<u>Feasibility of SCR Technology for NOx Control Technology for the Milton R. Young Station, Center, North Dakota</u>

Expert Report of

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ON BEHALF OF THE

UNITED STATES DEPARTMENT OF JUSTICE

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1. INTRODUCTION AND OVERVIEW

1.1 Information Required for the Expert Report

The following is a listing of the items provided with this report:

(1) This report contains my personal opinions, conclusions and the reasons therefore.

(2) The body of the report and **Appendix A** list the data and other information considered in forming these opinions.

(3) **Appendix B** provides a copy of the e-mail correspondence with several selective catalytic reduction (SCR) catalyst manufacturers and SCR equipment vendors concerning the technical feasibility of tail-end SCR (TESCR).

(4) **Appendix C** includes a listing of publications authored during the past ten years.

(5) Section III presents a statement of my qualifications; my resume is attached as **Appendix D**.

(6) I am being compensated for the preparation of this report and my testimony by the U.S. Department of Justice.

(7) I have provided previous testimony within the preceding four years as an expert at trial or by deposition.

1.2 Purpose of the Report

This report is written under a consulting contract and pursuant to a request from the Department of Justice (DOJ) for an analysis of whether or not the SCR technology would be a technically feasible and available technology for the reduction of nitrous oxides (NOx) for installation at the Milton R. Young Station located near Center, North Dakota.

A preliminary Best Available Control Technology (BACT) determination for control of NOx for the M.R. Young Station conducted by the Division of Air Quality of the North Dakota Department of Health[1] (the Department) concludes that the SCR technology is not

[1] Preliminary Best Available Control Technology Determination for Nitrogen Oxides for M.R. Young Station Units 1 and 2, Division of Air Quality ND Department of Health, 918 E. Divide Avenue, Bismarck, ND, June 2008.

technically feasible at this time. I was asked to review the information in and provided by this preliminary BACT determination and render an expert opinion concerning the technical feasibility of the SCR technology for retrofit at the M.R. Young Station.

2. SUMMARY OF CONCLUSIONS

In summary, and for the reasons described herein, I have concluded that the SCR technology is technically feasible and principally available for installation at both units at the Milton R. Young Station for NOx reduction. I have further concluded that even though the high-dust SCR (HDSCR) principle was investigated in some detail prior to the BACT determination:

- The depth of the investigation concerning the technical feasibility of HDSCR in this case by means of pilot testing conducted at the Coyote Station (Coyote Pilot Testing) was insufficient and the conclusions drawn from this pilot testing were speculative and premature.

- Virtually no investigation of the technical feasibility of low-dust SCR (LDSCR) and TESCR was conducted at all and both distinctly different SCR principles were incorrectly treated as if they would be essentially the same.

- The HDSCR Coyote Pilot Testing was ill-designed and inadequately conducted.

- The data generated by the Coyote Pilot Testing for these reasons is inconclusive and meaningless of the purpose of this determination.

- The conclusions suggested by the Department based on the data presented are not reasonably founded but premature, purely speculative and mostly incorrect.

Consequently, it is my opinion that the conclusions presented by the North Dakota Department of Health in the BACT determination[2], namely, that the SCR technology is not technically feasible at this time for both units at the M.R. Young Station, is wrong. Such a conclusion cannot be drawn correctly based on the available data. The SCR technology must be considered principally, technically feasible for Minnkota's Milton R. Young Station. This is even true for HDSCR even though not without significant but technically resolvable challenges, which may result in HDSCR not being the economically most advantageous SCR principle. However, whether HDSCR, LDSCR or TESCR is the economically most viable SCR solution for M.R. Young is beyond the scope of this report.

Finally, I have concluded that no sufficiently detailed investigation was conducted for LDSCR and/or TESCR in this case and the record of investigation provided by the

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[2] Preliminary Best Available Control Technology Determination for Nitrogen Oxides for M.R. Young Station Units 1 and 2, Division of Air Quality ND Department of Health, 918 E. Divide Avenue, Bismarck, ND, June 2008.

Department is insufficient, inadequate and incomplete. Both of these SCR principles were incorrectly treated by the Department as being essentially the same, which is incorrect and unacceptable as the flue gas composition and characteristics entering a LDSCR are completely different from the one entering a TESCR.

The statement made by the Department that none of the various principles of the SCR technology (HDSCR, LDSCR, TESCR) can be considered applicable and technically feasible at this time is not only purely speculative but factually incorrect. As a matter of fact a quick vendor survey conducted by me confirmed that all contacted vendors consider TESCR as being unquestionably technically feasible, available and applicable for M.R. Young Station. This was not only unanimously confirmed by all leading catalyst manufacturers (Argillon, CERAM, Cormetech, Haldor Topsoe and Hitachi) but also by leading SCR equipment vendors (Alstom, Babcock Power and Babcock & Wilcox). Furthermore, these SCR equipment vendors and catalyst manufacturers confirmed my opinion by stating that they also consider LDSCR as technically feasible and probably even HDSCR, however not without significant but resolvable technical challenges such as limiting the boiler outlet temperature variations to a range tolerable for SCR catalyst and eliminating the popcorn ash problem. The temperature variations at the boiler outlets appear to be the biggest hurdle for the application of HDSCR at this time; however, this issue is considered to be technically resolvable as indicated by Babcock & Wilcox[3], who supplied both boilers at M.R. Young Station. Answering the question of whether or not the extent of modifications of existing equipment required to resolve the temperature variation issue makes HDSCR economically less attractive in comparison to LDSCR or even TESCR is beyond the scope of this report.

However, it is my opinion that the available data presented in the Department's BACT determination[4] is insufficient, inconclusive and interpreted largely incorrectly when concluding the HDSCR is technically infeasible. This conclusion cannot be supported by the available data at all. Furthermore, concluding that LDSCR and/or TESCR are not technically feasible based on the available data is incorrect, since no relevant data was presented that supports such a conclusion in any way. Based on my more than 20 years of SCR experience and my evaluation of the vendor responses, it is my opinion that the SCR technology is technically feasible and principally available for installation at both units at the Milton R. Young Station for NOx reduction. The only design engineering challenge is the proper selection of the best suitable type of SCR principle[5] to be applied and the correct SCR process and catalyst design. This, however, is neither a question of technical feasibility nor of applicability or availability of the SCR technology but simply a question of economics.

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3 E-mail from Steve Moormann (Babcock &Wilcox) to Robert Blakley (Burns & McDonnell) dated July 18, 2007.

4 Preliminary Best Available Control Technology Determination for Nitrogen Oxides for M.R. Young Station Units 1 and 2, Division of Air Quality ND Department of Health, 918 E. Divide Avenue, Bismarck, ND, June 2008.

5 Defined by its location on the flue gas pass as HDSCR, LDSCR or TESCR.

3. QUALIFICATIONS

I have been involved in the business development, proposal engineering and estimating, project management, process and design engineering, component and equipment procurement, construction, erection, commissioning and start-up and operation of air pollution control equipment for utility and industrial power plants as well as waste incinerators (municipal waste, hazardous waste, sewage sludge, medical waste etc.) in a variety of capacities for over twenty years. I began my career in the field of air pollution control in 1983 as a staff engineer working for Mercedes-Benz in automobile engine development adapting standard type European automobile engines with catalytic converters, secondary air injection systems, exhaust gas recirculation systems etc. in order to comply with more stringent emission regulations in entities such as California, the U.S. (48 states), Japan etc.

In late 1987, I accepted a position with L&C Steinmüller GmbH in Germany, which was one of the leading engineering and equipment vendors supplying power utility boilers, including the associated air pollution control equipment. Initially, my field of responsibility included business development for all environmental control technologies (air, water, waste) in Southern Germany. In 1990, I became Department Manager of the Department of Gas Cleaning for waste incineration facilities. In 1993, I became General Manager for Flue Gas Cleaning at L&C Steinmüller. Between 1988 and 1999, I was personally fully involved in the following retrofit phases in Europe:

- Retrofitting all fossil fuel fired boilers (utility and industrial) with a thermal heat input of more than 300 MW with flue gas desulfurization (FGD) systems ensuring a continuous SO_2 removal efficiency of at least 85% at all times, mostly wet limestone forced oxidation (LSFO) FGDs producing wallboard quality gypsum as a byproduct. This retrofit phase started in Western Europe in the late 1970s and ended in Eastern Europe in the late 1990s. FGD retrofits focused on Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, Germany, Greece, Holland, Hungary, Poland, Slovenia, Slovakia, Spain, Sweden, Turkey and the U.K.

- Retrofitting all fossil fuel fired boilers with a thermal heat input of more than 300 MW with nitrous oxide removal (DeNOx) systems ensuring a NOx emission rate of less than 100 ppm[6] at all times, almost exclusively selective catalytic reduction (SCR) DeNOx systems. This retrofit phase started in Europe in the mid 1980s and is still ongoing. SCR retrofits focused on Austria, Belgium, Denmark, Finland, Germany, Holland, Italy, and Sweden.

- Retrofitting all waste incineration facilities regardless of the type of waste (municipal, industrial, hazardous, sewage sludge, medical etc.) with extensive flue gas cleaning

[6] At the following flue gas characteristics: NOx concentration by volume on a dry basis @ 5% O_2, 1 atm., 273 K.

systems for the removal of acid gases (SOx, HCl, HF), NOx, particulate matter (PM), heavy metals including mercury (Hg), cadmium (Cd), lead (Pb) and numerous others as well as dioxins (PCDD) and furans (PCDF). This retrofit phase started in Europe in the early 1990s and is still ongoing. Waste incinerator retrofits focused on Austria, Denmark, Finland, France, Germany, Holland, Norway, Sweden, and the U.K.

In 1999, I became a co-founder and Managing Director of E&EC – Energy & Environmental Consultants GmbH, an international engineering consulting firm with offices in Germany and a representation in the U.S. Through E&EC I assisted a German SCR catalyst manufacturer in a concentrated effort to supply SCR catalyst and system expertise to the North American market. Also, through E&EC I assisted Babcock Borsig Power in Germany to align their German subsidiary Babcock Borsig Power Environment (former L&C Steinmüller) with their U.S. subsidiary DB Riley (today Babcock Power) in Worcester, Massachusetts in order to take full advantage of the business opportunities provided through the NOx SIP call under the Clean Air Act Amendments (CAAA) Title I Groundlevel Ozone Requirements[7].

Three months into the project, I was offered to take over the environmental business unit of DB Riley, Inc. (later renamed Babcock Borsig Power, Inc., now renamed Babcock Power, Inc.) in Worcester, Ma. After accepting this position, I was responsible for the SCR retrofits for the coal-fired units of American Electric Power (AEP), Detroit Edison (DTE), Duke Power, Louisville Gas & Electric (LG&E) and its subsidiaries Kentucky Utilities (KU) and Western Kentucky Energy (WKE), all now consolidated under E.ON-US, Northern Utilities (NU), Pennsylvania Power & Light (PP&L), Santee Cooper (SC), and Wisconsin Electric Energies (WE Energies) as well as the development of the emerging markets for FGDs and mercury-removal technologies. I left DB Riley and refocused on E&EC shortly before DB Riley's German parent company declared bankruptcy.

Through E&EC I founded SCR-Tech LLC together with a German partner and was acting president of SCR-Tech between 2001 and 2005. SCR-Tech was dedicated to providing the North American utility industry with SCR management and catalyst regeneration services.

After the sale of SCR-Tech in 2004, I left SCR-Tech in 2005 and joined Steag LLC, a wholly owned subsidiary of Steag AG in Germany. Steag AG (now renamed Evonik Steag GmbH) is part of Evonik Industries AG and dedicated to power generation and engineering. Evonik Steag GmbH owns and operates more than 10,000 MW of mostly coal-fired power plants around the world. In 2005, I accepted the position as president of Evonik Energy Services LLC (formerly Steag LLC), which has been dedicated to serve the North American utility industry with SCR design and management services since 1992 and also with catalyst regeneration services since 2007.

Through E&EC, I am also assisting the North American utility industry in their SCR and

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[7] Call by USEPA for State Implementation Plans in 19 Eastern States in order to reduce the NOx emissions of large sources (e.g. coal fired power plants) as required by the 1990 Clean Air Act Amendments (CAAA) under Title I – Groundlevel Ozone.

FGD needs by fully utilizing my experience and expertise, which I developed over the past 21 years working as an engineer solely in the area of air pollution control systems for fossil fuel fired power plants and waste incineration facilities with a focus on FGDs and SCRs.

4. THE MILTON R. YOUNG STATION: BACKGROUND

The M. R Milton Station consists of two North Dakota lignite-fired steam electric generation units, with gross electric generating capacities of approximately 257 megawatts electric (MWe) (Unit 1) owned by Minnkota Power Cooperative and 477 MWe (Unit 2) owned by Square Butte Electric Cooperative. The units went into operation in 1970 (Unit 1) and 1977 (Unit 2). Both units feature cyclone-fired Babcock & Wilcox (B&W) boilers followed by tubular air pre-heaters. Air pollution control equipment consists of overfire air (OFA) systems for both units (Unit 2 OFA is scheduled in 2007 and Unit 1 OFA in 2009), a cold-side electrostatic precipitator (ESP) for particulate matter (PM) control for both units and a lime/fly ash wet scrubber for sulfur dioxide (SO_2) control for Unit 2[8]. Unit 1 will be retrofitted also with a wet lime scrubber supplied by Marsulex, which is scheduled to commence operation in April 2011[9]. Additionally, Minnkota Power Cooperative and Square Butte Electric Cooperative are committed to retrofit BACT for NOx control for both units under a Consent Decree with the United States and the State of North Dakota, dated July 27, 2006. The NOx control technology to be retrofitted must be determined by a top-down BACT Analysis, which must evaluate various technologies including SCR.

5. SCR TECHNOLOGY

The selective catalytic reduction (SCR) technology was originally developed in Japan under a government grant in the 1970s and subsequently retrofitted to most Japanese fossil fuel fired power plants[10]. SCR involves injecting gaseous ammonia generated from UREA, aqueous or anhydrous ammonia into the flue gas at a specific temperature before it reaches a catalyst. The catalyst significantly lowers the temperature required to complete the reaction of the injected ammonia with NO_x (mostly nitrogen oxide NO and nitrogen dioxide NO_2) to form nitrogen and water. Therefore the SCR reactor can be operated at a lower temperature zone at a suitable location in the flue gas path. Compared to the same reactions taking place without the presence of a catalyst, which is commonly referred to as selective non-catalytic reduction (SNCR) and requires flue gas temperatures between 1,500 F (~800 °C) and 2000 F

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8 Milton R. Young Station – Our Jewel on the Prairie, brochure published by Minnkota Power Cooperative and Square Butte Electric Cooperative on Minnkota's website: www.minkota.com.

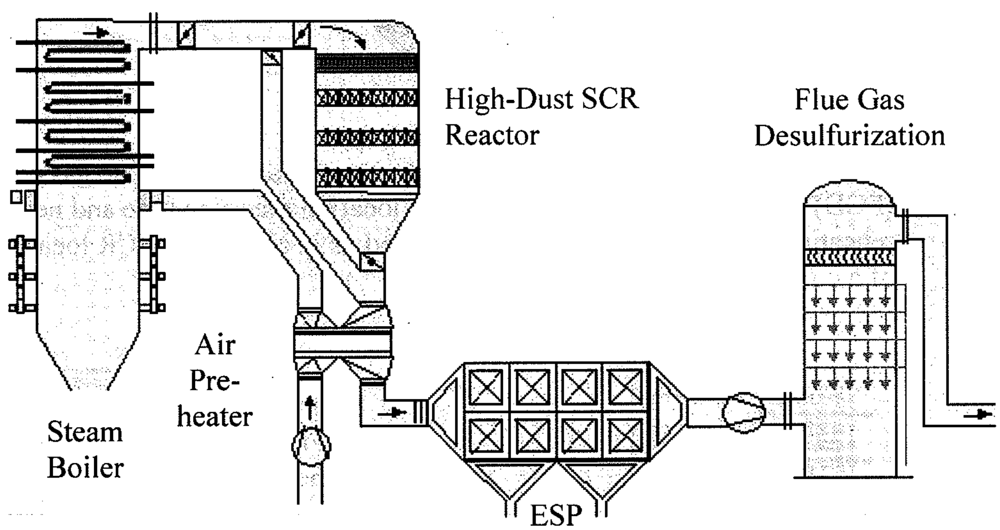
9 McIlvaine Utilitiy E-Alert #868, April 4, 2008.

10 Ando, Jumpei, "SO_2 and NO_x Removal for Coal Fired Boilers in Japan," presented at the Seventh Symposium on Flue Gas Desulfurization, May, 1992.

