Recent Operating Results of the Five New Wet FGD Installations For Ameren Corporation

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ABSTRACT

Hitachi Power Systems America, Ltd. has recently completed the Start-Up, Performance Testing and several months of operation on the five (5) Wet Limestone Forced Oxidation Scrubbers (WFGD) installed in Missouri and Illinois for Ameren. Ameren Corporation is the parent of utility companies that serve 2.4 million electric customers and 1 million natural gas customers in a 64,000 square-mile area of Missouri and Illinois.
This paper will discuss the project backgrounds along with the design and operating performance of the advanced SO_2 reduction technology that was implemented on these five units.

The performance of these WFGDs has delivered ultralow SO_2 emissions which also demonstrates the capability to reliably deliver CO_2 capture ready clean flue gas for future carbon capture programs where single digit PPM SO_2 emissions are required. The paper will discuss the advanced design features and performance of these WFGD systems including SO_2, SO_3, PM, and mercury capture efficiencies. These installations are reliably achieving over 99% SO_2 reductions without the use of additives, internal packing/trays or other chemical additions.

With the new Utility MACT requirements expected to be finalized soon, these units will have the advantage of their excellent multi-pollutant control aspects. It will be most important to achieve lower acid gasses, mercury, and filterable PM emissions in light of the new regulations.

INTRODUCTION

Ameren as part of their continued investments in environmental improvements at their operating plants awarded in April 2006 five (5) WFGDs along with the associated wet limestone grinding systems, piping, rotating equipment, valves and instrumentation and controls to Hitachi Power Systems America, Ltd. (HPSA). The WFGDs are located at three of Ameren's coal fired power plants as shown in Figures 1, 2 and 3 which include;

- Sioux Units 1 & 2 (2 x 535 MW) West Alton, MO
- Duck Creek Unit 1 (465 MW) Canton, IL
- Coffeen Unit 1 (360 MW) & Unit 2 (590 MW) Coffeen, IL

Advanced design features were employed into the WFGDs to accommodate the wide range of inlet flue gas sulfur and chlorine concentrations and to maximize SO_2 removal efficiency. The vessels themselves, or spray towers, are made of carbon steel which was flake glass lined to allow continuous operation to chloride levels as high as 50,000 ppm. With respect to the scrubber inlet ducts they were made of Hastelloy C276 (UNS N10276).

With all five wet limestone forced oxidation scrubbers successfully coming online between May 2009 and January 2011 performance has been superior with the ability of achieving over 99% SO_2 reductions without the use of additives or internal packing/trays. The performance to date of these WFGDs has consistently delivered ultralow SO_2 emissions in addition to the removal of other pollutants. Beyond SO_2 capture, the WFGDs also effectively remove SO_3, particulate matter, and oxidized mercury, etc. The design basis for the WFGDs included SO_2 removal efficiency of 99%, SO_3 removal efficiency of 60%, mercury (Hg) removal as it pertains to oxidized mercury of 90% and particulate (PM) removal to less than 0.015 lb/MMBtu. In addition, the WFGDs have all operated to date with an availability of 100%.

Fig. 1 Sioux Units 1 & 2

Fig. 2 Duck Creek Unit 1

Fig. 3 Coffeen Units 1 & 2

WFGD DESIGN AND EQUIPMENT SELECTION

HPSA's advanced spray tower streamlined design for high efficiency and low power consumption and equipment selection was based on optimizing both the installed and overall life cycle costs. Wherever possible the duplication of equipment was maximized to simplify operations and maintenance along with stocking of spare parts. Key design criteria included an SO_2 removal efficiency of 99% while using limestone slurry with up to 95% passing through a 325 mesh screen with the potential to operate at chloride levels as high as 50,000 ppm, while producing gypsum with an oxidation level of greater than or equal to 99%.

Basic design criteria for the WFGDs with respect to incoming flue gas as specified by Ameren is presented in Table 1.

