UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION OF THE RESPONSE TO GENERIC LETTER 94-03

EDWIN I. HATCH NUCLEAR PLANT, UNITS 1 AND 2

GEORGIA POWER COMPANY, ET AL.

DOCKET NOS. 50-321 AND 50-366

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. It 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," dated 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 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 of GE RICSIL-054, or 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 which does not have a core shroud) to address the potential for cracking in the core shrouds. GL 94-03 requested BWR licensees to take the following actions:

9503010132 950223
PDR ADOCK 05000321
P PDR

- inspect the 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 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 (BWROG) on coordination of inspections, evaluations, and repair options for all BWR internals susceptible to intergranular stress corrosion cracking.

Georgia Power Company (GPC), the licensee for Hatch Units 1 and 2, responded to GL 94-03 on August 24, 1994 (Reference 1). On September 2, 1994, GPC submitted for NRC staff review and approval the modification design for Hatch Unit 1 core shroud (Reference 2).

For Hatch Unit 2, GPC submitted the scope for the re-inspection of the Hatch Unit 2 core shroud, and indicated that they intend to implement a modification of the Hatch Unit 2 core shroud during the fall 1995 refueling outage (RFO) in the same manner as was implemented for the Hatch Unit 1 shroud during the fall 1994 RFO (Reference 1).

The following sections provide the staff's assessment of the likelihood for the development of intergranular stress corrosion cracking (IGSCC) in the core shroud at Hatch Unit 1, and discuss the revised inspection scope for the Hatch Unit 1 core shroud modification. They also provide the staff's assessment of Hatch Unit 2 shroud inspection completed during the spring 1994 RFO and GPC's basis for justifying continued operation of the Hatch Unit 2 reactor until the fall 1995 RFO.

2.0 Evaluation of Justification for Continued Operation of Hatch Units 1 and 2

For Hatch Unit 1, GPC completed the installation of a modification to the core shroud during the 1994 RFO which commenced on September 21, 1994. The core shroud modification was implemented in lieu of comprehensive core shroud examinations. The modification involves the installation of a number of symmetrically placed tie rod assemblies into the annulus between the reactor vessel wall and the core shroud. The modification ensures the structural integrity of the core shroud in the event that significant cracks develop in the shroud welds. The staff completed a review of the modification and found it acceptable as documented in a safety evaluation report (SER) dated September 30, 1994 (Reference 3).

For Hatch Unit 2, GPC performed an inspection of the core shroud during the Unit 2 spring 1994 (March-April 1994) RFO. Structural evaluations of the circumferential shroud welds have indicated that the Hatch Unit 2 core shroud will maintain its structural margins for at least two operating cycles. Therefore, as a minimum, justification for operation of the Hatch Unit 2 reactor is acceptable until the fall 1995 RFO.

2.1 Susceptibility of the Hatch Units 1 and 2 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 of 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 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, electrochemical 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. Industry initiatives have included the introduction of hydrogen water chemistry as a means of lowering ECPs (i.e., making the ECPs more negative) in the RCS. The effectiveness of hydrogen water chemistry in reducing the susceptibility of core shrouds to IGSCC initiation has not been fully evaluated; however, its effectiveness in reducing IGSCC in recirculation system piping has been demonstrated.

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.

Georgia Power has reviewed the materials as well as the fabrication and operational histories (water chemistry and on-line years) of the Hatch Unit 1 core shroud and has submitted this information to the staff in their response to GL 94-03. The Hatch Unit 1 plant-specific susceptibility factors are summarized below.

i) The top flange ring, top guide support ring and core support plate ring are each constructed from six arc segments that were cut from rolled type 304 stainless steel plates, with carbon contents of ~0.060 %C.