(~1,100 °C), the SCR process allows for a much higher NOx removal efficiency compared to the SNCR process while ensuring a very low (typically less than 2 ppmvd @ 3% O_2) ammonia slip. Continuous NOx removal efficiencies of well above 90% with NOx outlet concentrations well below 0.05 lbs/MMBtu[11] have been reported[12].

Various principles of the SCR technology are commonly described foremost by the SCR reactor's location within the flue gas path. Three main categories of SCR systems with one being split into two subcategories are known for fossil fuel fired utility boilers, namely:

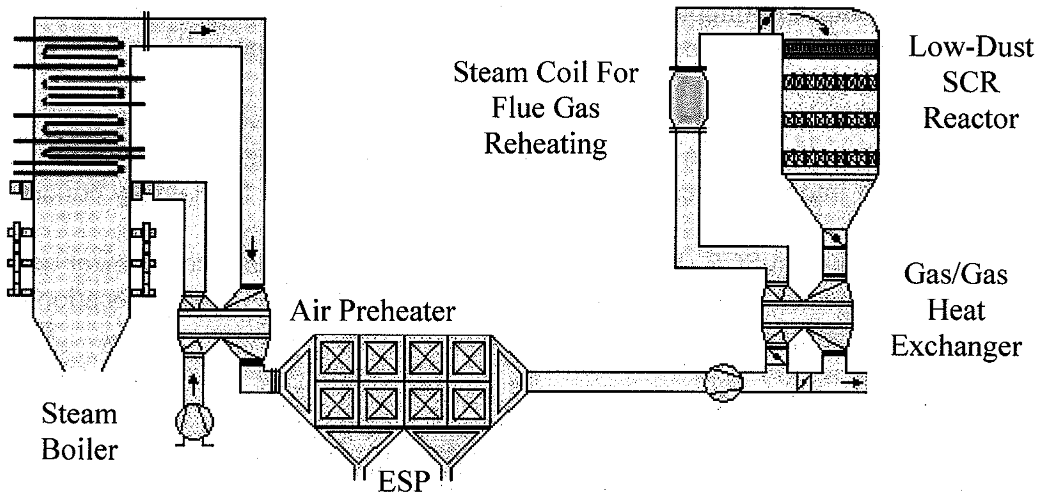
- High-dust SCR (HDSCR) located between the boiler's economizer outlet and the air perheater inlet upstream of the ESP (pictured below). At this location typically no reheating of the flue gas is required.



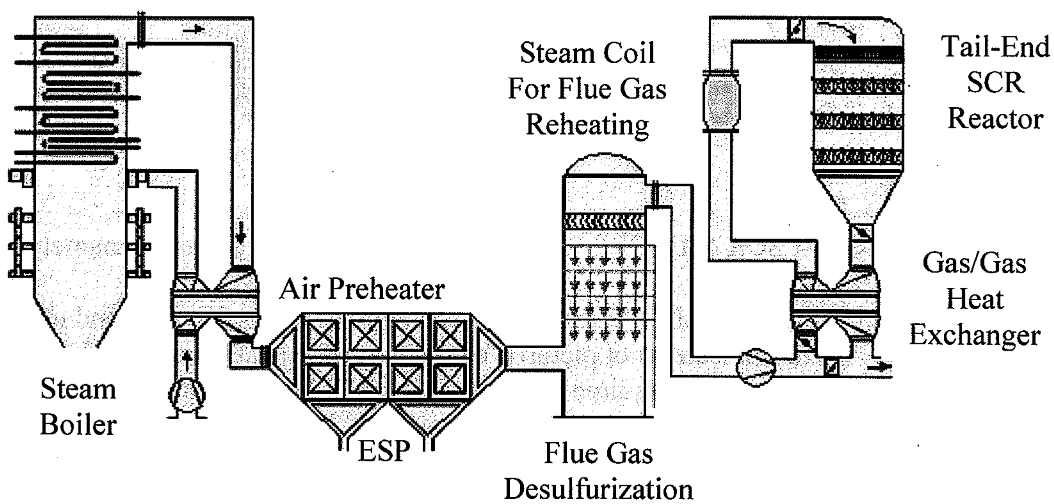
- Low-dust SCR (LDSCR), which is split into two subcategories, namely:
    - o Hot-side LDSCR located downstream of a hot-side ESP and upstream of the air preheater (not pictured below). At this location no reheating of the flue gas is typically required as the hot-side ESP is also upstream of the air pre-heater.
    - o Cold-side LDSCR located downstream of the air preheater as well as downstream of a cold-side ESP (pictured below). At this location reheating of the flue gas is typically required as the cold-side ESP is downstream of the air preheater.

[11] MMBtu = million British thermal units.

[12] Erickson, C., S. Straight, L. Hutcheson, "Coal-Fired SCR Operating Experience with High Removal Efficiency and Low-NOx Firing Systems", Babcock Power's website: www.babcockpower.com.



- Tail-end SCR (TESCR) located downstream of a dry or wet flue gas desulfurization (FGD) system (pictured below). At this location the same type and net quantity of reheating of the flue gas is always required as in case of LDSCR located downstream of a cold-side ESP pictured above.



After the technology was initially installed in Japan, SCR began to be used in Europe, mainly in Germany during the 1980s, where legislation introduced in 1983[13] required all power plants to drastically reduce the NOx emissions by the end of the decade. As a result, the first HDSCR on a coal-fired power plant in Europe went into operation in 1985 (Altbach Power

[13] EPA-450/3-92-004, Office of Air and Radiation, Office of Air Quality Planning and Standards, "Summary of NOx Control Technologies and their Availability and Extent of Application", February 1992.

Station Unit 5[14]), the first TESCR in Europe went into operation in 1986 (Hamburg Hafen Generating Station Unit 1[15]) and the first LDSCR went into operation in 1988 (Walsum Cogeneration Plant Unit 7[16]). By the end of the 1980s, SCRs were used in a wide variety of coal-fired power plants worldwide after Austria, Denmark, Germany, Holland and Japan had retrofitted most of their coal fired power plants with SCR systems for NOx removal. Even the first HDSCR on a lignite or brown coal fired utility boiler went into operation in Austria in 1990 (Voitsberg Power Station Unit 3[17]). By the end of the 1980s, well over 100 SCR systems had been installed in Europe on more than 30,000 MW of coal fired generating capacity with most SCRs representing retrofits of coal fired generating units[18, 19].

As reported by the Electric Power Research Institute (EPRI)[20], an institution solely funded by and dedicated to the electric utility industry, by 1989 the SCR technology was fully developed in two basic forms, namely as HDSCRs and as TESCRs. It is worth mentioning that the TESCR principle was mainly developed for the use on cyclone-fired and other wet bottom boilers because of their very high catalyst deactivation rates resulting from high arsenic levels in the flue gas in case of fly ash re-injection into the furnace for internal vitrification and no arsenic mitigation by means of limestone addition. Furthermore, TESCRs were also applied in some cases due to space constraints and/or difficult retrofit sites where the installation of a HDSCR would have caused elongated periods of downtime of the unit. In total about 40% of the SCR retrofits in Europe were TESCRs.

EPRI[21/]reports that all European SCR systems visited during a field trip in 1988 consistently met their design removal efficiencies of up to 88% in HDSCRs and TESCRs operating in coal fired units firing coals with sulfur contents up to 1.5 %wt. This overall finding was solidified by 1989 after additional years of operating experience.

EPRI reported heat rate penalties on the unit between 1 and 3% resulting from the necessity of flue gas reheating in case of cold-side LDSCR and/or TESCR. Such flue gas reheating requires the use of a gas/gas heat exchanger, in which the flue gas coming from the SCR

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[14] Fisia Babcock GmbH (formerly L&C Steinmüller GmbH) and Babcock Power, Inc. reference lists SCR systems.

[15] Ibid

[16] Ibid

[17] Reference list on CERAM's website: www.frauenthal.net.

[18] Technical Feasibility and Cost of SCR NOx Control in Utility Applications, RP 1256-8 prepared by United Engineers and Constructors, Inc. for Electric Power Research Institute (EPRI), August 1989.

[19] EPA-450/3-92-004, Office of Air and Radiation, Office of Air Quality Planning and Standards, "Summary of NOx Control Technologies and their Availability and Extent of Application", February 1992.

[20] Technical Feasibility and Cost of SCR NOx Control in Utility Applications, RP 1256-8 prepared by United Engineers and Constructors, Inc. for Electric Power Research Institute (EPRI), August 1989.

[21] Ibid

reactor outlet is used to reheat the flue gas going to the SCR reactor inlet similarly to an air preheater. These gas/gas heat exchangers can be designed as rotary type, tubular or plate type heat exchangers. All three types have been utilized successfully. Since a 100% efficient heat transfer from the outgoing to the incoming flue gas is physically impossible, a comparatively small amount of additional energy must be provided for reheating the flue gas downstream of the gas/gas heat exchanger to the SCR reactor inlet temperature. This additional energy, which is needed to overcome the temperature gradient of the gas/gas heat exchanger, amounts to an additional heating of the flue gas of typically between 45 degrees F (25 K) and no more than 90 degrees F (50 K) with amounts known as low as 18 degrees F (10 K). Flue gas reheating is most commonly accomplished in one of two ways, namely:

- In case of coal-fired power plants or when steam of sufficiently high pressure and temperature is available, a steam coil is used for flue gas reheating. The use of steam for flue gas reheating is generally the most economical and advantageous method as it neither increases the flue gas flow rate nor adds any additionally constituents (i.e. NOx) to the flue gas. Steam reheating is particularly economically advantageous in coal-fired power plants, which are "turbine limited" meaning the boiler can generate more high pressure steam at full load than the turbine needs for generating its maximum electrical output. In such a case, the surplus generated high pressure steam, which cannot be used for generating electricity, is ideally suitable for the use of steam reheating of the flue gas without or only minimal impact on the generating capacity of the unit. In this case, the heat rate penalty of the unit may be eliminated entirely.

- In case no steam or only steam of insufficient temperature and pressure is available as it is the case in many non-power plant applications, natural gas duct burners are typically used for flue gas reheating. Such flue gas reheating results in some additional operating cost for natural gas, which, however, can at least partially be offset by significantly prolonged catalyst life of typically well over 100,000 SCR operating hours, a smaller overall SCR reactor, less installed catalyst volume and a smaller catalyst pitch[22]. In some cases the additional operating costs can be completely offset by the elimination of extended unit downtime, which would be necessary for an HDSCR retrofit, and the availability of excess high pressure steam, thus making TESCR the most economical solution.

- EPRI[23] reported TESCR systems in Europe to achieve NOx removal efficiencies between 83 and 92% with cost between US$ 180 – 225 per kW and HDSCR systems to achieve NOx removal efficiencies between 65 and 88% with cost between US$ 65 – 200 per kW. Considering the fact that this was reported in 1989, in other words more than a decade before the SCR retrofit phase in the U.S. resulting from the

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[22] Sobolewski, H, H. Hartenstein, H. Rhein, "STEAG's Long Term SCR Catalyst Experience and Cost", The 2005 EPRI Workshop on Selective Catalytic Reduction, Louisville, KY, November 2005.

[23] Technical Feasibility and Cost of SCR NOx Control in Utility Applications, RP 1256-8 prepared by United Engineers and Constructors, Inc. for Electric Power Research Institute (EPRI), August 1989.

CAAA NOx SIP call[24] and considering the fact that the cost of almost all SCRs retrofitted in North America were within this range, it can be reasonably expected that the retrofit cost for TESCR will also fall approximately within the range determined by EPRI back in 1989.

All European and North American HDSCRs have achieved their targeted NOx emission rates without any major operational problems. Early design flaws mostly resulting from inadequate flow conditions and flue gas distribution problems were mostly corrected by about 1990. By early 2000 more than 23,000 MW of SCRs were in operation in Japan and more than 55,000 MW in Europe[25], of which about 40% are TESCRs. Currently, more than an estimated 250,000 MW of HDSCRs are successfully operating worldwide on utility boilers with an estimated more than 100,000 MW in North America. The balance can be found in Europe (Austria, Belgium, Denmark, Finland, France, Germany, Holland, Italy, Portugal, Spain, Sweden, Turkey, etc,) and Asia (China, Japan, Korea, Taiwan, etc.).

By 1989/1990 approximately 18,000 MW of TESCRs were in operation or near completion on coal-fired utility boilers in Europe. At the same time almost four years of extremely positive operating experience had been collected on the first TESCR, which went into operation in Hamburg in 1986. Today after more than 20 years of TESCR operating experience, catalyst lifetime in excess of 100,000 is considered normal[26].

As a result of this extremely positive long term operating experience with TESCR, this principle was generally adopted as a universally applicable SCR solution for all types and compositions of flue gases incompatible for HDSCR due to the catalyst deactivation characteristics. Incompatible conditions for HDSCR can be either due to:

- physical parameters of the flue gas, which are unacceptable, such as temperature, ash content, etc., or

- chemical composition of the flue gas, which may cause uneconomically rapid catalyst deactivation such as higher concentrations of gaseous arsenic, phosphorus, sodium, potassium, calcium, magnesium, chromium, barium, selenium, etc..

Consequently, TESCRs were installed for NOx control on a wide variety of high temperature combustion and other thermal processes including:

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[24] Call by USEPA for State Implementation Plans in 19 Eastern States in order to reduce the NOx emissions of large sources (e.g. coal fired power plants) as required by the 1990 Clean Air Act Amendments (CAAA) under Title I – Groundlevel Ozone.

[25] Sanyal, A., W. Allison, "Lessons Learned from SCR Experience of Coal-Fired Units in Japan, Europe and USA; Are These Enough?" Presented at the 2002 DOE Conference Selective Catalytic Reduction and Non Catalytic Reduction for NOx Control, Pittsburgh, PA, May 2002.

[26] Sobolewski, H, H. Hartenstein, H. Rhein, "STEAG's Long Term SCR Catalyst Experience and Cost", The 2005 EPRI Workshop on Selective Catalytic Reduction, Louisville, KY, November 2005.

- municipal solid waste incinerators (1989)
- hazardous waste incinerators (1990)
- sewage sludge incinerators (1990)
- hospital and medical waste incinerators (1990)
- crematories (1991)
- pharmaceutical waste incinerators (1992)
- refinery crackers (1994)
- glass smelters (1994)
- blast furnace and coke gas combustors (1994)
- nitric acid plants (1994)
- biomass furnaces (1994)
- construction debris and waste wood combustors (1995)
- electric arc furnaces (1996)
- ammunition and chemical weapons incinerators (1997)
- ethylene crackers (1997)
- Orimulsion boilers (1999)
- roller mills (2000)
- photovoltaic cell production (2002)
- hydrogen reformers (2003)
- steel coil heat treatment facilities (2003)
- sintering plants (2003)
- steel pickling (2005)

In short, almost every high NOx producing process imaginable was successfully retrofitted with TESCR systems making the SCR technology the most widely used secondary NOx reduction technology worldwide. As a matter of fact, in many cases, HDSCRs or LDSCRs were successfully installed and operated despite the fact that original pilot testing often suggested severe, rapid catalyst deactivation and seriously questioned the technical feasibility of either one of these two SCR principles for these applications. Examples include:

- lignite or brown coal fired boilers (HDSCR, 1990)
- cyclone fired and other wet bottom boilers with fly ash re-injection (HDSCR, 1991)
- heavy fuel oil (HDSCR, 1992)
- municipal solid waste incinerators (LDSCR, 1992)
- hazardous waste incinerators (LDSCR, 1995)
- roller mills (LDSCR, 2000)
- cement kilns (HDSCR, 2003)
- biomass (HDSCR, 2006)

Two of the most recent examples of this development in the U.S. are the ongoing HDSCR retrofits on PRB-fired utility boilers as well as at several utility boilers firing Texas lignite. Once again, initial pilot testing seemed to have suggested that catalyst deactivation through fly ash pluggage and chemical poisoning may be too rapid to make HDSCR economically viable. For example, in case of PRB-fired utility boilers, HDSCR pilot testing conducted at Dynegy's Baldwin Energy Center (Baldwin Pilot Testing) yielded results that clearly suggested that PRB caused "significant accumulations of ash on the catalyst, on both macroscopic and microscopic levels. On a macroscopic level, there were significant observable accumulations that plugged the entrance as well as the exit of the catalyst sections. On a microscopic level, the ash materials filled pores in the catalyst and, in many cases, completely masked the pores within 4 months[27]."

During HDSCR pilot testing at Luminant's Sandow Generating Station Unit 4 catalyst deactivation was determined to be about 20% after approximately 2,900 hours before increasing to approximately 50% after some 3,500 hours due to catalyst plugging[28]. Based on an extrapolation of this data a HDSCR would not likely have reached 10,000 operating hours prior to catalyst needed to be added or exchanged. For comparison purposes, typical SCR catalyst design requires an addition or exchange of catalyst during an outage when the total

[27] Benson, A. J. D. Laub, C. R. Crocker, J. H. Pavlish, „SCR catalyst performance in flue gas derived from subbituminous and lignite coals", Fuel Processing Technology 86 (2005) pages 577 – 613, 2005.

