

MAY -3 2017

DIVISION OF AIR QUALITY

Site Name: ATK Launch Systems Inc.

Owner: Orbital ATK Inc.

Contact: Jason Wells
P.O. Box 707
Brigham City, UT 84302

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DAQ-2017-006102

Description of Facility:

The Promontory facility is located in a rural area of Box Elder County approximately 24 miles northwest of Brigham City, Utah. The facility is a manufacturer of propellants, explosives, flares and related specialty products. PM_{2.5} and precursor emissions at the facility are generated from the following sources: (1) boilers, (2) emergency generators and similar internal combustion engines, (3) operations using VOC compounds, (4) testing and (5) open burning.

The site contains 21 natural gas and 19 fuel oil fired boilers. Table 1 and Table 2 identify the facility's natural gas and fuel oil boilers, respectively. Fuel oil boilers use ultra-low sulfur (< 15 PPM) fuel, and are located in areas where natural gas is not available.

All emergency generators, engines and other mobile sources are listed in Table 3. Equipment identified on this list uses ultra-low sulfur fuel exclusively, and is maintained and operated in accordance with 40 CFR Part 60, Subpart IIII and 40 CFR Part 63, Subpart ZZZZ requirements.

VOC sources include paint booth operations, chemical process solvents, and miscellaneous cleaning operations. Other VOC emissions are associated with fuel consumption from boilers, mobile sources and engines.

Energetic materials are tested during the manufacturing process to verify reactivity characteristics. Completed products are also tested to verify performance standards are met. Direct PM_{2.5} emissions and NO_x are the most likely emissions contributed from energetic material testing. Test quantities range from 75 grams up to 1.4 million pounds.

Open burning is the method used to treat the majority of reactive waste produced at the site. The process is regulated by the Utah Division of Waste Management and Radiation Control through a Subpart X hazardous waste treatment permit. Permitted operations and treatment quantities are derived from the results of a human health risk assessment designed to evaluate potential impacts to nearby receptors. Air emissions related to open burning are direct PM_{2.5}, NO_x, and VOC.

The site has 65 dust collection systems which control emissions from a variety of manufacturing operations. PM_{2.5} emissions from these collection systems are generally low due to the effectiveness of newer filtration material to remove fine particulate.

Recent Permitting Actions:

Title V administrative amendment by source (Project #OPP0100090029)
4/05/2017

- Modification to incorporate changes resulting from the issuance of AO's DAQE-AN100090133-16 and DAQE-AN100090134-17.
- Added 93 hp generator to building M-340.
- Removed paint booth M-079-PB01 from Group 5 and replaced it with paint booth T-021B- PB01 from Group 3.
- Reference to paint booth T-021B- PB01 deleted from Group 3.
- Deleted M-079-DC01 Paint Sanding Dust Collector from Group 5.
- Deleted M-179-PB01 Paint Booth from Group 7.
- Deleted M-053-OV05 Bake Off Oven with Afterburner from Group 10.

Title V administrative amendment by source (Project #OPP0100090028)
11/08/2016

- Modification to incorporate changes resulting from the issuance of AO's DAQE-AN100090130-16 and DAQE-AN100090132-16.
- Added HCL Storage Tank Scrubber.
- Removed natural gas fired boiler (Bldg M-010, 8.37 MM Btu/hr).
- Added Cleaver Brooks boiler (12.55 MM Btu/hr, rating of 9 ppm for NOx).
- Added clarification that fuel sulfur requirements for some units are more stringent than R307-203-1(1).
- Added clarification that records for the M-705 Waste Water Treatment Facility shall be kept on a daily basis.
- Restructured monitoring and recordkeeping for the M-705 Waste Water Treatment Facility to agree with new AO.
- Added construction notification requirement for the HCL Scrubber approved for the M-705 Waste Water Treatment Facility.
- Added 0.0015 fuel sulfur weight percent requirement for All Natural Gas and Diesel Fired Boilers.
- Removed construction notification requirement for the Cleaver Brooks burner onto the Wickes boiler in Building M-576.

- Removed GHG requirement from Reviewer Comments.

Title V significant modification (Project #OPP0100090025)
04/14/2016

- Modification to incorporate changes resulting from the issuance of AO's DAQE-AN100090126-15 and DAQE-AN100090127-15.
- Add Propane-Fired Burn-Off Oven to Group 10.
- Replaced the burner on one of the M-576 Wickes Boilers. The new burner is a Cleaver Brooks rated for 9 ppm NOx.
- Updating boiler requirements for 40 CFR Part 63, Subpart DDDDD.

Title V renewal application (Project #OPP0100090024)
06/10/2015

- Renewal.
- Addition of 40 CFR Part 63, Subpart DDDDD requirements for boilers.
- Addition of R307-335-4 requirements for degreasers.

Title V administrative amendment - enhanced AO (Project #OPP0100090023)
07/3/2014

- Modification to incorporate changes resulting from the issuance of AO's DAQE-AN100090124-14 and DAQE-AN100090125-14.
- Remove KOSMO Test Site from the Title V permit per issuance of DAQE-AN100090124-14
- Replace dust collector M-174-DC02 with Wet Scrubber M-174 per issuance of DAQE-AN100090125-14.
- Update RICE requirements.
- Reorganization of permit requirements and edits requested by source to represent current operations.

Title V administrative amendment - enhanced AO (Project #OPP0100090022)
09/30/2013

- Modification to incorporate changes resulting from the issuance of AO's DAQE-AN100090123-13 and DAQE-AN100090122-13.
- Relocate 3.35 MMBTU boiler from Bldg M-338 to Bldg T-021A.
- Relocate 2.51 MMBTU boiler from Bldg T-021A to Bldg M-338.
- Remove two 13.6 MM BTU Boilers from M-113

Existing PTE / Allowable Emissions (tons/yr)

Table 1 shows the current potential to emit (PTE) values for the facility. The values are the sum of PTE issued in the approval orders listed in Table 2.