---

[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 μs/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.

ii) Weld residual stress levels are considered to be high based on weld shrinkage estimates.

iii) The Hatch Unit 1 reactor had initially been operated with a high-ionic content reactor coolant. The initial five year average coolant conductivity for Hatch Unit 1 was 0.411 μs/cm, which is considered high relative to the majority of U.S. BWRs (where the conductivities range from ~0.123 μs/cm to 0.717 μs/cm, and average ~ 0.340 μs/cm for the 36 U.S. domestic BWRs).

iv) GPC has operated the Hatch Unit 1 reactor for 12.8 cumulative years at full power, which is slightly above the average for the entire population of U.S. BWRs (range is 3.7 years - 17.8 years)

v) The Hatch Unit 2 reactor had initially been operated with a high-ionic content reactor coolant. The initial five year average coolant conductivity for Hatch Unit 2 was 0.459 μs/cm, which is considered high relative to the majority of U.S. BWRs (where the conductivities range from ~0.123 μs/cm to 0.717 μs/cm, and average ~ 0.340 μs/cm for the 36 U.S. domestic BWRs).

vi) GPC has operated the Hatch Unit 2 reactor for 10 cumulative years at full power, which is slightly above the average for the entire population of U.S. BWRs (range is 3.7 years - 17.8 years)

The BWR Vessel Internals Project (BWRVIP) has determined that the Hatch Units 1 and 2 shrouds are highly susceptible to IGSCC, and has rated them as Category "C" shrouds (Reference 4). Considering the above plant-specific susceptibility factors as well as the experience gained from inspections conducted at and other BWRs, the staff finds that the BWRVIP assessment of the Hatch Unit 1 and 2 shrouds is acceptable, and concludes that significant cracking of the Hatch Units 1 and 2 core shrouds cannot be ruled out.

2.2 Modification of the Hatch Unit 1 Core Shroud

Georgia Power did not schedule an inspection of the Hatch Unit 1 core shroud for the fall 1994 refueling outage (RFO), which commenced September 21, 1994. Instead, the licensee installed a modification to the Hatch Unit 1 core shroud.

Georgia Power submitted an assessment of the proposed modification to the staff on September 2, 1994 (Reference 2). It involves the installation of four low tension tie rod assemblies into the annulus of the reactor. The modification is designed to structurally replace all circumferential welds, H1 - H8, in the shroud. The staff reviewed the licensee's shroud modification submittal and accepted the design. The staff issued an SER to GPC on September 30, 1994 (Reference 3).

2.2.1 Inspection of Core Shroud Repair Components

The staff concluded in the SER, dated September 30, 1994 (Reference 4), that a structural modification of the Hatch Unit 1 core shroud was acceptable in lieu of implementing comprehensive core shroud inspections. The staff also concluded that the design of the modification was acceptable for implementation. The licensee included in the submittal of September 2, 1994, their scope for pre-repair and post-repair examinations of the core shroud (Reference 2). The amended scope included the following inspections.

- Pre-modification - Enhanced VT-1 inspections of the four gussets to be used in the modification design, including the welds between the gussets and both the reactor pressure vessel (RPV) wall and the shroud support plate.

- Post-modification - Enhanced VT-1 inspections of all clevis pins used in the modification, each core plate wedge assembly, each stabilizer assembly in contact between the RPV wall and the upper contact, mid support contact and lower contact, and each stabilizer assembly in contact between the shroud and the upper support and lower spring.

The staff concluded that the changes to the inspection scope of the repair components were in accordance with the "BWR Core Shroud Repair Design Criteria," which were proposed by the BWRVIP Repair Technical Subcommittee on August 18, 1994 (Reference 5), and amended on September 13, 1994 (Reference 6).

The scope of the licensee's modification submittal did not include any criteria for augmented, non-destructive examinations (i.e., augmented inservice inspections) of the repair assemblies during subsequent refueling outages. In a letter to R. A. Pinelli, Chairman of the BWR Owners Group, dated August 31, 1994 (Reference 7), the staff stated that it considers the modifications of core shrouds to be alternatives to Section XI of the ASME Code. Such alternatives to the ASME Code fall under the scope of 10 CFR 50.55a. The staff has therefore taken the position that licensees implementing shroud modifications/repairs would be required to augment their Inservice Inspection (ISI) Programs to include examination of the modification/repair designs. This position is stated in Section 2.2.7 of the staff's SER, "Safety Evaluation on Boiling Water Reactor (BWR) Core Shroud Repair Design Criteria," which was issued to the BWRVIP Repair Technical Subcommittee on September 29, 1994 (Reference 8). Therefore, per the SER dated September 30, 1994, the staff requested that GPC submit its augmented ISI scope for inspection of the gussets and tie rod assemblies during subsequent refueling outages (Reference 3). The licensee submitted its augmented inspection scope for inspecting the tie rod assemblies on December 19, 1994 (Reference 9). The staff will issue a separate correspondence regarding the December 19, 1994, submittal.

