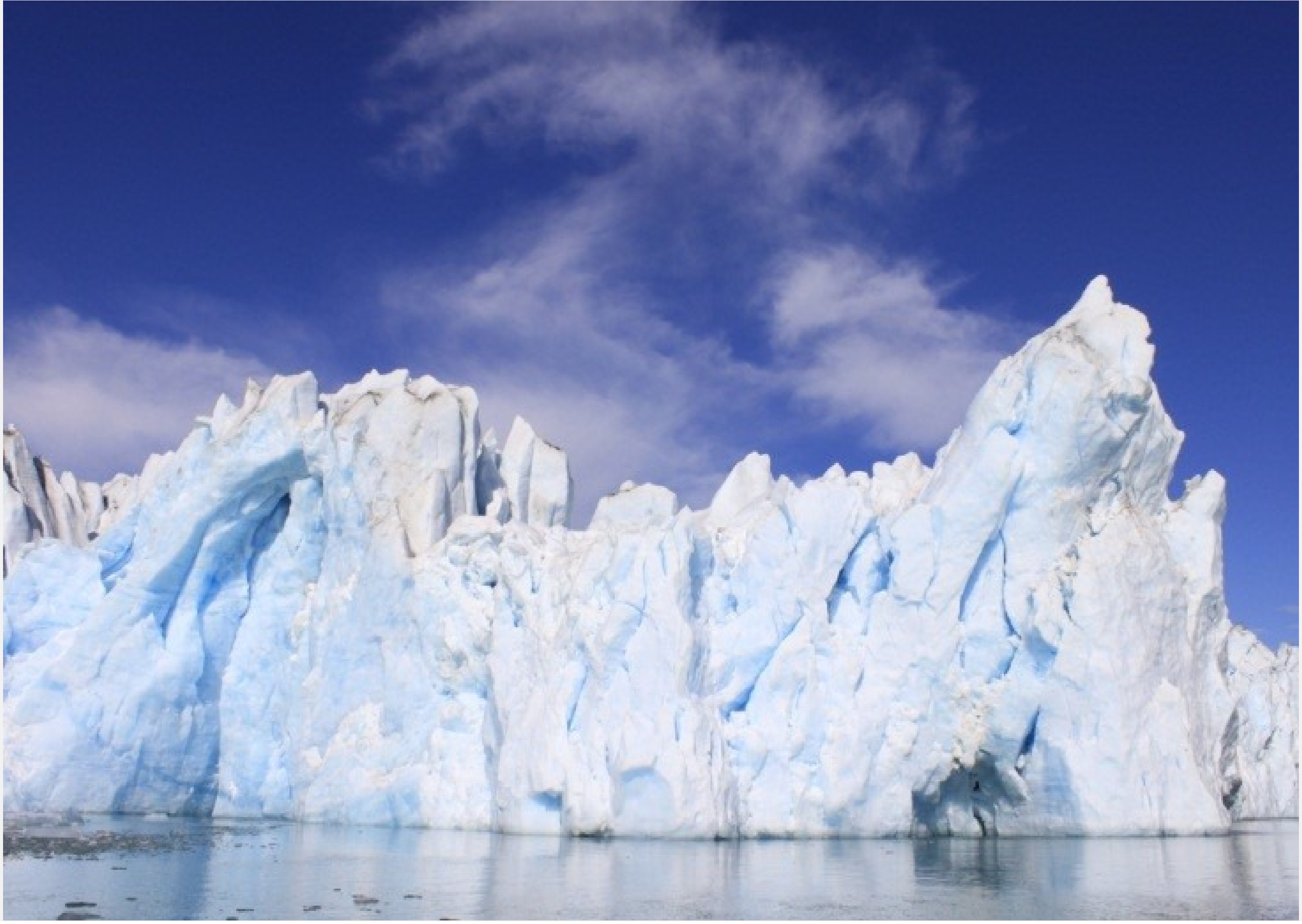

BACT Analysis

Agrium Kenai, Alaska

Kenai Nitrogen Operation

5 August 2019

Project No.: 0497868

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BACT Analysis

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1. BEST AVAILABLE CONTROL TECHNOLOGY (BACT) BACKGROUND

1.1 Introduction

Agrium U.S. Inc. (Agrium) was issued Air Quality Control Construction Permit AQ0083CPT06 on 6 January 2015 for the proposed restart of a portion of it fertilizer production facility (Facility) at the Kenai Nitrogen Operation in Kenai, Alaska. In a letter dated 4 March 2016, the Alaska Department of Environmental Conservation (ADEC) extended the deadline by which construction must commence by eighteen (18) months until 6 January 2018. In a second letter dated 3 October 2017, the ADEC extended the deadline by which construction must commence by an additional eighteen (18) months until 6 July 2019.

Since the issuance of the ADEC letter dated 3 October 2017, Agrium has decided to replace the five (5) existing 37.6 MMBtu/hr Solar Turbines identified as Units 55, 56, 57, 58, and 59. The replacement Solar Turbines will each have a maximum rated heat input capacity of 55.443 MMBtu/hr. The new Solar Turbines will utilize the existing Waste Heat Boilers (Units 50, 51, 52, 53, and 54) for heat recovery. Due to the increase in heat input capacities of the new Solar Turbines, the required supplemental heat input capacity of the 50.0 MMBtu/hr Waste Heat Boilers have decreased. The Waste Heat Boilers once integrated with the new Solar Turbines, will now only have heat input capacities of 46.729 MMBtu/hr, each. Since the heat input capacities of the Waste Heat Boilers are changing, as are the potential emissions, Agrium is providing updated top-down BACT analyses for these affected units, in addition to the top-down BACT analyses for the new Solar Turbines.

In addition, Agrium is proposing to install Selective Catalytic Reduction (SCR) for NOx control on the Package Boilers (Units 44, 48, and 49). These emission units went through PSD BACT as part of the permitting for AQ0083CPT06. Under the Air Quality Control Construction Permit, BACT for NOx was identified as use of ultra low NOx burners. SCR is considered to provide the same, if not a higher, control efficiency than the use of ultra low NOx burners.

This document is presented as Attachment C to the 2019 Prevention of Significant Deterioration (PSD) permit application for the Facility and presents the Best Available Control Technology (BACT) review for the affected units at the Facility. It also contains an evaluation of BACT for the unaffected units originally permitted in the PSD Construction Permit. In addition, this document includes information contained in appendices as follows:

- Appendix A RBLC Search Summary – This appendix includes the search results of the USEPA RACT/BACT/LAER Clearinghouse (RBLC) database to identify the permit limits on similar sources in the United States. The table also includes permit limit information for recently issued permits that are not in the RBLC.
- Appendix B Cost Estimates – This appendix includes information on the cost estimates for various air pollution control equipment.

This document incorporates by reference additional information contained in the original application that has not changed from the original application, including process descriptions.

1.2 Regulatory Basis for BACT Analysis

Section 163(3) of the Clean Air Act (CAA) defines Best Available Control Technology (BACT) as:

> *"An emission limitation based on the maximum degree of reduction of each pollutant subject to regulation under [the CAA] emitted from or which results from any major emitting facility, which the permitting authority, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such facility through application of production processes and available methods, systems, and techniques, including fuel cleaning, clean fuels, or treatment or innovative fuel combustion techniques for control of each such pollutant."*

Based on projected potential emission rates, BACT is required for the following criteria pollutants:

- Nitrogen Oxides (NO_X)
- Carbon Monoxide (CO)
- Volatile Organic Compounds (VOC)
- Particulate Matter (PM)
- Particulate Matter ≤ 10 microns in aerodynamic diameter (PM_{10})
- Particulate Matter ≤ 2.5 microns in aerodynamic diameter ($PM_{2.5}$)

In addition, the proposed project is subject to a BACT review for the greenhouse gas (GHG) pollutants under EPA's Tailoring Rule. The regulated GHGs include the following:

- Carbon Dioxide (CO_2)
- Methane (CH_4)
- Nitrous Oxide (N_2O)
- Carbon Dioxide Equivalent (CO_2e)

Where CO2e represents the CO2 equivalence of the emissions. CO2e emissions are calculated as the sum of the mass emissions of each individual GHGs adjusted for its respective global warming potential (GWP). The GWP values are included in Table A-1 of the Greenhouse Gas Mandatory Reporting Rule found in 40 CFR 98, Subpart A.

1.3 Five-Step Top-Down BACT Process

This BACT analysis is conducted following EPA's "top-down" BACT approach, as described in EPA's *Draft New Source Review Workshop Manual* (EPA 1990). The five basic steps of a top-down BACT analysis are listed below:

Step 1: Identify potential control technologies
Step 2: Eliminate technically infeasible options
Step 3: Rank remaining control technologies by control effectiveness
Step 4: Evaluate the most effective controls and document results
Step 5: Select BACT

The first step is to identify potentially "available" control options for each emission unit triggering PSD, for each pollutant under review. Available options consist of a comprehensive list of those technologies with a potentially practical application to the emission unit in question. The list includes technologies used to satisfy BACT requirements, innovative technologies, and controls applied to similar source categories.

For this analysis, the following sources were investigated to identify potentially available control technologies:

- EPA's RACT/BACT/LAER Clearinghouse (RBLC) database.
- EPA's New Source Review website.
- In-house experts.
- State air regulatory agency contacts.
- Technical articles and publications.
- A number of permits issued for similar sources that have not yet been entered into the RBLC.
- Guidance documents and personal communications with federal and state agencies.

After identifying potential technologies, the second step is to eliminate technically infeasible options from further consideration. To be considered feasible for BACT, a technology must be commercially available and applicable to a given emission unit.

The third step is to rank the technologies not eliminated in Step 2 in order of descending control effectiveness for each pollutant of concern. If the highest ranked technology is proposed as BACT, it is not necessary to perform technical or economic evaluation of the selected or less effective control technologies identified as outlined in Step 4. Potential adverse impacts, however, must still be identified and evaluated.

The fourth step entails an evaluation of energy, environmental, and economic impacts for determining a final level of control. The evaluation begins with the most stringent control option and continues until a technology under consideration cannot be eliminated based on adverse energy, environmental, or economic impacts. The economic or "cost-effectiveness" analysis is conducted in a manner consistent with EPA's *OAQPS Control Cost Manual, Sixth Edition*[1] and subsequent revisions.

Cost effectiveness is expressed in terms of dollars per ton of pollutant removed ($/ton). The costs in the numerator of that expression are determined by adding the annualized capital cost and the annual operation and maintenance costs of a given control device under evaluation. Annualized costs are determined by the following equation:

$$\text{Annualized equipment cost in \$/yr} = PV(i / [1 - (1 + i) -n])$$

Where:
PV = Present value of the equipment;
i = Interest rate (cost of money); and
n = Number of years of the life of the equipment.

The annual mass (ton) of pollutant removed is determined by multiplying the annual uncontrolled emission rate by the expected control efficiency. The uncontrolled emission rate may, in some cases, be the rate after some level of control. In addition, the annual emission rate may be the potential to emit, or a level based on limited hours of operation.

The fifth and final step is to select as BACT the emission limit from application of the most effective of the remaining technologies under consideration for each pollutant of concern.

[1] USEPA, *OAQPS Control Cost Manual, Sixth Edition* (Research Triangle Park, NC, 2002)

2. SUMMARY OF AFFECTED EMISSION UNITS AND POLLUTANTS

2.1 Brief Facility Description

Air Quality Control Construction Permit AQ0083CPT06 permitted Agrium to construct a facility consisting of an agricultural fertilizer production facility. The facility will consist of three (3) distinct plants:

1. Plant 4 – Ammonia Plant
2. Plant 5 – Urea Plant
3. Plant 6 – Supporting Utility Plant

Each plant within the permitted facility includes several emission units. In the synthetic ammonia production process, natural gas molecules are reduced to carbon and hydrogen. The hydrogen is then purified and reacted with nitrogen to produce ammonia. Ammonia is synthesized by reacting hydrogen with nitrogen at a molar ratio of 3 to 1, then compressing and cooling the gas. Nitrogen is obtained from the air, while hydrogen is obtained from the catalytic steam reforming of natural gas.

Generally, there are six process steps to produce synthetic ammonia using the catalytic steam reforming process as follows:

1. Natural gas desulfurization,
2. Catalytic steam reforming,
3. Carbon monoxide (CO) shift,
4. Carbon dioxide (CO2) removal,
5. Methanation, and
6. Ammonia synthesis.

