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THE SCR RETROFIT AT THE MONTOUR STEAM ELECTRIC STATION

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SCOPE

This paper discusses the design, construction, startup and successful operation of a complete Selective Catalytic Reduction (SCR) NO_X system on the Unit No. 2 Steam Generator at PPL Corporation's PPL Montour, LLC power station. The Unit 1 SCR System is presently being installed. This work was undertaken in an alliance between PPL and DB Riley, Inc. (now BBP, Inc.)

PPL Montour LLC Units No. 1 and 2 are rated at 745 MW gross and 755 MW gross maximum continuous load. Units 1 and 2 and were placed in service in 1972 and 1973 respectively. On each unit, the flue gas is discharged from one outdoor boiler, tangentially fired, supercritical, combined circulation, pulverized bituminous coal-fired, divided furnace, single reheat, positive pressure. The boiler has been retrofitted with a NO_X reduction system, comprising concentric firing, with both close-coupled and separated overfire air. It has a maximum emergency rating of 5,700,000 pounds of steam per hour at 785 MW gross, with superheater outlet conditions of 3,830 psig and 1,010°F. Reheater outlet conditions are 644 psig at 1,005°F. Steam soot blowing equipment consists of 72 water-wall deslaggers, 16 long retractable soot blowers and two air heater soot blowers.

This project was completed with the installation of the SCR system in conjunction with replacement of the Unit 2 electrostatic precipitators and new induced draft fans, for operation during the 2000 ozone season. PPL opted for early compliance with the pending NO_X emission limits. The installation of the SCR system for Unit No. 1 is scheduled for completion prior to the 2001 ozone season.

BBP, Inc.'s scope of supply includes the reactor, all associated support steel, ductwork, isolation/bypass dampers, expansion joints, access and testing provisions, platforms and stairs, as well as initial catalyst charge and complete reagent unloading, storage and injection system. PPL's scope included the erection and construction of the SCR system.

The SCR System was installed in the high dust/high temperature position (see Figure 1).

