**24.0**	**Burners**
Baseline Actual Emissions	**107.23**	**tpy**
Current Emission Rate	**0.104**	**lb/MMBtu**
Control Efficiency	**71%**	
Heater Capacity	**248.4**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from Vendor Quotation and *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	COST ($)
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC) - Average equipment and labor from Vendor Quotation	334,786
	Instrumentation (10% of EC)	33,479
	Sales taxes (5% of EC)	16,739
	Freight (8% of EC)	26,783
	Subtotal - Purchased Equipment Costs (PEC)	**411,787**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc. - Average labor from Vendor Quotation	409,640
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**409,640**
TOTAL DIRECT COSTS (TDC)		**821,427**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (5% of PEC)	20,589
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (10% of PEC)	41,179
	Start-up (1% of PEC)	4,118
	Performance Test (1% of PEC)	4,118
	Contingency (3% of PEC)	12,354
TOTAL INDIRECT COSTS, IC		**82,357**
TOTAL CAPITAL INVESTMENT (TCI)		**903,784**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 210-13H1**	
Control	**ULNB**	
Rated Heat Input	**235.4**	**MMBtu/hr**
Number of Burners	**24.0**	**Burners**
Baseline Actual Emissions	**107.23**	**tpy**
Current Emission Rate	**0.104**	**lb/MMBtu**
Control Efficiency	**71%**	
Heater Capacity	**248.4**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	24,854
	24,854
Utilities	
None	
Subtotal - Utilities	**0.0**
TOTAL ANNUAL DIRECT COSTS	**24,854**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**24,854**
Annualized Cost Factor		
Equipment Life (years) =	10	
Interest Rate (%) =	20	
Annualized Cost Factor		0.24
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		903,784
TOTAL ANNUAL CAPITAL REQUIREMENT		**215,573**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**240,427**

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RACT Update 2015
NOx RACT Control Cost Effectiveness

Source	**Unit 210-13H1**	
Control	**LNB & SNCR**	
Rated Heat Input	**235.4**	**MMBtu/hr**
Number of Burners	**24.0**	**Burners**
Baseline Actual Emissions	**107.23**	**tpy**
Current Emission Rate	**0.104**	**lb/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**248.4**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies
Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	**COST ($)**
DIRECT COSTS - LNB		
	Purchased Equipment Costs	
	Equipment Cost (EC)	559,711
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**559,711**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC) - LNB		**559,711**
INDIRECT INSTALLATION COSTS - LNB		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	16,791
TOTAL INDIRECT COSTS, IC - LNB		**16,791**
DIRECT COSTS - SNCR		
	Purchased Equipment Costs	
	Equipment Cost (EC)	1,190,601
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**1,190,601**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC) - SNCR		**1,190,601**
INDIRECT INSTALLATION COSTS - SNCR		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	35,718
TOTAL INDIRECT COSTS, IC - SNCR		**35,718**
TOTAL CAPITAL INVESTMENT (TCI) - LNB		**576,503**
TOTAL CAPITAL INVESTMENT (TCI) - SNCR		**1,226,319**
TOTAL CAPITAL INVESTMENT (TCI)		**1,802,822**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 210-13H1**	
Control	**LNB & SNCR**	
Rated Heat Input	**235.4**	**MMBtu/hr**
Number of Burners	**24.0**	**Burners**
Baseline Actual Emissions	**107.23**	**tpy**
Current Emission Rate	**0.104**	**lb/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**248.4**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	49,578
	49,578
Utilities	
Ammonia Cost	15,569
Electricity Cost	1.1
Fuel Penalty Cost ($4.88/Mscf)	295,973
Subtotal - Utilities	**311,542**
TOTAL ANNUAL DIRECT COSTS	**361,120**

COST COMPONENT:			**COST ($)**
TOTAL ANNUAL O&M COSTS			**361,120**
Annualized Cost Factor - LNB			
	Equipment Life (years) =	10	
	Interest Rate (%) =	20	
Annualized Cost Factor			0.24
Annualized Cost Factor - SNCR			
	Equipment Life (years) =	20	
	Interest Rate (%) =	20	
Annualized Cost Factor			0.21
CAPITAL RECOVERY COSTS			
TOTAL CAPITAL REQUIREMENT			1,802,822
TOTAL ANNUAL CAPITAL REQUIREMENT			**389,342**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***			**750,462**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 210-13H1**	
Control	**SNCR**	
Rated Heat Input	**235.4**	**MMBtu/hr**
Number of Burners	**24.0**	**Burners**
Baseline Actual Emissions	**107.23**	**tpy**
Current Emission Rate	**0.104**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**248.4**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

COST COMPONENT:		COST ($)
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	1,190,601
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**1,190,601**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**1,190,601**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	35,718
TOTAL INDIRECT COSTS, IC		**35,718**
TOTAL CAPITAL INVESTMENT (TCI)		**1,226,319**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 210-13H1**	
Control	**SNCR**	
Rated Heat Input	**235.4**	**MMBtu/hr**
Number of Burners	**24.0**	**Burners**
Baseline Actual Emissions	**107.23**	**tpy**
Current Emission Rate	**0.104**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**248.4**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	33,724
	33,724
Utilities	
Ammonia Cost	15,569
Electricity Cost	1.1
Fuel Penalty Cost ($4.88/Mscf)	295,973
Subtotal - Utilities	**311,542**
TOTAL ANNUAL DIRECT COSTS	**345,266**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**345,266**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		1,226,319
TOTAL ANNUAL CAPITAL REQUIREMENT		**251,833**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**597,099**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 860-2H2**	
Control	**SNCR**	
Rated Heat Input	**69.8**	**MMBtu/hr**
Number of Burners	**3.0**	**Burners**
Baseline Actual Emissions	**107.00**	**tpy**
Current Emission Rate	**0.350**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**73.6**	**GJ/hr**
Burner Heat Release Rate	**31.1**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	**COST ($)**
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	574,111
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**574,111**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**574,111**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	17,223
TOTAL INDIRECT COSTS, IC		**17,223**
TOTAL CAPITAL INVESTMENT (TCI)		**591,334**

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NOx RACT Control Cost Effectiveness

Source	**Unit 860-2H2**	
Control	**SNCR**	
Rated Heat Input	**69.8**	**MMBtu/hr**
Number of Burners	**3.0**	**Burners**
Baseline Actual Emissions	**107.00**	**tpy**
Current Emission Rate	**0.350**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**73.6**	**GJ/hr**
Burner Heat Release Rate	**31.1**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	16,262
	16,262
Utilities	
Ammonia Cost	15,536
Electricity Cost	1.1
Fuel Penalty Cost ($4.88/Mscf)	87,761
Subtotal - Utilities	**103,298**
TOTAL ANNUAL DIRECT COSTS	**119,559**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**119,559**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		591,334
TOTAL ANNUAL CAPITAL REQUIREMENT		**121,434**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**240,994**

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NOx RACT Control Cost Effectiveness

Source	**Unit 860-2H3**	
Control	**SNCR**	
Rated Heat Input	**174.7**	**MMBtu/hr**
Number of Burners	**4.0**	**Burners**
Baseline Actual Emissions	**124.73**	**tpy**
Current Emission Rate	**0.163**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**184.3**	**GJ/hr**
Burner Heat Release Rate	**55.4**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	**COST ($)**
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	995,539
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**995,539**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**995,539**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	29,866
TOTAL INDIRECT COSTS, IC		**29,866**
TOTAL CAPITAL INVESTMENT (TCI)		**1,025,405**

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NOx RACT Control Cost Effectiveness

Source	**Unit 860-2H3**	
Control	**SNCR**	
Rated Heat Input	**174.7**	**MMBtu/hr**
Number of Burners	**4.0**	**Burners**
Baseline Actual Emissions	**124.73**	**tpy**
Current Emission Rate	**0.163**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**184.3**	**GJ/hr**
Burner Heat Release Rate	**55.4**	**GJ/hr**

COST COMPONENT:	COST ($)
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	28,199
	28,199
Utilities	
Ammonia Cost	18,109
Electricity Cost	1.3
Fuel Penalty Cost ($4.88/Mscf)	219,653
Subtotal - Utilities	**237,764**
TOTAL ANNUAL DIRECT COSTS	**265,962**

COST COMPONENT:		COST ($)
TOTAL ANNUAL O&M COSTS		**265,962**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		1,025,405
TOTAL ANNUAL CAPITAL REQUIREMENT		**210,574**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**476,536**

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NOx RACT Control Cost Effectiveness

Source	**Unit 860-2H4**	
Control	**ULNB**	
Rated Heat Input	**99.4**	**MMBtu/hr**
Number of Burners	**3.0**	**Burners**
Baseline Actual Emissions	**117.55**	**tpy**
Current Emission Rate	**0.270**	**lb/MMBtu**
Control Efficiency	**50%**	
Heater Capacity	**104.9**	**GJ/hr**
Burner Heat Release Rate	**43.1**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from Vendor Quotation and *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

COST COMPONENT:	COST ($)
DIRECT COSTS	
Purchased Equipment Costs	
Equipment Cost (EC) - Average equipment and labor from Vendor Quotation	171,370
Instrumentation (10% of EC)	17,137
Sales taxes (5% of EC)	8,569
Freight (8% of EC)	13,710
Subtotal - Purchased Equipment Costs (PEC)	**210,785**
Direct Installation Costs	
Foundations & supports; handling & erection; electrical; piping; etc. - Average labor from Vendor Quotation	409,640
Site Preparation / Buildings- Included above	- - -
Subtotal - Direct Installation Costs	**409,640**
TOTAL DIRECT COSTS (TDC)	**620,425**
INDIRECT INSTALLATION COSTS	
Engineering Costs (5% of PEC)	10,539
Construct. & Field Expenses (Included in above costs)	- - -
Contractor Fees (10% of PEC)	21,079
Start-up (1% of PEC)	2,108
Performance Test (1% of PEC)	2,108
Contingency (3% of PEC)	6,324
TOTAL INDIRECT COSTS, IC	**42,157**
TOTAL CAPITAL INVESTMENT (TCI)	**662,583**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 860-2H4**	
Control	**ULNB**	
Rated Heat Input	**99.4**	**MMBtu/hr**
Number of Burners	**3.0**	**Burners**
Baseline Actual Emissions	**117.55**	**tpy**
Current Emission Rate	**0.270**	**lb/MMBtu**
Control Efficiency	**50%**	
Heater Capacity	**104.9**	**GJ/hr**
Burner Heat Release Rate	**43.1**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	18,221
	18,221
Utilities	
None	
Subtotal - Utilities	**0.0**
TOTAL ANNUAL DIRECT COSTS	**18,221**

COST COMPONENT:			**COST ($)**
TOTAL ANNUAL O&M COSTS			**18,221**
Annualized Cost Factor			
	Equipment Life (years) =	10	
	Interest Rate (%) =	20	
Annualized Cost Factor			0.24
CAPITAL RECOVERY COSTS			
TOTAL CAPITAL REQUIREMENT			662,583
TOTAL ANNUAL CAPITAL REQUIREMENT			**158,041**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***			**176,262**

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NOx RACT Control Cost Effectiveness

Source	**Unit 860-2H4**	
Control	**LNB & SNCR**	
Rated Heat Input	**99.4**	**MMBtu/hr**
Number of Burners	**3.0**	**Burners**
Baseline Actual Emissions	**117.55**	**tpy**
Current Emission Rate	**0.270**	**lb/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**104.9**	**GJ/hr**
Burner Heat Release Rate	**43.1**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

COST COMPONENT:		COST ($)
DIRECT COSTS - LNB		
	Purchased Equipment Costs	
	Equipment Cost (EC)	3,907,832
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**3,907,832**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC) - LNB		**3,907,832**
INDIRECT INSTALLATION COSTS - LNB		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	117,235
TOTAL INDIRECT COSTS, IC - LNB		**117,235**
DIRECT COSTS - SNCR		
	Purchased Equipment Costs	
	Equipment Cost (EC)	709,765
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**709,765**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC) - SNCR		**709,765**
INDIRECT INSTALLATION COSTS - SNCR		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	21,293
TOTAL INDIRECT COSTS, IC - SNCR		**21,293**
TOTAL CAPITAL INVESTMENT (TCI) - LNB		**4,025,067**
TOTAL CAPITAL INVESTMENT (TCI) - SNCR		**731,057**
TOTAL CAPITAL INVESTMENT (TCI)		**4,756,124**

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NOx RACT Control Cost Effectiveness

Source	**Unit 860-2H4**	
Control	**LNB & SNCR**	
Rated Heat Input	**99.4**	**MMBtu/hr**
Number of Burners	**3.0**	**Burners**
Baseline Actual Emissions	**117.55**	**tpy**
Current Emission Rate	**0.270**	**lb/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**104.9**	**GJ/hr**
Burner Heat Release Rate	**43.1**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	130,793
	130,793
Utilities	
Ammonia Cost	17,067
Electricity Cost	1.2
Fuel Penalty Cost ($4.88/Mscf)	124,977
Subtotal - Utilities	**142,046**
TOTAL ANNUAL DIRECT COSTS	**272,839**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**272,839**
Annualized Cost Factor - LNB		
Equipment Life (years) =	10	
Interest Rate (%) =	20	
Annualized Cost Factor		0.24
Annualized Cost Factor - SNCR		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		4,756,124
TOTAL ANNUAL CAPITAL REQUIREMENT		**1,110,197**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**1,383,037**

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NOx RACT Control Cost Effectiveness

Source	**Unit 860-2H4**	
Control	**SNCR**	
Rated Heat Input	**99.4**	**MMBtu/hr**
Number of Burners	**3.0**	**Burners**
Baseline Actual Emissions	**117.55**	**tpy**
Current Emission Rate	**0.270**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**104.9**	**GJ/hr**
Burner Heat Release Rate	**43.1**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

COST COMPONENT:		COST ($)
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	709,765
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**709,765**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**709,765**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	21,293
TOTAL INDIRECT COSTS, IC		**21,293**
TOTAL CAPITAL INVESTMENT (TCI)		**731,057**

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NOx RACT Control Cost Effectiveness

Source	**Unit 860-2H4**	
Control	**SNCR**	
Rated Heat Input	**99.4**	**MMBtu/hr**
Number of Burners	**3.0**	**Burners**
Baseline Actual Emissions	**117.55**	**tpy**
Current Emission Rate	**0.270**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**104.9**	**GJ/hr**
Burner Heat Release Rate	**43.1**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	20,104
	20,104
Utilities	
Ammonia Cost	17,067
Electricity Cost	1.2
Fuel Penalty Cost ($4.88/Mscf)	124,977
Subtotal - Utilities	**142,046**
TOTAL ANNUAL DIRECT COSTS	**162,150**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**162,150**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		731,057
TOTAL ANNUAL CAPITAL REQUIREMENT		**150,127**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**312,277**

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NOx RACT Control Cost Effectiveness

