Selective Catalytic Reduction (SCR)
Technical Feasibility
For
M.R. Young Station

I. Introduction

On July 27, 2006 a Consent Decree was entered by the United States District Court for the District of North Dakota for Civil Action No. 1:06-CV-034, United States of America and the State of North Dakota versus Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative. The Consent Decree resolved alleged violations of the Federal Clean Air Act and the North Dakota Air Pollution Control Rules (NDAC 33-15) including the Prevention of Significant Deterioration Rules (NDAC 33-15-15). Section V, Paragraph 65, of the Consent Decree required Minnkota Power Cooperative and Square Butte Power Cooperative (hereafter Minnkota) to submit to the Department for review and approval, a nitrogen oxides (NO_x) top-down Best Available Control Technology (BACT) analysis for the two existing units at the M.R. Young Station. The Consent Decree required Minnkota to evaluate various technologies including selective catalytic reduction (SCR), selective noncatalytic reduction (SNCR), over-fire air (OFA) and rich reagent injection (RRI). Minnkota must also submit any additional information requested by the Department or the U.S. Environmental Protection Agency (hereafter EPA) which is pertinent to the BACT determination. On October 9, 2006, the Department received the required BACT analyses.

Under Section III, paragraphs 23 and 24 of the Consent Decree, the BACT analysis must be made in accordance with the provisions of Chapter B of EPA's New Source Review Workshop Manual[9] (hereafter NSR Manual). As discussed in the NSR Manual, the steps for conducting a BACT analysis using the "top down" approach are as follows:

Step 1: Identify All Control Technologies.

- List is comprehensive.

Potentially applicable control alternatives can be categorized in three ways.

- Inherently Lower-Emitting Processes/Practices, including the use of materials and production processes and work practices that prevent emissions and result in lower "production-specific" emissions; and

- Add-on Controls, such as scrubbers, fabric filters, thermal oxidizers and other devices that control and reduce emissions after they are produced.

- Combinations of Inherently Lower Emitting Processes and Add-on Controls. For example, the application of combustion and post-combustion controls to reduce NO_x emissions at a gas-fired turbine.

The top-down BACT analysis should consider potentially applicable control techniques from all three categories. Lower-polluting processes should be considered based on demonstrations made on the basis of manufacturing identical or similar products from identical or similar raw materials or fuels. Add-on controls, on the other hand, should be considered based on the physical and chemical characteristics of the pollutant-bearing emission stream. Thus, candidate add-on controls may have been applied to a broad range of emission unit types that are similar, insofar as emissions characteristics, to the emissions unit undergoing BACT review.

Step 2: Eliminate Technically Infeasible Options.

- A demonstration of technical infeasibility should be clearly documented and should show, based on physical, chemical, and engineering principles, that technical difficulties would preclude the successful use of the control option on the emissions unit under review.

The NSR Manual[9] provides guidance for determining whether a control option is technically infeasible. Two concepts are important in making this determination, "availability" and "applicability". A technology is considered "available" if it can be obtained through commercial channels or is otherwise available within the common sense meaning of the word. An available technology is "applicable" if it can reasonably be installed and operated on the source type under consideration. A technology that is available and applicable is considered technically feasible.

Regarding "availability" the NSR Manual[9] states:

"A control technique is considered available, within the context presented above, if it has reached the licensing and commercial sales stage of development. A source would not be required to experience extended time delays or resource penalties to allow research to be conducted on a new technique. Neither is it expected that an applicant would be required to experience extended trials to learn how to apply a technology on a totally new and dissimilar source type. Consequently, technologies in a pilot scale testing stages of development would not be considered available for BACT review."

With respect to "applicability" the NSR Manual[9] states:

"Technical judgment on the part of the applicant and the review authority is to be exercised in determining whether a control alternative is applicable to the source type under consideration. In general, a commercially available control option will be presumed applicable if it has been or is soon to be deployed (e.g., is specified in a permit) on the same or a similar source type. Absent a showing of this type, technical feasibility would be based on examination of the physical and chemical characteristics of the pollutant-bearing gas stream and comparison to the gas stream characteristics of the source types to which the technology had been applied previously. Deployment of the control technology on an existing source with similar gas stream characteristics is generally sufficient basis for concluding technical feasibility barring a demonstration to the contrary.

For process-type control alternatives the decision of whether or not it is applicable to the source in question would have to be based on an assessment of the similarities and differences between the proposed source and other sources to which the process technique had been applied previously. Absent an explanation of unusual circumstances by the applicant showing why a particular process cannot be used on the proposed source the review authority may presume it is technically feasible.

In practice, decisions about technical feasibility are within the purview of the review authority. Further, a presumption of technical feasibility may be made by the review authority based solely on technology transfer. For example, in the case of add-on controls, decisions of this type would be made by comparing the physical and chemical characteristics of the exhaust gas stream from the unit under review to those of the unit from which the technology is to be transferred. Unless significant differences between source types exist that are pertinent to the successful operation of the control device, the control option is presumed to be technically feasible unless the source can present information to the contrary."

Step 3: Rank Remaining Control Technologies By Control Effectiveness

This includes:

- control effectiveness (percent pollutant removed);
- expected emission rate (tons per year);

- expected emission reduction (tons per year);
- energy impacts (Btu, KW-hr);
- environmental impacts (other media and the emissions of toxic and hazardous air emissions); and
- economic impacts (total cost effectiveness and incremental cost effectiveness).

Step 4: Evaluate Most Effective Controls and Document Results

- Case-by-case consideration of energy, environmental, and economic impacts.
- If the most effective option is not selected as BACT, evaluate next most effective control option.

Step 5: Select BACT

- Most effective option not rejected is BACT and establish emission limit or work practice standard.

The Department solicited public comments on its preliminary BACT determination for nitrogen oxides (NO_x) controls at the M.R. Young Station (MRYS). Comments from the Environmental Protection Agency and several environmental groups disagreed with the conclusion that high dust SCR (HDSCR), low dust SCR (LDSCR) and tail end SCR (TESCR) were technically infeasible. Comments from other parties agreed with the Department's preliminary determination. The Department has evaluated the comments and has reaffirmed its preliminary

determination that HDSCR is technically infeasible. However, the Department now believes LDSCR and TESCR are technically feasible.

This document explains the Department's current views on technical feasibility. This document does not represent a final Department action. The Department will make its final BACT determination after the remaining steps for conducting a BACT analysis have been completed. Minnkota will be required to submit additional information necessary for the Department to make its final BACT determination including an evaluation of the cost of LDSCR and TESCR.

II. High Dust Selective Catalytic Reduction (HDSCR)

HDSCR, or conventional SCR, refers to an SCR system that is installed prior to any air pollution control equipment and usually between the economizer outlet and air heater inlet. HDSCR has been installed on many pulverized coal and cyclone boilers firing bituminous and subbitiminous coal in the United States.

A. Public Comments

1. NDDH's Technical Feasibility Analysis of High Dust SCR is Incorrect and Based Upon Flawed Data

The NSR Manual states "A demonstration of technical infeasibility is based on a technical assessment considering physical, chemical and engineering principles,

and/or empirical data showing that the technology would not work on the emissions unit under review, or that unresolvable technical difficulties would preclude the successful deployment of the technique."

The Department asked EPA's consultant, Mr. Roger Christmann, if he was aware of any installation in the world where HDSCR had been applied to a facility with as high of sodium loading as at MRYS. Mr. Christmann indicated no. This indicates that there has never been a design established for a flue gas with the chemical characteristics found at MRYS. Simple mathematics prepared by the Department shows that the flue gas at MRYS is much higher in sodium and other catalyst deactivation chemicals than other power plant flue gases. EPA seems to ignore the fact that the sodium at MRYS is the soluble form (organically associated) which is a more potent catalyst deactivation chemical than the insoluble (inorganically associated) form found in other coals. EPA tries to dismiss this showing by ratioing the loading of Powder River Basin (PRB) subbituminous coal to bituminous coal without indicating the actual loading. The Department showed the actual loading (lb/dscf and lb/wscf) as well as the ratio to other facilities. When you start out with a very small loading, as is the case with bituminous coal, a large ratio for subbituminous coal also gives you small loading. As EPA's own consultant points out, SCR has never been applied to sodium loading as high as at MRYS.

Minnkota and its consultants have documented very well the effect of soluble sodium on an SCR catalyst. Although the Coyote testing did not provide any deactivation rate data for high soluble sodium North Dakota lignite, it did show that an HDSCR design for subbituminous coal will probably not work successfully with North Dakota lignite. As Sargent and Lundy pointed out, there is no known solution for the soluble alkalis such as the soluble sodium and potassium found in North Dakota lignite. EPA ignores the chemical differences between Texas lignite and North Dakota lignite.