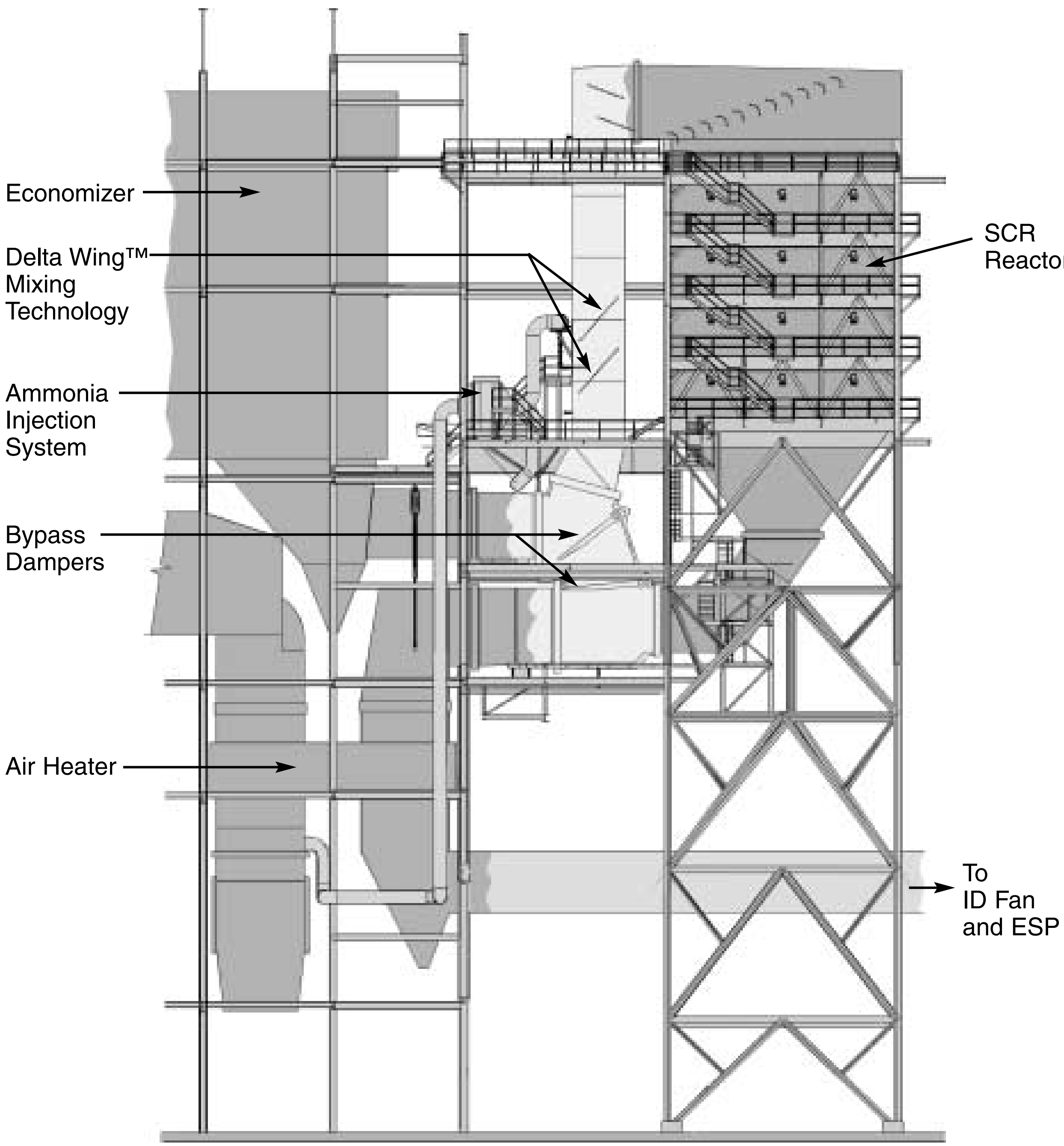

Figure 1 SCR Cross Section

Early in the design phase, BBP, Inc. constructed a scale "flow" model of the SCR installation. The scope of the model included the economizer, all ductwork from the economizer outlet connection up to the SCR, the reactor, the outlet duct, the air heater entrance, and all equipment in between. Flow model tests were performed to assure complete mixing and uniformity of all gas species, gas temperature, and uniform flow distribution. This was accomplished by strategic placement of turning vanes, Delta Wing™ mixing devices, and utilization of the ductwork configuration itself to achieve maximum performance at minimum gas pressure loss. This pressure loss was quantified by the flow model test. A second larger scale "dust" model was constructed for the purpose of examining dust distribution. The configuration from the "flow" model was incorporated into the dust model and necessary adjustments were made to insure no dust deposits or layout were present in the system. The final dust model configuration was back-checked by the flow model and the final configuration was released for design detailing.

EQUIPMENT AND SERVICES FURNISHED BY BBP, INC.

The SCR system consists of two reactors for Unit No. 2 and the ammonia storage and unloading system for Units 1 and 2. Major equipment included:

a. Reactor designed for outdoor installation in a high temperature location.

b. Process engineering and design and automated controls design.

c. Catalyst cleaning system with automatic controls.

d. Access and inspection doors.

e. Complete system of connecting ducts including transition pieces to existing equipment and ducts as well as required flow distribution devices.

f. Expansion joints.

g. Ammonia injection system, gas mixing and distribution devices using the patented Delta Wing™ technology.

h. Tie-in and bypass dampers.

i. Complete structural steel supports.

j. Complete system of platforms, walkways and stairs for operation, maintenance and testing, including provisions for catalyst removal and installation.

k. Necessary revisions to existing ducts and structures required for the installation.

l. Ammonia feed system, including unloading, storage, feed pumps, controls, and leak detection and suppression system. (Common for Units 1 and 2).

m. Initial charge of catalyst for two layers of the reactor based on 7,600 hours of operation (two OTAG seasons).

n. Start-up assistance to PPL start and test engineers.

