APPENDIX

U.S. NUCLEAR REGULATORY COMMISSION
REGION IV

NRC Inspection Report: 50-285/91-02 Operating License: DPR-40

Docket: 50-285

Licensee: Omaha Public Power District (OPPD)
444 South 16th Street Mall
Mail Stop 8E/EP4
Omaha, Nebraska 68102-2247

Facility Name: Fort Calhoun Station (FCS)

Inspection At: FCS, Blair, Nebraska

Inspection Conducted: January 7-11, 1991

Inspectors: L. E. Ellershaw, Reactor Inspector, Materials and Quality Programs Section, Division of Reactor Safety — 1/30/91 Date

for I. Barnes — L. D. Gilbert, Reactor Inspector, Materials and Quality Programs Section, Division of Reactor Safety — 1/30/91 Date

for I. Barnes — R. C. Stewart, Reactor Inspector, Materials and Quality Programs Section, Division of Reactor Safety — 1/30/91 Date

Approved: I. Barnes — I. Barnes, Chief, Materials and Quality Programs Section, Division of Reactor Safety — 1/30/91 Date

Inspection Summary

Inspection Conducted January 7-11, 1991 (Report 50-285/91-02)

Areas Inspected: Routine, announced inspection of the service water (SW) system and followup on control element drive mechanism (CEDM) housing cracking.

Results: Within the areas inspected, it was identified (paragraph 2.1.2) that the testing of individual heat exchangers in the Component Cooling Water (CCW)/ Raw Water (RW) systems was not completed. Inspector followup items were identified (paragraphs 2.1.2, 2.1.3 and 2.1.4) pertaining to the failure to complete the testing, to establishment of a program document for inspection of the CCW/RW systems and review of the complete as-built verification. The licensee's program for inspection, testing, and maintenance of the SW system, with the exception of the above problem was found to be consistent with the requirements of the Technical Specifications (TSs) and commitments made in response to Generic Letter 89-13. Observation of surveillance tests and the review of data for completed RW system surveillance tests indicated that the licensee was satisfactorily implementing their inservice testing (IST) program. Metallurgical evaluation of cracking in the #9 and #13 spare CEDM housings has identified the failure mechanism to be transgranular stress corrosion cracking, with the root cause attributed to the failure to vent the housings since plant startup. The licensee's actions to investigate this problem were found to be both comprehensive and commendable.

DETAILS

1. PERSONS CONTACTED

OPPD

*W. G. Gates, Division Manager, Nuclear Operations
*S. K. Gambhir, Division Manager, Engineering
*T. L. Patterson, Manager, Fort Calhoun Station
*R. L. Jaworski, Manager, Station Engineering
*J. K. Gasper, Manager, Training
*J. W. Chase, Manager, Nuclear Licensing
*L. T. Kusek, Manager, Nuclear Safety Review
*D. Matthews, Supervisor, Station Licensing
*C. J. Brunnert, Supervisor, Operations Quality Assurance
*B. Schmidt, Supervisor, Secondary Chemistry
*G. Cook, Nuclear Licensing Engineer
J. D. Kecy, Supervisor, System Engineering
K. R. Henry, Lead Primary System Engineering
F. G. Buck, Raw Water/Component Cooling Water System Engineer
R. Lisowyj, Special Services Engineer
M. Anielak, Reactor Operator

NRC

*R. V. Azua, Project Engineer

The inspectors also interviewed other licensee employees during the inspection.

*Denotes attendance at exit interview conducted on January 11, 1991.

2. SERVICE WATER SYSTEM

At FCS, the Service Water (SW) system defined in the General Design Criterion 44 "Cooling Water" of 10 CFR Part 50, Appendix A, is comprised of the Raw Water (RW) system and the Component Cooling Water (CCW) system. Both of these systems provide for the transfer of heat loads to the plant's ultimate heat sink, the Missouri River.

The CCW system is a closed loop system used to transfer heat from various components to the RW system, which discharges to the Missouri River. The RW system is a once-through cooling water system which removes heat from the CCW system. The RW system is also capable of providing direct cooling water through the CCW piping to selected safety-related components in the event that the CCW system is unavailable.