Source	**Unit 860-2H5**	
Control	**SNCR**	
Rated Heat Input	**155.0**	**MMBtu/hr**
Number of Burners	**4.0**	**Burners**
Baseline Actual Emissions	**110.66**	**tpy**
Current Emission Rate	**0.163**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**163.5**	**GJ/hr**
Burner Heat Release Rate	**49.3**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	COST ($)
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	926,577
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**926,577**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**926,577**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	27,797
TOTAL INDIRECT COSTS, IC		**27,797**
TOTAL CAPITAL INVESTMENT (TCI)		**954,374**

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NOx RACT Control Cost Effectiveness

Source	**Unit 860-2H5**	
Control	**SNCR**	
Rated Heat Input	**155.0**	**MMBtu/hr**
Number of Burners	**4.0**	**Burners**
Baseline Actual Emissions	**110.66**	**tpy**
Current Emission Rate	**0.163**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**163.5**	**GJ/hr**
Burner Heat Release Rate	**49.3**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	26,245
	26,245
Utilities	
Ammonia Cost	16,067
Electricity Cost	1.2
Fuel Penalty Cost ($4.88/Mscf)	194,884
Subtotal - Utilities	**210,952**
TOTAL ANNUAL DIRECT COSTS	**237,198**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**237,198**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		954,374
TOTAL ANNUAL CAPITAL REQUIREMENT		**195,987**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**433,184**

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NOx RACT Control Cost Effectiveness

Source	**Unit 860-2H7**	
Control	**SNCR**	
Rated Heat Input	**59.0**	**MMBtu/hr**
Number of Burners	**4.0**	**Burners**
Baseline Actual Emissions	**40.57**	**tpy**
Current Emission Rate	**0.157**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**62.2**	**GJ/hr**
Burner Heat Release Rate	**20.0**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	COST ($)
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	519,031
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**519,031**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**519,031**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	15,571
TOTAL INDIRECT COSTS, IC		**15,571**
TOTAL CAPITAL INVESTMENT (TCI)		**534,602**

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NOx RACT Control Cost Effectiveness

Source	**Unit 860-2H7**	
Control	**SNCR**	
Rated Heat Input	**59.0**	**MMBtu/hr**
Number of Burners	**4.0**	**Burners**
Baseline Actual Emissions	**40.57**	**tpy**
Current Emission Rate	**0.157**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**62.2**	**GJ/hr**
Burner Heat Release Rate	**20.0**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	14,702
	14,702
Utilities	
Ammonia Cost	5,891
Electricity Cost	0.4
Fuel Penalty Cost ($4.88/Mscf)	74,182
Subtotal - Utilities	**80,073**
TOTAL ANNUAL DIRECT COSTS	**94,774**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**94,774**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		534,602
TOTAL ANNUAL CAPITAL REQUIREMENT		**109,784**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**204,558**

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NOx RACT Control Cost Effectiveness

Source	**Unit 864-PH1**	
Control	**LNB & SNCR**	
Rated Heat Input	**80.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**58.52**	**tpy**
Current Emission Rate	**0.167**	**lb/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**84.4**	**GJ/hr**
Burner Heat Release Rate	**13.2**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	COST ($)
DIRECT COSTS - LNB		
	Purchased Equipment Costs	
	Equipment Cost (EC)	221,897
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**221,897**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC) - LNB		**221,897**
INDIRECT INSTALLATION COSTS - LNB		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	6,657
TOTAL INDIRECT COSTS, IC - LNB		**6,657**
DIRECT COSTS - SNCR		
	Purchased Equipment Costs	
	Equipment Cost (EC)	623,069
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**623,069**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC) - SNCR		**623,069**
INDIRECT INSTALLATION COSTS - SNCR		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	18,692
TOTAL INDIRECT COSTS, IC - SNCR		**18,692**
TOTAL CAPITAL INVESTMENT (TCI) - LNB		**228,554**
TOTAL CAPITAL INVESTMENT (TCI) - SNCR		**641,762**
TOTAL CAPITAL INVESTMENT (TCI)		**870,315**

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NOx RACT Control Cost Effectiveness

Source	**Unit 864-PH1**	
Control	**LNB & SNCR**	
Rated Heat Input	**80.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**58.52**	**tpy**
Current Emission Rate	**0.167**	**lb/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**84.4**	**GJ/hr**
Burner Heat Release Rate	**13.2**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	23,934
	23,934
Utilities	
Ammonia Cost	8,496
Electricity Cost	0.6
Fuel Penalty Cost ($4.88/Mscf)	100,585
Subtotal - Utilities	**109,082**
TOTAL ANNUAL DIRECT COSTS	**133,016**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**133,016**
Annualized Cost Factor - LNB		
Equipment Life (years) =	10	
Interest Rate (%) =	20	
Annualized Cost Factor		0.24
Annualized Cost Factor - SNCR		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		870,315
TOTAL ANNUAL CAPITAL REQUIREMENT		**186,305**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**319,321**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 864-PH1**	
Control	**ULNB**	
Rated Heat Input	**80.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**58.52**	**tpy**
Current Emission Rate	**0.167**	**lb/MMBtu**
Control Efficiency	**64%**	
Heater Capacity	**84.4**	**GJ/hr**
Burner Heat Release Rate	**13.2**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from Vendor Quotation and *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	**COST ($)**
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	293,125
	Instrumentation (included in Furnace Modifications)	- - -
	Sales taxes (added below to all materials and equipment)	- - -
	Freight (added below to all materials and equipment)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**293,125**
	Direct Installation Costs	
	Direct Labor - Header Improvements	185,155
	Direct Labor - Burner Install	28,500
	Direct Labor - Piping Modifications	65,669
	Direct Labor - Furnace Modifications (Instrumentation)	23,750
	Direct Labor - Demolition	5,873
	Subtotal - Direct Installation Costs	**308,947**
TOTAL DIRECT COSTS (TDC)		**602,072**
INDIRECT INSTALLATION COSTS		
	Sales Tax and Freight (5% of EC)	14,656
	Temporary Construction (10% of all labor hours @ $75/hour)	19,727
	Turnaround Overtime Premium (10% of Direct Installation Costs)	30,895
	Construction Equipment (2% of Direct Installation Costs)	6,179
	Construction Supervision (5% of Direct Installation Costs)	15,447
TOTAL INDIRECT COSTS, IC		**86,904**
OTHER COSTS		
	Detailed Engineering (30% of TDC + IC)	206,693
	Construction Management (5% of TDC + IC)	34,449
	Subtotal - Total Prime Contract (TDC + IC + Detailed Engineering + Construction Management)	**930,118**
	Escalation (5% of Total Prime Contract)	46,506
	Contingency (25% of Total Prime Contract + Escalation)	244,156
	Owner's Cost (10% of Total Prime Contract + Escalation + Contingency)	122,078
TOTAL CAPITAL INVESTMENT (TCI)		**1,342,858**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 864-PH1**	
Control	**ULNB**	
Rated Heat Input	**80.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**58.52**	**tpy**
Current Emission Rate	**0.167**	**lb/MMBtu**
Control Efficiency	**64%**	
Heater Capacity	**84.4**	**GJ/hr**
Burner Heat Release Rate	**13.2**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	36,929
	36,929
Utilities	
None	
Subtotal - Utilities	**0.0**
TOTAL ANNUAL DIRECT COSTS	**36,929**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**36,929**
Annualized Cost Factor		
Equipment Life (years) =	10	
Interest Rate (%) =	20	
Annualized Cost Factor		0.24
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		1,342,858
TOTAL ANNUAL CAPITAL REQUIREMENT		**320,302**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**357,231**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 864-PH1**	
Control	**SNCR**	
Rated Heat Input	**80.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**58.52**	**tpy**
Current Emission Rate	**0.167**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**84.4**	**GJ/hr**
Burner Heat Release Rate	**13.2**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	COST ($)
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	623,069
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**623,069**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**623,069**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	18,692
TOTAL INDIRECT COSTS, IC		**18,692**
TOTAL CAPITAL INVESTMENT (TCI)		**641,762**

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NOx RACT Control Cost Effectiveness

Source	**Unit 864-PH1**	
Control	**SNCR**	
Rated Heat Input	**80.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**58.52**	**tpy**
Current Emission Rate	**0.167**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**84.4**	**GJ/hr**
Burner Heat Release Rate	**13.2**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	17,648
	17,648
Utilities	
Ammonia Cost	8,496
Electricity Cost	0.6
Fuel Penalty Cost ($4.88/Mscf)	100,585
Subtotal - Utilities	**109,082**
TOTAL ANNUAL DIRECT COSTS	**126,731**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**126,731**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		641,762
TOTAL ANNUAL CAPITAL REQUIREMENT		**131,790**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**258,520**

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NOx RACT Control Cost Effectiveness

Source	**Unit 864-PH11**	
Control	**LNB & SNCR**	
Rated Heat Input	**74.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**47.00**	**tpy**
Current Emission Rate	**0.145**	**lb/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**78.1**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	COST ($)
DIRECT COSTS - LNB		
	Purchased Equipment Costs	
	Equipment Cost (EC)	204,024
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**204,024**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC) - LNB		**204,024**
INDIRECT INSTALLATION COSTS - LNB		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	6,121
TOTAL INDIRECT COSTS, IC - LNB		**6,121**
DIRECT COSTS - SNCR		
	Purchased Equipment Costs	
	Equipment Cost (EC)	594,595
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**594,595**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC) - SNCR		**594,595**
INDIRECT INSTALLATION COSTS - SNCR		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	17,838
TOTAL INDIRECT COSTS, IC - SNCR		**17,838**
TOTAL CAPITAL INVESTMENT (TCI) - LNB		**210,145**
TOTAL CAPITAL INVESTMENT (TCI) - SNCR		**612,433**
TOTAL CAPITAL INVESTMENT (TCI)		**822,578**

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NOx RACT Control Cost Effectiveness

Source	**Unit 864-PH11**	
Control	**LNB & SNCR**	
Rated Heat Input	**74.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**47.00**	**tpy**
Current Emission Rate	**0.145**	**lb/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**78.1**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	22,621
	22,621
Utilities	
Ammonia Cost	6,824
Electricity Cost	0.5
Fuel Penalty Cost ($4.88/Mscf)	93,042
Subtotal - Utilities	**99,866**
TOTAL ANNUAL DIRECT COSTS	**122,486**

COST COMPONENT:			**COST ($)**
TOTAL ANNUAL O&M COSTS			**122,486**
Annualized Cost Factor - LNB			
	Equipment Life (years) =	10	
	Interest Rate (%) =	20	
Annualized Cost Factor			0.24
Annualized Cost Factor - SNCR			
	Equipment Life (years) =	20	
	Interest Rate (%) =	20	
Annualized Cost Factor			0.21
CAPITAL RECOVERY COSTS			
TOTAL CAPITAL REQUIREMENT			822,578
TOTAL ANNUAL CAPITAL REQUIREMENT			**175,891**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***			**298,378**

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NOx RACT Control Cost Effectiveness

Source	**Unit 864-PH11**	
Control	**ULNB**	
Rated Heat Input	**74.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**47.00**	**tpy**
Current Emission Rate	**0.145**	**lb/MMBtu**
Control Efficiency	**59%**	
Heater Capacity	**78.1**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from Vendor Quotation and *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	COST ($)
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	293,125
	Instrumentation (included in Furnace Modifications)	- - -
	Sales taxes (added below to all materials and equipment)	- - -
	Freight (added below to all materials and equipment)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**293,125**
	Direct Installation Costs	
	Direct Labor - Header Improvements	185,155
	Direct Labor - Burner Install	28,500
	Direct Labor - Piping Modifications	65,669
	Direct Labor - Furnace Modifications (Instrumentation)	23,750
	Direct Labor - Demolition	5,873
	Subtotal - Direct Installation Costs	**308,947**
TOTAL DIRECT COSTS (TDC)		**602,072**
INDIRECT INSTALLATION COSTS		
	Sales Tax and Freight (5% of EC)	14,656
	Temporary Construction (10% of all labor hours @ $75/hour)	19,727
	Turnaround Overtime Premium (10% of Direct Installation Costs)	30,895
	Construction Equipment (2% of Direct Installation Costs)	6,179
	Construction Supervision (5% of Direct Installation Costs)	15,447
TOTAL INDIRECT COSTS, IC		**86,904**
OTHER COSTS		
	Detailed Engineering (30% of TDC + IC)	206,693
	Construction Management (5% of TDC + IC)	34,449
	Subtotal - Total Prime Contract (TDC + IC + Detailed Engineering + Construction Management)	**930,118**
	Escalation (5% of Total Prime Contract)	46,506
	Contingency (25% of Total Prime Contract + Escalation)	244,156
	Owner's Cost (10% of Total Prime Contract + Escalation + Contingency)	122,078
TOTAL CAPITAL INVESTMENT (TCI)		**1,342,858**

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NOx RACT Control Cost Effectiveness

Source	**Unit 864-PH11**	
Control	**ULNB**	
Rated Heat Input	**74.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**47.00**	**tpy**
Current Emission Rate	**0.145**	**lb/MMBtu**
Control Efficiency	**59%**	
Heater Capacity	**78.1**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

COST COMPONENT:	COST ($)
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	36,929
	36,929
Utilities	
None	
Subtotal - Utilities	**0.0**
TOTAL ANNUAL DIRECT COSTS	**36,929**

COST COMPONENT:		COST ($)
TOTAL ANNUAL O&M COSTS		**36,929**
Annualized Cost Factor		
Equipment Life (years) =	10	
Interest Rate (%) =	20	
Annualized Cost Factor		0.24
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		1,342,858
TOTAL ANNUAL CAPITAL REQUIREMENT		**320,302**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**357,231**

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NOx RACT Control Cost Effectiveness

Source	**Unit 864-PH11**	
Control	**SNCR**	
Rated Heat Input	**74.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**47.00**	**tpy**
Current Emission Rate	**0.145**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**78.1**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	**COST ($)**
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	594,595
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**594,595**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**594,595**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	17,838
TOTAL INDIRECT COSTS, IC		**17,838**
TOTAL CAPITAL INVESTMENT (TCI)		**612,433**

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NOx RACT Control Cost Effectiveness

Source	**Unit 864-PH11**	
Control	**SNCR**	
Rated Heat Input	**74.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**47.00**	**tpy**
Current Emission Rate	**0.145**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**78.1**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	16,842
	16,842
Utilities	
Ammonia Cost	6,824
Electricity Cost	0.5
Fuel Penalty Cost ($4.88/Mscf)	93,042
Subtotal - Utilities	**99,866**
TOTAL ANNUAL DIRECT COSTS	**116,707**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**116,707**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		612,433
TOTAL ANNUAL CAPITAL REQUIREMENT		**125,767**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**242,475**

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NOx RACT Control Cost Effectiveness