EQUIPMENT AND SERVICES PROVIDED BY PPL

PPL provided the following equipment, services and facilities:

a. New foundations for SCR reactor and ductwork, including grounding grid connections at grade.

b. Foundations, leak containment, and leak suppression system for reagent tanks.

c. ID Booster fans to overcome guaranteed SCR and precipitator pressure drop.

d. Lighting, telephone, and public address system extensions.

e. SCR reagent control house at grade for new unloading, storage, and feed systems.

f. Air heaters and economizer outlet.

g. Thermal insulation and lagging.

h. Relocation of aboveground and underground interferences.

i. Final painting of exposed steel surfaces.

j. Fire protection.

k. Site improvements such as roadways and any new rail sidings for ammonia delivery and unloading plus associated unloading equipment enclosures.

l. Design and installation of instrument air piping.

m. Replacement of the existing ESP with a new significantly larger ESP.

n. Erection and installation.

o. DCS-based control system for SCR and auxiliaries (dampers, damper hydraulics, ammonia unloading and injection, dilution air, etc.

FUEL DATA

Fuel fired in the boiler can be any eastern bituminous coal as defined in ASTM-D-388 as Class II, medium volatile and high volatile A, B and C bituminous coal. There are no specific restrictions to any coal from any mine within the above category. Prior to the selection of the catalyst, an extensive testing program was undertaken to examine the coals most commonly used at Montour. The reported arsenic poisoning of the catalyst at two other US plants burning similar coals prompted this examination.

The SCR experience in Europe, as it relates to arsenic poisoning of catalyst, was mainly a function of (1) the firing method, usually wet bottom, and (2) the high gaseous arsenic concentrations due to ash recirculation from the ESP to the furnace. This firing method and ash recirculation caused the gaseous arsenic concentrations to build within the 'closed loop' of Furnace-SCR-ESP-Furnace. The high gaseous arsenic concentrations caused rapid catalyst deactivation.

Unlike the past experience, the PPL furnace is dry bottom with no ash recirculation. The high gaseous arsenic concentrations measured at PPL were not due to a "closed loop," but instead due to firing relatively high arsenic coals with very low active calcium oxide in the ash. This combination allowed high gaseous arsenic to exist in the flue gas that would pass over the catalyst and thereby threatened the catalyst life. The addition of limestone to the coal provided sufficient active calcium in the flyash to capture the gaseous arsenic and thereby protect the catalyst from arsenic poisoning and premature deactivation.

The Montour system examination found that several of the coals had arsenic to calcium ratios that could lead to rapid deactivation of the catalyst. Some of the coals had over 100 ppm of arsenic and less than 1% CaO. A test program was undertaken to evaluate the feasibility of injecting limestone to control arsenic poisoning. This injection of limestone was of primary concern to PPL since the Montour boilers tended to have a high slagging characteristic. The test program found the optimum limestone feed rate without causing any slagging in the boiler. Based on this study a limestone feeding system was installed to insure that life of the catalyst would be preserved.

ARRANGEMENT OF EQUIPMENT

The SCR structure is supported on a structural steel frame from extends from the level of the top of the foundations at elevation 528.5' to the main reactor support elevation at 667'. The economizer outlet plenums and air heater inlet ductwork were reused where possible. BBP, Inc. was responsible for designing of new ducts with sufficient expansion provision, and determining the proper fixed point for the replaced plenums and inlet ducts to assure uniform expansion with no additional load imposed upon the economizer casing or air heater housing.