2.1 Generic Letter 89-13 (92701)

By letter dated July 18, 1989, "Service Water System Problems Affecting Safety-Related Equipment (Generic Letter 89-13)," NRC requested all nuclear power plant licensees to commit to certain tests and evaluations of SW systems and to respond to this requirement for information within 180 days of receipt of the generic letter (GL). In addition, each licensee was required to confirm that all of the recommended actions or their justified alternatives had been implemented within 30 days of such implementation. OPPD, in response to the five recommended actions contained in GL 89-13, addressed their SW program for FCS by letter dated January 26, 1990. During this inspection, the inspectors reviewed the actions taken by OPPD to fulfill the commitments made to the NRC and observed the following.

2.1.1 Biofouling Control

Recommended Action I of GL 89-13 addressed the need to implement and maintain an ongoing program of surveillance and control to reduce significantly the incidence of flow blockage problems resulting from biofouling. Enclosure 1 to GL 89-13 described a program acceptable to the NRC for meeting the objectives of Recommended Action I and consisted of surveillance and control techniques. OPPD responded by stating that a visual inspection of the intake structure for macroscopic biological fouling organisms would be conducted on an annual basis, and samples of water and substrate would be collected annually to determine if Asiatic clams have populated the water source. OPPD also stated that there has not been any evidence of biofouling identified in the RW, CCW, circulating water, or water plant systems during inspections and maintenance activities since plant startup; therefore, no additional control techniques would be implemented.

The inspectors reviewed the results of the first annual inspection of the intake structure which was performed during RO-90 (the 1990 refueling outage). While there was a slight buildup of algae on the intake structure's concrete walls (approximately 1 mil), there was no evidence of Asiatic clams or any biological fouling. The main flow paths were clear and clean, and the suction bells of the RW pumps were free of obstructions and appeared to be in good condition. While the report did not clearly indicate that water and substrate samples were taken, the system engineer stated that he had taken samples and visually examined them for evidence of Asiatic clam existence. The inspectors noted that the annual inspection requirements had been incorporated into the preventive maintenance program, with each of the intake structure's RW cells being identified in its own preventive maintenance order work plan. While the work plan did provide instructions for the need to acquire samples for further examination, it did not state what the samples were or where they were to be taken from, and of what the further examinations were to consist. The work plan also stated that a visual examination was to be performed in order to detect indications of biological fouling that could degrade RW system performance and that the results of the inspection were to be documented. The inspectors questioned the apparent lack of specificity regarding what constituted acceptable inspection results. It was explained that the work plan instructions referred to the Generic Letter, which did contain the necessary specificity; however, the inspectors noted that the Generic Letter identified in the work plan instructions was GL 89-12, which pertains to operator licensing examinations. The licensee stated that this editiorial error would be corrected.

2.1.2 System Testing

Recommended Action II of GL 89-13 required a test program to be established to verify the heat transfer capability of all safety-related heat exchangers cooled by SW. The recommendation also included alternative methods that would be considered acceptable. OPPD responded and stated that a test program for verifying heat transfer capability of individual heat exchangers in the CCW/RW systems would be implemented. The response identified the following safety-related heat exchangers in the CCW/RW systems and their test frequencies: CCW - quarterly; Letdown Cooling - once per year; Spent Fuel Pool Cooling - once per year, and Shutdown Cooling - once per refueling outage. It also specified the performance parameters to be tested (i.e., heat transfer rates and cleanliness factors). OPPD stated that the test procedures used would provide directions for testing the heat exchangers, and testing frequencies would be reevaluated based on the trending results of the test data, and any reduction in heat transfer capability would be detected and appropriate corrective actions taken. OPPD further stated, "this test program will begin during the 1990 refueling outage."

The inspectors requested the applicable procedures and test data acquired to date. It was learned that the test program had not been implemented and that test procedures had been developed for only the Spent Fuel Pool and CCW heat exchangers. The inspectors were informed that an attempt had been made to test the CCW heat exchangers; however, the test was terminated when it became obvious that the results were not consistent with what was expected. Evaluation determined that the existing piping and instrumentation configuration would not allow accurate measurement of a required parameter (i.e., differential pressure across the tube and shell side of the individual heat exchangers). This resulted in the initiation of Modification Request MR-FC-90-034 on April 28, 1990, to allow for the installation of the necessary equipment. The inspectors were informed that the modification would not be implemented until the 1991 refueling outage (RO-91), which is scheduled to begin during November 1991.

