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CONDITION ASSESSMENT PROGRAMS FOR BOILER AND PIPING COMPONENTS AT THE BIG CAJUN II POWER STATION

by

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ABSTRACT

This paper presents an overview of the comprehensive condition assessment programs conducted on the major boiler and piping components of two units at the Big Cajun II power station of Cajun Electric Power Cooperative.

These programs have been performed during each major outage scheduled for the units over a five-year period.

In the paper, attention is focused on significant findings and their associated resolutions. These problem areas include high temperature header and piping components.

A summary, with tables, of the pertinent results in the form of observations, findings, conclusions, with remedial actions, is presented. The recommendations include items for replacement, retrofit, repair, monitoring, and study.

INTRODUCTION

During the past five years, DB Riley has conducted condition assessment programs on the boiler island components of Units No. 1 and 2 at Cajun Electric's Big Cajun II power station in New Roads, Louisiana. We formalized and instituted these programs following the discovery of serious cracking in a radiant superheater outlet header of the Unit No. 1 boiler in September 1992.

During each scheduled annual maintenance outage, an assessment program consisting of review, inspection, nondestructive testing, metallurgical evaluation, and detailed reporting has been performed. These tasks were applied to all the regions, components, and equipment of the boiler island. More specific attention was given to the critical drum, header, and tubing components of the boiler, and to the piping components and supports of the high energy steam and feedwater lines.

Currently, Cajun has increased the intervals between these outages from twelve to eighteen months. This practice has become prevalent in the industry, with the length of time between scheduled outages increased from twelve months to as long as thirty-six months.

DB Riley initiated the full condition assessment programs on the boiler No. 1 components in the spring of 1993. The assessment of the steam piping also began at this time. In the fall of 1995, a program was initiated to evaluate the feedwater piping components at the boiler No. 1 inlet due to industry concerns with thinning caused by flow accelerated corrosion.

BACKGROUND

Cajun Electric Power Cooperative's Big Cajun II, Units 1 and 2 are DB Riley TURBO® Furnace units (580 MW and 575 MW, net output respectively), which burn low-sulfur western coal. Each unit was designed to operate at 2620 psig, 1005°/1005°F, with a steam flow capacity of 4.3 million lbs/hour. See the Figure 1 side elevation drawing of the boilers. The units began commercial operation in 1980-81. Since then, Unit 1 has logged approximately 120,000 hours of operation, with over 220 starts. Both boiler units were originally designed to be base loaded. As with many such designed boilers, however, the units are subjected to typical daily load cycling from 35 to 100 percent of full load capacity.

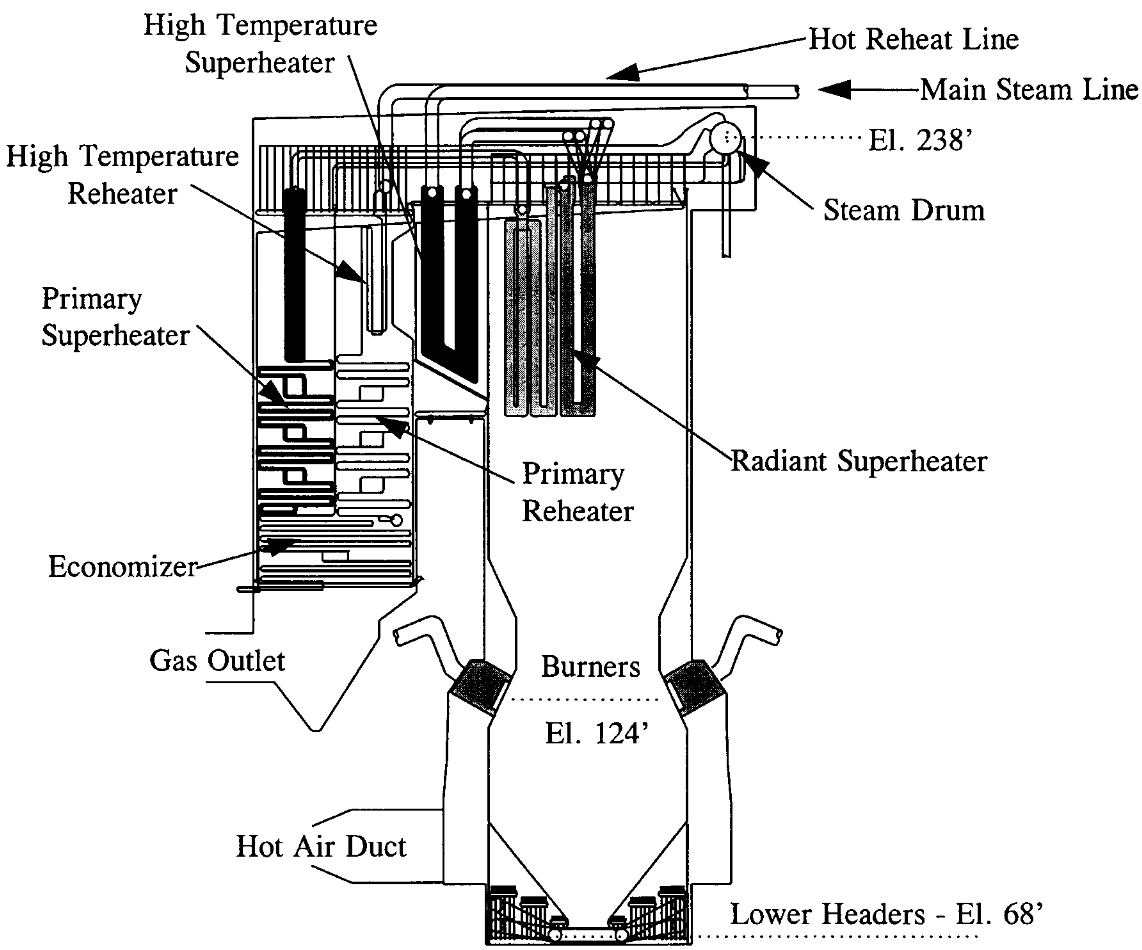

Figure 1 Side elevation of Big Cajun II, Units No. 1 and 2

During a forced outage of the Unit 1 boiler in September of 1992, extensive internal borehole and ligament cracking was discovered in one of the twin radiant superheater outlet headers. Based on the results of a comprehensive engineering evaluation of the cracked header, the unit was returned to service with derated and base loaded operating conditions until the headers could be replaced. The headers were replaced in April of 1993. A complete description of these items, relative to the cracked header, is presented in the Reference (1), (2) and (3) documents.

