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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RESPONSE TO GENERAL LETTER 94-03

PEACH BOTTOM ATOMIC POWER STATION, UNIT 3

PECO ENERGY COMPANY

DOCKET NO. 50-277

1.0 BACKGROUND

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, which does not have a core shroud) 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:

- inspect their core shrouds no later than the next scheduled refueling outage;

Enclosure 1

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

The PECO Energy Company (PECo), the licensee for the Peach Bottom Atomic Power Station Unit 3 (PBAPS 3), responded to GL 94-03 on August 24, 1994 (Reference 1). Part of the licensee's response included PECo's inspection scope for the planned re-inspections of the PBAPS 3 core shroud, which have been scheduled for refueling outage (RFO) 3R10 in the fall of 1995. The licensee completed an inspection of the PBAPS 3 core shroud during the previous RFO in the fall of 1993. The General Electric Nuclear Energy Division formally submitted the examination results and assessment of core shroud structural integrity to the NRC by letter dated December 3, 1993 (Reference 2). PECo amended the results and assessment by letter dated March 14, 1994 (Reference 3).

2.0 STAFF'S EVALUATION OF THE LICENSEE'S RESPONSE TO GL 94-03

PECo completed a limited visual inspection of the PBAPS 3 core shroud during the 3R9 RFO in the fall of 1993. The licensee has planned a more comprehensive inspection of the PBAPS 3 core shroud for the next RFO, scheduled for the fall of 1995.

2.1 Susceptibility of the PBAPS 3 Core Shroud 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 that 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, 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 10 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.

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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.

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.

PECo has reviewed the materials, fabrication and operational histories of the PBAPS 3 core shroud and has submitted this information to the staff in their response to GL 94-03. The PBAPS 3 plant-specific susceptibility factors are summarized below:

- The shroud support, top guide support, and core support plate rings are fabricated from two welded 304 stainless steel, forged ring segments, with carbon contents of ~0.030%. The shroud shell region was fabricated by welding rolled 304 stainless steel plates together. The carbon content of the PBAPS 3 shroud plates are in the range of 0.050 - 0.065%.

- Welding of the shroud plates and rings for circumferential welds H1 - H6 was accomplished by submerged arc welding using ER308 filler metal. Welding of the bi-metallic weld, H7, was accomplished by gas metal arc welding using filler metal 82. Weld residual stress levels resulting from these fabrication processes are high.

- PBAPS 3 operated at high reactor coolant ionic content levels during the initial years of operation. The initial five year average coolant conductivity for PBAPS 3 was 0.695 μS/cm, which is considerably higher than the average for other U.S. BWRs (where the conductivities range from ~0.123 μS/cm to 0.717 μS/cm, and average ~ 0.340 μS/cm).

- PBAPS 3 has operated for 11 cumulative years at full power, which is slightly above the median for U.S. BWRs (range is 3.7 years - 17.8 years, with a median of 10.8 years).

A review of the plant-specific factors which increase the potential for IGSCC in BWR core shrouds reveals that PBAPS 3 initially operated at high reactor coolant conductivity during the first five cycles of operation. In addition, the carbon content of the material which comprises the PBAPS 3 core shroud is relatively high. On these bases, the Boiling Water Reactor Vessels & Internals Project (BWRVIP) has classified the PBAPS 3 core shroud as a susceptible Category "C" shroud. The staff has also determined that the PBAPS 3 core shroud is susceptible to IGSCC, and therefore concludes that the BWRVIP's susceptibility assessment is acceptable. This conclusion is supported by the identification of moderate cracking during the previous core shroud inspection. This is discussed further in the following section.

2.2 Inspection of the Peach Bottom Unit 3 Core Shroud

PECo inspected the PBAPS 3 core shroud during RFO 3R9 in the fall of 1993. The staff previously reviewed the licensee's evaluation of the PBAPS 3 core shroud and determined that the licensee's assessment justified continued operation of PBAPS 3 for the current operating cycle (Operating Cycle 10). The staff's assessments of the licensee's inspection scope and flaw evaluation are provided in References 4 and 5 listed under Section 5.0 of this Safety Evaluation (SE, The following is a description and staff assessment of the licensee's core shroud inspection.

2.2.1 Inspection Scope and Results for Core Shroud Examinations

The inspections completed during RFO 3R9 were done in accordance with recommendations of SIL-572, Revision 1. The scope of the inspections included examination via enhanced VT-1 methods. The licensee initially completed a partial examination of the core shroud circumferential welds. Their original inspection scope required enhanced VT-1 examinations at eight (8) cell locations of the H1, H2, H3, H4, and H5 welds. The licensee expanded the inspection scope after discovering indications at the H3 and H4 welds.