OPPD's failure to implement the commitment to verify heat exchanger capability during the 1990 refueling outage as specified in their response to GL 89-13, resulted from a breakdown in the tracking of the commitment to closure. However, the root cause appeared to be inadequate engineering in the preparation of the test procedure, in that the lack of necessary instrumentation taps was not recognized before the test was run. The licensee was requested to review this issue including the apparent cause and response to the NRC. Completion of this item is considered an inspector followup item (285/9102-01).

2.1.3 System Inspections and Evaluation

Recommended Action III of GL 89-13 required the establishment of a routine inspection and maintenance program for open-cycle service water system piping and components to ensure that corrosion, erosion, silting, and biofouling cannot degrade the performance of the safety-related systems served by service water. OPPD responded by stating that an inspection and maintenance program will be implemented for the major components of the CCW and RW systems that will ensure their reliability to meet their designed safety functions. This program will consist of an initial cleaning and flushing preventive maintenance (PM) activity along with an inspection to establish baseline conditions. As for other components, the licensee stated that the existing inservice inspection and PM programs adequately cover the maintenance activities on the rest of the components in the CCW and RW systems. The inspection and maintenance programs will begin during RO-90 and a long-term PM scheduling interval determined for each component by the end of RO-91.

The licensee completed the initial cleaning and flushing operations on the four open-cycle CCW heat exchangers as follows: AC-1B was completed prior to the beginning of RO-90, AC-1A and AC-1D were completed during RO-90, and AC-1C was completed following the outage. The inspectors reviewed the system engineer's inspection reports associated with the cleaning and flushing of the CCW heat exchangers. The inspection reports stated that the end covers were removed from both ends of the CCW heat exchangers and the heat exchangers inspected before, during, and after cleaning. The reports indicated that sand and debris were removed during the cleaning operation, but there was no indication of any biological fouling. Although a 1/8- to 3/16-inch layer of calcium carbonate buildup was removed from the walls of the water box area of the heat exchangers, the tube sheet and stainless ste ` tubes of the heat exchangers were found to be very clean. The report for AC-1A stated that eddy current examination was performed on the tubes of the heat exchanger with no indication of tube wall thinning or cracking. The heat exchangers were hydrostatically tested on the shell side with no leakage identified through the tube walls. After replacing the end covers, the heat exchangers were satisfactorily hydrostatically tested on the RW side. A post-maintenance test to assure a flow of greater than 3000 gpm of raw water through each CCW heat exchanger was satisfactorily performed before the heat exchangers were declared operable and returned to service.

The inspectors also reviewed maintenance work orders which documented that the flushing and cleaning operations were accomplished in accordance with Procedure SP-AC-FLUSH for the following closed-cycle CCW system heat exchangers during RO-90: Containment Spray Pump Bearing Cooler Unit SI-3A, Low Pressure Safety Injection Pump Bearing Cooler Unit SI-1A, High Pressure Safety Injection Pump Bearing Cooler Unit SI-2A, High Pressure Safety Injection Pump Bearing Cooler Unit SI-2B, and Reactor Coolant Pump Bearing Lube Oil and Seal Cooler Unit RC-3D.

During RO-90, several major isolation valves were removed from both the RW and CCW systems for refurbishment at which time the valve internals and adjacent piping were inspected for biofouling and degradation. The system engineer's report stated that no indication of biofouling was present at any of the locations inspected in both the RW and CCW systems. However, some degradation was reported that was identified during the inspection of the RW system. Degradation was noted on various components; this consisted of erosion of valve internals and piping which were subject to severe flow impingement by the sandy water coming from the Missouri River. The inspectors reviewed the corrosion/erosion monitoring program related to the RW and CCW systems. Although the monitoring program included components which had been identified as showing degradation, the inspectors expressed concern that a routine inspection program in response to GL 89-13 had not been clearly articulated in any of the program documents. In response, the licensee stated that engineering would develop a program basis document for this purpose. This issue will be considered an inspector followup item (285/9102-02).