2.3 Inspection of the Hatch Unit 2 Core Shroud during Spring 1994 RFO

2.3.1 Scope of Previous Core Shroud Inspection

The licensee's shroud inspections were performed prior to issuance of GL 94-03, and were considered by the staff to be comprehensive at the time of inspection. UT examinations of the Hatch Unit 2 core shroud were performed using the GE Corporation O.D. Tracker UT Scanner, the GE SMART 2000 Data Acquisition/Analysis System, and a PC based motion controller (GE Motion Controller). Enhanced VT-1 examinations were performed in accordance with the recommendations of SIL-572, Rev. 1. The VT-1 examinations were performed using a high resolution camera capable of resolving a 0.001 inch wire on a gray background.

The licensee included a description of the inspection scope of the Hatch Unit 2 core shroud conducted during the most recent RFO. The inspections of the shroud included an examination of the following shroud locations:

- 100% UT examinations (from the O.D. surface) of the accessible areas of welds H1 - H4, and

- partial enhanced VT-1 (visual) inspections from the O.D. surface of shroud welds H5, H6a, H6b, H7 and H8, at the 0° and 180° azimuthal locations.

2.3.2 Inspection Results

During the previous inspections of the Unit 2 core shroud, cracking was identified at several locations of the circumferential weld. The following summarizes the inspection results:

- five indications at shroud weld H1, with the longest indication being approximately 9 inches in length,

- nine indications at shroud weld H2, with the longest indication being approximately 159 inches in length (~ 1/4 around the circumference of the shroud at this location),

- eight indications at shroud weld H1, with the longest indication being ~17 inches in length,

- fifteen indications at shroud weld H4, with the longest indication being approximately 11 inches in length, and

- no indications were discovered in the areas inspected on the H5 - H8 welds.

2.3.3 Evaluation and Assessment of Inspection Results

General Electric performed a flaw evaluation of the H1 - H4 weld indications in order to show the Hatch Unit 2 core shroud would maintain its structural margins for the next Unit 2 operating cycle (Reference 10). The flaw evaluation of the was included as part of the GPC's response to GL 94-03. The analyses involved calculating the maximum allowable flaw lengths and the stress magnitudes of the core shroud. Both limit load and linear elastic fracture mechanics (LEFM) methods were used for the analysis of the H4 weld indications since the H4 weld is located near the core in an area of high neutron fluence. Only limit load analysis was performed for evaluation of the H1, H2 and H3 welds, where the neutron fluence levels are lower. The licensee's flaw evaluations included adjustments to account for crack proximities, crack growth and non-destructive examination uncertainties.

The licensee's flaw evaluation concluded that the Hatch Unit 2 core shroud has sufficient remaining ligament and will meet the structural margin requirements of Section XI of the ASME Code for the remainder of the current operating cycle. The staff has reviewed the licensee's flaw evaluation of the Hatch Unit 2 core shroud and concluded that the licensee's flaw evaluation uses a conservative method for determining structural integrity and is, therefore, acceptable.

3.0 CONCLUSIONS

The staff has reviewed the licensee's response to GL 94-03 and has determined that the licensee has provided the operational history, materials and fabrication-related information requested in the GL.

Based on its review of this information, the staff concludes that the Hatch Unit 1 core shroud modification is designed to assume the most severe loads during normal operating, transient, and design basis event conditions. Furthermore, the staff concludes that the implementation of the core shroud modification would ensure the structural integrity of the Hatch Unit 1 core shroud.