Source	**Unit 864-PH12**	
Control	**LNB & SNCR**	
Rated Heat Input	**85.1**	**MMBtu/hr**
Number of Burners	**12.0**	**Burners**
Baseline Actual Emissions	**44.36**	**tpy**
Current Emission Rate	**0.119**	**lb/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**89.8**	**GJ/hr**
Burner Heat Release Rate	**9.3**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies
Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	**COST ($)**
DIRECT COSTS - LNB		
	Purchased Equipment Costs	
	Equipment Cost (EC)	249,396
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**249,396**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC) - LNB		**249,396**
INDIRECT INSTALLATION COSTS - LNB		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	7,482
TOTAL INDIRECT COSTS, IC - LNB		**7,482**
DIRECT COSTS - SNCR		
	Purchased Equipment Costs	
	Equipment Cost (EC)	646,607
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**646,607**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC) - SNCR		**646,607**
INDIRECT INSTALLATION COSTS - SNCR		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	19,398
TOTAL INDIRECT COSTS, IC - SNCR		**19,398**
TOTAL CAPITAL INVESTMENT (TCI) - LNB		**256,878**
TOTAL CAPITAL INVESTMENT (TCI) - SNCR		**666,005**
TOTAL CAPITAL INVESTMENT (TCI)		**922,883**

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NOx RACT Control Cost Effectiveness

Source	**Unit 864-PH12**	
Control	**LNB & SNCR**	
Rated Heat Input	**85.1**	**MMBtu/hr**
Number of Burners	**12.0**	**Burners**
Baseline Actual Emissions	**44.36**	**tpy**
Current Emission Rate	**0.119**	**lb/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**89.8**	**GJ/hr**
Burner Heat Release Rate	**9.3**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	25,379
	25,379
Utilities	
Ammonia Cost	6,440
Electricity Cost	0.5
Fuel Penalty Cost ($4.88/Mscf)	106,998
Subtotal - Utilities	**113,438**
TOTAL ANNUAL DIRECT COSTS	**138,818**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**138,818**
Annualized Cost Factor - LNB		
Equipment Life (years) =	10	
Interest Rate (%) =	20	
Annualized Cost Factor		0.24
Annualized Cost Factor - SNCR		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		922,883
TOTAL ANNUAL CAPITAL REQUIREMENT		**220,129**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**358,946**

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NOx RACT Control Cost Effectiveness

Source	**Unit 864-PH12**	
Control	**ULNB**	
Rated Heat Input	**85.1**	**MMBtu/hr**
Number of Burners	**12.0**	**Burners**
Baseline Actual Emissions	**44.36**	**tpy**
Current Emission Rate	**0.119**	**lb/MMBtu**
Control Efficiency	**50%**	
Heater Capacity	**89.8**	**GJ/hr**
Burner Heat Release Rate	**9.3**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from Vendor Quotation and *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	COST ($)
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	333,261
	Instrumentation (included in Furnace Modifications)	- - -
	Sales taxes (added below to all materials and equipment)	- - -
	Freight (added below to all materials and equipment)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**333,261**
	Direct Installation Costs	
	Direct Labor - Header Improvements	185,155
	Direct Labor - Burner Install	42,750
	Direct Labor - Piping Modifications	65,669
	Direct Labor - Furnace Modifications (Instrumentation)	23,750
	Direct Labor - Demolition	6,390
	Subtotal - Direct Installation Costs	**323,714**
TOTAL DIRECT COSTS (TDC)		**656,975**
INDIRECT INSTALLATION COSTS		
	Sales Tax and Freight (5% of EC)	16,663
	Temporary Construction (10% of all labor hours @ $75/hour)	21,195
	Turnaround Overtime Premium (10% of Direct Installation Costs)	32,371
	Construction Equipment (2% of Direct Installation Costs)	6,474
	Construction Supervision (5% of Direct Installation Costs)	16,186
TOTAL INDIRECT COSTS, IC		**92,889**
OTHER COSTS		
	Detailed Engineering (30% of TDC + IC)	224,959
	Construction Management (5% of TDC + IC)	37,493
	Subtotal - Total Prime Contract (TDC + IC + Detailed Engineering + Construction Management)	**1,012,317**
	Escalation (5% of Total Prime Contract)	50,616
	Contingency (25% of Total Prime Contract + Escalation)	265,733
	Owner's Cost (10% of Total Prime Contract + Escalation + Contingency)	132,867
TOTAL CAPITAL INVESTMENT (TCI)		**1,461,532**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 864-PH12**	
Control	**ULNB**	
Rated Heat Input	**85.1**	**MMBtu/hr**
Number of Burners	**12.0**	**Burners**
Baseline Actual Emissions	**44.36**	**tpy**
Current Emission Rate	**0.119**	**lb/MMBtu**
Control Efficiency	**50%**	
Heater Capacity	**89.8**	**GJ/hr**
Burner Heat Release Rate	**9.3**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	40,192
	40,192
Utilities	
None	
Subtotal - Utilities	**0.0**
TOTAL ANNUAL DIRECT COSTS	**40,192**

COST COMPONENT:			**COST ($)**
TOTAL ANNUAL O&M COSTS			**40,192**
Annualized Cost Factor			
	Equipment Life (years) =	10	
	Interest Rate (%) =	20	
Annualized Cost Factor			0.24
CAPITAL RECOVERY COSTS			
TOTAL CAPITAL REQUIREMENT			1,461,532
TOTAL ANNUAL CAPITAL REQUIREMENT			**348,609**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***			**388,801**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 864-PH12**	
Control	**SNCR**	
Rated Heat Input	**85.1**	**MMBtu/hr**
Number of Burners	**12.0**	**Burners**
Baseline Actual Emissions	**44.36**	**tpy**
Current Emission Rate	**0.119**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**89.8**	**GJ/hr**
Burner Heat Release Rate	**9.3**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

COST COMPONENT:	COST ($)
DIRECT COSTS	
Purchased Equipment Costs	
Equipment Cost (EC)	646,607
Instrumentation (Included in above costs)	- - -
Sales taxes (Included in above costs)	- - -
Freight (Included in above costs)	- - -
Subtotal - Purchased Equipment Costs (PEC)	**646,607**
Direct Installation Costs	
Foundations & supports; handling & erection; electrical; piping; etc.	0
Site Preparation / Buildings- Included above	- - -
Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)	**646,607**
INDIRECT INSTALLATION COSTS	
Engineering Costs (Included in above costs)	- - -
Construct. & Field Expenses (Included in above costs)	- - -
Contractor Fees (Included in above costs)	- - -
Start-up (Included in above costs)	- - -
Performance Test (Included in above costs)	- - -
Contingency (3% of PEC)	19,398
TOTAL INDIRECT COSTS, IC	**19,398**
TOTAL CAPITAL INVESTMENT (TCI)	**666,005**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 864-PH12**	
Control	**SNCR**	
Rated Heat Input	**85.1**	**MMBtu/hr**
Number of Burners	**12.0**	**Burners**
Baseline Actual Emissions	**44.36**	**tpy**
Current Emission Rate	**0.119**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**89.8**	**GJ/hr**
Burner Heat Release Rate	**9.3**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	18,315
	18,315
Utilities	
Ammonia Cost	6,440
Electricity Cost	0.5
Fuel Penalty Cost ($4.88/Mscf)	106,998
Subtotal - Utilities	**113,438**
TOTAL ANNUAL DIRECT COSTS	**131,753**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**131,753**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		666,005
TOTAL ANNUAL CAPITAL REQUIREMENT		**136,768**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**268,522**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 870-H01**	
Control	**SCR**	
Rated Heat Input	**97.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**14.87**	**tpy**
Current Emission Rate	**0.035**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**102.3**	**GJ/hr**
Burner Heat Release Rate	**15.8**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

COST COMPONENT:	COST ($)
DIRECT COSTS	
Purchased Equipment Costs	
Equipment Cost (EC)	3,725,363
Instrumentation (Included in above costs)	- - -
Sales taxes (Included in above costs)	- - -
Freight (Included in above costs)	- - -
Subtotal - Purchased Equipment Costs (PEC)	**3,725,363**
Direct Installation Costs	
Foundations & supports; handling & erection; electrical; piping; etc.	0
Site Preparation / Buildings- Included above	- - -
Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)	**3,725,363**
INDIRECT INSTALLATION COSTS	
Engineering Costs (Included in above costs)	- - -
Construct. & Field Expenses (Included in above costs)	- - -
Contractor Fees (Included in above costs)	- - -
Start-up (Included in above costs)	- - -
Performance Test (Included in above costs)	- - -
Contingency (3% of PEC)	111,761
TOTAL INDIRECT COSTS, IC	**111,761**
TOTAL CAPITAL INVESTMENT (TCI)	**3,837,124**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 870-H01**	
Control	**SCR**	
Rated Heat Input	**97.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**14.87**	**tpy**
Current Emission Rate	**0.035**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**102.3**	**GJ/hr**
Burner Heat Release Rate	**15.8**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	105,521
	105,521
Utilities	
Ammonia Cost	2,159
Catalyst Replacement Cost	30,801
Electricity Cost	0.2
Subtotal - Utilities	**32,960**
TOTAL ANNUAL DIRECT COSTS	**138,481**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**138,481**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		3,837,124
TOTAL ANNUAL CAPITAL REQUIREMENT		**787,978**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**926,459**

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NOx RACT Control Cost Effectiveness

Source	**Unit 870-H01**	
Control	**SNCR**	
Rated Heat Input	**97.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**14.87**	**tpy**
Current Emission Rate	**0.035**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**102.3**	**GJ/hr**
Burner Heat Release Rate	**15.8**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	**COST ($)**
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	699,432
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**699,432**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**699,432**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	20,983
TOTAL INDIRECT COSTS, IC		**20,983**
TOTAL CAPITAL INVESTMENT (TCI)		**720,415**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 870-H01**	
Control	**SNCR**	
Rated Heat Input	**97.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**14.87**	**tpy**
Current Emission Rate	**0.035**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**102.3**	**GJ/hr**
Burner Heat Release Rate	**15.8**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	19,811
	19,811
Utilities	
Ammonia Cost	2,159
Electricity Cost	0.2
Fuel Penalty Cost ($4.88/Mscf)	121,960
Subtotal - Utilities	**124,119**
TOTAL ANNUAL DIRECT COSTS	**143,930**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**143,930**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		720,415
TOTAL ANNUAL CAPITAL REQUIREMENT		**147,942**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**291,872**

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NOx RACT Control Cost Effectiveness

Source	**Unit 870-H02**	
Control	**SCR**	
Rated Heat Input	**53.0**	**MMBtu/hr**
Number of Burners	**4.0**	**Burners**
Baseline Actual Emissions	**8.12**	**tpy**
Current Emission Rate	**0.035**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**55.9**	**GJ/hr**
Burner Heat Release Rate	**18.2**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	**COST ($)**
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	2,589,606
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**2,589,606**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**2,589,606**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	77,688
TOTAL INDIRECT COSTS, IC		**77,688**
TOTAL CAPITAL INVESTMENT (TCI)		**2,667,294**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 870-H02**	
Control	**SCR**	
Rated Heat Input	**53.0**	**MMBtu/hr**
Number of Burners	**4.0**	**Burners**
Baseline Actual Emissions	**8.12**	**tpy**
Current Emission Rate	**0.035**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**55.9**	**GJ/hr**
Burner Heat Release Rate	**18.2**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	73,351
	73,351
Utilities	
Ammonia Cost	1,180
Catalyst Replacement Cost	16,829
Electricity Cost	0.1
Subtotal - Utilities	**18,009**
TOTAL ANNUAL DIRECT COSTS	**91,360**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**91,360**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		2,667,294
TOTAL ANNUAL CAPITAL REQUIREMENT		**547,746**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**639,106**

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NOx RACT Control Cost Effectiveness

Source	**Unit 870-H02**	
Control	**SNCR**	
Rated Heat Input	**53.0**	**MMBtu/hr**
Number of Burners	**4.0**	**Burners**
Baseline Actual Emissions	**8.12**	**tpy**
Current Emission Rate	**0.035**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**55.9**	**GJ/hr**
Burner Heat Release Rate	**18.2**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

		COST COMPONENT:	**COST ($)**
DIRECT COSTS			
	Purchased Equipment Costs		
		Equipment Cost (EC)	486,685
		Instrumentation (Included in above costs)	- - -
		Sales taxes (Included in above costs)	- - -
		Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)		**486,685**
	Direct Installation Costs		
	Foundations & supports; handling & erection; electrical; piping; etc.		0
	Site Preparation / Buildings- Included above		- - -
	Subtotal - Direct Installation Costs		**0**
TOTAL DIRECT COSTS (TDC)			**486,685**
INDIRECT INSTALLATION COSTS			
	Engineering Costs (Included in above costs)		- - -
	Construct. & Field Expenses (Included in above costs)		- - -
	Contractor Fees (Included in above costs)		- - -
	Start-up (Included in above costs)		- - -
	Performance Test (Included in above costs)		- - -
	Contingency (3% of PEC)		14,601
TOTAL INDIRECT COSTS, IC			**14,601**
TOTAL CAPITAL INVESTMENT (TCI)			**501,286**

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NOx RACT Control Cost Effectiveness

Source	**Unit 870-H02**	
Control	**SNCR**	
Rated Heat Input	**53.0**	**MMBtu/hr**
Number of Burners	**4.0**	**Burners**
Baseline Actual Emissions	**8.12**	**tpy**
Current Emission Rate	**0.035**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**55.9**	**GJ/hr**
Burner Heat Release Rate	**18.2**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	13,785
	13,785
Utilities	
Ammonia Cost	1,180
Electricity Cost	0.1
Fuel Penalty Cost ($4.88/Mscf)	66,638
Subtotal - Utilities	**67,818**
TOTAL ANNUAL DIRECT COSTS	**81,603**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**81,603**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		501,286
TOTAL ANNUAL CAPITAL REQUIREMENT		**102,942**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**184,545**

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NOx RACT Control Cost Effectiveness

Source	**Unit 859-1H1**	
Control	**SCR**	
Rated Heat Input	**98.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**8.58**	**tpy**
Current Emission Rate	**0.020**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**103.4**	**GJ/hr**
Burner Heat Release Rate	**16.0**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	**COST ($)**
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	3,748,431
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**3,748,431**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**3,748,431**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	112,453
TOTAL INDIRECT COSTS, IC		**112,453**
TOTAL CAPITAL INVESTMENT (TCI)		**3,860,884**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 859-1H1**	
Control	**SCR**	
Rated Heat Input	**98.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**8.58**	**tpy**
Current Emission Rate	**0.020**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**103.4**	**GJ/hr**
Burner Heat Release Rate	**16.0**	**GJ/hr**

COST COMPONENT:	COST ($)
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	106,174
	106,174
Utilities	
Ammonia Cost	1,246
Catalyst Replacement Cost	31,118
Electricity Cost	0.1
Subtotal - Utilities	**32,365**
TOTAL ANNUAL DIRECT COSTS	**138,539**