2.1.4 As-Built Verification

Recommended Action IV of GL 89-13 required confirmation that the SW system will perform its intended function in accordance with the licensing basis for the plant. The confirmation should include recent system walkdown inspections to ensure that the as-built system was in accordance with the appropriate licensing basis documentation. OPPD responded by stating that their confirmatory program would consist of the following four items:

A. Complete the design basis reconstitution for the RW/CCW systems and evaluate the as-built condition documented by the system walkdowns.

B. Evaluate the results of the system performance tests to determine that the RW/CCW systems are operating within their respective design basis.

C. Review the RW/CCW systems to determine their ability to perform required safety functions in the event of failure of a single active component.

D. Reconcile system walkdowns and design basis open items with the RW/CCW design basis documents to the extent necessary to verify system operability.

The response also stated that this program would be completed prior to leaving Mode 4 upon completion of RO-91.

Regarding Item A, documentation was provided to the inspectors which showed that a design basis review had been performed by Stone & Webster Engineering Corporation. The design basis review was contained in document SDBD-AC-RW-101, "Design Basis Document-Raw Water," Revision 0, dated March 1990. The inspectors' review revealed the document to be comprehensive and detailed with respect to design basis requirements, technical description, system modifications, limitations and precautions, and the operating parameters. Section 8 of this document provided a verification summary and included a chronological discussion of RW system as-built walkdowns. The walkdowns consisted of a piping and instrumentation drawing (P&ID) verification performed in 1980, a walkdown of the RW system's electrical and instrument and control system in 1984, and a walkdown during and after RO-88 in order to reverify P&IDs, stress isometrics, and system modifications.

The inspectors were informed that none of the other items had been completed as of the date of this inspection. Therefore, the completion of the remaining items is considered to be an inspector followup item (285/9102-03).

2.1.5 Procedures and Maintenance

Recommended Action V of GL 89-13 required a confirmation that maintenance practices, operating and emergency procedures, and training that involves the SW system are adequate to ensure that safety-related equipment cooled by the SW system will function as intended and that operators of this equipment will perform effectively. The confirmation was to include recent reviews of practices, procedures, and training. OPPD responded by addressing their Safety Enhancement Program (SEP) which had previously been instituted to improve the overall level of safety at FCS. Three SEP items (41, 48, and 49) dealt specifically with an upgrade to the PM program, procedure upgrade, and training, respectively. While the SEP items were generic in nature (i.e., not system specific), the inspectors were able to verify by documentation review that the RW/CCW systems had been included. The methodology used to identify the specific RW/CCW system equipment as candidates for the PM program consisted of component selection and the performance of failure mode and effects analysis. These actions identified equipment and provided the recommended PM tasks based on information such as failure history and vendor data. The following equipment has been incorporated into the PM program and identified on a unique preventive maintenance order (PMO), which describes, as a minimum, the equipment, the maintenance procedure, work to be performed, frequency, measuring and test equipment to be used, and post-maintenance testing: CCW side of three Containment Spray Pump Seal Coolers; CCW side of four Reactor Coolant Pump Seal and Lube Oil Coolers; CCW side of two Low Pressure Safety Injection Pump Seal Coolers; CCW side of three Charging Pump Seal Coolers; CCW side of three High Pressure Safety Injection Pump Seal Coolers, and the CCW side of four Containment Air Coolers. The other components of the RW/CCW systems are identified under the test program discussed in Recommended Action II above, and the Operations Surveillance Test Program.

The inspectors verified by review of the procedure master index and a sampling of RW procedures that the applicable emergency operating procedures, maintenance procedures, and surveillance test procedures had been revised. The inspectors also verified that training sessions had been conducted for maintenance and operations personnel with respect to the revised maintenance and surveillance test procedures. The training and qualification records of the RW/CCW system engineer were reviewed to verify that he had received the specified system training and that he had qualified based on successful completion of both oral and written examinations.