The new SCR installation consisted of the following:

1. Two sets of reactors and associated ductwork, which are symmetrical about the boiler centerline.
2. An inlet ductwork system from the outlet flange of the existing economizer to the new SCR inlet duct, with provisions to bypass the SCR. This resulted in an independent inlet ductwork system for each reactor.
3. An outlet ductwork system from the SCR reactor to the air heater inlet, which resulted in an independent outlet ductwork system for each new reactor.
4. A bypass duct, with dampers, to permit bypassing the SCR reactor, and divert the flue gas from each inlet duct system directly into the respective outlet duct system.

The system design included a complete new duct system to connect the existing economizer outlet with the SCR inlet flange(s). A complete new outlet duct system was provided to attach outlet flange(s), and terminate in a convenient location at the air heater housing. This resulted in two SCR inlet and two SCR outlet tie-in points. New acid-resistant expansion joints and all required dampers and transition pieces connecting the reactor equipment with existing economizer outlet and air heater inlet were installed.

The installation was arranged such that there was no interference with the normal operation of the existing equipment during the field erection of the new SCR except for the necessary outage required tying into and modifying the existing ductwork. All of the structural steel required support the SCR was installed prior to the outage. The SCR was installed using module construction technique prior to the outage.

New booster fans and electrostatic precipitators were purchased and installed by PPL concurrently with the new SCR, and were installed to the west of the existing stacks. The existing electrostatic precipitators were removed from service and demolished during the SCR tie-in outage. The outage was scheduled for seven and a half weeks.

BBP, Inc. developed an arrangement for the SCR, ductwork, and support steel to satisfy its required size, site arrangement and access requirements, cost considerations, existing equipment and structures, as well as flue gas velocity and distribution requirements. This arrangement was installed while the boiler was operating, thus minimizing outage time. A significant portion of the outage time was required to cut out the old ESP and to install replacement ductwork.

DELTA WING™ MIXING TECHNOLOGY

It is quite common to have temperature or constituent concentration differences in a flow stream. A typical non-uniform flow stream would be the flue gas leaving a boiler with less than a full complement of burners in service. For instance, the temperature or oxygen concentration can be different from “side-to-side” exiting the boiler even though the gas has passed through tube bundles and been in a turbulent flow regime. This turbulent gas flow does not necessarily generate homogeneous flue gas. There is no “side-to-side” mixing.

The Delta Wing™ Mixer receives flue gas such as this boiler exit gas and makes it homogeneous. It mixes all gas characteristics: temperature, oxygen concentration, dust concentration, NO_X concentration, ammonia concentration, SO_3 concentration, etc. The mixer itself is an obstruction in the duct, usually a stationary disk or triangular plate, oriented at a slant to the flow direction. Upstream of this device is turbulent, but not necessarily homogeneous, flue gas. Immediately downstream of this device are large violent vortices. The duct may have four or five mixers over a 40-foot wide duct and the resulting vortices cover the whole cross sectional area of the duct. If the test model of the system indicates it is necessary, a second set of mixing devices can be added downstream of the first set, usually at the 90° turn just before the reactor. The result of these vortices, as they flow downstream and mix with adjacent vortices, is well-mixed homogenous gas (see Figure 2).