[28] Smith, R, J. Bennett, D. Broske, "Impacts of Texas Lignite on SCR Catalyst Life and Performance", presented at the 2007 EPRI SCR Workshop in Pensacola, Florida, November 2007.

reactor potential has reached between 60% and 75% of the original value when equipped with all new catalyst.

Yet, in both cases, at Baldwin and Sandow, HDSCR has become the NOx control method of choice. Currently, more than fifty (50) PRB-fired boilers including at least twenty two (22) cyclone-fired units have successfully operated HDSCRs without any of the problems suggested based on the Baldwin Pilot Testing results[29]. Likewise, HDSCRs are being installed at several utility units burning Texas lignite including Oak Grove 1 & 2[30], Sandow 4[31] & 5[32], Martin Lake 1, 2 & 3[33] and Limestone 3[34].

In case of a TESCR installation, the situation is dramatically less challenging resulting from the fact that the flue gas downstream of a wet scrubber, which a TESCR is exposed to, is extremely clean compared to what the catalyst is exposed to in a HDCSR upstream of the ESP. Downstream of an ESP and a wet scrubber in excess of 99% of the fly ash is removed in the ESP[35] and between 90% and 95% of SO_2 is removed in the wet scrubber[36], thus leaving very little if anything in the flue gas that is critical for catalyst deactivation.

Additionally, downstream of a wet scrubber, the flue gas has gone through its dew point after being cooled to saturation while passing through the wet scrubber. Going through the dew point of the flue gas, which is typically between 110 F (~43 °C) and 150 F (~65°C), means that all condensable catalyst poisons such as alkali and earth alkali salts, arsenic and phosphorus oxides will inevitably have condensed and, along with all other highly water soluble gaseous catalyst poisons including sodium and potassium sulfates, phosphates and carbonates, will have been mostly removed by the wet scrubber. In a wet scrubber all water soluble compounds including water soluble alkali sulfates, phosphates and carbonates as well as all residual alkali vapors are virtually quantitatively removed as a result of their extremely high water solubility.

The very small residual amounts (less than 1%) of small particles (< 5 μm) passing through the ESP consist of condensed vapors or aerosols including sulfuric acid, alkali sulfates, earth-

[29] Benson, A. J. D. Laub, C. R. Crocker, J. H. Pavlish, „SCR catalyst performance in flue gas derived from subbituminous and lignite coals", Fuel Processing Technology 86 (2005) pages 577 – 613, 2005.

[30] E-Mail from Randy Sadler on behalf of Cindy Khalaf, President of Argillon LLC, supplier of the SCR catalyst for Oak Grove 1 & 2, dated June 24, 2008.

[31] McIlvaine Utiltiy E-Alert #870 dated April 18, 2008.

[32] Jones, B., Introductory presentation at the Gulf Coast Power Association Spring Conference, April 2006.

[33] McIlvaine Utiltiy E-Alert #874 dated May 16, 2008.

[34] McIlvaine Utility E-Alert #871 dated April 25, 2008.

[35] Milton R. Young Station – Our Jewel on the Prairie, brochure published by Minnkota Power Cooperative and Square Butte Electric Cooperative on Minnkota's website: www.minkota.com.

[36] Ibid

alkaline oxides and silicates. These small particles often act as condensation nuclei during the rapid flue gas quenching in the inlet of the wet scrubber and are largely removed by this mechanism. Thus, their already small quantity downstream of the ESP is reduced further, typically by at least 50% across a wet scrubber. This means that compared to a HDSCR, catalyst installed in a TESCR is confronted with less than 0.5% of the particulate matter and less than 5 – 10% of the acid gases, vapors and other water soluble compounds, which cause catalyst deactivation. Consequently, the experienced catalyst deactivation rate is correspondingly slower.

It must be noted that particle bound compounds add very little to the chemical catalyst poisoning causing deactivation. Only gaseous compounds or in liquid dissociated ions of salts of these compounds are chemical catalyst poisons. However, as explained earlier, these gaseous compounds are largely removed in a wet scrubber and the remaining concentrations downstream of a wet scrubber are typically so negligible that the result is and in extraordinarily slow catalyst deactivation. Furthermore, the flue gas is being reheated in a TESCR prior to entering the catalyst, which means that these very small residual concentrations of chemical catalyst poisons including alkali and earth alkali sulfates and phosphates as well as the flue gas itself are at least 400 degrees (200 K) above their respective dew points, which virtually eliminates the possibility of these residual catalyst poisons condensing in the pores of the catalyst. In general, the condensation temperature or dew point of any compound including these gaseous catalyst poisons is a function of the flue gas temperature and the compound's concentration in the flue gas. As noted above, the residual concentrations of catalyst poisons are very small in a TESCR downstream of a wet scrubber and the difference between their dew point temperature, which is the flue gas temperature at the outlet of the wet scrubber and the TESCR operating temperature is very large due to the reheating of the flue gas. Consequently, any type penetration of these chemical catalyst poisons and subsequent condensation in the catalyst pores is at least extremely unlikely if not physically impossible at the TESCR operating conditions.

The virtually negligible residual amount of gaseous catalyst poisons entering a TESCR compared to an HDSCR results directly in an almost proportionally extended catalyst life. Based on 20 years of extraordinarily successful full scale TESCR operating experience in Europe, a catalyst life of typically well more than 100,000 hours must be considered the norm rather than the exception. Several TESCRs after wet bottom utility boilers are still in operation after 20 years with the initial fill of catalyst and no replacement, exchange or addition[37].

Additionally, the minimal concentration of catalyst poisons entering a TESCR and the resulting very slow long-term catalyst deactivation (as experienced over 20 years of operation of TESCRs) led to the reduction in operating temperatures for TESCRs as shown in the graph below, which can be found on Argillon's website[38]. Argillon, who is one of the

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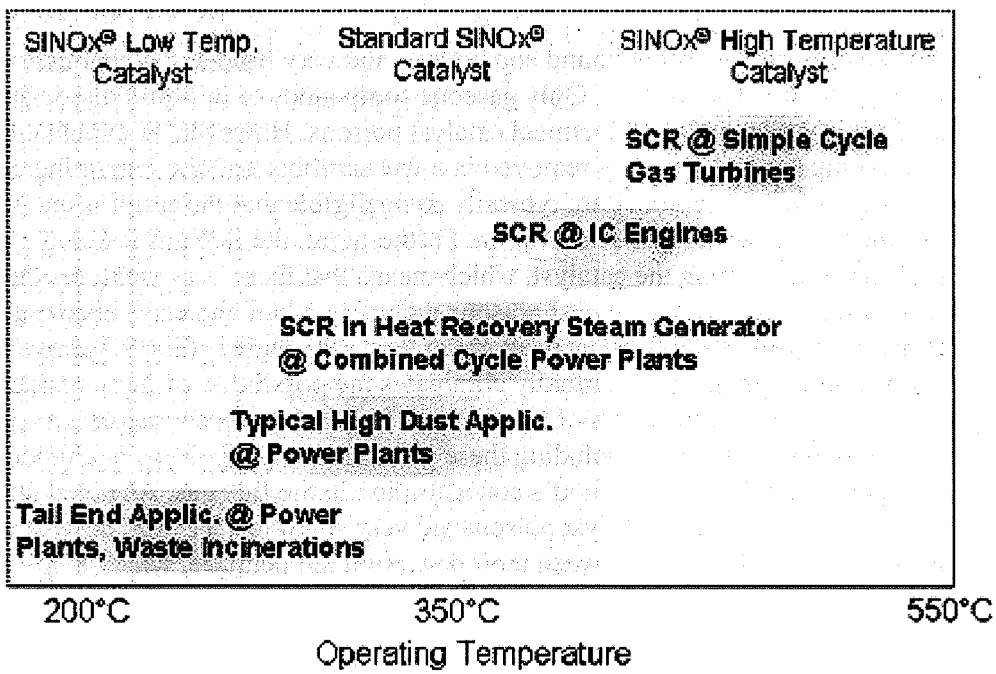
[37] Sobolewski, H, H. Hartenstein, H. Rhein, "STEAG's Long Term SCR Catalyst Experience and Cost", The 2005 EPRI Workshop on Selective Catalytic Reduction, Louisville, KY, November 2005.

[38] Argillon's website: www.argillon.com.

leading catalyst manufacturers of honeycomb as well as plate catalyst marketed under the trade name SINOx, has a wealth of experience in all types of SCR applications (HDSCR, LDSCR, TESCR) with more than 500 SCR installations worldwide[39]. Based on Argillon's extensive experience, Argillon promotes the use of TESCR in a temperature range between approximately 300 F (~150 °C) and no more than about 570 F (300 °C) as can be seen in the graph below.



As a matter of fact, for purely economic reasons and regardless of the fuel burned, no TESCR system in Europe operates today at a temperature greater than about 550 F (~290 °C). Today, the majority of TESCRs behind plants such as municipal and hazardous waste incinerators, which have an incomparably greater fuel variability and much higher concentrations of the entire spectrum of catalyst poisons (arsenic, barium, calcium, chromium, magnesium, phosphorus, potassium, selenium, sodium, thallium, etc.) than any coal-fired boiler will ever have, operate downstream of wet scrubbers and/or baghouses or activated carbon reactors (ACR) at temperatures as low as 300 F (~150 °C). These low temperature TESCR operations have been extremely successful for over a decade now with minimal to no catalyst deactivation experienced.

CERAM is another leading manufacturer of honeycomb SCR catalyst and with well over 500 SCR installations worldwide, more than 100 of which are LDSCR and TESCR installations. CERAM, arguably one of the most experienced suppliers of TESCR catalyst, fully confirms this concept of lowering the TESCR temperature. CERAM sees no need for a TESCR operating temperature of more than about 554 F (290 °C) even in case of a wet bottom boiler

[39] Argillon's website: www.argillon.com

such as a cyclone fired unit burning the most complex and difficult fuels including North Dakota lignite[40]. As a matter of fact, the only thing that dictates the minimum SCR operating temperature are the residual SO_2 and SO_3 concentrations in the flue gas, which determine the ABS reaction equilibrium[41] and thus the probability for ABS deposition on the catalyst and in the gas/gas heat exchanger. This, however, is not an irreversible catalyst poisoning issue but rather a reversible fouling problem not related to the SCR catalyst per se but simply to the reaction chemistry between H_2O, SO_3 and NH_3 in the flue gas at various temperatures.

In summary it can be stated that the SCR technology is the most widely used secondary NOx control technology in the world. It is technically feasible and applicable to a large number of thermal processes including all types of utility boilers burning any kind of fuel. In my professional experience gained over the last 20 years with the SCR technology, neither the design of the boiler or the combustion system nor the composition of the fuel burned has ever posed an irresolvable technical obstacle, which made the application of the SCR technology in one of its principles (HDCSR, LDSCR, TESCR) technically infeasible. The only challenge is the proper selection of the appropriate type of SCR principles (HDSCR, LDSCR or TESCR) and the correct SCR process and catalyst design. This selection, however, is neither a question of technical feasibility or applicability nor of availability of the SCR technology but simply a question of economics.

6. SCR EVALUATION

In June 2008, the North Dakota Department of Health's Division of Air Quality issued a "Preliminary Best Available Control Technology Determination for Control of Nitrogen Oxides for M.R. Young Station Units 1 and 2[42]", in which it determined "that SCR is not technically feasible for North Dakota lignite-fired cyclone boilers." This determination seems to rest largely on five documents provided by Minnkota Power, namely:

1. Minnkota's Best Available Control Technology Analysis Study for Milton R. Young Station Unit 1, October 2006.[43]

2. Square Butte's Best Available Control Technology Analysis Study for Milton R.

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[40] Personal conversation with John Cochran, President of CERAM Environmental, Inc., on June 25, 2008.

[41] The reaction equilibrium between ammonium sulfate ($(NH_4)_2SO_4$) and ammonium hydrogen sulfate (NH_4HSO_4), which is often incorrectly referred to as ammonium bisulfate or ABS, in the flue gas. Both, ammonium sulfate and ammonium hydrogen sulfate are products of the inevitable reaction of gaseous sulfur trioxide (SO_3) and ammonia (NH_3) contained in the flue gas upstream of the SCR catalyst.

[42] Preliminary Best Available Control Technology Determination for Control of Nitrogen Oxides for M.R. Young Station Units 1 and 2, Division of Air Quality, North Dakota Department of Health, 918 East Divide Avenue, Bismarck, North Dakota.

[43] NOx Best Available Control Technology Analysis Study for Milton R. Young Station Unit 1 Minnkota Power Cooperative, Inc., Revised Final Report, October 2006, 311777.

Young Station Unit 2, October 2006.[44]

3. SCR Catalyst Performance in Flue Gases Derived From Subbituminous and Lignite Coals, A. Benson, et al.[45]

4. Application of SCR Technology to North Dakota Lignite Fuels, Power Point Presentation slides by Sargent and Lundy, LLC, May 2007.[46]

5. Additional Information and Discussion of Vendor Responses on SCR Technical Feasibility, North Dakota's NOx BACT Determination for Milton R. Young Station Units 1 and 2, May 2008.[47]

These five documents are seemingly reasonably recent with the first and second document dated October 2006 and the forth and fifth documents dated May 2007 and May 2008, respectively. However, the third document even though published in 2005 was already accepted for publication in mid 2004 and the actual HDSCR catalyst pilot testing at the Coyote Station (Coyote Pilot Testing) and at the Baldwin Energy Center (Baldwin Pilot Testing) that lasted at least 6 months at each plant was conducted as early as 2000/2001[48]. This is relevant, since the Coyote Pilot Testing, which was conducted following the Baldwin Pilot Testing, used the same pilot test reactor equipped with the same Haldor Topsoe catalyst that was used at the Baldwin Pilot Testing[49]. Based on the Baldwin Pilot Test results the technical feasibility of HDSCR at Baldwin's cyclone-fired Units 1 & 2 burning 100% PRB would have been at least highly questionable and a BACT determination similarly conducted as the one by the Department for the M.R. Young Station would most likely have reached the same conclusion as was reached for the M.R. Young Station, namely that the SCR is technically infeasible for retrofit at the Baldwin Energy Center. However, the full scale HDSCRs at Baldwin Units 1 & 2 were commissioned in 2002 and 2003 and have since been in service for more than 45,000 hours without any of the problems indicated during the Baldwin Pilot Testing.

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[44] NOx Best Available Control Technology Analysis Study for Milton R. Young Station Unit 2 Minnkota Power Cooperative, Inc. Operating Agent for Square Butte Electric Cooperative, Owner. Revised Final Report, October 2006, 311777.

[45] Benson, A. J. D. Laub, C. R. Crocker, J. H. Pavlish, „SCR catalyst performance in flue gas derived from subbituminous and lignite coals", Fuel Processing Technology 86 (2005) pages 577 – 613, 2005.

[46] Sargent and Lundy, LLC, "Application of SCR Technology to North Dakota Lignite Fuels", a Power Point presentation, May 2007.

[47] Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative, "Additional Information and Discussion of Vendor Responses on SCR Technical Feasibility, North Dakota's NOx BACT Determination for Milton R. Young Station Units 1 & 2", May 8, 2008.

[48] E-mail from Flemming Hansen (Haldor Topsoe) dated June 30, 2008.

[49] Benson, A. J. D. Laub, C. R. Crocker, J. H. Pavlish, „SCR catalyst performance in flue gas derived from subbituminous and lignite coals", Fuel Processing Technology 86 (2005) pages 577 – 613, 2005.

At Associated Electric's New Madrid Station Units 1 & 2, both cyclone-fired units burning 100% PRB, HDSCRs were commissioned in 1999/2000 already and have been in operation successfully since then. Numerous other cyclone-fired units burning 100% PRB were retrofitted with HDSCRs and have also been operating successfully[50, 51]. This clearly proves that the results obtained during the Baldwin Pilot Testing with this particular SCR catalyst and this particular pilot test reactor design cannot be considered representative for a full scale HDSCR installation at the same unit. Baldwin Units 1 & 2 don't use the type of Haldor Topsoe catalyst used in the Baldwin and Coyote Pilot Testing but instead use Argillon plate catalyst. New Madrid Units 1 & 2 also don't use the type of Haldor Topsoe catalyst used in the Baldwin and Coyote Pilot Testing but instead use Cormetech honeycomb catalyst. Also, the HDSCR reactors at Baldwin and New Madrid were properly designed and are adequate to meet the challenges of this application and not as ill-designed and fundamentally flawed as the Baldwin and Coyote Pilot Testing reactor and catalyst design. This fact along with the conclusion that the Coyote Pilot Testing[52] didn't provide much useful data was pointed out clearly by the Department.