The synthetic ammonia produced at the Ammonia Plant is used as feedstock for the Urea Plant at the facility and will also be sold as a product. In the Urea Plant, urea is produced by reacting ammonia and CO_2.

A more detailed description of the permitted facility and associated air emission units is provided in the Appendix A of the original BACT analysis.

2.2 Package Boilers Units (Units 44, 48, and 49)

The three (3) Package Boilers at the plant are natural gas-fired boilers used to generate steam for plant operations. Emissions of regulated pollutants from the Package Boilers include:

- Nitrogen Oxides (NOx)
- Carbon Monoxide (CO)
- Volatile Organic Compounds (VOC)
- Particulate Matter (PM)
- Particulate Matter ≤ 10 microns in aerodynamic diameter (PM10)
- Particulate Matter ≤ 2.5 microns in aerodynamic diameter (PM2.5)
- Carbon Dioxide (CO2)
- Methane (CH4)
- Nitrous Oxide (N2O)
- Carbon Dioxide Equivalent (CO2e)

2.3 Waste Heat Boilers (Units 50, 51, 52, 53, and 54)

The five (5) Waste Heat Boilers at the plant are natural gas-fired units used to generate steam for the plant using natural gas and waste heat from the turbines. Emissions of regulated pollutants from the Waste Heat Boilers include:

- Nitrogen Oxides (NOx)
- Carbon Monoxide (CO)
- Volatile Organic Compounds (VOC)

- Particulate Matter (PM)
- Particulate Matter ≤ 10 microns in aerodynamic diameter (PM10)
- Particulate Matter ≤ 2.5 microns in aerodynamic diameter (PM2.5)
- Carbon Dioxide (CO2)
- Methane (CH4)
- Nitrous Oxide (N2O)
- Carbon Dioxide Equivalent (CO2e)

2.4 Solar Turbine/Generator Sets (Units 55, 56, 57, 58, and 59)

The five (5) proposed Solar Turbines/Generator Sets are natural gas-fired units primarily used to generate electricity for use at the plant site. Emissions of regulated pollutants from the Solar Turbines include:

- Nitrogen Oxides (NOx)
- Carbon Monoxide (CO)
- Volatile Organic Compounds (VOC)
- Particulate Matter (PM)
- Particulate Matter ≤ 10 microns in aerodynamic diameter (PM10)
- Particulate Matter ≤ 2.5 microns in aerodynamic diameter (PM2.5)
- Carbon Dioxide (CO2)
- Methane (CH4)
- Nitrous Oxide (N2O)
- Carbon Dioxide Equivalent (CO2e)

3. CRITERIA POLLUTANT BEST AVAILABLE CONTROL TECHNOLOGY (BACT) ANALYSIS

Criteria pollutants subject to BACT Analysis for this project include:

- Carbon Monoxide (CO)
- Nitrogen Oxides (NOX)
- Volatile Organic Compounds (VOC)
- Particulate Matter (PM)
- Particulate Matter ≤ 10 microns in aerodynamic diameter (PM10)
- Particulate Matter ≤ 2.5 microns in aerodynamic diameter ($PM_{2.5}$)

Generally, these pollutants are the result of natural gas combustion at the planned facility; although, sources other than combustion sources are included at the facility. The sections below include a BACT Analysis for the regulated criteria air pollutants emitted from each emission unit. Greenhouse gas (GHG) pollutants are addressed in Section 4.0 of this document.

3.1 Package Boilers (Units 44, 48, and 49)

KNO currently has three existing natural gas-fired package boilers at its facility. As a part of the BACT Analysis, KNO has evaluated the costs to retro-fit these boilers as compared to the costs of constructing new units. KNO has determined that it is most cost effective to replace the three existing package boilers with three new package boilers. As a result, this analysis will focus on BACT for new boilers rather than for existing boilers. The following subsections present the step-by-step BACT review for the Package Boilers for each applicable criteria pollutant including CO, NO_X, VOC, and $PM/PM_{10}/PM_{2.5}$.

The boilers are subject to the boiler MACT standard under 40 CFR Part 63, Subpart DDDDD; however, there are no emission limits in that rule for natural gas combustion sources that will impact this BACT. The Package Boilers are also subject to a New Source Performance Standard (NSPS) under 40 CFR Part 60 Subpart Db.

3.1.1 BACT Evaluation for CO Emissions from the Package Boilers

Step 1 – Identify All Available Control Technologies

Review of the RBLC database identified two control technologies for control of CO emissions from natural gas-fired boilers - Good Combustion Practices (GCP), and in a couple instances, an Oxidation Catalyst (OC). Emission limits range from 0.0013 to 0.84 lb/mmBtu for natural gas combustion. Available control technologies for the control of CO emissions include good combustion practices, oxidation catalyst, and thermal oxidation. Most of the RBLC entries used the AP-42 emission factor for open combustion of natural gas. The Iowa Fertilizer Corporation (IFC) boiler used a much lower emission rate and the RBLC entry shows that compliance is unverified.

Step 2 – Eliminate Technically Infeasible Options

<u>Oxidation Catalyst</u>

Oxidation catalysts use a noble metal catalyst to reduce the activation energy of the oxidation reaction:

$$2CO + O_2 \rightarrow 2CO_2$$

Although oxidation catalysts are used to reduce CO emissions from natural gas-fired combustion turbines, they have limited demonstration in reducing CO emissions from natural gas-fired boilers. To be effective, the oxidation catalyst must be placed in a location with gas temperatures of at least 600 ˚F. The typical excess oxygen levels in natural gas-fired boilers and heaters are in the range of 3 –

6%. These low excess oxygen levels limit the potential effectiveness of an oxidation catalyst on a boiler or furnace exhaust; however, this technology is carried forward for control of CO emissions from the Package Boilers.

Thermal Oxidation

Thermal oxidation has never been required nor used on a natural gas-fired boiler, and the effectiveness of the technology in reducing CO emissions from natural gas-fired boilers is questionable. Thermal oxidation would involve injecting additional air into the flue gas and heating the oxygen enriched mixture to approximately 1,500 ˚F to oxidize CO to carbon dioxide. However, since the combustion of the reheat fuel would itself result in CO emissions, there is no evidence that thermal oxidation would result in overall reductions in CO emission.

Since thermal oxidation has never been demonstrated on a natural gas-fired boiler, and because there is no evidence that it could reduce CO emissions, thermal oxidation is not a technically feasible CO control technology for the Package Boilers.

Good Combustion Practices

GCPs typically include the following elements:

1. Sufficient residence time to complete combustion
2. Providing and Maintaining proper air/fuel ratio
3. High temperatures and low oxygen levels in the primary combustion zone
4. High enough overall excess oxygen levels to complete combustion and maximize thermal efficiency
5. Proper fuel gas supply system designed to minimize effects of contaminants or fluctuations in pressure and flow on the fuel gas delivered

Combustion efficiency is dependent on the gas residence time, the combustion temperature, and the amount of mixing in the combustion zone. Each of these parameters is incorporated into the design of the burners and the fire box of a boiler or furnace to optimize combustion and minimize fuel consumption. In addition to the above parameters the level of oxygen in the boiler is important to GCP. Therefore, combustion control is accomplished primarily through boiler design as it relates to time, temperature, and mixing, and through boiler operation as it relates to excess oxygen levels. Combustion design for modern boilers is intended to simultaneously minimize formation of CO and NOx emissions. This is a difficult task, since emissions of NOx and emissions of CO are inversely related. That is, measures used to reduce NOx emissions often lead to increases in CO emissions. Therefore, the boiler design to minimize CO emissions is interrelated with the boiler design to minimize NOx formation.

Step 3 – Rank Remaining Control Technologies by Control Effectiveness

GCPs are planned for the fuel burning equipment at the facility and represent the baseline BACT for the boilers; therefore, an oxidation catalyst represents the highest ranked level of control for CO emissions from the Package Boilers.

Step 4 – Evaluate Most Effective Controls and Document Results

The cost to install a catalytic oxidation system was evaluated and determined to have an estimated cost of $44,800 per ton of CO removed. A cost summary spreadsheet is provided in Appendix B. For CO emissions this level of cost is considered to be economically infeasible. A CO-catalyst for control of CO emission from the Package Boilers is eliminated from further consideration as representing BACT for this source.

Step 5 – Select BACT

Agrium proposes the use of Good Combustion Practices as the BACT for CO emissions from the Package Boilers. CO Emissions from the Package Boilers will be limited to 50 ppmv at 3% O_2. Initial compliance with the proposed emission limit will be demonstrated by conducting an initial stack test.

3.1.2 BACT Evaluation for VOC Emissions from the Package Boilers

Step 1 – Identify All Available Control Technologies

Options for the control of VOC emissions from the Package Boilers are the same as the CO emission control options - GCPs, oxidation catalyst, and thermal oxidation.

Step 2 – Eliminate Technically Infeasible Options

For the same reasons given for CO control from the Package Boilers exhaust, thermal oxidation is eliminated from further consideration. A CO oxidation catalyst will provide some level of control of VOC emissions in addition to CO emissions and is carried forward in this review along with the baseline control provided by GCP.

Step 3 – Rank Remaining Control Technologies by Control Effectiveness

GCPs are planned for the fuel burning equipment at the facility and represent the baseline BACT for the boilers; therefore, an oxidation catalyst represents the highest ranked level of control for VOC emissions from the Package Boilers.

Step 4 – Evaluate Most Effective Controls and Document Results

A cost estimate for a CO-catalyst to control VOC emissions from the Package Boilers is included in Appendix B of this document. The cost estimate shows that the cost of control is $383,584 per ton of VOC controlled. This level of cost is excessive and the CO-catalyst option is dropped from further consideration as representing BACT for VOC emissions from the Package Boilers.

Step 5 – Select BACT

Agrium proposes the use of Good Combustion Practices as the BACT for VOC emissions from the Package Boilers. VOC Emissions from the Package Boilers will be limited to 0.0054 lb/MMBtu.

3.1.3 BACT Evaluation for NO_X Emissions from the Package Boilers

Step 1 – Identify All Available Control Technologies

Options for the control of NO_X emissions from the Package Boilers include Selective Catalytic Reduction (SCR), Selective Non-Catalytic Reduction (SNCR), Low-NOx Burners (LNB), Ultra Low-NOx Burners (ULNB), and Good Combustion Practices (GCP).

Step 2 – Eliminate Technically Infeasible Options

Selective Catalytic Reduction (SCR)

Selective Catalytic Reduction (SCR) is a control technology in which ammonia or urea is injected into the exhaust gas before it is passed over a catalyst. The gas stream then reacts with the catalyst to form nitrogen (N_2). Optimum NO_X reduction occurs between 480°F and 800°F[2]. SCR systems typically operate at reduction efficiencies of 70% to 90%[3]. A typical SCR system consists of reagent storage, reagent injection equipment, catalyst housing and catalyst, and associated system control instrumentation. SCR is technically feasible for control of NOx emissions from the Package Boilers and is carried forward in this BACT review.

Selective Non-Catalytic Reduction (SNCR)

Selective Non-Catalytic Reduction (SNCR) involves the injection of ammonia or urea into the post-combustion flue gas. Typical SNCR reduction efficiencies are 30% to 50%[4]. NO_X reduction reactions

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[2] U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for SCR. http://www.epa.gov/ttncatc1/dir1/fscr.pdf.

[3] U.S. EPA, Office of Air Quality Planning and Standards. OAQPS Control Cost Manual Section 4-2 Chapter 2, 6th edition. EPA 452/B-02-001. Research Triangle Park, NC. January 2002.

[4] Ibid.

occur at temperatures between 1600°F and 2100°F[5]. A typical SNCR system consists of reagent storage, multi-level reagent-injection equipment, and associated control instrumentation. The SNCR reagent storage and handling systems are similar to those for SCR systems. However, because of higher stoichiometric ratios, both ammonia and urea SNCR processes require three or four times more reagent as SCR systems to achieve a high level of NOx reductions.

Effluent gas temperatures from the Package Boilers exhaust undergo extensive heat recovery and are not high enough to effectively utilize SNCR so the reagent would need to be injected into the Package Boilers. The gas residence times in the temperature window of greater than one second are needed for optimal SNCR performance while the catalytic reformer design residence time range is less than a second. In addition, review of available literature and the RBLC database indicate that there are no installations of SNCR for control of NO_X emissions from package boilers of this type. This is likely because SCR can be implemented and achieve a higher level of control. For these reasons, SNCR is not technically feasible and is eliminated from further consideration.