2.2 Inservice Testing of Pumps and Valves (73756)

The purpose of this portion of the inspection was to assess the licensee's inservice testing (IST) program, including implementation with respect to the raw water (RW) system and the requirements of the ASME Code and Generic Letter 89-04, "Guidance on Developing Acceptable Inservice Testing Programs."

2.2.1 IST Program Review

The licensee's second 10-year IST Program for pumps and valves (September 26, 1983 to September 26, 1993) Revision 5, dated October 1, 1990, is based on the applicable requirements of the ASME Boiler and Pressure Vessel Code, 1980 Edition through winter of 1980 Addenda, 10 CFR 50.55a, and Generic Letter 89-04, dated April 3, 1989.

The licensee's Revision 4 to the IST program was accepted by NRR by letter dated August 17, 1989.

Revision 5 of the IST program incorporates guidance provided by Generic Letter 89-04, and OPPD's upgrade of the overall IST program. Revision 5 of the IST program was submitted to NRR on October 8, 1990. The NRC staff's safety evaluation report has not currently been issued. Other documents reviewed during the inspection are listed in the Attachment to this report.

2.2.2 Observation of Inservice Tests

During the inspection, the inspectors observed the quarterly operability tests conducted on RW Pump AC-10A and RW Pump Discharge Check Valves RW-125, -115, -117, and -121. The tests were conducted by a reactor operator in accompaniment with the RW system engineer and I&C technician. The inspectors observed that the quarterly check valve backflow and full flow tests were conducted in accordance with Procedure OP-ST-RW-3004, "Raw Water System Category C Check Valve Inservice Test." The inspectors observed that the tests were performed sequentially in accordance with the procedure and that the results of all check valve tests were well within the acceptance criteria. At the conclusion of the check valve tests, the RO and system engineer performed the quarterly test on RW Pump AC-10A in accordance with Procedures OP-ST-RW-3001, "Raw Water Pump Quarterly Inservice Test," and SE-EQT-RW-0002, "Post-Maintenance Test Raw Water Pumps," with satisfactory results obtained.

The inspectors observed that each of the tests was conducted and documented in accordance with the specific procedural requirements.

2.2.3 Review of Surveillance Test Records

The inspectors requested the completed surveillance operability test reports for the four RW pumps and the completed valve stroke times tests on eight RW air operated butterfly valves. The requested records are listed in the Attachment to this report. The records established that the requirements of ASME Code Section XI, Generic Letter 89-04, IST Plan, test procedures, and Technical Specifications were met for: (a) quarterly testing of pumps and valves, (b) increased frequency testing of pumps and valves, (c) post-maintenance testing of pumps, (d) establishing reference (baseline) data for pumps, and (e) establishing criteria for the acceptable, alert, and required action ranges for pumps and valves.

No violations or deviations were identified in this area of the inspection.

3. FOLLOWUP ON CONTROL ELEMENT DRIVE MECHANISM (CEDM) HOUSING CRACKING (92701)

3.1 Background

During the period of October 21 through December 1, 1990, FCS experienced an increase in unidentified reactor coolant system leakage from 0.15 to 0.4 gpm. Licensee actions taken to investigate the source of the leakage and corrective actions implemented are discussed in NRC Inspection Report 50-285/90-45. After receipt of intermittent alarms from fire detectors located near the cooling fans for the CEDMs, the licensee determined that a primary leak probably existed in the area of the reactor vessel head and commenced on December 14, 1990, to take the plant to hot standby (Mode 2) to allow an inspection to be performed.

Visual examination on December 15, 1990, of the reactor vessel head area revealed the presence of boric acid crystals on the #9 spare CEDM housing and on the head insulation adjacent to the housing. This spare CEDM housing was one of four (i.e., #7, #9, #11, and #13) that were installed in the reactor vessel head to provide for additional reactivity control should plutonium recycle fuel be used. Two of the spare CEDM housings, #9 and #13, contained a natural circulation spoiler which restricted flow of hot reactor coolant to the top of the housing. The other two spare CEDM housings, #7 and #11, were utilized in 1984 as penetrations for heated junction thermocouples for the reactor vessel level monitoring system. The natural circulation spoilers were removed from the #7 and #11 CEDM housings as part of this design change. After removal of attached boric acid crystals from the #9 CEDM housing, licensee personnel confirmed that a through-wall defect was present in the upper housing at a location not associated with a pressure boundary weld. The plant was then placed in cold shutdown (Mode 4) to allow removal of the #9 spare CEDM housing from the reactor vessel head for investigation of the nature and cause of the defect.