TABLE 1. Potential to Emit (tons/year)

PM ₁₀	PM _{2.5}	SO ₂	NO _x	VOC	CO	NH ₃	Chlorine	HCl	Other HAPs	CO _{2e}
600.9	32.18	8.63	165.02	203.34	132.50	11.35	76.80	571.66	113.81	85,148.95

TABLE 2. Current Approval Orders

Approval Order	Approval Order	AO Date
Waste water treatment plant E-541 & M422	DAQE-802-94	22-Sep-94
M-705 Water Treatment Facility	DAQE-AN100090130-16	5-Oct-16
Safety Clean Degreasers	DAQE-389-96	12-Apr-96
Produce Various energetic materials in M-590 For Explosive manufacturing	DAQE-012-00	5-Jan-00
Natural gas & oil fired boilers	DAQE-AN100090132-16	5-Oct-16
Shuttle rocket motor testing	AN0009105-05	1-Aug-05
Emergency Generators	DAQE-AN100090133-16	19-Dec-16
T-75 and other testing operations except Large Motor	DAQE-AN100090124-14	14-Mar-14
Main Plant -- Groups 1-10 and S503 Burn-off oven	DAQE-AN100090126-15	14-Oct-15

Emissions Information / Discussion

2014 has been designated the baseline year for actual emissions from the facility. A summary of 2014 emissions, as reported in the Air Emission Inventory submission, is shown in Table 3.

TABLE 3. 2014 Emissions Summary (tons)

PM ₁₀	PM _{2.5}	SO _x	NO _x	VOC	CO	NH ₃	Chlorine	HCl	Other HAPs
45.88	19.13	1.86	51.02	31.18	117.18	0.44	0.26	4.7	6.9

The 2014 emissions inventory is a reasonable baseline for continuous emissions from the facility. PM and HCl values can be impacted by static testing depending on the number of tests conducted in a given year. PM and HCl evolved from static testing are unique emissions from a unique process.

Evaluation of Best Available Control Technology

ATK's BACT evaluation focuses on the following permitted sources with direct PM_{2.5} and PM_{2.5} precursor emissions (SO_x, NO_x, and VOC):

- Testing and open burning of energetic materials
- Boiler operations
- Emergency generators
- Coating and cleaning operations

Controls for emissions not related to direct PM_{2.5} or precursors were not evaluated. The BACT evaluation is broken down into possible control technologies to remove PM_{2.5} or precursor emissions from the aforementioned sources. In many cases, available controls are already required by existing permit requirements or federal standards.

BACT Evaluation for PM_{2.5} Emissions

Option 1: Controls for Open Burning Energetic Waste

Description

As a manufacturer of propellants, explosives and pyrotechnics (PEP), ATK Launch Systems plays a vital role in supporting the nation's defense and space programs. Waste disposal processes create safety challenges unique to this industry; where employee safety is the prime concern. Minimizing employee exposure to PEP materials is a core safety philosophy. This philosophy is carried out by limiting the amount of PEP waste stored for extended periods of time. Open burning energetic waste limits quantities onsite and ensures reduced exposure to employees.

ATK Launch Systems completed an open burning risk assessment under the direction of the Division of Waste Management and Radiation Control (DWMRC) to satisfy requirements for a treatment permit under 40 CFR Part 264, Subpart X. Open burning limits are the direct result of the risk assessment process to protect human health and the environment.

Identify Control Technologies for Open Burning Energetic Waste

Table 4 lists possible control technologies compatible with open burning energetic waste.

TABLE 4 Control Technologies for Open Burning Energetic Waste

No.	Control Technology	Pollutant Controlled
1	Relocate the OBOD facility outside the Salt Lake City Non-attainment Area (SLCNAA)	PM ₁₀ , PM _{2.5} , NO _x , NH ₃ , VOC
2	Transport waste to a commercial disposal facility outside the SLCNAA	PM ₁₀ , PM _{2.5} , NO _x , NH ₃ , VOC
3	Develop a treatment process with add-on controls to reduce emissions	PM ₁₀ , PM _{2.5} , NO _x , NH ₃ , VOC
4	Enhanced waste minimization efforts	PM ₁₀ , PM _{2.5} , NO _x , NH ₃ , VOC

1. Relocate the OBOD facility outside the SLCNAA.

Transporting waste to a facility developed by ATK outside the non-attainment area was evaluated. Costs for the hypothetical facility were based on purchasing 640 acres in a remote area of Box Elder County. The site requirements include access roads, security, electrical power service, water service and buildings. ATK would need to complete both the Division of Air Quality and the Division of Solid and Hazardous Waste permitting processes prior to construction of the facility.

2. Transport waste to a commercial disposal facility outside the SLCNAA.

Transporting waste to a commercial disposal facility outside the SLCNAA was evaluated to reduce emissions. A limited number of facilities are available in the country to accept

energetic wastes. However, the facilities that can receive the type of waste generated at ATK Launch Systems do not have enough capacity to treat all of the material.

3. Develop a treatment process with add-on controls to reduce emissions

The option of developing a process to treat energetic compounds using a process with add-on controls to minimize emissions was evaluated. Types of energetic materials requiring disposal include bulk Class 1.1 and Class 1.3 propellants, flare illuminants, military-grade high-explosives and developmental energetic compounds. These energetic compounds may contain metal powders, oxidizers, and a variety of high explosive compounds.

The Department of Defense (DOD) has developed the technology to deactivate military munitions which are appropriately sized to be treated in a controlled process using add-on controls. This process is also available commercially with limited capacity. The energetic compounds typical disposed using this option are manufactured articles containing limited quantities of energetic compounds which do not exceed the treatment process limits.

4. Enhanced waste minimization efforts

ATK maintains a pollution prevention and waste minimization program to reduce open burning. Open burning has been reduced by implementing process changes, and by employee generated efforts to reduce the quantity of waste generated. Additional efforts to reduce open burning include process changes to reduce batch sizes to minimize scrap quantities, and to segregate waste by PEP contamination level.

Technical Feasibility

1. Relocate the OBOD facility outside the SLCNAA.

Current manufacturing processes do not produce wastes meeting Department of Transportation (DOT) packaging weight and dimension requirements. Modifying manufacturing process to produce wastes meeting DOT packaging requirements potentially increases employee exposure and increases safety risks to employees. The DOT testing and approval process prevents obtaining approvals in a timely fashion which delays implementing the option. PEP wastes typically exit the manufacturing process prior to being finalized and are less stable than finalized product. Unstable and uncharacterized wastes can't be shipped and require disposal onsite. Shipping PEP wastes outside the SLCNAA increases the quantity of waste PEP compounds transported on public roads, and potentially increases risks to the public. Obtaining environmental permits for this facility could delay and possibly prohibit implementation of this option. An implementation date of no earlier than 2023 is provided as an indicator that permitting could require a minimum of a decade from the start date. Due to the combination of permitting and technical challenges, this option is not technically feasible.