COST COMPONENT:	COST ($)
TOTAL ANNUAL O&M COSTS	**138,539**
Annualized Cost Factor	
Equipment Life (years) = 20	
Interest Rate (%) = 20	
Annualized Cost Factor	0.21
CAPITAL RECOVERY COSTS	
TOTAL CAPITAL REQUIREMENT	3,860,884
TOTAL ANNUAL CAPITAL REQUIREMENT	**792,858**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***	**931,397**

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NOx RACT Control Cost Effectiveness

Source	**Unit 859-1H1**	
Control	**SNCR**	
Rated Heat Input	**98.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**8.58**	**tpy**
Current Emission Rate	**0.020**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**103.4**	**GJ/hr**
Burner Heat Release Rate	**16.0**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

COST COMPONENT:	**COST ($)**
DIRECT COSTS	
Purchased Equipment Costs	
Equipment Cost (EC)	703,749
Instrumentation (Included in above costs)	- - -
Sales taxes (Included in above costs)	- - -
Freight (Included in above costs)	- - -
Subtotal - Purchased Equipment Costs (PEC)	**703,749**
Direct Installation Costs	
Foundations & supports; handling & erection; electrical; piping; etc.	0
Site Preparation / Buildings- Included above	- - -
Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)	**703,749**
INDIRECT INSTALLATION COSTS	
Engineering Costs (Included in above costs)	- - -
Construct. & Field Expenses (Included in above costs)	- - -
Contractor Fees (Included in above costs)	- - -
Start-up (Included in above costs)	- - -
Performance Test (Included in above costs)	- - -
Contingency (3% of PEC)	21,112
TOTAL INDIRECT COSTS, IC	**21,112**
TOTAL CAPITAL INVESTMENT (TCI)	**724,862**

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NOx RACT Control Cost Effectiveness

Source	**Unit 859-1H1**	
Control	**SNCR**	
Rated Heat Input	**98.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**8.58**	**tpy**
Current Emission Rate	**0.020**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**103.4**	**GJ/hr**
Burner Heat Release Rate	**16.0**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	19,934
	19,934
Utilities	
Ammonia Cost	1,246
Electricity Cost	0.1
Fuel Penalty Cost ($4.88/Mscf)	123,217
Subtotal - Utilities	**124,464**
TOTAL ANNUAL DIRECT COSTS	**144,397**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**144,397**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		724,862
TOTAL ANNUAL CAPITAL REQUIREMENT		**148,855**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**293,252**

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NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-2**	
Control	**ULNB & SCR**	
Rated Heat Input	**155.0**	**MMBtu/hr**
Number of Burners	**16.0**	**Burners**
Baseline Actual Emissions	**174.48**	**tpy**
Current Emission Rate	**0.257**	**lb/MMBtu**
Control Efficiency	**96%**	
Heater Capacity	**163.5**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from Vendor Quotation and *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

COST COMPONENT:	COST ($)
DIRECT COSTS - ULNB	
Purchased Equipment Costs	
Equipment Cost (EC)	722,539
Instrumentation (included in Furnace Modifications)	- - -
Sales taxes (added below to all materials and equipment)	- - -
Freight (added below to all materials and equipment)	- - -
Subtotal - Purchased Equipment Costs (PEC)	**722,539**
Direct Installation Costs	
Direct Labor - Header Improvements	356,630
Direct Labor - Burner Install	90,000
Direct Labor - Piping Modifications	573,250
Direct Labor - Furnace Modifications (Instrumentation)	158,500
Direct Labor - Demolition	47,619
Subtotal - Direct Installation Costs	**1,225,999**
TOTAL DIRECT COSTS (TDC) - ULNB	**1,948,538**
INDIRECT INSTALLATION COSTS - ULNB	
Sales Tax and Freight (5% of EC)	36,127
Temporary Construction (10% of all labor hours @ $75/hour)	58,388
Construction Equipment (2% of Direct Installation Costs)	24,520
Construction Supervision (5% of Direct Installation Costs)	61,300
TOTAL INDIRECT COSTS, IC - ULNB	**180,334**
OTHER COSTS - ULNB	
Detailed Engineering (30% of TDC + IC)	638,662
Construction Management (5% of TDC + IC)	106,444
Subtotal - Total Prime Contract (TDC + IC + Detailed Engineering + Construction Management)	**2,873,978**
Escalation (5% of Total Prime Contract)	143,699
Contingency (40% of Total Prime Contract + Escalation)	1,207,071
Owner's Cost (10% of Total Prime Contract + Escalation + Contingency)	422,475
DIRECT COSTS - SCR	
Purchased Equipment Costs	
Equipment Cost (EC)	4,939,968
Instrumentation (Included in above costs)	- - -
Sales taxes (Included in above costs)	- - -
Freight (Included in above costs)	- - -
Subtotal - Purchased Equipment Costs (PEC)	**4,939,968**
Direct Installation Costs	
Foundations & supports; handling & erection; electrical; piping; etc.	0
Site Preparation / Buildings- Included above	- - -
Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC) - SCR	**4,939,968**
INDIRECT INSTALLATION COSTS - SCR	
Engineering Costs (Included in above costs)	- - -
Construct. & Field Expenses (Included in above costs)	- - -
Contractor Fees (Included in above costs)	- - -
Start-up (Included in above costs)	- - -
Performance Test (Included in above costs)	- - -
Contingency (3% of PEC)	148,199
TOTAL INDIRECT COSTS, IC - SCR	**148,199**
TOTAL CAPITAL INVESTMENT (TCI) - ULNB	**4,647,222**
TOTAL CAPITAL INVESTMENT (TCI) - SCR	**5,088,167**
TOTAL CAPITAL INVESTMENT (TCI)	**9,735,389**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-2**	
Control	**ULNB & SCR**	
Rated Heat Input	**155.0**	**MMBtu/hr**
Number of Burners	**16.0**	**Burners**
Baseline Actual Emissions	**174.48**	**tpy**
Current Emission Rate	**0.257**	**lb/MMBtu**
Control Efficiency	**96%**	
Heater Capacity	**163.5**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	267,723
	267,723
Utilities	
Ammonia Cost	25,332
Catalyst Replacement Cost	49,218
Electricity Cost	1.8
Subtotal - Utilities	**74,552**
TOTAL ANNUAL DIRECT COSTS	**342,275**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**342,275**
Annualized Cost Factor - ULNB		
Equipment Life (years) =	10	
Interest Rate (%) =	20	
Annualized Cost Factor		0.24
Annualized Cost Factor - SCR		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		9,735,389
TOTAL ANNUAL CAPITAL REQUIREMENT		**2,153,357**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**2,495,632**

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NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-2**	
Control	**ULNB**	
Rated Heat Input	**155.0**	**MMBtu/hr**
Number of Burners	**16.0**	**Burners**
Baseline Actual Emissions	**174.48**	**tpy**
Current Emission Rate	**0.257**	**lb/MMBtu**
Control Efficiency	**86%**	
Heater Capacity	**163.5**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from Vendor Quotation and *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	COST ($)
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	722,539
	Instrumentation (included in Furnace Modifications)	- - -
	Sales taxes (added below to all materials and equipment)	- - -
	Freight (added below to all materials and equipment)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**722,539**
	Direct Installation Costs	
	Direct Labor - Header Improvements	356,630
	Direct Labor - Burner Install	90,000
	Direct Labor - Piping Modifications	573,250
	Direct Labor - Furnace Modifications (Instrumentation)	158,500
	Direct Labor - Demolition	47,619
	Subtotal - Direct Installation Costs	**1,225,999**
TOTAL DIRECT COSTS (TDC)		**1,948,538**
INDIRECT INSTALLATION COSTS		
	Sales Tax and Freight (5% of EC)	36,127
	Temporary Construction (10% of all labor hours @ $75/hour)	58,388
	Construction Equipment (2% of Direct Installation Costs)	24,520
	Construction Supervision (5% of Direct Installation Costs)	61,300
TOTAL INDIRECT COSTS, IC		**180,334**
OTHER COSTS		
	Detailed Engineering (30% of TDC + IC)	638,662
	Construction Management (5% of TDC + IC)	106,444
	Subtotal - Total Prime Contract (TDC + IC + Detailed Engineering + Construction Management)	**2,873,978**
	Escalation (5% of Total Prime Contract)	143,699
	Contingency (40% of Total Prime Contract + Escalation)	1,207,071
	Owner's Cost (10% of Total Prime Contract + Escalation + Contingency)	422,475
TOTAL CAPITAL INVESTMENT (TCI)		**4,647,222**

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NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-2**	
Control	**ULNB**	
Rated Heat Input	**155.0**	**MMBtu/hr**
Number of Burners	**16.0**	**Burners**
Baseline Actual Emissions	**174.48**	**tpy**
Current Emission Rate	**0.257**	**lb/MMBtu**
Control Efficiency	**86%**	
Heater Capacity	**163.5**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	127,799
	127,799
Utilities	
None	
Subtotal - Utilities	**0.0**
TOTAL ANNUAL DIRECT COSTS	**127,799**

COST COMPONENT:			**COST ($)**
TOTAL ANNUAL O&M COSTS			**127,799**
Annualized Cost Factor			
	Equipment Life (years) =	10	
	Interest Rate (%) =	20	
Annualized Cost Factor			0.24
CAPITAL RECOVERY COSTS			
TOTAL CAPITAL REQUIREMENT			4,647,222
TOTAL ANNUAL CAPITAL REQUIREMENT			**1,108,468**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***			**1,236,267**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-2**	
Control	**SCR**	
Rated Heat Input	**155.0**	**MMBtu/hr**
Number of Burners	**16.0**	**Burners**
Baseline Actual Emissions	**174.48**	**tpy**
Current Emission Rate	**0.257**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**163.5**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

COST COMPONENT:	COST ($)
DIRECT COSTS	
Purchased Equipment Costs	
Equipment Cost (EC)	4,939,968
Instrumentation (Included in above costs)	- - -
Sales taxes (Included in above costs)	- - -
Freight (Included in above costs)	- - -
Subtotal - Purchased Equipment Costs (PEC)	**4,939,968**
Direct Installation Costs	
Foundations & supports; handling & erection; electrical; piping; etc.	0
Site Preparation / Buildings- Included above	- - -
Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)	**4,939,968**
INDIRECT INSTALLATION COSTS	
Engineering Costs (Included in above costs)	- - -
Construct. & Field Expenses (Included in above costs)	- - -
Contractor Fees (Included in above costs)	- - -
Start-up (Included in above costs)	- - -
Performance Test (Included in above costs)	- - -
Contingency (3% of PEC)	148,199
TOTAL INDIRECT COSTS, IC	**148,199**
TOTAL CAPITAL INVESTMENT (TCI)	**5,088,167**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-2**	
Control	**SCR**	
Rated Heat Input	**155.0**	**MMBtu/hr**
Number of Burners	**16.0**	**Burners**
Baseline Actual Emissions	**174.48**	**tpy**
Current Emission Rate	**0.257**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**163.5**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

COST COMPONENT:	COST ($)
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	139,925
	139,925
Utilities	
Ammonia Cost	25,332
Catalyst Replacement Cost	49,218
Electricity Cost	1.8
Subtotal - Utilities	**74,552**
TOTAL ANNUAL DIRECT COSTS	**214,477**

COST COMPONENT:		COST ($)
TOTAL ANNUAL O&M COSTS		**214,477**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		5,088,167
TOTAL ANNUAL CAPITAL REQUIREMENT		**1,044,888**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**1,259,365**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-2**	
Control	**LNB & SNCR**	
Rated Heat Input	**155.0**	**MMBtu/hr**
Number of Burners	**16.0**	**Burners**
Baseline Actual Emissions	**174.48**	**tpy**
Current Emission Rate	**0.257**	**lb/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**163.5**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from Vendor Quotation and *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	COST ($)
DIRECT COSTS - LNB		
	Purchased Equipment Costs	
	Equipment Cost (EC) - Assumed to be 80% of ULNB EC ($)	578,031
	Instrumentation (included in Furnace Modifications)	- - -
	Sales taxes (added below to all materials and equipment)	- - -
	Freight (added below to all materials and equipment)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**578,031**
	Direct Installation Costs	
	Direct Labor - Header Improvements	356,630
	Direct Labor - Burner Install	90,000
	Direct Labor - Piping Modifications	573,250
	Direct Labor - Furnace Modifications (Instrumentation)	158,500
	Direct Labor - Demolition	47,619
	Subtotal - Direct Installation Costs	**1,225,999**
TOTAL DIRECT COSTS (TDC) - LNB		**1,804,030**
INDIRECT INSTALLATION COSTS - LNB		
	Sales Tax and Freight (5% of EC)	28,902
	Temporary Construction (10% of all labor hours @ $75/hour)	58,388
	Construction Equipment (2% of Direct Installation Costs)	24,520
	Construction Supervision (5% of Direct Installation Costs)	61,300
TOTAL INDIRECT COSTS, IC - LNB		**173,109**
OTHER COSTS - LNB		
	Detailed Engineering (30% of TDC + IC)	593,142
	Construction Management (5% of TDC + IC)	98,857
	Subtotal - Total Prime Contract (TDC + IC + Detailed Engineering + Construction Management)	**2,669,138**
	Escalation (5% of Total Prime Contract)	133,457
	Contingency (40% of Total Prime Contract + Escalation)	1,121,038
	Owner's Cost (10% of Total Prime Contract + Escalation + Contingency)	392,363
DIRECT COSTS - SNCR		
	Purchased Equipment Costs	
	Equipment Cost (EC)	926,577
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**926,577**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC) - SNCR		**926,577**
INDIRECT INSTALLATION COSTS - SNCR		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	27,797
TOTAL INDIRECT COSTS, IC - SNCR		**27,797**
TOTAL CAPITAL INVESTMENT (TCI) - LNB		**4,315,996**
TOTAL CAPITAL INVESTMENT (TCI) - SNCR		**954,374**
TOTAL CAPITAL INVESTMENT (TCI)		**5,270,370**

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RACT Update 2015
NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-2**	
Control	**LNB & SNCR**	
Rated Heat Input	**155.0**	**MMBtu/hr**
Number of Burners	**16.0**	**Burners**
Baseline Actual Emissions	**174.48**	**tpy**
Current Emission Rate	**0.257**	**lb/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**163.5**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

COST COMPONENT:	COST ($)
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	144,935
	144,935
Utilities	
Ammonia Cost	25,332
Electricity Cost	1.8
Fuel Penalty Cost ($4.88/Mscf)	194,884
Subtotal - Utilities	**220,218**
TOTAL ANNUAL DIRECT COSTS	**365,154**

COST COMPONENT:		COST ($)
TOTAL ANNUAL O&M COSTS		**365,154**
Annualized Cost Factor - LNB		
Equipment Life (years) =	10	
Interest Rate (%) =	20	
Annualized Cost Factor		0.24
Annualized Cost Factor - SNCR		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		5,270,370
TOTAL ANNUAL CAPITAL REQUIREMENT		**1,225,450**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**1,590,604**