With respect to the catalyst vendor "guarantees", all of the vendors that Minnkota contacted indicated that pilot scale testing was either required or should be done prior to applying high dust SCR technology to a North Dakota lignite-fired boiler. Minnkota has provided information that indicates the potential for greatly reduced catalyst life due to the chemical characteristics of the flue gas. Although two vendors indicated a catalyst life which the Department would consider as a "successful application" of HDSCR technology at MRYS, others did not give such an indication. All vendors indicated the flue gas temperature problems (too hot or too cold) must be resolved for the application of HDSCR to be successful. No solution to this problem has been found at this time. EPA has indicated that some of the vendors may have been prompted by Minnkota, or its consultants, to indicate that pilot testing should be done. Even if some vendors may have been "prompted" to make these statements, it is irrelevant since the vendors could have chosen not to make the statement.

Although the Texas CEQ has determined that HDSCR is technically feasible for Texas lignite, the chemical constituents of North Dakota lignite that affect the feasibility of HDSCR are quite different. The State of Louisiana recently determined that HDSCR was not technically feasible for an activated carbon plant because of the flue gas characteristics of the lignite used in the process.

The NSR Manual[9] indicates that an add-on control technology is only technically feasible if it can lead to "successful operation" or "successful deployment." The Department has indicated that anything less than 10,000 hours of catalyst life would not be successful operation of the SCR system and thus technically infeasible. Kling et. al.[2] conducted pilot and bench sale testing of SCR catalysts when subjected to flue gas from the combustion of biomass. The testing was conducted using three different types of catalyst. Catalyst Type A was typical of that used for coal-fired boilers, Type B was a "bio-optimized" catalyst with an increased vanadium content and Type C had a very high vanadium content. Kling[2], and later Zheng et. al[3], have concluded that it is the alkali aerosols that are less than or equal to 0.1 micrometers that cause most of the catalyst deactivation. In North Dakota lignite, the alkali metals are generally associated with the organic matter of the lignite while in other coals the alkaline constituents are associated with the inorganic portion of the coal (e.g. clays). The combustion of the organically associated alkaline elements causes them to vaporize; when they condense, they form submicron aerosols. The combustion of inorganically

associated alkalis causes only a small portion to vaporize. Minnkota has supplied information that indicates these condensed alkali aerosols have a mass mean diameter of approximately 0.1 micrometers. Therefore, 50% of the aerosols would be less than 0.1 micrometers in size on a mass basis. The average mass of sodium oxide and potassium oxide emitted from the MRYS boilers was calculated at 3.05×10^{-5} lb/dscf (524 mg/Nm^3) and 9.01×10^{-6} lb/dscf (155 mg/Nm^3), respectively.

Crespi[6] has provided data that suggests potassium oxide is approximately twice as potent a catalyst deactivation chemical on a molar basis (1.3 times on a mass basis) than sodium oxide. The equivalent potassium oxide emission rate for MRYS based on this data would be 558 mg/Nm^3. The aerosols are most likely in the sulfate form.[5] This would lead to an equivalent potassium sulfate emission rate of 1034 mg/Nm^3.

Kling[2] found a deactivation rate of 21-52% over 1500 hours for fuel made up of tree bark and 30% demolition wood waste. This fuel has a potassium chloride loading of 16.7 mg/Nm^3 and a sodium chloride loading of 5.8 mg/Nm^3. The Kling[2] results were for aerosols with an aerodynamic diameter of less than 0.1 micrometers. If all of the sodium and potassium in lignite vaporizes, 50% of the total loading would be less than or equal to 0.1 micrometers or 517 mg/Nm^3 of equivalent potassium sulfate. Zheng[3] has suggested that potassium chloride is two and one half times more potent catalyst poison than potassium sulfate (0.4%

per day versus 1% per day). An equivalent loading of sodium and potassium for a HDSCR at MRYS as potassium chloride would be 207 mg/Nm^3. This loading is nearly 10 times that of the Kling[2] testing. The Kling[2] results suggest 2,885-7,140 hours until 100% deactivation. The higher loading at the North Dakota facilities suggests a much higher deactivation rate and a shorter catalyst life.

Zheng et. al.[3] found a catalyst deactivation rate of 0.4% per day for a potassium sulfate. The testing was conducted using a concentration of 20-30 mg/Nm^3 of potassium sulfate with a mass mean diameter of 0.55 micrometers. Although data is not available to determine the loading of aerosols with a diameter less than 0.55 micrometers, a comparison to the fraction less than 0.1 micrometers indicates a concentration 17-26 times larger than the concentration in Zheng's tests. The 0.4% deactivation rate per day is equivalent to 6000 hours at 100% deactivation. For a HDSCR, the flue gas from the MRYS would likely produce a higher deactivation rate.

The recent testing by Kling[2] and Zheng[3] indicate that it is unlikely that a HDSCR will achieve 10,000 hours of catalyst life when combusting Center lignite at MRYS. In fact, the catalyst life could be only a few thousand hours as suggested by the pilot scale testing at the Coyote Station.

2. MRYS Temperature Variation Issue Related to HDSCR

EPA has indicated the temperature problems with HDSCR can be resolved.

Mr. Steve Moorman of Babcock and Wilcox in a July 18, 2007 email stated the resolution of the temperature problem would require a technical feasibility analysis of a "very complex nature" to determine if boiler modifications could bring furnace exit gas temperatures into the range needed for compatibility with operation of HDSCR. Modifications outside of the boiler may solve the temperature problem; however, a study would be required. EPA's statement that the technical issues with the temperature issue can be resolved appears to be premature.

The email also states "Our budget estimate to complete this study is $275,000 to $400,000 including the performance test, project management costs and travel expenses. We project the study will require 20 to 24 weeks to complete including the time to run the performance tests." The NSR Manual[9] states: "A control technique is considered available, within the context presented above, if it has reached the licensing and commercial sales stage of development. A source would not be required to experience extended time delays or resource penalties to allow research to be conducted on a new technique. Neither is it expected that an applicant would be required to experience extended trials to learn how to apply a technology on a totally new and dissimilar source type. Consequently,

technologies in the pilot scale testing stages of development would not be considered available for BACT review." The Department considers the time and money necessary to determine if the temperature problems can be overcome to be excessive.

3. EPA's Conclusion on HDSCR

When considering application of HDSCR to a cyclone boiler burning North Dakota lignite, the MRYS is considered a new source type. In the past, EPA has recognized cyclone boilers, and more generally slag tap furnaces, that burn lignite from North Dakota, South Dakota and Montana as a separate source category for NO_x emissions in the New Source Performance Standards, Subparts D and Da. This separate category was established primarily based on the use of high sodium lignite. Not until EPA developed a fuel and furnace neutral standard was this category replaced. The replacement of this category was apparently done without an evaluation of the flue gas characteristics of North Dakota lignite. The NSR Manual[9] states "Add-on controls, on the other hand, should be considered based on the physical and chemical characteristics of the pollutant-bearing emission stream. Thus, candidate add-on controls may have been applied to a broad range of emission unit types that are similar, insofar as emissions characteristics, to the emission unit undergoing BACT review." (NSR Manual, Chapter B, Section IV.A).

Minnkota has demonstrated that the flue gas characteristics at MRYS are different from other coal-fired boilers where HDSCR has been applied. The NSR Manual states "A source would not be required to experience time delays or resource penalties to allow research to be conducted on a new technique. Neither is it expected that an applicant would be required to experience extended trials to learn how to apply a technology on a totally new and dissimilar source type." (Chapter B, Section IV.B). Minnkota is not required to conduct extensive and expensive feasibility analyses for modifying the boiler to correct temperature problems that make HDSCR infeasible.

EPA has indicated that catalyst regeneration is a viable option (that is currently used in practice) for restoring catalyst life either in-situ, on-site, or off-site water washing. EPA cites a PowerPoint presentation at the 2007 NO_x Round Table and Expo by Reinhold Environmental Limited as evidence that this technique is available. DOJ's consultant, Mr. Hans Hartenstein, also made a presentation at the referenced Expo. In Mr. Hartenstein's presentation the following statement is made "Regeneration = Removal of catalyst poisons plus restoration of catalytically active ingredients - can typically not be done in-situ or on-site, but should be done off-site to ensure required close process control." EPA may be referring to "rejuvenation" of a catalyst for which Mr. Hartenstein states "Removal of catalyst poisons without the need for replenishing catalytically active compounds - can **sometimes** [emphasis added] be done in-situ, but is most commonly done either on-site or off-site." These statements were also made by

Ehrnschwender and Holsccher at the February 2008 Expo (Considerations for Catalyst Deactivation and Regeneration When Firing Biomass). Minnkota and its consultants have addressed this issue by stating "Regarding the contention of Hartenstein, there is extremely limited experience with in-situ catalyst cleaning on coal-fired units. ENBW in Germany developed this technique, but it has never had a commercial success. It has also never been used for blinded or chemically poisoned catalyst, but only for mechanically plugged catalyst." There is no evidence regarding the effectiveness of washing to rejuvenate an SCR catalyst on the MRYS. Pilot scale testing would be necessary to determine the feasibility of this catalyst maintenance technique.

4. <u>The NDDH BACT Determination Incorrectly Applies the Concept of Pilot Testing in EPA's NSR Manual to Conclude that SCR is not Technically Feasible</u>

EPA states that "For determining whether a control option is available, EPA's NSR Manual does not describe the comparison of gas stream characteristics between the source under review and other sources."