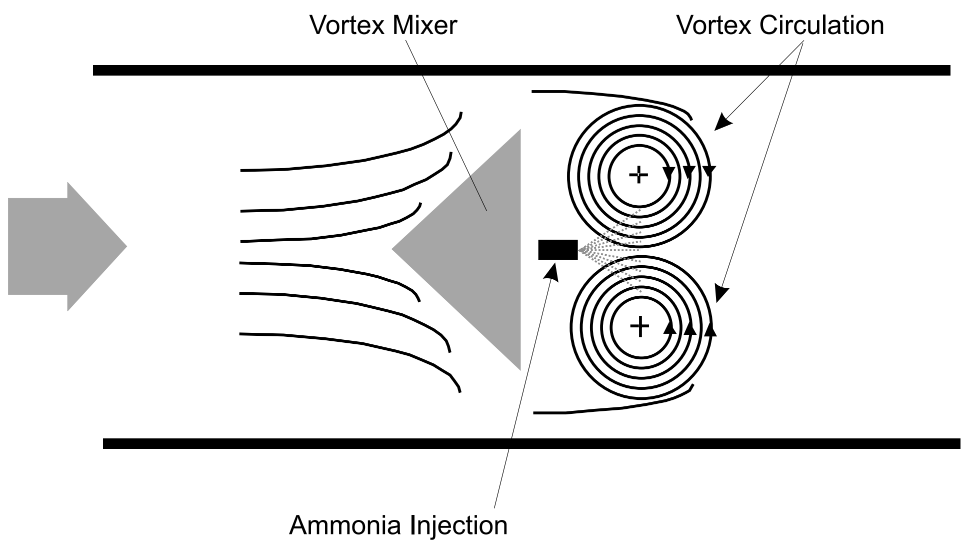

Figure 2 Diagram of Air Flow Using Delta Wing™ Mixing Technology

These vortices consistently form in relation to the mixing device size, position, and orientation in the ductwork system. Because of this, we are assured of two key factors:

(1) The vortices can be well modeled, i.e., predetermined, in a 3D model based on a scaled geometry of the ductwork system and mixing device size, position, and orientation

(2) The vortices are not dependent on gas flow quantity and therefore will consistently form over a large range of gas flows and boiler outlet conditions.

These two key factors have been proven numerous times by the scale model used in all of our projects and by the correspondence between the “modeled” and “real world” performance measurements in the actual systems. They have consistently performed well over a range of gas flows exceeding the normal turndown range of the boiler.

For SCR system applications, the vortex zone immediately downstream of the mixer is the location of the ammonia injection nozzles. The best means of assuring uniform ammonia distribution in combination with uniform NO_X distribution and temperature is to achieve a well-mixed homogeneous gas.

This condition is also achieved at reduced load conditions. Other systems, such as grid ammonia injection systems are “tuned” to perform best at full load gas flow. A typical grid system uses multiple nozzle injection points, and when tuned, each point may be required to deliver different ammonia flow quantities. As the total flue gas quantity is reduced, the gas characteristics such as temperature distribution and NO_X distribution change. The ammonia flow also changes with flue gas quantity. At part load conditions, the grid system goes “out of tune” and performs less than optimally.

Other so-called “static mixing devices” or “riffles” are applied to SCR systems and have not proven effective. By passing the gas through multiple non-parallel channels, they attempt to redirect the gas from one position on the cross section of the duct to a different position. They are not effective when compared to vortex mixing, and have limited application in very large ducts. Furthermore, they are subject to the same difficulties when faced with mixing reduced gas flows, especially the dust component.

With the vortex mixing technology, the performance is consistently optimal over the entire load range because homogeneity is achieved over the entire load range. This mixing advantage allows the Delta Wing™ system to reach NO_X reductions of greater than 95%.

BOOSTER FANS

Two booster fans were installed by PPL on each unit to overcome the additional pressure loss of the SCR system and added ductwork. A new precipitator was also installed. Precipitator and fan installation was concurrent with SCR erection. The booster fans cause the SCR to operate under negative pressure at some loads and positive pressure at other loads. The balance point between positive and negative pressures at full load is intended to remain approximately within or near the existing air heaters.

A common duct plenum in the booster fan inlet ductwork on each unit, with a damper was installed between “A” and “B” ductwork. In addition, the new precipitator inlet ductwork contained a common plenum, which will maintain flow through both SCR reactors in the event of single booster fan operation. One booster fan is capable of 80% of the combined design flow of 2,800,000 ACFM.

SCR DESIGN BASIS

The following characteristics define the design basis for the SCR:

a. Twelve month per year operation with two years between catalyst charges.

b. 2 ppm ammonia slip at 90% NO_X reduction at 7,600 hours.

c. Inlet NO_X of 0.4 lbs/MMBtu.

d. Maximum system pressure drop of 7.63 iwc with full complement of catalyst.

