SESSION 3B

ESP USER EXPERIENCE AND FIELD STUDIES

REFURBISHMENT OF BALDWIN UNITS #1 AND #2 ELECTROSTATIC PRECIPITATORS

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Abstract

The two Joy/Western weighted-wire electrostatic precipitators for Baldwin Power Station, Units #1 and 2, experienced extensive corrosion, concentrated at the top of the units and on the exterior walls, jeopardizing their structural integrity. Either major rebuild/upgrade (refurbishment) or replacement was required. Refurbishment was the chosen option and Research-Cottrell was awarded the job, partially due to their modular construction approach. The work on Unit 1 was completed during a 16 week outage in the Fall of 1992 and Unit 2 will be completed within a 10 week outage in the Spring of 1996. This paper addresses the refurbishment/replacement decision, bid evaluation, construction activities, and performance results, if available.

Introduction

The Baldwin Power Station is located thirty-five miles southeast of St. Louis, Missouri and is Illinois Power's largest generating station. The station consists of three 585 MW units. Units 1 and 2 have Babcock and Wilcox balanced draft, cyclone-fired, universal pressure boilers with Westinghouse tandem-compound, quadruple-exhaust, reheat turbines and generators. Joy/Western weighted wire electrostatic precipitators were supplied as original equipment to treat the flue gas. The station is a "mine mouth" plant burning Southern Illinois bituminous coal having a heating value of 10,800 BTU/lb, 13% moisture, 10% ash, and 2.9% sulfur. All three units are generally base loaded but have seen more minimum load operation since the full-power licensing of Illinois Power's Clinton Nuclear Station. Baldwin Units 1 and 2 were declared commercial in May 1970 and March 1973, respectively.

Electrostatic Precipitators (ESPs)

Both Units 1 and 2 original electrostatic precipitators were Joy/Western weighted wire ESPs with nine inch (9") plate spacing. The ESPs were six chambers wide with 36 gas passes per chamber. Both had a plate height of 30 feet with a treatment length of 24 feet, yielding an effective collection area of 311,040 square feet. The design SCA was 179.4 ft2/1000 cfm based on the design flow of 1.73 million cfm, although the actual flow has always been greater.

The ESPs were four fields deep with eight wires per field, making the total number of wires 6,912 for each unit. The ESPs were powered by 12 General Electric PCB fluid filled transformer-rectifier sets. Voltage controls were Joy/Western and rapper controls were AVC. Collector plates and wires were cleaned with vibrators, 144 total for the plates and 48 for the wires. The ESPs operate at an inlet temperature of 320°F. Regulatory limits for the units are 0.20 lb/mmBTU particulate emissions rate and 30% opacity.

The condition of the Baldwin Unit 1 and 2 ESPs was such that they needed extensive maintenance and would not last for the life of the plant. Even though they controlled opacity and particulate emissions within compliance limits, corrosion, concentrated at the top of the units and on the exterior walls, had jeopardized their structural integrity. Another problem was gas flow, and consequently velocities, through the precipitators were considerably higher than design, resulting in lower collection efficiencies than originally expected. Also, flow distribution had been a known problem since initial testing. Further, performance degradation had resulted from bowed collector plates causing the failure of discharge electrodes. In most instances, these failures required the de-energization of fields, reducing efficiency and reliability.

Refurbish Versus Replace Decision

Cost and outage time requirements were the major factors in the decision process. The costs of the two options clearly supported refurbishment. Replacement was estimated to cost as much as three times that of refurbishment because replacement required new ductwork, new foundations and support steel, new ash removal system, and demolition of the old precipitators.

Conversely, outage time requirements supported replacement. The new ESPs could be erected in an unused area and would require only a short tie-in outage. However, Illinois Power was satisfied that refurbishment could be completed during a 10 week outage, the time required for a turbine overhaul. A 16 week outage scheduled for cyclone replacement in the Fall of 1992 provided an ideal opportunity for the refurbishment of Unit 1 precipitator. Lessons to be gleaned from the 16 week outage would provide the assurance to Illinois Power that refurbishment of Unit 2 could be completed without a 10 week turbine overhaul scheduled for the Spring of 1996.