Low NO_X Burners

Low NO_X Burners are used to minimize combustion related NO_X emissions by reducing peak flame temperatures. The basic principle involves reducing the temperature of combustion to minimize the formation of thermal NOx in the combustion process.

Ultra Low NO_X Burners

Ultra Low NO_X burners use a similar technique as Low NO_X Burners, however they also employ flue gas recirculation to lower the flame temperature and achieve lower NOx formation than LNB.

Good Combustion Practices

Good Combustion Practices are outline in the CO BACT review for the Package Boilers.

Step 3 – Rank Remaining Control Technologies by Control Effectiveness

The remaining control technologies and their associated control efficiencies are shown in the table below.

Table 1 NOx Control Efficiencies for the Package Boilers

Control Technology	Control Efficiency
SCR and Low NOx Burners	85% - 95%
SCR	70% - 90%
Ultra Low NO_X Burners	50% - 90%
Low NO_X Burners6	40% - 60%
Good Combustion Practices	N/A

Step 4 – Evaluate Most Effective Controls and Document Results

KNO has been provided with design specifications for boilers using SCR capable of meeting 0.01 lb/MMBtu. This emission rate is comparable to units identified in the RBLC that have been permitted using SCR. Because no RBLC entries required the use of SCR and Low NOx burners, the cost to install low NOx burners on these boilers has not been evaluated.

Step 5 – Select BACT

Agrium proposes the use of SCR as BACT for NO_X emissions from the Package Boilers. NO_X Emissions from the Package Boilers will be limited to 0.01 lb/MMBtu. This limit is comparable to the

[5] U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for SNCR. http://www.epa.gov/ttn/catc/dir1/fsncr.pdf .

[6] U.S. EPA Technical Bulletin – Nitrogen Oxides (NO_X), why and how they are controlled. EPA-456/F-99-006R. November 1999.

top level BACT determinations for natural gas-fired package boilers. Compliance with the proposed emission limit will be demonstrated through the use of NO_x CEMS.

3.1.4 BACT Evaluation for $PM/PM_{10}/PM_{2.5}$ Emissions from the Package Boilers

Step 1 – Identify All Available Control Technologies

Options for the control of $PM/PM_{10}/PM_{2.5}$ emissions from the Package Boilers include fabric filters, cartridge filters, mechanical separators, wet and dry electrostatic precipitators (ESP), wet scrubbers, venturi scrubbers, and good combustion practices. It is important to note that the estimated particulate matter emission rate from the Package Boilers stack is 7.6 lb/MMscf or 0.007 gr/dscf. This is a low level of particulate emission and is too low for add-on control.

Step 2 – Eliminate Technically Infeasible Options

<u>Fabric Filters</u>

Fabric Filters or baghouses are comprised of an array of filter bags contained in housing. Air passes through the filter media from the “dirty” to the “clean” side of the bag. These devices undergo periodic bag cleaning based on the build-up of filtered material on the bag as measured by pressure drop across the device. The cleaning cycle is set to allow operation within a range of design pressure drop. Fabric Filters are characterized by the type of cleaning cycle - mechanical-shaker, pulse-jet, and reverse-air. Fabric Filter systems have control efficiencies of 99% to 99.9%7, and are generally specified to meet a discharge concentration of filterable particulate (e.g., 0.01 grains per dry standard cubic feet). Because the filterable particulate emissions resulting from natural gas combustion are so low (0.007 gr/dscf), Fabric Filters are not used to control particulate emissions from natural gas combustion sources. For this reason Fabric Filters are considered technically infeasible and are dropped from further consideration in this BACT review.

<u>Cartridge Collectors</u>

Cartridge Collectors involve the use of filter media supported on a wire framework to collect filterable particulate matter from an air stream or exhaust. Typical Cartridge Collectors have control efficiencies of 99.99% to 99.999%8. Use of a HEPA type filter can achieve even greater control efficiency. Cartridge Collectors generally do not have a means of self-cleaning and are replaced when the pressure drop across the filter becomes excessive and impedes air flow or fan operation. Cartridge Filters are not practical for use to control emissions from a continuous operation and have never been used to control filterable particulate emissions from a natural gas combustion source. For these reasons Cartridge Collectors are not carried forward in this BACT review.

<u>Mechanical Separators</u>

Separators are often referred to as “precleaners,” and are typically used to reduce the inlet loading of $PM/PM_{10}/PM_{2.5}$ to control devices further downstream by removing large particles. Typical inlet grain loading values for Separators are 4 – 110 gr/ft^3 9. Mechanical Separators are never used for particulate control from natural gas combustion sources because the small particle size and low filterable particulate emissions from natural gas combustion. Mechanical Separators are considered technically infeasible and are not carried further in this evaluation.

[7] U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for Fabric Filters. http://www.epa.gov/ttn/catc/dir1/ff-shaker.pdf, http://www.epa.gov/ttn/catc/dir1/ff-revar.pdf, http://www.epa.gov/ttn/catc/dir1/ff-pulse.pdf

[8] U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for Fabric Filters. http://www.epa.gov/ttn/catc/dir1/ff-cartr.pdf

[9] U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for Fabric Filters. http://www.epa.gov/ttn/catc/dir1/fmechan.pdf

Wet and Dry Electrostatic Precipitators (ESP)

Wet and Dry Electrostatic Precipitators (ESPs) remove particles from a gas stream by electrically charging particles with a discharge electrode in the gas path and then collecting the charged particles on grounded. The inlet air is quenched with water on a Wet ESP to saturate the gas stream and ensure a wetted surface on the collection plate. This wetted surface along with a period deluge of water is what cleans the collection plate surface. Wet ESPs typically control streams with inlet grain loading values of 0.5 – 5 gr/ft^3 and have control efficiencies between 99% and 99.9%10. Wet ESPs have the advantage of controlling some amount of condensable particulate matter. The collection plates in a Dry ESP are periodically cleaned by a rapper or hammer that sends a shock wave that knocks the collected particulate off the plate. Dry ESPs typically control streams with inlet grain loading values of 0.5 – 5 gr/ft^3 and have control efficiencies between 99% and 99.9%11. Both Wet and Dry ESPs are considered to be technically infeasible for filterable and condensable particulate matter control from the Package Boilers because of the low level of emissions from natural gas combustion (0.007 gr/dscf) and are not carried forward in this BACT review.

Wet Scrubbers

Wet Scrubbers use a scrubbing solution to remove PM/PM_{10}/$PM_{2.5}$ from an exhaust gas streams. The mechanism for particulate collection is impaction and interception by water droplets. Wet Scrubbers are configured as counter-flow, cross-flow, or concurrent flow, but typically employ counter-flow where the scrubbing fluid is in the opposite direction as the gas flow. Wet Scrubbers have control efficiencies of 50% - 99%12. One advantage of wet Scrubbers is that they can be effective on condensable particulate matter. A disadvantage of a Wet Scrubber is that they consume water and produce wastewater and sludge. Wet Scrubbers are never used for particulate control on natural gas fired combustion units because of the low particulate emissions resulting from natural gas combustion (0.007 gr/dscf). Wet Scrubbers are considered to be technically infeasible for filterable and condensable particulate matter control from the Package Boilers and are not carried forward in this BACT review.

Venturi Scrubbers

Venturi Scrubbers for the gas and liquid (scrubbing fluid) into a venturi throat to enhance the gas-liquid contact to remove particulate matter removal. The PM/PM_{10}/$PM_{2.5}$ containing droplets are then settled out by gravity in an expanded section of the exhaust duct. Venturi Scrubbers control streams with inlet grain loadings of 0.1 – 50 gr/ft^3 and have control efficiencies of 70% - 99%13. Like other wet control systems, Venturi Scrubbers have the advantage of controlling some level of condensable particulate matter. Venturi Scrubbers are never used for particulate control on natural gas fired combustion units because of the low particulate emissions resulting from natural gas combustion (0.007 gr/dscf). Venturi Scrubbers are considered to be technically infeasible for filterable and condensable particulate matter control from the Package Boilers and are not carried forward in this BACT review.

Good Combustion Practices

Good Combustion Practices typically include the following elements:

1. Sufficient residence time to complete combustion
2. Providing proper air/fuel ratio
3. High temperatures and low oxygen levels in the primary combustion zone

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[10] U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for Fabric Filters. http://www.epa.gov/ttn/catc/dir1/fwespwpi.pdf

[11] U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for Fabric Filters. http://www.epa.gov/ttn/catc/dir1/fdespwpi.pdf

[12] U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for Fabric Filters. http://www.epa.gov/ttn/catc/dir1/fpack.pdf, http://www.epa.gov/ttn/catc/dir1/fsprytwr.pdf

[13] U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for Fabric Filters. http://www.epa.gov/ttn/catc/dir1/fventuri.pdf

4. High enough overall excess oxygen levels to complete combustion and maximize thermal efficiency
5. Proper fuel gas supply system design to minimize effects of contaminants or fluctuations in pressure and flow on the fuel gas delivered

A review of the RBLC for reformers also indicates that no add-on controls have been implemented to control PM/PM_{10}/$PM_{2.5}$ emissions from natural gas fired boilers. This is due to the fact that natural gas contains almost no inert materials and generates very little particulate matter emissions. Therefore all add-on controls are considered technically infeasible.

Step 3 – Rank Remaining Control Technologies by Control Effectiveness

Based on the analysis above, the only technically feasible control technology for control of PM/PM_{10}/$PM_{2.5}$ emissions from the Package Boilers is the use of Good Combustion Practices. Therefore no ranking is necessary.

Step 4 – Evaluate Most Effective Controls and Document Results

The only remaining control technology is the use of Good Combustion Practices. Therefore no further evaluation is necessary.

Step 5 – Select BACT

Agrium proposes the use of Good Combustion Practices as BACT for PM/PM_{10}/$PM_{2.5}$ emissions from the Package Boilers. PM/PM_{10}/$PM_{2.5}$ Emissions from the Package Boilers will be limited to 0.0074 lb/MMBtu. Agrium will record total fuel usage for the Package Boilers to ensure compliance.

3.2 Waste Heat Boilers (Units 50, 51, 52, 53, and 54)

KNO operates five natural gas fired waste heat boilers that utilize waste heat from the five solar turbines to generate steam. The following subsections present the step-by-step BACT review for the waste heat boilers for each applicable criteria pollutant including CO, NO_X, VOC, and PM/PM_{10}/$PM_{2.5}$.

3.2.1 BACT Evaluation for CO Emissions from the Waste Heat Boilers

Step 1 – Identify All Available Control Technologies

Review of the RBLC database identified two control technologies for control of CO emissions from natural gas-fired boilers - Good Combustion Practices (GCP), and in one instance, an Oxidation Catalyst (OC). Emission limits range from 0.035 to 0.14 lb/mmBtu for natural gas combustion. Available control technologies for the control of CO emissions include good combustion practices, oxidation catalyst, and thermal oxidation.

Step 2 – Eliminate Technically Infeasible Options

<u>Oxidation Catalyst</u>

Oxidation catalysts use a noble metal catalyst to reduce the activation energy of the oxidation reaction:

$2CO + O_2 \rightarrow 2CO_2$

Although oxidation catalysts are used to reduce CO emissions from natural gas-fired combustion turbines, they have limited demonstration in reducing CO emissions from natural gas-fired boilers. To be effective, the oxidation catalyst must be placed in a location with gas temperatures of at least 600 ˚F. The typical excess oxygen levels in natural gas-fired boilers and heaters are in the range of 3 – 6%. In contrast to typical natural gas-fired boilers, the Waste heat boilers operate at a high excess air due to Waste heat from combustion turbines. As a result, oxidation catalysts are not practical for these units. Oxidation catalyst is eliminated as a viable control option.

Thermal Oxidation

Thermal oxidation has never been required nor used on a natural gas-fired boiler, and the effectiveness of the technology in reducing CO emissions from natural gas-fired boilers is questionable. Thermal oxidation would involve injecting additional air into the flue gas and heating the oxygen enriched mixture to approximately 1,500 ˚F to oxidize CO to carbon dioxide. However, since the combustion of the reheat fuel would itself result in CO emissions, there is no evidence that thermal oxidation would result in overall reductions in CO emission.