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NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-2**	
Control	**LNB & FGR**	
Rated Heat Input	**155.0**	**MMBtu/hr**
Number of Burners	**16.0**	**Burners**
Baseline Actual Emissions	**174.48**	**tpy**
Current Emission Rate	**0.257**	**lb/MMBtu**
Control Efficiency	**55%**	
Heater Capacity	**163.5**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from Vendor Quotation and *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	COST ($)
DIRECT COSTS - LNB		
	Purchased Equipment Costs	
	Equipment Cost (EC) - Assumed to be 80% of ULNB EC ($)	578,031
	Instrumentation (included in Furnace Modifications)	- - -
	Sales taxes (added below to all materials and equipment)	- - -
	Freight (added below to all materials and equipment)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**578,031**
	Direct Installation Costs	
	Direct Labor - Header Improvements	356,630
	Direct Labor - Burner Install	90,000
	Direct Labor - Piping Modifications	573,250
	Direct Labor - Furnace Modifications (Instrumentation)	158,500
	Direct Labor - Demolition	47,619
	Subtotal - Direct Installation Costs	**1,225,999**
TOTAL DIRECT COSTS (TDC) - LNB		**1,804,030**
INDIRECT INSTALLATION COSTS - LNB		
	Sales Tax and Freight (5% of EC)	28,902
	Temporary Construction (10% of all labor hours @ $75/hour)	58,388
	Construction Equipment (2% of Direct Installation Costs)	24,520
	Construction Supervision (5% of Direct Installation Costs)	61,300
TOTAL INDIRECT COSTS, IC - LNB		**173,109**
OTHER COSTS - LNB		
	Detailed Engineering (30% of TDC + IC)	593,142
	Construction Management (5% of TDC + IC)	98,857
	Subtotal - Total Prime Contract (TDC + IC + Detailed Engineering + Construction Management)	**2,669,138**
	Escalation (5% of Total Prime Contract)	133,457
	Contingency (40% of Total Prime Contract + Escalation)	1,121,038
	Owner's Cost (10% of Total Prime Contract + Escalation + Contingency)	392,363
DIRECT COSTS - FGR		
	Purchased Equipment Costs	
	Equipment Cost (EC)	372,376
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**372,376**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC) - FGR		**372,376**
INDIRECT INSTALLATION COSTS - FGR		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	11,171
TOTAL INDIRECT COSTS, IC - FGR		**11,171**
TOTAL CAPITAL INVESTMENT (TCI) - LNB		**4,315,996**
TOTAL CAPITAL INVESTMENT (TCI) - FGR		**383,548**
TOTAL CAPITAL INVESTMENT (TCI)		**4,699,544**

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NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-2**	
Control	**LNB & FGR**	
Rated Heat Input	**155.0**	**MMBtu/hr**
Number of Burners	**16.0**	**Burners**
Baseline Actual Emissions	**174.48**	**tpy**
Current Emission Rate	**0.257**	**lb/MMBtu**
Control Efficiency	**55%**	
Heater Capacity	**163.5**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	129,237
	129,237
Utilities	
Electricity Cost	19,204
Subtotal - Utilities	**19,204**
TOTAL ANNUAL DIRECT COSTS	**148,441**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**148,441**
Annualized Cost Factor		
Equipment Life (years) =	10	
Interest Rate (%) =	20	
Annualized Cost Factor		0.24
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		4,699,544
TOTAL ANNUAL CAPITAL REQUIREMENT		**1,120,948**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**1,269,389**

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NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-2**	
Control	**SNCR**	
Rated Heat Input	**155.0**	**MMBtu/hr**
Number of Burners	**16.0**	**Burners**
Baseline Actual Emissions	**174.48**	**tpy**
Current Emission Rate	**0.257**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**163.5**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

COST COMPONENT:	COST ($)
DIRECT COSTS	
Purchased Equipment Costs	
Equipment Cost (EC)	926,577
Instrumentation (Included in above costs)	- - -
Sales taxes (Included in above costs)	- - -
Freight (Included in above costs)	- - -
Subtotal - Purchased Equipment Costs (PEC)	**926,577**
Direct Installation Costs	
Foundations & supports; handling & erection; electrical; piping; etc.	0
Site Preparation / Buildings- Included above	- - -
Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)	**926,577**
INDIRECT INSTALLATION COSTS	
Engineering Costs (Included in above costs)	- - -
Construct. & Field Expenses (Included in above costs)	- - -
Contractor Fees (Included in above costs)	- - -
Start-up (Included in above costs)	- - -
Performance Test (Included in above costs)	- - -
Contingency (3% of PEC)	27,797
TOTAL INDIRECT COSTS, IC	**27,797**
TOTAL CAPITAL INVESTMENT (TCI)	**954,374**

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NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-2**	
Control	**SNCR**	
Rated Heat Input	**155.0**	**MMBtu/hr**
Number of Burners	**16.0**	**Burners**
Baseline Actual Emissions	**174.48**	**tpy**
Current Emission Rate	**0.257**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**163.5**	**GJ/hr**
Burner Heat Release Rate	**12.3**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	26,245
	26,245
Utilities	
Ammonia Cost	25,332
Electricity Cost	1.8
Fuel Penalty Cost ($4.88/Mscf)	194,884
Subtotal - Utilities	**220,218**
TOTAL ANNUAL DIRECT COSTS	**246,464**

COST COMPONENT:	**COST ($)**
TOTAL ANNUAL O&M COSTS	**246,464**
Annualized Cost Factor	
Equipment Life (years) = 20	
Interest Rate (%) = 20	
Annualized Cost Factor	0.21
CAPITAL RECOVERY COSTS	
TOTAL CAPITAL REQUIREMENT	954,374
TOTAL ANNUAL CAPITAL REQUIREMENT	**195,987**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***	**442,451**

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NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-3**	
Control	**SCR**	
Rated Heat Input	**60.0**	**MMBtu/hr**
Number of Burners	**6.0**	**Burners**
Baseline Actual Emissions	**15.77**	**tpy**
Current Emission Rate	**0.060**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**63.3**	**GJ/hr**
Burner Heat Release Rate	**13.6**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

COST COMPONENT:		COST ($)
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	2,790,232
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**2,790,232**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**2,790,232**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	83,707
TOTAL INDIRECT COSTS, IC		**83,707**
TOTAL CAPITAL INVESTMENT (TCI)		**2,873,939**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-3**	
Control	**SCR**	
Rated Heat Input	**60.0**	**MMBtu/hr**
Number of Burners	**6.0**	**Burners**
Baseline Actual Emissions	**15.77**	**tpy**
Current Emission Rate	**0.060**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**63.3**	**GJ/hr**
Burner Heat Release Rate	**13.6**	**GJ/hr**

COST COMPONENT:	COST ($)
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	79,033
	79,033
Utilities	
Ammonia Cost	2,289
Catalyst Replacement Cost	19,052
Electricity Cost	0.2
Subtotal - Utilities	**21,342**
TOTAL ANNUAL DIRECT COSTS	**100,375**

COST COMPONENT:		COST ($)
TOTAL ANNUAL O&M COSTS		**100,375**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		2,873,939
TOTAL ANNUAL CAPITAL REQUIREMENT		**590,182**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**690,557**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-3**	
Control	**SNCR**	
Rated Heat Input	**60.0**	**MMBtu/hr**
Number of Burners	**6.0**	**Burners**
Baseline Actual Emissions	**15.77**	**tpy**
Current Emission Rate	**0.060**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**63.3**	**GJ/hr**
Burner Heat Release Rate	**13.6**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	**COST ($)**
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	524,292
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**524,292**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**524,292**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	15,729
TOTAL INDIRECT COSTS, IC		**15,729**
TOTAL CAPITAL INVESTMENT (TCI)		**540,021**

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NOx RACT Control Cost Effectiveness

Source	**Unit 137 F-3**	
Control	**SNCR**	
Rated Heat Input	**60.0**	**MMBtu/hr**
Number of Burners	**6.0**	**Burners**
Baseline Actual Emissions	**15.77**	**tpy**
Current Emission Rate	**0.060**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**63.3**	**GJ/hr**
Burner Heat Release Rate	**13.6**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	14,851
	14,851
Utilities	
Ammonia Cost	2,289
Electricity Cost	0.2
Fuel Penalty Cost ($4.88/Mscf)	75,439
Subtotal - Utilities	**77,729**
TOTAL ANNUAL DIRECT COSTS	**92,579**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**92,579**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		540,021
TOTAL ANNUAL CAPITAL REQUIREMENT		**110,897**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**203,476**

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NOx RACT Control Cost Effectiveness

Source	**Unit 1332 H-2**	
Control	**SCR**	
Rated Heat Input	**60.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**10.51**	**tpy**
Current Emission Rate	**0.040**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**63.3**	**GJ/hr**
Burner Heat Release Rate	**10.2**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	**COST ($)**
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	2,790,232
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**2,790,232**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**2,790,232**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	83,707
TOTAL INDIRECT COSTS, IC		**83,707**
TOTAL CAPITAL INVESTMENT (TCI)		**2,873,939**

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NOx RACT Control Cost Effectiveness

Source	**Unit 1332 H-2**	
Control	**SCR**	
Rated Heat Input	**60.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**10.51**	**tpy**
Current Emission Rate	**0.040**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**63.3**	**GJ/hr**
Burner Heat Release Rate	**10.2**	**GJ/hr**

COST COMPONENT:	COST ($)
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	79,033
	79,033
Utilities	
Ammonia Cost	1,526
Catalyst Replacement Cost	19,052
Electricity Cost	0.1
Subtotal - Utilities	**20,578**
TOTAL ANNUAL DIRECT COSTS	**99,612**

COST COMPONENT:		COST ($)
TOTAL ANNUAL O&M COSTS		**99,612**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		2,873,939
TOTAL ANNUAL CAPITAL REQUIREMENT		**590,182**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**689,794**

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NOx RACT Control Cost Effectiveness

Source	**Unit 1332 H-2**	
Control	**SNCR**	
Rated Heat Input	**60.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**10.51**	**tpy**
Current Emission Rate	**0.040**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**63.3**	**GJ/hr**
Burner Heat Release Rate	**10.2**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies
Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

COST COMPONENT:		COST ($)
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	524,292
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**524,292**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**524,292**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	15,729
TOTAL INDIRECT COSTS, IC		**15,729**
TOTAL CAPITAL INVESTMENT (TCI)		**540,021**

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NOx RACT Control Cost Effectiveness

Source	**Unit 1332 H-2**	
Control	**SNCR**	
Rated Heat Input	**60.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**10.51**	**tpy**
Current Emission Rate	**0.040**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**63.3**	**GJ/hr**
Burner Heat Release Rate	**10.2**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	14,851
	14,851
Utilities	
Ammonia Cost	1,526
Electricity Cost	0.1
Fuel Penalty Cost ($4.88/Mscf)	75,439
Subtotal - Utilities	**76,965**
TOTAL ANNUAL DIRECT COSTS	**91,816**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**91,816**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		540,021
TOTAL ANNUAL CAPITAL REQUIREMENT		**110,897**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**202,713**

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NOx RACT Control Cost Effectiveness

Source	**Unit 1332 H-400**	
Control	**ULNB**	
Rated Heat Input	**186.0**	**MMBtu/hr**
Number of Burners	**36.0**	**Burners**
Baseline Actual Emissions	**48.88**	**tpy**
Current Emission Rate	**0.060**	**lb/MMBtu**
Control Efficiency	**50%**	
Heater Capacity	**196.2**	**GJ/hr**
Burner Heat Release Rate	**6.5**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from Vendor Quotation and *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	**COST ($)**
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC) - Average equipment and labor from Vendor Quotation	428,166
	Instrumentation (10% of EC)	42,817
	Sales taxes (5% of EC)	21,408
	Freight (8% of EC)	34,253
	Subtotal - Purchased Equipment Costs (PEC)	**526,645**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc. - Average labor from Vendor Quotation	409,640
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**409,640**
TOTAL DIRECT COSTS (TDC)		**936,285**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (5% of PEC)	26,332
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (10% of PEC)	52,664
	Start-up (1% of PEC)	5,266
	Performance Test (1% of PEC)	5,266
	Contingency (3% of PEC)	15,799
TOTAL INDIRECT COSTS, IC		**105,329**
TOTAL CAPITAL INVESTMENT (TCI)		**1,041,614**

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NOx RACT Control Cost Effectiveness

Source	**Unit 1332 H-400**	
Control	**ULNB**	
Rated Heat Input	**186.0**	**MMBtu/hr**
Number of Burners	**36.0**	**Burners**
Baseline Actual Emissions	**48.88**	**tpy**
Current Emission Rate	**0.060**	**lb/MMBtu**
Control Efficiency	**50%**	
Heater Capacity	**196.2**	**GJ/hr**
Burner Heat Release Rate	**6.5**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	28,644
	28,644
Utilities	
None	
Subtotal - Utilities	**0.0**
TOTAL ANNUAL DIRECT COSTS	**28,644**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**28,644**
Annualized Cost Factor		
Equipment Life (years) =	10	
Interest Rate (%) =	20	
Annualized Cost Factor		0.24
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		1,041,614
TOTAL ANNUAL CAPITAL REQUIREMENT		**248,449**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**277,093**

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NOx RACT Control Cost Effectiveness

Source	**Unit 1332 H-401**	
Control	**ULNB**	
Rated Heat Input	**233.0**	**MMBtu/hr**
Number of Burners	**36.0**	**Burners**
Baseline Actual Emissions	**61.23**	**tpy**
Current Emission Rate	**0.060**	**lb/MMBtu**
Control Efficiency	**50%**	
Heater Capacity	**245.8**	**GJ/hr**
Burner Heat Release Rate	**8.1**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies
Costs derived from Vendor Quotation and *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

COST COMPONENT:	**COST ($)**
DIRECT COSTS	
Purchased Equipment Costs	
Equipment Cost (EC) - Average equipment and labor from Vendor Quotation	428,166
Instrumentation (10% of EC)	42,817
Sales taxes (5% of EC)	21,408
Freight (8% of EC)	34,253
Subtotal - Purchased Equipment Costs (PEC)	**526,645**
Direct Installation Costs	
Foundations & supports; handling & erection; electrical; piping; etc. - Average labor from Vendor Quotation	409,640
Site Preparation / Buildings- Included above	- - -
Subtotal - Direct Installation Costs	**409,640**
TOTAL DIRECT COSTS (TDC)	**936,285**
INDIRECT INSTALLATION COSTS	
Engineering Costs (5% of PEC)	26,332
Construct. & Field Expenses (Included in above costs)	- - -
Contractor Fees (10% of PEC)	52,664
Start-up (1% of PEC)	5,266
Performance Test (1% of PEC)	5,266
Contingency (3% of PEC)	15,799
TOTAL INDIRECT COSTS, IC	**105,329**
TOTAL CAPITAL INVESTMENT (TCI)	**1,041,614**

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NOx RACT Control Cost Effectiveness

