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ATTACHMENT 4

SO_2, NO_X, AND MERCURY REDUCTION STUDY

Sargent & Lundy LLC

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September 24, 2010
Project No. 12715-001
Letter No. BSP-SL-OTP-0013

Otter Tail Power Company
Big Stone Plant

SL-010408 Draft Report
SO_2, NO_x, and Mercury Reduction Study
Conceptual Engineering Design Report

Mr. Mark Rolfes
Otter Tail Power Company
215 S. Cascade Street
Fergus Falls, MN 56538-0496

Dear Mr. Rolfes:

Enclosed is the draft SO_2, NO_x, and Mercury Reduction Study for your comments. We look forward to walking you through the results and answer any questions you may have.

Please do not hesitate contacting me if you have any questions.

Yours very truly,

Ken A. Mixer
Project Manager

KAM:km
Enclosure – All Recipients
File No. 2.03
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OTTER TAIL POWER COMPANY

BIG STONE PLANT

SO_2, NO_X, AND MERCURY REDUCTION STUDY

CONCEPTUAL ENGINEERING DESIGN REPORT

SL-010408
Draft Report

September 24, 2010
Project 12715-001

Prepared by

Sargent & Lundy LLC

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09-24-2010
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APPENDIXES

ABBREVIATIONS AND ACRONYMS

Abbreviation or Acronym	Explanation
acfm	actual cubic feet per minute
ACI	activated carbon injection
AFUDC	allowance for funds used during construction
AHJ	Authority Having Jurisdiction
AIG	ammonia injection grid
AQCS	air quality control system
ARSD	Administrative Rules of South Dakota
[TRADE SECRET DATA BEGIN	TRADE SECRET DATA ENDS]
BACT	Best Available Control Technology
BART	Best Available Retrofit Technology
BOP	balance-of-plant
Btu	British thermal unit
BC	brine concentrator
CAIR	Clean Air Interstate Rule
CAMR	Clean Air Mercury Rule
CCR	coal combustion residual
CFB	circulating fluidized bed combustor or combustion
CFR	Code of Federal Regulations
CLS	cold-lime softener
CO	carbon monoxide
D/F	dioxin/furan
DCS	distributed control system
DENR	Department of Environment and Natural Resources (South Dakota)
EEGT	economizer exit gas temperature
EGU	electric generating unit
EPA	U.S. Environmental Protection Agency
ESP	electrostatic precipitator
FD	forced draft
FGD	flue gas desulfurization
FGR	flue gas recirculation
FM	Factory Mutual
GA	general arrangement
GHG	greenhouse gas
H_2	hydrogen

ABBREVIATIONS AND ACRONYMS

Abbreviation or Acronym	Explanation
H_2O	water
HAP	hazardous air pollutant
HHV	higher heating value
HMI	human-machine interface
hp	horsepower
hr	hour
I/O	input/output
ICR	Information Collection Request
ID	induced draft
in. w.c.	inches water column
lb	pound
LPA	large-particle ash
LSD	lime spray dry
LSFO	limestone forced oxidation
MACT	Maximum Achievable Control Technology
MCR	maximum continuous rating
MBtu	million British thermal unit
MW	megawatt
MWh	megawatt-hour
N_2	nitrogen gas
NAAQS	National Ambient Air Quality Standard(s)
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NH_3	ammonia
NO_2	nitrogen dioxide
NOI	Notice of Intent
NO_X	Nitrogen oxides
NPDES	National Pollutant Discharge Elimination System
NPRM	Notice of Proposed Rulemaking
NSPS	New Source Performance Standards
NSR	New Source Review
O&M	operations and maintenance
O_2	oxygen
OEM	original equipment manufacturer

ABBREVIATIONS AND ACRONYMS

Abbreviation or Acronym	Explanation
OFA	overfire air
OSHA	Occupational Safety and Health Administration
PAC	powder-activated carbon
PC	pulverized coal
PLC	programmable logic controller
PM	particulate matter
ppm	parts per million
ppmv	parts per million volume
PRB	Powder River Basin
PSD	Prevention of Significant Deterioration
psia	pounds per square inch absolute
psig	pounds per square inch gauge
RAT	reserve auxiliary transformer
RCRA	Resource Conservation and Recovery Act
RO	reverse osmosis
RPS	Renewable Portfolio Standards
RTD	resistance temperature detector
SCR	selective catalytic reduction
SDA	spray dry absorber
SIP	state implementation plan
SNCR	selective non-catalytic reduction
SNCR	selective non-catalytic reduction
SO_2	sulfur dioxide
SO_3	sulfur trioxide
SOFA	separated overfire air
SWD	surface water discharge
TiO_2	titanium oxide
UAT	unit auxiliary transformer
UPS	uninterruptible power supply
V_2O_4	vanadium tetroxide
V_2O_5	vanadium pentoxide
VFD	variable-frequency drive
wacfm	wet actual cubic feet per minute

1. EXECUTIVE SUMMARY

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Otter Tail Power Company (OTP) is required to install Air Quality Control System (AQCS) equipment at its Big Stone Plant (Big Stone or the plant) to reduce emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_X) based on a Best Available Retrofit Technology (BART) determination filed by the South Dakota Department of Environment and Natural Resources (DENR). The BART requires the AQCS system to include flue gas desulfurization (FGD) for SO_2 reduction, and selective catalytic reduction (SCR) with separated overfire air (SOFA) for NO_X reduction. BART did not include mercury reduction requirements; however, because it is expected that the utility Maximum Achievable Control Technology (MACT) will require about reduction when implemented by the end of 2011, mercury reduction technology was also evaluated. The AQCS retrofit work is to be completed by the end of 2015 and the South Dakota DENR determination states that the retrofit AQCS system must be operational by January 15, 2016.

The AQCS system proposed for the conceptual design as presented herein will allow Big Stone to operate within the emissions limits listed in Table 1-1.

Table 1-1. Emission Levels

Parameter	Value
PM (filterable)	
SO_2	
NO_X	
Hg	

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At OTP's request, Sargent & Lundy, L.L.C. (S&L) conducted a conceptual design study and prepared estimated costs for the AQCS needed to comply with the South Dakota DENR BART determination. The AQCS retrofit proposed comprises a dry FGD system with new baghouse, SOFA, anhydrous-based SCR, ACI, and the associated ancillary balance-of-plant (BOP) systems.

The capital costs of the AQCS retrofit were estimated separately, one for NO_X-related work (SCR and SOFA) and one for SO_2 related work (dry FGD with a baghouse and ACI). The costs are summarized in Table 1-2.

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Table 1-2. Capital Cost Summary

Parameter	SCR	Dry FGD with New Baghouse
Direct and construction indirect cost,		
Indirect cost,		
Contingency @		
Escalation,		
Owner's cost,	Included in dry FGD	
Total project cost, $M		
Total AQCS Cost,		

The capital cost represents completion of installation in the summer of and a commercial operation date of . The estimate is based on current market prices and escalation is included to reflect the operation date. The estimate does not include extra contingency for escalation that can occur due to excessive cost increases in equipment, material, or labor. Such escalation occurred between 2005 and 2008, when all utility projects were paying premiums because of the excessive escalation that applied over all utility projects. The Big Stone AQCS project appears to be ahead of other potential AQCS projects that could be initiated as the environmental regulations become more defined in 2011. Specifically, it is anticipated that AQCS vendors and construction contractors will become increasingly busy as these new projects are initiated, which could result in market-related price increases. It is recommended that OTP consider steps to avoid or minimize the impact of market escalation. Awarding contracts as early as possible may position OTP ahead of the other utilities also retrofitting AQCS equipment.

The first-year and total levelized O&M costs are summarized in Table 1-3.

Table 1-3. First-Year O&M Costs

Parameter	SCR	Dry FGD with New Baghouse
First-Year Fixed O&M,		
First-Year Variable O&M,		
Total First-Year O&M,		
Levelized O&M,		

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The outage required in weeks. This outage is based on the boiler modifications being the critical path. The boiler modifications need to be evaluated in more detail if it is desired to shorten the outage length.

The permitting evaluation considered whether other environmental rules or regulations might alter the BART requirements for AQCS retrofit. In our opinion, the proposed dry FGD with baghouse and SCR could be considered Best Available Control Technology (BACT) for a new sub-bituminous-fired unit, and the ACI system should meet future MACT requirements. OTP installing dry FGD with baghouse, SCR, and ACI as a retrofit, in our judgment, will meet the regulations expected for the next years.

Two major issues needed evaluation in order to complete the above detailed conceptual design scenarios. A screening study was completed that evaluated (1) three options using wet FGD or dry FGD systems and (2) two locations where the SCR reactor could be built. With the detailed conceptual cost estimate completed, these decisions were reviewed to ensure that the decisions had not changed. The screening study cost results are shown in Table 1-4.

