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NUCLEAR REGULATORY COMMISSION
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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

GPU NUCLEAR CORPORATION AND

JERSEY CENTRAL POWER & LIGHT COMPANY

OYSTER CREEK NUCLEAR GENERATING STATION

DOCKET NO. 50-219

INSPECTION AND REPAIRS OF ISOLATION CONDENSER SYSTEM PIPING

1.0 INTRODUCTION

During the current Oyster Creek refueling outage, augmented ultrasonic testing (UT) was performed on the recirculation system piping in accordance with IE Bulletin 82-03. No intergranular-stress-corrosion-cracking (IGSCC) indications were reported. In a hydrostatic testing of the "A" loop isolation condenser (IC) leakage from two small pin-holes was observed from the 8-inch return (condensate) line outside the containment near weld NE-2-12. The IC system consists of two loops of steam (supply) lines (12" and 16") and condensate (return) lines (8" and 10"). All the piping is made of type 316 stainless steel materials. Subsequently, all the IC piping welds (124) outside the containment were ultrasonically inspected. A total of 27 welds including 10 welds in the condensate lines (nine welds in 8" lines and one weld in 10" line) and 17 welds in the steam lines (11 welds in 12" lines and 6 welds in 16" line) were reported to show crack-like indications. All reported crack indications were oriented in the circumferential direction and located in the heat affected zones. Fifteen welds in the IC system inside the containment were also ultrasonically inspected and no crack-like indications were detected.

2.0 DISCUSSION AND EVALUATION

2.1 Inspection

Qualified UT personnel from GPU Nuclear Corporation (GPUN) and Virginia Corporation of Richmond (VCR) performed the ultrasonic examinations. Crack detection, discrimination and sizing were performed primarily by GPUN. VCR performed only confirmatory crack depth sizing on welds showing crack-like indications. The licensee indicated that one of the VCR UT personnel participating in the crack depth sizing took the UT sizing course given by EPRI at the NDE Center, Charlotte, North Carolina and passed the examinations. For some welds, the depth sizing results reported by the two teams did not always agree, with variations as much as 64% of the wall thickness. Region I has determined that the GPUN UT procedures, calibration standards, equipment and IGSCC detection capabilities were satisfactorily demonstrated in accordance with IE Bulletin 83-02, and that the same procedures and techniques were used in the UT examination. Region I also indicated that all GPUN UT personnel conducting these inspections have received appropriate training in IGSCC inspection using service induced IGSCC cracked thick-wall pipe specimens. As will be shown later, the UT sizing data were not relied upon for any repair considerations.

The radiographic examinations were also performed to assist the discrimination between the root geometry and cracks. The ultrasonic examinations identified 27 (22%) IC welds (class 2) outside the containment that contained crack-like indications. Of these, eight welds were classified as "suspect" because these welds could not be confirmed as cracks or classified as geometric reflectors. These suspect welds were conservatively treated as cracked welds. One of the suspect welds was later replaced and no cracks were found on that weld by penetrant examination. Of the 27 cracked welds, 9 welds were replaced and 17 welds were overlay repaired.

2.2 Failure Analysis

Two welds (NE-2-12 and NE-2-13) from the condensate line loop "A" and two welds (NE-1-15, loop A and NE-1-61, loop B) from the supply line were removed for failure analysis. General Electric's (GE) Turbine Technology Laboratory, GPUN's contractor, evaluated welds NE-1-15, NE-2-13, and the bottom half of NE-2-12 (containing the leaker). Brookhaven National Laboratory (BNL), the NRC's contractor, evaluated weld NE-1-61 and the top half of weld NE-2-12. GE performed liquid penetration examination on the inside surface of weld NE-2-13 which is a "suspect" weld. The weld revealed no crack indications. Both GE and BNL used scanning electron microscopy and conventional metallography to study the failure mode in the three cracked welds (NE-2-12, NE-1-15 and NE-1-61). They reported that all the cracks in these welds were intergranular, covered with heavy oxides and located adjacent to the weld bead.

The IC condensate return lines are normally stagnant and at ambient temperature because the condensate return isolation valves are closed during normal operating condition. The staff generally does not expect IGSCC to occur at ambient temperature because the initiation of IGSCC is a temperature-dependent process. However, the licensee reported that during the early operating years, the IC system was used quite frequently (at least 33 times), and extensive leakage through the condensate return isolation valves was observed at least seven times during the period of 1976 to 1980. The steam leakage through the isolation valves elevated the temperature of the condensate return lines and thus, accelerated the initiation of the cracks in the condensate return lines. Based on the reported operating history, the staff believes that the cracking probably occurred during the period when extensive leakage through the isolation valves was observed. This is also consistent with the observed heavy oxides on the fracture surfaces, which indicates that the cracks were not initiated recently.

Therefore, the staff considers that the cracking in the condensate return lines could be unique to Oyster Creek.

2.3 Repair

GE performed the weld overlay design of the 18 cracked welds for the licensee. The repair overlay was designed to meet the ASME Code Section XI IWB 3640 requirements and to provide a full structural reinforcement of the cracked weld. The overlay thickness was calculated based on a pressure of 1090 psi (corresponding to the technical specification limit for the opening of the electro-mechanical relief valves), and the maximum dead weight (3.3 ksi) and seismic (5.1 ksi) stresses enveloping all 18 cracked welds.