2. Transport waste to a commercial disposal facility outside the SLCNAA.

The option to transport waste to commercial disposal facilities outside the non-attainment area was evaluated. Similar to transporting waste to an OBOD facility outside the SLCNAA, this option requires DOT approval to ship waste energetics on public roads. Bulk shipments may not be possible, resulting in manufacturing delays and employee safety concerns. In

addition, commercial facilities in operation do not have capacity to treat all of ATK's energetic waste as it is generated. Therefore, it is likely that waste would be stored for longer periods of time while waiting for shipment. This markedly increases risk to facilities and personnel. Due to capacity limitations at commercial facilities and the limited ability to ship bulk energetic waste on public roads; this option is considered technically infeasible.

3. Develop a treatment process with add-on controls to reduce emissions

Assuming the use of the current treatment technologies, treating energetic wastes using thermal treatment at the Promontory facility with add-on controls would require an overhaul in current manufacturing and handling procedures. Thermal treatment conducted in contained chambers requires the energetic material being treated to be of specific size and composition. In most processes at ATK, PEP is generated heterogeneously ranging from small amounts of PEP contamination to bulk propellant. Normalizing the waste stream would require employee handling to sort material. Furthermore, some materials would need to be reduced into quantities acceptable for treatment. Both would be labor intensive and significantly increase employee exposure compared to bulk open burning.

Due to the composition of energetic compounds produced at ATK, the requirement for air pollution control (APC) devices would be much greater than a typical incinerator or combustion chamber. APC devices would require the capability to treat combustion products generated from combusting metals, oxidizers, polymers and plastics. The heterogenic nature of the material makes it difficult to design controls effective for all pollutants.

Due to the nature of energetic compounds, there is a portion of wastes that could not be combusted in a closed chamber because of the explosive potential, and would require treatment by open burning or open detonation.

There are no known technologies available capable of treating the diversity of waste generated at the facility with sufficient throughput. The technology would need to be developed from operations that most resemble those at ATK. This option may not be technically feasible to treat all wastes generated at the facility.

4. Enhanced waste minimization efforts

A task force charged to minimize the amount of energetic waste generated and to find alternative paths to disposal could reduce the overall amount of waste that needs to be thermally treated. The task force would be required to develop appropriate, alternative technologies for particular waste streams that present low risk to employee safety and facilities. The effort could potential reduce energetic waste open burning by approximately 20%.

Economic Feasibility of Remaining Controls

Table 5 lists remaining control technologies feasible for open burning energetic waste.

TABLE 5. Remaining Control Technologies for Open Burning Energetic Waste

No	Name of Control Technology	Total Capital Cost	Annualized Cost of Control	Annual Pollutant Removal**	Cost/Ton
1	Develop a treatment process with add-on controls to reduce emissions	\$40,000,000	3,000,000*	29.2 tons PM _{2.5} 2.9 tons NO _x	\$93,458
2	Enhanced waste minimization efforts	-	200,000	5.9 tons PM _{2.5} 0.58 tons NO _x	\$30,864

* 20 year lifecycle + 50% O&M per year
 ** Assumes 1,000,000 lbs PEP burned per year

1. Develop a treatment process with add-on controls to reduce emissions

Uncertainty associated with developing these costs includes the potential for facility, manufacturing and process change requirements. These variables present a high level of uncertainty, and could prevent or delay full implementation.

Costs for this option are based on combustion chambers built for other facilities in the country. In general, the facilities have steady, predictable waste streams. An additional 20% was added to the capital cost to account for uncertainty in developing an appropriate process.

Due to uncertainty in developing an effective and reliable process, the overall capital cost and annual cost/ton for pollutant removal is unreasonable. In addition, due to development time and funding cycles, it would be at least five years before the project could be fully implemented.

2. Enhanced Waste minimization

Initiating a waste minimization task force would require an expected annual investment of \$200,000. The cost would cover development initiatives required to remove targeted waste streams from OBOD. However, only 20% of the energetic waste generated would be compatible with alternative processing without introducing increased risk to employee safety and facilities. The nearly \$31,000/ton pollutant removal is unreasonable for the limited benefit.

Option 2: Controls for Testing Energetic Material

Description

There currently are no control technologies for PM_{2.5} emissions or precursors generated during testing of propellants, energetic or pyrotechnics.

Identify Control Technologies for Testing Energetic Material

Table 6 lists possible control technologies compatible with energetic material testing.

TABLE 6. Control Technologies for Testing Energetic Material

No.	Control Technology	Pollutant Controlled
1	Develop a new rocket motor testing site outside the SLCNAA	PM ₁₀ , PM _{2.5} , NO _x , NH ₃ VOC
2	Test rocket motors at an existing facility located outside the SLCNAA	PM ₁₀ , PM _{2.5} , NO _x , NH ₃ VOC
3	Provide add-on controls at the present location for rocket motor testing	PM ₁₀ , PM _{2.5} , NO _x , NH ₃ VOC
4	Provide add-on controls for production testing	PM ₁₀ , PM _{2.5} , NO _x , NH ₃ VOC

1. Develop a new rocket motor testing site outside the SLCNAA.

Moving rocket motor testing to a facility developed by ATK outside the non-attainment area was evaluated. Costs for the hypothetical facility were based on purchasing 1280 acres in a remote area of Box Elder County. Site requirements include access roads, security, electrical power, water service and buildings. Site development would also be subject to completing New Source Review, Approval Order and possibly Title V Operating Permit requirements.

The ATK Promontory facility has a long history of static testing large rocket motors for both the National Aeronautics and Space Administration (NASA) and the DOD. The existing location has unique large motor testing capabilities that are not available at other locations in the United States. The site is a national asset, and plays a vital role in developing and testing launch vehicles for both space exploration and national defense

2. Test rocket motors at an existing facility located outside the SLCNAA.

There are no existing facilities with the required capabilities to test large motors (100,000 to 1,400,000 lbs propellant) outside the SLCNAA. Therefore, a facility would need to be designed and constructed to meet testing requirements for large motors. In addition, there are limited facilities in the nation that can test medium size motors (10,000 to 100,000 lbs propellant). In most cases, those facilities are government owned and at capacity to fulfill the operating agency's needs. Other existing facilities are privately owned by competing manufacturers. The ATK test facility is an asset to provide testing for government customers as well as protect intellectual property.

3. Provide add-on controls at the present location for rocket motor testing.

No add-on controls exist for rocket motor sizes tested at the ATK facility.