Table 1-4. Capital Cost Summary (All FGD Options with SCR Behind Boiler)

Parameter	Option 1, Dry FGD with Existing Baghouse and SCR	Option 2 Dry FGD with New Baghouse and SCR	Option 3 Wet FGD with Existing Baghouse and SCR
FGD,			
SCR,			
Total Capital Cost,			
Delta,			

TRADE SECRET DATA ENDS]

A dry FGD system that uses a new baghouse was the least-cost option for FGD. A second dry FGD option reuses the existing baghouse. As the costs used in the screening study did not change significantly, the previously determined cost difference remains. Dry FGD with a new baghouse is still the recommended FGD system for Big Stone. This technology option offers the lowest cost and lowest risk of cost increase due to unknowns associated with reinforcing a majority of the ductwork and structures, and will be able to follow load without significant O&M issues. The option of reusing the existing baghouse has significant cost issues related to reinforcing structures, has higher risk of cost increase and extending the outage, and has significant risk of increasing O&M because of the solids that could drop out in the ducts ahead of the baghouse.

The second major issue for the Big Stone AQCS retrofit is where to locate the SCR. The screening recommended the location the SCR immediately behind the boiler. This location usually is cost-effective when evaluating SCR on utility boilers. The concern was that if significant boiler steel had to be modified to tie in the SCR, this location's costs might increase. During the conceptual design, several trips were made to evaluate the SCR location and the conclusion is that it can be retrofit without the impacts that were initially considered problematic in the screening study. The detailed conceptual design confirms the SCR located behind the boiler is optimal.

Other screening studies were completed, and used to focus the conceptual design effort to a final general arrangement and design. While these screening studies did not have the impact of the wet versus dry FGD study, they were important to completing the effort. Table 1-5 below lists the mini studies and summarizes the major conclusions.

The next steps for moving the project forward are:

- Authorize the project to proceed with design of the AQCS retrofit
- Start permitting of the project
- Start detailed design of the project
- Review solutions to reduce the cost of lowering economizer outlet and SCR inlet services

Table 1-5. Summary of Screening Studies Completed for Conceptual Design

Study	Conclusion
Location of SCR (Appendix B)	The SCR reactor located behind the boiler is more cost-effective than located to the side of the unit (south).
SCR Reagent Study (Appendix E)	Using anhydrous ammonia is lowest cost compared with urea and aqueous ammonia. Anhydrous ammonia is potentially more dangerous, but when the safety features are factored in, is cost-effective. This study should consider when SOFA is used because the SCR will require less reagent.
In-Boiler NO$_X$ Reduction (Appendix F)	Two SOFA approaches were developed. The greater capital cost approach was included because it allows the lowest economizer outlet NO$_X$. However, outlet NO$_X$ level is only marginally lower, so these two systems will be evaluated in detailed design.
[TRADE SECRET DATA BEGINS	
Economizer Gas Outlet Temperature Reduction (Appendix F)	recommended several internal boiler modifications to control the temperature to between 750°F and 625°F. The modifications are expensive, at about in capital. These costs and alternative approaches will be considered during detail engineering.
Wet v. Dry FGD (Appendix B)	Dry FGD is significantly more cost-effective than wet FGD. The PRB fuel with low-sulfur content typically favors this outcome on middle-sized installations. A new baghouse is the lowest risk compared to reusing the existing baghouse. The costs are similar, but favor a new baghouse as well.
Solid Waste Handling (Appendix M)	A pneumatic solid waste handling system will transport solids (FGD waste and fly ash) to a new silo located next to the existing silo. Both silos will be used. Scrapers and articulated trucks will then be used to transport the ash to the onsite landfill. It is not cost-effective to transport the solids to the landfill pneumatically.
Water Balance and Brine Concentrator (Appendix D)	Installing a reverse osmosis system is cost-effective compared to continued operation of the brine concentrator. The brine uses considerably more power, which makes it more costly than building the new reverse osmosis (RO) system.
NFPA 85 Compliance (Appendix C)	Reinforcing the boiler and air heater is recommended to avoid the risk of implosion. The new fans will be capable of pulling double the negative pressure of the existing fans and this increases the risk of implosion. The current boiler is designed for a very low pressure, +3/-7, and using controls to protect the boiler is very risky. provided a budgetary cost of reinforcement, which is included in the cost estimate. TRADE SECRET DATA ENDS]
Selection of ID Fan (Appendix G)	Two centrifugal fans are recommended with variable-frequency drives (VFD). Two fans rather than four are less costly to install. Using VFD technology allows power savings at low load operation.
Mercury Reduction Evaluation (Appendix L)	Activated carbon injection (ACI) is the recommend method to reduce mercury. ACI can achieve 90% reduction when injected ahead of the dry FGD system with baghouse. Specific requirements for mercury reduction are not yet known, but are expected to be established in 2011, which would be applicable to the Big Stone retrofit work.

2. BASIS OF STUDY

2.1 PURPOSE

Prior to development of the conceptual engineering study as presented herein, S&L performed a screening study to determine which SO_2 technology (wet vs. dry) and which SCR location (behind the boiler vs. south of the boiler) would be the optimal choice for Big Stone. The screening study concluded that dry FGD with SCR located directly behind the boiler was the best approach. Details of the screening study (SL-010303) are provided in Appendix B.

The primary drivers for the project are the regulatory requirements associated with the Regional Haze Rule, which was promulgated to protect the visibility in national parks, national forests, and other national areas. OTP submitted a BART study to the South Dakota DENR that stated Big Stone needed to implement technology to reduce sulfur dioxide (SO_2) and oxides of nitrogen (NO_X) emissions.

The work was done using a step-by-step approach. The first step was to prepare several mini studies that focused on the overall conceptual design scope. Table 2-1 lists the mini studies and summarizes the major conclusions.

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Study	Conclusion
Location of SCR (Appendix B)	The SCR reactor located behind the boiler is more cost-effective than located to the side of the unit (south).
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Solid Waste Handling (Appendix M)	A pneumatic solid waste handling system will transport solids (FGD waste and fly ash) to a new silo located next to the existing silo. Both silos will be used. Scrapers and articulated trucks will then be used to transport the ash to the onsite landfill. It is not cost-effective to transport the solids to the landfill pneumatically.
Water Balance and Brine Concentrator (Appendix D)	Installing a reverse osmosis system is cost-effective compared to continued operation of the brine concentrator. The brine uses considerably more power, which makes it more costly than building the new reverse osmosis (RO) system.
NFPA 85 Compliance (Appendix C)	Reinforcing the boiler and air heater is recommended to avoid the risk of implosion. The new fans will be capable of pulling double the negative pressure of the existing fans and this increases the risk of implosion. The current boiler is designed for a very low pressure, +3/-7, and using controls to protect the boiler is very risky. provided a budgetary cost of reinforcement, which is included in the cost estimate. TRADE SECRET DATA ENDS]
Selection of ID Fan (Appendix G)	Two centrifugal fans are recommended with variable-frequency drives (VFD). Two fans rather than four are less costly to install. Using VFD technology allows power savings at low load operation.
Mercury Reduction Evaluation (Appendix L)	Activated carbon injection (ACI) is the recommend method to reduce mercury. ACI can achieve 90% reduction when injected ahead of the dry FGD system with baghouse. Specific requirements for mercury reduction are not yet known, but are expected to be established in 2011, which would be applicable to the Big Stone retrofit work.