Furthermore, CERAM in one of their responses explicitly stated their belief that "the information and test work presented indicate that it is certainly premature to assume that there is a fatal flaw for the use of high duct SCR behind cyclones burning North Dakota lignite. The concerns presented are similar in argument to those that where used 10 years ago against the application of PRB for high dust (SCR) applications[53]". CERAM continues stating that "concerns reported by Dr. Benson[54] regarding high sodium contents and fine fume are duly noted, but inadequate evidence is presented that this could be a fatal flaw to application of (HD)SCR considering the flawed pitch and resultant pluggage of the (Haldor Topsoe) catalyst (used) during (the) Coyote Station testing[55]". This view of CERAM was further discussed in a personal conversation with Mr. Kurt Orehovsky, Product Manager of

[50] NOx Best Available Control Technology Analysis Study for Milton R. Young Station Unit 1 Minnkota Power Cooperative, Inc., Revised Final Report, October 2006, 311777.

[51] NOx Best Available Control Technology Analysis Study for Milton R. Young Station Unit 2 Minnkota Power Cooperative, Inc. Operating Agent for Square Butte Electric Cooperative, Owner. Revised Final Report, October 2006, 311777.

[52] Benson, A. J. D. Laub, C. R. Crocker, J. H. Pavlish, „SCR catalyst performance in flue gas derived from subbituminous and lignite coals", Fuel Processing Technology 86 (2005) pages 577 – 613, 2005.

[53] Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative, "Additional Information and Discussion of Vendor Responses on SCR Technical Feasibility, North Dakota's NOx BACT Determination for Milton R. Young Station Units 1 & 2", May 8, 2008.

[54] Benson, A. J. D. Laub, C. R. Crocker, J. H. Pavlish, „SCR catalyst performance in flue gas derived from subbituminous and lignite coals", Fuel Processing Technology 86 (2005) pages 577 – 613, 2005.

[55] Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative, "Additional Information and Discussion of Vendor Responses on SCR Technical Feasibility, North Dakota's NOx BACT Determination for Milton R. Young Station Units 1 & 2", May 8, 2008.

CERAM's SCR Catalyst Division[56]. Mr. Orehovsky clearly stated that CERAM reviewed all available data carefully and thoroughly and sees currently no reason why HDSCR would be technically infeasible at M.R. Young Station, however, only after resolving the temperature variation problem. He pointed out that CERAM would not expect any extraordinarily high catalyst deactivation or pluggage at a cyclone-fired unit burning North Dakota lignite if in fact an HDSCR system would be properly designed and operated. CERAM's extensive experience with lignite and biomass fired units equipped with HDSCR support this position.

Despite that clear statement and despite the ongoing proof in form of the success of the HDSCRs at New Madrid, Baldwin and many other cyclone-fired units burning 100% PRB, the only field data the Department relied upon concerning the expected catalyst deactivation and pluggage of an HDCSR installed at M.R. Young Units 1 and 2 is the data obtained from the ill-designed and fundamentally flawed Coyote Pilot Testing.

Admittedly, the Coyote Pilot Testing results seem to indicate worse pluggage than the Baldwin Pilot Testing results. However, it must be noted that the same pilot test reactor and the same catalyst, which had been already used (and plugged) at Baldwin was subsequently used at Coyote. The well known fact that catalyst that had been plugged and only mechanically cleaned is more likely to quickly plug again than new, unused catalyst was simply ignored. Furthermore, it is more than reasonable to expect that lignite fired units will cause a higher rate of catalyst deactivation in an HDSCR than a PRB fired unit. This fact was also proven during the Sandow 4 pilot testing[57] but is no reason for considering the SCR technology in general as technically infeasible. In case of Sandow 4 and other units burning Texas lignite HDSCR was even considered to be more economically viable than LDSCR or TESCR with the technical feasibility not even being a question.

Given the fact that the same pilot test reactor and catalyst were used for the Baldwin and subsequently for the Coyote Pilot Testing, it can be clearly stated that the reason for the pilot testing results at Coyote being worse than at Baldwin was because of the pilot test reactor and catalyst designs and the execution of the pilot testing, all of which were already inadequate for the Baldwin application but disastrous for the Coyote application. Yet, the unanswered question remains, why is it unreasonable to assume that a properly designed and operated HDSCR at M.R. Young Units 1 and 2 could be as successful as it has been and continues to be at New Madrid, Baldwin and the many other cyclone-fired units burning 100% PRB despite the fact that the results of the Baldwin Pilot Testing seemed to indicate the exact opposite? Based on this clear and indisputable evidence would not every reasonable engineer first suspect that the reason for the failure of the Coyote Pilot Testing was the ill-designed test pilot reactor and catalyst and the flawed execution of the pilot testing just as it was the case at Baldwin? However, instead of trying to answer these most important questions objectively and correctly, the Department jumped to the highly premature and speculative conclusion that the SCR technology regardless of the selected principle (HDSCR,

[56] Personal conversation with Mr. Kurt Orehovsky in Vienna, Austria, on July 7, 2008.

[57] Smith, R, J. Bennett, D. Broske, "Impacts of Texas Lignite on SCR Catalyst Life and Performance", presented at the 2007 EPRI SCR Workshop in Pensacola, Florida, November 2007.

LDSCR or TESCR) cannot be applied successful at the M.R. Young Station.

The Department lists the following twelve (12) conclusions that result in the Department's largely speculative and unsubstantiated determination "that high dust SCR is not technically feasible at this time for both units at the M.R. Young Station", the validity of which are discussed in detail in the following sections.

6.1 Variability of Fuel Composition

Lignite from the Center Mine is highly variable in heat and ash contents and in the constituents that make up ash, which will affect SCR design and operation. This is an undisputed fact, however, not only true for lignite from the Center Mine but for all coals regardless whether it is anthracite, bituminous, sub-bituminous, lignite, brown coal etc. As a matter of fact, these listed classifications are nothing but the result of the extremely high variability of the various types of coal. Each class in itself has a high variability again, which unquestionably affects SCR design and operation. This high variability includes also the compounds sodium and potassium (as further discussed in several subsequent sections) as well as all other catalyst poisons. Bituminous and sub-bituminous coals, which are considered relatively unproblematic for HDSCR design and operation, may serve as an example for this typical variability. Bituminous and sub-bituminous coal-fired boilers constitute the vast majority of HDSCRs in the world even though the:

- The heating value ranges from less than 8,000 Btu/lb to more than 13,000 Btu/lb.
- The ash content can vary by one order of magnitude from as low as 4 %wt. to as high as 40 %wt.
- Sulfur contents also vary easily by one order of magnitude from less than 0.5%wt. in sub-bituminous to more than 5%wt in bituminous coal.
- Likewise arsenic content range over an order of magnitude from less than 3 ppm to more than 40 ppm.

The list of similarly wide ranges of concentrations and/or variability for individual constituents of bituminous and sub-bituminous coals could be extended for almost every element of the Periodic Table. However, I am not aware of one single case where this high variability of the heat and ash contents of the coals and/or of the constituents that make up the ash precluded one of the principles of the SCR technology (HDSCR, LDSCR, TESCR) from being technically feasible and applicable.

Thus, it remains unexplained why the Department's conclusion that "lignite from the Center Mine is extremely variable in heat content, ash content and in the constituents that make up the ash", leads to the determination that the SCR technology is not technically feasible. Even though the statement that "this variability will affect the design and operation of an SCR system", is only correct with respect to a HDSCR and maybe partially to a LDSCR, it is most definitely not plausible for a TESCR. In case of TESCR the preceding air pollution control equipment (ESP and wet FGD) as well as the flue gas reheating system of a TESCR, which typically includes a gas-gas heat exchanger and steam coil upstream of the SCR reactor, virtually eliminate even the most extreme variability in the fuel and its resulting flue gas composition upstream of the SCR catalyst. It is intuitively obvious that the coal's variability in heat and ash content and in the constituents that make up the ash is no longer of any relevance in case of a TESCR system after more than 99% of the ash has been removed in the upstream air pollution control equipment[58].

6.2 Results of the Coyote Pilot Testing

The Department correctly states that "the only pilot testing that has ever been conducted on a unit firing North Dakota lignite was at the Coyote Station[59]. The pilot scale SCR was plugged after 2 months and little useful data was obtained". The Department further alludes to the fact that "the pilot testing at the Coyote Station did not provide much useful data, and in hind-sight, was ill-designed for a unit combusting North Dakota lignite". Yet despite the Department's indisputably correct and valid recognition of this as well as the facts that:

- no deactivation data exists and no conclusions should be drawn from this ill-designed and highly flawed Coyote Pilot Testing;

- several SCR equipment suppliers (Alstom, Babcock Power) clearly stated that , an "(HD)SCR system could be successfully utilized on a boiler fired with Northern lignite"[60];

- several catalyst manufacturers (CERAM, Haldor Topsoe) clearly stated and that concerns reported by Dr. Benson[61] regarding high sodium contents and fine fume are duly noted, but inadequate evidence is presented that this could be a fatal flaw to application of SCR considering the flawed pitch and resultant pluggage of the (Haldor Topsoe) catalyst during Coyote Station testing"[62];

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58 Milton R. Young Station – Our Jewel on the Prairie, brochure published by Minnkota Power Cooperative and Square Butte Electric Cooperative on Minnkota's website: www.minkota.com.

59 Benson, A. J. D. Laub, C. R. Crocker, J. H. Pavlish, „SCR catalyst performance in flue gas derived from subbituminous and lignite coals", Fuel Processing Technology 86 (2005) pages 577 – 613, 2005.

60 Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative, "Additional Information and Discussion of Vendor Responses on SCR Technical Feasibility, North Dakota's NOx BACT Determination for Milton R. Young Station Units 1 & 2", May 8, 2008.

61 Benson, A. J. D. Laub, C. R. Crocker, J. H. Pavlish, „SCR catalyst performance in flue gas derived from subbituminous and lignite coals", Fuel Processing Technology 86 (2005) pages 577 – 613, 2005.

62 Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative, "Additional Information and Discussion of Vendor Responses on SCR Technical Feasibility, North Dakota's NOx BACT Determination

- several catalyst manufacturers (CERAM, Haldor Topsoe), who have experience with high sodium and potassium containing fuels, offered industry standard type catalyst performance guarantees (NOx removal efficiency, SO_2/SO_3 conversion rate, pressure drop, NH_3 slip, catalyst lifetime)[63];

the Department still concludes that "the Coyote testing demonstrates to the Department that North Dakota lignite firing will have more severe effects (plugging and catalyst deactivation) than units firing sub-bituminous coal when the same design is employed".

This statement promotes three basic questions, namely:

a. How can the Coyote Pilot Testing demonstrate to the Department that North Dakota lignite firing will have more severe effects (plugging and catalyst deactivation) when no catalyst deactivation data exists and the pilot scale SCR reactor at the Coyote Station plugged very quickly because the reactor was ill-designed and the selected catalyst design not suitable, particularly for a unit combusting North Dakota lignite?

b. Does the Department have any additional information that may substantiate the Department's otherwise completely unfounded conclusion and that wasn't provided to the contacted vendors including Alstom, Babcock Power, CERAM and Haldor Topsoe so that they reached the essentially opposite conclusion?

c. Why does the Department imply that the same catalyst and SCR design employed for units firing sub-bituminous coal must also be used for M.R. Young Station?

As pointed out earlier, this is relevant since in the early 2000s, when the Coyote Pilot Testing[64] was conducted, the results of which provide the only catalyst relevant field data for the Department's conclusion concerning the rapid pluggage and deactivation of catalyst in a HDSCR, no long term full scale HDCSR operating experience was available from Associated Electric's New Madrid Station, which was the first one to install HDSCR on a cyclone-fired unit burning PRB. Yet, as pointed out by Burns & McDonnell, today a significant number of cyclone-fired units in the U.S. burning PRB successfully operate HDSCRs[65, 66, 67].

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for Milton R. Young Station Units 1 & 2", May 8, 2008.

[63] Ibid

[64] Benson, A. J. D. Laub, C. R. Crocker, J. H. Pavlish, „SCR catalyst performance in flue gas derived from subbituminous and lignite coals", Fuel Processing Technology 86 (2005) pages 577 – 613, 2005.

[65] NOx Best Available Control Technology Analysis Study for Milton R. Young Station Unit 1 Minnkota Power Cooperative, Inc., Revised Final Report, October 2006, 311777.

[66] NOx Best Available Control Technology Analysis Study for Milton R. Young Station Unit 2 Minnkota Power Cooperative, Inc. Operating Agent for Square Butte Electric Cooperative, Owner. Revised Final Report, October 2006, 311777.

The Department further states that "besides catalyst deactivation, it is likely that a high-dust SCR would experience plugging problems (deposition on the catalyst surface) due primarily to the carryover of popcorn ash from the boiler". This statement is also quite puzzling, since the formation of popcorn ash is a commonly known phenomenon that has first caused catalyst pluggage in Germany in the mid 1990s[68] and is also a well known problem in the U.S. since the early 2000s. However, it has been solved successfully[69] by the use of properly designed popcorn ash removal systems[70].

The Department's statement that "the advances made in the last few years for controlling popcorn ash are not shown to be applicable to a cyclone boiler burning North Dakota lignite" is not only purely speculative but defies all common engineering sense. Various designs and types of popcorn ash screens have been installed in a wide variety of units in the U.S. and are operating successfully. I believe that no engineering company with SCR experience including Sargent and Lundy and Burns & McDonnell would seriously argue the fact that properly designed popcorn ash screens could be successfully installed at M.R. Young Station's Units 1 and 2 without additional pilot scale testing. Needless to add that in case of a LDSCR or TESCR any concern over popcorn ash would be considered absurd simply by virtue of the location of the LDSCR or TESCR in the flue gas path downstream of the ESP (LSDCR) and wet scrubber (TESCR).

Furthermore, the Department's statement that "operation of an SCR system for only 2 months between catalyst replacements is not considered successful operation of SCR technology," implies that the catalyst in a properly designed full scale HDSCR at the M.R. Young Station would have to be replaced every two (2) months. Again, no deactivation data was ever determined during or after the Coyote Pilot Testing to substantiate this claim. This forces the conclusion that the mostly useless data obtained from the ill-designed and flawed Coyote Pilot Testing was improperly and incorrectly used by the Department to speculatively extrapolate to what may or may not happen in a properly designed HDSCR system.

This bold speculative extrapolation to a catalyst life of only two (2) months between replacements in a full scale HDSCR is particularly interesting since the Department immediately contradicts its own conclusion by postulating that "without pilot testing, the life of the catalyst cannot be predicted with any reasonable certainty." Assuming this latter statement is true and further reiterating the fact that no deactivation testing from pilot testing

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[67] Sargent and Lundy, LLC, "Application of SCR Technology to North Dakota Lignite Fuels", a PowerPoint presentation, May 2007.

[68] Hartenstein, H., H. Gutberlet, L. Licata, "Utility Experience with SCR in Germany", a paper presented at the Sixteenth Annual International Pittsburgh Coal Conference, October 1999.

[69] Sargent and Lundy, LLC, "Application of SCR Technology to North Dakota Lignite Fuels", a PowerPoint Presentation, May 2007.

[70] Martin, M., M. Harrell, J, Jancauskas, H. Hartenstein, H. Sobolewski, "Large Particel Ash (LPA) Screen Retrofits at Coal-Fired Units in Indiana and Ohio", DOE-NETL Conference on SCR/SNCR, 2006.

is available, how can the Department assert that a properly designed full scale HDSCR system would operate for only two (2) months between catalyst replacements while stating at the same time that the life of the catalyst cannot be predicted without further pilot testing?

Furthermore, the Department's bold postulation of an expected catalyst life of only two (2) months between replacements is made despite the fact that two (2) experienced catalyst suppliers (Haldor Topsoe and CERAM) offered firm performance and lifetime guarantees[71] for their catalyst installed in an HDSCR of considerably more than the 10,000 hour threshold arbitrarily defined by the Department. Why the Department ignores all these facts and concludes that it can predict the expected catalyst life better than even the most experienced catalyst manufactures remains unknown.

6.3 Soluble Sodium

The Department concludes that "the combustion of (North Dakota) lignite produces soluble sodium compounds, which cause more severe catalyst deactivation than insoluble sodium compounds". Even though this statement may be generally correct, it remains unclear and unexplained, why soluble sodium compounds, which can only penetrate into the catalyst and deactivate the catalytically active vanadium pentoxide (V_2O_5) when in they are either in the gas phase or as sodium ions (Na^+) dissociated in a liquid, would be present in the gas phase or in a liquid and therefore in a mobile form.