There has never been SCR technology applied to a boiler that combusts North Dakota lignite. EPA has recognized in the past, that cyclone boilers, such as those at Minnkota, that burn lignite from North Dakota is a separate source category for NO_x emission limits under the New Source Performance Standards, Subpart D and Da. Chapter B, Section IV.A, Identify Alternative Emission

Control Techniques **(Step 1)** [emphasis added] states "The top-down BACT analysis should consider potentially applicable control techniques from all three categories. Lower polluting processes should be considered based on demonstrations made on the basis of manufacturing identical or similar products from identical or similar raw materials or fuels. **Add-on controls, on the other hand, should be considered based on the physical and chemical characteristics of the pollutant-bearing emission stream. Thus, candidate add-on controls may have been applied to a broad range of emission unit types that are similar, insofar as emissions characteristics, to the emissions unit undergoing BACT review.**" [emphasis added] Clearly, identification of control options under Step 1 must take into account the flue gas characteristics. If the flue gas characteristics can be shown to prevent successful application of the technology to the source under view, the technology is not identified as "potentially applicable" to the source in Step 1 and is therefore not commercially available under Step 2. Minnkota has shown that the flue gas characteristics for a HDSCR at MRYS are different from that at any other coal-fired power plant where SCR has been installed. Mr. Roger Christmann, EPA consultant, stated that he was not aware of any power plant where HDSCR had been applied with as high of sodium loading as MRYS.

HDSCR technology designed for other coal-fired power plants is not applicable to a North Dakota lignite-fired unit and there is no commercially available design. Pilot scale testing would be necessary to show whether HDSCR can work

successfully. As Sargent and Lundy (S&L) pointed out, there are no known solutions for the catalyst surface masking and catalyst deactivation caused by the soluble alkalis (Na_2O and K_2O) found in North Dakota lignite. S&L indicated that some thresholds or limits are yet to be defined for HDSCR involving ash with greater than 2% Na_2O and greater than 1% K_2O. Ash from MRYS contains an average 4.4% Na_2O and 1.3% K_2O. The Na_2O can be as high as 13% and K_2O as high as 7%. Any pilot scale testing would be used to obtain data on the soluble alkalis and ash characteristics and compare the findings with experience on Powder River Basin Coal.

The pilot scale testing for a HDSCR would not be for optimizing an existing applicable control technology. It would be for researching solutions for the high soluble alkalis and possibly designing a new SCR system for a new and dissimilar source category.

5. <u>The NDDH BACT Determination Frustrates the Technology Forcing Function of the BACT that was Intended by Congress.</u>

MRYS is a different source category based on its flue gas characteristics at a HDSCR location. The Department has taken the position that the flue gas characteristics at the MRYS would preclude the successful application of existing HDSCR technology. Decisions regarding technical feasibility are based on the flue gas characteristics, not whether it has been applied to a coal-fired boiler or

some other general source category. We believe Congress never intended forcing a technology on a source when there is a low probability of successful deployment of that technology.

B. Conclusions

Recent testing by Kling[2] and Zheng[3] suggest a low probability of achieving successful application of HDSCR technology by MRYS. The high concentration of sodium and potassium in the flue gas will rapidly deactivate the catalyst. The results suggest much less than 10,000 hours of catalyst life which the Department believes is necessary for successful application of HDSCR.

Minnkota has supplied data indicating temperature problems (both too high and too low) at the location of HDSCR which will affect the catalyst life. Babcock and Wilcox has estimated that a study of the temperature problems could take up to 24 weeks and cost up to $400,000. The NSR manual indicates that a company is not expected to experience extended trials to learn how to apply a technology.

Based on the flue gas characteristics at the location of the high dust SCR and the temperature problems (both too high and too low), the Department does not consider HDSCR to be technically feasible for MRYS.

III. Tail End SCR and Low Dust SCR

A. Introduction

SCR systems placed between the particulate control device and sulfur dioxide control equipment are called low dust SCR (LDSCR). Systems that are placed downstream of the particulate matter (PM) and sulfur dioxide (SO_2) control systems are generally referred to as tail end SCR (TESCR). This is in contrast to a HDSCR location where none of the particulate matter and sulfur dioxide has been removed from the flue gas. LDSCR and TESCR systems have been used on coal-fired and biomass fired boilers in the United States as well as other countries. However, no SCR system including a low dust or tail end SCR has ever been operated on a boiler firing North Dakota lignite. The flue gas produced by the combustion of North Dakota lignite contains high concentrations of alkali aerosols (primarily sodium and potassium). Cyclone boilers, such as the two units at the M.R. Young Station, produce higher concentrations of submicron aerosols than conventional pulverized or fluidized bed boilers. The higher temperature in the cyclone boilers vaporizes the organically associated sodium and potassium in North Dakota lignite. When these elements condense, they form submicron aerosols. Minnkota[1] (p. 12) has indicated that the condensed vapors have a mean diameter of approximately 0.1 micrometers. Papers by Kling[2] and Zheng[3] have indicated that the aerosols with a diameter less than or equal to 0.1 micrometers cause the greatest catalyst deactivation.

The NSR Manual[9] states that decisions regarding technically feasibility are made by comparing the physical and chemical characteristics of the exhaust gas stream from the unit under review to those of the unit from which the technology is being transferred. Unless significant differences between the source types exist that are pertinent to the successful operation of the control device, the control option is presumed to be technically feasible unless the source can present information to the contrary.

Since no LDSCR or TESCR system has ever been applied to a boiler that combusts North Dakota lignite, an evaluation of the flue gas characteristics was made to determine if they were substantially different from facilities that have successfully applied SCR technology or to determine if empirical data would indicate whether low dust or tail end SCR can be successfully applied.

B. Flue Gas Characteristics

At the MRYS, both units use an electrostatic precipitator (ESP) to control PM emissions. Unit 2 is equipped with a wet scrubber to control SO_2 emissions while a wet scrubber will be constructed for Unit 1. Minnkota[4] (p.20) has provided an analysis of the particulate matter emitted from Unit 2 which can be used for evaluation of TESCR. The analysis indicated the PM was 6.56% sodium (Na), 2.26% potassium (K), 5.71% sulfur (S), 57.52% oxygen (O) and the remaining other elements.

The sodium and potassium after the ESP and wet scrubber is most likely in sulfate form[5] (p.32). If all of the sodium and potassium is in the sulfate form, sodium sulfate and potassium sulfate would comprise approximately 25% of the total particulate matter emitted from Unit 2 (see Appendix A). Minnkota has indicated that the sample of the particulate matter that was analyzed was obtained while some flue gas was bypassing the SO_2 scrubber. The amount of sodium, potassium and/or sulfur in the sample could be biased high when compared to a sample when all flue gas passes through the wet scrubber.

A review of the latest PM stack tests at M.R. Young Unit 2 (8/07 and 5/08) indicated an average PM emission rate of 10.61 milligrams per normal cubic meter (mg/Nm^3 at 6% O_2 – see Appendix B). Based on 25% of the PM being sodium and potassium sulfate, the combined emission rate of these two compounds is approximately 2.7 mg/Nm^3. This indicates a sodium and potassium removal efficiency of greater than 99% by the ESP and wet scrubber.

Minnkota has submitted data from a study by Markowski[5] (p.31) which indicated that approximately 81% of the sulfate emitted after the Unit 2 wet scrubber is less than 1.1 micrometers in size and approximately 36% is less than 0.26 micrometers in size. Based on the latest stack tests and the Markowski data, the submicron sodium sulfate plus potassium sulfate emission rate would be less than 2.2 mg/Nm^3 and the emission rate of sodium and potassium sulfate less than 0.26 micrometers in size would be approximately

1.0 mg/Nm^3. These values are similar to those Markowski reported which were 1.335 mg/m^3 and 0.602 mg/m^3 respectively.

C. Catalyst Deactivation

The two primary flue gas constituents that will cause SCR catalyst deactivation in a low dust or tail end configuration are sodium and potassium, most likely in sulfate form[5] (p.32-35). Crespi et.al.[6], in their paper regarding the Amager Station, presented a graph which shows the effect of various poisons on the activity of vanadia – titania catalysts. Minnkota[1] (page 21) provided similar information that indicates that potassium oxide is a more potent catalyst poison on a molar basis than sodium oxide. Although no actual data is supplied, analysis of the graph indicates that potassium oxide is 1.7[7] – 2.0[8] times more potent catalyst poison than sodium oxide (on a molar basis) up to a poison to vanadium/titanium ratio of 0.5 (see Appendix C). Because potassium oxide has a larger molecular weight than sodium oxide, the poisoning ratio is 1.1 – 1.3 on a mass basis.

As indicated earlier, Kling[2] and Zheng[3] have indicated that the aerosols less than or equal to 0.1 micrometers cause the catalyst deactivation. Data are not available to calculate the portions of the PM emissions from Unit 2 that would be less than or equal to 0.1 micrometers. A conservative assumption is that all of the sodium and potassium sulfate less than 0.26 micrometers is less than or equal to 0.1 micrometers. Based on this assumption and the PM analysis data, the total emission rate for sodium and potassium

sulfate combined that is less than or equal to 0.1 micrometers is size is estimated at 0.98 mg/Nm^3 of which 0.78 mg/Nm^3 is sodium sulfate.