Refurbish Versus Replace Decision (Continued)

The advantages of replacement, which including the somewhat intangible benefits of Illinois Power's strategic goal of Environmental Leadership, could not offset the significant cost advantage of refurbishment. With cost control in mind, and armed with the belief that a refurbished precipitator would provide and exceed the ash removal efficiency required, the decision to refurbish was an obvious choice.

Refurbishment Specifications

The major items in the specifications included the following:

1. Repair/replace all areas effected by corrosion, including, at a minimum, structural members, exterior wall and roof casings, and outlet ducts.

2. Replace insulation and lagging to prevent cold spots and corrosion due to excessive heat transfer.

3. Replace collecting plates with improved design to restore clearances and limit the potential for bowing.

4. Replace wires, likely to be damaged during removal. Favorable consideration to be given to the installation of a rigid discharge electrode system and wide plate spacing instead of the existing weighted wire system.

5. Modify the inlet ducts to improve flow distribution. Velocity testing and a model study will be required to determine appropriate modifications.

6. Replace vibrators with rappers to improve collector plate and discharge electrode cleaning.

7. Install new rapper controls to provide greater flexibility in cleaning optimization and to limit flyash re-entrainment.

8. Install new digital automatic voltage controls to control sparking and to maintain higher average power levels.

9. Replace transformer-rectifier sets and main power transformers to eliminate the risks associated with PCB equipment. Larger T-R sets will be considered to supply additional power to the voltage system.

10. Install slide bearings under the precipitator to prevent potential distortion of internal members.

11. Reinforce casing and hoppers as required, to conform with NFPA standards of a design internal pressure of +/- 35 inches W.C.

Refurbishment Specifications (Continued)

12. Guarantees:

    - 0.15 lb/mmBTU maximum particulate emissions rate
    - 30% maximum opacity
    - Gas velocity distribution measured at the middle of the first mechanical field will be such that at least 85% of the velocity measurements will be less than or equal to 115% of the average velocity, and 99% will be less than or equal to 140% of the average velocity.

13. Pricing was requested for both 10 week and 16 week completion schedules.

Bid Evaluation

Bids were solicited from 11 precipitator contractors on December 18, 1991, with the outage starting August 28, 1992. Return of the bids were required by January 30, 1992. Two contractors declined to submit bids and two others combined to submit a single bid. Six of the eight bids received included pricing for a 10 week completion schedule which strengthened our confidence in being able to complete the refurbishment during a 10 week outage. To take advantage of reduced pricing, additional time was allowed for the Unit 1 refurbishment, since it was available due to the scheduled cyclone burner modifications. Unit 2 will not have the luxury of this additional time.

Only three of the contractors were willing to provide "all" the required guarantees, Research-Cottrell being one of these. This fact, in addition to cost, immediately reduced the number of bidders given further consideration. The one item which differentiated Research-Cottrell's bid from all the others was their modular construction approach.

Illinois Power's Perspective

The specification allowed for reuse of existing internal structural framing with the exception of structural members which were corroded and required repair or replacement. The sections of the structural members visible between the top of the collector plates and the hot roof had all experienced some degree of corrosion and would most likely require replacement. Due to limited access, the condition of most of the structural members below the tops of the collector plates could not be assessed without removal of the plates. Therefore, the condition of the structural members would not be known until after significant demolition had occurred. Concerns included the possibility of extending the outage if significant replacement of structural members was required and the successful bidder had not adequately planned for such an occurrence, the potential for disputes between Illinois Power and the contractor regarding the extent of replacement, and the cost, since this would have been time and material work and an accurate estimate could not be provided prior to the outage.