The original cracking in the Unit No. 1 header bore holes and ligament fields was attributed to the combined effects of creep and fatigue. Figure 2 shows the I.D. cracking. This damage had mostly occurred in the early years of operation, due to recorded over temperature conditions and many cold start-ups due to an excessive number of boiler trip events.

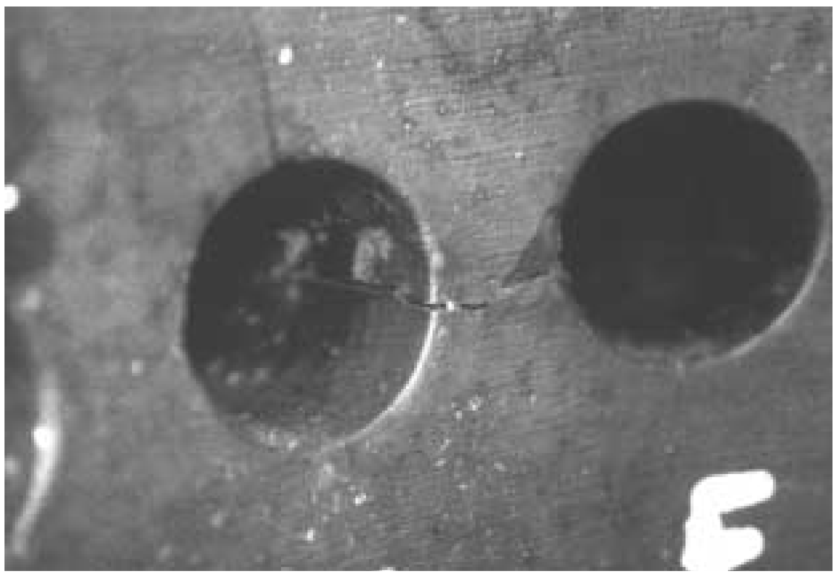

Figure 2 Unit No. 1 radiant superheater outlet header ligament cracking

During a short outage in December of 1992, the radiant superheater outlet headers on the Unit No. 2 boiler were examined. No evidence of component cracking was found.

Records for the first few years of boiler operation have been reviewed and reveal that during the first two years of operation, Units 1 and 2 experienced severe steam temperature control problems. Outlet steam temperatures ran as much as 200°F above design. The installation of additional steam attemperation, along with control system modifications, improved temperature control considerably. Main and reheat steam temperatures could be operated at design, while radiant superheater outlet steam temperatures continued to run approximately 100°F above design.

CONDITION ASSESSMENT PROGRAMS

DB Riley initiated condition assessment programs for the Units No. 1 and 2 boiler and piping components in the spring of 1993. Since then, three full programs have been completed for Unit No. 1 and four full programs conducted for Unit No. 2. For each program we performed the following condition assessment tasks for the boiler and piping components.

- Submit Pre-inspection Plan
  - Review of Records
  - Visual Inspections
    - Pressure Parts
    - Boiler Setting
    - Air and Flue Gas Systems
    - Fuel Systems
    - Piping Support Systems
  - Outside Diameter Measurements
  - Internal Video Inspections
    - Boiler Headers and Piping
    - Spray Station Assemblies
  - Metallurgical Examinations
    - Field Replication
    - Tube Samples
  - Non-destructive Testing
    - Ultrasonic Thickness Survey
    - Ultrasonic Shear Wave Testing
    - Magnetic Particle Testing
  - Component Condition Assessments
  - Final Reporting

For each program a complete visual inspection was performed. In addition, a video inspection, non-destructive testing, and metallographic testing was performed on critical boiler and piping components. At subsequent outages, the testing tasks would be expanded to cover the remaining components with typical problem or suspect areas being retested.

The hot reheat piping for both units was originally fabricated from rolled and welded plate stock. Therefore, portions of the longitudinal welds on these piping lines were tested during each outage.

Reporting is an ongoing process during a condition assessment program. Daily reporting by the DB Riley team leader to the designated Cajun interface person has helped to initiate any immediate or short term repairs or replacements. At the conclusion of the program, a close-out meeting is held to discuss the major findings and conclusions to effect longer term retrofit and monitoring items. Subsequent to the inspection and completion of the analysis, DB Riley issues a detailed, comprehensive final report, including the metallurgical analysis results. In the reports, recommendations are prioritized and categorized as "immediate," "near term," and "long term."

The recommendations from a typical program will include items from every area and component of the boiler and piping. They will highlight regions of tube thinning, over temperature exposure or other evidence of distress. There are many maintenance items, which involve minor repair and/or a monitoring program.

A summary of the more significant pressure part problem items from the condition assessment programs is presented in Table 1.