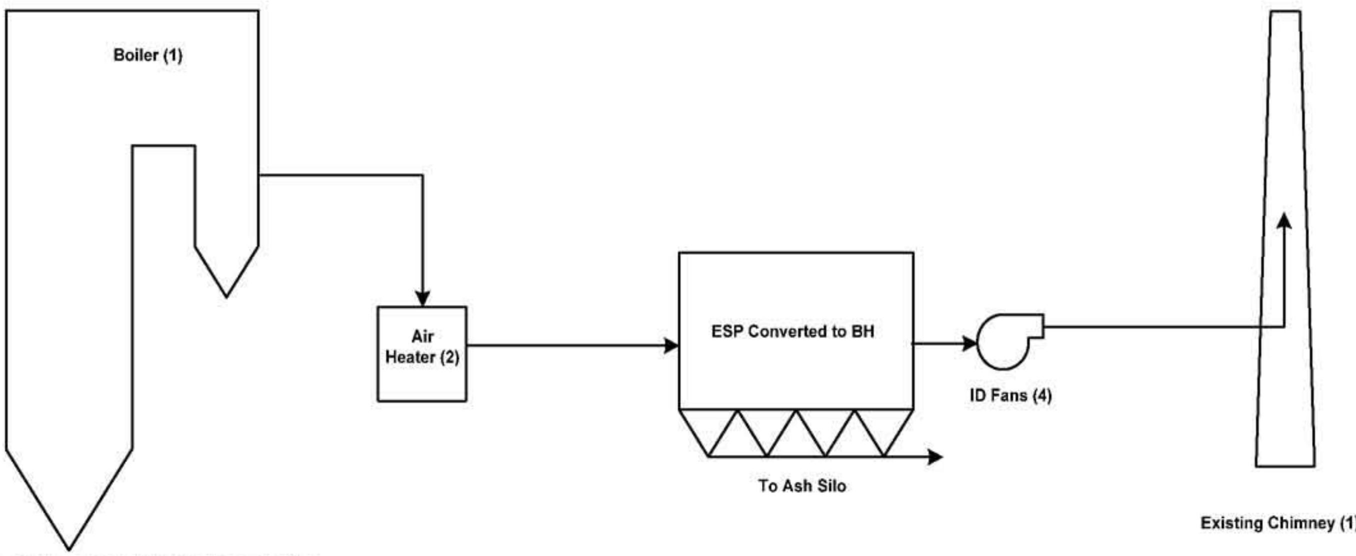
After completion of the mini studies, the conceptual design was completed as presented herein. This report addresses the following:

- Conceptual design with general arrangement (GA) drawings for dry FGD, SCR, and ACI, and technology screening and SCR location
- National Fire Protection Association (NFPA) 85 compliance
- Balance-of-plant (BOP) issues such as water treatment, ammonia delivery, boiler modifications, and fan selection
- Electrical single-line diagram
- Piping interconnection
- Implementation schedule and cash flow
- Capital and O&M cost estimates
- Permitting evaluation
- Constructibility review
- Next steps toward project implementation

2.2 EXISTING EQUIPMENT

Figure 2-1 depicts the existing equipment arrangement at Big Stone in the form of a simplified process flow diagram (PFD).

Figure 2-1. Existing Big Stone Equipment Arrangement



[TRADE SECRET DATA BEGINS
The Big Stone boiler was originally designed to burn lignite fuel and began operation in 1975. Designed by , the boiler is a Caroline-type balanced-draft pump-assisted radiant machine. The cyclone furnace originally included a predry system with hammer mill crushers on each fuel delivery circuit. In 1995, the boiler was converted to burn Powder River Basin (PRB) fuel. With the conversion to PRB fuel, the NO_X emissions rose significantly and the predry system was removed to allow for a simplified SOFA system to be installed in the existing predry ports. The boiler also has a flue gas recirculation (FGR) system to control main steam and reheat temperatures. Since the FGR fan capacity was reduced, the unit operates using only one of the two gas recirculation fans.

From the boiler, flue gas travels to two regenerative-type, vertical-shaft air heaters, each equipped with secondary and primary air ducts. The unit was originally designed with an electrostatic precipitator (ESP). In 2001, the ESP was converted to an system, whereby it functioned both as an ESP and fabric filter for particulate control. This system was the first of its kind and the installation was to demonstrate the technology. However, there were operational problems with the demonstration
TRADE SECRET DATA ENDS]

technology, which resulted in conversion of the entire particulate collector to a conventional pulse-jet fabric filter in 2007. Ash is currently sent to a fly ash storage silo located directly south of the plant, where it is then trucked to a landfill. Flue gas from the fabric filter flows to four centrifugal induced draft (ID) fans. There were no ID fan changes at the time of the conversion of the ESP to a fabric filter. Currently, the unit is ID fan-limited and does not have the capability of being upgraded to overcome the additional pressure drop. The ID fans discharge the flue gas to the chimney, which has two breech openings.

2.3 UNIT DESIGN BASIS

Big Stone is a 495-MW (gross) cyclone furnace that fires PRB coal. S&L initiated its evaluation using the unit's maximum design permitted heat input, as provided by OTP, to generate mass balances. The heat input to the unit is a primary parameter used to calculate the quantity of flue gas that would need treatment. The amount of flue gas that needs to be treated is one of the parameters used to size various emission control technology equipment. Since the amount of flue gas would increase parallel with the heat input, the maximum design permitted heat input was used as the basis for the sizing of equipment and the capital cost estimates. The equipment sizing and design basis using the more typical operating heat input can be reviewed further during detail engineering. The design basis parameters used in this evaluation are listed in Table 2-2.

Note that Big Stone, designed for base load service, is located in a region with significant wind-generated power potential. With the development of wind farms, OTP anticipates a shift in the Big Stone load profile toward more frequent cycling duty, meaning daily operation at loads of 50% maximum continuous rating (MCR) and lower. This study takes into account daily cycling of the unit.

Table 2-2. Design Basis Parameters

Parameter	Value
MCR output, MW	495
Heat input, MBtu/hr	5,609
O_2 at economizer outlet, vol %	2.50
Air heater in-leakage, wt % of total	15
Humidity, lb/lb dry air	0.025
Fly ash/bottom ash split	50:50

2.4 FUEL INFORMATION

The conceptual engineering study is based on burning typical PRB coal. OTP provided numerous ultimate and proximate analyses to S&L, based on which, a typical operating coal was defined. Any of the options considered can provide good SO_2 control for the typical range of PRB coals available. Table 2-3 identifies the design fuel analysis used in the study.

Table 2-3. Design Fuel Analysis

Parameter	Value (wt%)
Carbon	49.86
Hydrogen	3.60
Nitrogen	0.72
Sulfur	0.40
Oxygen	12.05
Chlorine	0.01
Fluorine	0.01
Moisture	27.35
Ash	6.00
HHV, Btu/lbs	8,200

2.5 OPERATING CONDITIONS

The operating conditions used for the conceptual engineering study are defined in Table 2-4.

Table 2-4. Current Operating Conditions

Parameter	Value
Average SO_2 emissions, lbs/MBtu	0.92
Average NO_X emissions, lbs/MBtu	0.80
Average Hg emissions, lbs/TBtu	8.00
Startup fuel	#2 Fuel Oil

Parameter	Value
100% MCR:	
Coal feed rate (ton/hr)	685,000
Total flue gas flow at air heater outlet, acfm	2,427,000
Average flue gas temperature at air heater outlet, °F (±25°F)	325
Average pressure at air heater outlet, in. H_2O	-19.5
40% MCR (minimum load):	
Total flue gas flow at air heater outlet, acfm	878,000
Average flue gas temperature at air heater outlet, °F (±25°F)	250
Average flue gas pressure at air heater outlet, in. H_2O	-10.0

2.6 ECONOMIC INFORMATION

Table 2-5 lists the major economic parameters that were used in the variable O&M costs as well as the economic evaluations throughout the study. These values were developed both by OTP and S&L.

Table 2-5. Major Economic Parameters [TRADE SECRET DATA BEGINS

Parameter	Value
Amortization life,	
Interest rate for discounting,	
Capital escalation rate,	
O&M escalation rate,	
Levelized fixed charge rate,	
Capacity factor,	
Auxiliary electric power energy charge,	
Ash disposal cost (placement only),	
Water,	
Lime (truck delivery),	
Activated carbon (truck delivery),	
Anhydrous ammonia (truck delivery),	

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3. CONCEPTUAL DESIGN FOR SCR, DRY FGD, AND ACI

3.1 DESCRIPTION OF MODIFICATIONS

3.1.1 Process Flow

[TRADE SECRET DATA BEGINS

Figure 3-1 is a PFD depicting the installation of the SCR, dry FGD and ACI systems. The new equipment installed for the project is shown in blue and equipment taken out of service in red. Flue gas will travel from the two outlets of the economizer to SCR reactors. Ductwork will be routed from the outlet of the SCR back to the air heater. There will be no bypass around the SCR for startup or low-load operation. Flue gas will then travel from the outlet of the air heaters through a long duct to the spray dry absorbers (SDAs). Activated carbon will be injected in the ductwork ahead of the SDAs. The flow will then travel from the new SDAs to new baghouses, per absorber. Finally, the flue gas will travel to new replacement ID fans, per baghouse/absorber combination, then to the existing chimney.