3.2 Licensee Visual Examination

Visual examination of the removed #9 spare CEDM housing identified that the through-wall defect was an axial crack which was approximately 3/4 inch in length at the outside surface of the housing. The crack was found by borescopic examination to be approximately 2 7/8 inches in length at the inside surface of the housing. It was also noted that a weld overlay was present on the inside surface of the housing at the crack location, with the crack traversing the weld overlay and extending up into the base material above the overlay. An additional axial crack, approximately 2 inches in length, was observed during borescopic examination of the inside surface of the housing at a location recorded by the licensee as 120° from the through-wall crack. [Later examination by ABB-Combustion Engineering (ABB-CE) recorded the second crack as being located at approximately 145° from the through-wall crack]. This second crack also traversed the weld overlay and extended up into the base material above the overlay.

The origination of the cracks on the inside surface of the housing at a location where residual stresses would be present (i.e., as a result of deposition of a weld overlay), coupled with the fact that the #9 and #13 spare housings had not been vented during vessel fill operations since plant startup in 1973, led to development of a preliminary root cause scenario. Specifically, it was postulated that not venting would have created an oxygenated primary water inside the CEDM housings which may have led to stress corrosion cracking at the weld overlay region where residual stresses were present. It was therefore determined to remove the #13 spare CEDM housing from the reactor vessel head for examination, in that it had experienced the same service conditions as #9. Borescopic examination of the removed #13 spare CEDM housing identified that axial cracks, similar to those found in the #9 spare CEDM housing, were present on the inside surface in the weld overlay region. Sample sections (21 1/2 inches in length) containing the observed cracks were cut from both the #9 and #13 CEDM housings and shipped to ABB-CE for failure analysis.

3.3 Review of ABB-CE Failure Analysis

The inspectors reviewed the results of the failure analysis of the #9 and #13 spare CEDM housings contained in ABB-CE Report TR-MCC-169, "Metallurgical Evaluation of Cracking in Fort Calhoun Spare CEDM Upper Pressure Housings Serial Nos. 9 and 13," dated January 1991. A summary of the failure analysis information is listed below.

3.3.1 Residual Stresses

Reductions in diameter of 0.020 and 0.023 inches, respectively, were measured after making longitudinal cuts through sections of the #9 and #13 spare CEDM housings. These reductions were calculated to represent the presence of minimum residual tensile hoop stresses of 9.5 ksi and 10.9 ksi, respectively, at the inside surface of the two housings in the weld overlay region.

3.3.2 ABB-CE Visual Examination

Two cracks were identified on the inside surface of each housing in the region of the weld overlay. The surface lengths and approximate azimuthal locations were measured to be:

Housing	Location	Surface Length (inches)
#9	15°	2.8 (Through-wall crack)
#9	160°	2.3
#13	160°	2.7 (Estimated)*
#13	300°	2.2 (Estimated)*

*A portion of the crack above the weld overlay was unintentionally lost during initial sectioning. The estimated value was derived based on 60 percent of the crack length occurring in the weld overlay.

The cracks were oriented in a nominally axial direction, with deviations in direction occurring between 0° and 25° from axial. No other evidence of cracking was observed in other regions of the housings. Some burnishing of the weld overlay was noted as a result of contact with the natural circulation spoiler. No correlation was found, however, between the rubbing marks and crack initiation.

3.3.3 Fractographic Examination

After opening of the cracks, it was observed that each crack was elliptical in shape and originated at the inside surface of the housing. All of the cracks exhibited concentric beach marks or rings which is indicative that the cracks propagated in increments. Penetration of the part through-wall cracks was found to be 86 percent for the 160° location in the #9 spare CEDM housing, and 95 percent and 70 percent, respectively, for the 160° and 300° locations in the #13 spare CEDM housing. Each of the cracks showed origins near the upper edge of the weld overlay, with the part through-wall crack in the #9 spare CEDM housing also exhibiting an adjacent second origin. The aspect ratios (crack length/maximum penetration) for each of the cracks was found to be quite consistent, varying from 3.6 to 4.0.