4. Production testing with add-on controls

There are no readily available, proven add-on controls for capturing emissions from small-scale production testing

Technical Feasibility

1. Develop a new rocket motor testing site outside the SLCNAA.

To offer the same capacity as the current test facility, a new facility would need to have three rocket motor test stands and four production test facilities constructed. The implementation schedule to build the new test facility would be impractical. In addition, obtaining environmental permits for this facility could delay and possibly prohibit implementation altogether. An estimated implementation date of no earlier than 2027 is likely. Due to the combination of permitting and technical challenges, this option is technically infeasible.

2. Test rocket motors at an existing facility located outside the SLCNAA.

The existing location has been developed by NASA and the DOD, and has unique test capabilities for large motors that are not available at other locations in the United States. The site is a national asset, and plays a vital role developing heavy lift vehicles for both space exploration and national defense. There are no existing facilities with the required capabilities to test large motors outside the SLCNAA. The lack of existing facilities that can provide the same functionality as the current facility makes this option technically infeasible.

3. Prove add-on controls at the present location for rocket motor testing.

There are no existing add-on controls for rocket motor testing. An EPA study used to develop the *National Emission Standards for Hazardous Air Pollutants: Test Cells/Stands* concluded there is no viable emission control device for rocket motor tests. Refer to the Federal Register/Vol.67, No. 93/Tuesday, May 14, 2002/ Proposed Rules; page 34557.

“A number of characteristics of the exhaust from rocket engine testing (extremely high temperatures, extremely high volumetric flow rates, and very short test durations) and the infrequent timing of testing raise a number of unique problems that must be resolved for an emission control device to be considered a viable option for reducing HAP emissions from test cells/stands used for testing rocket engines. Consequently, we could identify no candidate MACT technologies for analysis. Without a viable emission control device, we are unable to estimate the potential costs associated with it use. Similarly, we are unable to estimate the potential reduction in HAP emissions which might result from the use of such a device.

Thus, we concluded that MACT for existing sources is the MACT floor. Consequently, MACT for existing test cells/stands used for testing rocket engines is no reduction in HAP emissions.”

Since the NESHAP evaluation in 2002, the status of add-on controls for test facilities for rocket motor testing has not changed. Therefore, this option is technically infeasible.

4. Production testing with add-on controls

Although production testing is typically done with small PEP quantities compared to full-scale tests, the testing is conducted in specific facilities with unimpeded ventilation.

Introducing add-on controls to the ventilation system introduces risks to the facility and personnel due to the exhaust rate needed to prevent back-pressure. This risk makes the option technically infeasible.

Economic Feasibility of Remaining Controls

No controls have been found that are technically feasible.

Option 3: Controls for Process Dust Collection

Description

Currently, most process dust emissions are collected by fabric filter. In some cases, wet scrubbers are used to alleviate the risk of fire when strong oxidizing materials are involved. Two infrequently used cutting processes are controlled by single or tandem cyclones.

Identify Control Technologies for Process Dust Collection

Table 7 lists possible control technologies compatible with process dust collection.

TABLE 7. Control Technologies for Process Dust Collection

No.	Control Technology	Pollutant Controlled
1	Enhanced Fabric Filter	PM ₁₀ , PM _{2.5}
2	Wet Scrubber	PM ₁₀ , PM _{2.5}
3	Cyclone	PM ₁₀ , PM _{2.5}

1. Enhanced Fabric Filter

Most process dust collection is performed with standard 80/20 cellulose, polyester blend filters. This type of filter has an approximately 70% efficiency on particulate in the 1-3 micron range. Enhanced fabric filters typically include an additional membrane layer to increase filtration efficiency for fine particulate. Nanofiber membranes or PTFE membranes can increase efficiency to 90-95%.

2. Wet Scrubber

Wet scrubbers are used where strong oxidizing chemicals are processed. Wet scrubbers reduce the flammability risk compared to fabric filtration. Wet scrubbers used in these processes are approximately 90% efficient in removing fine particulate.

3. Cyclones

Stand-alone cyclones (not combined with fabric filter) are used in two operations. In both cases the process generates shavings that are effectively removed by the cyclone.

Technical Feasibility

1. Enhanced Fabric Filter

A fabric filter with an enhanced membrane layer should be feasible in operations where dust loading is not a concern. The enhanced fabric filter will be evaluated for dust collectors with the highest estimated PM_{2.5} emissions.

2. Wet Scrubber

Wet scrubbers are only implemented in areas where fabric filtration is not suitable. Otherwise, wet scrubbers are not considered a best available control for normal process dust.

3. Cyclones

Cyclones are not a best available control for most dust collection processes at the facility

Economic Feasibility of Remaining Controls

1. Enhanced Fabric Filter

Enhanced fabric filtration is a technically feasible control that could potentially remove more PM_{2.5} in processes where loading is not a limitation. An economic analysis was conducted to evaluate cost for using the control on dust collection systems that are responsible for most of the facility's direct PM_{2.5} emissions. Results are shown in Table 7a. Calculations are shown in the Appendix.

	Emission Reduction Cost per Ton				
Pollutant	PM _{2.5}	SO _x	NO _x	NH ₃	VOC
Quantity (tons)	0.6	N/A	N/A	N/A	N/A
Cost per ton	\$4,800	N/A	N/A	N/A	N/A

The analysis is based on replacing 24 filter bags in each of four dust collectors used to control carbon fiber dust (M005-DC-01, M005-DC-02, M113-DC-01, and M113-DC-02). Annual emissions were estimated from PM₁₀ values recorded in the 2014 air emission inventory. The replacement filter bags include a nanofiber membrane that would increase PM_{2.5} filtration efficiency by approximately 25% (based on minimum efficiency rating value). The increased filtration efficiency would reduce direct PM_{2.5} emissions by a total of 0.6 tons/year from the four dust collectors. The cost to install upgraded filters would be an estimated \$3,120/dust collector. Fabric filters with a nanofiber membrane typically cost 30% more than standard filters. The total increase in cost to replace the filters annually is \$2,880. The control is economically feasible as long as dust loading does not require more frequent filter changes.

Option 4: Natural Gas and Fuel Oil Combustion

Description

PM_{2.5} is produced during incomplete combustion of natural gas and fuel oil. Emissions are greatly reduced when equipment is properly maintained to maximize combustion efficiency.

Identify Control Technologies for Natural Gas and Fuel Oil Combustion

Table 8 lists possible control technologies available for natural gas and fuel oil combustion.