Typical problem areas identified for the other boiler and piping components are listed as follows:

- Excess flyash found throughout the boiler and flue gas regions
- Leaks in penthouse roof causing corrosion of components and structural members
- Damaged and missing air heater steam coil modules
- Oily deposits found in the forced draft fans
- Required sootblower maintenance and operational review
- Boiler casing, lagging and insulation repairs and maintenance
- Required furnace ash hopper repairs
- Air duct, gas duct, and expansion joint maintenance and repairs
- Burner parts maintenance, repair and replacement
- Restoration of support members, shields and baffles for primary reheater pendants
- Inspection and maintenance of header and piping support hanger rods
- Repair of tube seals at penthouse floor and furnace/backpass roof interfaces
- Monitoring of tube bowing and misalignment in economizer, primary superheater and high temperature reheater
- Repair of broken and distorted buckstay parts
- Minor repairs and maintenance of steam drum internal components, including vortex breaker welds at downcomers

Two major problem areas which were identified during the course of the programs involved components of the radiant superheater crossover piping systems and hot reheat piping lines. They are described more fully as follows.

RADIANT SUPERHEATER CROSSOVER SYSTEM

As noted earlier, the first serious problems, internal cracking in a radiant superheater outlet header, were found in the fall of 1992. The two outlet headers on the Unit No. 1 boiler were replaced in the spring of 1993.

During the spring 1993 condition assessment program on the Unit No. 1 boiler, additional problems were found in the radiant superheater crossover piping components. These included visible crack indications in the existing weld prep regions of the four crossover piping lines at the new radiant superheater outlet header nozzles. In addition, radial crack indications were found in the internal bore holes of the four pipes at threaded locations for radiographic plugs. Figure 3 depicts a plan view of the crossover system, and Figure 4 shows the cracking in a pipe weld.

Cracking was also identified in the circumferential welds in elbows between the outlet header nozzles and the downstream attemperators. Cracking was repaired in all of the aforementioned locations. Minor crack indications were also found in the attemperator