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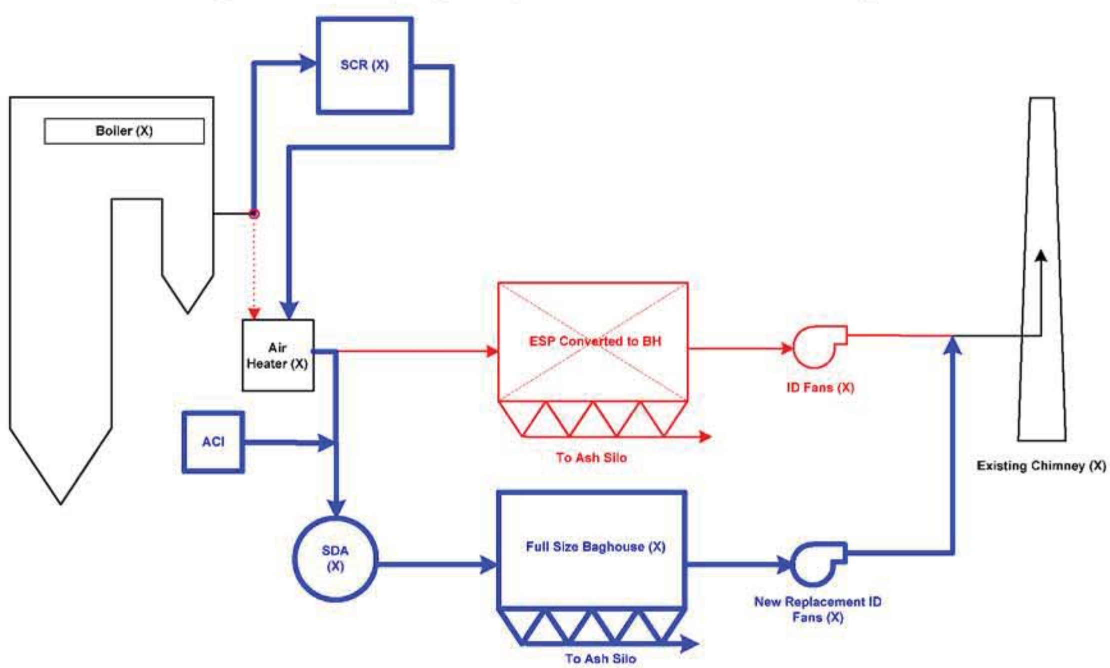
Figure 3-1. SCR, Dry FGD, and ACI Process Flow Diagram



3.1.2 General Arrangements

A preliminary set of general arrangement (GA) drawings are shown in Appendix A. The drawings show the layout of the major AQCS equipment for the project based on preliminary sizing of the equipment, ductwork, and buildings. The existing and new structures were modeled three-dimensionally (3-D). Walkdowns were performed to ensure there were no major discrepancies between the existing design drawings and the actual conditions. In addition, a walkdown of the plant was performed specifically to review the constructibility of the new systems using the most up-to-date of these GA drawings.

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The GA drawings show the SCR installed after the economizer and before the air heater. The SCR system includes the SCR inlet ductwork, SCR reactors, SCR outlet ductwork, and an ammonia storage and forwarding system. The location of the SCR reactors is relatively close to the boiler economizer outlet on the west side of the boiler. SCR reactors are supported by structural steel trusses spanning north-south over the existing baghouse and baghouse inlet ductwork. There are catalyst levels in each SCR reactor, with sootblowers on the and sonic horns on . An enclosure (roof, siding, and floors) will surround all SCR access areas and the ammonia injection grid (AIG) area. The ammonia storage and forwarding system is located south of the plant near the other material loading and unloading areas. This location was chosen based on the prevailing wind directions shown on the wind rose in the area of Big Stone plant. The prevailing winds are generally in the plant east-west direction and in the event that there is an ammonia leak, plant personnel will frequently be outside of the immediate area of impact.

The dry FGD system, including new baghouses, blower building, and ID fans with variable-frequency drives (VFDs) are located south of the existing baghouse and chimney. The inlet ductwork for the dry FGD system will tie in at the existing baghouse inlet ductwork and the outlet of the new ID fans will tie in at the existing expansion joints located at the chimney breeching. These tie-ins will be performed during the spring plant outage. The existing baghouses and ID fans will be demolished starting with the spring outage. This will allow the space to be used for the water treatment building and a makeup water storage tank. TRADE SECRET DATA ENDS]

The lime storage system, reagent preparation (lime slurry and recycle ash) system, and solid waste storage system are located near the south side of the dry FGD and baghouse systems. With this arrangement, material loading and unloading is generally centralized in one location and these systems are readily accessible to the process equipment using the overhead pipe rack. As part of these systems, an enclosed slurry sump basin is shown west of the recycle building. The basin will be used for flushing, washdown, and clean out of the recycle and lime slurry systems. Once the solids in the basin settle, the water can be recovered and reused in the process and the solids can be sent to the landfill.

The ACI system silo and ACI prefabricated electrical building are located east of the dry FGD system inlet ductwork. The ACI injection grid is located to the north of the SDAs in the top of the inlet ductwork. Piping and conduit for the ACI system will be supported above grade by the ductwork support steel and, if necessary, by a short pipe rack from the ACI silo to the duct support steel.

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An auxiliary power upgrade is being provided for the AQCS equipment. New equipment for the auxiliary power upgrade is located east of the turbine building and consists of a 230-kV line coming in from the switchyard to a reserve auxiliary transformer (RAT) and a unit auxiliary transformer (UAT) that ties in to the existing isolated phase bus tap. These transformers will be connected by above-grade cable bus to 13.8-kV switchgear in the prefabricated main electrical power distribution building located along the south side of the boiler building. Electrical power distribution will be provided by electrical equipment located within prefabricated electrical power distribution buildings, which include the main electrical power distribution building, a lime preparation and recycle electrical building, and a baghouse electrical building. As shown on the GA drawings, these buildings are strategically located near the new electrical loads. Each of the prefabricated buildings will be elevated approximately 4-5 feet above grade to allow bottom-cable tray entry. TRADE SECRET DATA ENDS]

The main pipe rack shown on the GA drawings generally runs north-south between the equipment and buildings. The pipe rack will be used for routing above-ground piping, cable trays, and conduits.

Storage for the AQCS equipment spare parts will be provided in a new pre-engineered warehouse located northwest of the chimney and near the existing plant warehouse area.

All structures will be enclosed and access will be provided by stairways and walkways from the existing and new structures. One six-person elevator will also be provided near the north SDA, which will have elevator stops to the SDA penthouse and each of the SCR catalyst levels.

3.2 BOILER MODIFICATIONS

3.2.1 Separated Overfire Air

Operating cyclone-equipped boilers at reduced airflow or at substoichiometric conditions (less air than is theoretically required for complete combustion) substantially minimizes/reduces fuel NO_X formation. With the unique combustion characteristics of a cyclone furnace, significant NO_X reduction at an overall lower cost can be realized by air staging techniques.

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Based on a study conducted by (see Appendix F), two potential SOFA designs that provide optimum mixing of the balance of combustion air with the main combustion zone flue gas during the second stage of combustion with the furnace region (i.e., the burnout zone) were reviewed.

- Option 1 – SOFA at existing FGR elevation 1202'-9": 12 SOFA ports with windbox takeoffs.
- Option 2 – SOFA at higher elevation 1254'-0": 14 SOFA ports and duct runs with front and rear plenum plus platform and stairway additions/modifications.

The difference in NO_X performance between the two SOFA port elevation locations is currently projected to be only about . However, the estimated budgetary capital costs and schedule for the two options vary considerably as discussed in Appendix F. For the conceptual design, Option 2 was chosen and included in the capital cost estimate. During detail engineering, the lower-cost Option 1 will be evaluated further.

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3.2.2 Economizer Exit Gas Temperature Control

For the SCR catalyst to operate efficiently, the bulk average gas temperature leaving the economizer needs to be no greater than 750°F with variation of less than +20°F at a "dirty" boiler condition at full load (3,638,000 lbs/hr main steam flow) and greater than 625°F with variation of less than -20°F at a "clean" boiler condition at minimum load (1,627,000 lbs/hr main steam flow).

The economizer exit gas temperature (EEGT) at full load and clean boiler conditions is currently 792°F and the unit is not achieving the 1005°F steam temperatures. The EEGT at minimum load is currently 645°F. Therefore, in order to achieve an acceptable temperature range for the SCR catalyst to operate efficiently, convection pass modifications are required as shown in Appendix F.

The convection pass modifications consist of the following major modifications:

- New reheat and inlet bank, including an additional reheat pendant superheater bank for increased total surface area.
- New primary superheater, including an additional horizontal primary superheater bank for increased total surface area. [TRADE SECRET DATA BEGINS
- new economizer banks. TRADE SECRET DATA ENDS]
- Remove and not replace the small FGR economizers, pending confirmation that the FGR fan is compatible with the 750°F +20°F flue gas temperatures.
- The FGR intake "doghouses" will be lowered and redesigned with the addition of new support trusses.

The convection pass modifications recommended above are predicted to achieve an EEGT at full load (3,638,000 lbs/hr main steam flow) dirty condition of 733°F. At minimum load (1,627,000 lbs/hr main steam flow) clean, the achievable EEGT is predicted to be 635°F. These recommended modifications not only achieve the target EEGT range, but are also expected to attain desired superheat and reheat steam outlet temperatures. For the conceptual design, the costs for the modifications described above and shown in Appendix F were included in the capital cost estimate.