Reactor Casing Design

Each of the SCR reactors was designed for a maximum of four layers of catalyst. The total projected volume of catalyst is based on twelve- month operation and a two-year catalyst replacement cycle. The initial catalyst fill consisted of one half layer in the top and a full layer in the second position.

The SCR reactor casing, rectifier, inlet and outlet diffusers, etc. were externally stiffened and internally braced, and continuously seal-welded for gas- and liquid-tightness. The reactor casing was designed to support its entire own dead weight, the dead weight of the rectifier, and any ducts, equipment and access facilities attached to it and the following additional and associated loads. The most important feature of any reactor design is the ability to handle the thermal expansion from ambient conditions to more than 750°F.

Catalyst

The catalyst consists of standard modules that are arranged using a 6 x 21 layout in each reactor. Each reactor is 73' x 41'. The reactor was sized to accept either plate or honeycomb type catalyst. The catalyst blocks were assembled and installed, using carts that permit handling the catalyst with a minimum of manual lifting. The initial filling of the catalyst was done using the existing construction cranes on site.

KWH's honeycomb catalyst was selected. A total of 671 m3 of 7.1-mm pitch was used in the initial fill. The reactor's maximum catalyst capacity was designed to permit eventual twelve-month operation, with the same two-year replacement cycle, and 2 ppm ammonia slip. The catalyst has a rate of conversion of SO_2 to SO_3 of less than 1.5%. The top layer was initially filled with a half layer of and the second layer was a full layer. The third and fourth layers were left empty for future use.

The access platforms and monorail system at each catalyst elevation were designed to simplify the replacement process, permitting replacement of a complete layer of catalyst in less than five days.

Dampers

The ductwork included dampers to direct the flue gas through the SCR reactor or to bypass the SCR and return the gas back to the air heaters. Dampers were designed for zero leakage. This system is equipped with Bachmann Diverter Dampers. Each diverter assembly (two per reactor) is equipped with two flap-type blades (SRC inlet/bypass and SCR outlet). Blades measure 12 feet (hinge to tip) by 34 feet wide or 20 feet wide. Inboard assemblies are 20 feet wide, outboard assemblies are 34 feet wide. Dampers are hydraulically driven.

Ammonia Reagent System

The reagent unloading, storage, and feed system includes the capability to transfer anhydrous ammonia from trucks (two trucks at a time) as well as rail cars (one rail car at a time) to either of two 60,000-gallon ammonia storage tanks. There are pumps (one operating/one spare) to feed liquid anhydrous ammonia to the process from ammonia storage tanks, and all interconnecting piping to feed ammonia into the flue gas entering the SCR reactor. BBP, Inc. also provided an ammonia leak detection system around the storage and unloading areas. PPL provided a deluge system to minimize off-site ammonia vapor in the event of a storage tank or pipe leak.

The unloading and storage system is common to both Unit 1 and Unit 2.

Piping in the vicinity of the unloading and storage area allows for the isolation of either storage tank with the system in operation, for inspection.

SCR Soot Blowers

BBP, Inc. provided steam driver soot blowers for the projects. Each catalyst layer has its own soot blowers, with a separate sootblowing system for each reactor.

Expansion Joints

Expansion joints were provided in each inlet duct and each outlet duct to prevent undue stress on either the ducts or the SCR. BBP, Inc. was responsible for replacing expansion joints at connections to existing facilities. Expansion joints are constructed of acid-resistant fabric.

All expansion joints were completely protected with a metal "dust shield" to prevent ash abrasion of the joints and designed to prevent binding in the "hot" or "cold" position. The expansion joints are capable of withstanding temperature variations between 0°F and 850°F.

