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SAFETY EVALUATION OF THE RESPONSE TO GL 94-03

FOR PERRY NUCLEAR POWER PLANT

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1.0 INTRODUCTION

The core shroud in a Boiling Water Reactor (BWR) is a stainless steel cylindrical component within the reactor pressure vessel (RPV) that surrounds the reactor core. The core shroud serves as a partition between feedwater in the reactor vessel's downcomer annulus region and the cooling water flowing up through the reactor core. In addition, the core shroud provides a refloodable volume for safe shutdown cooling and laterally supports the fuel assemblies to maintain control rod insertion geometry during operational transients and accidents.

In 1990, crack indications were observed at core shroud welds located in the beltline region of an overseas BWR. This reactor had completed approximately 190 months of power operation before discovery of the cracks. As a result of this discovery, General Electric Company (GE), the reactor vendor, issued Rapid Information Communication Services Information Letter (RICSIL) 054, "Core Support Shroud Crack Indications," on October 3, 1990, to all owners of GE BWRs. The RICSIL summarized the cracking found in the overseas reactor and recommended that at the next refueling outage, plants with high-carbon-type 304 stainless steel shrouds perform a visual examination of the accessible areas of the seam welds and associated heat-affected zone (HAZ) on the inside and outside surfaces of the shroud.

Subsequently, a number of domestic BWR licensees performed visual examinations of their core shrouds in accordance with the recommendations in GE RICSIL 054 or in GE Services Information Letter (SIL) 572, which was issued in late 1993 to incorporate domestic inspection experience. Of the inspections performed to date, significant cracking was reported at several plants. The combined industry experience from these plants indicates that both axial and circumferential cracking can occur in the core shrouds of GE designed BWRs.

On July 25, 1994, the NRC issued Generic Letter (GL) 94-03, "Intergranular Stress Corrosion Cracking of Core Shrouds in Boiling Water Reactors," to all BWR licensees (with the exception of Big Rock Point) to address the potential for cracking in their core shrouds. GL 94-03 requested BWR licensees to take the following actions with respect to their core shrouds:

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- inspect their core shrouds no later than the next scheduled refueling outage;
- perform a safety analysis supporting continued operation of the facility until the inspections are conducted;
- develop an inspection plan which addresses inspections of all shroud welds, and which delineates the examination methods to be used for the inspections of the shroud, taking into consideration the best industry technology and inspection experience to date on the subject;
- develop plans for evaluation and/or repair of the core shroud; and
- work closely with the BWR Owners Group on coordination of inspections, evaluations, and repair options for all BWR internals susceptible to intergranular stress corrosion cracking.

The Cleveland Electric Illuminating Company, the licensee for the Perry Nuclear Power Plant (PNPP), responded to GL 94-03 on August 24, 1994. The licensee's response included a current schedule for inspecting the PNPP core shroud, justification supporting continued operation of the plant, a description of the shroud, and a discussion of past core shroud inspection results. This Safety Evaluation gives the staff's assessment of the licensee's response to GL 94-03.

2.0 JUSTIFICATION FOR CONTINUED OPERATION AND SCHEDULE FOR INSPECTION

The following is the staff's assessment of the licensee's basis for justifying continued operation of PNPP from July 25, 1994, the date of issuance of GL 94-03, until the licensee can inspect the PNPP core shroud.

The licensee has tentatively scheduled a core shroud inspection for the first quarter of 1996, subject to additional lessons learned from inspections at other plants and the recommendations of the BWR Vessel and Internals Project (BWRVIP). The staff position regarding the recommended schedule for inspection of the licensee's core shroud is in agreement with the BWRVIP inspection guidelines (Reference 1). Licensees of "Category A" plants should inspect their core shroud no later than the first outage after the plant surpasses 8 on-line years of operation. PNPP is categorized as an "A" plant. Therefore, the licensee may opt to reschedule the core shroud inspection date in accordance with staff approved BWRVIP guidelines.

2.1 Susceptibility of Core Shrouds to IGSCC

The core shroud cracks, which are the subject of GL 94-03, result from intergranular stress corrosion cracking (IGSCC) which is most often associated with sensitized material near the component welds. IGSCC is a time-dependent phenomena requiring a susceptible material, a corrosive environment, and a tensile stress within the material.

Industry experience has shown that austenitic stainless steels with low carbon content are less susceptible to IGSCC than stainless steels with higher carbon content. BWR core shrouds are constructed from either type 304 or 304L stainless steel. Type 304L stainless steel has a lower carbon content than type 304 stainless steel. During the shroud fabrication process when the sections of the core shroud are welded together, the heating of the material adjacent to the weld metal sensitizes the material. Sensitization involves carbon diffusion out of solution forming carbides at grain boundaries upon moderate heating. The formation of carbides at the grain boundaries depletes the chromium in the adjacent material. Since the corrosion resistance of stainless steel is provided by the presence of chromium in the material, the area adjacent to the grain boundary depleted of chromium is thereby susceptible to corrosion. Increased material resistance to IGSCC will result if the carbon content is kept below 0.035%, as specified for type 304L grade material.

Currently available inspection data indicate that shrouds fabricated with forged ring segments are more resistant to IGSCC than rings constructed from welded plate sections. The current understanding for this difference is related to the surface condition resulting from the two shroud fabrication processes. Welded shroud rings are constructed by welding together arcs machined from rolled plate. This process exposes the short transverse direction in the material to the reactor coolant. Elongated grains and stringers in the material exposed to the reactor coolant environment are believed to accelerate the initiation of IGSCC.