3.2.3 Boiler Reinforcement

The Big Stone AQCS project has various emission control options are under consideration that will add equipment to the flue gas path downstream of the boiler. The new emission control equipment will increase the system pressure drop and new ID fans will be used to provide the additional draft capacity needed to compensate for the pressure drop. The existing fans are capable of approximately 30" WG of static head, while the new fans will be capable of nearly double this amount. With such a large increase in ID fan capability, both the steady-state and transient pressures can increase to the level that the boiler, baghouse, and/or ducts are at risk of being imploded. A study of the risk of implosion was performed. The report from the study is provided in Appendix C.

The furnace section of the boiler has a steady-state deign pressure of +3"/-7" WG, but the transient pressure design of the furnace is unknown. Similarly, the economizer section of the boiler has a steady-state design pressure of -23" WG, but the transient pressure design limit of the furnace economizer section is unknown. The Big Stone furnace has experienced a master fuel trip (MFT) transient that exceeded -10" WG, and new larger ID fans will have the capability to generate transients with a greater magnitude than created by the current ID fans.

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As part of the evaluation, it was determined that the boiler would probably not have sufficient strength to withstand a future MFT event. Therefore, reinforcement of the boiler to withstand a reasonable negative pressure spike is recommended to minimize the risk of implosion. The furnace should be reinforced to withstand a transient of at least , the economizer to , and the air heater to . Other parts of the existing flue gas path would also require reinforcement to withstand a reasonable negative pressure, though many of these are being replaced with new duct.

Boiler manufacturers typically recommend reinforcing the furnace to WG, but insurance companies do not typically require furnace reinforcement to WG. Furnace reinforcement to WG is reasonable and the amount of reinforcement required can be minimized by using VFDs, for example, to help reduce the pressure transient. Insurance carriers have agreed with this level of protection on past projects. OTP should approach the insurance carrier with this proposed level of protection.

Based on the recommendation to reinforce the furnace to at least WG, NFPA 85 evaluations and studies of other similar boilers, and input from , the estimated budgetary capital costs and schedule for boiler reinforcement to WG are included in the capital cost estimate.

An estimated budgetary capital cost for furnace reinforcement to WG is not available without a more detailed study by the original boiler supplier ( ). However, the cost is expected to be significantly higher since furnace reinforcement to WG is expected to require buckstay replacement, roof support modifications, and windbox modifications. TRADE SECRET DATA ENDS]

A review of the proposed flue gas system hardware changes, software changes, control methodology, and conclusions in the report provided in Appendix C by the Authority Having Jurisdiction (AHJ), which is Factory Mutual (FM), is still required.

3.3 SCR REACTOR AND CATALYST

3.3.1 Design Summary

Table 3-1 identifies the major design parameters for the SCR reactor and catalyst.

Table 3-1. SCR Reactor Design Summary

Parameter	Performance
Volumetric flue gas flow	3,350,000 acfm
Inlet NO_X rate, average	0.80 lbs/MBtu
Design catalyst inlet velocity	16.5 ft/s
Economizer outlet temperature (full load)	750 (±20°F)
Economizer outlet temperature (low load)	625 ±20°F
SCR SO_2-to-SO_3 oxidation	2.0% [TRADE SECRET DATA BEGINS
NH_3 slip, maximum at end of catalyst life	
Design removal efficiency	
Number of catalyst layers per reactor	
Catalyst modules per layer	
Catalyst volume per layer	
Reactor	
Inlet riser	
Sootblower	
Sonic horns	TRADE SECRET DATA ENDS]
SCR hopper on outlet	Space allocated; need will be determined in detailed design

3.3.2 SCR Reactor [TRADE SECRET DATA BEGINS

Big Stone will have SCR reactors. The unit has air heaters; therefore, having reactor per air heater will ensure the best possible flow balance.

The cross-sectional area of the SCR reactor is set by the design volume of gas and the target catalyst inlet velocity and is not dependent on the inlet NO_X concentration. The design criterion for gas volume is 3,350,000 acfm at the economizer outlet and the target velocity at the catalyst inlet is a maximum of 18 ft/s. Although it would be ideal to have a square SCR reactor, the length-to-width ratio is determined by the physical dimensions of the catalyst modules that comprise each catalyst layer. Module sizes offered by SCR catalyst vendors are standardized to provide flexibility to utilities in choosing from a variety of catalyst vendors instead of being restricted to the initial catalyst supplier. They are approximately 950 mm in width and 1,900 mm in length. The design reactor cross-sectional area must also include space for the support steel needed to accommodate the catalyst layer. Because the reactor width and length are set by the physical design of the catalyst and support, the velocity at the catalyst inlet must be calculated from a proposed reactor configuration. Several iterations were performed to determine a configuration that meets the velocity criteria established.

The reactor height is set by the number of catalyst layers required, which is determined by the overall catalyst volume required to achieve the NO_X reduction guaranteed. The reactor will have levels for catalyst. The first layers initially will be supplied by the SCR vendor, and the layer will be a spare layer that will be loaded after approximately 16,000 hours of operation. Similar to the cross-sectional area dimensions of the reactor, the catalyst layer heights are bound by the height of the catalyst elements. The module heights will be limited to 5.5 feet to ensure that Big Stone will have the flexibility to load any catalyst supplier's modules. The SCR will be expected to operate within an 8" to 10" w.c. pressure drop range (large-particle ash [LPA] screen through SCR exit duct). TRADE SECRET DATA ENDS]

The SCR reactor will have an inlet and outlet sampling grid to measure the NO_X and NH_3 distributions at the SCR inlet and outlet. At a given location along the width of the reactor at the outlet, a bundle of sampling tubes is inserted and flanged to the reactor. Each tube in a bundle has different lengths that extend varying distances through the reactor. Several tube bundles are installed at the outlet in an arrangement that allows a "grid" to be formed of sampling locations. This sampling grid will be used to tune the ammonia injection grid (AIG) to optimize the NO_X/NH_3 distributions at the reactor outlet. The sampling grid at the outlet will also be used during performance testing to demonstrate that the Contractor's design meets the guaranteed performance. It is not expected to be used for continuous monitoring of the SCR.

3.3.3 Large-Particle Ash Screen

Most PRB coals produce large agglomerations of fly ash termed *popcorn ash*. Popcorn ash can have an impact on SCR performance if not removed before the catalyst. It can plug the openings in the catalyst and render those sections of catalyst ineffective for NO_X reduction.

The method most widely used to remove the popcorn ash has been the installation of a screen. This typically is a perforated plate coated with erosion-resistant material or thick wire screen, also coated with erosion-resistant material. However, based on the industry experience, the average velocity through the open area of the screen should not exceed 45-50 ft/sec. Installations, with 70-ft/sec or higher average velocity, have experienced severe erosion problems. Typical pressure drop across the screen (with 50-60% open screen) will be in the range of 0.5-0.75 inches w.c. The plugging of the screen can be detected by monitoring the pressure drop across the screen.

3.3.4 Internal Online Cleaning [TRADE SECRET DATA BEGINS

The sootblowers required for cleaning the catalyst beds typically use steam and are of the rake-type design. They would be located approximately 18-20 inches above the layer of catalyst and would be situated such that when fully retracted (approximately 6.5 feet), they provide access to the catalyst without requiring sootblower removal. The steam cleaning medium has a supply pressure of 35-60 psi, and superheat of 50°F. Typically, the total amount of sootblowing steam required for SCR systems is 40-50 lbs/hr of steam per megawatt. The sootblowers are not used continuously rather once per shift or once a day during initial operation and as required based on experience. The sootblower controls are typically programmable logic controller (PLC)-based with an operator interface in the main control room however can be integrated to the distributed control system (DCS) if required.

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A large number of high-dust SCR systems are retrofitted with air-powered sonic horns at each catalyst elevation to allow the removal of accumulated fly ash. Sonic horns have the advantage of eliminating the potential addition of moisture to the SCR system and operate at much lower power requirements than steam sootblowers. Sonic horns are recommended because of their lower installed cost and successful applications at similar installations. Due to

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excessive ash buildup due to PRB coal ash characteristics, installation of sootblowers on the layer of the catalyst is recommended. TRADE SECRET DATA ENDS]

3.3.5 Catalyst

Catalyst formulation and type are the two primary design issues that need to be evaluated before selecting a catalyst. Catalyst formulation involves the selection of elements used to avoid the damaging effects of flue gas and ash constituents, as well as to provide operational stability in various temperatures. The coals and operating conditions at Big Stone do not require a unique catalyst formulation that would significantly affect the cost of the catalyst. However, significant boiler upgrade cost is being incurred to create a temperature range at the SCR inlet to allow conventional materials to be used.