Kling[2] has provided catalyst deactivation rates for various biomass fuels which produce a flue gas that contains sodium and potassium aerosols. The testing was conducted using different types of honeycomb W_2O_5/TiO_2 SCR catalyst. Type A catalyst was catalyst typically applied at coal-fired power plants, Type B was a "bio-optimized" catalyst with increased vanadium content, and Type C had an even higher vanadium content.

For a mixture of peat and 15% wood, the flue gas contained 4.4 mg/Nm^3 of potassium and 0.8 mg/Nm^3 of sodium aerosols with an aerodynamic particle diameter less than 0.1 micrometers.

	Peat + 15% Wood[a]	Center Lignite[b]
Potassium (mg/Nm^3)	4.4	0.20
Sodium (mg/Nm^3)	0.8	0.78

[a] As chloride

[b] As sulfate

The maximum deactivation rate was 12% in 768 hours using Type A catalyst. Another result indicated 15% deactivation in 1488 hours using Type B catalyst. The shorter test

result on peat plus 15% wood indicates 6400 hours to 100% deactivation while the longer test result indicates 9920 hours to 100% deactivation. Regarding the deactivation rates, Kling et.al[2] stated "Exposure of this kind of short samples gives a larger deactivation compared to a full-length catalyst [1, 4] that is mainly a consequence of turbulence of the inlet of the catalyst, before laminar flow is attained."

The sodium concentration in the flue gas after the wet scrubber from Center lignite is similar to that of the peat plus 15% wood; however, the potassium content is approximately 17 times lower. It appears the catalyst life for an SCR at M.R. Young Station should be substantially longer than that estimated for peat plus 15% wood.

Zheng et.al.[3] found a deactivation rate of 0.4% per day for potassium sulfate or 6000 hours to 100% deactivation. The testing was conducted at a loading of 20-30 mg/Nm^3. The aerosols varied in size from 0.07 micrometers to 1.05 micrometers with a mass mean diameter of 0.55 micrometers. The Markowski data indicates that approximately 53% of outlet sulfate was less than or equal to 0.52 micrometers. Based on the latest stack tests at M.R. Young Unit 2, this equates to a total emission rate of approximately 1.4 mg/Nm^3 for those sodium and potassium sulfate aerosols less than 0.52 micrometers. The Minnkota emission rate is substantially less (14-21 times) than the Zheng testing.

The above results do not consider the fact that potassium is a more potent catalyst poison than sodium and chlorides are more potent than sulfates. These facts make it even more likely that the catalyst life will be longer than the testing indicated by Kling[2] and Zheng[3]

since Center lignite combustion at MRYS produces primarily sodium sulfate aerosols while biomass combustion produces primarily potassium chloride aerosols.

For a LDSCR application, the only air pollution control device prior to SCR will be a dry electrostatic precipitator (ESP). Stack test results from the FINE Particles – Technology, Environmental and Health Technology Programme[13] suggests that an ESP on a biomass boiler will have a control efficiency of greater than 90% for submicron particles and can achieve greater than 96% for particles less than 0.1 micrometers in size. This is consistent with AP-42[12] data for Kraft recovery boilers which indicates an ESP can remove more than 98% of the submicron particulate matter in the flue gas which is primarily sodium sulfate[14]. Similar results are reported for coal-fired/biomass boilers by Mohr[15], Lind[16] and the Power Station Emissions Handbook[17]. This indicates that most of the submicron sodium and potassium aerosols, including those aerosols less than 0.1 micrometers in size, will be removed by the electrostatic precipitators at MRYS.

Minnkota has submitted data on the ash composition that accumulated on the electrodes of the Power Span ECO electrodes during a pilot test[11] (p. 26). The data suggests that the sodium and potassium concentration in the particulate matter downstream of the Unit I ESP is higher than the concentration in the particulate matter downstream of the Unit II wet scrubber. However, the concentration is less than a factor of two higher. The total loading of sodium and potassium, as indicated by the data submitted by Minnkota, would still be considerably less than the loadings in the Kling[2] and Zheng[3] tests. This suggests

that the catalyst deactivation rate of a LDSCR at MRYS should be lower than in the referenced tests.

D. Vendor Information

The U.S. Department of Justice, through their contractor Mr. Hans Hartenstein, has provided emails from various catalyst and SCR system providers[10] (Appendix D). Each of the responses from the vendors indicated that tail end SCR is technically feasible for the Milton R. Young Station.

The Department contacted three of the vendors, Ceram Environmental, Haldor Topsoe and Babcock Power. The companies generally confirmed the information in the emails to Mr. Hartenstein. Babcock Power indicated they had no worries about getting 10,000 hours of catalyst life at the M.R. Young Station. However, they recommended "coupon" testing prior to design of the SCR. Ceram was convinced it was technically feasible; however, their representative did acknowledge that if the sodium and potassium aerosols are making it through the ESP and wet scrubber, catalyst deactivation could be a problem. Haldor Topsoe indicated that the catalyst deactivation at M.R. Young would be manageable if the catalyst is kept dry during outages. Although no written guarantees have been provided by the vendors, it appears that vendors are willing to provide them for a tail end SCR at the M.R. Young Station.

E. Biomass Facilities using LDSCR/TESCR

There are no boilers that combust North Dakota lignite and are equipped with SCR technology. LDSCR and TESCR has been applied to coal-fired boilers in Europe, Asia and the United States. However, in general, other U.S. coals are much lower in the organically associated alkalis that cause SCR catalyst deactivation. Biomass fired boilers have flue gas characteristics that more closely approximate those from North Dakota lignite. At least four biomass boilers that are equipped with tail end or low dust SCR are currently in operation in the United States. The boilers are spreader stoker design and use an electrostatic precipitator as the primary particulate matter control device. These include:

- Whitefield Power & Light, New Hampshire – Boiler uses whole tree chips and has operated since October 2004.

- Bridgewater Power, New Hampshire – Boiler uses whole tree chips and has operated since October 2007.

- Pine Tree Power, New Hampshire – Biomass combustion.

- Boralex Stratton, Maine – Boiler uses whole tree chips, waste wood, and construction and demolition waste. The boiler has operated since December 2004.

The Department is also aware of proposed TESCR or LDSCR installations at the Burlington Electric Plant in Vermont, Synterprise Global Solutions in Tennessee and the Amager Heat and Power Plant near Copenhagen, Denmark. The Amager Station is also allowed to burn coal and may not be required to operate the TESCR when combusting biomass.

Although there are boilers that combust 100% biomass and utilize LDSCR for NO_x control, there is no information about the actual loading of potassium and sodium aerosols at the inlet to the SCR. The New Hampshire Department of Environmental Services (NHDES) was contacted regarding the biomass boilers that use LDSCR. The Whitefield Power Plant is a 16 MWe spreader stoker that is equipped with a multiclone and electrostatic precipitator for particulate matter control. The NHDES confirmed the boiler had been operating for approximately four years. NHDES was not aware of any catalyst deactivation problems at this facility. The plant has a NO_x emission limit of 0.075 lb/10^6 Btu. The other facilities in New Hampshire are similar; however, they have not operated as long. No data was available regarding the loading of potassium and sodium at the inlet of the SCR.

F. Conclusions

In the June 2008 Preliminary Best Available Control Technology Determination for Control of Nitrogen Oxides for M.R. Young Station Units 1 and 2, the Department

concluded that an SCR system must have a catalyst life of at least 10,000 hours before SCR technology could be deemed successfully applied to the source. The life of the catalyst will depend on many factors including the reduction efficiency required, the allowable ammonia slip, the volume of catalyst used, the plant load variability, the coal flue gas characteristics, the makeup of the catalyst (e.g. high vanadium catalyst will last longer than a catalyst with a lower vanadium content), the design of the reactor system, the number of catalyst layers, the catalyst management plan, and other factors. The catalyst could be replaced when deactivation has reached 50% or less or it could be replaced at a higher deactivation point depending on the system's ability to meet the regulatory requirements for the NO_x emission rate and/or ammonia slip rate.

No data has been found from an actual operating facility which has similar flue gas characteristics to M.R. Young Station that use high dust, low dust or tail end SCR. However, experimental and pilot scale testing by Kling[2] and Zheng[3] provides empirical data for comparison. The total sodium and potassium loading of aerosols less than 0.1 micrometers expected at the inlet of a TESCR at M.R. Young Station is expected to be at least 5 times less than found in the Kling tests on peat plus 15% wood. Kling's data indicated up to 9920 hours before 100% deactivation for catalyst type B. Zheng's[3] data suggested 6,000 hours before 100% deactivation when exposed to potassium sulfate aerosols with an mean diameter of 0.55 micrometers at a concentration which is 14-21 times higher than the concentration of sodium and potassium aerosols of this size expected after a wet scrubber at M.R. Young Station. The loading at a low dust location would also be substantially less than the loading in the Kling or Zheng tests. Kling[2] also

pointed out that the testing probably over estimates the deactivation rate because of turbulence in the pilot scale inlet of the catalyst which would be more laminar in a full scale SCR.