The argument raised by Minnkota and reiterated by the Department that the formation of low temperature sodium-calcium-magnesium sulfates and phosphates poses the most significant problem for the successful operation of SCR catalysts in a HDSCR may be true with respect to catalyst deactivation. However, the simple comparison of emission rates of these compounds with the fly ash is not a correct and appropriate way to derive any meaningful prediction concerning the expected catalyst deactivation. Even though the Department correctly states that "the catalyst deactivation rate may not be directly proportional to the emission rates of the various constituents", incorrectly continues that "it does provide a means of comparison of the flue gas characteristics". Unfortunately, the Department fails to realize what was pointed out by one of the most experienced catalyst suppliers, namely that "sodium is not a poison to catalyst at SCR operating temperatures[72]." Thus, the elaborate comparison of emission factors of sodium, potassium, calcium and magnesium emission factors with the fly ash may have some academic value but is effectively meaningless for the correct prediction of catalyst deactivation, since particle bound sodium, potassium, calcium and magnesium in the fly ash are not mobile and therefore are not catalyst poisons.

Typically, sodium and potassium sulfates, so called pyrosulfate compounds, have very high

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[71] Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative, "Additional Information and Discussion of Vendor Responses on SCR Technical Feasibility, North Dakota's NOx BACT Determination for Milton R. Young Station Units 1 & 2", May 8, 2008.

[72] Ibid

boiling points well above any possible SCR operating temperature. Thus, it is highly unlikely that any appreciable quantities of these pyrosulfates will be present in the SCR in the gas phase. This, however, would be necessary in order to cause severe and rapid catalyst deactivation. Therefore, under these conditions these compounds are not a major concern.

Alternatively, these pyrosulfate compounds would have to be present in a liquid so that their dissociated ions (i.e. Na^+, K^+) would be mobile in order to enter the catalyst pores and react with the catalyst's active sites. However, these compounds will only be present in the catalyst in a liquid form if either the SCR operating temperature is too low or during shut down when cooling the SCR reactor to temperatures below the moisture dew point. Since the melting point of most pyrosulfates is well above the typical HDSCR operating temperature of 650 – 750 F (343 – 400 °C) the intrusion of liquid pyrosulfates is no major concern with respect to a severe, rapid catalyst deactivation. Therefore, even catalyst suppliers state clearly that "sodium is not a poison to catalyst at SCR operating temperatures. Significant deactivation can occur if condensed moisture transports sodium residing at the surface into the catalyst pore structure during outage or layup[73]". Since the HDSCR operating temperature must be expected to be maintained at well above 650 F (343 °C) at all times, no liquid ever occurs during SCR operation not even in the inner pores as the temperature is too high even for capillary condensation. This well known fact is one of the main reasons why HDSCR operating temperatures are selected to be typically in the range between 600 F (315 °C) and 800 F (427 °C). Maintaining the required minimum SCR operating temperature at all times is an absolute requirement for all HDSCRs regardless of fuel type and/or boiler/burner configuration and has nothing to do with North Dakota lignite and/or cyclone-fired boilers.

As pointed out earlier, the condensation of moisture in the pores of the SCR catalyst typically occurs only during shut-down and subsequent cooling of an SCR reactor. Thus, reducing the number of shut-downs, which result in cooling the SCR catalyst to below the moisture dew-point, is always advantageous for all HDSCRs regardless of fuel- and/or firing type.

Given the fact that sixty (60) start-ups were reported for M.R. Young Unit 1[74] within a five (5) year period and sixty two (62) start-ups for the same period for M.R. Young Unit 2[75], it can be easily calculated that this equates to an average of approximately twelve (12) start-ups per year or roughly one (1) per month. However, in case of Unit 1 only six (6) and in case of Unit 2 only seventeen (17) were considered "cold" start-ups, which are defined as the boiler having been without fuel-firing for more than seventy two (72) hours[76]. During shut-downs

[73] Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative, "Additional Information and Discussion of Vendor Responses on SCR Technical Feasibility, North Dakota's NOx BACT Determination for Milton R. Young Station Units 1 & 2", May 8, 2008.

[74] NOx Best Available Control Technology Analysis Study for Milton R. Young Station Unit 1 Minnkota Power Cooperative, Inc., Revised Final Report, October 2006, 311777.

[75] NOx Best Available Control Technology Analysis Study for Milton R. Young Station Unit 2 Minnkota Power Cooperative, Inc. Operating Agent for Square Butte Electric Cooperative, Owner. Revised Final Report, October 2006, 311777.

[76] Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative, Responses to NDDH and EPA

of less than seventy two (72) hours, SCR reactors are typically "buttoned up hot", which means the SCR reactor is isolated from the flue gas path during shut down by means of putting it in a bypass mode while the SCR is still at its design operating temperature. The cooling rate of such a "buttoned up hot" SCR reactor is known to be extremely slow. Unless forced cooled with ambient air no "buttoned up hot" SCR reactor loses more than approximately 50 – 100 degrees and therefore gets nowhere near the sulfuric acid or even the moisture condensation temperature in a seventy two (72) hour period.

Therefore, catalyst deactivation by means of soluble sodium compounds in the ash being dissociated into a liquid and penetrating into the catalyst pores and reacting there with the catalytically active V_2O_5 must be expected to be rather slow. Since the actually experienced catalyst deactivation rate due to this effect has never been measured, the respective conclusion postulated by the Department cannot be considered more than an unsubstantiated speculation.

6.4 Differences in Flue Gas Composition

The Department concludes that "the flue gas generated at the M.R. Young Station is different from the flue gas at any plant where SCR technology has been applied". The absoluteness of this statement, which is not even limited to power plants, is quite amazing as it indubitably implies that the Department has complete detailed knowledge not only of the flue gas composition of every other power plant in the world equipped with an SCR system but also of every other plant in the world where the SCR technology is applied. Even though theoretically possible, the lack of any data from all these other plants strongly suggests that this may be highly questionable and largely overreaching. As a matter of fact, I am sure that I could easily present to the Department several plants where the SCR technology has been applied successfully that the Department doesn't even know that these plants existed.

Furthermore, the Department states that this absolute uniqueness is "primarily due to the high ash concentration of soluble sodium compounds and the total loading of catalyst deactivation chemicals". Again, as discussed in section 6.3 and clearly pointed out by catalyst suppliers, sodium is not a catalyst poison at SCR operating temperatures[77]. The claimed uniqueness of the flue gas generated at the M.R. Young Station appears to be highly speculative and completely unproven as comparisons were only drawn to:

- bituminous coal (specifically mentioning Pennsylvania coal);
- sub-bituminous coal (specifically mentioning Wyoming PRB);

Comments Regarding SCR Technical Feasibility and Non-SCR Concerns Milton R. Young Station Unit 1 and Unit 2 NOx BACT Analysis Study, April 18, 2007.

[77] Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative, "Additional Information and Discussion of Vendor Responses on SCR Technical Feasibility, North Dakota's NOx BACT Determination for Milton R. Young Station Units 1 & 2", May 8, 2008.

- other lignites (specifically mentioning Texas lignite).

Needless to say that Pennsylvania coal is not the only bituminous coal in the world, Wyoming PRB is not the world's only sub-bituminous coal and Texas lignite is referred to as Texas lignite for the simple reason that it is somewhat unique to Texas compared to the many other types of lignites and brown coals around the world. Thus, the Department's statement in its far reaching and absolute form must either be considered extraordinarily uninformed or only correct if rigorously limited to the three specific coal types mentioned. In that sense this conclusion has little if any relevance to the question of the technical feasibility of the SCR technology to the M.R. Young Station and should be simply ignored as completely irrelevant.

6.5 Experience of Burns and McDonnell and Sargent and Lundy

The Department concludes that "both Burns and McDonnell and Sargent and Lundy have extensive experience with the design and operation of SCR systems". The fact of the matter is, however, that the SCR experience of Burns & McDonnell must be considered rather limited for a number of reasons, namely Burns & McDonnell has provided SCR related services for only seventeen (17) power plants[78]. At least ten (10) of these are not even in operation yet and only two (2) SCR projects are retrofits. Thus, Burns & McDonnell has very little experience with SCR retrofits and the only two (2) SCR retrofits, in which Burns and McDonnell was involved as Owner's Engineer, namely Hoosier Energy's Merom Station and HMPL's Henderson Station, have accumulated any appreciable long-term operating experience. However, in both of these cases, Burns & McDonnell's scope was limited to portions completely irrelevant to SCR process and catalyst design such as balance-of-plant design including foundations, electrical, controls integration, civil and contract oversight[79]. In the case of the Henderson Station, the SCR was supplied by Alstom and the catalyst by Cormetech. All process design, catalyst selection and design and all relevant process performance guarantees were provided by either Alstom or Cormetech. None were provided by Burns & McDonnell. In the case of the Merom Station, the SCR was supplied by Lurgi and the catalyst by KWH. Again, all process design, catalyst selection and design and all relevant process performance guarantees were provided by either Lurgi or KWH. None were provided by Burns & McDonnell.

Detailed design is currently being provided by Burns & McDonnell for only one (1) power plant, namely Associated Electric's Thomas Hill Units 1, 2 and 3. The SCRs are currently under construction and Burns & McDonnell lists conceptual design and studies, structural

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[78] Summary of Responses to EPA/DOH Questions on Minnkota Power's NOx BACT Analysis for Milton R. Young Units 1 & 2, Presentation by EERC, Minnkota Power, Burns & McDonnell to NDDH and U.S. EPA, May 23, 2007.

[79] Ibid

design, balance of plant design and construction management as services provided[80]. It is worth noting that again none of these services have anything to do with the SCR process or catalyst design. The only service provided by Burns & McDonnell for this one (1) SCR retrofit project at least remotely related to SCR process design was the selection of the reagent and the catalyst manufacturer. However, reagent selection is irrelevant for catalyst deactivation and/or pluggage and the SCR catalyst itself is supplied by CERAM including the design, sizing as well as all process performance guarantees[81]. Thus, the catalyst selection performed by Burns and McDonnell was nothing more than recommending CERAM as the catalyst supplier presumably on the basis of a lowest price competitive bidding process.

In summary it is worth noting that Burns & McDonnell has neither provided SCR process design and/or SCR process performance guarantees in one single case nor ever operated any SCR system. Thus, the Department's conclusion concerning Burns & McDonnell's "extensive experience with the design and operation of SCR systems" seems to be based on a surprising lack of familiarity of the true capabilities and limitations of these architect engineering (A/E) firms. Concerning the "extensive operating experience" the Department's conclusion is plain wrong and for the remainder coarsely exaggerating as no A/E ever provides any process and/or catalyst design and/or performance guarantees.

Even though Sargent and Lundy claims significantly more SCR experience than Burns & McDonnell, Sargent and Lundy has also only acted as an A/E for SCR retrofits. Sargent and Lundy lists to have been involved in approximately 27,000 MWs of SCRs as an A/E. This represents a little more than one fifth ($^1/_5$) of the SCRs retrofitted to coal-fired units in North America[82] or less than half of the 46% claimed by Sargent and Lundy. Despite Sargent and Lundy's greater involvement in SCR retrofits as an A/E compared to Burns & McDonnell, it must be noted that Sargent and Lundy has also never provided any SCR process and/or catalyst design and/or performance guarantees and never operated any SCR systems. Thus, the Department's conclusion concerning Sargent and Lundy's "extensive experience with the design and operation of SCR systems" seems to be also based on a lack of familiarity of the true capabilities and limitations of these architect engineering (A/E) firms. Concerning the "extensive operating experience" the Department's conclusion is plain wrong and for the remainder at least highly questionable as no A/E ever provides and process and/or catalyst design and/or performance guarantees.

In general it must be noted that all services, which are critical for SCR system process design and process performance guarantees, including:

- process design;

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[80] Summary of Responses to EPA/DOH Questions on Minnkota Power's NOx BACT Analysis for Milton R. Young Units 1 & 2, Presentation by EERC, Minnkota Power, Burns & McDonnell to NDDH and U.S. EPA, May 23, 2007.

[81] Reference list on CERAM's website: www.frauenthal.net.

[82] Sargent and Lundy LLC, "Application of SCR Technology to North Dakota Lignite Fuels", a PowerPoint Presentation, May 2007.

- catalyst sizing and design;
- flow modeling and SCR rector design;
- process performance guarantees;
- catalyst performance guarantees;

have never been and most likely will never be provided by neither Burns and McDonnell nor Sargent and Lundy. All these critical services are always either supplied by an SCR equipment supplier (Alstom, Babcock Power, Babcock & Wilcox, etc.) or by the catalyst manufacturer (Argillon, CERAM, Cormetech, Haldor Topsoe, Hitachi, etc.). As a matter of fact, all catalyst related performance guarantees (NOx removal efficiency or activity, SO_2/SO_3 conversion rate, catalyst life or deactivation rate, etc.) are never provided by anyone other than the catalyst manufacturers. Even the SCR equipment suppliers only pass through the catalyst performance guarantees obtained from the catalyst manufacturer to the end customer. And at least two (2) of these catalyst manufacturers, namely Haldor Topsoe and CERAM were clearly willing to provide industry standard type performance guarantees for their catalyst[83]. Notably, both of these catalyst manufacturers have extensive HDSCR experience with high sodium and potassium containing fuels such as biomass and/or lignite. It remains unclear why the Department didn't exploit the statements of these highly experienced catalyst manufacturers further but rather relied on the A/E's who have no SCR process and/or catalyst design experience, have never provided any SCR process and/or catalyst related performance guarantees and have absolutely no SCR operating experience.

6.6 Development Stage of High-Dust SCR

The Department states that "to design and install an SCR system for a cyclone-fired unit firing North Dakota lignite without obtaining additional data from bench scale would be experimentation". This conclusion is again in clear disagreement with the statement of catalyst manufacturers such as Haldor Topsoe and CERAM, who were willing to provide industry standard type catalyst performance guarantees even for HDSCR. This clearly indicates that both of these highly experienced catalyst manufacturers see no need for obtaining additional data from bench scale experimentation but feel to be in the position to design and install a HDSCR system at M.R. Young's Units 1 and 2.

Needless to say that no catalyst manufacturer and/or SCR system supplier will turn down the opportunity for additional bench scale and/or pilot testing if offered as it always effectively presents itself as a welcome possibility for risk free research paid by others. Also needless to say, every A/E, who typically charges billable manhours, will favor bench scale and/or pilot

[83] Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative, "Additional Information and Discussion of Vendor Responses on SCR Technical Feasibility, North Dakota's NOx BACT Determination for Milton R. Young Station Units 1 & 2", May 8, 2008.

testing, thus extending the life of the project and therefore the amount of manhours billable.

Furthermore, even if HDSCR would not be economically viable, LDSCR or TESCR certainly would be and are indubitably technically feasible and applicable as clearly indicated by the multitude of applications of this principle of the SCR technology to a wide range of processes (see also section 5 of this report). Why the Department essentially ignores all the statements by these catalyst manufacturers and insists stubbornly that their provided SCR catalyst design[84] is experimentation, remains a mystery.

6.7 Temperature Variations

The Department correctly states that "the temperature variation of the flue gas entering the (HD)SCR will adversely affect the performance and must be resolved for successful application of this technology". However, the large temperature variations present at these units is very unusual for coal-fired units including cyclone-fired units. It is a unit specific problem related to the very unique design of the backpass of the boiler and the air preheater rather than to cyclone-fired boilers and/or North Dakota lignite. According to the boiler supplier Babcock & Wilcox only four (4) of these type boilers including the two (2) at M.R. Young Station were ever built[85], which clearly makes this the exception rather than the rule. In fact, such large temperature variations would not be tolerable for any HDSCR installed after any type of firing system (single or opposed wall-fired, tangentially-fired, turbo-fired, cyclone-fired, etc.) burning any type of fuel (bituminous, sub-bituminous, lignite, brown, etc. coal, oil, gas, biomass, etc.). Thus, the temperature variation problem, which Babcock & Wilcox indicated can be technically resolved by incorporating the appropriate and necessary measures for the modification of the boiler's backpass and possibly the lignite pre-drying system[86], is no reason to determine that the SCR technology is technically infeasible for cyclone-fired units burning North Dakota lignite. In a worst case scenario it may make HDSCR the economically less attractive alternative compared to LDSCR or TESCR due to the very unique boiler design employed at the M.R. Young Station.

6.8 Catalyst Erosion

The Department concludes that "there are unresolved issues regarding catalyst erosion from the ash generated at the M.R. Young Station". This conclusion is not substantiated by any data and at least highly disputable based on long-term SCR operating experience in Europe. Units equipped with HDSCR systems firing up to 40% ash waste coals have been in

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[84] Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative, "Additional Information and Discussion of Vendor Responses on SCR Technical Feasibility, North Dakota's NOx BACT Determination for Milton R. Young Station Units 1 & 2", May 8, 2008.

[85] E-mail from Steve Moormann (Babcock &Wilcox) to Robert Blakley (Burns & McDonnell) dated 07/18/07.