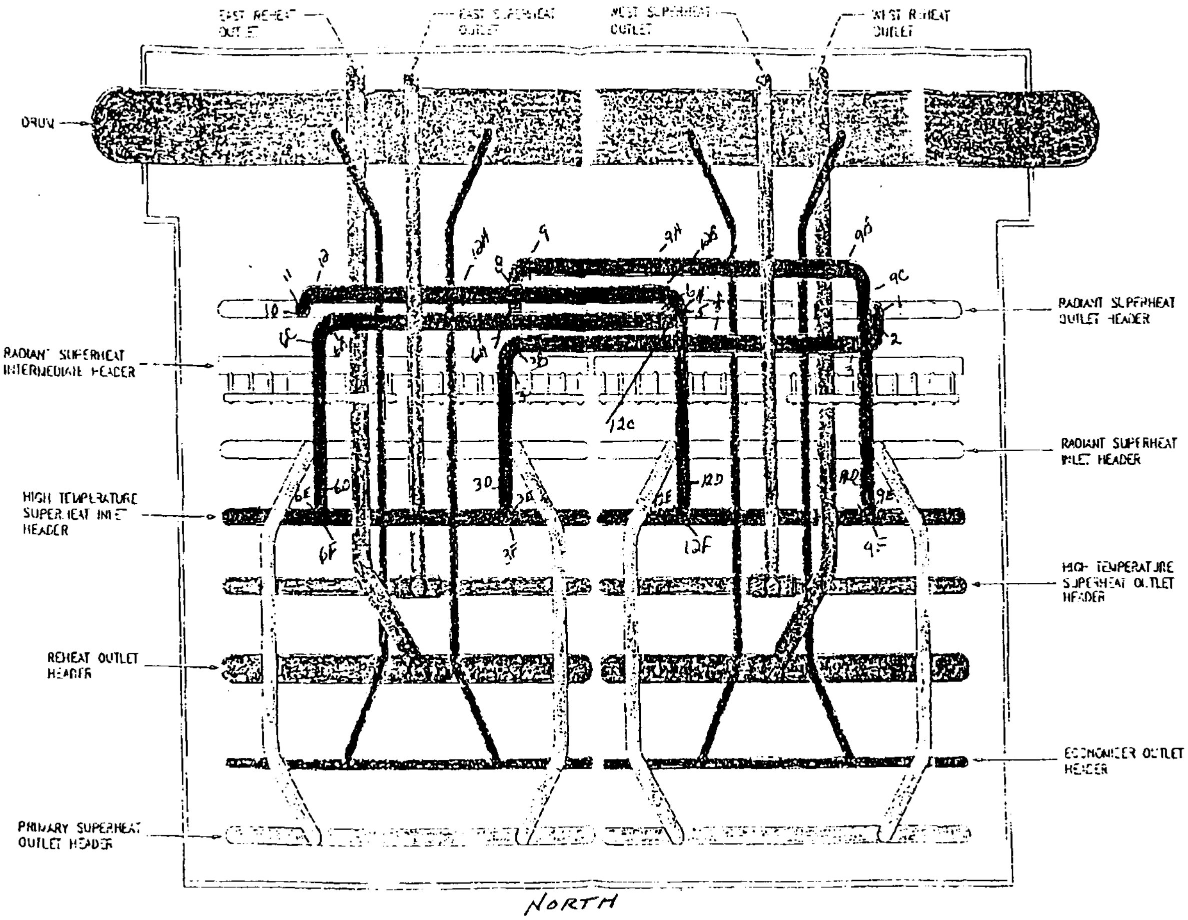

Figure 3 Plan view of the penthouse headers and crossover piping system

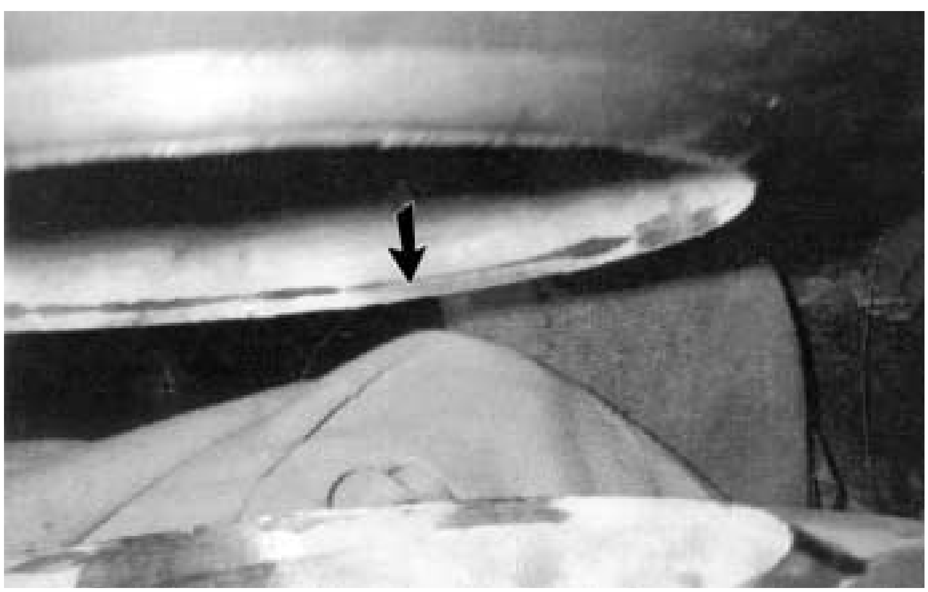

Figure 4 Photograph of the dye penetrant test indicting the crack in the circumferential weld of the radiant superheater outlet piping

lining anchor welds, and in the high temperature superheater inlet headers. These indications were all designated for monitoring. A schematic sketch of the crossover piping to the attemperators is shown in Figure 5.

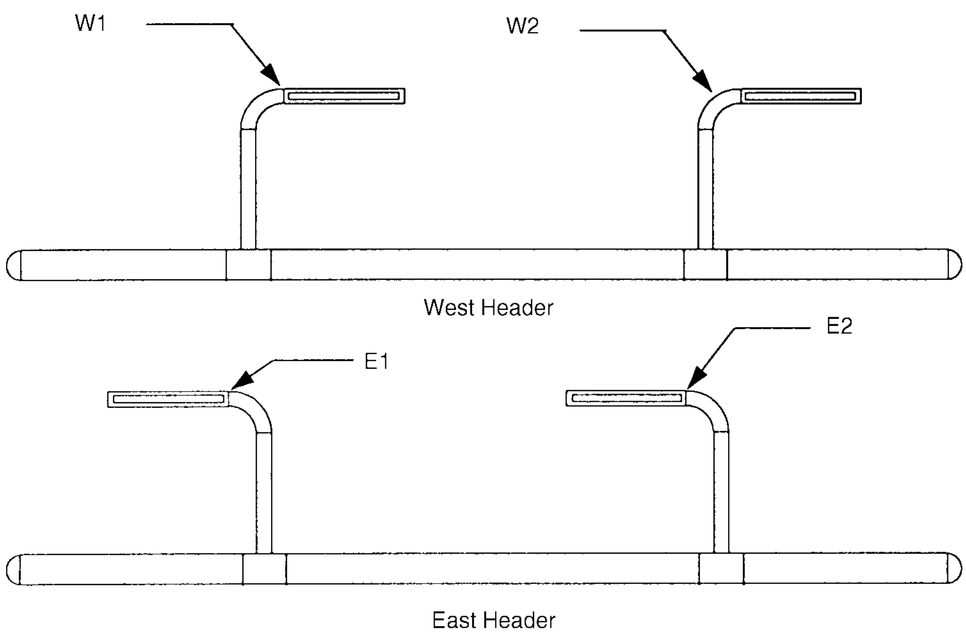

Figure 5 Spray piping, front view
Radiant superheater outlet headers, terminal piping, and spray assemblies

All of these instances of cracking were attributed to thermal fatigue and over temperature conditions experienced by the components early in the life of the boiler. Because of the higher temperatures experienced by the radiant superheater components, spray stations were added to the primary superheater systems soon after the boilers first went into service.

Similar problems were found with the radiant superheater crossover piping components in boiler No. 2 during a spring, 1996 outage. During this program, all of the girth welds in the system were examined by magnetic particle and ultrasonic shear wave methods. Many inside surface cracks were identified in the pipe welds, including those downstream of the attemperator stations. A repair program was initiated immediately, and sample metal pieces retained for later laboratory analysis.

A detailed metallurgical and stress analysis study to more accurately determine the cause of this component cracking was performed by DB Riley for Cajun Electric. The Reference (4) report addresses this study. The ID indications, in the sample weldments, were found to be thermally assisted fatigue cracks. They were located on the inside surface at base metal sites with geometric discontinuities. There was no evidence of creep damage or microstructural overheating in the metal specimens. The depths of the cracks were found to be less than originally estimated by the ultrasonic testing. See Figures 6 and 7. In the laboratory, some weld locations were found to have bands of stringer inclusions, which were present in the original material. These are not detrimental, but may be the cause of false indications in the field ultrasonic testing.