The surfaces of the cracks were examined by scanning electron microscopy (SEM) to determine the mode of failure and energy dispensive spectrometry (EDS) was utilized to determine if contaminants were present. The SEM examinations identified that each of the cracks was transgranular in nature. The EDS analyses identified the presence of the major elements of the base material (i.e., Type 348 columbium stabilized austenitic stainless steel), but did not identify the presence of any relevant contaminants. The inspectors noted that the EDS technique was only semi-quantitative and was not an optimal approach for detection of contaminants.

3.3.4 Microstructural Evaluation

Metallographic examination of samples from each housing confirmed that the cracks were transgranular in nature and exhibited branching. This mode of crack propagation is characteristic of transgranular stress corrosion cracking. The grain size of the housings was found to be ASTM No. 6 at the center of the wall and ASTM No. 7 near the outer surface. Some coarsening of the grain structure (ASTM No. 4) adjacent to the weld overlay was observed, which would be attributable to the thermal cycles of the welding process. Microhardness surveys found that the bulk hardness of the housings was equivalent to 85-90 Rockwell B which is typical for solution annealed material. Samples of the housings in the overlay region were also etched in accordance with ASTM A262 Practice A to determine the susceptibility to intergranular attack. The results indicated that the housing material, including the weld heat affected zone regions, was not susceptible to intergranular attack.

3.3.5 Chemical Analysis

Chemical analysis of the #9 and #13 spare CEDM housings (using X-ray fluorescence and a standard combustion technique for determination of carbon content) found that the composition was in accordance with the requirements of the applicable SA-312 Type 348 specification. The carbon, sulfur, and phosphorus contents were noted to be somewhat higher than reported on the original material certifications. The inspectors observed that only a semi-quantitative analysis using the EDS technique had been performed of the weld overlay, but did not consider that this was significant with respect to the observed cracking.

3.3.6 Discussion

Metallurgical evaluation of the #9 and #13 spare CEDM housings identified that the cracking was transgranular and branching in nature, which is characteristic of transgranular stress corrosion cracking. Austenitic stainless steels are known to be susceptible to stress corrosion cracking in the presence of tensile stresses and a suitably aggressive environment. The cracking originated at locations (i.e., adjacent to a weld overlay) where residual tensile hoop stresses of at least 10 ksi were calculated to be present. The actual value for residual stresses was probably significantly higher (i.e., the calculation averaged the residual stress through the wall of the housing, whereas peak stresses would be expected to occur adjacent to the weld overlay). The total tensile hoop stress, after addition of 11 ksi that results from the operating pressure of 2100 psi, was thus in excess of 21 ksi at the weld overlay region. ABB-CE determined, assuming the temperature of the CEDM housing was approximately 400°F in the region of cracking, that the stress level present during plant operations was at least 70 percent of the typical 400°F yield strength value of 30 ksi. Review by ABB-CE of the technical literature identified a limited amount of source information regarding susceptibility of austenitic stainless steels to transgranular stress corrosion cracking in oxygenated high temperature water. The review did indicate that oxygen was a strong accelerator of stress corrosion cracking and identified data showing the susceptibility of Type 304 austenitic stainless steel to transgranular stress corrosion cracking in 550°F water containing 100 ppm oxygen. An additional reference was also noted where high dissolved oxygen and chloride ion levels of 0.2 and 1 ppm resulted in transgranular cracking of slightly sensitized Type 304 austenitic stainless steel.

Bounding calculations performed by ABB-CE of the potential oxygen concentrations in the unvented #9 and #13 spare CEDM housings were found to be between 300 and 1300 ppm. Estimates of the decay of the oxygen concentration in the housings by diffusion indicated that high levels would remain for greater than a complete fuel cycle. The presence of the natural circulation spoiler would reduce the effectiveness of natural circulation in removing oxygen from the water in the housings.