The types of catalyst available include plate, corrugated, and honeycomb. The plate-type catalyst consists of a catalyst coating over a metal plate or wire mesh. The corrugated-type catalyst consists of catalyst coating over a fiberglass substrate. The honeycomb catalyst is manufactured as a homogeneous or coated catalyst. The homogeneous catalyst manufacturing process involves the mixing of titanium oxide (TiO_2) and vanadium oxide (V_2O_5) and extruding the mixture using a dye. The honeycomb catalyst, especially the extruded type, has a larger amount of catalyst per volume than the plate-type. The corrugated-type catalyst is a design variation of the honeycomb catalyst. This type of catalyst design reduces costs and space requirements of the reactor. However, the plate-type catalyst is more resistant to plugging because of its resistance to fly ash erosion and is more easily cleaned. Any of the three types of catalyst could be used at Big Stone and typically, the catalyst volume will not change based on the type of catalyst chosen. Recommendation on a specific type of catalyst will be made in detail engineering.

3.3.6 SCR Access and Catalyst Replacement [TRADE SECRET DATA BEGINS

The catalyst replacement features typically include either one or two doors and a trolley system or grating to move the catalyst into the reactor. Based on a previous time-motion study performed by S&L, it was determined that using a pallet truck to move the catalyst in the reactor offers the best approach to change-out catalyst and grating is used to support the catalyst and allow the pallet truck to move freely. The large reactor volume required at Big Stone will require doors at each catalyst level to move the catalyst in and out of reactor.
TRADE SECRET DATA ENDS]

Access to each layer of catalyst would be provided on one side of each reactor. The access doors would be at least four feet wide and seven feet tall and will be used to replace catalyst beds. Catalyst modules will be lifted from grade using an air-tugger or electric hoist and placed on the working elevation or directly onto a waiting pallet truck. Permanent gallery will be specified internal to the reactor such that pallet trucks can be moved inside through the loading doors to place the modules in position and remove them during replacement. No overhead trolleys or rails are necessary for loading of the catalyst modules inside the reactor.

The sootblowers would not have to be removed during catalyst replacement in that adequate access will be available by fully retracting the sootblowers during the replacement process. The sonic horns will also not interfere with catalyst replacement.

Access galleries will be provided at each catalyst level, at the AIG, at the sootblowers, and at the measurement grids. Smaller access doors would also be provided at each catalyst layer to allow for inspections and catalyst sampling.

3.4 SCR REAGENT SUPPLY

3.4.1 Description [TRADE SECRET DATA BEGINS

S&L conducted a study of ammonia delivery systems (report SL-010364 provided in Appendix E) that compared anhydrous ammonia, 19% aqueous ammonia, 29% aqueous ammonia and urea. The study concluded that the most cost-effective reagent to use for the SCR was anhydrous ammonia; however, it considered to highly hazardous by the Occupational Safety and Health Administration (OSHA) and is subject to the most stringent regulatory requirements. Consideration for plant personnel and public safety must be given in the final decision-making process. Note that the study assumed an inlet NO_X of 0.80 lbs/MBtu. The study (see Appendix F) shows that the installation of SOFA would reduce the NO_X at the inlet of the SCR to approximately NO_X. This will significantly reduce the amount of anhydrous ammonia injected and thereby reduce the O&M costs. During detail engineering, the impact of this lower inlet NO_X will be reviewed. TRADE SECRET DATA ENDS]

3.4.2 Design Summary

Table 3-2 identifies the major design parameters for the Big Stone anhydrous ammonia system. Note that the conceptual design and capital cost estimate of the anhydrous ammonia system include the use of vaporizers. The industry is starting to consider direct injection (elimination of the vaporizers) of anhydrous ammonia and this concept will be reviewed further in detail engineering. This would again favor the use of anhydrous ammonias the reagent of choice.

Table 3-2. Anhydrous Ammonia Design Summary

Parameter	Performance
Design ammonia feed rate	1,573 lbs/hr
Inlet NO_X rate, average	0.80 lbs/MBtu
NO and NO_2 distribution	95% NO/5%NO_2
	[TRADE SECRET DATA BEGINS
Ammonia storage	
Storage capacity	
Number of tanks	
Vaporization skid	
Pump skid	
Dilution air skid	
Number of anhydrous ammonia trucks/week	
	TRADE SECRET DATA ENDS]
Injection location	Ammonia injection grid located in SCR riser ductwork
Safety features	Portable eye wash station, shower and deluge near ammonia tanks, portable eyewash station near AIG

3.4.3 Ammonia Injection Grid

Ammonia would be distributed through an AIG. There are two types of AIG designs used in SCR technology - a multiple-zone tunable grid design and lances/injectors followed by static mixers.

The multiple-zone design includes hundreds of nozzles and valves that allow control of ammonia in an X x Y array such that the ammonia flow rate can be controlled to each zone to produce a uniform NO_X concentration at the catalyst outlet. This type of design had been used in SCR systems installed in Japan and Europe in the early 1980s to achieve 70-80% NO_X removal efficiency. The tunable-type of system is not usually used in U.S. installations, as utilities in the U.S. rely on a longer SCR inlet duct, injection lances, and static mixers to provide a uniform ammonia feed to the catalyst. The tunable-type system could be used when the inlet to the SCR is shorter.

Most SCR installations in the U.S. rely on static mixers to provide uniform distribution of the ammonia at the inlet of the first catalyst layer. After the flue gas is taken from the economizer, a long duct section is used to house the AIG and static mixers. The injection lances provide some uniformity of ammonia injection across the duct, but the static mixers closely follow and they mix the ammonia and flue gas so a uniform mixture reaches the catalyst. The SCR duct, mixers, and reactor are modeled using a physical model and the uniformity of ammonia distribution is verified. For high-efficiency SCR designs, static mixers with ammonia injectors or lances described above have been widely used. Utility installations have achieved 90% NO_X reduction with this approach.

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The conceptual design of the SCR systems at Big Stone has the AIG located approximately five feet after the last transition in the ductwork. This ensures that a proper flow pattern has developed prior to the ammonia being injected. The static mixers are located approximately 12 feet after the AIG. Static mixers are installed to achieve a uniform NO_X/NH_3 ratio and velocity distribution before entering the catalyst. It is generally recommended to include to hydraulic diameters between the AIG and the catalyst face to ensure sufficient mixing.

TRADE SECRET DATA ENDS]

3.5 FGD ABSORBERS

3.5.1 Description

S&L conducted a screening study SO_2 technology (wet vs. dry) that concluded dry FGD to be the optimal choice for Big Stone. Results of that screening study are included in Appendix B (SL-010303).

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Big Stone Plant will have SDAs, with each absorber treating of the flue gas. The SDAs will be 62 feet in diameter. The absorber will be a vertical open-chamber, with cross-current contact between the lime slurry and flue gas. The SDAs will be constructed of carbon steel since the PRB coal fired at Big Stone does not pose a significant concern for chloride or SO_3 corrosion. Some utilities in the eastern U.S. have applied alloy wallpaper or a spray coat for corrosion protection. These measures are not included in this conceptual design. Each SDA will also have atomizers. The conceptual design of the Big Stone SDA includes atomizers per SDA. The number of atomizers varies between vendors; however, for the conceptual study, S&L used the more conservative design. Slurry atomization is the key performance criterion in reducing SO_2 from the flue gas. Slurry is introduced to each

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absorber as a fine mist of droplets. This fine mist of droplets creates a large surface area in which the flue gas can mix. Atomizers, either rotary or dual-fluid, produce the fine droplets needed for effective SO_2 removal in a spray dryer system. The conceptual design is based on a rotary atomizer in the SDA. The SDA will be expected to operate within at about 6" w.c. pressure drop. Duct to and from will add some more pressure drop.

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absorbers will share a common penthouse for weather protection during maintenance activities on the atomizers. A spare atomizer will also be stored or will stand in the penthouse of each SDA. The penthouse will have a vacuum system to clean the area. Also, service water for hose stations will be provided to clean some areas that are susceptible to slurry spills. A drain to grade and a sump at grade to accumulate the washdown will be needed in these areas. The penthouse will require heating and ventilation. The penthouse walls will have two inches of insulation but no interior metal lagging. Additionally, insulation typically is not lagged on the interior of buildings. If the insulation becomes damaged, it would be visible to plant personnel and therefore should be repaired. There will be a jib crane and hoist, common to both SDAs, in the penthouse to raise and lower equipment and tools from grade. Also, a new elevator is included in the conceptual design located near the SDAs for personnel and maintenance access. A minimal amount of solids will fall out in the SDA hopper, and will have to be shoveled out. A new Dumpster is included in the conceptual cost estimate to collect these solids.