Figure 6 View of the cut cross sectioned surface showing the location of the crack at the taper transition at the ID of the elbow

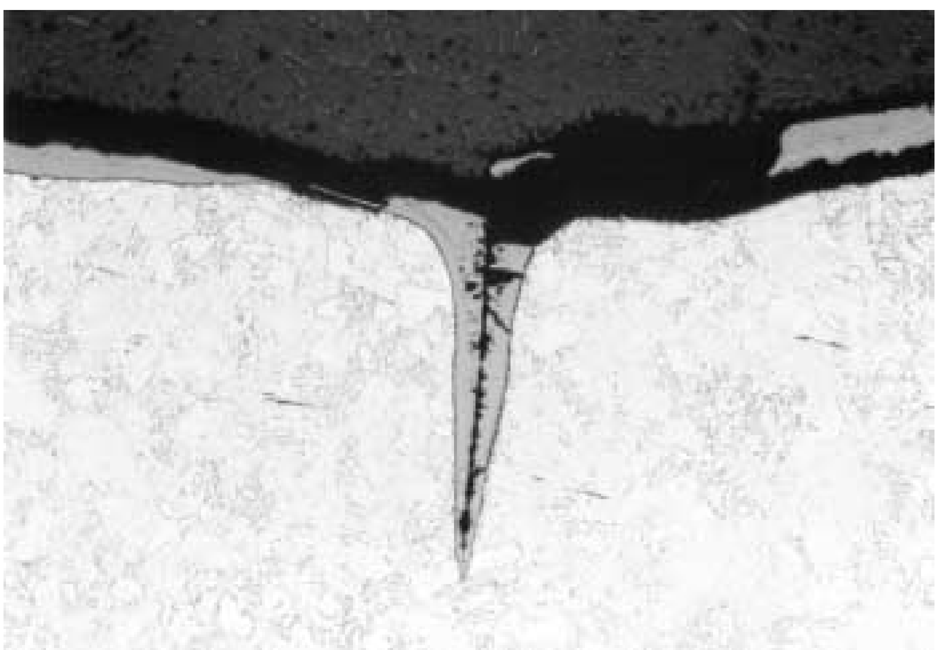

Figure 7 The oxide filled crack at the ID surface. The crack is a thermally-assisted fatigue crack measuring 40 mils deep. Stringer inclusions can also be seen beside the crack

Stress analysis cases were run for a computer model of the crossover piping system, which includes the radiant superheater outlet and high temperature superheater inlet headers. See the Figure 8 schematic drawing of the piping model. The results of the stress analysis cases shows that under normal operating conditions, and even for a higher temperature (upset) condition, the piping system loadings satisfy the requirements of the ASME B31.1 Power Piping Code, Reference (5). However, when the model was run with non-functioning supports, then the maximum stresses exceeded the code allowables.

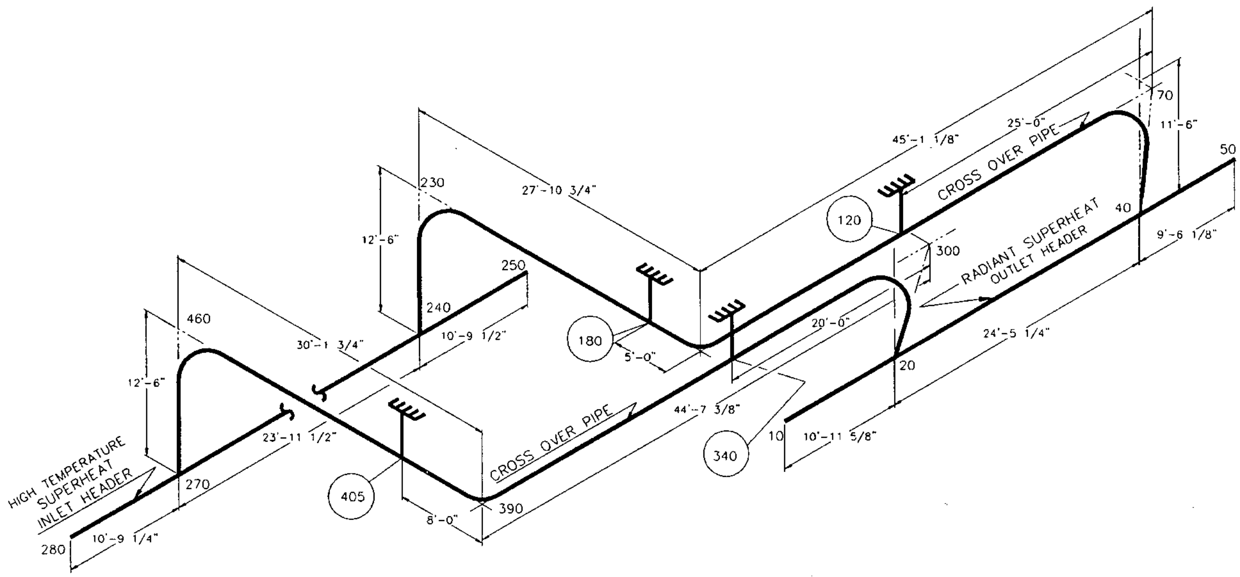

Figure 8 Piping model developed for the radiant superheater crossover piping analysis

HOT REHEAT STEAM PIPING SYSTEM

As discussed earlier, the Units No. 1 and 2 hot reheat piping lines are fabricated from ASTM A155 - Class 2-1/4 alloy steel plate, which is joined with a longitudinal seam weld. The finished pipe has a nominal inside diameter of 23 inches and a minimum wall thickness of 1.124 inches. The piping has a design temperature of 1015°F. The maximum operating pressure is 600 psig. Figure 9 is an isometric sketch of the hot reheat piping system, and the main steam piping system is depicted in Figure 10.

The condition assessment of the steam piping was begun on the Unit 1 lines during the 1993 spring outage. During the Unit No. 1 1995 fall outage, some indications were identified by ultrasonic shear wave testing, and surface creep damage was observed by metallographic replication, in portions of the long seam and girth welds of the hot reheat piping in the turbine building. These findings resulted in the removal of plug samples for metallurgical evaluation. In lieu of performing weld repairs to the piping, a three foot long piece of the hot reheat piping was removed for a comprehensive analytical testing program. The spool piece was cut eighteen inches on each side of a circumferential weld, and contained two offset portions of long seam weld. See Figure 11. The results of this program are presented in detail in the Reference (6) and (7) documents, and are summarized herein, as follows.