Source	**Unit 1332 H-401**	
Control	**ULNB**	
Rated Heat Input	**233.0**	**MMBtu/hr**
Number of Burners	**36.0**	**Burners**
Baseline Actual Emissions	**61.23**	**tpy**
Current Emission Rate	**0.060**	**lb/MMBtu**
Control Efficiency	**50%**	
Heater Capacity	**245.8**	**GJ/hr**
Burner Heat Release Rate	**8.1**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	28,644
	28,644
Utilities	
None	
Subtotal - Utilities	**0.0**
TOTAL ANNUAL DIRECT COSTS	**28,644**

COST COMPONENT:	**COST ($)**
TOTAL ANNUAL O&M COSTS	**28,644**
Annualized Cost Factor	
Equipment Life (years) = 10	
Interest Rate (%) = 20	
Annualized Cost Factor	0.24
CAPITAL RECOVERY COSTS	
TOTAL CAPITAL REQUIREMENT	1,041,614
TOTAL ANNUAL CAPITAL REQUIREMENT	**248,449**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***	**277,093**

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NOx RACT Control Cost Effectiveness

Source	**Unit 433 H-1**	
Control	**SCR**	
Rated Heat Input	**260.0**	**MMBtu/hr**
Number of Burners	**18.0**	**Burners**
Baseline Actual Emissions	**39.86**	**tpy**
Current Emission Rate	**0.035**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**274.3**	**GJ/hr**
Burner Heat Release Rate	**18.1**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	COST ($)
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	6,746,408
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**6,746,408**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**6,746,408**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	202,392
TOTAL INDIRECT COSTS, IC		**202,392**
TOTAL CAPITAL INVESTMENT (TCI)		**6,948,800**

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NOx RACT Control Cost Effectiveness

Source	**Unit 433 H-1**	
Control	**SCR**	
Rated Heat Input	**260.0**	**MMBtu/hr**
Number of Burners	**18.0**	**Burners**
Baseline Actual Emissions	**39.86**	**tpy**
Current Emission Rate	**0.035**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**274.3**	**GJ/hr**
Burner Heat Release Rate	**18.1**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	191,092
	191,092
Utilities	
Ammonia Cost	5,787
Catalyst Replacement Cost	82,559
Electricity Cost	0.4
Subtotal - Utilities	**88,346**
TOTAL ANNUAL DIRECT COSTS	**279,438**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**279,438**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		6,948,800
TOTAL ANNUAL CAPITAL REQUIREMENT		**1,426,981**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**1,706,420**

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NOx RACT Control Cost Effectiveness

Source	**Unit 433 H-1**	
Control	**SNCR**	
Rated Heat Input	**260.0**	**MMBtu/hr**
Number of Burners	**18.0**	**Burners**
Baseline Actual Emissions	**39.86**	**tpy**
Current Emission Rate	**0.035**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**274.3**	**GJ/hr**
Burner Heat Release Rate	**18.1**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	COST ($)
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	1,263,765
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**1,263,765**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**1,263,765**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	37,913
TOTAL INDIRECT COSTS, IC		**37,913**
TOTAL CAPITAL INVESTMENT (TCI)		**1,301,678**

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NOx RACT Control Cost Effectiveness

Source	**Unit 433 H-1**	
Control	**SNCR**	
Rated Heat Input	**260.0**	**MMBtu/hr**
Number of Burners	**18.0**	**Burners**
Baseline Actual Emissions	**39.86**	**tpy**
Current Emission Rate	**0.035**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**274.3**	**GJ/hr**
Burner Heat Release Rate	**18.1**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	35,796
	35,796
Utilities	
Ammonia Cost	5,787
Electricity Cost	0.4
Fuel Penalty Cost ($4.88/Mscf)	326,903
Subtotal - Utilities	**332,690**
TOTAL ANNUAL DIRECT COSTS	**368,486**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**368,486**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		1,301,678
TOTAL ANNUAL CAPITAL REQUIREMENT		**267,308**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**635,794**

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NOx RACT Control Cost Effectiveness

Source	**Unit 1232 B-104**	
Control	**SCR**	
Rated Heat Input	**70.0**	**MMBtu/hr**
Number of Burners	**12.0**	**Burners**
Baseline Actual Emissions	**54.27**	**tpy**
Current Emission Rate	**0.177**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**73.9**	**GJ/hr**
Burner Heat Release Rate	**7.8**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	COST ($)
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	3,061,366
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**3,061,366**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**3,061,366**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	91,841
TOTAL INDIRECT COSTS, IC		**91,841**
TOTAL CAPITAL INVESTMENT (TCI)		**3,153,207**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 1232 B-104**	
Control	**SCR**	
Rated Heat Input	**70.0**	**MMBtu/hr**
Number of Burners	**12.0**	**Burners**
Baseline Actual Emissions	**54.27**	**tpy**
Current Emission Rate	**0.177**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**73.9**	**GJ/hr**
Burner Heat Release Rate	**7.8**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	86,713
	86,713
Utilities	
Ammonia Cost	7,879
Catalyst Replacement Cost	22,227
Electricity Cost	0.6
Subtotal - Utilities	**30,107**
TOTAL ANNUAL DIRECT COSTS	**116,820**

COST COMPONENT:			**COST ($)**
TOTAL ANNUAL O&M COSTS			**116,820**
Annualized Cost Factor			
	Equipment Life (years) =	20	
	Interest Rate (%) =	20	
Annualized Cost Factor			0.21
CAPITAL RECOVERY COSTS			
TOTAL CAPITAL REQUIREMENT			3,153,207
TOTAL ANNUAL CAPITAL REQUIREMENT			**647,532**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***			**764,352**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 1232 B-104**	
Control	**SNCR**	
Rated Heat Input	**70.0**	**MMBtu/hr**
Number of Burners	**12.0**	**Burners**
Baseline Actual Emissions	**54.27**	**tpy**
Current Emission Rate	**0.177**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**73.9**	**GJ/hr**
Burner Heat Release Rate	**7.8**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	**COST ($)**
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	575,097
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**575,097**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**575,097**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	17,253
TOTAL INDIRECT COSTS, IC		**17,253**
TOTAL CAPITAL INVESTMENT (TCI)		**592,350**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Unit 1232 B-104**	
Control	**SNCR**	
Rated Heat Input	**70.0**	**MMBtu/hr**
Number of Burners	**12.0**	**Burners**
Baseline Actual Emissions	**54.27**	**tpy**
Current Emission Rate	**0.177**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**73.9**	**GJ/hr**
Burner Heat Release Rate	**7.8**	**GJ/hr**

COST COMPONENT:	COST ($)
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	16,290
	16,290
Utilities	
Ammonia Cost	7,879
Electricity Cost	0.6
Fuel Penalty Cost ($4.88/Mscf)	88,012
Subtotal - Utilities	**95,892**
TOTAL ANNUAL DIRECT COSTS	**112,182**

COST COMPONENT:		COST ($)
TOTAL ANNUAL O&M COSTS		**112,182**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		592,350
TOTAL ANNUAL CAPITAL REQUIREMENT		**121,643**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**233,825**

RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Boiler #39**	
Control	**SCR**	
Rated Heat Input	**495.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**86.72**	**tpy**
Current Emission Rate	**0.040**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**522.3**	**GJ/hr**
Burner Heat Release Rate	**76.6**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Utility Boilers* - EPA-453/R-94-023

	COST COMPONENT:	**COST ($)**
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	7,358,414
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**7,358,414**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**7,358,414**
TOTAL INDIRECT COSTS, IC	Assumed to be 30% of Direct Costs	**2,207,524**
TOTAL CAPITAL INVESTMENT (TCI)		**9,565,938**

	COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS		
	Operation and Maintenance Labor	
	Maintenance Labor and Material (2.75% of TCI)	263,063
		263,063
	Utilities	
	Ammonia Cost	14,276
	Catalyst Replacement Cost	178,209
	Electricity Cost	1.0
	Subtotal - Utilities	**192,486**
TOTAL ANNUAL DIRECT COSTS		**455,549**

RACT Update 2015
NOx RACT Control Cost Effectiveness

Source	**Boiler #39**	
Control	**SCR**	
Rated Heat Input	**495.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**86.72**	**tpy**
Current Emission Rate	**0.040**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**522.3**	**GJ/hr**
Burner Heat Release Rate	**76.6**	**GJ/hr**

COST COMPONENT:		COST ($)
TOTAL ANNUAL O&M COSTS		**455,549**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		9,565,938
TOTAL ANNUAL CAPITAL REQUIREMENT		**1,964,428**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**2,419,977**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Boiler #39**	
Control	**SNCR**	
Rated Heat Input	**495.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**86.72**	**tpy**
Current Emission Rate	**0.040**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**522.3**	**GJ/hr**
Burner Heat Release Rate	**76.6**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

COST COMPONENT:		COST ($)
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	1,859,711
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**1,859,711**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**1,859,711**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	55,791
TOTAL INDIRECT COSTS, IC		**55,791**
TOTAL CAPITAL INVESTMENT (TCI)		**1,915,503**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Boiler #39**	
Control	**SNCR**	
Rated Heat Input	**495.0**	**MMBtu/hr**
Number of Burners	**8.0**	**Burners**
Baseline Actual Emissions	**86.72**	**tpy**
Current Emission Rate	**0.040**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**522.3**	**GJ/hr**
Burner Heat Release Rate	**76.6**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	52,676
	52,676
Utilities	
Ammonia Cost	12,591
Electricity Cost	0.9
Subtotal - Utilities	**12,592**
TOTAL ANNUAL DIRECT COSTS	**65,269**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**65,269**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		1,915,503
TOTAL ANNUAL CAPITAL REQUIREMENT		**393,361**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**458,630**

RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Boiler #40**	
Control	**SCR**	
Rated Heat Input	**660.0**	**MMBtu/hr**
Number of Burners	**10.0**	**Burners**
Baseline Actual Emissions	**115.63**	**tpy**
Current Emission Rate	**0.040**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**696.3**	**GJ/hr**
Burner Heat Release Rate	**81.4**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Utility Boilers* - EPA-453/R-94-023

	COST COMPONENT:	**COST ($)**
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	8,938,050
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**8,938,050**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**8,938,050**
TOTAL INDIRECT COSTS, IC	Assumed to be 30% of Direct Costs	**2,681,415**
TOTAL CAPITAL INVESTMENT (TCI)		**11,619,465**

	COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS		
	Operation and Maintenance Labor	
	Maintenance Labor and Material (2.75% of TCI)	319,535
		319,535
	Utilities	
	Ammonia Cost	19,035
	Catalyst Replacement Cost	237,612
	Electricity Cost	1.4
	Subtotal - Utilities	**256,648**
TOTAL ANNUAL DIRECT COSTS		**576,183**

RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Boiler #40**	
Control	**SCR**	
Rated Heat Input	**660.0**	**MMBtu/hr**
Number of Burners	**10.0**	**Burners**
Baseline Actual Emissions	**115.63**	**tpy**
Current Emission Rate	**0.040**	**lb/MMBtu**
Control Efficiency	**85%**	
Heater Capacity	**696.3**	**GJ/hr**
Burner Heat Release Rate	**81.4**	**GJ/hr**

COST COMPONENT:			**COST ($)**
TOTAL ANNUAL O&M COSTS			**576,183**
Annualized Cost Factor			
	Equipment Life (years) =	20	
	Interest Rate (%) =	20	
	Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS			
	TOTAL CAPITAL REQUIREMENT		11,619,465
	TOTAL ANNUAL CAPITAL REQUIREMENT		**2,386,133**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***			**2,962,316**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Boiler #40**	
Control	**SNCR**	
Rated Heat Input	**660.0**	**MMBtu/hr**
Number of Burners	**10.0**	**Burners**
Baseline Actual Emissions	**115.63**	**tpy**
Current Emission Rate	**0.040**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**696.3**	**GJ/hr**
Burner Heat Release Rate	**81.4**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	COST ($)
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	2,210,084
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**2,210,084**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**2,210,084**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	66,303
TOTAL INDIRECT COSTS, IC		**66,303**
TOTAL CAPITAL INVESTMENT (TCI)		**2,276,387**

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NOx RACT Control Cost Effectiveness

Source	**Boiler #40**	
Control	**SNCR**	
Rated Heat Input	**660.0**	**MMBtu/hr**
Number of Burners	**10.0**	**Burners**
Baseline Actual Emissions	**115.63**	**tpy**
Current Emission Rate	**0.040**	**lb/MMBtu**
Control Efficiency	**40%**	
Heater Capacity	**696.3**	**GJ/hr**
Burner Heat Release Rate	**81.4**	**GJ/hr**

COST COMPONENT:	COST ($)
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	62,601
	62,601
Utilities	
Ammonia Cost	16,789
Electricity Cost	1.2
Subtotal - Utilities	**16,790**
TOTAL ANNUAL DIRECT COSTS	**79,390**

COST COMPONENT:	COST ($)
TOTAL ANNUAL O&M COSTS	**79,390**
Annualized Cost Factor	
Equipment Life (years) = 20	
Interest Rate (%) = 20	
Annualized Cost Factor	0.21
CAPITAL RECOVERY COSTS	
TOTAL CAPITAL REQUIREMENT	2,276,387
TOTAL ANNUAL CAPITAL REQUIREMENT	**467,471**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***	**546,861**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**FCC 868**	
Control	**SCR**	
Maximum Annual Throughput	**47.5**	**MBPD**
Average Stackflow	**142.8**	**MMscf/day**
Baseline Actual Emissions[1]	**130.20**	**tpy**
Current Emission Rate[2]	**50.00**	**ppmvd @ 0% O_2**
Control Efficiency	**90%**	

[1] **Emissions based on 2013 AIMS report stack flows scaled to 47.5 MBPD.**

[2] **Concentration established to comply with the Second Amendment to Civil Action No. 05-02866.**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Documentation of NOx Control Cost Estimates* - EPA-HQ-OAR-2007-0011-0089

	COST COMPONENT:	**COST ($)**
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	9,500,000
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**9,500,000**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**9,500,000**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	285,000
TOTAL INDIRECT COSTS, IC		**285,000**
TOTAL CAPITAL INVESTMENT (TCI)		**9,785,000**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**FCC 868**	
Control	**SCR**	
Maximum Annual Throughput	**47.5**	**MBPD**
Average Stackflow	**142.8**	**MMscf/day**
Baseline Actual Emissions[1]	**130.20**	**tpy**
Current Emission Rate[2]	**50.00**	**ppmvd @ 0% O_2**
Control Efficiency	**90%**	

[1] Emissions based on 2013 AIMS report stack flows scaled to 47.5 MBPD.

[2] Concentration established to comply with the Second Amendment to Civil Action No. 05-02866.