The expanded scope included the following examinations:

- 100% enhanced VT-1 from the inside diameter (ID) of the H3 and H4 welds;
- 100% enhanced VT-1 of accessible areas of weld H4 on the outside diameter (OD);
- enhanced VT-1 examinations of the H3 weld from the OD in areas where cracking was not indicated on the ID;
- an enhanced VT-1 examination of the H3 weld from the OD in areas where cracking was indicated on the ID;
- enhanced VT-1 examinations at six (6) locations of the H6 weld;
- enhanced VT-1 examinations at two (2) locations of the respective H7 and H8 welds;
- enhanced VT-1 examination of one (1) vertical weld between the H3 and H4 welds; and
- enhanced VT-1 examination of the of the mid-shroud plates.

The licensee's VT-1 examinations identified a large (~105 inch) crack in the H3 weld (the weld joining the top guide support ring to the upper mid-shroud shell). Less extensive cracking was also found at the H4 weld (< 30 inches total). Minor cracking was determined to exist at weld H1 and at one of the vertical shroud welds.

2.2.2 Evaluation of the Peach Bottom 3 Core Shroud Inspection Results

PECo's evaluation and disposition of the inspection data was the basis for justifying operation of the PBAPS 3 Unit during the current operating cycle (Cycle 10). PECo issued a preliminary draft on the Peach Bottom Unit 3 core shroud flaw evaluation during the PECo/NRC meeting of November 3, 1993, at Rockville, Maryland. PECo formally submitted this flaw evaluation to the staff on December 3, 1993 (Reference 2), and amended it on March 14, 1994 (Reference 3). The licensee's flaw evaluation was performed in accordance with the methods found in General Electric (GE) Document GENE-523-141-1093, "Evaluation and Screening Criteria for the Peach Bottom Unit 3 Shroud Indications," Rev. 0 (Reference 2) and Rev. 1 (Reference 3). The licensee's submittal included the results of the PBAPS 3 core shroud inspections performed during the previous RFO.

Flaw evaluations of the PBAPS 3 shroud were performed in accordance with the structural margin criteria found in Section XI of the ASME Code. Evaluations of the indications of the PBAPS 3 core shroud, which included adjustments to account for crack proximities, crack growth and non-destructive examination uncertainties, indicated that the PBAPS 3 core shroud would maintain sufficient structural integrity for the current operating cycle (Operating Cycle 10).

2.2.3 Staff Assessment of the Peach Bottom Unit 3 Inspection and Evaluation

The staff concluded (References 4 and 5), after reviewing PECo's inspection scope for the VT-1 examinations, that the inspection scope was sufficient to ascertain the condition of the PBAPS 3 shroud. The staff also concluded (References 4 and 5) that the licensee's flaw evaluation method was acceptable and that PBAPS 3 core shroud would meet structural margin requirements during the current operating cycle. PECo is required by GL 94-03 to submit its inspection scope for re-inspection of the PBAPS 3 core shroud 90 days prior to entering the fall 1995 RFO.

3.0 CONCLUSIONS

Based on a review of the PBAPS 3 core shroud materials, fabrication processes and operating history, the staff concludes that the licensee's core shroud is susceptible to IGSCC. PECo completed an examination of the PBAPS 3 core shroud during RFO 3R9. The licensee's assessment of identified weld cracking indicates that the PBAPS 3 core shroud will maintain sufficient structural margins throughout the current operating cycle. The staff concluded that the licensee's flaw evaluation of the PBAPS 3 core shroud was acceptable and justified operation of the PBAPS 3 reactor for the current operating cycle (References 4 and 5).

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. If the licensee identifies any core shroud cracking requiring an analysis per the ASME code, details of such evaluations must also be submitted to the NRC for review.

It should be noted that the industry is currently encountering difficulties performing comprehensive inspections of lower shroud welds and /or lower vessel regions due to NDE equipment accessibility problems. The staff urges licensees to work with the members of the EPRI NDE Center in order to develop improved tooling for inspections of shroud welds and lower vessel regions which are highly obstructed. Should improved inspections techniques become available, the staff recommendation is for licensee's to re-inspect the lower shroud welds at the earliest opportunity.