Illinois Power's Perspective (Continued)

Research-Cottrell's modular approach eliminated all these concerns because it inherently replaced all of the internal structural members. Cost savings are also attributed to this approach. Some of the modules would be built prior to the outage using a straight 40-hour work week for the first four weeks, followed by a second shift thereafter. The modular approach eliminated the need to determine what internal members could be saved which would have surely slowed the demolition process. It also served to make slide bearing installation much easier, with the top 4' of the existing hoppers to be replaced for this reason.

Based on cost and their modular construction approach, Research-Cottrell was awarded the contract on March 12, 1992.

Research-Cottrell's Perspective

Items 1, 10 and 11 from the Refurbishment Specification requirements above, prompted Research-Cottrell to offer a new precipitator on the existing support structures and of very similar configuration to that existing. The precipitator would, however, be designed such that it could be erected in modular sections beforehand and then moved to their final resting position during the outage and following demolition of the existing Joy units. This was so that the work could be accomplished within the allotted schedule.

The modular precipitator is somewhat more expensive than a conventional "stick built" but in this instance it did offer to mitigate numerous concerns not the least of which was short outage. The cost differential was less than 6% based on Research-Cottrell's in-house analysis.

The concerns mitigated were:

1. "Repair/replace all areas affected by corrosion". It was impossible to identify these areas before the outage or to adequately plan for accommodate extensive repairs within the outage window. In the proposal stage costing this unknown could not be done so as to be equitable to both parties.

2. "Slide bearings to be installed to prevent distortion". The existing Joy design had no bearings. The precipitators sat on a skirt which mated with the support structure through metal to metal contact. Research-Cottrell's experience with these designs caused it to question the condition of the beams and whether they could be back fitted with bearings. In previous such repairs these beams need to be replaced. As with the aforementioned item, how does a contractor plan and accommodate beam procurement and replacement within the context of such a short outage?

   In a modular concept these components are replaced and are not the issue.

Research-Cottrell's Perspective

3. "Reinforce casing and hoppers to meet a design of plus or minus 35 inches water column". Referring to item 1 above, how can a design to accommodate this requirement be formulated when the condition and integrity of the casing which is to be reused is unknown?

The modular design was clearly the approach to use to satisfy all the project requirements from Research-Cottrell's perspective. Obviously Illinois Power agreed and honored Research-Cottrell with the award of the contract.

Modular Design

Once Research-Cottrell settled on the modular design in the bid stage of this project, Engineering was mobilized and produced the required design.

The design required that the structural casing and all of the precipitator internals could be assembled and constructed on a temporary foundation and support structure, then at the time of outage, the Modules would be installed on the permanent support and require minimal connection time. The specific constraints of the site, the location and geometry of the permanent supports, the selection of lift crane, and the size of the precipitator were the factors which effected the size and weight of an individual module.

Precipitator design details were developed which facilitated the erection process and also provided for complete internal supports for the collecting electrodes and discharge electrodes. The modules were built without the hoppers in order to allow maximum access by the field crews, and saved weight for installation considerations. The hoppers were attached from below after module installation.

Since the modules were built with the internals installed, a special lifting rig was designed which eliminated distortion forces associated with heavy lifts from effecting the integrity of the completed structural casing.

Construction

Research-Cottrell selected the modular construction technique to assure that the refurbishment of the Baldwin Station Unit 2 precipitator will be completed during the scheduled ten week outage. The following sequence outlines the plan of construction to be utilized for both the Unit 1 sixteen week outage and the Unit 2 ten week outage.

1. Temporary foundations will be installed north and west of the existing chimney for supporting the precipitator pre-assembly support grids.

2. The support girds will be erected, leveled and squared. The steel support grids will be approximately six feet high and designed to permit the pre-assembly of twelve precipitator modules.

3. The precipitator modules will be assembled, plumed, leveled and squared prior to completing the required structural welding.

4. After each modular casing is completed, the upper hopper sections and lower steadying frame will be installed.

5. The fully shop fabricated collecting plates will be installed, plumbed and spaced prior to securing their upper end pads to the plate anvil beams.