TRADE SECRET DATA ENDS]

3.5.2 Design Summary

Table 3-3 identifies the major design parameters for the Big Stone FGD absorbers.

Table 3-3. FGD Absorber Design Summary

Parameter	Performance
Volumetric flue gas flow	2,427,000 acfm
Inlet temperature	325°F
Inlet SO_2, average	0.92 lbs/MBtu [TRADE SECRET DATA BEGINS
Outlet SO_2	
Approach to adiabatic saturation	30°F
Number of SDAs	
Diameter of each SDA	
Number of rotary atomizers per SDA	TRADE SECRET DATA ENDS]
SDA residence time	Minimum of 10 seconds

3.6 PULSE-JET BAGHOUSE

3.6.1 Description

S&L's screening study (Appendix B, SL-010303) evaluated whether the existing baghouse could be reused. The existing baghouse at Big Stone is 37 years old and most baghouses and ESPs are typically replaced after 30-40 years. Per the screening evaluation, it was determined that the increase in negative pressure on the existing baghouse and ductwork will require extensive reinforcement from the addition of SO_2 and NO_X reduction AQCS technology.

The existing baghouse is designed to handle a continuous operating pressure of up to negative 25 inches w.c. and OTP currently operates the baghouse at approximately negative 28 inches w.c. For dry FGD technology, implementing an SDA could add up to 7-10 inches w.c. of additional negative pressure before the flue gas enters the baghouse. Installation of SCR will add even more negative pressure ahead of the baghouse (approximately 8-10 inches w.c.). The existing baghouse and ductwork remaining in place will be unable to handle the additional negative pressure. In addition, the existing baghouse fly ash handling system will also need major modifications due to the increased solid loading with an SDA. The screening study determined that it was more cost-effective to install a new baghouse than take risk in modifying the existing baghouse. Therefore, the conceptual design and cost-estimate includes a new baghouse.

[TRADE SECRET DATA BEGINS

The new baghouse will reduce emissions to less than of filterable particulate matter (PM). The opacity will be less than on a six-minute average. In addition to PM and opacity, the baghouse also removes of the overall SO_2 removed in the system due to the layer of sorbent on the surface of the bags and the intimate contact as gas passes through the cake. The baghouse is sized using a gross air-to-cloth ratio of 3.6 fpm. There is a spare compartment per casing, which allows the unit to operate with these compartments off line for maintenance. The baghouse will be expected to operate within a 6" to 8" w.c. pressure drop range (flange-to-flange) with all the compartments in service.

The collected solids will be removed from the baghouse hoppers with a pressurized material handling system. A vacuum pneumatic conveying system will be installed that requires 14' of clearance between the hopper room floor and the hopper outlet flange. The material handling system will be suspended from the hoppers to allow the material handling system to expand at the same temperature as the casing. There will be some solids that fall out in the hopper enclosure when the unit is off line and as hopper doors are opened, but this should be minimal. Dry deposits would be vacuumed up as part of house cleaning, but service water is also provided to wash down the area if needed.

Hoppers will have sledge plates, vibrators, and poke holes to keep the solids flowing in the hopper. These accessories will be accessed from grade and a hopper platform is not included. Hopper heaters will keep the lower third of the hopper warm and free from condensation. Additionally, the hopper is covered with of insulation, which is removable so the heaters can be changed-out without harm to the insulation.

The bags will be cleaned with dry and oil-free compressed air. blower and dryer trains will supply air to the penthouse of each of the casings. The blowers will be air-cooled and will have an inlet air duct from the outside of the enclosure. blower train will be located in the hopper enclosure area of each baghouse casing and there will be a crossover pipe between casings tying the systems together. Receivers to store the air will be included. These air systems will be sized to deliver the bag cleaning air, the motive air for the baghouse dampers, air for the ACI silo fluidization, control air for the material handling system in the hopper enclosure, and other

TRADE SECRET DATA ENDS]

miscellaneous systems. It is recommended that separate air receivers be used for the cleaning air and the damper air. This will ensure that air is available to operate the dampers if power is lost to the plant.

[TRADE SECRET DATA BEGINS

The baghouse plenum will either be a top-door-type or a walk-in plenum-type. The top-door design will allow staff to remove the door and step down onto the tube sheet for maintenance. A hoist system is provided to allow the large compartment door to be removed for access. A vacuum break is needed on each compartment to allow easy removal of the door. The walk-in plenum design will allow access to the tube sheet by access doors (x). The area above the tube sheet is a confined space and needs ventilation and special precautions. The advantage of the walk-in plenum is that air in leakage is minimized because the doors are smaller and can be tightly shut to seal air out. In comparison, the top-door design has a large perimeter of gasket that is difficult to keep in top condition, and allows in-leakage. Both designs work successfully after a dry FGD. TRADE SECRET DATA ENDS]

A penthouse will protect from elements of weather. Heat and ventilation will be included to control temperature to 10°F above ambient temperature or 55°F, whichever is greater. The outlet and bypass dampers operators will be accessible within the penthouse, as well as the bag-cleaning air-pulsing header. A jib crane and hoist by the original equipment manufacturer (OEM) will enable boxes of bags, cages, or tool-boxes to be lifted to the penthouse and to lower pneumatic operators to grade.

Utility baghouses have inlet and outlet dampers for each baghouse compartment, which will allow for a compartment to be taken off line and for plant staff to enter the compartment to check for bag leaks. The ducts and compartments are all normally under negative pressure so the typical utility design allows safe entry into the compartments.

3.6.2 Design Summary

Table 3-4 identifies the major design parameters for the Big Stone pulse-jet baghouses.

Table 3-4. Pulse-Jet Baghouse Design Summary

Parameter	Performance
Volumetric flue gas flow	2,141,000 acfm
Particulate load	231,000 lbs/hr
Inlet temperature	167°F
Casings	[TRADE SECRET DATA BEGINS
Compartments per casing	
Baghouse footprint	
Number of bags	
Air-to-cloth with all compartments on line	3.60
Air-to-cloth with one compartment off line per casing	4.10
Bag length	
Bag material	PPS
Size and velocity of inlet plenum	
	Velocity = 3,600 fpm
Size and velocity of outlet plenum	18' x18'
	Velocity = 3,600 fpm
Number of hoppers	
Insulation	TRADE SECRET DATA ENDS]

3.7 LIME RECEIVING AND PREPARATION

3.7.1 Description [TRADE SECRET DATA BEGINS

The conceptual design is based on lime being delivered to Big Stone via truck. The plant will have lime silo with bin vent filters for dust control when it is being filled. The silos will be adjacent to the unloading area. The trucks will have on-board blowers that will pneumatically convey lime to the long-term storage silo. One lime truck will be unloaded in approximately 1-2 hours. If the silo design calls for a taller silo or faster unloading is needed, a

TRADE SECRET DATA ENDS]

stationary truck unloader can be added. Rail deliveries could also be studied further to allow for lower lime cost. However, rail deliveries would require significantly more capital cost for rail spurs and equipment.

Lime will gravity-feed from the silo hopper into the slakers in the reagent preparation building. The slakers can either be the ball mill- or detention-type. The primary function of the slaker is to hydrate the dry pebble lime into a slurry and create fine particles of $Ca(OH)_2$. The hydrated form of lime is the most reactive form and is necessary for high levels of SO_2 removal. The slurry from the slakers will discharge through grit screens into lime slurry storage tanks and will be agitated until needed for injection into the SDA. This system can also provide slurry to the existing cold-lime softener (CLS) so that the lime storage and slurry system there can be eliminated. Costs for demolition of the existing lime storage and slurry system have not been included in the estimate.

Removing grit is very important in the dry FGD process because it can plug the atomizer nozzles. Each slaker will have an external classifier or grit removal screen, whose main function is to separate large oversized grit and impurities from the slurry solution. Eventually, the oversized grit will be rejected from the system. The grit will be placed in Dumpsters and eventually hauled away. With the design coal and high-quality lime, a Dumpster should be adequate, but in some instances Dumpsters may not be sufficient to handle the volumes, and a grit pit might be needed. A front-end loader would be used to scoop and place the grit in a truck for disposal. The conceptual design is based on detention slakers, which would have piles of grit dumped to grade that would then need to be hauled off to disposal each day.

3.7.2 Design Summary

Table 3-5 identifies the major design parameters for the Big Stone lime receiving and preparation system.