Existing biomass boilers are using LDSCR successfully. Although the boilers are not cyclone fired units, the New Hampshire units use similar PM control devices as M.R. Young Station (i.e. ESP). The potassium chloride emitted from the biomass boilers is a much more potent catalyst poison than the sodium sulfate emitted at the MRYS. The Whitefield Plant has operated for more than four years without deactivation problems. Kling[2] has referred to "bio-optimized" catalyst and higher vanadium catalysts that appears to have a longer life than the typical coal-fired boiler SCR catalyst for a given concentration of sodium and potassium aerosols. A bio-optimized catalyst (high vanadium content) will be installed at the Amager Station[6] (p. 13). Vendors believe that TESCR is technically feasible and can be successfully applied at M.R. Young Station.

Based on the empirical data available at that time, vendor information that TESCR is feasible at the M.R. Young Station and the use of low dust SCR on biomass fired boilers, the Department concludes that tail end and low dust SCR appear to be technically feasible at M.R. Young Station.

References

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Appendix A

Analysis of Unit II
Stack Test Filter

MINNKOTA UNIT 2
FILTER ANALYSIS

ELEMENT	% OF ELEMENT ON FILTER	MOLECULAR WEIGHT	MOLES [a]
Na	6.56	23.0	0.285
K	2.26	39.1	0.058
S	5.71	32.1	0.178
O	57.52	16.0	3.595

[a] *BASED ON 100 GRAMS OF PM*

2 Na + 1 S + 4 O --> Na_2SO_4

0.285 MOLES OF SODIUM AVAILABLE
NEED (0.285/2)*(1) MOLES OF SULFUR = 0.142 MOLES
NEED (0.285/2)*(4) MOLES OF OXYGEN = 0.570 MOLES

TOTAL WT. Na_2SO_4 = (23)(0.285) + (32.1)(.142) + (16)(.570) = 20.2 grams
POTENTIAL Na_2SO_4 = 20.2 g/100 g *100% = 20.2%

2 K +1 S + 4 O --> K_2SO_4

0.058 MOLES OF POTASSIUM AVAILABLE
NEED (0.058/2)(1) MOLES OF SULFUR = 0.029 MOLES
NEED (0.058/2)(4) MOLES OF OXYGEN = 0.116 MOLES

TOTAL WEIGHT K_2SO_4 = (39.1)(.058) + (0.029)(32.1) + (16)(.116) = 5.05 grams
POTENTIAL K_2SO_4 = 5.05%

the strands. These particles are rich in sodium and sulfur as compared to the filter materials. Figure 18 shows a region of the filter that was not exposed to flue gas and the fiber stands do not have particles bonded to the surfaces.

Table 5. Morphological analysis results for filter sample 001.
Results expressed as weight percent on an elemental basis.

Fig.	Pt/Area	Description	Na	Mg	Al	Si	S	Cl	K	Ca	Ti	Fe	Ba	O
14	1*	Overall area - 100x	5.98	1.83	2.62	10.85	3.80	0.00	2.29	11.10	0.00	2.31	0.00	59.21
	2*	Overall area - 100x	5.95	2.40	2.82	10.93	5.42	0.00	2.25	11.30	0.40	2.46	0.00	56.07
	3*	Overall area - 100x	7.31	1.99	2.23	8.73	7.38	0.00	2.28	9.86	0.00	1.11	0.00	59.10
	4*	Overall area - 100x	5.66	2.54	2.20	9.47	5.27	0.00	2.54	10.08	0.00	3.05	1.65	57.56
	5	Light particle	1.21	3.33	5.47	7.65	1.38	0.00	1.40	13.44	0.00	6.76	1.85	57.52
	6	Dark particle	6.40	9.79	1.47	10.75	6.24	0.00	3.76	7.84	0.00	1.06	0.00	52.68
	7	Light particle	0.57	3.99	7.49	8.94	1.74	0.19	1.15	15.67	0.43	3.83	0.00	56.01
	8	Overall area - 100x	8.50	2.62	2.45	10.04	6.81	0.00	2.12	9.26	0.50	2.40	0.00	55.30
	9	Overall area - 100x	5.95	1.97	2.64	11.03	5.58	0.00	2.09	10.21	0.86	1.78	0.00	57.90
	10	Light particle	0.78	4.20	6.78	11.26	0.00	0.00	1.24	15.37	0.00	3.70	5.10	51.56
	11*	Blank edge of filter	0.00	0.93	5.11	20.20	0.00	0.00	0.93	13.83	0.00	0.00	0.00	59.00
	12*	Blank edge of filter	0.00	1.19	4.95	19.69	0.00	0.00	1.16	16.52	0.00	0.59	0.00	55.91
15	13	Small, light particles	3.00	3.30	3.10	7.72	2.91	0.00	1.40	11.02	0.00	3.49	1.89	62.18
	14	Small bonded particles	2.93	1.25	1.02	10.04	6.99	0.00	4.06	29.33	0.00	5.38	2.93	36.08
	15	Large dark particle	10.25	9.68	0.00	1.41	22.60	0.00	3.74	2.16	0.00	0.00	0.00	50.15
	16	Large dark particles	13.40	11.82	0.00	1.30	10.30	0.00	2.28	0.96	0.00	2.17	0.00	57.78
	17	Small bonded particles	4.39	3.56	2.17	10.95	6.88	0.00	2.77	14.02	0.51	2.83	0.00	51.92
	18	Small bonded particles	1.49	2.82	5.86	10.45	4.93	0.00	3.19	26.01	1.19	8.23	0.00	35.84
Average		**Overall areas**	**6.56**	**2.23**	**2.49**	**10.17**	**5.71**	**0.00**	**2.26**	**10.30**	**0.29**	**2.18**	**0.27**	**57.52**
		Light particles	**1.39**	**3.71**	**5.71**	**8.89**	**1.51**	**0.05**	**1.30**	**13.88**	**0.11**	**4.44**	**2.21**	**56.82**
		Dark particles	**10.02**	**10.43**	**0.49**	**4.49**	**13.05**	**0.00**	**3.26**	**3.65**	**0.00**	**1.08**	**0.00**	**53.54**
		Small bonded particles	**2.94**	**2.54**	**3.02**	**10.48**	**6.27**	**0.00**	**3.34**	**23.12**	**0.57**	**5.48**	**0.98**	**41.28**
		Filter edge	**0.00**	**1.06**	**5.03**	**19.94**	**0.00**	**0.00**	**1.04**	**15.18**	**0.00**	**0.30**	**0.00**	**57.46**

* = areas not specifically noted or shown in electron micrograph Figure 14.

Appendix B

Calculation of Emissions Rate
For
M.R. Young Station

MINNKOTA
STACK TEST RESULTS

UNIT	DATE OF TEST	PM EMISSION RATE (gr/dscf)	OXYGEN CONTENT (%)	PM EMISSION RATE (mg/m^3)	PM EMISSION RATE (mg/Nm^3) [a]	PM EMISSION RATE (mg/Nm^3) at 6% O_2
1	6/9/2008	0.0026	8.6	5.95	6.39	7.74
1	8/29/2007	0.0031	5.9	7.09	7.61	7.56
	AVERAGE	0.00285	7.25	6.52	7.00	7.65
2	5/7/2008	0.0042	7.4	9.61	10.32	11.38
2	O8/28/2007	0.0039	6.4	8.92	9.58	9.84
	AVERAGE	0.00405	6.9	9.27	9.95	10.61

[a] ***ADJUSTED TO 0 ° C***

TAIL END SCR

FROM FILTER ANALYSIS Na = 6.56% OF PM AND K = 2.26%.
IF ALL Na AND K IS SULFATE FORM, Na_2SO_4 = 20.2% AND K_2SO_4 = 5.05% OF PM.

UNIT	DATE OF TEST	POTENTIAL Na_2SO4 EMISSION RATE (mg/Nm^3)	POTENTIAL K_2SO_4 EMISSION RATE (mg/Nm^3)	EQ. K_2SO_4 [b] EMISSION RATE (mg/Nm^3)	EQ. K_2SO_4 [b,c] EMISSION RATE < 0.52 um (mg/Nm^3)	EQ. KCl [c,d] EMISSION RATE < 0.26 um (mg/Nm^3)
1	6/9/2008	1.56	0.39	1.59	0.85	0.23
1	8/29/2007	1.53	0.38	1.56	0.83	0.23
AVG.		***1.55***	***0.39***	***1.57***	***0.84***	***0.23***
2	5/7/2008	2.30	0.57	2.34	1.24	0.34
2	O8/28/2007	1.99	0.50	2.03	1.08	0.30
AVG.		***2.14***	***0.54***	***2.19***	***1.16***	***0.32***

[b] ***BASED ON CRESPI DATA INDICATING POTASSIUM IS 1.3 TIMES MORE POTENT CATALYST POISON THAN SODIUM ON A MASS BASIS.***
[c] ***BASED ON MARKOWSKI DATA THAT INDICATES 53.1% OF SULFATE IS LESS THAN 0.52 um AND 36.5% IS LESS THAN 0.26 um.***
[d] ***BASED ON ZHENG'S DATA THAT INDICATED A DEACTIVATION RATE OF 1% PER DAY FOR KCl AND 0.4% PER DAY FOR K_2SO_4.***

ZHENG TO MINNKOTA LOADING RATIO = (20-30 mg/Nm^3)/(1.16 mg/Nm^3) = <u>17.2 TO 25.9</u>

KLING (PEAT + 15% WOOD) TO MINNKOTA LOADING RATIO = (4.4 + 0.8/1.3 mg/Nm^3)/(0.32 mg/Nm^3) = <u>15.7</u>
NOTE: THIS IS CONSERVATIVE SINCE LESS THAN 36.5% OF SULFATE AT MINNKOTA WILL PROBABLY HAVE A DIAMETER OF 0.1 um OR LESS.