ABB-CE concluded from its metallurgical evaluation that the failure to vent the spare CEDM housings was a primary factor in causing the cracking. The active CEDM housings were not considered to be susceptible to this failure mechanism, in that: (a) they are self-venting through the rotating seals when the control elements are inserted and withdrawn, and (b) local water chemistry is maintained closer to bulk water composition as a result of the exchange of water inventory that occurs in the CEDM housings during movement of the mechanism and control elements. The #7 and #11 spare CEDM housings were considered as possible locations where incipient cracks may be present, as a result of being operated unvented from start-up until 1984 when the heated junction thermocouples were installed. It was additionally determined that the venting procedures used since 1984 may not have been fully effective in ensuring no entrained air was present. ABB-CE accordingly recommended that additional examination be performed of these two CEDM housings to ensure that no cracks were present that could propagate through-wall prior to the next outage. It was further recommended that a detailed examination be performed of the #7 and #11 spare CEDM housings during the next outage after removal of the reactor vessel head.

3.4 Ultrasonic Examination of #7 and #11 Spare CEDM Housings

An ultrasonic examination of the #7 and #11 spare CEDM housings was performed by Ebasco Services Incorporated on December 29 and 30, 1990, using Ebasco Procedure FC-UT-1, "Ultrasonic Examination of Class 1 & 2 Piping Welds Joining Similar & Dissimilar Materials," Revision 5. The examination was performed using a 44° shear wave transducer, a 45° refracted longitudinal wave transducer, and a 0° longitudinal wave transducer. The area examined included the crack origination area at the top of the weld overlay plus 3 inches above and 3 inches below. No crack type indications were found to be present on the inside surface of the two spare CEDM housings.

No violations or deviations were identified in this area of the inspection.

4. EXIT INTERVIEW

An exit interview was conducted on January 11, 1991, with those personnel denoted in paragraph 1 in which the inspection findings were summarized. No information was presented to the inspectors that was identified by the licensee as proprietary. Subsequent to this inspection, OPPD contacted the inspectors on January 17, 1991, and stated that a letter would be sent to the NRC Region IV office by February 19, 1991, describing their actions and schedules with respect to the inspector followup item identified in paragraph 2.1.3 above.

ATTACHMENT

Procedure: SEI-27, "Inservice Inspection and Testing Program," dated August 22, 1990

Procedure: SOG-23, Standing Order Procedure, "Surveillance Test Program," Revision 33, dated April 1, 1990

Procedure: OP-ST-RW-3001, "Raw Water Pump Quarterly Inservice Test"

Pump Nos. AC-10A, B, C, and D, tests conducted April 13, 1990
Pump Nos. AC-10A, B, C, and D tests conducted May 19, 1990
Pump No. AC-10A, test conducted October 19, 1990
Pump No. AC-10B, test conducted August 21, 1990
Pump No. AC-10C, test conducted August 2, 1990
Pump No. AC-10A, test conducted July 25, 1990
Pump No. AC-10D, test conducted October 29, 1990
Pump No. AC-10D, test conducted August 6, 1990
Pump No. AC-10A, test conducted January 10, 1991

Procedure: ST-RW-2, "Post-Maintenance Operability Test Raw Water Pumps"

Pump No. AC-10A, test conducted January 22, 1990
Pump No. AC-10C, test conducted January 26, 1990
Pump No. AC-10A, test conducted August 8, 1990
Pump No. AC-10D, test conducted August 6, 1990
Pump No. AC-10B, test conducted August 25, 1990
Pump No. AC-10C, test conducted August 2, 1990
Pump No. AC-10B, test conducted January 26, 1990
Pump No. AC-10B, test conducted January 25, 1990
Pump No. AC-10D, test conducted January 25, 1990

Procedure: OP-ST-RW-3011, "AC-10B Raw Water Pump Quarterly Test," test conducted November 14, 1990

Procedure: OP-ST-RW-3021, "AC-10C Raw Water Pump Quarterly Inservice Test," test conducted October 25, 1990

Procedure: OP-ST-RW-3002, "Raw Water System Category A and B Valve Exercise Test," Quarterly test for Valves HCV-2880A through HCV-2883B, tests conducted December 30, 1990