[86] Ibid

successful operation for almost two (2) decades now without any major operating problems or excessive catalyst erosion[87]. The average ash content of Center Mine North Dakota lignite, which has an average heating value of approximately 50% of bituminous coal, is less than about 8%wt[88]. Hence, approximately twice as much lignite must be burned for the same heat input compared to average bituminous coal. This, however, results still only in an equivalent average ash content of about 16%wt. of comparable bituminous coal, which is a factor of approximately 2.5 lower than the maximum ash content that HDSCRs have been exposed to successfully in Europe. As a matter of fact, bituminous coals with ash contents in the range of 12 – 15 %wt. are considered normal in Europe and pose no erosion threat to SCR catalyst whatsoever. Consequently, preventing excessive ash erosion of the catalyst is simply a matter of correct SCR design as has been proven extensively in Europe. Neither Burns & McDonnell nor Sargent and Lundy have any experience with HDSCR designs for higher ash coals or any experience with the operation of HDSCRs on high ash units.

This leads to the conclusion that the Department's concerns over seemingly unresolved issues regarding catalyst erosion appear to be the result of a simple lack of knowledge of the many HDSCRs that have been subjected to much harsher conditions for almost two (2) decades now.

6.9 Catalyst Poisoning, Blinding and Plugging

The Department correctly states that "poisoning, blinding and plugging of a catalyst are affected by the geometries and properties of the catalyst". However, subsequently, the Department concludes that "cyclone firing of Fort Union lignite and Center Mine coal results in a flue gas stream that highly accelerates poisoning, blinding and plugging (of pores) due to the rich sodium and potassium vapors, particles and ammonia sulfates (due to ammonia injection) in lignite-fired cyclone flue gas". The categorical absoluteness of this statement is impressive as it rest solely on the highly questionable results of the ill-designed Coyote Pilot Testing[89]. As already elaborated on in detail in sections 6.2 and 6.3 of this report and confirmed by the Department[90], the data of the referenced Coyote Pilot Testing is more or less useless. Despite the facts that:

- No deactivation data of the catalyst was ever determined during or after the Coyote

[87] Sobolewski, H, H. Hartenstein, H. Rhein, "STEAG's Long Term SCR Catalyst Experience and Cost", The 2005 EPRI Workshop on Selective Catalytic Reduction, Louisville, KY, November 2005.

[88] Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative, Responses to NDDH and EPA Comments Regarding SCR Technical Feasibility and Non-SCR Concerns Milton R. Young Station Unit 1 and Unit 2 NOx BACT Analysis Study, April 18, 2007.

[89] Benson, A. J. D. Laub, C. R. Crocker, J. H. Pavlish, „SCR catalyst performance in flue gas derived from subbituminous and lignite coals", Fuel Processing Technology 86 (2005) pages 577 – 613, 2005.

[90] Page 7 of the Preliminary Best Available Control Technology Determination for Nitrogen Oxides for M.R. Young Station Units 1 and 2, Division of Air Quality ND Department of Health, 918 E. Divide Avenue, Bismarck, ND, June 2008.

Pilot Testing.

- The combination of the fatally flawed Coyote Pilot Testing reactor design, the inadequacy of the selected catalyst type and the extremely poor execution of the test runs caused the severe catalyst pluggage after only two (2) months rather than the flue gas composition and/or ash characteristics as pointed by highly experienced catalyst manufacturers including CERAM and Haldor Topsoe[91], who provided the catalyst for the Baldwin and Coyote Pilot Testing.

- The catalyst manufacturers most experienced with similar fuels (i.e. biomass, PRB, brown coal, etc.) clearly stated[92] that:

    - "the deactivation rate of the catalyst will be high but manageable" (Haldor Topsoe);

    - "the information and test work presented indicate that it is certainly premature to assume that there is a fatal flaw for the use of high dust SCR behind cyclones firing North Dakota lignite" (CERAM);

    - they "are willing to warrant the catalyst performance" based on industry standard terms (Haldor Topsoe);

    - "a commercial offering regarding this project" can be provided (CERAM);

the Department boldly decided that "the engineering solutions of a larger SCR reactor, more catalyst and larger pitch do not resolve the rapid plugging of catalyst pores". This conclusion is in sharp contrast to the statements provided not only by the catalyst manufacturers most experienced with similar types of fuels but also with the statements made by some of the most experienced SCR system suppliers (Alstom, Babcock Power), who "expect that an SCR system could be successfully utilized on a boiler fired with Northern lignite fuel[93]".

The Department continues stating that "there is no catalyst vendor solution to reduce or eliminate pore plugging. The chemical and physical process of pore plugging cannot be reversed, which dictates catalyst change out." This statement is simply incorrect as several well proven methods exist for successfully reducing and/or eliminating pore plugging and completely reversing sodium and potassium poisoning of the catalyst. For instance, Alstom in their correspondence with Burns & McDonnell points out several times[94] that as a result of

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[91] Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative, Responses to NDDH and EPA Comments Regarding SCR Technical Feasibility and Non-SCR Concerns Milton R. Young Station Unit 1 and Unit 2 NOx BACT Analysis Study, April 18, 2007.

[92] Ibid

[93] Ibid

[94] Ibid

the highly efficient flue gas cleaning equipment upstream of a LDSCR or TESCR, the installation of a LDSCR or TESCR would eliminate these issues. Furthermore, Haldor Topsoe points out that "the expected poisons are mostly water soluble, therefore periodic water washing of the catalyst can be used to regain activity and to increase overall service life[95]". This is a clear reference towards the various in-situ[96], on-site[97] and off-site[98] catalyst washing, rejuvenation and regeneration processes that are commercially available and have been successfully used in the U.S. as well as in Europe for more than a decade now. These methods have proven beyond any doubt the possibility of regaining the catalyst's full initial activity for a fraction of the cost of new catalyst. They can also be applied multiple times to the same catalyst, particularly in case of sodium and potassium poisoning as well as fly ash pluggage, where simple washing either in-situ[99] or on site[100] has yielded excellent results. These various washing, rejuvenation and regeneration technologies have been utilized successfully by the U.S. utility industry since early 2003[101].

Why the Department ignores these facts and makes a statement in clear contradiction to all this evidence remains unknown.

6.10 Lack of Pilot Scale Testing Data

The Department states that "without pilot testing, the long term NOx reduction efficiency, the volume of the reactor, the catalyst pitch, life of the catalyst, or even type of the catalyst to be used cannot be predicted with a high degree of confidence." This statement is most interesting as is seems to be in clear contradiction to the Department's previous statements that:

- "Cyclone firing of Fort Union lignite and Center Mine coal results in a flue gas stream that highly accelerates poisoning, blinding and plugging (of pores) due to the rich sodium and potassium vapors, particles and ammonia sulfates (due to ammonia

[95] Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative, Responses to NDDH and EPA Comments Regarding SCR Technical Feasibility and Non-SCR Concerns Milton R. Young Station Unit 1 and Unit 2 NOx BACT Analysis Study, April 18, 2007.

[96] Maier, H, W. Götz, "In Situ Catalyst Regeneration – a Cost Saving Technology for SCR Operators", a paper presented at Power Gen, 2001.

[97] Nagai, Y., Y. Inatsune, I. Morita, Y. Kato, K. Yokoyama, K. Ito, P. Otte, "Rejuvenation of the SCR Catalyst at Mehrum", a paper presented at the Electric Power Conference, 2004.

[98] Hartenstein, H., H. Gutberlet, "Catalyst Regeneration – An Integral Part of Proper Catalyst Management", The 2001 EPRI Workshop on Selective Catalytic Reduction, 2001.

[99] Maier, H, J. Matschke, "Recent Experience With SCR Catalyst Regeneration", a paper presented at the DOE-NETL Conference on SCR/SNCR, 2001.

[100] www.envirgy.com/en/references/catalyst_regeneration.

[101] www.ebinger-kat.com/en/referenzen.php.

injection) in lignite-fired cyclone flue gas".

- "The engineering solutions of a larger SCR reactor, more catalyst and larger pitch do not resolve the rapid plugging of catalyst pores."

- "The pilot scale (HD)SCR that was deployed at the Coyote Station was plugged and the catalyst pores deactivated after 2 months (approx. 1,430 hours)" The Department believes successful operation is considerably more than a few thousand hours of operation."

How can the Department postulate on one hand that without further pilot testing long term NOx reduction efficiency or in other words catalyst deactivation and therefore catalyst life cannot be predicted with a high degree of confidence, while claiming on the other hand with the seemingly highest degree of confidence that:

- The flue gas composition leads to highly accelerated catalyst poisoning, blinding and plugging?

- Successful operation is considerably more than a few thousand hours based on the fact that the ill-design HDSCR pilot test reactor plugged after only two (2) months?

Likewise how can the Department postulate on one hand that such fundamental HDSCR design parameters as volume of the SCR reactor, catalyst pitch and type of catalyst cannot be predicted with a high degree of confidence, while claiming on the other hand with the seemingly highest degree of confidence that no engineering solutions of a larger SCR reactor, more catalyst volume and larger pitch exist to resolve the rapid plugging of catalyst pores? Unfortunately, the Department fails to resolve these obviously diametrically contradicting statements.

Yet, it must be noted that the Department's claims concerning the rapid catalyst poisoning, blinding and plugging as well as the claim that no engineering solutions exist to mitigate these, are solely based on the highly questionable results of the ill-designed Coyote Pilot Testing. At the same time, however, the Department states that without additional pilot testing none of these necessary predictions could be made since the Coyote Pilot Testing was ill-designed and didn't provide much useful data[102]. This contradiction further nurtures the impression that the Department either solely relies upon or completely negates the Coyote Pilot Testing results depending on what ever seems to favor the particular argument against SCR at the moment.

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[102] Preliminary Best Available Control Technology Determination for Nitrogen Oxides for M.R. Young Station Units 1 and 2, page 7, Division of Air Quality ND Department of Health, 918 E. Divide Avenue, Bismarck, ND, June 2008.

6.11 Lack of Vendor Guarantees

The Department states that "vendors cannot without further pilot testing, guarantee SCR system performance for M.R. Young Station boilers firing North Dakota lignite". This statement is simply incorrect as both CERAM and Haldor Topsoe clearly stated that they would be willing to offer industry standard type performance guarantees[103] for their catalyst for a HDSCR system installed at M.R. Young Station – see also the discussion in section 6.9 of this report.

The Department's claim that "even the most optimistic vendors don't offer true guarantees of catalyst performance", is as incorrect as the first statement. Both, Haldor Topsoe and CERAM clearly stated that they would be willing to offer industry standard type guarantees for the performance of their catalyst for a HDSCR at M.R. Young Station. The fact that the Department argues that "the guarantee is limited to the contract value" merely unveils the Department's surprising lack of familiarity with the type and extent of performance guarantees provided within the utility industry. The fact of the matter is that no equipment vendor in the utility industry ever accepts any liability for performance guarantees above and beyond the full amount of the contract value, which is exactly what was offered i.e. by Haldor Topsoe[104]. This is not only common practice in the utility industry but also a well known fact to all A/E's including Burns & McDonnell and Sargent and Lundy. If asked, none of the eight (8) participants in the SCR Vendor Query would offer an unlimited liability or even a limit of liability of more than the contract value for performance guarantees. Burns & McDonnell as well as Sargent and Lundy, who themselves never provide any type of process or system performance guarantees what so ever, are fully aware of this fact and will surely admit to it if asked.

It is worth mentioning that in case a project such as an SCR retrofit at M.R. Young Station would be carried out by an A/E such as Burns & McDonnell or Sargent and Lundy as an owner's engineer for Minnkota and/or Square Butte, the only performance guarantees the owner (in this case Minnkota and/or Square Butte) would ever receive would be the various system performance independent guarantees for the performance of the individual equipment and components supplied by the individual vendors including the one from the catalyst supplier. Each of these individual equipment and component performance guarantees would be limited to the value of and the equipment and/or component supplied by the respective vendor and simply passed through by the A/E to the owner. Thus, none of these individual performance guarantees would come even remotely close to covering the entire value of the SCR retrofit as each one would represent only a small portion of the entire project. The owner (in this case Minnkota and/or Square Butte) would have no performance guarantee for

[103] Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative, Responses to NDDH and EPA Comments Regarding SCR Technical Feasibility and Non-SCR Concerns Milton R. Young Station Unit 1 and Unit 2 NOx BACT Analysis Study, April 18, 2007.

[104] Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative, "Additional Information and Discussion of Vendor Responses on SCR Technical Feasibility, North Dakota's NOx BACT Determination for Milton R. Young Station Units 1 & 2", May 8, 2008.

the entire SCR system and not even any kind of system performance guarantee from the A/E that all the individually purchased pieces of equipment and/or components fit together as intended so that the entire system performs as intended.

As a matter of fact, the type and extent of performance guarantees offered by the catalyst suppliers CERAM and Haldor Topsoe including the stated limitation of liability are most certainly exactly the same as were provided for each and every SCR project, in which Burns & McDonnell and Sargent and Lundy were ever involved.

If an owner seeks a true system performance guarantee that covers the entire scope of the project, no A/E is needed. As a matter of fact, an A/E is a hindrance in such a case as such true complete system performance guarantees are only offered by complete system suppliers such as Alstom, Babcock Power or Babcock & Wilcox. Contrary to an A/E, these true system suppliers are willing and able to provide the entire scope of a turn-key SCR retrofit including complete system performance guarantees for up to the value of the entire retrofit project, which is then again the value of the contract. Such a turn-key supply, however, eliminates the need for an owner to additionally pay an A/E, which is the simple reason why these types of contracts are not favored by the A/Es. Yet, the most successful SCR retrofits in the U.S. were done as turn-key installations without the use of an A/E.

6.12 Review Authority

The Department claims the review authority for this case. I do not comment on this.

6.13 Conclusions

In conclusion, it must be stated that the Department made numerous factually incorrect claims, conclusions and statements as outlined in detail above. The most significant ones include:

- The conclusion that HDSCR is not technically feasible based on the data obtained from the ill-designed HDSCR Coyote Pilot Testing that provided little useful data – see sections 6.2, 6.3 and 6.9.

- The conclusion that HDSCR is not technically feasible based on the lack of any meaningful pilot testing data because the HDSCR Coyote Pilot Testing was ill-designed and provided little useful date – see sections 6.4, 6.6, 6.8 6.10 and 6.11.

- The statement that Burns & McDonnell and Sargent and Lundy have extensive experience with the design and operation of SCR systems – see section 6.5.

- The claim that vendors cannot guarantee SCR system performance for M.R. Young Station – see section 6.11.

- The claim that LDSCR and TESCR are not technically feasible based on the data obtained from the ill-designed HDSCR Coyote Pilot Testing that provided little useful data and must be considered completely irrelevant altogether for an LDSCR and/or TESCR design and application.

It is worth pointing out that the Department contradicted its own statements numerous times, particularly concerning the quality of the data of the HDSCR Coyote Pilot Testing and the unavailability of any really useful data from said pilot testing. No explanation was offered why the HDSCR Coyote Pilot Testing data is condemned as inadequate in some cases, yet hailed as offering the absolute truth in some other cases. Depending on what seems to best fit the argument at the moment that HDSCR is not technically feasible for the M.R. Young Station, the Department seems to either solely rely on this essentially useless Coyote Pilot Testing data, which appears to be the case for the Department's conclusions concerning catalyst:

- poisoning, blinding and plugging;
- deactivation and lifetime;

or seems to complain that no reliable pilot testing data is available, which appears to be the case for the Department's conclusions concerning catalyst:

- erosion;
- sizing (type, pitch, volume);
- performance guarantees from the vendors.

The incorrectness of the Department's conclusions concerning the expected catalyst deactivation as well as the performance guarantees was pointed out by some of those, who know best, namely the catalyst manufacturers and SCR system suppliers[105].

The Department's arguments concerning fuel variability and ash composition are true for all coals and by no means unique to this application and thus of no relevance to this case. Likewise, the argument concerning unacceptable temperature variations and possible popcorn ash problems are also of no further relevance to this case as all these issues would have to and can be successfully resolved regardless of the type of combustion system (i.e. cyclone fired) and/or the type of fuel burned (i.e. North Dakota lignite).

Finally, the Department's conclusions against the technical feasibility of LDSCR and TESCR are completely unsubstantiated and erroneous. Not only does the Department fail to

[105] Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative, "Additional Information and Discussion of Vendor Responses on SCR Technical Feasibility, North Dakota's NOx BACT Determination for Milton R. Young Station Units 1 & 2", May 8, 2008.

correctly distinguish and separate these two (2) distinctly different types of SCR systems, it also concludes that "the (catalyst) deactivation issue for low-dust and tail-gas SCR remains as with the high-dust SCR". Deciphered in detail, this is the Department's only single argument against the application of a LDSCR or TESCR, since all other argued issues are admitted to be "not unresolvable". Unfortunately, the Department again bases its erroneous conclusion concerning LDSCR and TESCR solely on the data obtained during the ill-designed HDSCR Coyote Pilot Testing. As little if any relevance this essentially useless data may have for an HDSCR application it most certainly has absolutely no relevance for a possible LDSCR and/or TESCR application. The Department fails to recognize this.