MINNKOTA POWER COOP.
UNIT 2
HIGH DUST SCR

	Na_2O	K_2O	EQ. K_2O [a]	EQ. K_2SO_4 [b]	EQ. KCl [c]	EQ. KCL [d] (< 0.1 um)
AVG. EMISSION RATE (lb/dscf)	3.051E-05	9.014E-06	3.248E-05	6.013E-05	2.405E-05	1.203E-05
AVG. EMISSION RATE (mg/Nm^3)	524	155	558	1034	413	207

[a] *BASED ON CRESPI DATA WHICH INDICATES K_2O IS 1.3 TIMES MORE POTENT CATALYST POISON THAT Na_2O ON A MASS BASIS.*
[b] *BASED ON A MOLECULAR WEIGHT OF 94 FOR K_2O AND 174 FOR K_2SO_4 AND ASSUMING ALL Na & K IS IN SULFATE FORM.*
[c] *BASED ON ZHENG'S DATA THAT INDICATED A DEACTIVATION RATE OF 1% PER FOR DAY FOR KCl AND 0.4% PER DAY FOR K_2SO_4.*
[d] *BASED O0N 50% OF AEROSOLS LESS THAN 0.1 MICRONS IN SIZE.*

*MINNKOTA TO ZHENG LOADING RATIO = (1034 mg/Nm^3)*0.50 / (20-30 mg/Nm^3) = 25.9 TO 17.2*

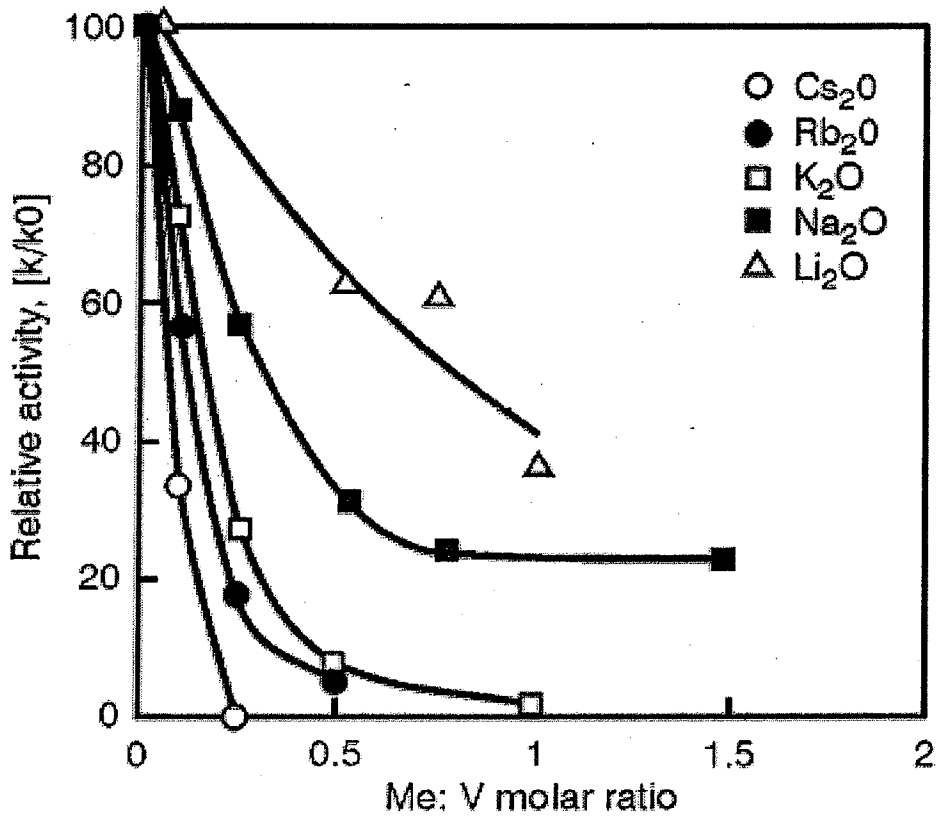
MINNKOTA TO KLING LOADING RATIO (BARK + 30% DEMOLITION WOOD) = (207 mg/Nm^3) / (16.7 + 5.8/1.3) = 9.8

Appendix C

Analysis of Na_2O and K_2O
Poisoning Potency

DEPARTMENT ANALYSIS

Na_2O and K_2O DEACTIVATION POTENCY



CONTAMINANT	RELATIVE ACTIVITY	MOLAR RATIO	Na_2O/K_2O MOLAR RATIO
Na_2O	30%	0.55	
			2.20
K_2O	30%	0.25	
Na_2O	40%	0.42	
			2.00
K_2O	40%	0.21	
Na_2O	60%	0.25	
			1.79
K_2O	60%	0.14	
AVERAGE			***2.00***

Appendix D

Vendor Information
Tail End SCR

Appendix B: SCR Vendor Query Correspondence

1. Vendor Correspondence with SCR system suppliers

1.1 E-Mail correspondence with Clay Erickson, Babcock Power (SCR System Vendor – extensive tail-end SCR experience)

From: cerickson@babcockpower.com [mailto:cerickson@babcockpower.com]
Sent: Thursday, June 19, 2008 15:59
To: Hans Hartenstein
Cc: jlangone@babcockpower.com; tlicata@babcockpower.com
Subject: Re: Tail-end SCR

Hans,

Babcock Power has reviewed the Milton Young plant in the past, based on these reviews Babcock Power finds

- A tail-end SCR is technically and commercial feasible
- Babcock Power does not recommend or require additional pilot testing only proper flue gas characterization as with any SCR system per performed
- Will provide commercial guarantees for the SCR and catalyst performance (activity, pressure drop and SO_2/SO_3 conversion rate) and lifetime

Babcock Power has the largest SCR experience list in the world; from this experience we are completely confident in the application of a tail end system at Milton Young. If you have further questions please let me know.

With best regards,
Clay

Clayton Erickson, PhD
Director, Process Engineering
Babcock Power Inc.
5 Neponset Street
Worcester, MA 01606

T: 508-854-4039 F: 508-854-1177
M: 508-245-2383

From: "HansHartenstein"<Hans.Hartenstein@Evonik-EnergyServices.us>
Sent: 06/18/2008 12:16
To: <cerickson@babcockpower.com>
Subject: Tail-end SCR

Clay,

As discussed during our phone conversation today, during which you stated that Babcock Power considers a high-dust SCR principally, technically feasible even though not without technically resolvable challenges for Minnkota's Milton R. Young Station, I would also be interested in Babcock Power's position on the technical feasibility of a tail-end SCR (downstream of a wet scrubber including

flue gas reheat) Given your knowledge about the plant (cyclone-fired B&W boilers, ESP, wet scrubber) and the fuel (ND lignite), would Babcock Power:

- Consider a tail-end SCR technically feasible?
- Recommend or require additional pilot testing?
- Be willing to provide commercial guarantees for catalyst performance (activity, pressure drop and SO_2/SO_3 conversion rate) and lifetime? If so what would these be?

Given the fact that tail-end SCRs in Germany including the ones built by your licensor Fisia Babcock (most of which are on wet bottom boilers) went into operation in the late 1980s and most of them still operate on the initial fill of catalyst after almost 20 years and up to 130,000 operating hours, I would assume that Babcock Power / Fisia Babcock has sufficient confidence in your tail-end SCR experience to competently respond to these questions. Please let me know if you have any additional questions. Thanks.

Best regards,
Hans Hartenstein

1.2 E-Mail Correspondence with Don Tonn, Babcock & Wilcox (SCR System Vendor – no tail-end SCR experience)

From: Tonn, Donald P [mailto:dptonn@babcock.com]
Sent: Monday, June 23, 2008 16:06
To: Hans Hartenstein
Subject: RE: Tail-end SCR

Hans:

Please note my responses to your questions in the referenced email below.