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. The staff's current position with regard to the scope of inspections is a recommendation for the inspection of 100% of the accessible core shroud welds. 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 REFERENCES

1. Letter from G. A. Hunger, Jr., Director of Licensing, PECO Energy Company, to the U.S. Nuclear Regulatory Commission forwarding the "Peach Bottom Atomic Power Station, Units 2 and 3, Limerick Generating Station Units 1 and 2 Response to Generic Letter 94-03, 'Intergranular Stress Corrosion Cracking of Core Shroud in Boiling Water Reactors,'" dated August 24, 1994.

2. Letter from M. L. Herrera and H. Mehta, General Electric Nuclear Energy, to the U.S. Nuclear Regulatory Commission forwarding the General Electric "Evaluation and Screening Criteria for the Peach Bottom Unit-3 Shroud Indications," Rev. 0, (GENE-523-141-1093) dated December 3, 1993.

3. Letter from G. A. Hunger, Jr., Director of Licensing, PECO Energy Company, to the U.S. Nuclear Regulatory Commission forwarding the General Electric "Evaluation and Screening Criteria for the Peach Bottom Unit-3 Shroud Indications," Rev. 1, (GENE-523-141-1093) dated March 14, 1994.

4. NRC internal memorandum from Jack R. Strosnider, Chief, Materials and Chemical Engineering Branch, Division of Engineering, to Larry E. Nicholson, Acting Director, Project Directorate, I-2, Division of Reactor Projects I/II, forwarding staff's "Evaluation of Peach Bottom Shroud Cracks," dated November 9, 1993.

5. Stephen Dembek, Project Manager, Project Directorate I-2, Division of Reactor Projects - I/II, Office of Nuclear Reactor Regulation, issuance of "Meeting Summary, Evaluation of Core Shroud Indications at Peach Bottom, Unit 3 (TAC No. M88099)," dated December 2, 1993.

Principal Contributor: J. Medoff

Date: February 6, 1995

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RESPONSE TO GENERIC LETTER 94-03

PEACH BOTTOM ATOMIC POWER STATION, UNIT 2

PECO ENERGY COMPANY

DOCKET NO. 50-277

1.0 BACKGROUND

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.

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

The PECO Energy Company (PECo), the licensee for the Peach Bottom Atomic Power Station Unit 2 (PBAPS 2), responded to GL 94-03 on August 24, 1994 (Reference 1). Part of the licensee's response included PECo's inspection scope for the planned inspection of the PBAPS 2 core shroud, scheduled for refueling outage (RFO) 2R10, which commenced on September 16, 1994. PECo also submitted an analysis of its proposed modification for the shroud circumferential welds. This modification was not implemented during the Unit 2 RFO 2R10. The staff's evaluation of PECo's proposed modification will be addressed in a separate Safety Evaluation Report (SER).

2.0 EVALUATION OF THE LICENSEE'S RESPONSE TO GL 94-03

PECo scheduled and performed comprehensive inspections of the PBAPS 2 core shroud during the unit's RFO 2R10, which commenced on September 16, 1994. The following gives the staff's assessment of the susceptibility of the PBAPS 2 core shroud, the scope of the inspection completed during RFO 2R10, and the licensee's assessment of identified cracking.

2.1 Susceptibility of the PBAPS 2 Core Shroud 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 that 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, 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 10 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.

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[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.

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.

PECo has reviewed the materials, fabrication and operational histories of the PBAPS 2 core shroud and has submitted this information to the staff in their response to GL 94-03. The PBAPS 2 plant-specific susceptibility factors are summarized below:

- The shroud support, top guide support, and core support plate rings are fabricated from two welded 304 stainless steel, forged ring segments, with carbon contents of ~0.030%. The shroud shell region was fabricated by welding rolled 304 stainless steel plates together. The carbon content of the PBAPS 2 shroud plates are in the range of 0.050 - 0.065%.

- Welding of the shroud plates and rings for circumferential welds H1 - H6 was accomplished by submerged arc welding using ER308 filler metal. Welding of the bi-metallic weld, H7, was accomplished by gas metal arc welding using filler metal 82. Weld residual stress levels resulting from these fabrication processes are high.

- PBAPS 2 operated at high reactor coolant ionic content levels during the initial years of operation. The initial five year average coolant conductivity for PBAPS 2 was 0.593 μS/cm, which is considerably higher than the average for other U.S. BWRs (where the conductivities range from ~0.123 μS/cm to 0.717 μS/cm, and average ~ 0.340 μS/cm).

- PBAPS 2 has operated for 11.8 cumulative years at full power, which is slightly above the median for U.S. BWRs (range is 3.7 years - 17.8 years, with a median of 10.8 years).