Table 3-5. Lime Receiving and Preparation Design Summary

Parameter	Performance
Lime silo storage	[TRADE SECRET DATA BEGINS
Lime silo capacity	
Pebble lime quality	90% CaO minimum
	¾" x 0" lump size
Fresh lime feed	
Slaker	
Lime slurry storage tank	
Lime slurry transfer pumps	
Lime slurry, wt% solids	20%
Makeup water tank (use in recycle system)	
Slurry sump basin	
Slurry makeup water tank (use in slaker)	
Slaker water requirement	76 gpm
Slaking temperature requirement	170°F minimum
Number of lime trucks/week	17
Lime preparation building	TRADE SECRET DATA ENDS]

3.8 RECYCLE SOLIDS PREPARATION

3.8.1 Description

The recycle slurry is recycled to the SDAs to reduce lime consumption. There is residual activity and alkalinity left in the lime after it has been passed through the system once; therefore, it is re-introduced to gain additional lime utilization. Also, a droplet of ash and lime mixture dries faster than a droplet of lime alone. This will reduce the time required to dry the slurry in the absorber and also prevent localized lime droplets coming in contact with the SDA walls.

Waste solids will be collected in the new pulse-jet baghouse. The solids will be transported to either the recycle silo or to the waste silo. The system will be controlled to send ash to the dry FGD recycle silo until full, and then to send the waste to the waste silo until the recycle silo needs more waste. Solids primarily will be sent to the recycle silo, but about 25% of the time will be sent to the waste silo.

The recycle system is located in its own building. A portion of the waste solids from the baghouse will be sent to a recycle silo located within this building. The dry waste from this silo flows to a premix tank, where it is combined with water. The slurry overflows to a recycle holding tank, which then overflows into a recycle slurry storage tank. Mixing in the premix tank is difficult due to a dry, dusty waste being mixed with water. The material in the premix tank has the consistency of a paste-like material and, therefore, requires more maintenance than other parts of the system. This recycle system allows the lime to be passed through the SDA several times, which allows each particle of lime to be utilized more. Thus, the lime particles that did not absorb SO_2 the first time through the system have the chance to do so several more times. The dry FGD recycle system will require significant maintenance because mixing a dry powder with water is more troublesome than slaking lime. The recycle premix tank, if not agitated continuously, can set up to the consistency of concrete and require a jackhammer in order to clean out.

3.8.2 Design Summary

Table 3-6 identifies the major design parameters for the Big Stone recycle lime receiving and preparation system.

Table 3-6. Lime Receiving and Preparation Design Summary

Parameter	Performance
	[TRADE SECRET DATA BEGINS
Recycle silo storage	
Recycle slurry mix tank	
Recycle slurry storage tank	
Recycle slurry pumps	
Recycle slurry, wt% solids	40%
Makeup water requirement	556 gpm
Solids to recycle silo	196,000 lbs/hr
Recycle building	TRADE SECRET DATA ENDS]

3.9 SOLID WASTE HANDLING

3.9.1 Description [TRADE SECRET DATA BEGINS

The dry FGD process adds several times more solids to the inlet of the baghouse, and these solids must be transported to either the recycle or the waste silo. The new solid waste handling system will collect waste from the hoppers in the new baghouses. The waste will be pneumatically conveyed from the baghouse hoppers to either the existing ash silo or the new waste silo. Both silos will be used. silo will have bin vent filter. The existing silo bin vent filter is not large enough for the increased waste that will be sent to it; therefore a new bin vent filter is included. Since one silo will be operated at any given time, the redundancy requirement for the bin vent filter has been built in. TRADE SECRET DATA ENDS]

Detailed information on the ash handling system and solid waste disposal is provided in Appendix M (SL-010402). In addition, the report identified the most cost-effective method to transport the ash to the existing landfill. A new landfill will not be required as there is sufficient capacity in the existing landfill. The study recommended transport of the waste by truck with the ejector feature. However, OTP would prefer using scrapers in lieu of the trucks since this is the current practice at Big Stone.

3.9.2 Design Summary

Table 3-7 identifies the major design parameters for the Big Stone solid waste handling system.

Table 3-7. Solid Waste Handling Design Summary

Parameter	Performance
Coal, HHV	8,200 Btu/lb
Ash content	6%
Bottom to fly ash split	50/50
Distance from baghouse to fly ash silos	[TRADE SECRET DATA BEGINS
Ash piping	
Total solids to hoppers	231,000 lbs/hr
Solids to storage silos	35,000 lbs/hr
Fly ash transport rate	Two times the make rate TRADE SECRET DATA ENDS]

[TRADE SECRET DATA BEGINS

Parameter	Performance
Dry ash density	45 lbs/ft^3
Ash Haul Equipment	
Bin vent filters (one per silo)	
Waste storage silo	
Waste blower building	TRADE SECRET DATA ENDS]

3.10 ACI SYSTEM FOR MERCURY REDUCTION

3.10.1 Description

[TRADE SECRET DATA BEGINS

An ACI system will be provided that is designed for mercury removal. Appendix L provides details on the mercury control evaluation (SL-010393). For the ACI efficiency, the SO_3 needs to be at or less where the carbon is injected. Since Big Stone burns PRB, staying below the level will not be an issue. Also, experience has shown that with PRB fuels, halogenated powder-activated carbon (PAC) is more effective than non-halogenated PAC.

The carbon is injected prior to the SDA. Injecting before the SDA helps to oxidize some of the elemental mercury to oxidized mercury since the chlorides have not been removed yet. Injecting before the spray dryer also increases the residence time for the carbon to react with the mercury. However, the greatest amount of mercury is removed in the baghouse. The carbon uniformly accumulates on the bags in the baghouse and creates a cake with the fly ash. The flue gas gets pulled through the carbon accumulation and this is where the majority of the mercury is removed.

The GA drawing in Appendix A shows the ACI silo located directly south of the boiler building and west of the SDAs. This location reduces the length of piping needed to the injection location. The silo will be filled by trucks, which will pull up next to the silo and use their onboard blowers to unload the carbon into the silo. The truck's driver will have a control panel that connects to the operating room. Operators will send a signal alerting the truck driver to fill the silo. As trucks carry about 40,000 lbs of carbon, the silo will hold about truck loads of carbon and the plant will need about truck delivery per week. TRADE SECRET DATA ENDS]

3.10.2 Design Summary

Table 3-8 identifies the major design parameters for the Big Stone ACI system.

[TRADE SECRET DATA BEGINS

Table 3-8. ACI Design Summary

Parameter	Performance
Design injection rate	which is 5 lbs/mmacf halogenated PAC
Expected Injection rate	lbs/hr which is 2 lbs/mmacf halogenated PAC
Number of silos	
Silo size	
Silo storage quantity	
ACI electrical building	
Injection trains	
Safety features	Portable eye was station in base of silo
	Grating on top of silo, but no enclosure
Injection location	At least 60', 1 second prior to the SDA
Piping	
Level detectors	One radar detector to measure carbon level TRADE SECRET DATA ENDS]

3.11 ID FANS

3.11.1 Description

The new SCR and dry FGD equipment and the new interconnecting ductwork will add pressure drop to the Big Stone flue gas draft system. The existing ID fans do not have the capability of pulling the additional draft necessary; therefore, the fans will be removed from service and new replacement fans will be installed after the new baghouse to handle the entire flue gas path. The replacement fans would be designed to overcome the draft loss of the boiler, SCR, air heater, SDA, baghouse and ductwork/dampers. Appendix G provides details on fan design alternatives (SL-010396). Two fan arrangements and two fan technologies were evaluated:

[TRADE SECRET DATA BEGINS

- centrifugal fans with variable-frequency drive (VFD).
- centrifugal fans with VFDs or axial fans with variable-pitch blades.

Inlet dampers and variable inlet vane flow controls were not considered with the centrifugal fans due to their rapid fall-off in operating efficiency when volume flows are reduced below 85% of the normal full load flow. The results of the study concluded that OTP should install centrifugal fans with VFDs based on installation, operating and maintenance advantages. TRADE SECRET DATA ENDS]

3.11.2 Design Summary

Table 3-9 identifies the major design parameters for the Big Stone ID fans.

Table 3-9. ID Fan Design Summary

Parameter	Performance
Percent of total flow per fan	[TRADE SECRET DATA BEGINS
Number of fans	TRADE SECRET DATA ENDS]
Fan type	Centrifugal with variable frequency drives
Test block condition:	
Flow	2,052,000 acfm
Static pressure	50" w.g. (static rise for test block flow plus 10%)
Motor size	12,000 horsepower (hp)

3.12 DUCTWORK

3.12.1 Description

The ductwork system is generally categorized in two ways – hot-side and cold-side, based on the location in the flue gas route and the operating temperature to which it is subjected. In addition to discussions of standard hot- and cold-side ductwork arrangements, the study also considered the use of SCR reactor boxes in relation to those arrangements, as discussed below.