Since thermal oxidation has never been demonstrated on a natural gas-fired boiler, and because there is no evidence that it could reduce CO emissions, thermal oxidation is not a technically feasible CO control technology for the Waste Heat Boilers.

Good Combustion Practices

GCPs typically include the following elements:

1. Sufficient residence time to complete combustion
2. Providing and Maintaining proper air/fuel ratio
3. High enough overall excess oxygen levels to complete combustion and maximize thermal efficiency
4. Proper fuel gas supply system designed to minimize effects of contaminants or fluctuations in pressure and flow on the fuel gas delivered

Combustion efficiency is dependent on the gas residence time, the combustion temperature, and the amount of mixing in the combustion zone. Each of these parameters is incorporated into the design of the burners and the fire box of a boiler or furnace to optimize combustion and minimize fuel consumption. In addition to the above parameters the level of oxygen in the boiler is important to GCP. Therefore, combustion control is accomplished primarily through boiler design as it relates to time, temperature, and mixing, and through boiler operation as it relates to excess oxygen levels. Combustion design for modern boilers is intended to simultaneously minimize formation of CO and NOx emissions.

This is a difficult task, since emissions of NOx and emissions of CO are inversely related. That is, measures used to reduce NOx emissions often lead to increases in CO emissions.

Therefore, the boiler design to minimize CO emissions is interrelated with the boiler design to minimize NOx formation.

Step 3 – Rank Remaining Control Technologies by Control Effectiveness

GCPs are planned for the fuel burning equipment at the facility and represent the baseline BACT for the boilers. Because no other feasible control options are available for CO control from Waste Heat Boilers, this is considered to be the best control option available.

Step 4 – Evaluate Most Effective Controls and Document Results

GCPs are considered to be the best control technology available. As a result, no further analysis of control options is necessary.

Step 5 – Select BACT

Agrium proposes the use of Good Combustion Practices as the BACT for CO emissions from the Waste Heat Boilers. CO Emissions from the Waste Heat Boilers will be limited to 50 ppmv at 15% O_2. Initial compliance with the proposed emission limit will be demonstrated by conducting an initial stack test.

3.2.2 BACT Evaluation for VOC Emissions from the Waste Heat Boilers

Step 1 – Identify All Available Control Technologies

Options for the control of VOC emissions from the Waste Heat Boilers are the same as the CO emission control options - GCPs, oxidation catalyst, and thermal oxidation.

Step 2 – Eliminate Technically Infeasible Options

For the same reasons given for CO control from the Waste Heat Boilers oxidation catalyst and thermal oxidation are eliminated from further consideration.

Step 3 – Rank Remaining Control Technologies by Control Effectiveness

GCPs are planned for the fuel burning equipment at the facility and represent the best available controls for VOC emissions from Waste Heat Boilers.

Step 4 – Evaluate Most Effective Controls and Document Results

GCPs are considered to be the best control technology available. As a result, no further analysis of control options is necessary.

Step 5 – Select BACT

Agrium proposes the use of Good Combustion Practices as the BACT for VOC emissions from the Waste Heat Boilers. VOC emissions from the Waste Heat Boilers will be limited to 0.0054 lb/MMBtu.

3.2.3 BACT Evaluation for NO_X Emissions from the Waste Heat Boilers

Step 1 – Identify All Available Control Technologies

Options for the control of NO_X emissions from the Waste Heat Boilers include Selective Catalytic Reduction (SCR), Selective Non-Catalytic Reduction (SNCR), Low-NOx Burners (LNB), Ultra Low-NOx Burners (ULNB), and Good Combustion Practices (GCP).

Step 2 – Eliminate Technically Infeasible Options

Selective Catalytic Reduction (SCR)

Selective Catalytic Reduction (SCR) is a control technology in which ammonia or urea is injected into the exhaust gas before it is passed over a catalyst. The gas stream then reacts with the catalyst to form nitrogen (N_2). Optimum NO_X reduction occurs between 480°F and 800°F[14]. SCR systems typically operate at reduction efficiencies of 70% to 90%[15]. A typical SCR system consists of reagent storage, reagent injection equipment, catalyst housing and catalyst, and associated system control instrumentation. SCR is technically feasible for control of NOx emissions from the Waste Heat Boilers and is carried forward in this BACT review.

Selective Non-Catalytic Reduction (SNCR)

Selective Non-Catalytic Reduction (SNCR) involves the injection of ammonia or urea into the post-combustion flue gas. Typical SNCR reduction efficiencies are 30% to 50%[16]. NO_X reduction reactions occur at temperatures between 1600°F and 2100°F[17]. A typical SNCR system consists of reagent storage, multi-level reagent-injection equipment, and associated control instrumentation. The SNCR reagent storage and handling systems are similar to those for SCR systems. However, because of higher stoichiometric ratios, both ammonia and urea SNCR processes require three or four times more reagent as SCR systems to achieve a high level of NOx reductions.

Effluent gas temperatures from the Waste Heat Boilers exhaust undergo extensive heat recovery and are not high enough to effectively utilize SNCR so the reagent would need to be injected into the Waste Heat Boilers. The gas residence times in the temperature window of greater than one second are needed for optimal SNCR performance while the Waste Heat Boiler design residence time range

[14] U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for SCR. http://www.epa.gov/ttncatc1/dir1/fscr.pdf.

[15] U.S. EPA, Office of Air Quality Planning and Standards. OAQPS Control Cost Manual Section 4-2 Chapter 2, 6th edition. EPA 452/B-02-001. Research Triangle Park, NC. January 2002.

[16] Ibid.

[17] U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for SNCR. http://www.epa.gov/ttn/catc/dir1/fsncr.pdf.

is less than a second. In addition, review of available literature and the RBLC database indicate that there are no installations of SNCR for control of NO_X emissions from boilers of this size. This is likely because SCR can be implemented and achieve a higher level of control. For these reasons, SNCR is not technically feasible and is eliminated from further consideration.

Low NO_X Burners

Low NO_X Burners are used to minimize combustion related NO_X emissions by reducing peak flame temperatures. The basic principle involves reducing the temperature of combustion to minimize the formation of thermal NOx in the combustion process.

Ultra Low NOX Burners

Ultra Low NO_X burners use a similar technique as Low NO_X Burners, however they also employ flue gas recirculation to lower the flame temperature and achieve lower NOx formation than LNB.

Good Combustion Practices

Good Combustion Practices are outlined in the CO BACT review for the Waste Heat Boilers.

Step 3 – Rank Remaining Control Technologies by Control Effectiveness

The remaining control technologies and their associated control efficiencies are shown in the table below.

Table 2 NOx Control Efficiencies for the Waste Heat Boilers

Control Technology	Control Efficiency
SCR/Low NOx Burners	85%-95%
SCR	70% - 92%
Ultra Low NO_X Burners	50% - 70%
Low NO_X Burners18	40% - 60%
Good Combustion Practices	N/A

Step 4 – Evaluate Most Effective Controls and Document Results

Low NOx Burners in combination with SCR is identified as the most effective control technology available. Because the Waste Heat Boilers at KNO are existing units, the Waste Heat Boilers would need to be retrofitted with replacement burners. KNO has performed an analysis of the cost to install low NOx burners on each of the Waste Heat Boilers, which would allow the unit to meet a lower NOx emission rate. This cost analysis is provided in Appendix B. This analysis shows that the additional cost incurred by installing low NOx burners would be $111,105/ton of NOx controlled. KNO considers this cost to be above the level that is reasonable for NOx control costs.

Step 5 – Select BACT

Agrium proposes the use of SCR as BACT for NO_X emissions from the Waste Heat Boilers. NO_X Emissions from the Waste Heat Boilers will be limited to 0.008 lb/MMBtu, or a stack NOx emission rate of 7 ppmv at 15% O_2. Due to the relatively small size of these units, the fact they are existing units, and costs to install low NOx Burners, SCR is considered to be the best control technology available to limit NOx from these units.

3.2.4 BACT Evaluation for $PM/PM_{10}/PM_{2.5}$ Emissions from the Waste Heat Boilers

Step 1 – Identify All Available Control Technologies

Options for the control of $PM/PM_{10}/PM_{2.5}$ emissions from the Waste Heat Boilers include fabric filters, cartridge filters, mechanical separators, wet and dry electrostatic precipitators (ESP), wet scrubbers,

[18] U.S. EPA Technical Bulletin – Nitrogen Oxides (NOX), why and how they are controlled. EPA-456/F-99-006R. November 1999.

venturi scrubbers, and good combustion practices. It is important to note that the estimated particulate matter emission rate from the Waste Heat Boilers stack is 7.6 lb/MMscf or 0.007 gr/dscf, which is a low level of particulate emission.

Step 2 – Eliminate Technically Infeasible Options

Fabric Filters

Fabric Filters or baghouses are comprised of an array of filter bags contained in housing. Air passes through the filter media from the "dirty" to the "clean" side of the bag. These devices undergo periodic bag cleaning based on the build-up of filtered material on the bag as measured by pressure drop across the device. The cleaning cycle is set to allow operation within a range of design pressure drop. Fabric Filters are characterized by the type of cleaning cycle - mechanical-shaker, pulse-jet, and reverse-air. Fabric Filter systems have control efficiencies of 99% to 99.9%[19,] and are generally specified to meet a discharge concentration of filterable particulate (e.g., 0.01 grains per dry standard cubic feet). Because the filterable particulate emissions resulting from natural gas combustion are so low (0.007 gr/dscf), Fabric Filters are not used to control particulate emissions from natural gas combustion sources. For this reason Fabric Filters are considered technically infeasible and are dropped from further consideration in this BACT review.

Cartridge Collectors

Cartridge Collectors involve the use of filter media supported on a wire framework to collect filterable particulate matter from an air stream or exhaust. Typical Cartridge Collectors have control efficiencies of 99.99% to 99.999%[20]. Use of a HEPA type filter can achieve even greater control efficiency. Cartridge Collectors generally do not have a means of self-cleaning and are replaced when the pressure drop across the filter becomes excessive and impedes air flow or fan operation. Cartridge Filters are not practical for use to control emissions from a continuous operation and have never been used to control filterable particulate emissions from a natural gas combustion source. For these reasons Cartridge Collectors are not carried forward in this BACT review.

Mechanical Separators

Separators are often referred to as "precleaners," and are typically used to reduce the inlet loading of $PM/PM_{10}/PM_{2.5}$ to control devices further downstream by removing large particles. Typical inlet grain loading values for Separators are 4 – 110 gr/ft^3 [21]. Mechanical Separators are never used for particulate control from natural gas combustion sources because the small particle size and low filterable particulate emissions from natural gas combustion. Mechanical Separators are considered technically infeasible and are not carried further in this evaluation.

Wet and Dry Electrostatic Precipitators (ESP)

Wet and Dry Electrostatic Precipitators (ESPs) remove particles from a gas stream by electrically charging particles with a discharge electrode in the gas path and then collecting the charged particles on grounded. The inlet air is quenched with water on a Wet ESP to saturate the gas stream and ensure a wetted surface on the collection plate. This wetted surface along with a period deluge of water is what cleans the collection plate surface. Wet ESPs typically control streams with inlet grain loading values of 0.5 – 5 gr/ft^3 and have control efficiencies between 99% and 99.9%[22]. Wet ESPs have the advantage of controlling some amount of condensable particulate matter. The collection plates in a Dry ESP are periodically cleaned by a rapper or hammer that sends a shock wave that

19 U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for Fabric Filters. http://www.epa.gov/ttn/catc/dir1/ff-shaker.pdf, http://www.epa.gov/ttn/catc/dir1/ff-revar.pdf, http://www.epa.gov/ttn/catc/dir1/ff-pulse.pdf

20 U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for Fabric Filters. http://www.epa.gov/ttn/catc/dir1/ff-cartr.pdf

21 U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for Fabric Filters. http://www.epa.gov/ttn/catc/dir1/fmechan.pdf

22 U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for Fabric Filters. http://www.epa.gov/ttn/catc/dir1/fwespwpi.pdf

knocks the collected particulate off the plate. Dry ESPs typically control streams with inlet grain loading values of 0.5 – 5 gr/ft^3 and have control efficiencies between 99% and 99.9%[23]. Both Wet and Dry ESPs are considered to be technically infeasible for filterable and condensable particulate matter control from the Waste Heat Boilers because of the low level of emissions from natural gas combustion (0.007 gr/dscf) and are not carried forward in this BACT review.