The PBAPS 2 and Peach Bottom Unit 3 (PBAPS 3) reactors have operated for approximately the same amount of time at full power, and have in common a history of operation with high ionic content reactor coolants during the initial five years of power operation. As a basis for comparison, previous inspections of circumferential and vertical welds in the PBAPS 3 core shroud revealed the existence of a moderately sized crack (~105 inches in length) along the lower heat affected zone of the shroud's H3 circumferential weld, in addition to some less significant cracking at the H1 and H4 weld locations. From the perspective of materials and fabrication methods, the PBAPS 2 core shroud was fabricated in the same manner as was the PBAPS 3 core shroud. The Boiling Water Reactor Vessels & Internals Project (BWRVIP) has classified the PBAPS 2 core shroud as a susceptible Category "C" shroud. The staff finds that the BWRVIP's categorization of the PBAPS 2 core shroud is acceptable and considers the core shroud at PBAPS 2 to be as susceptible to IGSCC as the core shroud in the PBAPS 3 sister unit.

2.2 Inspection of the Peach Bottom Unit 2 Core Shroud

By letter dated November 7, 1994, PECo submitted the PBAPS 2 core shroud inspection scope, examination results and their flaw evaluation.

2.2.1 Scope of Core Shroud Inspection

The PBAPS 2 shroud examinations were performed using the ultrasonic testing (UT) methods developed by the General Electric Corporation (GE). The UT examinations utilized GE's Smart-2000 Data Acquisition System and the GE OD Tracker and suction cup scanners. The extent of the planned UT examinations included all accessible portions of circumferential shroud welds H1 - H7. The UT examinations were performed using three UT transducers, a 45° shear wave transducer, a 60° longitudinal wave transducer, and a creeping wave transducer which was used to pick up surface indications. The creeping wave transducer was not used on the H3 weld due to equipment failure. The licensee also performed some additional enhanced VT-1 examinations of shroud weld H6, which was highly obstructed by the proximity of the jet pumps and therefore highly inaccessible to the GE UT equipment. The licensee indicated that it had completed the following PBAPS 2 core shroud UT examinations:

- 33% of the length (230") of weld H1, distributed over 66% of the weld's circumference,
- 84% of the length (583") of weld H2,
- 88% of the length (574") of weld H3,
- 89% of the length (580") of weld H4,
- 83% of the length (540") of weld H5,
- 10% of the length (148") of weld H6, plus an additional 13% of weld H6 by enhanced VT-1 examination techniques, and
- 9% of the length (59") weld H7, in areas which were accessible by way of the access hole covers.

2.2.2 Core Shroud Examination Results

The following summarizes the cracking identified at each weld during the examination of the PBAPS 2 core shroud.

- H1 Weld - The examination detected 11 indications by UT using 45°S/60°RL transducers, totalling 33.93 inches, with a maximum length of 4.75 inches and a maximum depth of 0.74 inches at Indication #7;
- H2 Weld - Examinations were negative for indications;
- H3 Weld - 19 indications were detected by UT using 45°S/60°RL transducers, totalling 68.48 inches, with the maximum length being 8.75 inches at Indication #16 (indications were not depth sized).

- H4 Weld - 8 indications were identified, totalling 11.46 inches, with the maximum length of 5.76 inches at Indication #4 (indications were not depth sized) as detected by UT using 45°S/60°RL transducers, and remaining seven indications detected by UT creeping wave measurements;
- H5 Weld - 1 indication 2.28 inches in length was detected by UT creeping wave (indication was not depth sized);
- H6 Weld - 1 indication was detected by UT using 45°S/60°RL transducers, 4.73 inches in length and 0.45 inches in depth;
- H7 Weld - examinations were negative for indications.

The licensee's inspections of welds H6, the core support ring-to-lower shroud weld, H7, the lower shroud-to-shroud support cylinder weld, and H8, the shroud support cylinder-to-jet pump support ledge weld, were conducted through accessible areas of the access hole covers. Interference from jet pump assemblies, the reactor core, and other internals located at lower vessel elevations limited access to the lower shroud welds. The licensee's inspection plan is consistent with the staff's position recommending a 100% inspection of all accessible shroud weld areas.