CONSTRUCTION FEATURES

Each reactor was installed in four lifts. The rectifier above each reactor was erected in one major lift, partially assembled, with smaller lifts of the perimeter trusses due to overall weight limitations. Similarly the rectifier cap was erected partially assembled, due to weight. The inlet duct pieces were also ground-assembled into larger pieces, and each erected in three lifts.

Each reactor was preassembled including the Delta Wings™, insulation, and piping and installed on the ground.

SYSTEM STARTUP

The startup of the SCR NO_X reduction system was not complicated and proceeded without major problems. Prior to the startup, an extensive training program was conducted for PPL's operating and maintenance staff. This training program was a significant factor in minimizing delays or problems during the startup phase.

Prior to bringing the SCR system on line, the boilers were brought up to full load from the outage period. The boiler was run for approximately three weeks prior to bleeding flue gas into the reactors. This period gave the PPL and BBP, Inc. startup engineers an opportunity to make all of the system checks and adjustments.

The following are some of the problems that were encountered during the startup period:

- The reactor inlet and outlet NO_X monitors required modifications to their seal air gaskets. While modifications to the monitors were being made, the SCR system was run at the ~80% reduction as a conservative approach to avoid the potential for ammonia slip. To operate the system during this period, the system was run in manual mode using a fixed relationship between ammonia flow and boiler load, with the CEMS NO_X outlet reading used as feedback for ammonia trim. Upon repair of the NO_X analyzers, the system was returned to the normal design control logic.
- Because of the low velocities and very low static pressure in the air to the damper seal air system and ammonia dilution air system, it was very difficult to calibrate and verify the seal air and dilution air flows.
- It was also found that the piping arrangement caused flow stratification entering the dilution air heat exchangers, limiting their heat transfer effectiveness. It was found that temperature set points could be achieved only with both the primary and backup heat exchangers operating. Flow distribution plates have corrected this condition.
- The ammonia rail car unloading compressors are somewhat oversized, and draw vapors out of the tanks at a rate that exceeds the excess flow valve capacity. They must be operated with a vapor balance valve slightly open, to permit recycling some vapor from the outlet to inlet of the compressor.
- The damper hydraulic system has had leaks. The second unit will have welded joints, to the extent possible. We are still looking for a permanent solution to the leaks on the first unit.

CONCLUSIONS

Unit No. 2 has just completed its first ozone season of operations. During this first year of operations, no operating problems developed. Construction on Unit No.1 is proceeding and will be on line prior to the next ozone season.

The application of the Delta Wing™ technology was demonstrated during the startup and operations during the first season. Once the SCR system went into operation, the system was never taken out of service to make adjustments. The 90% NO_X reduction was achieved with the initial settings from the flow model test.

The successful execution of this contract in a technical alliance between BBP, Inc. and PPL for the design and procurement of the SCR system, many components of which were configured for this project in a "first-of-a-kind" manner.

The successful construction and start-up of the SCR system from initial start-up to the end of the first OTAG season avoided any forced outages for repairs or adjustments. This statement includes not only the SCR system, but all other systems as well. It is a most significant accomplishment on the part of the PPL Design, Construction, and Commissioning Team that the new ESP's, the new ID Fans, the new control system, etc. were all put into service so successfully. This accomplishment has the very high value of both reliable power generation and full environmental compliance.

Performance at the required levels has been achieved including 90% NO_X reduction from an inlet of 0.45 lbs/10^6 Btu. The SCR System pressure drop was less than projected for the initial catalyst fill, and the ammonia slip as monitored by the ammonia in the ash shows no signs of exceeding the design value or increasing with time. The following is a summary of the performance test results:

Test Condition	Guaranteed Value	Measured Value
NO_X removal efficiency	90%	91.2%
NH_3 slip	2 ppmdv (EOL)	< 1
Pressure loss	7.63 iwc	5.92 iwc (calculated)

The catalyst was protected from arsenic poisoning and premature deactivation by a limestone addition system while maintaining the boiler operation free of slagging, fouling, or other operability concerns.