Regards,
Donald P. Tonn
Babcock & Wilcox Power Generation Group
AQCS Technology
Phone 330-860-1986
Cell 330-289-7795

From: Hans Hartenstein [mailto:Hans.Hartenstein@Evonik-EnergyServices.us]
Sent: Wednesday, June 18, 2008 13:25
To: Tonn, Donald P
Subject: Tail-end SCR

Don,

As discussed during our phone conversation today, during which you stated that Babcock & Wilcox considers a tail-end SCR (downstream of a wet scrubber including flue gas reheat) principally technically feasible for Minnkota's Milton R. Young Station, I would be interested in Babcock & Wilcox's position on the following questions. Given your knowledge about the plant (cyclone-fired B&W boilers, ESP, wet scrubber) and the fuel (ND lignite), would Babcock & Wilcox:

- Consider a tail-end SCR technically feasible? Yes
- Recommend or require additional pilot testing? Requires further discussion with catalyst suppliers.

- Be willing to provide commercial guarantees for catalyst performance (activity, pressure drop and SO_2/SO_3 conversion rate) and lifetime? If so what would these be? While B&W has considered tail-end SCR systems on other projects we have not had these commercial guarantee discussions with the catalyst suppliers for the North Dakota lignite application. Before consideration of providing these guarantees a comfort level would be required after obtaining guarantees from catalyst suppliers.

Given the fact that tail-end SCRs in Germany went into operation in the late 1980s and most of them still operate on the initial fill of catalyst after almost 20 years and up to 130,000 operating hours, I would assume that Babcock & Wilcox has sufficient confidence in tail-end SCR systems to competently respond to these questions. Please let me know if you have any additional questions. Thanks.

Best regards,
Hans Hartenstein

2. Vendor Correspondence with SCR Catalyst Manufacturers

2.1 E-Mail Correspondence with Cindy Khalaf, Argillon (Catalyst Manufacturer – extensive tail-end SCR experience)

From: Khalaf Cindy R [mailto:cindy.khalaf@argillon.com]
Sent: Tuesday, June 24 2008 14:15
To: Hans Hartenstein
Subject: Re: Argillon Tail-end SCR

No problem.
Regards,
Cindy

From: Hans Hartenstein <Hans.Hartenstein@Evonik-EnergyServices.us>
Sent: Tuesday, June 24, 2008, 16:45
To: Khalaf Cindy R
Subject: RE: Argillon Tail-end SCR

Cindy,

Thanks a bunch for taking the time to respond. I greatly appreciate your answer. I'll keep you posted where this thing is going.

Best regards,
Hans Hartenstein
http://www.evonik-energyservices.us

From: Sadler Randy [mailto:randy.sadler@argillon.com]
Sent: Tuesday, June 24, 2008 08:15 AM

To: Hans Hartenstein
Cc: Khalaf Cindy R
Subject: Argillon Tail-end SCR
Importance: High

On behalf of Cindy Khalaf -

Hans,

Further to our phone call, as far as I know, Argillon has more tail end experience than any other SCR catalyst manufacturer and, as you noted, we also have experience with high dust, German lignite SCRs. Argillon also won the first US lignite SCR catalyst project (Luminant Oak Grove 1 & 2) and provided commercial guarantees. These units are not in service yet. So, yes, we consider ourselves able to answer these questions competently.

Consider a tail-end SCR technically feasible?

Yes, we consider this configuration to be technically feasible. As you know, tail end SCRs are often used when there are significant catalyst poisons in a flue gas stream. A wet scrubber can remove most of these poisons, resulting in very low catalyst deactivation.

Recommend or require additional pilot testing?

For a high dust configuration, we would say definitely. For a tail-end configuration, we would say no. We would only like to see a flue gas analysis for conditions at the inlet to the SCR in order to predict deactivation rate.

Be willing to provide commercial guarantees for catalyst performance (activity, pressure drop and SO_2/SO_3 conversion rate) and lifetime? If so what would these be?

Generally speaking, yes, we would provide guarantees for DeNOx & slip as specified (not to exceed 90% or 2 ppm), 24k hours life, SO_2 conversion rate - low but value TBD, pressure drop - value TBD. Of course we would have to see the technical specifications before being more specific. In addition, tail-end SCRs perform much longer, so depending on the application specifics, customer, etc., we may decide to extend the operating life guarantees. This is a commercial decision and will be reviewed on a case-by case basis.

If you have any more questions, please let me know.

Regards,
Cindy

Cindy R. Khalaf
Argillon LLC
President
Tel: 678.341.7520
Mobile: 770.331.9571
FAX: 678.341.7509
Email: cindy.khalaf@argillon.com
5895 Shiloh Road, Ste. 101
Alpharetta, GA 30005

From: Hans Hartenstein [mailto:Hans.Hartenstein@Evonik-EnergyServices.us]
Sent: Thursday, June 19, 2008 16:29

To: Khalaf Cindy R
Subject: Tail-end SCR

Cindy,

As discussed during our phone conversation today, during which you stated that Argillon considers a high-dust SCR principally technically, feasible based on your high-dust SCR experience with lignite fired units in Europe even though not without technically resolvable challenges for Minnkota's Milton R. Young Station, I would also be interested in Argillon's position on the technical feasibility of a tail-end SCR (downstream of a wet scrubber including flue gas reheat). Given your knowledge about the plant (cyclone-fired B&W boilers, ESP, wet scrubber) and the fuel (ND lignite), would Argillon:

- Consider a tail-end SCR technically feasible?
- Recommend or require additional pilot testing?
- Be willing to provide commercial guarantees for catalyst performance (activity, pressure drop and SO_2/SO_3 conversion rate) and lifetime? If so what would these be?

Given the fact that tail-end SCRs in Germany including the ones equipped with Argillon catalyst went into operation in the late 1980s and most of them still operate on the initial fill of catalyst after almost 20 years and up to 130,000 operating hours, I would assume that Argillon has sufficient confidence in your tail-end SCR experience to competently respond to these questions. Please let me know if you have any additional questions. Thanks.

Best regards,
Hans Hartenstein

2.2 E-Mail Correspondence with John Cochran, CERAM Environmental (Catalyst Manufacturer – extensive tail-end SCR experience)

From: John Cochran [mailto:John.Cochran@ceram-usa.com]
Sent: Wednesday, June 25, 2008 15:14
To: Hans Hartenstein
Cc: Greg Holscher; Noel Rosha; Orehovsky Kurt
Subject: RE: Request for Information

Hans,

CERAM certainly considers the use of a tail-end SCR on applications such as the Milton R. Young Station as technically feasible provided a proper design approach is used. CERAM has the experience from more than 100 tail-end and low dust applications dating from 1988 that would substantiate our opinion. For a tail-end approach we see no need for additional pilot testing. As such, we can provide full commercial guarantees for catalyst performance (activity or lifetime, conversion rate, pressure drop, etc.).

The choice between high dust and tail-end processes certainly should consider capital costs, operating costs and process risk. Based on our experience certainly process risk would favor a tail-end approach, but albeit for most circumstances at a higher "all-in" cost. Should very high retrofit factors be present for a high dust arrangement then the relative economic factors may even favor a tail-end approach.

I hope this information is useful to your evaluation. Please advise should you have any further

questions or information needs. Thanks.

Best Regards,
John Cochran

CERAM Environmental, Inc.
www.frauenthal.net
913.239.9896 (phone)
913.205.5615 (cell)

This e-mail and any attachments are confidential. If you have received this electronic transmission in error, please reply to the sender regarding the error and permanently delete the original message and any attachments.

From: Hans Hartenstein [mailto:Hans.Hartenstein@Evonik-EnergyServices.us]
Sent: Tuesday, June 17, 2008 7:20
To: John Cochran
Subject: Request for Information

John,

As discussed during our phone conversation today, during which you stated that CERAM considers a high-dust SCR principally technically, feasible even though not without technically resolvable challenges for Minnkota's Milton R. Young Station, I would also be interested in CERAM's position on the technical feasibility of a tail-end SCR (downstream of a wet scrubber including flue gas reheat) Given your knowledge about the plant (cyclone-fired B&W boilers, ESP, wet scrubber) and the fuel (ND lignite), would CERAM:

- Consider a tail-end SCR technically feasible?
- Recommend or require additional pilot testing?
- Be willing to provide commercial guarantees for catalyst performance (activity, pressure drop and SO_2/SO_3 conversion rate) and lifetime? If so what would these be?

Given the fact that tail-end SCRs in Germany including the ones equipped with CERAM catalyst (Herne 1, 2 and 3, Voerde (West) 1 and 2, Lünen 10 and 11 – all of which are wet bottom boilers) went into operation in the late 1980s and most of them still operate on the initial fill of catalyst after almost 20 years and up to 130,000 operating hours, I would assume that CERAM has sufficient confidence in your tail-end SCR experience to competently respond to these questions. Please let me know if you have any additional questions. Thanks.