TABLE 8. Control Technologies for Natural Gas and Fuel Oil Combustion

No.	Control Technology	Pollutant Controlled
1	Work Practice Standards	PM _{2.5}
2	Run-time limitations on RIC engines	PM _{2.5} , NO _x , SO _x

1. Work Practice Standards for boilers and generators

40 CFR, Part 63, Subpart DDDDD, or Boiler MACT, requires a tune-up and inspection schedule for natural gas and fuel oil boilers to minimize poor combustion. The scheduled frequency is based on boiler heat input rating, with larger boilers checked more frequently.

The Reciprocating and Internal Combustion Engine (RICE) rule requires maintenance and fuel checks on emergency backup generators and limits the number of hours generators can be used for non-emergency purposes. The combined effect of the rule is to reduce emissions through limits on fuel combustion and minimizing poor combustion.

2. Run-time limitations on RIC Engines

Reciprocal and internal combustion engines are limited by Subpart ZZZZ and Subpart IIII to 100 hours/year for maintenance. In addition, all emergency backup generators at the facility are limited to a yearly fuel limit.

Technically Feasibility

1. Work Practice Standards for boilers and generators

Technically feasible and supports preventative maintenance and energy conservation plans

2. Run-time limitations on RIC Engines

Program is in place and is technically feasible

Economic Feasibility of Remaining Controls

1. Work Practice Standards for boilers and generators

Adherence to work practice standards is an effective and technically feasible control for fine particulate emissions. An economic analysis was conducted to determine the cost of the control for each ton of fine particulate removed. Results are shown in Table 8a. Calculations are shown in the Appendix.

TABLE 8a.

Pollutant	Emission Reduction Cost per Ton				
	PM _{2.5}	SO _x	NO _x	NH ₃	VOC
Quantity (tons)	0.30	0.03	3.92	N/A	0.21
Cost per ton	ND	ND	\$7,143	N/A	ND

Reduction estimated from difference between 80% and 70% combustion efficiency
ND, not determined because economically feasible for other pollutants

The estimated emission reduction is based on the removal of pollutants by increasing boiler combustion efficiency by 10%. Greater combustion efficiency is achieved when boilers are properly tuned. Annual tuning for all boilers cost an average of \$3,000 per year. Pollutant reduction for generators is generally less due to reduce run time, but proper maintenance and fuel quality contributes an average 15% additional pollutant removal. The annual cost to sample and analyze generator fuel is estimated at \$3,600. Routine generator maintenance is estimated at \$21,000/year to perform quarterly preventative maintenance checks. The work practice standards provide a modest reduction in PM_{2.5} and precursor emissions.

2. Run-time limitations on RIC Engines

No additional cost

BACT Evaluation SO₂ Emissions

Option 1: Ultra Low Sulfur Fuel in Boilers

Description

There are 17 fuel oil boilers at the site. All 17 boilers are smaller than 10 MMBTU/HR capacity, and were installed between 1960 and 2000. The boilers are located in remote areas where natural gas is not available. Ultra-low sulfur fuel is the only fuel oil used in the boilers.

Identify Control Technologies for SO_x Emissions from Boilers

Table 9 lists possible control technologies available for SO_x Emissions from Boilers.

TABLE 9. Control Technologies for Natural Gas and Fuel Oil Combustion

No.	Control Technology	Pollutant Controlled
1	Ultra-low Sulfur Fuel	SO _x

1. Ultra-low Sulfur Fuel in Boilers

Ultra-low sulfur fuels are limited to 15 ppm sulfur content by weight. NSPS boilers are limited to a sulfur content of 0.5% by weight. As a result of using ultra-low sulfur fuel, SO_x emissions are reduced by over 97%.

Technical Feasibility

1. Ultra-low Sulfur Fuel in Boilers

The only fuel oil being delivered to the facility is ultra-low sulfur fuel. The option is technically feasible.

Economic Feasibility of Remaining Controls

1. Ultra-low Sulfur Fuel in Boilers

The only fuel oil being delivered to the facility is ultra-low sulfur fuel. The option is economically feasible.

Option 2: Ultra-Low Sulfur Fuel in Engines, Mobile Sources and Fugitive Sources.

Description

The site contains a variety of engines, mobile sources and fugitive sources. The largest category of stationary engines is emergency generators which are operated for routine maintenance or

during power outages only. Each emergency generator is typically operated less than 100 hours per year. Refer to Table 3 for a complete list. The last category on Table 3 is miscellaneous use of fuel oil for testing such as when it is used as part of a DOT classification test. All uses combined accounted for 1.06 tons of sulfur dioxide emissions in 2008.

Identify Control Technologies for SO_x Emissions from Engines, Mobile and Fugitive Sources

Table 10 lists possible control technologies available for natural gas and fuel oil combustion.

TABLE 10. Control Technologies for Natural Gas and Fuel Oil Combustion

No.	Control Technology	Pollutant Controlled
1	Ultra-low Sulfur Fuel	SO _x

1. Ultra-low Sulfur Fuel in Engines, Mobile and Fugitive Sources

Ultra-low sulfur fuel has 97% lower sulfur content than low sulfur diesel used in non-road engines. Ultra-low sulfur fuels are required to be used by the RICE standard. In addition, ultra-low sulfur fuel is required to be used in tractors, construction equipment, etc. operated on the plant. Finally ultra-low sulfur diesel is the only approved diesel that can be used during test operations.

Technical Feasibility

1. Ultra-low Sulfur Fuel in Engines, Mobile and Fugitive Sources

The only fuel oil being delivered to the facility is ultra-low sulfur fuel. The option is technically feasible.

Economic Feasibility of Remaining Controls

1. Ultra-low Sulfur Fuel in Engines, Mobile and Fugitive Sources

The only fuel oil being delivered to the facility is ultra-low sulfur fuel. The option is economically feasible.

BACT Evaluation NO_x Emissions

Option 1: Upgrade Largest Boilers with NO_x Controls

Description

The facility currently operates thirty eight (38) boilers at various locations on the 20,000 acre facility. Twenty one (21) boilers are located in the South Area and operate on natural gas. Seventeen (17) boilers, located in remote locations where natural gas is not available, burn fuel oil. The four largest natural gas boilers were evaluated. One of the boilers is 71 MMBTU/hr input heat rating and is already controlled to a 9 ppm NO_x emission rate that meets BACT. A second 71 MMBTU/hr boiler is used in a backup capacity and is restricted to a 100,000 MCF rolling 12 month natural gas limit. Two other boilers are 25 MMBTU/hr and are uncontrolled for NO_x. The cost estimates reported in this submission are preliminary, and are based on previous boiler upgrades. An engineering evaluation will be required for an accurate estimate.