A noticeably poor and incomplete attempt was made to provide at least some, however, not meaningful data for the flue gas and fly ash composition downstream of the ESP. This clearly suggests the lack of any meaningful data for the correct evaluation of an LDSCR. The only data provided was some sampling performed downstream of the ESP at a temperature of 300 F (149 °C), which is well below the temperature range of 650 – 750 F (343 – 400 °C) required for LDSCR operation. Therefore, the deposition data cited by the Department from Minnkota's November 9, 2007 response to comments[106] is not relevant for the flue gas conditions present in a LDSCR and even less for the flue gas conditions in a TESCR. Unquestionably, the condensation of vapors including pyrosulfates and gaseous compounds responsible for the stickiness of the ash is a function of temperature as condensation of vapors and gaseous compounds occurs progressively at lower temperatures. The Department fails to explain how data concerning the stickiness of the ash particles collected on a silicon dioxide surface at 300 F (149 °C) would have any significant relevance for the prediction of catalyst pore pluggage by ash particles at 650 – 750 F (343 – 400 °C).

Absolutely no useful data characterizing the conditions downstream of the wet FGD was provided, thus making any conclusion concerning a TESCR nothing but presumptive speculation. The only at least somewhat factual attempts to argue why catalyst deactivation downstream of a wet scrubber could be an issue is the Department's comment concerning the Minn-Dak Farmer's Coop's coal fired boilers and some convoluted data[107], which presumably obtained by means of stack testing downstream of the wet scrubber at M.R. Young Station's Unit 2.

Using the Minn-Dak boilers 7A and 7B as an example, the Department argues that "Minn-Dak had trouble complying with its particulate matter emission limit due to sodium compounds passing through the air pollution control device. In order to maintain compliance, the ash Na_2O content of the coal combusted had to be limited". The Department argues that this is sufficient support for the Department's conclusion that "alkali mineral compounds are not removed by the ESP or SO_2 scrubbing system". As a result the Department argues that "it

[106] Response letter to EPA's October 4, 2007 letter sent from Minnkota Power Cooperative, Inc. to Mr. Terry O'Clair, Director, Division of Air Quality at the North Dakota Department of Health, dated November 9, 2007.

[107] Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative, Responses to NDDH and EPA Comments Regarding SCR Technical Feasibility and Non-SCR Concerns Milton R. Young Station Unit 1 and Unit 2 NOx BACT Analysis Study, April 18, 2007.

appears a significant amount of sodium compounds, a catalyst poison, will enter a low-dust or tail-gas SCR system. The deactivation issue for low-dust and tail-gas SCR will remain the same as for the high-dust SCR. The research, design and pilot testing needed to develop an SCR system that will have reasonable success makes this technology also not applicable at this time."

As will be shown in detail in section 7 of this report, no research, design and/or pilot testing is needed to install a TESCR that will have complete success at M.R. Young Station. The Minn-Dak experience cited by the Department, however, is by no means of any relevance to the technical feasibility of a TESCR at M.R. Young Station, yet it seems to form the sole and only basis for the Department's reasoning that TESCR is not applicable at this time. Reviewing Minn-Dak's Air Pollution Control Title V Permit to Operate[108] and the North Dakota Department of Health's Inspection Report[109], it becomes evident that neither the particulate matter removal device nor the wet scrubber are comparable to the air pollution control equipment installed or under construction at M.R. Young Station. Minn-Dak's boilers 7A and 7B, which are two Babcock & Wilcox stoker-fired boilers burning coal, biogas and natural gas, are equipped with multi-cyclones and co-current venturi scrubbers rather than ESPs and counter-current spray towers. The coal burned was reported to be sub-bituminous coal from the Spring Creek Coal Company in Montana rather than North Dakota lignite[110]. Not only is the partitioning of the ash constituents of the coal that occurs in a cyclone-fired boiler different from that in a stoker-fired boiler[111] but also is said partitioning different for different coals. Thus, using data from a stoker-fired unit burning PRB to predict the partitioning at a cyclone-fired unit burning North Dakota lignite is simply inappropriate.

As correctly stated by the Department, Minn-Dak has a restriction on the sodium content in the coal at 2.8% Na_2O on a dry mass basis in the coal ash in order to meet the particulate emission limit of 45.5 lb/hr, which, however, equates to 0.40 lb/10^6 Btu rather than 0.10 lb/10^6 Btu as erroneously claimed by the Department. It is critically important to note that the sub-bituminous coal fired at Minn-Dak[112] has an ash content of approximately 4 – 5%, which is typical for sub-bituminous coal and not about 8 – 10% on average as North Dakota lignite. In other words, North Dakota lignite has about twice the amount of ash compared to sub-bituminous coal. Furthermore, it is important to realize that the sub-bituminous coal burned at Minn-Dak has only between 0.3% and 0.5% sulfur, which means that the uncontrolled SO_2

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[108] State of North Dakota, Department of Health, Division of Air Quality, Air Pollution Control Title V Permit to Operate, Permit Number T5-X78001 issued on 7/31/2006.

[109] North Dakota Department of Health, Inspection Report, issued on 10/27/2003.

[110] Ibid

[111] Response letter to EPA's October 4, 2007 letter sent from Minnkota Power Cooperative, Inc. to Mr. Terry O'Clair, Director, Division of Air Quality at the North Dakota Department of Health, dated November 9, 2007.

[112] State of North Dakota, Department of Health, Division of Air Quality, Air Pollution Control Title V Permit to Operate, Permit Number T5-X78001 issued on 7/31/2006.

emissions range between 0.7 lb/10^6 Btu and 1.1 lb/10^6 Btu[113], which compares very favorably to a permitted emission limit of 3.0 lb/10^6 Btu. The measured SO_2 emission rate was reported to be around 0.1 lb/10^6 Btu at a time when the uncontrolled emission rate was theoretically and not accounting for any SO_2 being captured in the fly ash only about 0.7 lb/10^6 Btu (based on the coal data included in the report), which suggests a SO_2 removal rate of no more than at the most 70%[114]. Combining this with the fact that these stoker fired units have no ESP but are equipped with only multi-cyclones as primary particulate control devices, suggests very strongly that the co-current venturi scrubbers were never intended to remove any significant amounts of SO_2 but where designed as additional particulate removal devices.

Multi-cyclones are comparatively simple devices designed for the removal of only the coarsest fly ash particles. Therefore, multi-cyclones have not been used in utility boilers for more than 40 years anymore. Due to the fact that multi-cyclones are based on the principal of centrifugal forces removing the particles, only the largest and heaviest particles can be removed. Contrary to that, ESPs electrically charge all sizes of particles, which are then removed in an electric field as a result of their electric charge. Therefore, ESPs are much more effective removal devices for particulate matter, particularly for very small particles.

Since PRB is known to generate a comparatively large fraction of very fine ash particles and since these stoker-fired units were most likely not designed for burning PRB, it is quite conceivable why the units didn't meet their particulate emission limit while burning PRB. Not being equipped with particulate control devices suitable for the removal of fine particles, limiting the sodium content in the ash serves as means to limit the amount of very small particles formed.

Co-current venturi scrubbers are particulate removal devices, which operate on the principle of inertial impaction of smaller particles on water droplets as a result of largely different velocities. Again, only the larger particles have enough mass and therefore inertia to be removed successfully. Small particles with a small mass and therefore very little inertia follow the gas stream and successfully evade impaction. Contrary to that, counter-current spray towers designed for SO_2 removal are based on the principle of offering a large amount of finely dispersed liquid for the rapid cooling of the flue gas to its saturation temperature followed by the absorption of gaseous air pollutants such as SO_2. During the rapid cooling of the flue gas with a large excess of water, the very small particles, which provide a comparatively large surface area, act as condensation nuclei and are absorbed into the scrubbing solution. Also, the flue gas residence time in a counter-current spray tower is much longer than in a co-current venturi scrubber, which further assists removing small particles.

Suggesting that the flue gas inlet composition to a TESCR downstream of an ESP and a counter-current wet flue gas desulfurization scrubber is even similar to the flue gas composition downstream of a multi-cyclone and a co-current venturi scrubber designed for

[113] North Dakota Department of Health, Inspection Report, issued on 10/27/2003.

[114] Ibid

coarse particulate removal is truly creative. Yet, the fact of the matter remains that the Minn-Dak experience is not comparable to the situation at the M.R. Young Station due to the different:

- coal burned (PRB versus North Dakota lignite);
- combustion system design (stoker fired versus cyclone fired);
- primary particulate matter removal device (multi-cyclone versus ESP);
- wet scrubber design and purpose (co-current venturi for particulate removal versus counter-current spray tower for SO_2 removal).

Thus, the Minn-Dak experience must be considered completely meaningless and irrelevant for the possible application of a TESCR at the M.R. Young Station.

In Minnkota's April 18, 2007 response to question from the Department[115], Minnkota states that "stack sampling was conducted downstream of the ESP and wet FGD on Unit 2." However, it remains unclear whether the data provided represents samples taken downstream of the ESP or samples taken downstream of the wet scrubber. Furthermore, even if the data represents samples downstream of the wet scrubber, it is unknown whether the samples were taken downstream of the wet scrubber but upstream of the bypassing flue gas re-entering the flue gas stream to the stack or downstream of the bypass re-entry point. These questions are very relevant, since the flue gas stream downstream of the ESP and upstream of the wet scrubber is significantly different from the flue gas downstream of the wet scrubber. Likewise, the flue gas stream downstream of the wet scrubber but upstream of the bypass re-entry point is significantly different than the flue gas downstream of the bypassing flue gas re-entering the flue gas stream coming from the wet scrubber to the stack. An e-mail string between Minnkota and Burns & MacDonnell[116] seems to indicate that at least the sampling may have been done downstream of the wet scrubber and downstream of the bypass re-entry point of the flue gas for reheating. If this is confirmed than this data is completely useless for the correct characterization of the flue gas stream entering a TESCR as approximately 18% of the flue gas bypassed the wet scrubber at the time of sampling[117]. This means that the flue gas sampled clearly does not represent what would enter a TESCR as everything that is removed in a wet scrubber was still present in almost one fifth of the flue gas during sampling. Since the sampling was clearly not intended to characterize the flue gas composition entering a TESCR but intended to prove the particulate removal downstream of the ESP, this data cannot be considered relevant for any reasonable judgment concerning the technical feasibility of a TESCR.

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[115] Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative, Responses to NDDH and EPA Comments Regarding SCR Technical Feasibility and Non-SCR Concerns Milton R. Young Station Unit 1 and Unit 2 NOx BACT Analysis Study, April 18, 2007.

[116] E-mail string from John Graves (Minnkota) to Robert Blakely (Burns & McDonnell) dated April 12, 2007.

[117] Ibid

Also, no flue gas characteristics (temperatures, velocity, composition, etc.) at the sampling point are provided. Without exact knowledge of all these important details, the provided data is useless even for any reasonable judgment concerning a LDSCR. However, even if some of this missing information would be made available, the data would still be meaningless unless the total mass flow or at least the total concentration of the various compounds in the flue gas would be provided. The provided data only offers a morphological composition analysis of the samples expressed in relative percentages of the various elements as a portion of the entire sample. No information about the absolute amount of the various compounds as well as their aggregate state was made available, which renders the data in its provided form as absolutely useless for any meaningful interpretation concerning expected catalyst deactivation rates. Why only this by itself completely useless portion of the data was provided while all information needed to make the data possibly meaningful was withheld (assuming that this information exists), remains unknown.

While the Department devotes forty (40) pages of the seventy two (72) page document to arguments why HDSCR should be considered technically not feasible, little more than two (2) pages are dedicated to LDSCR and TESCR combined. Of these two (2) pages little more than one (1) page deals with possible site constraints and flue gas reheating, both of which are correctly dismissed as being economic considerations instead of technical feasibility issues, thus leaving about only one (1) page for the combined evaluation of LDSCR and TESCR. This one (1) page states the Department's conclusion that a LDSCR and/or a TESCR are technically infeasible without presenting any relevant supporting data. The Department's conclusion rests solely on the incorrect, unsupported and unfounded claim that "the deactivation issue for low-dust and tail-gas SCR remains the same as for high-dust SCR". However, only a few paragraphs later, the Department contradicts this earlier statement by postulating that "catalyst deactivation of a low-dust or tail-gas SCR due to alkali compounds is an issue that will require extensive research, design and pilot testing to determine whether the technology can be successfully applied to units fired on North Dakota lignite". Either the Department can provide relevant supporting data for the claim that the deactivation issue in a TESCR remains the same as in a HDSCR, or such supporting data doesn't exist, in which case the claim is purely speculative and unsupported.

It is also a fact that the SCR Vendor Query conducted by Burns & McDonnell very specifically stated that it was solely directed towards HDSCR, thus ignoring LDSCR and TESCR. Why attempts by various vendors (Alstom, Babcock Power, CERAM) to also consider LDSCR and/or TESCR were seemingly ignored remains unexplained.

Thus, the final conclusion reached by the Department that HDSCR is not technically feasible is unacceptable. All the presented data, investigations, vendor information etc. most certainly don't allow the conclusion that HDSCR is not technically feasible. Concluding that HDSCR is technically infeasible is premature and unfounded.

Furthermore, the Department's conclusion that LDSCR and TESCR are both not technically feasible is clearly presumptive and speculative as this conclusion cannot be supported by any relevant data, investigation or vendor information. Additionally, it must be stated that this conclusion is wrong as the only one (1) claim of excessive catalyst deactivation made against TESCR is clearly technically not defendable.

In summary, this leads to the conclusion that the Department's statement that that SCR technology is not technically feasible for application at the M.R. Young Station's cyclone-fired units burning North Dakota lignite is incorrect. HDSCR may very well be technically feasible, LDSCR is most likely technically feasible and TESCR is most certainly technically feasible for application at the M.R. Young Station's cyclone-fired units burning North Dakota lignite. With at least one SCR principle, namely TESCR being most certainly technically feasible for the application at the M.R. Young Station, the Department's BACT analysis incorrectly eliminated the SCR technology from further consideration.

7. VENDOR QUERY TAIL-END SCR

In order to further substantiate the technical feasibility of TESCR for the M.R. Young Station, the same eight (8) vendors were contacted that also participated in the Vendor Query conducted by Burns & McDonnell[118]. Due to vacation schedules and other personal restrictions only six (6) of the eight (8) vendors contacted were able to provide written responses, while two (2) could provide only verbal responses. Also, time constraints demanded that the scope and extent of the discussion with these eight (8) vendors had to be limited to some very fundamental questions concerning TESCR.

Since catalyst deactivation seems to be the primary concern of the Department, more time was devoted to communication with the catalyst manufacturers (Argillon, CERAM, Cormetech, Haldor Tospoe, Hitachi) as they are ultimately the ones, who provide the process performance guarantees for the catalyst. Somewhat less time was devoted to the SCR equipment vendors, who ultimately also rely on the catalyst manufacturers for catalyst performance and deactivation information and guarantees. Therefore, the response of the catalyst manufacturers was considered to be most meaningful, particularly the responses of the ones with extensive TESCR experience. Again, more time was devoted to the companies with TESCR experience (Alstom, Argillon, CERAM, Babcock Power, Haldor Topsoe) compared to the ones with no TESCR experience (Babcock & Wilcox, Cormetech, Hitachi).

The following eight (8) vendors were contacted:

- SCR equipment vendors:
  - Alstom – Mr. Michael Philips was not available due to time constraints and therefore directed me to Mr. John Buschmann, SCR Product Manager at Alstom, who provided only a verbal response due to insufficient time for a

[118] Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative, Responses to NDDH and EPA Comments Regarding SCR Technical Feasibility and Non-SCR Concerns Milton R. Young Station Unit 1 and Unit 2 NOx BACT Analysis Study, April 18, 2007.

written response. Alstom has extensive TESCR experience.

- Babcock Power – Dr. Clayton Erickson provided a written statement. Babcock Power has access to extensive TESCR experience and is the equipment supplier of the LDCSR downstream of a cold-side ESP under construction as WE Energies' South Oak Creek Station.

- Babcock & Wilcox – Mr. Steve Moormann could not be reached. Instead, Mr. Donald Tonn, SCR Process Expert at Babcock & Wilcox in Barberton, OH was contacted and provided a written response. Babcock & Wilcox has no TESCR experience.

- SCR catalyst manufacturers:

  - Argillon – Mrs. Cindy Khalaf provided a written statement. Argillon has extensive TESCR experience.