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	269,088
	269,088
Utilities	
Ammonia and Catalyst Replacement Cost	1,330,000
Electricity Cost	1.4
Subtotal - Utilities	**1,330,001**
TOTAL ANNUAL DIRECT COSTS	**1,599,089**

COST COMPONENT:			**COST ($)**
TOTAL ANNUAL O&M COSTS			**1,599,089**
Annualized Cost Factor			
	Equipment Life (years) =	20	
	Interest Rate (%) =	20	
Annualized Cost Factor			0.21
CAPITAL RECOVERY COSTS			
TOTAL CAPITAL REQUIREMENT			9,785,000
TOTAL ANNUAL CAPITAL REQUIREMENT			**2,009,414**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***			**3,608,503**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**FCC 868**	
Control	**LoTOx**	
Maximum Annual Throughput	**47.5**	**MBPD**
Average Stackflow	**142.8**	**MMscf/day**
Baseline Actual Emissions[1]	**130.20**	**tpy**
Current Emission Rate[2]	**50.00**	**ppmvd @ 0% O_2**
Control Efficiency	**90%**	
Representative Heat Input[3]	**0.0**	**MMBtu/hr**
Heater Capacity	**0.0**	**GJ/hr**

[1] Emissions based on 2013 AIMS report stack flows scaled to 47.5 MBPD.

[2] Concentration established to comply with the Second Amendment to Civil Action No. 05-02866.

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Documentation of NOx Control Cost Estimates* - EPA-HQ-OAR-2007-0011-0089

	COST COMPONENT:	**COST ($)**
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	5,700,000
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**5,700,000**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**5,700,000**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	171,000
TOTAL INDIRECT COSTS, IC		**171,000**
TOTAL CAPITAL INVESTMENT (TCI)		**5,871,000**

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NOx RACT Control Cost Effectiveness

Source	**FCC 868**	
Control	**LoTOx**	
Maximum Annual Throughput	**47.5**	**MBPD**
Average Stackflow	**142.8**	**MMscf/day**
Baseline Actual Emissions[1]	**130.20**	**tpy**
Current Emission Rate[2]	**50.00**	**ppmvd @ 0% O_2**
Control Efficiency	**90%**	
Representative Heat Input[3]	**0.0**	**MMBtu/hr**
Heater Capacity	**0.0**	**GJ/hr**

[1] Emissions based on 2013 AIMS report stack flows scaled to 47.5 MBPD.

[2] Concentration established to comply with the Second Amendment to Civil Action No. 05-02866.

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	161,453
	161,453
Utilities	
None	
Subtotal - Utilities	**0**
TOTAL ANNUAL DIRECT COSTS	**161,453**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**161,453**
Annualized Cost Factor		
Equipment Life (years) =	10	
Interest Rate (%) =	20	
Annualized Cost Factor		0.24
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		5,871,000
TOTAL ANNUAL CAPITAL REQUIREMENT		**1,400,367**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**1,561,820**

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NOx RACT Control Cost Effectiveness

Source	**FCC 868**	
Control	**SNCR**	
Maximum Annual Throughput	**47.5**	**MBPD**
Average Stackflow	**142.8**	**MMscf/day**
Baseline Actual Emissions[1]	**130.20**	**tpy**
Current Emission Rate[2]	**50.00**	**ppmvd @ 0% O_2**
Control Efficiency	**40%**	
Representative Heat Input[3]	**683.3**	**MMBtu/hr**
Heater Capacity	**720.9**	**GJ/hr**

[1] Emissions based on 2013 AIMS report stack flows scaled to 47.5 MBPD.

[2] Concentration established to comply with the Second Amendment to Civil Action No. 05-02866.

[3] Representative heat input calculated based on stack flow rate using EPA Method 19 "*Determination of Sulfur Dioxide Removal Efficiency and Particulate Matter, Sulfur Dioxide, and Nitrogen Oxide Emission Rates*" Fd factor calculation

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	**COST ($)**
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	2,256,486
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**2,256,486**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**2,256,486**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	67,695
TOTAL INDIRECT COSTS, IC		**67,695**
TOTAL CAPITAL INVESTMENT (TCI)		**2,324,180**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**FCC 868**	
Control	**SNCR**	
Maximum Annual Throughput	**47.5**	**MBPD**
Average Stackflow	**142.8**	**MMscf/day**
Baseline Actual Emissions[1]	**130.20**	**tpy**
Current Emission Rate[2]	**50.00**	**ppmvd @ 0% O_2**
Control Efficiency	**40%**	
Representative Heat Input[3]	**683.3**	**MMBtu/hr**
Heater Capacity	**720.9**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	63,915
	63,915
Utilities	
Ammonia Cost	14,986
Electricity Cost	1.1
Subtotal - Utilities	**14,988**
TOTAL ANNUAL DIRECT COSTS	**78,902**

COST COMPONENT:			**COST ($)**
TOTAL ANNUAL O&M COSTS			**78,902**
Annualized Cost Factor			
	Equipment Life (years) =	20	
	Interest Rate (%) =	20	
Annualized Cost Factor			0.21
CAPITAL RECOVERY COSTS			
TOTAL CAPITAL REQUIREMENT			2,324,180
TOTAL ANNUAL CAPITAL REQUIREMENT			**477,286**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***			**556,188**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Diesel-Fired RICE IC-002**	
Control	**SCR (NO_x Control)**	
Rated Heat Input	**1.4**	**MMBtu/hr**
Number of Burners	**N/A**	**Burners**
Baseline Actual Emissions	**9.42**	**tpy**
Current Emission Rate	**4.410**	**lb NO_x/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**1.5**	**GJ/hr**
Burner Heat Release Rate	**N/A**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Diesel Retrofit Technology* - EPA420-R-07-005

Operating & Maintenance costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

COST COMPONENT:	**COST ($)**
DIRECT COSTS	
Purchased Equipment Costs	
Equipment Cost (EC)	16,000
Instrumentation (Included in above costs)	- - -
Sales taxes (Included in above costs)	- - -
Freight (Included in above costs)	- - -
Subtotal - Purchased Equipment Costs (PEC)	**16,000**
Direct Installation Costs	
Foundations & supports; handling & erection; electrical; piping; etc.	0
Site Preparation / Buildings- Included above	- - -
Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)	**16,000**
INDIRECT INSTALLATION COSTS	
Engineering Costs (Included in above costs)	- - -
Construct. & Field Expenses (Included in above costs)	- - -
Contractor Fees (Included in above costs)	- - -
Start-up (Included in above costs)	- - -
Performance Test (Included in above costs)	- - -
Contingency (3% of PEC)	480
TOTAL INDIRECT COSTS, IC	**480**
TOTAL CAPITAL INVESTMENT (TCI)	**16,480**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Diesel-Fired RICE IC-002**	
Control	**SCR (NO_x Control)**	
Rated Heat Input	**1.4**	**MMBtu/hr**
Number of Burners	**N/A**	**Burners**
Baseline Actual Emissions	**9.42**	**tpy**
Current Emission Rate	**4.410**	**lb NO_x/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**1.5**	**GJ/hr**
Burner Heat Release Rate	**N/A**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	453
	453
Utilities	
Ammonia Cost	3,926
Catalyst Replacement Cost	445
Electricity Cost	0.3
Subtotal - Utilities	**4,371**
TOTAL ANNUAL DIRECT COSTS	**4,824**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**4,824**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		16,480
TOTAL ANNUAL CAPITAL REQUIREMENT		**3,384**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**8,209**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Diesel-Fired RICE IC-002**	
Control	**Oxidation Catalyst (VOC Control)**	
Rated Heat Input	**1.4**	**MMBtu/hr**
Number of Burners	**N/A**	**Burners**
Baseline Actual Emissions	**0.77**	**tpy**
Current Emission Rate	**0.36**	**lb VOC/MMBtu**
Control Efficiency	**50%**	

Evaluated at New Firing Limit at 2013 Cost and Efficiencies
Costs derived from *vendor quote for 2220 hp genset.*

COST COMPONENT:	COST ($)
DIRECT COSTS	
Purchased Equipment Costs	
Equipment Cost (EC)	1,371
Instrumentation (Included in above costs)	- - -
Sales taxes (Included in above costs)	- - -
Freight (Included in above costs)	- - -
Subtotal - Purchased Equipment Costs (PEC)	**1,371**
Direct Installation Costs	
Foundations & supports; handling & erection; electrical; piping; insulation; etc.	4620
Site Preparation / Buildings- Included above	- - -
Subtotal - Direct Installation Costs	**4,620**
TOTAL DIRECT COSTS (TDC)	**5,991**
INDIRECT INSTALLATION COSTS	
Engineering Costs (Included in above costs)	- - -
Construct. & Field Expenses (Included in above costs)	- - -
Contractor Fees (Included in above costs)	- - -
Start-up (Included in above costs)	- - -
Performance Test (Included in above costs)	- - -
Contingency (3% of PEC)	41
TOTAL INDIRECT COSTS, IC	**41**
TOTAL CAPITAL INVESTMENT (TCI)	**6,032**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Diesel-Fired RICE IC-002**	
Control	**Oxidation Catalyst (VOC Control)**	
Rated Heat Input	**1.4**	**MMBtu/hr**
Number of Burners	**N/A**	**Burners**
Baseline Actual Emissions	**0.77**	**tpy**
Current Emission Rate	**0.36**	**lb VOC/MMBtu**
Control Efficiency	**50%**	

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	166
	166
Utilities	
Catalyst Replacement Cost	686
Subtotal - Utilities	**686**
TOTAL ANNUAL DIRECT COSTS	**851**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**851**
Annualized Cost Factor		
Equipment Life (years) =	10	
Interest Rate (%) =	20	
Annualized Cost Factor		0.24
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		6,032
TOTAL ANNUAL CAPITAL REQUIREMENT		**1,439**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**2,290**

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NOx RACT Control Cost Effectiveness

Source	**Diesel-Fired RICE IC-005**	
Control	**SCR (NO_x Control)**	
Rated Heat Input	**0.2**	**MMBtu/hr**
Number of Burners	**N/A**	**Burners**
Baseline Actual Emissions	**1.32**	**tpy**
Current Emission Rate	**4.410**	**lb NO_x/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**0.2**	**GJ/hr**
Burner Heat Release Rate	**N/A**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Diesel Retrofit Technology* - EPA420-R-07-005

Operating & Maintenance costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	**COST ($)**
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	16,000
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**16,000**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**16,000**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	480
TOTAL INDIRECT COSTS, IC		**480**
TOTAL CAPITAL INVESTMENT (TCI)		**16,480**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Diesel-Fired RICE IC-005**	
Control	**SCR (NO_x Control)**	
Rated Heat Input	**0.2**	**MMBtu/hr**
Number of Burners	**N/A**	**Burners**
Baseline Actual Emissions	**1.32**	**tpy**
Current Emission Rate	**4.410**	**lb NO_x/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**0.2**	**GJ/hr**
Burner Heat Release Rate	**N/A**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	453
	453
Utilities	
Ammonia Cost	550
Catalyst Replacement Cost	62
Electricity Cost	0.0
Subtotal - Utilities	**612**
TOTAL ANNUAL DIRECT COSTS	**1,065**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**1,065**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		16,480
TOTAL ANNUAL CAPITAL REQUIREMENT		**3,384**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**4,449**

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NOx RACT Control Cost Effectiveness

Source	**Diesel-Fired RICE IC-005**	
Control	**Oxidation Catalyst (VOC Control)**	
Rated Heat Input	**0.2**	**MMBtu/hr**
Number of Burners	**N/A**	**Burners**
Baseline Actual Emissions	**0.11**	**tpy**
Current Emission Rate	**0.36**	**lb VOC/MMBtu**
Control Efficiency	**50%**	

Evaluated at New Firing Limit at 2013 Cost and Efficiencies
Costs derived from *vendor quote for 2220 hp genset.*

COST COMPONENT:	COST ($)
DIRECT COSTS	
Purchased Equipment Costs	
Equipment Cost (EC)	1,371
Instrumentation (Included in above costs)	- - -
Sales taxes (Included in above costs)	- - -
Freight (Included in above costs)	- - -
Subtotal - Purchased Equipment Costs (PEC)	**1,371**
Direct Installation Costs	
Foundations & supports; handling & erection; electrical; piping; insulation; etc.	4620
Site Preparation / Buildings- Included above	- - -
Subtotal - Direct Installation Costs	**4,620**
TOTAL DIRECT COSTS (TDC)	**5,991**
INDIRECT INSTALLATION COSTS	
Engineering Costs (Included in above costs)	- - -
Construct. & Field Expenses (Included in above costs)	- - -
Contractor Fees (Included in above costs)	- - -
Start-up (Included in above costs)	- - -
Performance Test (Included in above costs)	- - -
Contingency (3% of PEC)	41
TOTAL INDIRECT COSTS, IC	**41**
TOTAL CAPITAL INVESTMENT (TCI)	**6,032**

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NOx RACT Control Cost Effectiveness

Source	**Diesel-Fired RICE IC-005**	
Control	**Oxidation Catalyst (VOC Control)**	
Rated Heat Input	**0.2**	**MMBtu/hr**
Number of Burners	**N/A**	**Burners**
Baseline Actual Emissions	**0.11**	**tpy**
Current Emission Rate	**0.36**	**lb VOC/MMBtu**
Control Efficiency	**50%**	

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	166
	166
Utilities	
Catalyst Replacement Cost	686
Subtotal - Utilities	**686**
TOTAL ANNUAL DIRECT COSTS	**851**

COST COMPONENT:	**COST ($)**
TOTAL ANNUAL O&M COSTS	**851**
Annualized Cost Factor	
Equipment Life (years) = 10	
Interest Rate (%) = 20	
Annualized Cost Factor	0.24
CAPITAL RECOVERY COSTS	
TOTAL CAPITAL REQUIREMENT	6,032
TOTAL ANNUAL CAPITAL REQUIREMENT	**1,439**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***	**2,290**

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NOx RACT Control Cost Effectiveness

Source	**Diesel-Fired RICE IC-006**	
Control	**SCR (NO_x Control)**	
Rated Heat Input	**0.2**	**MMBtu/hr**
Number of Burners	**N/A**	**Burners**
Baseline Actual Emissions	**0.65**	**tpy**
Current Emission Rate	**2.159**	**lb NO_x/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**0.2**	**GJ/hr**
Burner Heat Release Rate	**N/A**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Diesel Retrofit Technology* - EPA420-R-07-005

Operating & Maintenance costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	COST ($)
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	16,000
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**16,000**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**16,000**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	480
TOTAL INDIRECT COSTS, IC		**480**
TOTAL CAPITAL INVESTMENT (TCI)		**16,480**

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NOx RACT Control Cost Effectiveness

Source	**Diesel-Fired RICE IC-006**	
Control	**SCR (NO_x Control)**	
Rated Heat Input	**0.2**	**MMBtu/hr**
Number of Burners	**N/A**	**Burners**
Baseline Actual Emissions	**0.65**	**tpy**
Current Emission Rate	**2.159**	**lb NO_x/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**0.2**	**GJ/hr**
Burner Heat Release Rate	**N/A**	**GJ/hr**

COST COMPONENT:	COST ($)
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	453
	453
Utilities	
Ammonia Cost	269
Catalyst Replacement Cost	62
Electricity Cost	0.0
Subtotal - Utilities	**331**
TOTAL ANNUAL DIRECT COSTS	**785**