The overlay design is independent of the crack size as determined by the ultrasonic examination because the cracks in the repaired welds were assumed to be fully circumferential and extended through the original pipe wall. The designed minimum overlay thickness for various pipe sizes ranged from 0.25 inch to 0.40 inch, which did not include the thickness of the first layer that passed the Penetrant Test (PT) and the ferrite number tests. Radiography tests were performed on each finished weld overlay to ensure the structural and bonding integrity of the overlay.

The licensee has replaced the piping of nine welds (five 16" welds, two 12" welds and two 8" welds) which showed crack-like indications in the IC system. The replacement material for the 8" and 16" piping was purchased to type 316 stainless steel with carbon content not to exceed 0.05%, and the material of the 12" replacement piping was purchased to nuclear grade type 316 stainless steel. The nuclear grade type 316 stainless steel material for 8" and 16" pipe sizes was not available to meet the need date. The licensee reported that the replacement piping was upgraded to meet the requirements in ASME Section III subsection NC (class 2) and the welding process of low heat input was used during fabrication.

2.4 Evaluation

The staff has reviewed the licensee's submittals regarding the ultrasonic examination results, metallography evaluation, and weld overlay designs of the IC system piping at Oyster Creek to support continued service for one fuel cycle with 18 overlay repaired welds and 9 replaced welds in the IC piping system.

The staff has reviewed GE's weld overlay designs for the 18 IC welds showing crack-like indications. The overlays were designed to have a full structural strength and met all the repair guidelines in Generic Letter 84-11. Because of the current concerns regarding the conservatism of the ASME Code Section XI IWB 3640 limits, the staff performed an independent limit load analysis to evaluate the design safety margin that will be present in the GE's weld overlay designs. An enveloped calculation based on weld NE-2-80 in the condensate return line was performed.

Weld NE-2-80 has the thinnest overlay design (0.25 inch) and the largest thermal expansion stress (11.27 ksi). In the limit load analysis, the staff used a reduced flow stress of 45.5 ksi (corresponding to half of the ASME Code allowed yield stress plus tensile stress for 316 stainless steel at a temperature of 550°F) and included in the safety margin calculation the thermal stresses from the espansion (11.27 ksi) and overlay shrinkages (2.1 ksi). The "i" index of stress intensification factor was not considered in the thermal stresses. The thermal expansion stress for weld NE-2-80 was reported in a recent analysis of the IC system by MPR Associates, Inc. for the licensee, which was conservatively calculated based on a design temperature. The shrinkage stress was calculated based on the actual displacement measurements before and after repair. The staff's limit load calculations have shown that there is a safety factor of 5.2 on the bending stresses (8.25 ksi) which includes the primary (dead weight and seismic stresses) as well as the secondary (thermal expansion and shrinkage stresses) bending stresses. Therefore, the staff agrees with the licensee's conclusion that the continued operation of Oyster Creek for one fuel cycle with the 18 overlay repaired welds in the IC system is justified because the Code required structural safety margin in the 18 overlay repaired welds would be maintained.

During this refueling outage, the licensee replaced eight welds showing crack-like indications in the IC system. Two 12" welds were replaced with the nuclear grade type 316 stainless steel. Nuclear grade 316 stainless steel is considered to be not susceptible to IGSCC under normal BWR environment. The other six welds were replaced with conventional type 316 stainless steel material with carbon content not over 0.05%. Stainless steel piping with carbon content over 0.02% is considered to be susceptible to IGSCC in normal BWR environment because such materials are prone to sensitization when heated to elevated temperatures. It is known that an incubation period is required to initiate the IGSCC. The length of the incubation period depends on the environment, stress, and the degree of sensitization of the materials. Based on the BWR operating experiences, the staff does not expect significant cracks to be generated in the conventional austenitic stainless steel within a period of one fuel cycle. Furthermore, the piping was replaced by using a low heat input welding process to minimize the sensitization in the heat-affected zones. Therefore, the staff concludes that the six welds replaced with conventional type 316 stainless steel materials are acceptable for continued service of one fuel cycle.

The staff noted that the licensee relied on radiography tests (RT) to confirm the structural and bonding integrity of the repair overlays. This is not consistent with the present industry practice of using UT methods. RT is generally not as sensitive as UT in detecting the lack of bonding, lack of penetration and particularly, the small cracks in the overlays. UT is considered more sensitive than RT and should be used to confirm overlay integrity. However the staff acceptance of the RT results at this time is based on the following considerations:

(1) The overlay repaired IC welds are all class 2 welds located outside the containment. Monitoring of such welds for potential leakage can easily be made during normal operation.

(2) The NRC, Region I, has confirmed that the overlay repairs were properly performed in accordance with qualified procedures consistent with ASME Code Section XI requirements. Based on Region I's observations and the generally good experience with overlay repairs, the staff does not anticipate any major deficiencies in the structural and bonding integrity of the weld overlays applied at Oyster Creek.

(3) The licensee has agreed to ultrasonically inspect each overlay repaired weld during the next refueling outage to confirm the integrity of the overlays.

3.0 CONCLUSION

The staff has concluded that the Oyster Creek IC system piping has been inspected and repaired in accordance with all current staff guidelines, and that the plant can be safely returned to operation until the next refueling outage.

4.0 ACKNOWLEDGMENTS

W. Hazelton and W. Koo prepared this safety evaluation.

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