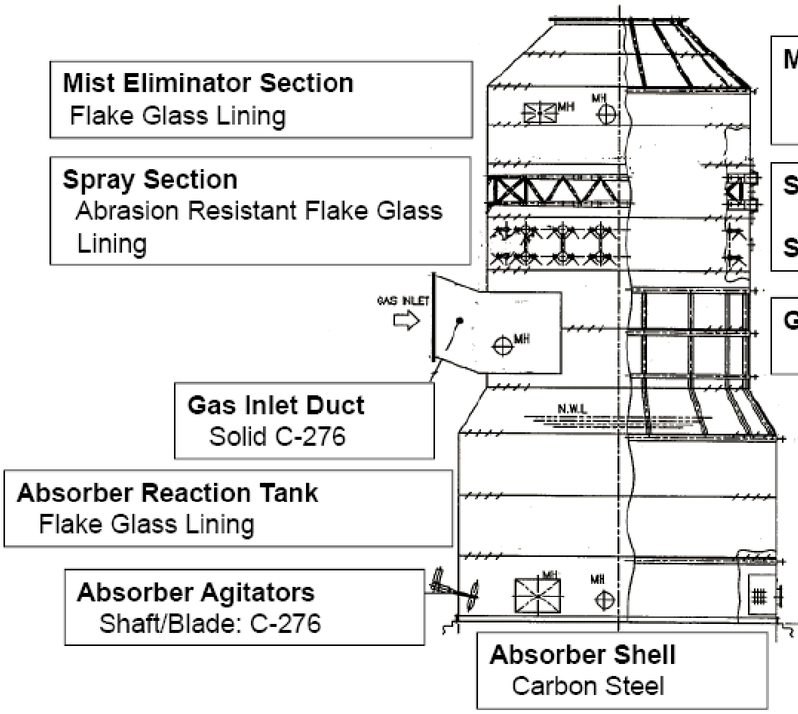
Table 1 – Basic Design Criteria

	Sioux 1 & 2	Duck Creek	Coffeen 1	Coffeen 2
Absorber MW	535	465	360	590
Coal Type	Bituminous/PRB	Bituminous	Bituminous	Bituminous
Sulfur Content (%)	2.15	3.41	3.47	3.47
Inlet SO_2 Conc (ppmd – 3% O_2)	2,048	3,325	3,304	3,304
Inlet SO_3 Conc. (ppmd – 3% O_2)	14 - 17	15 – 23	49 – 55	46 – 51
Inlet Dust (lb/10^6 Btu)	0.07	0.109	0.071	0.071
Gas Flow Rate (acfm)	1,915,000	1,485,900	1,337,200	2,214,400
Inlet Temp. (deg. F)	340	305	305	305

Process design criteria included having a gas velocity from 13 to 14 feet/second, a liquid to gas ratio (L/G) ranging from 140 to 160 gallons/10^3 ACF, a gas contact time in excess of 2.0 seconds, a liquid residence time of 6 minutes, and sufficient solids residence time in hours to assure guaranteed gypsum production.

With respect to materials of construction, which were selected for the high chloride operating condition, Figure 4 below describes both the vessel and its major components.

Fig. 4 Materials of Construction



It is worth noting that with respect to the Sioux WFGDs that Ameren Misssouri after construction of the absorbers had been initiated elected to line the inside of the vessels with Stebbins tiles versus the flake glass lining. This required a structural review of the vessels primarily at the transition cones because of the additional loading on the vessel walls caused by the tiles, which simply required the installation of additional external stiffeners. In order to minimize any differential expansion between the vessel walls and the internal tile and grout a high reflectance white paint was used externally.

With respect to absorber island equipment selection the duplication of equipment between plants was maximized to simplify overall operations and maintenance along with stocking of spare parts. Pertinent details of major support equipment are outlined below:

- All Recycle Slurry Pumps are Weir model 800TYGSL with varying motor sizes and gear boxes.
- All absorber Bleed Pumps are Weir model EEAH with a capacity of 1,600 gpm.
- All Oxidation Air Blowers are Siemens – Turblex model KA with varying motor sizes and gearboxes.
- All Oxidation Air Agitators are Philadelphia Mixing Solutions model 3850 with 75 HP motors.
- All Absorber Spray Nozzles are Spraying Systems type 4B-Hollow Cone made of silicon carbide.
- All Mist Eliminators are Munters model DV-210 vertical flow 2-stage elements.

- All Limestone Mills are Metso horizontal wet ball mills rated at 38 tph with Stock Equipment weigh belt feeders.

PERFORMANCE RELATED PROCESS DESIGN FEATURES

Incorporation of Hitachi's key process design criteria was essential in being able to guarantee an SO_2 removal efficiency of 99% while producing a high quality gypsum byproduct. As shown in Figure 5 the spray zone section and configuration of the different levels of spray headers and nozzles coupled with the quantity of slurry being recycled is critical. A typical spray header and nozzle arrangement design for an individual level is shown in Figure 6.