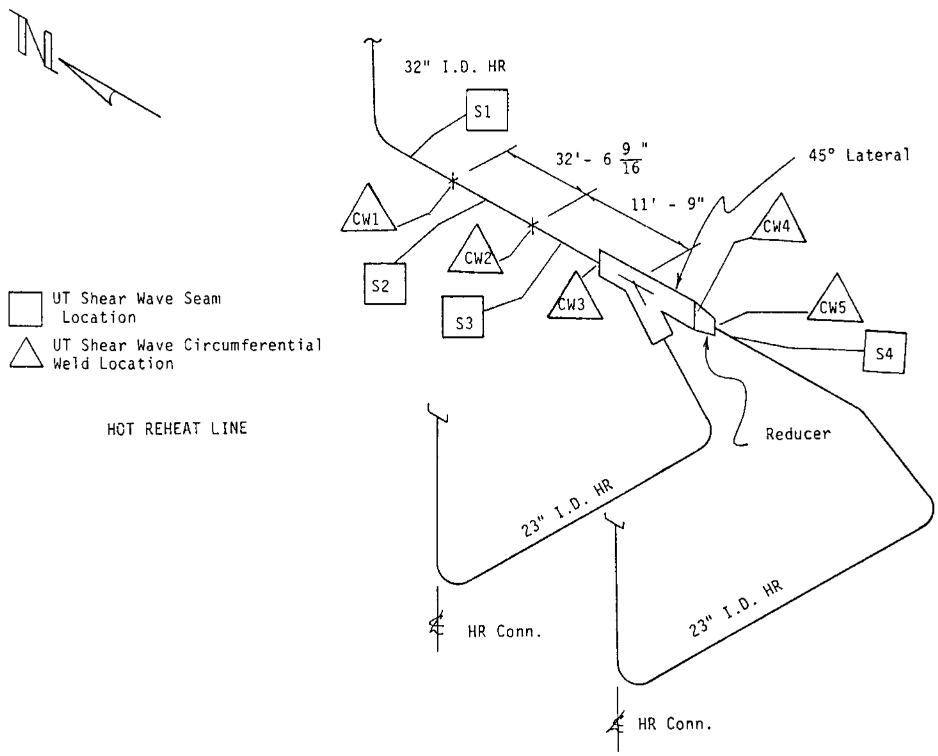

Figure 9 Typical hot reheat piping isometric drawing identifying the piping to be examined during condition assessment program

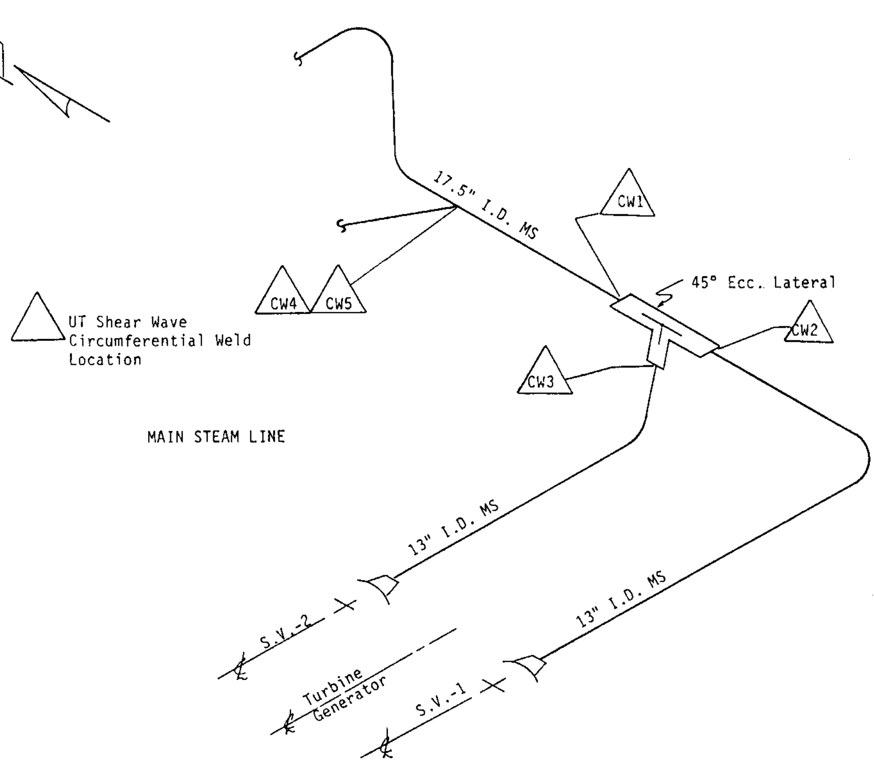

Figure 10 Typical main steam piping isometric drawing identifying the piping to be examined during condition assessment program