Wet Scrubbers

Wet Scrubbers use a scrubbing solution to remove PM/PM_{10}/$PM_{2.5}$ from an exhaust gas streams. The mechanism for particulate collection is impaction and interception by water droplets. Wet Scrubbers are configured as counter-flow, cross-flow, or concurrent flow, but typically employ counter-flow where the scrubbing fluid is in the opposite direction as the gas flow. Wet Scrubbers have control efficiencies of 50% - 99%[24]. One advantage of wet Scrubbers is that they can be effective on condensable particulate matter. A disadvantage of a Wet Scrubber is that they consume water and produce Wastewater and sludge. Wet Scrubbers are never used for particulate control on natural gas fired combustion units because of the low particulate emissions resulting from natural gas combustion (0.007 gr/dscf). Wet Scrubbers are considered to be technically infeasible for filterable and condensable particulate matter control from the Waste Heat Boilers and are not carried forward in this BACT review.

Venturi Scrubbers

Venturi Scrubbers for the gas and liquid (scrubbing fluid) into a venturi throat to enhance the gas-liquid contact to remove particulate matter removal. The PM/PM_{10}/$PM_{2.5}$ containing droplets are then settled out by gravity in an expanded section of the exhaust duct. Venturi Scrubbers control streams with inlet grain loadings of 0.1 – 50 gr/ft^3 and have control efficiencies of 70% - 99%[25]. Like other wet control systems, Venturi Scrubbers have the advantage of controlling some level of condensable particulate matter. Venturi Scrubbers are never used for particulate control on natural gas fired combustion units because of the low particulate emissions resulting from natural gas combustion (0.007 gr/dscf). Venturi Scrubbers are considered to be technically infeasible for filterable and condensable particulate matter control from the Waste Heat Boilers and are not carried forward in this BACT review.

Good Combustion Practices

Good Combustion Practices typically include the following elements:

1. Sufficient residence time to complete combustion
2. Providing proper air/fuel ratio
3. High temperatures and low oxygen levels in the primary combustion zone
4. High enough overall excess oxygen levels to complete combustion and maximize thermal efficiency
5. Proper fuel gas supply system design to minimize effects of contaminants or fluctuations in pressure and flow on the fuel gas delivered

A review of the RBLC for boilers also indicates that no add-on controls have been implemented to control PM/PM_{10}/$PM_{2.5}$ emissions from boilers at existing or recently permitted facilities. This is due to the fact that natural gas contains almost inert materials and generates very little particulate matter emissions. Therefore all add-on controls are considered technically infeasible.

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[23] U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for Fabric Filters. http://www.epa.gov/ttn/catc/dir1/fdespwpi.pdf

[24] U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for Fabric Filters. http://www.epa.gov/ttn/catc/dir1/fpack.pdf, http://www.epa.gov/ttn/catc/dir1/fsprytwr.pdf

[25] U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for Fabric Filters. http://www.epa.gov/ttn/catc/dir1/fventuri.pdf

Step 3 – Rank Remaining Control Technologies by Control Effectiveness

Based on the analysis above, the only technically feasible control technology for control of PM/PM_{10}/$PM_{2.5}$ emissions from the Waste Heat Boilers is the use of Good Combustion Practices. Therefore no ranking is necessary.

Step 4 – Evaluate Most Effective Controls and Document Results

The only remaining control technology is the use of Good Combustion Practices. Therefore no further evaluation is necessary.

Step 5 – Select BACT

Agrium proposes the use of Good Combustion Practices as BACT for PM/PM_{10}/$PM_{2.5}$ emissions from the Waste Heat Boilers. PM/PM_{10}/$PM_{2.5}$ Emissions from the Waste Heat Boilers will be limited to 0.0074 lb/MMBtu. Agrium will record total fuel usage for the Waste Heat Boilers to ensure compliance.

3.3 Solar Turbine/Generator Sets (Units 55, 56, 57, 58, and 59)

The five Solar Turbines at the facility are natural gas fired combustion turbines used to generate electricity. The following subsections present the step-by-step BACT review for the Solar Turbines for each applicable criteria pollutant including CO, NO_X, VOC, and PM/PM_{10}/$PM_{2.5}$.

3.3.1 BACT Evaluation for CO Emissions from the Solar Turbine/Generator Sets

Step 1 – Identify All Available Control Technologies

Review of the RBLC database identified two control technologies for control of CO emissions from natural gas-fired combustion turbines - Good Combustion Practices (GCP), and in two instances, an Oxidation Catalyst (OC). Available control technologies for the control of CO emissions include good combustion practices, oxidation catalyst, and thermal oxidation.

Step 2 – Eliminate Technically Infeasible Options

Oxidation Catalyst

Oxidation catalysts use a noble metal catalyst to reduce the activation energy of the oxidation reaction:

$$2CO + O_2 \rightarrow 2CO_2$$

Oxidation catalysts have been used to control CO emissions from combustion turbines in other applications, although the configuration of these units directs exhaust from the Solar Turbines through Waste Heat Boilers prior to discharge.

Thermal Oxidation

Thermal oxidation has never been required nor used on a natural gas-fired combustion turbine, and the effectiveness of the technology in reducing CO emissions from natural gas-fired combustion turbine is questionable. Thermal oxidation would involve injecting additional air into the flue gas and heating the oxygen enriched mixture to approximately 1,500 °F to oxidize CO to carbon dioxide. However, since the combustion of the reheat fuel would itself result in CO emissions, there is no evidence that thermal oxidation would result in overall reductions in CO emission.

Since thermal oxidation has never been demonstrated on a natural gas-fired combustion turbine, and because there is no evidence that it could reduce CO emissions, thermal oxidation is not a technically feasible CO control technology for the Solar Turbines.

Good Combustion Practices

GCPs typically include the following elements:

1. Sufficient residence time to complete combustion
2. Providing and Maintaining proper air/fuel ratio
3. High enough overall excess oxygen levels to complete combustion and maximize thermal efficiency
4. Proper fuel gas supply system designed to minimize effects of contaminants or fluctuations in pressure and flow on the fuel gas delivered

Combustion efficiency is dependent on the gas residence time, the combustion temperature, and the amount of mixing in the combustion zone. Each of these parameters is incorporated into the design of the burners and the combustion zone of a turbine to optimize combustion and minimize fuel consumption. In addition to the above parameters the level of oxygen in the combustion turbine is important to GCP. Therefore, combustion control is accomplished primarily through combustion turbine design as it relates to time, temperature, and mixing, and through combustion turbine operation as it relates to excess oxygen levels. Combustion design for modern combustion turbines is intended to simultaneously minimize formation of CO and NOx emissions. This is a difficult task, since emissions of NOx and emissions of CO are inversely related. That is, measures used to reduce NOx emissions often lead to increases in CO emissions. Therefore, the design to minimize CO emissions is interrelated with the design to minimize NOx formation.

Step 3 – Rank Remaining Control Technologies by Control Effectiveness

GCPs are planned for the fuel burning equipment at the facility and represent the baseline BACT. The use of an oxidation catalyst represents the highest ranked level of control for CO emissions from the Solar Turbines.

Step 4 – Evaluate Most Effective Controls and Document Results

A cost estimate for a CO-catalyst oxidizer for control of the CO emissions from Solar Turbines was performed. Due to the current design of these units, the evaluation was performed considering the exhaust and CO emissions from each Waste Heat Boiler/Solar Turbine combined unit. The computed cost to control CO using catalyst oxidation was computed to be $28,700 per ton. For CO emissions this level of cost is considered to be economically infeasible. A CO-catalyst for control of CO emission from the Solar Turbine/Generator Sets is eliminated from further consideration as representing BACT for this source.

Step 5 – Select BACT

Agrium proposes the use of Good Combustion Practices as the BACT for CO emissions from the Solar Turbines. CO Emissions from the Solar Turbines will be limited to 50 ppmv at 15% O_2. Initial compliance with the proposed emission limit will be demonstrated by conducting an initial stack test.

3.3.2 BACT Evaluation for VOC Emissions from the Solar Turbine/Generator Sets

Step 1 – Identify All Available Control Technologies

Options for the control of VOC emissions are the same as the CO emission control options - GCPs, oxidation catalyst, and thermal oxidation.

Step 2 – Eliminate Technically Infeasible Options

For the same reasons given for CO control from the exhaust, thermal oxidation is eliminated from further consideration. A CO oxidation catalyst will provide some level of control of VOC emissions in addition to CO emissions and is carried forward in this review along with the baseline control provided by GCP.

Step 3 – Rank Remaining Control Technologies by Control Effectiveness

GCPs are planned for the fuel burning equipment at the facility and represent the baseline BACT for the Solar Turbines; therefore, an oxidation catalyst represents the highest ranked level of control for VOC emissions from the Solar Turbines.

Step 4 – Evaluate Most Effective Controls and Document Results

A cost estimate for a CO-catalyst to control VOC emissions from the Solar Turbine is included in Appendix B of this document. As with the CO analysis above, this analysis is performed using the combined exhaust from a Solar Turbine/Waste Heat Boiler combined unit. The cost estimate shows that the cost of control is in excess of $1,074,457 per ton. This level of cost is excessive and the CO-catalyst option is dropped from further consideration as representing BACT for VOC emissions from the Solar Turbines.

Step 5 – Select BACT

Agrium proposes the use of Good Combustion Practices as the BACT for VOC emissions from the Solar Turbines. VOC Emissions from the Solar Turbines will be limited to 0.0021 lb/MMBtu.

3.3.3 BACT Evaluation for NO_X Emissions from the Solar Turbine/Generator Sets

Step 1 – Identify All Available Control Technologies

Options for the control of NO_X emissions from the include Selective Catalytic Reduction (SCR), Selective Non-Catalytic Reduction (SNCR), Low-NOx Burners (LNB), Ultra Low-NOx Burners (ULNB), Dry Low Emission (DLE) Combustion Technology, Water Injection, and Good Combustion Practices (GCP).

Step 2 – Eliminate Technically Infeasible Options

Selective Catalytic Reduction (SCR)

Selective Catalytic Reduction (SCR) is a control technology in which ammonia or urea is injected into the exhaust gas before it is passed over a catalyst. The gas stream then reacts with the catalyst to form nitrogen (N_2). Optimum NO_X reduction occurs between 480°F and 800°F[26]. SCR systems typically operate at reduction efficiencies of 70% to 90%[27]. A typical SCR system consists of reagent storage, reagent injection equipment, catalyst housing and catalyst, and associated system control instrumentation. SCR is technically feasible for control of NOx emissions from the Solar Turbines and is carried forward in this BACT review.

Selective Non-Catalytic Reduction (SNCR)

Selective Non-Catalytic Reduction (SNCR) involves the injection of ammonia or urea into the post-combustion flue gas. Typical SNCR reduction efficiencies are 30% to 50%[28]. NO_X reduction reactions occur at temperatures between 1600°F and 2100°F[29]. A typical SNCR system consists of reagent storage, multi-level reagent-injection equipment, and associated control instrumentation. The SNCR reagent storage and handling systems are similar to those for SCR systems. However, because of higher stoichiometric ratios, both ammonia and urea SNCR processes require three or four times more reagent as SCR systems to achieve a high level of NOx reductions.

Effluent gas temperatures from the exhaust undergo extensive heat recovery and are not high enough to effectively utilize SNCR so the reagent would need to be injected into the . The gas residence times

[26] U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for SCR. http://www.epa.gov/ttncatc1/dir1/fscr.pdf.

[27] U.S. EPA, Office of Air Quality Planning and Standards. OAQPS Control Cost Manual Section 4-2 Chapter 2, 6th edition. EPA 452/B-02-001. Research Triangle Park, NC. January 2002.

[28] Ibid.

[29] U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for SNCR. http://www.epa.gov/ttn/catc/dir1/fsncr.pdf.

in the temperature window of greater than one second are needed for optimal SNCR performance while the Solar Turbine design residence time range is less than a second. In addition, review of available literature and the RBLC database indicate that there are no installations of SNCR for control of NO_X emissions from combustion turbines of this size. This is likely because SCR can be implemented and achieve a higher level of control. For these reasons, SNCR is not technically feasible and is eliminated from further consideration.