Best regards,
Hans Hartenstein

2.3 E-Mail Correspondence with Scot Pritchard, Cormetech (Catalyst Manufacturer – no tail-end SCR experience)

From: Pritchard, Scot G. [mailto:PritchardSG@Cormetech.com]
Sent: Thursday, June 19, 2008 17:41
To: Hans Hartenstein
Subject: RE: Tail-end SCR

Hans,

I was thinking of if you put a coupon in the tailend location and it showed something weird then you would have to do something more elaborate i.e. A slipstream with longer hours, etc. We do not anticipate this - in fact you could probably do without the coupon test as well since I don't see any reason why this system would be any different the primary tail end experience i.e. Unlikely any nasties make it through the lower temperature environment and scrubber process. The coupon is OK but I really don't expect to see much. Finally, we have not done any specific coupon tests (because slipstream has been the primary way to evaluate) so we would need to think through the best way to do it - i.e. holder, mounting arrangement, test method, hours of exposure, etc. If you already have something in mind please let us know.
Hope that helps with the clarification.

Scot

From: "Hans Hartenstein" <Hans.Hartenstein@Evonik-EnergyServices.us>
Sent: Thursday, 6/19/08 4:26 pm
To: "Pritchard, Scot G." <PritchardSG@Cormetech.com>
Subject: RE: Tail-end SCR

Scot,

Thanks for the input from Cormetech, which is greatly valued. One question for clarification purposes only, though. Coupon tests and/or flue gas analysis would only be performed in order to characterize the flue gas going into the tail-end SCR as is needed for the design of any APC equipment. Obviously, nobody could offer any performance guarantees concerning what's coming out of a tail-end SCR without knowing what's going into it. You state that in case coupon tests would show a significant accumulation of catalyst poisons, a subsequent slip stream test, which is unquestionably more accurate and representative of a full scale - in this case tail-end - SCR, would be recommended. Stating this, do I understand you right that you would recommend this slip stream testing mainly for the purpose of properly characterizing the flue gas composition at the inlet to the tail-end SCR in order to provide a reliable basis for correct catalyst design? Do I assume correctly, that you would not require extensive and long-term (12 - 24 months) pilot testing with a slip stream reactor because you have serious doubts about the principal technical feasibility of a tail-end SCR for this application? Please clarify. Thanks.

Best regards,
Hans Hartenstein

From: Pritchard, Scot G. [mailto:PritchardSG@Cormetech.com]
Sent: Thursday, June 19, 2008 12:15
To: Hans Hartenstein
Subject: RE: Tail-end SCR

Hans,

Please see my input below.

As discussed during our phone conversation today, during which you stated that Cormetech considers a high-dust SCR principally technically, feasible even though not without technically resolvable challenges for Minnkota's Milton R. Young Station, I would also be interested in Cormetech's position on the technical feasibility of a tail-end SCR (downstream of a wet scrubber including flue gas reheat) Given your knowledge about the plant (cyclone-fired B&W boilers, ESP, wet scrubber) and the fuel (ND lignite), would Cormetech:

- Consider a tail-end SCR technically feasible? - yes

- Recommend or require additional pilot testing? - We generally do not consider coupon testing an accurate representation of an SCR, however in order to minimize cost and provide basic screening information we would suggest the potential use of a coupon sample test. If the coupon shows significant accumulation of catalyst poisons, a subsequent slipstream type test which is more representative of a full scale SCR i.e match velocity, AVs, etc. would be recommended.
- Be willing to provide commercial guarantees for catalyst performance (activity, pressure drop and SO_2/SO_3 conversion rate) and lifetime? If so what would these be? Presuming the coupon test does not show anything unusual (which we do not expect to see anything unusual) we would be willing to provide commercial guarantees for a low dust application. Basic guarantees would be associated with life (this would not include specific Ko and K/Ko as guarantees - the guarantee would be an efficiency and slip guarantee at a certain number of operating hours), SO2 conversion, pressure loss.

As discussed, the high dust application needs additional due diligence testing (slipstream, ash testing, etc.) as well as the practicality of the applicable operating temperature to establish the commercial stance for a high dust application on North Dakota Lignite. We have done such work for Texas lignite as well as other coal sources and other fuels/applications in the past and would expect to be able to achieve the same for this application. The economics for any given application would be considered on a case by case basis.
Let me know if you have any questions. Also I would appreciate anything of the final document that you can share.

Thank you and regards,

Scot Pritchard
VP, Sales & Marketing
Cormetech
919-595-8708 o
919-815-2380 c

From: Hans Hartenstein [mailto:Hans.Hartenstein@Evonik-EnergyServices.us]
Sent: Thursday, June 19, 2008 11:35 AM
To: Pritchard, Scot G.
Subject: Tail-end SCR

Scot,

As discussed during our phone conversation today, during which you stated that Cormetech considers a high-dust SCR principally technically, feasible even though not without technically resolvable challenges for Minnkota's Milton R. Young Station, I would also be interested in Cormetech's position on the technical feasibility of a tail-end SCR (downstream of a wet scrubber including flue gas reheat) Given your knowledge about the plant (cyclone-fired B&W boilers, ESP, wet scrubber) and the fuel (ND lignite), would Cormetech:

- Consider a tail-end SCR technically feasible?
- Recommend or require additional pilot testing?
- Be willing to provide commercial guarantees for catalyst performance (activity, pressure drop and SO_2/SO_3 conversion rate) and lifetime? If so what would these be?

Given the fact that tail-end SCRs in Germany (most of which are on wet bottom boilers) went into operation in the late 1980s and most of them still operate on the initial fill of catalyst after almost 20 years and up to 130,000 operating hours, I would assume that Cormetech has sufficient confidence in tail-end SCR systems to competently respond to these questions. Please let me know if you have any additional questions. Thanks.

Best regards,
Hans Hartenstein

2.4 E-Mail Correspondence with Flemming Hansen, Haldor Topsoe (Catalyst Manufacturer – extensive tail-end SCR experience)

From: Flemming Hansen [mailto:FGH@topsoe.com]
Sent: Friday, June 27, 2008 12:56
To: Hans Hartenstein
Subject: RE: Tail-end SCR

Hans,
Your understanding is what I meant to say.

Thanks

Flemming G. Hansen
Manager SCR DeNOx Catalyst
Haldor Topsoe, Inc.
281-228-5120 (office)
281-228-5129 (fax)
281-684-8820 (cell)
FGH@Topsoe.com
www.topsoe.com

"Hans Hartenstein" <Hans.Hartenstein@Evonik-EnergyServices.us>
06/24/2008 04:16 PM

To "Flemming Hansen" <FGH@topsoe.com>
cc

Subject RE: Tail-end SCR

Flemming,

Thanks for your note. Just to make sure that I understand you correctly. Is it correct to state that Haldor Topsoe feels fully confident that a tail-end SCR is technically feasible and would not experience any accelerated catalyst deactivation? Therefore, you would be willing to guarantee catalyst performance (NOx removal efficiency, pressure drop, SO_2/SO_3 conversion rate and catalyst lifetime) without any need for further pilot testing. Please confirm. Thanks.

Best regards,
Hans Hartenstein

From: Flemming Hansen [mailto:FGH@topsoe.com]
Sent: Dienstag, 24. Juni 2008 16:44
To: Hans Hartenstein

Subject: Re: Tail-end SCR

Hans,

Like you describe we have had very good operating experience with SCR in the clean environment after a scrubber or bag filter. There appears to be practically no catalyst deactivation and with the low amount of particulate the catalyst pitch can be small, which both leads to a compact SCR as compared to a high dust SCR.

Based on the clean flue gas after the FGD we would not require any further testing in order to guarantee a catalyst performance.

The actual guarantees would be as normally applied in a high dust installation and depend on the catalyst volume and operating conditions. At the low operating temperature expected at the tail-end position the SO_2 oxidation will be negligible.

I hope this confirmation will have your approval.

Flemming G. Hansen
Manager SCR DeNOx Catalyst
Haldor Topsoe, Inc.
281-228-5120 (office)
281-228-5129 (fax)
281-684-8820 (cell)
FGH@Topsoe.com
www.topsoe.com

"Hans Hartenstein" <Hans.Hartenstein@Evonik-EnergyServices.us>
06/24/2008 10:24 AM

To <fgh@topsoe.com>
cc
Subject Tail-end SCR

Flemming,

As discussed during our phone conversation today, during which you stated that Haldor Topsoe considers a high-dust SCR principally technically, feasible even though not without technically resolvable challenges for Minnkota's Milton R. Young Station, I would also be interested in Haldor Topsoe's position on the technical feasibility of a tail-end SCR (downstream of a wet scrubber including flue gas reheat) Given your knowledge about the plant (cyclone-fired B&W boilers, ESP, wet scrubber) and the fuel (ND lignite), would Haldor Topsoe:

- Consider a tail-end SCR technically feasible?
- Recommend or require additional pilot testing?
- Be willing to provide commercial guarantees for catalyst performance (activity, pressure drop and SO_2/SO_3 conversion rate) and lifetime? If so what would these be?

Given the fact that tail-end SCRs in Germany including the ones equipped with your catalyst have been in operation since the late 1980s and most of them still operate on the initial fill of catalyst after almost 20 years and up to 130,000 operating hours, I would assume that Haldor Topsoe has sufficient confidence in your tail-end SCR experience to competently respond to these questions. Please let me know if you have any additional questions. Thanks.

Best regards,
Hans Hartenstein