The licensee's flaw evaluation of the Hatch Unit 2 core shroud, which was submitted as part of the licensee's response to GL 94-03, indicates that the shroud is acceptable for continued service during the remainder of the current Unit 2 operating cycle, which concludes in the fall of 1995.

4.0 OUTSTANDING ISSUES

There are no outstanding issues or staff comments in regard to the licensee's previous inspections and evaluations of the Hatch Unit 2 core shroud. However, GL 94-03 requested that licensees should submit their plans for re-inspection/modification of the core shroud no later than 90 days prior to entering their plant's refueling outage.

It should be noted that the industry is currently encountering difficulties performing comprehensive inspections of lower shroud welds due to accessibility problems associated with NDE equipment. Currently, licensees are working with various vendors and members of the EPRI NDE Center in order to develop improved, reliable tooling for inspection of the lower shroud welds and the lower vessel regions which are highly obstructed. Should improved inspection techniques become available, the staff recommends that GPC inspect the lower shroud welds and lower vessel regions at the earliest opportunity.

Principal Contributor: J. Medoff, NRR

Date: February 23, 1995

5.0 REFERENCES

1. Letter from J. T. Beckham, Vice President, Georgia Power Company, to the U.S. Nuclear Regulatory Commission transmitting the "Edwin I. Hatch Nuclear Plant BWR Core Shroud Cracking Response to Generic Letter 94-03," dated August 24, 1994.

2. Letter from J. T. Beckham, Vice President, Georgia Power Company, to the U.S. Nuclear Regulatory Commission transmitting the "Edwin I. Hatch Nuclear Plant Unit 1 Installation of Core Shroud Stabilizers for Core Shroud Stabilizer Design Submittal," including supporting General Electric Corporation Documentation and Procedures, dated September 2, 1994.

3. Letter from Kahtan N. Jabbour, Project Manager, Project Directorate II-3, Division of Reactor Projects - I/II, Office of Nuclear Reactor Regulation, to Mr. J. T. Beckham, Vice President - Plant Hatch, Georgia Power Company, transmitting the "Safety Evaluation Report for Core Shroud Stabilizer Design - Edwin I. Hatch Nuclear Plant, Unit 1 (TAC No. M90270)," dated September 30, 1994.

4. Letter from Carl Terry, Executive Chairman of the BWRVIP Assessment Subcommittee, to the NRC, transmitting the "BWR Core Shroud Inspection and Evaluation Guidelines," dated September 2, 1994.

5. Letter from Carl D. Terry, Executive Chairman of the BWRVIP Assessment Committee, to the NRC, dated August 18, 1994, transmitting the "BWR Core Shroud Repair Design Criteria," dated August 18, 1994.

6. Letter from J. T. Beckham, Chairman, BWRVIP, to the NRC, dated September 13, 1994, transmitting the "Response to NRC Request for Additional Information (RAI) Regarding Boiling Water Reactor (BWR) Core Shroud Repair Design Criteria," and Including "Revision 1 of the Core Shroud Repair Design Criteria."

7. Letter from Ashok C. Thadani, Associate Director for Inspection and Technical Assessment, Office of Nuclear Reactor Regulation, NRC, to Robert A. Pinell, Chairman, BWR Owners Group, dated August 31, 1994, transmitting the staff's position on the "Boiling Water Reactor (BWR) Core Shroud Repair Design Criteria."

8. Letter from Brian W. Sheron, Director, Division of Engineering, Office of Nuclear Reactor Regulation, NRC, to Bruce McLeod, Chairman, BWRVIP Technical Subcommittee on Repair, dated September 29, 1994, transmitting the staff's "Safety Evaluation on Boiling Water Reactor (BWR) Core Shroud Design Criteria."

9. Letter from J. T. Beckham, Vice President, Georgia Power Company, to the NRC, dated December 19, 1994, transmitting the "Edwin I. Hatch Nuclear Plant - Unit 1 Core Shroud Stabilizers Augmented Inspection Program."

10. GE Nuclear Energy Report GENE 523-A86-0594, "Evaluation of the Indications in the Plant Hatch Unit-2 Core Shroud Welds H1, H2, H3, and H4," dated July 1994 and submitted with Reference 1 above.