Identify Control Technologies for NO_x Emissions from Largest Boilers

Table 11 lists possible control technologies available for natural gas and fuel oil combustion.

TABLE 11. Control Technologies for NO_x Emissions from Largest Boilers

No.	Control Technology-Combustion Control	Pollutant Controlled
1	Replace burner with low NO _x burner and Flue Gas Recirculation to achieve 9 ppm emission rate	NO _x
2	Selective non-catalytic reduction	NO _x
3	Selective catalytic reduction	NO _x

1. Low NO_x burner and Flue Gas Recirculation

This control technology is the most commonly used for boiler less than 100 MMBTU/hr heat input rating. It utilizes a specially designed burner that lowers combustion temperature to minimize NO_x formation during combustion. In addition, a portion of flue gas is comingled with combustion air to reduce temperature and oxygen content.

2. Selective non-catalytic reduction (SNCR)

This control technology involves the injection of a NO_x reducing agent, such as ammonia or urea, in the boiler exhaust gases at a temperature of approximately 1400-1600 °F. The ammonia or urea breaks down the NO_x in the exhaust gases into water and atmospheric nitrogen. Selective non-catalytic reduction technology is extremely difficult to apply to industrial boilers that modulate frequently. This is because the ammonia (or urea) must be injected in the flue gases at a specific flue gas temperature. In industrial boilers that modulate frequently, the location of the exhaust gases at the specified temperature is constantly changing. Thus, it is not technically feasible to apply selective non-catalytic reduction to industrial boilers that have high turndown capabilities and modulate frequently.

3. Selective catalytic reduction (SCR)

This control technology involves the injection of ammonia into the boiler exhaust gases with the presence of a catalyst. The catalyst allows the ammonia to reduce NO_x levels at lower exhaust temperatures than selective non-catalytic reduction. For this technology the exhaust gases can be between 500°-1200 °F. Based on literature from the boiler manufacturer, this technology is typically not used for boilers with inputs less than 100 MMBTU/hr (Cleaver Brooks Boiler Emission Guide, November 2010, page 12). All boilers are below the 100 MMBTU/hr input rating.

Technical Feasibility

1. Low NOx burner and Flue Gas Recirculation

Upgrading the boiler with a low NOx burner and flue gas recirculation are technically feasible. The achievable NOx emission rate is expected to be 9 ppm.

2. Selective non-catalytic reduction (SNCR)

This control technology involves the injection of a NO_x reducing agent, such as ammonia or urea, in the boiler exhaust gases at a temperature of approximately 1400-1600 °F. The ammonia or urea breaks down the NO_x in the exhaust gases into water and atmospheric nitrogen. Selective non-catalytic reduction technology is extremely difficult to apply to industrial boilers that modulate frequently. This is because the ammonia (or urea) must be injected in the flue gases at a specific flue gas temperature. In industrial boilers that modulate frequently, the location of the exhaust gases at the specified temperature is constantly changing. Thus, it is not technically feasible to apply selective non-catalytic reduction to industrial boilers that have high turndown capabilities and modulate frequently.

3. Selective catalytic reduction (SCR)

This control technology involves the injection of ammonia into the boiler exhaust gases with the presence of a catalyst. The catalyst allows the ammonia to reduce NO_x levels at lower exhaust temperatures than selective non-catalytic reduction. For this technology the exhaust gases can be between 500°-1200 °F. Based on literature from the boiler manufacturer, this technology is typically not used for boilers with inputs less than 100 MMBTU/hr (Cleaver Brooks Boiler Emission Guide, November 2010, page 12). All boilers are below the 100 MMBTU/hr input rating.

Economic Feasibility of Remaining Controls

1. Replace burner with low NOx burner and Flue Gas Recirculation

All costs are based on a preliminary data, and additional time will be required to accurately evaluate costs and implementation dates. Estimate includes annual costs for equipment depreciation and maintenance. Depreciation is based on a 20-year period. Annual Maintenance costs are based on 1% of the initial purchase price. Operating and energy costs are not included.

TABLE 11a. Cost for Natural Gas Burner Upgrades

No	Name of Control Technology	Total Capital Cost	Annualized Cost (20 years)	Amount & Type of Pollutant controlled	Cost/Ton
1	Replace 71 MMBTU/hr boiler burner with low NOx burner and Flue Gas Recirculation to achieve 9 ppm emission rate	\$900,000	\$45,000	3 tons NO _x	\$15,151
2	Replace both 25 MMBTU/hr boiler burners with low NOx burner and Flue Gas Recirculation to achieve 9 ppm emission rate	\$800,000	\$20,000	4.3 tons NO _x	\$9,346

1. Replace 71 MMBTU/hr boiler burner with low NOx burner and Flue Gas Recirculation

Upgrading the second 71 MMBTU/hr boiler would cost an estimated \$900,000 capital cost to implement and only result in a NOx reduction of 3 tons per year based on actual fuel use. A 20 year depreciation rate was used to calculate the cost per ton reduction. The \$15,151 cost per ton is unreasonable for the limited NOx reduction and the required capital cost.

2. Replace both 25 MMBTU/hr boiler burners with low NOx burner and Flue Gas Recirculation

Upgrading both 25 MMBTU/hr boilers would cost an estimated \$400,000 capital cost per boiler. A 20-year depreciation rate was used to calculate the cost per ton reduction. The \$9,300 cost per ton is unreasonable for the limited NOx reduction and the required initial capital cost.

BACT Evaluation VOC Emissions

Option 1: Control VOC from Paints and Solvents

Description

VOC emissions are controlled at the facility through VOC content limits and work practice standards. Most VOC emissions are fugitive emissions evolved from hand wiping during tooling and hardware preparation. As such, point source control is limited.

Identify Control Technologies for VOC Emissions from Paint and Solvent Sources

Table 12 lists possible control technologies available for natural gas and fuel oil combustion.

TABLE 12. Control Technologies for VOC Emissions from Paint and Solvents

No.	Control Technology	Pollutant Controlled
1	Low VOC Paints and Solvents	VOC
2	Work Practice Standards	VOC

1. Low VOC Paints and Solvents

Products manufactured at the facility are subject to strict specifications from NASA and Department of Defense requirements. Therefore, VOC content in paints and solvents used to produce products for those agencies are exempt in federal standards. VOC in paints and solvents used in other operations are regulated by state rules at the manufacturer level. Therefore, most non-exempt paints and solvents used at the facility are delivered as low-VOC content.