  - CERAM – Mr. John Cochran provided a written statement. CERAM has extensive TESCR experience.

  - Cormetech – Mr. Scot Pritchard provided a written statement. Cormetech has no TESCR experience but some LDSCR experience.

  - Haldor Topsoe – Mr. Flemming Hansen provided a written statement. Haldor Topsoe has extensive TESCR experience.

  - Hitachi – Mr. Anthony Favale provided only a verbal response due to insufficient time for a written response. Hitachi has no TESCR experience but some LDSCR experience.

Due to the time constraints, the person named above at each of the eight (8) vendors was contacted by phone and informed about the purpose of the discussion as well as asked whether he or she would be willing to provide a brief statement in writing per e-mail. All contacted people agreed to provide a written statement. However, Messrs. John Buschmann of Alstom and Anthony Favale of Hitachi who could provide only provide a verbal response due to time constraints as the written response would have arrived after the submission of this report.

All eight (8) vendors, namely three (3) SCR system suppliers (Alstom, Babcock Power and Babcock & Wilcox) and five (5) SCR catalyst suppliers (Argillon, CERAM, Cormetech, Haldor Topsoe and Hitachi) were asked to provide answers to the following three (3) questions:

Given your knowledge about the plant (cyclone-fired B&W boilers, ESP, wet scrubber) and the fuel (ND lignite), would *<company>*:

a. Consider a tail-end SCR technically feasible?

b. Recommend or require additional pilot testing?
c. 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?

All eight (8) vendors answered the question a. with a clear "yes". None of the vendors expressed even the slightest doubts that TESCR would not be technically feasible for both units at the M.R. Young Station. All three (3) contacted SCR system suppliers and all responding five (5) SCR catalyst suppliers consider TESCR to be unquestionably technically feasible for cyclone fired units burning North Dakota lignite.

All five (5) responding catalyst manufacturers answered question b. with a clear "no", thus dismissing any need for any further pilot testing for a TESCR application at M.R. Young Station.

Likewise, the SCR system suppliers Babcock Power and Alstom also dismissed any need for any additional pilot testing for a TESCR. The only SCR system supplier, who stated that they "would require further discussion with the catalyst suppliers", was Babcock & Wilcox. This caution is simply the result of the lack of experience of Babcock & Wilcox with TESCRs. Given the fact that even though Babcock & Wilcox has a license from Hitachi for SCR catalyst but Hitachi has no experience with TESCR either, such caution is no surprise.

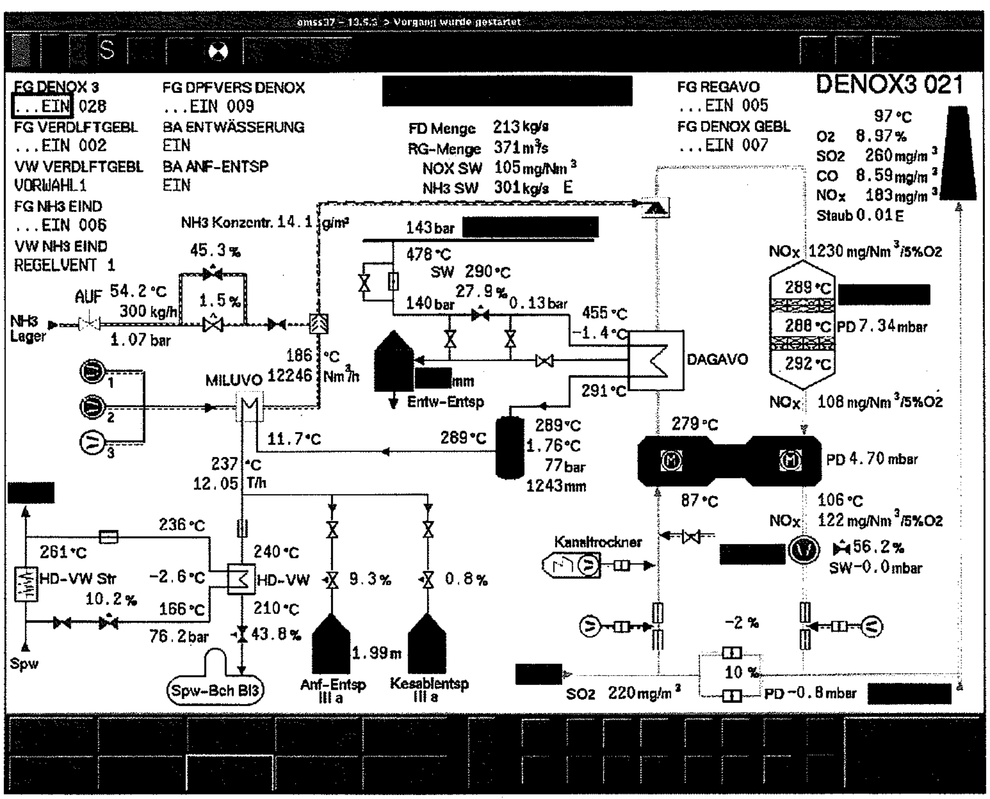
All five (5) responding catalyst suppliers and all three (3) SCR system suppliers answered question c. with a clear statement that they would provide common commercial performance guarantees. Argillon indicated 90% NOx removal efficiency at less than 2 ppmvd @ 3% O_2 NH_3 slip and greater 24,000 SCR operating hours catalyst life. Obviously, more details would have to be determined as the project would need to be defined better. Only Babcock & Wilcox stated that the commercial guarantees would have to be discussed first with the catalyst suppliers before passing them on to the buyer. Hitachi stated that they would have to see the exact flue gas composition in order to determine what commercial guarantees would be provided. Again, this can be explained by the fact that neither Babcock & Wilcox nor Hitachi has any TESCR experience and did not have time to evaluate a TESCR application for M.R. Young Station in sufficient detail.

Additionally, during the verbal discussions with all four (4) catalyst suppliers as well as all three (3) responding SCR systems suppliers, the contact persons made it very clear that their companies would not consider HDSCR as technically infeasible at this time. Particularly, all five (5) responding catalyst suppliers very adamantly stated that the existing knowledge does not support prematurely discarding HDSCR as a technically feasible possibility. All five (5) responding catalyst suppliers suggested that properly designed and executed HDSCR pilot testing would certainly be helpful to decide whether HDSCR would be more economically attractive than LDSCR or TESCR for the M.R. Young Station. The e-mail correspondence of all six (6) vendors, who responded in writing, is presented in detail in Appendix A.

8. SUMMARY

In summary, it must be concluded that TESCR is not only technically feasible but may be even the most economical SCR alternative for M.R. Young Station. As reiterated by the responding vendors, the very high removal efficiency of the ESP and wet FGD upstream of a TESCR combined with the flue gas reheating from the flue gas dew point provides flue gas conditions, which are unquestionably much more favorable for SCR catalyst than the conditions present in almost all HDSCRs. Two decades of TESCR experience in Europe have proven that TESCR can be successfully applied to the most complex processes and the most difficult flue gases. Catalyst replacement in most TESCRs has been minimal to none. Most coal-fired units equipped with TESCRs still utilize the initial catalyst fill after more than 130,000 SCR operating hours. Due to the greatly reduced mass flow of catalyst poisons to the SCR catalyst the catalyst deactivation rates in TESCRs have proven to be extremely low, in some cases barely measurable.

Additionally, minimal unit downtime for TESCR tie-in resulting in very little if any lost generation is a huge advantage for TESCRs as they can be constructed typically completely independent of and parallel to unit operation. Flue gas reheat cost is relatively low as the flue gas needs to be reheated with high pressure steam only by about 18 – 65 degrees (10 K – 35 K) and the condensate from the steam coil is typically further used for dilution air heating and subsequent feed water before returned to the condensate from the turbine.



The graph above presents a typical process flow diagram from a TESCR on a 300 MW coal-fired unit. This TESCR has operated for more than 130,000 hours for more 20 years now on the initial fill of catalyst with a continuous NOx removal efficiency in excess of 91%. As can be seen on the graph, the high pressure steam used for reheating is cooled from about 892 F (478 °C) to ultimately 410 F (210 °C) after dilution air and feedwater heating and prior to being discharged to the feedwater storage tank. Also worth noting is the small amount of only 18 degrees F (10 K) that need to be added to the flue gas by means of high pressure steam. As can be seen, the flue gas downstream of the gas-gas heat exchanger enters the steam coil with a temperature of approximately 534 F (279 °C) and enters the SCR reactor downstream of the steam coil with a temperature of only about 552 F (289 °C). This proves the high efficiency of the gas-gas heat exchanger and the small amount of high pressure steam needed for flue gas reheating, which makes this concept economically more attractive.

In the U.S. currently both 325 MW units at PSE&G's Mercer Generating Station are equipped with TESCRs with flue gas reheat downstream of the ESPs. Spray dryer absorbers followed by baghouses downstream are being added downstream of the SCRs, thus effectively converting them from TESCRs to LDSCRs. The same type SCR with flue gas reheat is currently being installed at WE Energies South Otter Creek Generating Station.

Thus, LDSCR and/or TESCR systems can neither be dismissed as being technically infeasible nor based on economic reasons. Particularly the TESCR principle was developed specifically in order to successfully adapt the SCR technology to units with the most difficult flue gas compositions and the most complex retrofit challenges. During its 22 years of extraordinarily successful operating history, the TESCR principle has not only unconditionally proven itself as one of the most viable SCR principles but certainly the most universally applicable of all SCR principles.

Appendix A: Data and Information Considered

"Alternative Control Technologies Document NO_x Emissions from Utility Boilers" March 1994. U.S. EPA, Office of Air and Radiation, Office of Air Quality Planning and Standards. This information can be found at website address: http://www.epa.gov/ttn/catc/dir1/utboiler.pdf.

Amended SIP Permit to Operate, letter from the North Dakota Department of Health to John Graves, Minnkota Power Cooperative, dated February 5, 2002.

Ando, Jumpei, "SO_2 and NO_x Removal for Coal Fired Boilers in Japan," presented at the Seventh Symposium on Flue Gas Desulfurization, May, 1992.

Argillon's website: www.argillon.com.

Assessment of SO_2 and NO_x Emission Control Technology in Europe, Air and Energy Engineering Research Laboratory, EPA-600/2-88-013, February 1988.

Attachment 10, "Initial Design" Boiler Heat Input Rating vs "As Built" Boiler Heat Input Rating, George W. Button, January. 2001.

Attachment 11, Expert Opinion Report, Maximum Boiler Heat Input Capacity Units 1 and 2 Milton R. Young Station, Minnkota Power Cooperative, Inc. Center, N.D., 58530, Robert L. Pearson, Ph.D., PE, CH2M Hill, 100 Inverness Terrace East, Englewood, CP 80224, ca. 2001.

Benson, A. J. D. Laub, C. R. Crocker, J. H. Pavlish, „SCR catalyst performance in flue gas derived from subbituminous and lignite coals", Fuel Processing Technology 86 (2005) pages 577 – 613, 2005.

"Compilation of Air Pollutant Emission Factors AP-42, Fifth Edition, Volume 1: Stationary Point and Area Sources, Chapter 1.1, Bituminous and Subbituminous Coal Combustion" dated July 1993.

Current Status of SCR in Japan. by: Yasuyuki Nakabayashi and Rikiya Abe, Research and Engineering office, Thermal Power Department, Electric Power Development Co., Ltd. Tokyo, Japan 100. ca 1987.

Cyclone NOx Control: Technology and Issues Assessment, Electric Power Research Institute, 1998.

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E-Mail from Randy Sadler on behalf of Cindy Khalaf, President of Argillon LLC, supplier of the SCR catalyst for Oak Grove 1 & 2, dated June 24, 2008.

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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)

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

Appendix C: Selected Papers Authored in Last Ten Years

Selected SCR related papers in English I have authored in the last ten years:

Licata, A., W. Schüttenhelm, H. Hartenstein, "Mercury and Dioxin Control for Municipal Waste Combustors", Asia-North American Waste Management Conference, Los Angeles, CA, USA 1998.

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Hartenstein, H., "Incineration Technologies", World Bank Workshop Series: Issues on Waste Disposal: Workshop 1 – Hazardous Wastes, Washington D.C., USA, 2004.

Wiese, S., D. Monnin, K. Sauvageau, H. Hartenstein, "O&M Cost Optimized SCR Operation and Management at AES' Somerset Station", The Mega Symposium – Combined Air Pollution Control Symposium, Washington D.C., USA 2004.

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Sobolewski, H, H. Hartenstein, H. Rhein, "STEAG's Long Term SCR Catalyst Experience and Cost", The 2005 EPRI Workshop on Selective Catalytic Reduction, Louisville, KY, USA 2005.

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Hartenstein, H., "SCR Management Ensures SCR Performance at Minimum Operating Cost", WPCA News, Issue 9 spring 2006, Chicago, IL, USA 2006

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Martin, M. H. Hartenstein, "Bench Scale Testing of Catalyst – History and Protocol", The 2006 EPRI Workshop on Selective Catalytic Reduction, Dearborn, MI, USA 2006

Hartenstein, H., "German Experience With Catalyst Regeneration", 2007 NOx Round Table Conference and Expo, Cincinnati, OH, USA 2007

Hartenstein, H., "STEAG's Catalyst Regeneration Process – Ten Years of Experience", 2007 NOx Round Table Conference and Expo, Cincinnati, OH, USA 2007

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Appendix D: Resume

Hans-Ulrich Hartenstein

Title:
Managing Director E&EC

Nationality:
German

Education:

- University of Stuttgart — B. Sc. in Mechanical Engineering
- University of Stuttgart — M.E. in Mechanical Engineering
- University of Florida — M.E. in Environmental Engineering
- University of Toronto — Global Executive MBA

General Experiences:

Mr. Hartenstein has been in the environmental field for over twenty years. His experience includes project development, project management and supervision, coordination and implementation of design and building projects for municipal waste-to-energy, hazardous waste incineration, and air pollution control facilities (SCR, FGD, Hg control, PCDD/PCDF control) in the power utility industry and waste-to-energy industry.

His responsibilities included project development, process engineering and management, procurement and construction supervision, start-up and commissioning, environmental and financial analysis, permitting application procedures and regulatory interfacing.

Mr. Hartenstein has been project management director of numerous air pollution control systems, one municipal waste-to-energy project, and four hazardous waste incineration projects. He has been involved in the development of eighteen environmental projects out of which seven also included permitting procedures and process design, two also included construction and one included complete start-up and commissioning.

Mr. Hartenstein has also directed development of waste management and air pollution control segments and managed a $ 61 million turnkey contract for 80 TPD hazardous waste incineration contract including a tail-end SCR. After completion of the facility Mr. Hartenstein was responsible for the initial 2 years of operation of the plant. He was also responsible for the successful negotiations of eight turn key mass burn, waste-to-energy contracts valued in excess of $ 600 million and he has successfully negotiated several international air pollution control technology licenses (SCR and FGD) among Polish, Korean, American and Japanese companies.

He has managed and supervised feasibility analysis, conceptual engineering and design, permitting final design, technology development, and project implementation and has assisted in project financial planning including assuring financing for several projects.

Since 1999 Mr. Hartenstein has been active mainly in the U.S. in the areas of SCR and FGD retrofits to fossil fuel fired electric utility generating stations. He expanded his initial focus on the design and construction of these SCR and FGD retrofits quickly into the areas of long term operation and maintenance of air pollution control equipment. His current focus is on most cost effective long term FGD and SCR management ensuring maximum performance at the lowest possible cost.

Positions Held:

- Environmental Engineer L&C Steinmüller GmbH[1)] 1987 – 1989
- Senior Environmental Engineer L&C Steinmüller GmbH[1)] 1989 – 1990
- Engineering Department Manager L&C Steinmüller GmbH[1)] 1990 – 1992
- Senior Engineering Director L&C Steinmüller GmbH[1)] 1992 – 1995
- Project Management Director L&C Steinmüller GmbH[1)] 1995 – 1997
- Plant Manager RVA Böhlen RVA Böhlen GmbH 1997 – 1999
- Senior Vice President Babcock Borsig Power, Inc.[2)] 2000 – 2001
- President SCR-Tech LLC 2001 – 2005
- President Evonik Energy Services LLC[3)] 2006 - present
- Managing Director E&EC GmbH 1999 – present

[1)] L&C Steinmüller GmbH has been acquired and renamed to Fisia Babcock GmbH
[2)] Babcock Borsig Power, Inc. has been acquired and renamed Babcok Power, Inc.
[3)] Steag LLC was renamed Evonik Energy Services LLC, no change in ownership

Professional Memberships

- Member of the World Pollution Control Association (WPCA)
- Invitational member of the Scientific Technical Advisory Panel (STAP) of the United Nations Environment Programme related to POPs and PTS.