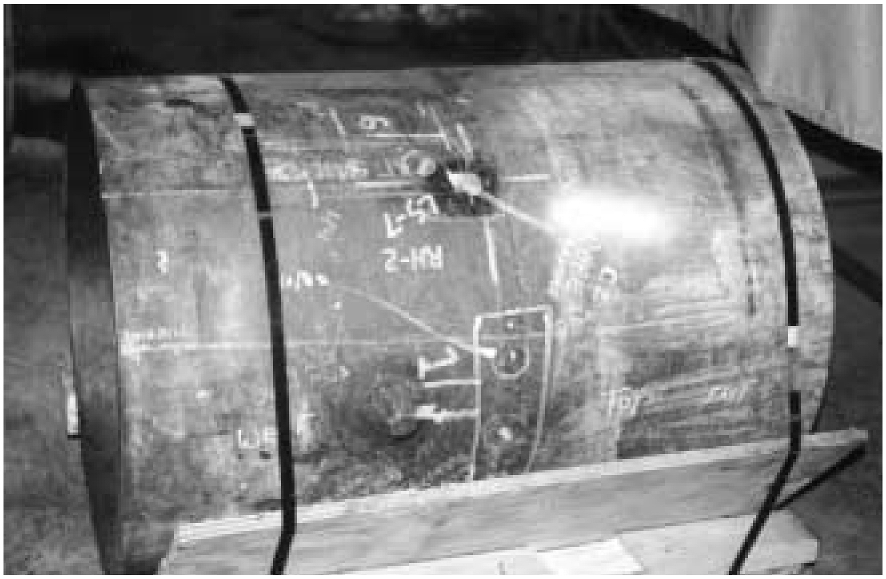

Figure 11 Hot reheat piping spool piece removed for testing and analysis.

This in depth analytical testing program consisted of the following tasks as listed below:

- Visual Inspection and Nondestructive Testing
    - Visual Inspection
    - Wet Fluorescent Magnetic Particle Testing
    - Radiographic Testing
    - Ultrasonic Testing
- Physical and Chemical Evaluation
    - Optical Metallography
    - Scanning Electron Microscopy
    - Spectrochemical Analysis
    - Hardness Testing
- Mechanical Testing
    - Stress-Rupture Testing
    - Elevated Temperature (J) Fracture Toughness Testing
    - Creep-Crack-Growth (C*) Testing
    - Remaining Creep Life Assessment

Based on the findings of the analyses and testing of the spool piece, which were conducted according to current industry guidelines for detecting damage in the weldments of high energy steam piping, the following conclusions were made for this component.

- Visual inspection yielded no evidence of gross defects in the spool piece. Unlike the inherent limitations of *in-situ* inspection of piping, laboratory analysis offered the obvious advantage of being able to examine the internal surface of the spool piece, by visual, nondestructive and destructive techniques. Figure 12 shows a macroetched end view of the spool piece including the longitudinal weld profile. The most significant finding was the presence of a non-uniform counterbore at the I.D. of the girth weld (it does not go completely around the circumference of the pipe). This discontinuity was introduced during joint preparation of the pipe ends prior to welding. This indication was initially identified as a crack indication, both by ultrasonic testing (UT) and radiography (RT), since the internal surface of the pipe could not be seen in the field.

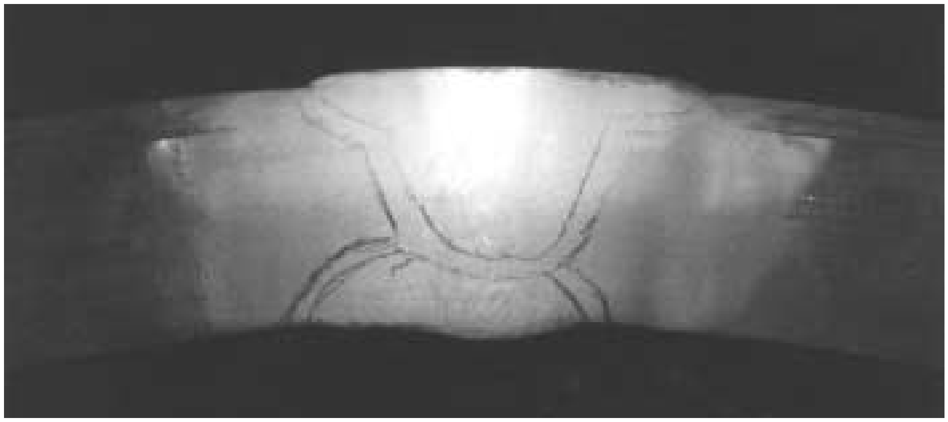

Figure 12 Image of the macro-etched end of the hot reheat piping spool piece. The etching identifies the asymmetry of the double-V seam weld.

- Indications were detected in the girth weld by both UT and RT. In the laboratory, the largest indication was identified as a fabrication-induced flaw, namely lack of root fusion, by metallographic examination. No evidence of creep damage was found to be associated with the flaw, when examined by optical microscopy.
- No evidence of creep damage was observed in the metallographically prepared specimens of the long seam or girth welds. The piping base metal showed only beginning-stage spheroidization showing that service temperatures have not seriously degraded the metal.
- A significant concentration of nonmetallic inclusions was observed in the weld metal of the upstream longitudinal weld, particularly evident along the fusion line in the cusp region of the weld. Chemical analysis of the weld material showed that the oxygen content is consistent with the use of an acid type flux during original fabrication. These inclusions are typical of those found in welds made by the submerged-arc welding process. One reference suggests that high concentrations of nonmetallic inclusions near the fusion line of long seam welds, as introduced by the welding process and acid type fluxes, may increase the likelihood for creep damage to initiate. Contrary to the observation of a high concentration of weld metal inclusions, the results of the cross-weld stress-rupture tests indicate that the stress-rupture life of the longitudinal seam weld has not been seriously degraded by their presence or by service conditions.
- Remaining creep life assessment was performed using the results of the stress rupture, high temperature toughness, and creep-crack-growth testing carried out on a specimen of the long seam weldment. The findings indicate that service temperatures and pressures have not significantly reduced the creep properties of the piping weldment, and furthermore, that the test results of the weldments are comparable to current industry findings for 2-1/4 Cr - 1 Mo base metal.
- The creep-crack-growth model shows that the average operating pressure of 509 psig and temperature of 1001°F for this steam piping are reasonable based on the parameters of the specimens tested and operational data reported. The speci-

mens prior to testing are shown in Figure 13. Adequate remaining life is expected under steady-state conditions and in the absence of material flaws or sustained, undue operational loading.