6. At this time, the upper high tension frames with the attached Dura-Trodes™ will be installed. The support frame is aligned while resting on dunnage blocks supported by the collecting plates.

7. After initial alignment of the high tension frames the hot roof panel will be positioned and welded in place. All equipment that will be housed within the penthouse will be placed on the hot roof.

8. The penthouse side and end walls and roof support columns can now be erected. The installation of the penthouse roof can now be completed.

9. The installation of the rappers and other miscellaneous equipment may proceed until the completed module is hoisted to its final location atop the modified support structure.

10. Each completed module will be erected starting from the center partition frame and working outward toward the north and south side frames. As each module is positioned on the pre-set slide plates it will be leveled and squared to mate with adjacent modules. After this final positioning is completed the modules will be permanently connected via bolting and welding to form a complete six chamber, two field precipitator.

<u>Construction</u> **(Continued)**

11. As each chamber is completed, the roof mounted electrical components will be tied into the new control panels located in the control house. The new controls will have been installed in the control house during the outage phase of the project.

12. While the low voltage wiring is being completed on the penthouse roof the final alignment and internal inspection of the precipitator will be completed. As each module has been inspected and approved, it will be locked and tagged to indicate that it is complete.

13. While the precipitator modules are being completed the outlet nozzles and ductwork will be installed. All associated access will be included with each component of the project.

14. Much of the insulation can be installed prior to erecting the precipitator modules. This will reduce the effort required by the insulation contractor between the erection of the modules and the end of the outage.

The refurbished ESP configuration was 2 fields in the direction of gas flow or a total of approximately 28 feet deep by six chambers across gas flow or a total of approximately 165 feet wide located on the boiler and stack centerline. Each of the twelve modules constructed comprised an erected weight of approximately 60 tons.

The lifting equipment on the job was sized to support erecting the modules in this fashion and to maximize the size of the demolished pieces. Lifting equipment consisted of one (1) Manitowac 4100 Series 3 ringer and one (1) Manitowac 4000 series crane. The logistics of the site dictated that the ringer would be located so as to set 6 of the modules, located on one of the two support tables working from the ESP centerline to the south. The crane was then broken down, relocated, and used to erect the six modules, located on the second support table to the north.

The new ESP modules were assembled on 2 temporary support steel tables, each table supporting 6 modules. One table was located north of the Unit 1 stack and the second table was located west of the Unit 1 stack.

The tables had dimensions of 84'-3"L x 31'-6"W x 6'-0"H. New caisson piles were installed to support the tables for the new modules.

One of the items that influenced Research-Cottrell's decisions to select a modular construction technique was the fact that the top of the existing precipitator support steel was approximately 70'-0" above grade. A special lifting frame was fabricated to distribute the loads evenly when lifting the modules. Once a module was disconnected from the support table, it took less than 45 minutes to have the new module sitting on top of the existing precipitator support steel.

Construction (Continued)

In addition to the large cranes, ESP pre-assembly and erection work was supported by one (1) 40-ton rough terrain crane, one (1) 25-ton rough terrain crane, and two (2) 60-foot manlifts. The main advantages to the modular approach were as follows:

1. access to virtually all sides of the modules yielded obvious advantage

2. proximity to laydown area minimized handling and double-handling of shop-fabricated casing components, and

3. construction "at grade" was significantly easier than had it been in place.

Pre-outage work was begun working a single-shift, 40-hour week. Four weeks later, a 40-hour per week night shift was added. The two-shift, 40 hour week was continued through the start of the outage, with a peak of 15 boilermakers on the day shift and seven on the night shift. At the start of the outage, approximately 80% of the module pre-assembly was complete. Six of the modules were worked essentially through completion, and the crew then rotated to the next group of six.