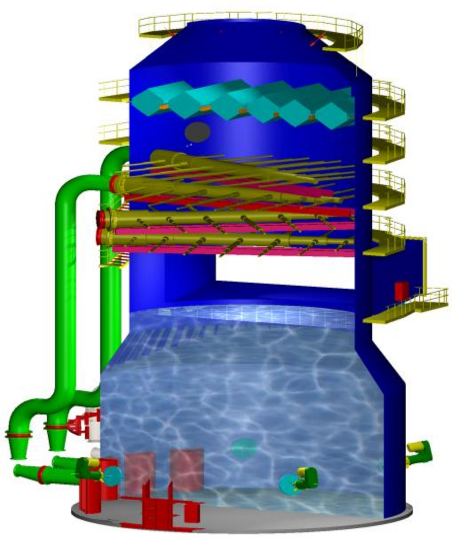


Fig. 5 Absorber Cross Section

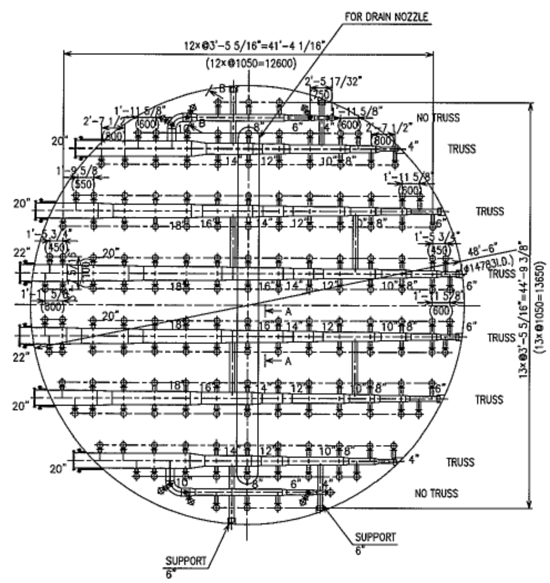


Fig. 6 Spray Header Design

The overall result of properly incorporating the key process design criteria when coupled with a high gas velocity of 13 to 14 feet/second produces the following:

- High spray flux which minimizes velocity variation
- High spray flux which maximizes gas to liquid contact
- Higher spray density near absorber walls increases spray coverage and eliminates sneakage
- Progressive flux density moves the gas away from the absorber wall toward the center

Figure 7 shows two spray header levels with nozzles trussed together with direct bonding of the SiC spray nozzles. Figure 8 displays the overlapping high density spray patterns resulting in the generation of fine droplets.

Fig. 7 Typical Spray Headers

Fig. 8 Overlapping High Density Spray Patterns

The design of the absorber reaction tank is also important when coupled with in-situ forced oxidation employing side mounted agitators and air lances. The result being a high level of solids for enhanced SO_2 removal and better dewatering coupled with sufficient residence time to ensure good gypsum crystal growth. Figure 9 shows a typical agitator and air lance arrangement which are spaced at the appropriate locations around the tank, while Figure 10 displays the dispersion of air bubbles.

Fig. 9 Agitator and Air Lance

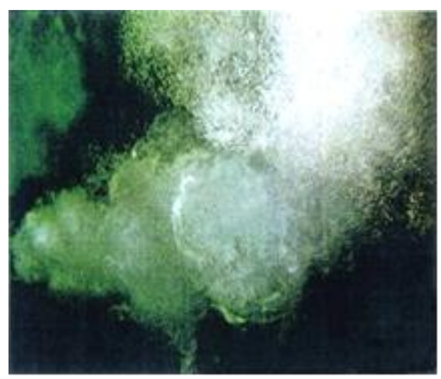
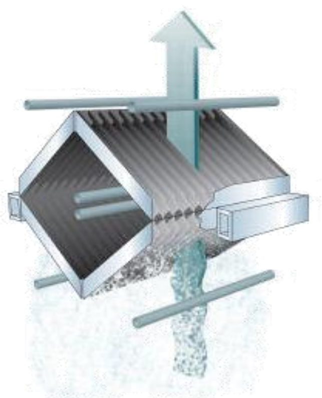


Fig. 10 Dispersion of Air Bubbles to Allow Forced Oxidation

Elimination of the maximum amount of mist which is allowed to leave the absorber is also a key feature. This was accomplished through the two stage mist eliminators installed at the top of the absorber just upstream of the outlet duct. Figure 11 displays a typical mist eliminator arrangement which results in a maximum entrained moisture carry over at the outlet of less than or equal to 0.070 grains/scf.