- A calibration block has subsequently been fabricated from the spool piece for future UT inspection of the Cajun piping.

Figure 13 Photograph of the varied spool piece specimens used in testing and analysis

SUMMARY

This paper has presented an overview of a series of scheduled condition assessment programs, performed over the past five years on the boiler and piping components of Units No. 1 and 2 at the Big Cajun II power station. The constituents of the programs for both boilers, and the more significant results have been described in detail herein.

The performance of these scheduled and repeat boiler condition assessment programs at Big Cajun II station has helped to provide continued safe and reliable operation of the units, with a decrease in the number of forced outages.

These programs were formulated and initiated following the discovery of internal cracking in a radiant superheater outlet header on the Unit No. 1 boiler in the fall of 1992. This cracking was attributed to the combined effects of creep and fatigue.

The condition assessment programs for the boilers and piping were initiated in the spring of 1993. Since then, three full programs have been performed for Unit No. 2. In the past, Cajun Electric would schedule annual (12 month) maintenance outages for the boilers. Now the interval between outages at Big Cajun II has been increased to eighteen months. This is a very common trend in the utility industry today. This pattern of scheduling less frequent outages requires much better record keeping and more detailed planning for inspection and maintenance items, in preparation for a boiler shut down period.

Two major problem areas which were found during the programs involved components of the radiant superheater crossover piping systems and the hot reheat steam piping lines. These items, with results, have been fully described herein and in the applicable referenced documents.

A summary of the more significant pressure part problem items resulting from the condition assessment programs for both boilers is presented in Table 1.

Table 1 Boiler and Piping Pressure Component Problem Areas

Component	Damage Type	Inspection Failure Cause	NDT Technique	Recommendations
Radiant S.H Outlet Header, Unit 2	Cracks in tube stubs and outlet nozzle welds	Thermal fatigue	Magnetic particle, UT shear wave and replication	Repair and monitor
Radiant S.H Crossover Piping, Units 1 and 2	Cracks in welds at nozzles, elbows and radiographic plugs and non-functional pipe supports	Thermal fatigue	Magnetic particle, UT shear wave, replication and visual inspection	Repair and monitor
Radiant Superheater Attemperators, Units 1 and 2	Cracks in spray nozzles and liner attachment welds	Thermal fatigue	Dye penetrant and video inspection	Replace and repair
High Temperature S.H. Inlet Header Units 1 and 2	Cracks in welds at nozzles	Thermal fatigue	Magnetic particle, UT shear wave and replication	Repair and monitor
Economizer Inlet Header, Units 1 and 2	Minor ID pitting	Corrosion fatigue	Video inspection	Monitor
Radiant S.H. Intermediate Bottle Headers, Unit No. 2	Cracks in nozzle welds	Thermal fatigue	Magnetic particle and UT shear wave	Repair
Primary Reheater Tubes, Units 1 and 2	Overheating, thinning, and sagging	Creep, graphitization and erosion	Visual inspection, UT thickness, replication and tube metallurgy	Monitor for replacement
Furnace Water Wall Tubes, Units 1 and 2	Thinning, OD damage	Sootblower erosion and slag falls	Visual inspection and UT thickness	Monitor for replacement. Evaluate sootblower operation.
Main Steam Piping Lines, Units 1 and 2	Indications in girth welds	Original flaws and thermal fatigue	UT shear wave and thickness, magnetic particle, replication, and O.D. measures	Repair and monitor
Hot Reheat Piping Lines, Units 1 and 2	Indications in girth and long seam welds	Original flaws and thermal fatigue	UT shear wave and thickness, magnetic particle, replication and O.D. measures	Repair and monitor
Downcomer Pipe Support, Unit 2	Deteriorated structural members	Original fabrication defects	Visual inspection	Repair or replace

RECOMMENDATIONS

The pattern of performing condition assessment programs on the boiler and piping components should be continued during each scheduled outage for the units. The programs can be altered based on previous history and results. Many of the items can be incorporated into a maintenance planning program. Monitoring of the major boiler and piping pressure components should be a part of every scheduled outage plan.

The continual monitoring program should, in particular, be applied to components of the radiant superheater crossover systems and the high energy steam and feedwater piping lines. Based on DB Riley's experience, it is recommended that the scope of inspection and testing for thinning of feedwater piping be expanded to include more components during future outages. In addition, the spray water piping lines to the attemperator stations and the main branch lines, off the high energy steam piping lines, should be included in the inspection and testing programs.

As part of the monitoring of the boiler and steam piping systems, the piping supports should be inspected for evidence of component deterioration in the form of corrosion etc., and functionality. If needed, the supports can be proof tested to insure that the units are capable of carrying their design loadings.

For future condition assessment programs of the superheater crossover and high energy steam piping lines, the specific non-destructive testing methodologies learned from the detailed laboratory studies of their components should be utilized. Also, the unique metal samples taken from the crossover piping weldments and hot reheat piping spool piece should be utilized for calibration purposes prior to the testing.

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3. Riley Stoker Corporation Report No. 93506, “Radiant Superheater Outlet Header Assessment,” dated December 10, 1992.

4. DB Riley Report No. 61920, ‘Radiant Superheater Outlet Header and Crossover Piping Stress Analysis and Metallurgy”, dated June 27, 1997.

5. ASME B31.1, Power Piping Code, 1995 Edition.

6. DB Riley Report No. 61933, “Evaluation of Hot Reheat Steam Piping Test Spool Piece Removed from The Big Cajun 11 Station”, dated March 21, 1997.

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