Dry Low Emissions (DLE) Combustion Technology

Dry Low Emissions (DLE)[30] combustion technology, sometimes also referred to as Dry Low NOx (DLN), is a lean pre-mix combustion system design. DLE pre-mixes the gaseous fuel and compressed air so that there are no local zones of high temperatures, or "hot spots," where high levels of NOx would form. Lean premixed combustion requires specially designed mixing chambers and mixture inlet zones to avoid flashback of the flame. Optimized application of DLN combustion requires an integrated approach for combustor and turbine design. The DLE combustor becomes an intrinsic part of the turbine design, and specific combustor designs must be developed for each turbine application. While NOx levels as low as 9 ppm have been achieved, most manufacturers typically offer a range of 15-25 ppm DLN/DLE combustion systems when operating on natural gas.

Water Injection

Water injection is frequently used to limit NOx emissions from combustion turbines, and is considered to be an available technology for the Solar Turbines for this smaller size capacity.

Good Combustion Practices

Good Combustion Practices are outline in the CO BACT review for the Solar Turbines.

Step 3 – Rank Remaining Control Technologies by Control Effectiveness

The remaining control technologies and their associated control efficiencies are shown in the table below.

Table 3 NOx Control Efficiencies for the Solar Turbine/Generator Sets

Control Technology	Control Efficiency
SCR/Water Injection Combination	80% - 95%
SCR	70% - 92%
Dry Low Emission Technology	50% - 70%
Water Injection	50% - 70%
Good Combustion Practices	N/A

Step 4 – Evaluate Most Effective Controls and Document Results

As illustrated in the table above, the combination of SCR and water injection is expected to result in the greatest level of NOx control from the Solar Turbines. KNO has made the decision to install SCR on the combined exhaust from the Solar Turbine/Waste Heat Boiler, and evaluated the cost that would be incurred through further control with the use of water injection. A cost analysis is provided in Appendix B, and estimates the cost of NOx control at $12,291 per ton of NOx controlled. KNO considers this cost to be excessive, and has eliminated water injection from further consideration as BACT.

Step 5 – Select BACT

Agrium proposes the use of SCR on the Solar Turbines for NO_X emissions at the Waste Heat Boiler outlet of 7 ppmv at 15% O_2. For the Solar Turbines, this will be equivalent to a NOx emission limit of 0.041 lb/MMBtu. Compliance with the proposed emission limit will be demonstrated by conducting an initial stack test to obtain an emission rate.

[30] U.S. EPA Combined Heat and Power Partnership, Catalog of CHP Technologies, Section 3. Technology Characterization – Combustion Turbines. https://www.epa.gov/sites/production/files/2015-07/documents/catalog_of_chp_technologies_section_3._technology_characterization_-_combustion_turbines.pdf

3.3.4 BACT Evaluation for $PM/PM_{10}/PM_{2.5}$ Emissions from the Solar Turbine/Generator Sets

Step 1 – Identify All Available Control Technologies

Options for the control of $PM/PM_{10}/PM_{2.5}$ emissions from the include fabric filters, cartridge filters, mechanical separators, wet and dry electrostatic precipitators (ESP), wet scrubbers, venturi scrubbers, and good combustion practices. It is important to note that the estimated particulate matter emission rate from the stack is 7.6 lb/MMscf or 0.007 gr/dscf, which is a low level of particulate emissions.

Step 2 – Eliminate Technically Infeasible Options

Fabric Filters

Fabric Filters or baghouses are comprised of an array of filter bags contained in housing. Air passes through the filter media from the “dirty” to the “clean” side of the bag. These devices undergo periodic bag cleaning based on the build-up of filtered material on the bag as measured by pressure drop across the device. The cleaning cycle is set to allow operation within a range of design pressure drop. Fabric Filters are characterized by the type of cleaning cycle - mechanical-shaker, pulse-jet, and reverse-air. Fabric Filter systems have control efficiencies of 99% to 99.9%[31], and are generally specified to meet a discharge concentration of filterable particulate (e.g., 0.01 grains per dry standard cubic feet). Because the filterable particulate emissions resulting from natural gas combustion are so low (0.007 gr/dscf), Fabric Filters are not used to control particulate emissions from natural gas combustion sources. For this reason Fabric Filters are considered technically infeasible and are dropped from further consideration in this BACT review.

Cartridge Collectors

Cartridge Collectors involve the use of filter media supported on a wire framework to collect filterable particulate matter from an air stream or exhaust. Typical Cartridge Collectors have control efficiencies of 99.99% to 99.999%[32]. Use of a HEPA type filter can achieve even greater control efficiency. Cartridge Collectors generally do not have a means of self-cleaning and are replaced when the pressure drop across the filter becomes excessive and impedes air flow or fan operation. Cartridge Filters are not practical for use to control emissions from a continuous operation and have never been used to control filterable particulate emissions from a natural gas combustion source. For these reasons Cartridge Collectors are not carried forward in this BACT review.

Mechanical Separators

Separators are often referred to as “precleaners,” and are typically used to reduce the inlet loading of $PM/PM_{10}/PM_{2.5}$ to control devices further downstream by removing large particles. Typical inlet grain loading values for Separators are 4 – 110 gr/ft^3 [33]. Mechanical Separators are never used for particulate control from natural gas combustion sources because the small particle size and low filterable particulate emissions from natural gas combustion. Mechanical Separators are considered technically infeasible and are not carried further in this evaluation.

Wet and Dry Electrostatic Precipitators (ESP)

Wet and Dry Electrostatic Precipitators (ESPs) remove particles from a gas stream by electrically charging particles with a discharge electrode in the gas path and then collecting the charged particles on grounded. The inlet air is quenched with water on a Wet ESP to saturate the gas stream and ensure a wetted surface on the collection plate. This wetted surface along with a period deluge of

[31] U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for Fabric Filters. http://www.epa.gov/ttn/catc/dir1/ff-shaker.pdf, http://www.epa.gov/ttn/catc/dir1/ff-revar.pdf, http://www.epa.gov/ttn/catc/dir1/ff-pulse.pdf

[32] U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for Fabric Filters. http://www.epa.gov/ttn/catc/dir1/ff-cartr.pdf

[33] U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for Fabric Filters. http://www.epa.gov/ttn/catc/dir1/fmechan.pdf

water is what cleans the collection plate surface. Wet ESPs typically control streams with inlet grain loading values of 0.5 – 5 gr/ft^3 and have control efficiencies between 99% and 99.9%[34]. Wet ESPs have the advantage of controlling some amount of condensable particulate matter. The collection plates in a Dry ESP are periodically cleaned by a rapper or hammer that sends a shock wave that knocks the collected particulate off the plate. Dry ESPs typically control streams with inlet grain loading values of 0.5 – 5 gr/ft^3 and have control efficiencies between 99% and 99.9%[35]. Both Wet and Dry ESPs are considered to be technically infeasible for filterable and condensable particulate matter control from the Solar Turbines because of the low level of emissions from natural gas combustion (0.007 gr/dscf) and are not carried forward in this BACT review.

Wet Scrubbers

Wet Scrubbers use a scrubbing solution to remove PM/PM_{10}/$PM_{2.5}$ from an exhaust gas streams. The mechanism for particulate collection is impaction and interception by water droplets. Wet Scrubbers are configured as counter-flow, cross-flow, or concurrent flow, but typically employ counter-flow where the scrubbing fluid is in the opposite direction as the gas flow. Wet Scrubbers have control efficiencies of 50% - 99%[36]. One advantage of wet Scrubbers is that they can be effective on condensable particulate matter. A disadvantage of a Wet Scrubber is that they consume water and produce e water and sludge. Wet Scrubbers are never used for particulate control on natural gas fired combustion units because of the low particulate emissions resulting from natural gas combustion (0.007 gr/dscf). Wet Scrubbers are considered to be technically infeasible for filterable and condensable particulate matter control from the Solar Turbines and are not carried forward in this BACT review.

Venturi Scrubbers

Venturi Scrubbers for the gas and liquid (scrubbing fluid) into a venturi throat to enhance the gas-liquid contact to remove particulate matter removal. The PM/PM_{10}/$PM_{2.5}$ containing droplets are then settled out by gravity in an expanded section of the exhaust duct. Venturi Scrubbers control streams with inlet grain loadings of 0.1 – 50 gr/ft^3 and have control efficiencies of 70% - 99%[37]. Like other wet control systems, Venturi Scrubbers have the advantage of controlling some level of condensable particulate matter. Venturi Scrubbers are never used for particulate control on natural gas fired combustion units because of the low particulate emissions resulting from natural gas combustion (0.007 gr/dscf). Venturi Scrubbers are considered to be technically infeasible for filterable and condensable particulate matter control from the Solar Turbines and are not carried forward in this BACT review.

Good Combustion Practices

Good Combustion Practices typically include the following elements:

1. Sufficient residence time to complete combustion
2. Providing proper air/fuel ratio
3. High enough overall excess oxygen levels to complete combustion and maximize thermal efficiency
4. Proper fuel gas supply system design to minimize effects of contaminants or fluctuations in pressure and flow on the fuel gas delivered

A review of the RBLC for reformers also indicates that no add-on controls have been implemented to control PM/PM_{10}/$PM_{2.5}$ emissions from combustion turbines at existing or recently permitted facilities.

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[34] U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for Fabric Filters. http://www.epa.gov/ttn/catc/dir1/fwespwpi.pdf

[35] U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for Fabric Filters. http://www.epa.gov/ttn/catc/dir1/fdespwpi.pdf

[36] U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for Fabric Filters. http://www.epa.gov/ttn/catc/dir1/fpack.pdf, http://www.epa.gov/ttn/catc/dir1/fsprytwr.pdf

[37] U.S. EPA Clean Air Technology Center, Air Pollution Control Technology Fact Sheet for Fabric Filters. http://www.epa.gov/ttn/catc/dir1/fventuri.pdf

This is due to the fact that natural gas contains almost inert materials and generates very little particulate matter emissions. Therefore all add-on controls are considered technically infeasible.

Step 3 – Rank Remaining Control Technologies by Control Effectiveness

Based on the analysis above, the only technically feasible control technology for control of $PM/PM_{10}/PM_{2.5}$ emissions from the Waste Heat Boilers is the use of Good Combustion Practices. Therefore no ranking is necessary.

Step 4 – Evaluate Most Effective Controls and Document Results

The only remaining control technology is the use of Good Combustion Practices. Therefore no further evaluation is necessary.

Step 5 – Select BACT

Agrium proposes the use of Good Combustion Practices as BACT for $PM/PM_{10}/PM_{2.5}$ emissions from the Solar Turbines. $PM/PM_{10}/PM_{2.5}$ emissions from the Solar Turbines will be limited to 0.0074 lb/MMBtu. Agrium will record total fuel usage for the Solar Turbines to ensure compliance.

4. GREENHOUSE GAS (GHG) BEST AVAILABLE CONTROL TECHNOLOGY (BACT) ANALYSIS

The GHGs subject to BACT Analysis for this project include:

- Carbon Dioxide (CO_2)
- Methane (CH_4)
- Nitrous Oxide (N_2O)
- Carbon Dioxide Equivalent (CO_{2e})

The sections below include a BACT Analysis for all GHGs emitted from each emission unit.

4.1 Package Boilers (Units 44, 48, and 49)

4.1.1 BACT Evaluation for GHG Emissions from the Package Boilers

Step 1 – Identify All Available Control Technologies

Options for the control of GHG emissions from the Package Boilers include:

Carbon Capture and Sequestration (CCS)

Carbon Capture

Post-combustion carbon capture technologies include absorption processes (liquid), hybrid solutions (mixed physical and chemical solvent), adsorption processes (solid surface, ionic liquid), and physical separation (membrane, cryogenic separation). These technologies are in various stages of development, ranging from the laboratory bench-scale through pilot-scale demonstrations which have been applied to coal-fired generation units and industrial facilities, such as refineries, cement plants, and biofuels plants. Numerous large-scale demonstration projects are also being planned and constructed throughout the United States and globally.

The CO_2 absorption processes under investigation include chemical and physical absorption. In chemical absorption, CO_2 is scrubbed from the flue gas through a chemical reaction with the scrubbing medium. In physical absorption systems, there is no chemical reaction between the CO_2 and the scrubbing medium. Generally, the energy to regenerate, or desorb the CO_2 from the scrubbing medium, is greater for chemical absorption than physical absorption, because the chemical reaction must be reversed in the chemical desorption/regeneration process.