2. Work Practice Standards

Work practice standards are the most effective to control fugitive VOC emissions. Standards require containers to be closed unless adding or removing a VOC containing material. This effectively limits the amount of evaporation that can occur.

Technical Feasibility

1. Low VOC Paints and Solvents

Using low VOC paints and solvents is technically feasible for non-exempt processes that occur at the facility.

2. Work Practice Standards

Work practice standards for controlling fugitive VOC emissions are already implemented at the facility and are an effective control

Economic Feasibility of Remaining Controls

1. Low VOC Paints and Solvents

Already implemented at the facility, no additional cost expected.

2. Work Practice Standards

Already implemented at the facility, no additional cost expected.

Results of Analysis

The following was determined to represent BACT for this source.

BACT Results for PM_{2.5} Emissions

Option 1: Controls for Open Burning Energetic Waste

There are no available, feasible controls for open burning energetic waste at the Promontory site. Therefore, the current operation meets BACT for PM_{2.5} emissions from open burning.

Option 2: Controls for Testing Energetic Material

There are no available, feasible controls for testing energetic material at the Promontory site. Therefore, the current operation meets BACT for PM_{2.5} emissions from energetic material testing.

Option 3: Controls for Process Dust Collection

Four dust collectors (two in building M5 and two in M113) with the highest 2014 PM_{2.5} emissions were evaluated to determine if enhanced fabric filters would reduce fine particulate emissions. Upgrading all four collectors to fabric filters with a nanofiber membrane could capture an additional 25% of fine particulate. The result is a 0.6 ton reduction based on 2014 air emission inventory values. The estimated cost is \$6,240 per ton to achieve the additional removal. However, cost could increase markedly if particulate loading results in more frequent filter changes to keep the process operating. The uncertainty and relatively small additional removal over current controls fail to distinguish this option as BACT. Therefore, the current operation meets BACT for PM_{2.5} emissions from process dust collection.

Option 4: Natural Gas and Fuel Oil Combustion

Work practice standards for boilers and run-time limitations for reciprocal and internal combustion engines are existing controls implemented to minimize fine particulate from the respective equipment. The controls come from federal standards designed to minimize hazardous air pollutants. Each is effective in maintaining good combustion practices when burning natural gas and fuel oil. Therefore, the existing controls meet BACT for PM_{2.5} emissions from natural gas and fuel oil combustion.

BACT Evaluation SO₂ Emissions

Option 1: Ultra-Low Sulfur Fuel in Boilers

Ultra-low sulfur is the only fuel delivered to the facility. This option already meets BACT to control SO_x emissions from boiler combustion.

Option 2: Ultra Low Sulfur Fuel in Engines, Mobile Sources and Fugitive Sources

Ultra-low sulfur is the only fuel delivered to the facility. This option already meets BACT to control SO_x emissions from generator engines, mobile sources and other combustion sources.

BACT Evaluation NO_x Emissions

Option 1: Upgrade Largest Boilers with NO_x Controls

Nearly two million dollars in capital cost would be required to remove approximately six tons of NO_x from natural gas boilers between 25 MMBTU/hr and 71 MMBTU/hr input. The cost is unreasonable for minimum gain and since the 71 MMBTU/hr boiler operates in a backup capacity. The existing equipment meets BACT for NO_x emissions from the largest natural gas boilers.

BACT Evaluation VOC Emissions

Option 1: Control VOC from Paints and Solvents

Most VOC emissions at the facility are fugitive emissions generated from a variety of manufacturing operations. The most effective control for these fugitive emissions are keeping chemical containers closed and properly managing waste. In addition, VOC content limits in products used at the facility limit emissions directly from the source. The combination of low-VOC content and work practice standards effectively minimize VOC emissions from manufacturing operations where point source control is limited. Therefore, this option is BACT to control VOC emissions.

Appendix I: Calculations

Table 5. Remaining Control Technologies for Open Burning Energetic Waste

Option 1: Develop a treatment process with add-on controls

Assumes add-on controls are 99% efficient in removing pollutants

$$29.5 \frac{\text{tons PM}_{2.5}}{\text{year}} - 0.3 \frac{\text{tons PM}_{2.5}}{\text{year}} = 29.2 \frac{\text{tons PM}_{2.5}}{\text{year}} \text{ reduced}$$

$$2.9 \frac{\text{tons NO}_x}{\text{year}} - 0.03 \frac{\text{tons NO}_x}{\text{year}} = 2.87 \frac{\text{tons NO}_x}{\text{year}} \text{ reduced}$$

Total PM_{2.5} and precursor reduced = 32.1 tons

Estimated capital cost of equipment based on Camp Minden burn unit designed for M6 propellant with ten percent uncertainty cost added.

\$40,000,000

Assuming equipment is in operation for 20 years and operation and maintenance cost are 50% of the yearly depreciation, the annualize cost is:

$$\$40,000,000 \div 20 \text{ years} = \frac{\$2,000,000}{\text{year}} \times 1.50 = \$3,000,000$$

Therefore...

$$\frac{\$3,000,000}{32.1 \text{ tons PM}_{2.5} \text{ and precursor reduced}} = \mathbf{\$93,458/\text{ton PM}_{2.5} \text{ and precursor reduced}}$$

Option 2: Enhanced waste minimization efforts

$$29.5 \frac{\text{tons PM}_{2.5}}{\text{year}} \times 0.20 = 5.9 \frac{\text{tons PM}_{2.5}}{\text{year}} \text{ reduced}$$

$$2.9 \frac{\text{tons NO}_x}{\text{year}} \times 0.20 = 0.58 \frac{\text{tons NO}_x}{\text{year}} \text{ reduced}$$

Estimated annual cost to run the waste reduction effort is \$200,000/year

Therefore...

$$\frac{\$200,000}{6.48 \text{ tons PM}_{2.5} \text{ and precursors reduced}} = \mathbf{\$30,864/ \text{ ton NO}_x \text{ reduced}}$$

Table 7a. Enhanced Fabric Filter for Process Dust Collection

PM_{2.5} Emissions from carbon fiber machining at M5 and M113 are controlled by four dust collectors, two in each building. The total PM_{2.5} emissions estimated from the 2014 AEI are 2.4 tons. Upgrading to a fabric fiber filter with a nanofiber membrane could potentially increase filtration efficiency by 25% for PM_{2.5} particles.

$$2.4 \frac{\text{tons PM}_{2.5}}{\text{year}} \times 0.25 = 0.6 \frac{\text{tons PM}_{2.5}}{\text{year}} \text{ reduced}$$