COST COMPONENT:	COST ($)
TOTAL ANNUAL O&M COSTS	**785**
Annualized Cost Factor	
Equipment Life (years) = 20	
Interest Rate (%) = 20	
Annualized Cost Factor	0.21
CAPITAL RECOVERY COSTS	
TOTAL CAPITAL REQUIREMENT	16,480
TOTAL ANNUAL CAPITAL REQUIREMENT	**3,384**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***	**4,169**

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NOx RACT Control Cost Effectiveness

Source	**Diesel-Fired RICE IC-006**	
Control	**Oxidation Catalyst (VOC Control)**	
Rated Heat Input	**0.2**	**MMBtu/hr**
Number of Burners	**N/A**	**Burners**
Baseline Actual Emissions	**0.11**	**tpy**
Current Emission Rate	**0.36**	**lb VOC/MMBtu**
Control Efficiency	**50%**	

Evaluated at New Firing Limit at 2013 Cost and Efficiencies
Costs derived from *vendor quote for 2220 hp genset.*

COST COMPONENT:		COST ($)
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	1,371
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**1,371**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; insulation; etc.	4620
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**4,620**
TOTAL DIRECT COSTS (TDC)		**5,991**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	41
TOTAL INDIRECT COSTS, IC		**41**
TOTAL CAPITAL INVESTMENT (TCI)		**6,032**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Diesel-Fired RICE IC-006**	
Control	**Oxidation Catalyst (VOC Control)**	
Rated Heat Input	**0.2**	**MMBtu/hr**
Number of Burners	**N/A**	**Burners**
Baseline Actual Emissions	**0.11**	**tpy**
Current Emission Rate	**0.36**	**lb VOC/MMBtu**
Control Efficiency	**50%**	

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	166
	166
Utilities	
Catalyst Replacement Cost	686
Subtotal - Utilities	**686**
TOTAL ANNUAL DIRECT COSTS	**851**

COST COMPONENT:	**COST ($)**
TOTAL ANNUAL O&M COSTS	**851**
Annualized Cost Factor	
Equipment Life (years) = 10	
Interest Rate (%) = 20	
Annualized Cost Factor	0.24
CAPITAL RECOVERY COSTS	
TOTAL CAPITAL REQUIREMENT	6,032
TOTAL ANNUAL CAPITAL REQUIREMENT	**1,439**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***	**2,290**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Diesel-Fired RICE IC-007**	
Control	**SCR (NO_x Control)**	
Rated Heat Input	**0.2**	**MMBtu/hr**
Number of Burners	**N/A**	**Burners**
Baseline Actual Emissions	**0.20**	**tpy**
Current Emission Rate	**0.657**	**lb NO_x/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**0.2**	**GJ/hr**
Burner Heat Release Rate	**N/A**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Diesel Retrofit Technology* - EPA420-R-07-005

Operating & Maintenance costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	**COST ($)**
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	16,000
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**16,000**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**16,000**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	480
TOTAL INDIRECT COSTS, IC		**480**
TOTAL CAPITAL INVESTMENT (TCI)		**16,480**

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NOx RACT Control Cost Effectiveness

Source	**Diesel-Fired RICE IC-007**	
Control	**SCR (NO_x Control)**	
Rated Heat Input	**0.2**	**MMBtu/hr**
Number of Burners	**N/A**	**Burners**
Baseline Actual Emissions	**0.20**	**tpy**
Current Emission Rate	**0.657**	**lb NO_x/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**0.2**	**GJ/hr**
Burner Heat Release Rate	**N/A**	**GJ/hr**

COST COMPONENT:	COST ($)
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	453
	453
Utilities	
Ammonia Cost	82
Catalyst Replacement Cost	62
Electricity Cost	0.0
Subtotal - Utilities	**144**
TOTAL ANNUAL DIRECT COSTS	**597**

COST COMPONENT:		COST ($)
TOTAL ANNUAL O&M COSTS		**597**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		16,480
TOTAL ANNUAL CAPITAL REQUIREMENT		**3,384**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**3,982**

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NOx RACT Control Cost Effectiveness

Source	**Diesel-Fired RICE IC-007**	
Control	**Oxidation Catalyst (VOC Control)**	
Rated Heat Input	**0.2**	**MMBtu/hr**
Number of Burners	**N/A**	**Burners**
Baseline Actual Emissions	**0.11**	**tpy**
Current Emission Rate	**0.36**	**lb VOC/MMBtu**
Control Efficiency	**50%**	

Evaluated at New Firing Limit at 2013 Cost and Efficiencies
Costs derived from *vendor quote for 2220 hp genset.*

	COST COMPONENT:	COST ($)
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	1,371
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**1,371**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; insulation; etc.	4620
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**4,620**
TOTAL DIRECT COSTS (TDC)		**5,991**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	41
TOTAL INDIRECT COSTS, IC		**41**
TOTAL CAPITAL INVESTMENT (TCI)		**6,032**

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NOx RACT Control Cost Effectiveness

Source	**Diesel-Fired RICE IC-007**	
Control	**Oxidation Catalyst (VOC Control)**	
Rated Heat Input	**0.2**	**MMBtu/hr**
Number of Burners	**N/A**	**Burners**
Baseline Actual Emissions	**0.11**	**tpy**
Current Emission Rate	**0.36**	**lb VOC/MMBtu**
Control Efficiency	**50%**	

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	166
	166
Utilities	
Catalyst Replacement Cost	686
Subtotal - Utilities	**686**
TOTAL ANNUAL DIRECT COSTS	**851**

COST COMPONENT:	**COST ($)**
TOTAL ANNUAL O&M COSTS	**851**
Annualized Cost Factor	
Equipment Life (years) = 10	
Interest Rate (%) = 20	
Annualized Cost Factor	0.24
CAPITAL RECOVERY COSTS	
TOTAL CAPITAL REQUIREMENT	6,032
TOTAL ANNUAL CAPITAL REQUIREMENT	**1,439**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***	**2,290**

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NOx RACT Control Cost Effectiveness

Source	**Diesel-Fired RICE IC-008**	
Control	**SCR (NO_x Control)**	
Rated Heat Input	**0.2**	**MMBtu/hr**
Number of Burners	**N/A**	**Burners**
Baseline Actual Emissions	**0.32**	**tpy**
Current Emission Rate	**1.084**	**lb NO_x/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**0.2**	**GJ/hr**
Burner Heat Release Rate	**N/A**	**GJ/hr**

Evaluated at New Firing Limit at 2013 Cost and Efficiencies

Costs derived from *Diesel Retrofit Technology* - EPA420-R-07-005

Operating & Maintenance costs derived from *Alternative Control Techniques Document - NOx Emissions from Process Heaters (Revised)* - EPA-453/R-93-034

	COST COMPONENT:	**COST ($)**
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	16,000
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**16,000**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; etc.	0
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**0**
TOTAL DIRECT COSTS (TDC)		**16,000**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	480
TOTAL INDIRECT COSTS, IC		**480**
TOTAL CAPITAL INVESTMENT (TCI)		**16,480**

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RACT Update 2015

NOx RACT Control Cost Effectiveness

Source	**Diesel-Fired RICE IC-008**	
Control	**SCR (NO_x Control)**	
Rated Heat Input	**0.2**	**MMBtu/hr**
Number of Burners	**N/A**	**Burners**
Baseline Actual Emissions	**0.32**	**tpy**
Current Emission Rate	**1.084**	**lb NO_x/MMBtu**
Control Efficiency	**70%**	
Heater Capacity	**0.2**	**GJ/hr**
Burner Heat Release Rate	**N/A**	**GJ/hr**

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	453
	453
Utilities	
Ammonia Cost	135
Catalyst Replacement Cost	62
Electricity Cost	0.0
Subtotal - Utilities	**197**
TOTAL ANNUAL DIRECT COSTS	**651**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**651**
Annualized Cost Factor		
Equipment Life (years) =	20	
Interest Rate (%) =	20	
Annualized Cost Factor		0.21
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		16,480
TOTAL ANNUAL CAPITAL REQUIREMENT		**3,384**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**4,035**

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NOx RACT Control Cost Effectiveness

Source	**Diesel-Fired RICE IC-008**	
Control	**Oxidation Catalyst (VOC Control)**	
Rated Heat Input	**0.2**	**MMBtu/hr**
Number of Burners	**N/A**	**Burners**
Baseline Actual Emissions	**0.11**	**tpy**
Current Emission Rate	**0.36**	**lb VOC/MMBtu**
Control Efficiency	**50%**	

Evaluated at New Firing Limit at 2013 Cost and Efficiencies
Costs derived from *vendor quote for 2220 hp genset.*

	COST COMPONENT:	COST ($)
DIRECT COSTS		
	Purchased Equipment Costs	
	Equipment Cost (EC)	1,371
	Instrumentation (Included in above costs)	- - -
	Sales taxes (Included in above costs)	- - -
	Freight (Included in above costs)	- - -
	Subtotal - Purchased Equipment Costs (PEC)	**1,371**
	Direct Installation Costs	
	Foundations & supports; handling & erection; electrical; piping; insulation; etc.	4620
	Site Preparation / Buildings- Included above	- - -
	Subtotal - Direct Installation Costs	**4,620**
TOTAL DIRECT COSTS (TDC)		**5,991**
INDIRECT INSTALLATION COSTS		
	Engineering Costs (Included in above costs)	- - -
	Construct. & Field Expenses (Included in above costs)	- - -
	Contractor Fees (Included in above costs)	- - -
	Start-up (Included in above costs)	- - -
	Performance Test (Included in above costs)	- - -
	Contingency (3% of PEC)	41
TOTAL INDIRECT COSTS, IC		**41**
TOTAL CAPITAL INVESTMENT (TCI)		**6,032**

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NOx RACT Control Cost Effectiveness

Source	**Diesel-Fired RICE IC-008**	
Control	**Oxidation Catalyst (VOC Control)**	
Rated Heat Input	**0.2**	**MMBtu/hr**
Number of Burners	**N/A**	**Burners**
Baseline Actual Emissions	**0.11**	**tpy**
Current Emission Rate	**0.36**	**lb VOC/MMBtu**
Control Efficiency	**50%**	

COST COMPONENT:	**COST ($)**
ANNUAL DIRECT COSTS	
Operation and Maintenance Labor	
Maintenance Labor and Material (2.75% of TCI)	166
	166
Utilities	
Catalyst Replacement Cost	686
Subtotal - Utilities	**686**
TOTAL ANNUAL DIRECT COSTS	**851**

COST COMPONENT:		**COST ($)**
TOTAL ANNUAL O&M COSTS		**851**
Annualized Cost Factor		
Equipment Life (years) =	10	
Interest Rate (%) =	20	
Annualized Cost Factor		0.24
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT		6,032
TOTAL ANNUAL CAPITAL REQUIREMENT		**1,439**
TOTAL ANNUALIZED COST ***(Total annual O&M cost and annualized capital cost)***		**2,290**

Group 27 – Emergency Generator and Fire Pump, & Group 28 – Internal Combustion Engines

Group	ID	Description	HP	< 500 hp (Y/N)	4° retarded relative to standard timing (Y/N)	< 500 hrs operation or capacity factor < 5% (Y/N)	RACT exempt (Y/N)	Tier	EF Source	NOx Emission Factor	NOx Emission Factor Units	VOC Emission Factor	VOC Emission Factor Units
27	EM-001	Caterpillar (model 3412DITTA) Emergency Generator	896	N	Unknown	Y[1]	Y	N/A	N/A	N/A	N/A	N/A	N/A
27	FP-010	24PEN4 Fire Pump #4	211	Y	Unknown	Y[1]	Y	N/A	N/A	N/A	N/A	N/A	N/A
27	FP-011	24P1 Fire Engine (Haenn's Wharf)	210	Y	Unknown	Y[1]	Y	N/A	N/A	N/A	N/A	N/A	N/A
27	FP-012	Fire Pump (1st and Wharf #8)	475	Y	Unknown	Y[1]	Y	N/A	N/A	N/A	N/A	N/A	N/A
27	FP-013	24P2 North Fire Pump (Haenn's Wharf)	210	Y	Unknown	Y[1]	Y	N/A	N/A	N/A	N/A	N/A	N/A
27	FP-014	24P3 South Fire Pump (Short Pier)	350	Y	Unknown	Y[1]	Y	N/A	N/A	N/A	N/A	N/A	N/A
27	FP-015	24PEN5 Fire Pump (North Yard)	250	Y	Unknown	Y[1]	Y	N/A	N/A	N/A	N/A	N/A	N/A
27	FP-016	24PEN6 Fire Pump (North Yard Wharf)	250	Y	Unknown	Y[1]	Y	N/A	N/A	N/A	N/A	N/A	N/A
27	FP-017	28P-1150A HF Mitigation Water Pump FP-12#1 (Unit 433)	487	Y	Unknown	Y[1]	Y	N/A	N/A	N/A	N/A	N/A	N/A
27	FP-018	28P-1150B HF Mitigation Water Pump FP+12 #2 (Unit 433)	487	Y	Unknown	Y[1]	Y	N/A	N/A	N/A	N/A	N/A	N/A
27	FP-019	Belmont Firehouse Williams Pump (fire pump) affixed to a trailer	750	N	Unknown	Y[1]	Y	N/A	N/A	N/A	N/A	N/A	N/A
28	IC-002	53P-800C pump	200	Y	Unknown	N[2]	N	No Tier	AP42 3.3-1	0.031	lb/hp-hr	2.51E-03	lb/hp-hr
28	IC-005	FE-5(2) Flood Control Pump Driver	28	Y	Unknown	N[2]	N	No Tier	AP42 3.3-1	0.031	lb/hp-hr	2.51E-03	lb/hp-hr
28	IC-006	Godwin 894572/4 Flood Control Pump Driver	115	Y	Unknown	N[2]	N	Tier 1	Tier 1	0.015	lb/hp-hr	2.51E-03	lb/hp-hr
28	IC-007	B-2623 Flood Control Pump Driver	102	Y	Unknown	N[2]	N	Tier 3	Tier 3	0.005	lb/hp-hr	2.51E-03	lb/hp-hr
28	IC-008	Engine Set 1290 (northside of 8 Sep)	214	Y	Unknown	Y[2]	N	Tier 2	Tier 2	0.008	lb/hp-hr	2.51E-03	lb/hp-hr

[1] Group 27 engines limited to 500 hours of operation per 12 month rolling period per TVOP condition 30(b)(2)
[2] Group 28 engines operating hours limited by TVOP as follows:

Sources	Annual Operating Hours
IC-002 (53P-800C pump)	458
IC-005 (FE-5(2) Flood Control Pump Driver)	2300
IC-006 (Godwin 894572/4 Flood Control Pump Driver)	1150
IC-007 (B-2623 Flood Control Pump Driver)	3050
IC-008 (Engine Set 1290 (northside of 8 Sep))	360