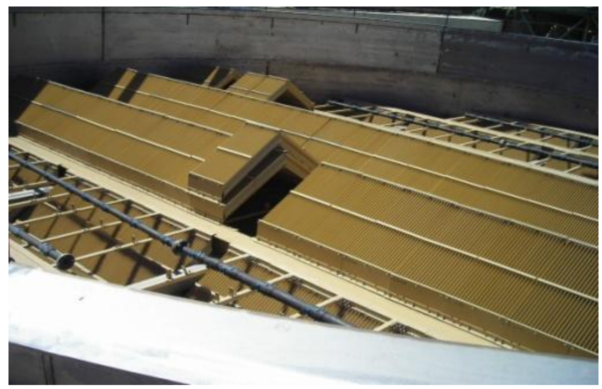


Fig. 11 Mist Eliminator Arrangement

OPERATING PERFORMANCE OF THE WFGDs

At the conclusion of the construction effort of all five (5) WFGDs, along with other modifications and improvements being made by Ameren, tie-in outages of sufficient duration were under taken and the units returned to service. Upon reaching continuous full load operation of the boilers the scrubbers were fine tuned and all in a position to initiate performance testing within four (4) weeks. Actual performance test dates for the individual units were:

- Duck Creek Unit 1 May 20, 21, 2009
- Coffeen Unit 1 February 3, 4, 5, 2010
- Coffeen Unit 2 May 11, 2010
- Sioux Unit 1 January 18, 19, 20, 2011
- Sioux Unit 2 December 16, 17, 2010

It is important to also realize that the type of coal being burned at all three Ameren plants had changed significantly from the basic criteria of primarily all bituminous coal to a large percentage of Power River Basin (PRB) coal. Specifically, the fuel blend of coal used during the tests and currently being consumed is:

- Duck Creek 70% PRB/30% Bituminous
- Coffeen 95% PRB/5% Bituminous
- Sioux 80% PRB/20% Bituminous

Results of the performance tests undertaken with respect to emissions are shown in the following tables, and appreciating the significant changes in the actual coal being burned from the design criteria, clearly indicates the ability of all five (5) WFGDs to perform at levels well in excess of the guarantee levels. Because of the identical design parameters of the units at Coffeen and Sioux their test results have been averaged.

Table 2 – Duck Creek Performance Test Results

Parameter	**Guarantee**	**Test Result**
Particulate Emissions	≤ 0.015 lb/MMBtu	0.0045 lb/MMBtu
SO_2 Removal	≥ 99% Removal	99.83% Removal
SO_2 Emissions	≤ 0.064 lb/MMBtu	0.0038 lb/MMBtu
SO_3 Removal	≥ 60% Removal	72.1% Removal
Mercury Removal	≥ 90% Removal of Oxidized Mercury	99.0% Removal

Table 3 – Coffeen Performance Test Results

Parameter	**Guarantee**	**Test Result**
Particulate Emissions	≤ 0.015 lb/MMBtu	0.0047 lb/MMBtu
SO_2 Removal	≥ 99% Removal	99.95% Removal
SO_3 Removal	≥ 60% Removal	67.45% Removal
Mercury Removal (Note)	≥ 90% Removal of Oxidized Mercury	84.35% Removal

Note: The slightly lower % removal of Oxidized Mercury is a result of the test being conducted while firing a 95% PRB/5% bituminous blend with very low speciation of Mercury into the ionic form. Consequently, one of the outlet results was below the quantitative limit. In addition, it should be noted the Hitachi guarantee is based on firing an Illinois coal that has an estimated chlorine content of 0.12%, while the tested fuel has an estimated chlorine content of less than 0.02%. This chlorine content is critical in speciating Mercury into the ionic form.

Table 4 – Sioux Performance Test Results

Parameter	**Guarantee**	**Test Result**
Particulate Emissions	≤ 0.015 lb/MMBtu	0.0062 lb/MMBtu
SO_2 Removal	≥ 99% Removal	99.65% Removal
SO_2 Emissions	≤ 0.04lb/MMBtu	0.005 lb/MMBtu
SO_3 Removal	≥ 60% Removal	72.25% Removal
Mercury Removal	≥ 90% Removal of Oxidized Mercury	98.7% Removal

In addition, the non-emission guarantees associated with a gypsum oxidation level of ≥ 99%, and the limestone consumption and power consumption levels required were all satisfactorily obtained.

CONCLUSIONS

The successful installation of all five (5) WFGDs and their ongoing continuous ability to consistently deliver ultralow SO_2 emissions in addition to the removal of other pollutants, has clearly established the ability to maximize the removal of critical pollutants from these coal fired electrical plants through the use of Hitachi's advanced spray tower wet scrubbers.

Ameren's continued investments in environmental improvements at their operating plants is a clear indication of their commitment to providing their customers with clean, reliable energy, while preserving, protecting and improving the environment.

Hitachi's WFGD experience on a worldwide basis with the completion of these five units and those currently in design and construction totals at 75 installations. Inlet SO_2 concentrations range from 500 to 4,000 ppm with absorber capacities to 1,050 MWs.