Chemical absorption is characterized by the occurrence of a chemical reaction between the gas component being absorbed and a component in the liquid to form a compound. The most prevalent chemical absorbents under investigation for CO_2 removal from flue gas are amine solvents. An amine is a class of basic, nitrogen-containing organic compounds derived from ammonia. Gas scrubbing systems employing amine solvents are used for a wide variety of gas or liquid hydrocarbon treatment applications where hydrogen sulfide (H_2S) or CO_2 is present in a gas or in a liquid hydrocarbon feed stream.

Close contact between the gas and the liquid amine solution is provided to promote the mass transfer between the target compound and the amine. Several amine solvents are commercially used in scrubbing solutions including monoethanolamine (MEA), diethanolamine (DEA), triethanolamine (TEA), diisopropanolamine (DIPA), diglycolamine (DGA), methyldiethanolamine (MDEA), n-methylethanolamine (NMEA), alkanolamine and various proprietary mixtures of these amines. A simple amine scrubbing solution consists of one or more of these amine solvents diluted to a typical 10 – 60 percent concentration range with water.

Other chemical absorbents currently under laboratory or bench-scale evaluation include a number of inorganic sorbents. A lithium-silicate based ceramic material38 developed by Toshiba is reported as

[38] Toshiba website - www.toshiba.co.jp/about/press/2003_06/pr2301.htm

having the ability to absorb CO_2 at up to 500 times its volume. Regeneration of the material and release of the CO_2 occurs when the material is heated above 1,300ºF.

In physical absorption, the chemical component being absorbed is more soluble in the liquid absorbent than the other gas components in a gas mixture, but that chemical component does not react chemically with the absorbent. Physical absorbents under investigation for CO_2 capture include propylene carbonate, Selexol™, Rectisol™ and Morphysorb™. Close contact between the scrubbing solvent and the gas forces the CO_2 into solution. Although the energy required to regenerate physical sorbents is lower than that of chemical sorbents, they are less effective than chemical sorbents at removing CO_2 in dilute gas streams.

A hybrid absorption approach involves a mixture of chemical and physical sorbents. In theory, the sorbent mixture can be tailored to the specific application. This process is also currently used to remove intermediate concentrations of CO_2 from natural gas in natural gas production.

Adsorption is a physical separation process. Laboratory evaluations of natural zeolite, manufactured zeolite molecular sieves, and activated carbon have all shown that these materials preferentially adsorb CO_2 over nitrogen, oxygen, and water vapor at elevated pressures. These materials show promise for CO_2 capture from high pressure gas streams. However, they have not shown high CO_2 capture potential for the dilute, lower pressure exhaust from a conventional combustion process. Desorption of the CO_2 is accomplished by reducing the pressure, known as a “pressure swing,” on the adsorbed CO_2, thus regenerating the adsorbent material and releasing the CO_2 for subsequent sequestration.

The physical separation technologies available utilize membrane separation and cryogenic separation. These technologies, including polymer-based membrane separation of CO_2, are in the initial stages of investigation. Membrane separation is potentially less energy intensive than other methods of CO_2 capture, because there is no chemical reaction or phase change in the process. Currently, the membrane materials being tested are prone to chemical and thermal degradation. In cryogenic separation of CO_2, the gas is cooled and compressed to condense CO_2. This process is only effective on dry gas streams with very high CO_2 concentrations and is not applicable to the dilute gas streams from a traditional combustion source.

There is ongoing research into algae strains that can uptake CO_2 from a concentrated stream and produce bio-fuel. The mechanism for CO_2 uptake is photosynthesis. This research is in the early stages, and there are no commercial products available at this time for treating CO_2 from traditional combustion sources.

Carbon Sequestration

To achieve the objective of reducing the atmospheric concentration of greenhouse gases (i.e., CO_2), CO_2 must be kept out of the atmosphere once it is captured. This process is referred to as carbon sequestration. Carbon sequestration is the long-term isolation of CO_2 from the atmosphere through physical, chemical, biological, or engineered processes. In general, carbon sequestration is achieved through storage in geologic formations or terrestrial ecosystems, or through conversion into commercial products.

Although beneficial reuse options are developing with solutions such as the use of captured material to enhance oil or gas recovery from well fields in the petroleum industry, currently, the demand for CO_2 for such applications is well below the ultimate quantity of CO_2 that is available for capture. Without a market to use the recovered CO_2, the material would instead require sequestration, or permanent storage. Geologic sequestration refers to the injection and storage of captured CO_2 in an underground location where it will not readily escape into the atmosphere, such as within deep rock formations at pressures and temperatures where CO_2 is in the supercritical phase (typically ½ mile or more below ground surface). In general, CO_2 storage could be successful in porous, high-permeability rock formations or deep saline formations that are overlain by a thick, continuous layer of low-permeability rock, such as a shale, where CO_2 may remain immobilized beneath the ground surface for extended periods of time. Other geologic formations deemed suitable for geologic sequestration include coal beds that are too thin or deep to be cost effectively mined and depleted oil and gas reservoirs, where in addition to CO_2 storage, economic gains may also be achieved (most notably through the use of enhanced oil recovery to obtain residual oil in mature oil fields).

An understanding of site-specific geologic studies and formation characteristics is critical to determine the ultimate CO_2 storage capacity and, ultimately the feasibility of geologic sequestration, for a particular area. Other factors to consider when determining the feasibility (both technical and economic) of geologic sequestration are the cost, constructability, and potential environmental impacts of infrastructure necessary for the transportation of captured CO_2 from the source to the ultimate geologic sequestration site; and the amount of measurement, monitoring (baseline, operational, etc.), and verification of CO_2 distribution required following injection into the subsurface to ensure the risk of leakage of CO_2 is minimized or eliminated.

Cogeneration/Combined Heat and Power (CHP)

Combined Heat and Power (CHP) or Cogeneration involves the production of useable heat and electricity from a single source. The use of CHP results in significant energy gains. Significant reductions in GHG emissions are achieved by recovering energy which would otherwise go to Waste.

Energy Efficient Design

Energy efficient designs can reduce the natural gas required to produce the necessary amount of steam. Therefore emissions of GHGs are reduced. Energy efficient design elements for boilers include combustion control optimization, tuning, instrumentation and controls, economizer, blowdown heat recovery, and condensate return system.

Alternative Fuels

The production of steam is the primary function of the Package Boilers. Natural gas is the lowest GHG-emitting fossil fuel that can be used for steam production. Natural gas also serves as the ammonia process used in several plant operations.

Step 2 – Eliminate Technically Infeasible Options

CCS technologies were identified in Step 1 as potentially feasible control alternatives. Although there are a number of completed or planned CCS projects, they are generally subsidized with government funding and are considered in the demonstration phase of the technology. The specific carbon capture technologies discussed in Step 1 are also in the developmental stage and none have been demonstrated in practice and generally rely on government subsidies for demonstration-phase funding.

Although the capture technologies for CO_2 are developing, after CO_2 is separated (captured), it must be prepared for beneficial reuse or transport to a sequestration or storage facility, if a storage facility is not locally available for direct injection. In order to transport CO_2, it must be compressed and delivered via pipeline to a storage facility.

According to a U.S. Department of Energy report, there is currently no enhanced oil recovery (EOR) underway in Alaska[39]. The report speculates that as the North Slope oil fields mature, EOR may be used to economically recover more reserves. The North Slope oil field is over 600 miles from the Agrium facility in Nikiski, Alaska. Closer to the facility, the Cook Inlet is a mature offshore oil field approximately 140 miles from Nikiski. Given that there is currently no EOR in Alaska and that the closest candidate oilfield would require extensive underwater piping, EOR is excluded from the evaluation of CCS options for the project.

Without a market to use the recovered CO_2, the material would instead require sequestration, or permanent storage. Sequestration of CO_2 is generally accomplished via available geologic reservoirs that must be either local to the point of capture, or accessible via pipeline to enable the transportation of recovered CO_2 to the permanent storage location. The United States 2012 Carbon Utilization and Storage Atlas (Fourth Edition published by the U.S. Department of Energy, Office of

[39] Basin Oriented Strategies for CO_2 Enhanced Oil Recovery, USDOE, March 2005

Fossil Energy) identifies an extensive saline aquifer directly below Nikiski as being "screened, high sequestration potential;" however, this area has not had detailed evaluation for CO_2 sequestration and lies in a fault zone. This saline aquifer is not deemed to be suitable for CCS at this time. In addition, CCS technologies for the ammonia production industry are considered to be in the research phase [1]. Therefore CCS is considered to be currently technically infeasible and is eliminated from further consideration for GHG BACT.

Furthermore, a review of the RBLC database from natural gas-fired heaters and boilers indicates that add-on control technologies have never been required or applied to reduce GHG emissions.

The Package Boilers are used to provide process steam to the plant. Significant process modifications would be required to convert the Package Boilers to CHP. These modifications would alter the purpose of the Package Boilers therefore CHP is considered to be technically infeasible. The plant already utilizes Solar Turbines to generate electricity for the plant.

The production of steam is the primary function of the Package Boilers. Natural gas is the lowest GHG-emitting fossil fuel that can be used for steam production. Because natural gas is an inherently low GHG emitting fuel and it is inherently available to the plant, alternative fuel firing is considered technically infeasible for the Package Boilers.

Step 3 – Rank Remaining Control Technologies by Control Effectiveness

The only remaining control technology is Energy Efficient Design, therefore no ranking is necessary.

Step 4 – Evaluate Most Effective Controls and Document Results

The only remaining control technology is Energy Efficient Design, therefore no further evaluation is necessary.

Step 5 – Select BACT

Agrium proposes the use of Energy Efficient Design as GHG BACT for the Package Boilers. Agrium proposes the following as energy efficient design parameters for the Package Boilers:

- Air inlet controls, heat recovery and condensate recovery;
- Package Boilers shall be designed to achieve a thermal efficiency of 80%; and
- CO_2 emissions from the package boilers shall not exceed 59.61 MMcf of natural gas combusted or 376,500 tpy (combined).

4.2 Waste Heat Boilers (Units 50, 51, 52, 53, and 54)

4.2.1 BACT Evaluation for GHG Emissions from the Waste Heat Boilers

Step 1 – Identify All Available Control Technologies

Options for the control of GHG emissions from the Waste Heat Boilers include:

Carbon Capture and Sequestration (CCS)

A detailed description of CCS is discussed in the GHG BACT Analysis for the Package Boilers.

Cogeneration/Combined Heat and Power (CHP)

Combined Heat and Power (CHP) or Cogeneration involves the production of useable heat and electricity from a single source. The use of CHP results in significant energy gains. Significant reductions in GHG emissions are achieved by recovering energy which would otherwise go to waste.

Energy Efficient Design

Energy efficient designs can reduce the natural gas required to produce the necessary amount of steam. Therefore emissions of GHGs are reduced. Energy efficient design elements for boilers

[1] Carbon Dioxide Capture and Storage in the Nitrogen and Syngas Industries," R. Strait and M. Nagvekar of KBR Technology, Nitrogen+Syngas, January/February 2010.

include combustion control optimization, tuning, instrumentation and controls, economizer, blowdown heat recovery, and condensate return system.

Alternative Fuels

Natural gas is the lowest GHG-emitting fossil fuel that can be used for steam production.

Step 2 – Eliminate Technically Infeasible Options

As discussed in the GHG BACT Analysis for the Package Boilers, CCS is not a technically feasible control technology. Therefore CCS is removed from consideration as a possible control technology.

The Waste Heat Boilers are used to recover energy from the Solar Turbines to provide process steam to the plant. In combination with the Solar Turbines these units are considered to be CHP.

The production of steam is the primary function of the Waste Heat Boilers. Natural gas is the lowest GHG-emitting fossil fuel that can be used for steam production. Because natural gas is an inherently low GHG emitting fuel and it is inherently available to the plant, alternative fuel firing is considered technically infeasible for the Waste Heat Boilers.

Step 3 – Rank Remaining Control Technologies by Control Effectiveness

The highest-ranking control technology is combined heat and power.

Step 4 – Evaluate Most Effective Controls and Document Results

The highest-ranking control technology is combined heat and power, therefore no further evaluation is necessary.

Step 5 – Select BACT

Agrium proposes the use of combined heat and power as GHG BACT for the Waste Heat Boilers. The 3-hour average CO_{2e} emissions from each waste heat boiler will be limited to 59.61 tons per million cubic foot (MMcf) and the combined CO_{2e} emissions from all waste heat boilers will be limited to 121,500 tons per year.