Assuming filters are changed once per year for each collector

$$24 \frac{\text{filters}}{\text{collector}} \times 4 \text{ collectors} = 96 \text{ filters}$$

Cost for upgraded filter is estimated at \$130.00/filter

$$96 \text{ filters} \times \frac{\$130.00}{\text{filter}} = \$12,480$$

Cost for the standard filter is estimated at \$100.00/filter

$$96 \text{ filters} \times \frac{\$100.00}{\text{filter}} = \$9,600$$

Cost to upgrade to the enhanced filter is:

$$\$12,480 - \$9,600 = \$2,880$$

Therefore...

$$\frac{\$2,880}{0.6 \text{ tons PM}_{2.5} \text{ reduced}} = \mathbf{\$4,800/ \text{ ton PM}_{2.5} \text{ reduced}}$$

Table 8a. Work Practice Standards for boilers and generators

Pollutant reduction values are based on a 10% reduction in emissions due to increased combustion efficiency. Emissions data comes from boiler and generator emissions provided in 2014 AEI. Cost per ton was based on the pollutant with the most reduction.

3.92 $\frac{\text{tons NOx}}{\text{year}}$ reduced

Estimated cost to tune boilers annually is \$3,000

Estimated annual fuel testing cost for generators is \$4,000

Estimated annual routine maintenance for generators is \$21,000

Therefore...

$$\frac{\$28,000}{3.92 \text{ tons NOx reduced}} = \$7,143/ \text{ton NOx reduced}$$

Table 11a. Replace burner with low NOx burner and Flue Gas Recirculation

M576 Backup Boiler (71 MMBTU/hr, 100,000 MCF natural gas limit, 70,000 MCF actual use):

NOx Emissions from Uncontrolled Burner (based on NG limit)

$$\text{NOx: } \frac{85 \text{ ppm NOx}}{850\ddagger} = 0.1 \frac{\text{lbs NOx}}{\text{MMBTU}} \quad \ddagger \text{ Factor from Clever Brooks Boiler Emission Guide, Appendix E, pg 34.}$$

$$0.1 \frac{\text{lbs NOx}}{\text{MMBTU}} * 0.001 \frac{\text{MMBTU}}{\text{scf}} = 0.0001 \frac{\text{lbs NOx}}{\text{scf}}$$

$$0.0001 \frac{\text{lbs NOx}}{\text{scf}} * 70,000,000 \frac{\text{scf}}{\text{year}} = 7,000 \frac{\text{lbs NOx}}{\text{year}} * \frac{1 \text{ ton}}{2000 \text{ lbs}} = 3.5 \frac{\text{tons NOx}}{\text{year}}$$

NOx Emissions from 9 ppm Rated Burner

$$\text{NOx: } \frac{9 \text{ ppm NOx}}{850\ddagger} = 0.0106 \frac{\text{lbs NOx}}{\text{MMBTU}} \quad \ddagger \text{ Factor from Clever Brooks Boiler Emission Guide, Appendix E, pg 34.}$$

$$0.0106 \frac{\text{lbs NOx}}{\text{MMBTU}} * 0.001 \frac{\text{MMBTU}}{\text{scf}} = 0.0000106 \frac{\text{lbs NOx}}{\text{scf}}$$

$$0.0000106 \frac{\text{lbs NOx}}{\text{scf}} * 100,000,000 \frac{\text{scf}}{\text{year}} = 1,060 \frac{\text{lbs NOx}}{\text{year}} * \frac{1 \text{ ton}}{2000 \text{ lbs}} = 0.53 \frac{\text{tons NOx}}{\text{year}}$$

$$3.5 \frac{\text{tons NOx}}{\text{year}} - 0.53 \frac{\text{tons NOx}}{\text{year}} = 2.97 \text{ tons NOx reduced}$$

Annualized capital cost over 20 years:

$$\frac{\$900,000}{20 \text{ years}} = \$45,000/\text{year}$$

Therefore...

$$\frac{\$45,000}{2.97 \text{ tons NOx reduced}} = \$15,151/\text{ton NOx reduced}$$

M14 Boilers (fuel use from 2014 Air Emission Inventory). Calculation is result for one boiler:

NOx Emissions from Uncontrolled Burner

$$\text{NOx: } \frac{85 \text{ ppm NOx}}{850\ddagger} = 0.1 \frac{\text{lbs NOx}}{\text{MMBTU}}$$

† Factor from Clever Brooks Boiler Emission Guide, Appendix E, pg 34.

$$0.1 \frac{\text{lbs NOx}}{\text{MMBTU}} * 0.001 \frac{\text{MMBTU}}{\text{scf}} = 0.0001 \frac{\text{lbs NOx}}{\text{scf}}$$

$$0.0001 \frac{\text{lbs NOx}}{\text{scf}} * 48,250,000 \frac{\text{scf}}{\text{year}} = 4,825 \frac{\text{lbs NOx}}{\text{year}} * \frac{1 \text{ ton}}{2000 \text{ lbs}} = 2.4 \frac{\text{tons NOx}}{\text{year}}$$

NOx Emissions from 9 ppm Rated Burner

$$\text{NOx: } \frac{9 \text{ ppm NOx}}{850\ddagger} = 0.0106 \frac{\text{lbs NOx}}{\text{MMBTU}}$$

† Factor from Clever Brooks Boiler Emission Guide, Appendix E, pg 34.

$$0.0106 \frac{\text{lbs NOx}}{\text{MMBTU}} * 0.001 \frac{\text{MMBTU}}{\text{scf}} = 0.0000106 \frac{\text{lbs NOx}}{\text{scf}}$$

$$0.0000106 \frac{\text{lbs NOx}}{\text{scf}} * 48,250,000 \frac{\text{scf}}{\text{year}} = 511.45 \frac{\text{lbs NOx}}{\text{year}} * \frac{1 \text{ ton}}{2000 \text{ lbs}} = 0.26 \frac{\text{tons NOx}}{\text{year}}$$

$$2.4 \frac{\text{tons NOx}}{\text{year}} - 0.26 \frac{\text{tons NOx}}{\text{year}} = \mathbf{2.14 \text{ tons NOx reduced}}$$

Annualized capital cost over 20 years for one boiler:

$$\frac{\$400,000}{20 \text{ years}} = \mathbf{\$20,000/\text{year}}$$

Therefore...

$$\frac{\$20,000}{2.14 \text{ tons NOx reduced}} = \mathbf{\$9,346/ \text{ton NOx reduced}}$$