Water chemistry also plays an important role in regard to IGSCC susceptibility. Industry experience has shown that plants which have operated with a history of high reactor coolant conductivity have been more susceptible to IGSCC than plants which have operated with lower conductivities[1]. Furthermore, industry experience has shown that reactor coolant systems (RCSs) which have been operated at highly positive, electro-chemical potentials (ECPs) have been more susceptible to IGSCC than RCSs that have been operated at more negative ECPs[2]. The industry has made a considerable effort to improve water chemistry at nuclear facilities over the past ten years.

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[1]Conductivity is a measure of the anionic and cationic content of liquids. As a reference, the conductivity of pure water is ~0.05 μs/cm. Reactor coolants with conductivities below 0.20 us/cm are considered to be relatively ion free; reactor coolants with conductivities above 0.30 μs/cm are considered to have a relatively high ion content.

[2]The electrochemical potential (ECP) is a measure of a material's susceptibility to corrosion. In the absence of an externally applied current, and therefore, for reactor internals in the RCS, the electrochemical potential is equal to the open circuit potential of the material. Industry experience has shown that crack growth rates in reactor internals are low when the ECP $\leq$ --0.230 volts.

Welding processes can introduce high residual stresses in the material at the weld joint. The high stresses result from thermal contraction of the weld metal during cooling. A higher residual tensile weld stress will increase the material's susceptibility to IGSCC. Although weld stresses are not easily quantified, previous investigation into weld stresses indicate that tensile stresses on the weld surface may be as high as the yield stress of the material. The stress decreases to compressive levels in the center of the welded section.

2.2 Basis for Continued Operation

In response to GL 94-03, the licensee submitted a justification for continued operation (JCO) based on the core shroud material's susceptibility to IGSCC. The following are the major factors considered in the staff's assessment:

- the limited operational time will minimize the extent of IGSCC, if any, in the PNPP core shroud;
- the reactor coolant conductivity has been much better, on average, than other operating BWRs; and
- the PNPP core shroud was constructed with low carbon materials which have a higher resistance to IGSCC initiation.

A longer time of operation increases the potential for the initiation and growth of IGSCC. PNPP had 4.1 on-line years at the time of their response to GL 94-03. Other BWRs with shrouds more susceptible to IGSCC which have accumulated considerably longer operational times have inspected their core shrouds. In none of these cases has a licensee identified cracks which diminished the structural margin of the core shroud to unacceptable levels. The operating time of PNPP is significantly less than for other BWRs which have inspected and found significant cracking.

PNPP operated at low reactor coolant ionic content levels during the initial years of operation. During the first five cycles of operation, the average reactor coolant conductivity for the PNPP coolant was 0.2 μS/cm, which is considerably lower than the average for the entire population of U.S. BWRs (where the conductivities range from ~0.123 μS/cm to 0.717 μS/cm, and average ~0.340 μS/cm). This plant was among the top performers in BWR water chemistry during the initial years of operation.

The PNPP core shroud is constructed from type 304L stainless steel with a carbon content less than 0.021%. The reduced carbon levels decrease the likelihood for core shroud IGSCC initiation as compared with shrouds fabricated from type 304 stainless steel.

Taking into account the above factors, and qualitatively comparing these factors with those of other BWRs with shroud inspection data, the staff concludes that the licensee's core shroud is susceptible to IGSCC, although to a lesser degree than core shrouds inspected at other BWRs. The possibility exists that the PNPP core shroud contains some degree of cracking. However, if any cracking exists, it is not likely to be significant. The staff and the BWROG have agreed upon the categorization of plants according to their relative susceptibility to core shroud IGSCC. Each plant is classified into one of three separate groups, Category A, B or C. Category A plants are considered least susceptible to IGSCC based on the factors discussed previously. PNPP is considered a Category A plant.

The staff has reviewed the inspection results for other BWRs with core shrouds more susceptible to IGSCC and notes that there has been no instance where a 360° through-wall crack existed in any plant that was inspected. Further, no BWR has exhibited any symptoms (power to flow mismatch) indicative of leakage through a 360° through-wall crack. All analyses performed by licensees for higher susceptibility plants show that even if cracking did exist, ligaments would exist to assure structural integrity.

Due to the combination of the above factors, an inspection of the PNPP core shroud is not immediately necessary because the likelihood of significant cracking is limited.

3.0 CONCLUSION

The staff concludes that while cracking cannot be entirely ruled out, the PNPP core shroud is not likely to contain cracks which could compromise its structural integrity. The low water conductivity, short operational time, and use of low carbon materials minimize the potential for the initiation and growth of structurally significant cracks. Because the possibility exists for core shroud IGSCC, the licensee should perform an inspection in accordance with the staff approved guidance for low susceptibility plants. This means an inspection should be performed no later than the first outage after the plant surpasses 8 on-line years of operation. The staff has reviewed the licensee's basis for justifying continued operation of PNPP and has determined that the licensee's materials-based JCO is acceptable.

4.0 OUTSTANDING ISSUES/FUTURE ACTIONS

In accordance with the reporting requirements of GL 94-03, the licensee shall submit to the NRC, no later than 3 months prior to performing the core shroud inspections, both the inspection plan and the licensee's plans for evaluating and/or repairing of the shroud based on the inspection results. In addition, results should be provided to the NRC within 30 days from the completion of the inspection.

The licensee indicated in their response that they may adjust their core shroud inspection schedule and scope per guidance from the BWRVIP. At present, the NRC has not approved the inspection guidelines proposed by the BWRVIP. Considerable differences remain with regard to the recommended scope of core shroud inspections. The staff cautions the licensee against modifying their plans according to BWRVIP recommendations, which have not undergone review and approval by the NRC. Should the licensee opt to install a preemptive repair in lieu of performing a comprehensive core shroud inspection, the only required inspection is that mandated in the staff approval of the repair option.

5.0 REFERENCE

"BWR Core Shroud Inspection and Evaluation Guidelines," GENE-523-113-084, September 1994.

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