The outage began on August 28, 1992, with a two shift operation through completion. Each shift worked five 10-hour days plus an eight-hour shift on Saturdays. Although manpower levels varied significantly during the outage, the average was approximately 35 men (including 10 electricians) on the day shift and approximately 15 men at night. Peak manpower was approximately 100 men over the two-shift operation.

As stated earlier, an extensive amount of additional work was undertaken during the 16 week outage schedule. After completion of the demolition of the existing precipitator, it was determined that six of the original hoppers would have to be replaced. These hoppers were damaged by fire many years earlier. Research-Cottrell was able to design the hoppers, procure material and install the replacement hoppers within the remaining timeframe. As per Illinois Power's requirements, Research-Cottrell was able to provide the Unit 1 gas flow path date of December 18, 1992.

Precipitator Configuration Change

	Old	New
Plate Spacing (inches)	9	16
Effective Collection Area (ft2)	311,040	181,682
Discharge Electrodes	Weighted wire (6,912 total)	Duratrodes (1,680 total)
Seal Air System	No	Yes
High Voltage Enclosures	Insulator Compartments	Penthouse
Controls	Joy/Western (Analog)	Forry (Digital)
T/R Sets	General Electric PCB fluid filled 78.5 KVA/1,100 MA 45 KV average	NWL Silicone filled 67.5 KVA/750 MA 105 KV peak
Plate and Wire Cleaning	Vibrators	Rappers
Duct Configuration @ Outlet	Open	Nozzles

Start-up/Problems

The unit was returned to service at 11:53 a.m. on December 20, 1992. Once the unit had achieved an appreciable load, opacity readings were found to indicate a performance level below that expected. Consequently, Research-Cottrell launched into a diagnostics program which was later joined by Illinois Power.

This program has included the following tests and observations:

- outlet emissions testing
- efficiency testing
- in-site resistivity measurements
- laboratory resistivity analysis
- monitoring precipitator operating power levels
- rapping cycle adjustments and tests
- visual inspections
- controls function investigation
- particle size distribution study
- re-performing the precipitator model study

Although numerous tests and observations have been made of the units operation, none have conclusively defined either the true nature of the problem or a solution. For example, in situ resistivity measurements with a mechanical collected sample indicate a resistivity range of 10E13 ohm-cm. A point to plane probe cannot or does not precipitate enough material for measurement until the samples are taken on the hot side of the air heater. At this point the measured resistivity is in the area of 10E7 ohm-cm. Other tests have developed similar conflicting data which is still in the process of analysis.

Some observations have, however, lead to significant progress. For example, arcing was noted to be occurring in the vicinity of the support insulator gaskets. Replacement of this potentially power input limiting obstruction has been effected.

Of all the tests and observations to-date, the singular most significant has been the finding that flow distribution is still significantly off the mark. An appreciable amount of cross flow exists in the precipitator hoppers and contributes to significant deterioration in performance. Although the initial modelling was not performed by Research-Cottrell, the re-performing of the tests were.

Recommended modifications to the distribution devices is to be implemented in early April. These should lead to the units meeting expected performance.

Lessons Learned

The decision to refurbish the precipitators using modular construction to meet the outage constraints set by Illinois Power was absolutely the correct one. Once demolition commenced, it became obvious that had the alternative choice been made, the schedule would have been in shambles. Even as it is, several hoppers did require total replacement but at least this was done within the time constraints available for this outage. This surely would not have been the case with the alternative choice. Research-Cottrell's insight and familiarity with work of this nature made realizing this project schedule possible.

In addition to the above, the project could have saved additional time had we:

- examined hoppers more closely using blastcleaning to facilitate inspection in advance of the outage
- realized that demolition could be expedited by dismantling larger sections, although this would have implications on the crane size, crews, etc.
- installed greater amounts of insulation, lagging and access on the ground than was done
- authorized additional non-operation impeding pre-outage work

Nevertheless, these lessons learned will be applied to the subsequent unit. That is not to say that Unit #1 has not also been a total success as regards to the demonstrated use of the modular technique and maintaining of the outage schedule.