4.3 Solar Turbines/Generator Sets (Units 55, 56, 57, 58, and 59)

4.3.1 BACT Evaluation for GHG Emissions from the Solar Turbines/Generator Sets

Step 1 – Identify All Available Control Technologies

Options for the control of GHG emissions from the Solar Turbines include:

Carbon Capture and Sequestration (CCS)

A detailed description of CCS is discussed in the GHG BACT Analysis for the Waste Heat Boilers.

Cogeneration/Combined Heat and Power (CHP)

Combined Heat and Power (CHP) or Cogeneration involves the production of useable heat and electricity from a single source. The use of CHP results in significant energy gains. Significant reductions in GHG emissions are achieved by recovering energy which would otherwise go to waste.

Alternative Fuels

The generation of electricity is the primary function of the Solar Turbines. Natural gas is the lowest GHG-emitting fossil fuel that can be used for combustion turbines.

Step 2 – Eliminate Technically Infeasible Options

As discussed in the GHG BACT Analysis for the Waste Heat Boilers, CCS is not a technically feasible control technology. Therefore CCS is removed from consideration as a possible control technology.

The Solar Turbines are used to generate electricity for the plant. By recovering energy from the Solar Turbines through the Waste Heat Boilers, the unit falls within the scope of combined heat and power.

Step 3 – Rank Remaining Control Technologies by Control Effectiveness

The only remaining control technology is combined heat and power.

Step 4 – Evaluate Most Effective Controls and Document Results

The only remaining control technology is Energy Efficient Design, therefore no further evaluation is necessary.

Step 5 – Select BACT

Agrium proposes the use of combined heat and power as GHG BACT for the Solar Turbines. The 3-hr average CO_2e emissions from each Solar Turbine will be limited to 59.61 tons/MMcf and the combined CO_2e emissions from all Solar Turbines will be limited to 135,000 tons per year.

5. BEST AVAILABLE CONTROL TECHNOLOGY (BACT) ANALYSIS UPDATES

This section of the analysis is provided as a supplement to the BACT analyses performed for the original PSD Construction Permit application for KNO, submitted in October 2014. This section provides an evaluation of RACT/BACT/LAER Clearinghouse (RBLC) results associated with permits issued since the original PSD permit was issued in January 2015. Based on the information provided below, KNO concludes that no new permits have been issued since the issuance of AQ0083COT06 that contain BACT limits that are inconsistent with the BACT determinations made for KNO as part of the original PSD Construction Permit.

Tables summarizing RBLC entries since the issuance of AQ0083COT06 are provided in Attachment B to this request. The results of all three analyses for emission units contained in the KNO PSD permit are summarized below:

5.1 Ammonia Tank Flare (Unit 11)

Ammonia Tank Flare (Unit 11) – One permit was identified with permit limits for ammonia tank flare emissions that was issued since January 2015. This permit was issued to Midwest Fertilizer Company LLC (RBLC ID IN-0263), and contained limits for PM10, PM2.5, NOx, CO, VOC, and CO2e. Emissions of all pollutants were controlled using “pilot and purge gas shall be natural gas, and process flaring minimization practices; operated with a flame present at all times; continuously monitored."

Emission limits established are consistent with standard emission factors for flares and natural gas combustion and are consistent with RBLC BACT determinations utilized as a basis for the KNO permit. The BACT approach and emission factors contained in this permit are consistent with those contained in the KNO permit.

5.2 Primary Reformer (Unit 12)

Two permits were identified that have been issued since January 2015. The first was a permit issued to Topchem Pollock, LLC (RBLC ID LA-0306), which was issued 20 December 2016 and updated 8 August 2017. This permit contains limits for CO and $PM_{2.5}$ that were based on good combustion practices, with a limit for CO based on an emission rate of 0.0824 lb/mmBtu of natural gas combusted and a $PM_{2.5}$ emission rate of 0.00745 lb/mmBtu of natural gas combusted. This is consistent with the control technology selected as BACT for the Primary Reformer for KNO and is based on consistent emission factors for CO and $PM_{2.5}$. The Topchem permit also contained a limit for CO_{2e} emissions that was established at 363,287 tons per year using control technology described as “energy efficiency measure”. The ton per year limit established in this permit is consistent with the emission factor utilized for CO_{2e} emissions in the KNO permit.

The other permit issued was for the Agrium facility in Borger, Texas (RBLC ID TX-0814). This permit contained a limit for CO_{2e} emissions of 564,019 tons per year utilizing “good engineering practices”. This is consistent with the approach utilized by KNO.

5.3 Startup Heater (Unit 13)

KNO identified several permits issued to facilities with startup heaters that have been issued since January 2015. This includes Gerdau Macsteel, Inc. – Gerdau Macsteel Monroe (RBLC ID MI-0438), Topchem Pollock LLC (RBLC ID LA-0306), Midwest Fertilizer Company LLC (RBLC ID IN-0263), Lake Charles Methanol LLC (RBLC ID LA-0305), Indeck Niles, LLC (RBLC ID MI-0423 (draft)), and Holland Board of Public Works (RBLC ID MI-0424). BACT controls for nearly all of these units were established as good combustion practices and the use of natural gas. Emission limits corresponding to BACT determinations for startup heaters relate to standard emission factors for natural gas combustion.

The NOx BACT control requirement for the unit identified in RBLC ID MI-0438, revised February 2019, was established as low NOx burners in addition to the use of natural gas and good combustion practices. The Michigan LAER/BACT requiring low NOx burners is for a new unit, not yet constructed, and the low NOx burners are being incorporated into the design parameters. The startup heater at Agrium KNO is an existing unit and was not designed with low NOx burner technology. During the permitting of AQ0083CPT06, there were other RBLC entries containing low NOx burners as a required control, however; the Agrium KNO BACT for NOx was determined to be limited use of the unit at 200 hours per year and an emission limit of 0.098 lb/MMBtu.

The BACT approach and emission limits contained in these permits are consistent with limits incorporated into, and evaluated against, during the permitting of AQ0083CPT06.

5.4 CO_2 Vent (Unit 14)

KNO identified two ammonia plant permits with CO_2 Vent Stack emissions that have been added to RBLC since January 2015. Each is briefly discussed below:

- Agrium US permit for facility in Borger, Texas (RBLC ID TX-0814). This permit limits CO_{2e} emissions to 843,150 tons per year using "good combustion practices".
- Topchem Pollock, LLC permit (RBLC ID LA-0306) with limit of 162,511 tons per year based on the use of pipeline quality natural gas and good combustion practices.

The BACT approach and technology are consistent with RBLC permit limits that existed at the time the KNO PSD permit was issued, and is consistent with limits set in the final KNO permit.

5.5 Small Flare and Emergency Flare (Units 22 and 23)

KNO identified three permits with BACT limits that were issued to sources with flares since the first January 2015. These facilities were Topchem Pollock, LLC (RBLC ID LA-0306), Midwest Fertilizer Company LLC (RBLC ID IN-0263), and Agrium US, Inc. (RBLC ID TX-0814). These permits included limits for PM_{10}, $PM_{2.5}$, NOx, CO, VOC, and CO_{2e}. Emissions of all pollutants were controlled using BACT described as "pilot and purge gas shall be natural gas", correct flare design, good combustion practices, process flaring minimization practices, and operation of flares with a flame present at all times. Emission limits established are consistent with standard emission factors for flares and natural gas combustion.

The BACT control measures and corresponding emission limits are consistent with BACT control measures and emission factors utilized by KNO for these units.

5.6 Urea Granulation (Units 35 and 36)

KNO identified one permit issued since January 2015 with limits established for urea granulation operations. This permit was issued to Midwest Fertilizer Company LLC (RBLC ID IN-0263). This permit contained limits for PM, PM_{10}, and $PM_{2.5}$ of 0.163 pounds per ton of material for a three-hour average. This limit was established on the basis of a wet scrubber. Although this permit was issued since the issuance of Agrium KNO's permit, this limit was contained in an earlier permit to Midwest Fertilizer Company LLC that was included in the ADEC Technical Analysis Report (TAR) that accompanied the final permit. Thus, no new emission limits for urea granulation operations have been established since the KNO permit was issued.

5.7 Cooling Tower (Unit 40)

Several BACT determinations for cooling towers have been made since January 2015, including cooling towers located at ammonia fertilizer manufacturing facilities. For particulate matter, the required BACT control technology is the use of high efficiency drift eliminators, with drift rates set as low as 0.0005%. These determinations are consistent with BACT determinations at the time the KNO BACT analysis was performed. Thus, no more stringent emission limits for BACT have been established for cooling towers since the KNO permit was issued.

As noted in the original KNO BACT analysis, the KNO cooling tower is a cross-flow tower that cannot achieve the lower drift elimination rates that counter flow cooling towers can achieve. Thus, no new information exists to change the BACT determination made for the KNO facility.

5.8 UF-85 Storage Tank (Unit 41A)

One permit has been issued since January 2015 with a BACT limit for urea storage tanks. This permit was issued to Toyota Motors Motor Vehicle Assembly Plant (TX-0846) and contained no numerical emission limitation. The BACT for these units was identified as the tank to be a white fixed roof storage tank equipped with a submerged fill tank. The KNO BACT is the most stringent limitation, with VOC emissions limited to 0.00004 lb/hr. Thus, no new information exists to change the BACT determination made for the KNO facility.

5.9 MDEA Storage Tanks (Units 41B and 41C)

No permits since the issuance of AQ0083CPT06 were identified with BACT emission limits specific to MDEA storage tanks. One permit has been issued since January 2015 with a BACT limit for storage tanks under process code 42.009. This permit was issued to Toyota Motors Motor Vehicle Assembly Plant (TX-0846) and was specific to storage tanks storing very low vapor pressure non gasoline automotive fluids – gear lube, engine oil, diesel fuel, urea, ATF, etc. Thus, no new information exists to change the BACT determination made for the KNO facility.

5.10 Urea Ship Loading (Unit 47)

No permits since the issuance of AQ0083CPT06 were identified with BACT emission limits for ship loading operations.

5.11 Urea Material Handling Units (Unit 47A, 47B, 47C, and 47D)

One permit was identified with permit limits for urea handling operations that was issued since January 2015. This permit was issued to Midwest Fertilizer Company LLC (RBLC ID IN-0263) for truck and rail loading operations, and contained limits for PM, PM_{10}, and $PM_{2.5}$. BACT was determined to be the use of baghouse dust collectors, and emissions were limited to 0.15 pounds per hour for PM, PM_{10}, and $PM_{2.5}$. This RBLC entry corresponds to a revised BACT limit for truck and rail loading operations originally included in RBLC ID IN-0180, permitted June 4, 2014 and was available for consideration during the permitting of AQ0083CPT06. The use of baghouse dust collectors is consistent with the BACT determination for KNO's urea handling units permitted in AQ0083CPT06.

5.12 Diesel Well Pump (Unit 65)

Several permits have been issued since January 2015 with BACT limits for small diesel-fired internal combustion engines. KNO did not document the RACT/BACT/LAER Clearinghouse (RBLC) results to identify the permits issued since January 2015. The technology and air quality considerations made as a part of the initial permit review for small internal combustion engines, under process type 17.210, remain the same. BACT for nearly all of the units evaluated initially between 2004 and 2014, as well as those issued since, is good combustion practices, occasionally coupled with limited use requirements. KNO's original BACT is consistent with the more recent determinations included in RBLC. Thus, no new information exists to change the BACT determination made for the KNO facility.

5.13 Gasoline Fire Pump (Unit 66)

Several permits have been issued since January 2015 with BACT limits for internal combustion engines identified as fire pumps. KNO did not document the RACT/BACT/LAER Clearinghouse (RBLC) results to identify the permits issued since January 2015. The technology and air quality considerations made as a part of the initial permit review for small internal combustion engines, under process type 17.200, remain the same. BACT for nearly all of the units evaluated initially between 2004 and 2014, as well as those issued since, is good combustion practices, occasionally coupled with limited use requirements. KNO's original BACT is consistent with the more recent ones included in the RBLC. Thus, no new information exists to change the BACT determination made for the KNO facility.

APPENDIX A RBLC SUMMARY

APPENDIX B COST ESTIMATES

ERM has over 160 offices across the following countries and territories worldwide

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