2.2.3 Assessment of the PBAPS 2 Core Shroud Inspection Results

Flaws identified in welds receiving a comprehensive examination during the fall 1994 RFO were evaluated in accordance with the methodology outlined in the "BWR Core Shroud Inspection and Flaw Evaluation Guidelines" (Reference 2). These guidelines closely follow the flaw evaluation guidelines found in Section XI of the ASME Code. The staff has reviewed the BWRVIP evaluation guidelines and approves of the use of the quantitative assessment methods.

The licensee's evaluations were based on the following assumptions and conditions:

- For welds that were largely accessible to examinations and for which comprehensive examinations were performed, all as-found indications were assumed to be through-wall, which removed the necessity for depth characterization. Additionally, any inaccessible areas were assumed to contain through-wall indications over their entire inaccessible lengths.

- For welds that were predominantly inaccessible to examination, conditions found within the inspected regions were extrapolated over the entire weld areas that were inaccessible to examination equipment. The extrapolated conditions were then evaluated for structural integrity. Thus, evaluations of the H1 and H6 welds, in which indications were found and which were sized for depth, were based upon the assumption that the majority of the welds' circumferences contained indications.

- For the H7 weld, in which no indications were found, calculations were performed to calculate the depth which could be tolerated assuming a 360° crack existed in the weld.

. As-found crack lengths were adjusted for crack growth, non-destructive examination uncertainties, and crack proximity factors in accordance with the guidelines (Reference 2).

Inspection results for those welds receiving comprehensive inspections were compared to the initial screening criteria established in GENE 523-176-1293, "Evaluation and Screening Criteria for the Peach Bottom Unit 2 Shroud" (Reference 3), and if unacceptable, evaluated for safety margins using limit load methodology found in the "BWR Core Shroud Inspection and Flaw Evaluation Guidelines" (Reference 2). The inspection results of the H3 and H4 welds were also subject to evaluation using linear elastic fracture machanics methods to account for high neutron fluences which are common at these weld elevations.

Safety margins were calculated against the most limiting design basis loading conditions, derived in GENE 523-176-1293, "Evaluation and Screening Criteria for the Peach Bottom Unit 2 Shroud" (Reference 3). This equated to use of faulted condition loadings for evaluations of circumferential welds H1 - H5, and upset condition loadings for circumferential welds H6 and H7. For all postulated loadings the licensee showed that the loadings conditions for the as-found conditions in welds H1 - H7 were less than the ASME Code stress intensity allowables. The licensee's evaluations of the PBAPS 2 core shroud indicate that the shroud will maintain its structural integrity even under the most severe loading conditions for a given shroud weld location. The staff has reviewed the licensee's methodology, and has determined that the licensee's method of evaluating the PBAPS 2 core shroud is acceptable and that the licensee's evaluation results justify operation of the PBAPS 2 unit for the next operating cycle.

3.0 CONCLUSIONS

Based on a review of the PBAPS 2 core shroud materials, fabrication processes and operating history the staff concludes that the licensee's core shroud is susceptible to IGSCC. PECo completed an examination of the PBAPS 2 core shroud during RFO 2R10. The licensee's evaluation of the PBAPS 2 core shroud indicates that the PBAPS 2 core shroud will maintain sufficient structural margins to justify operation of the PBAPS 2 reactor for another operating cycle without necessitating a modification of the PBAPS 2 core shroud.

4.0 OUTSTANDING ISSUES/FUTURE ACTIONS

The licensee's difficulty inspecting the some of the circumferential core shroud welds is not unique to this plant. It should be noted that the industry is currently encountering difficulties performing comprehensive inspections of lower shroud welds due to NDE equipment accessibility problems. The staff urges licensees to work with the members of the EPRI NDE Center in order to develop improved tooling for inspections of lower shroud welds and/or lower vessel regions which are highly obstructed. Should improved inspections techniques become available, the staff recommendation is for licensee's to reinspect the lower shroud welds at the earliest opportunity.

5.0 REFERENCES

1. Letter from G. A. Hunger, Jr., PECO to the U.S. Nuclear Regulatory Commission forwarding the "Peach Bottom Atomic Power Station, Units 2 and 3, Limerick Generating Station Units 1 and 2 Response to Generic Letter 94-03, 'Intergranular Stress Corrosion Cracking of Core Shroud in Boiling Water Reactors," dated August 24, 1994.

2. Letter From C. D. Terry, Executive Chairman, Assessment Committee, BWR Vessel & Internals Project, to the U.S. Nuclear Regulatory Commission forwarding the "BWR Core Shroud Inspection and Evaluation Guidelines," dated September 2, 1994.

3. M. L. Herrera and S. Raganath, "Evaluation and Screening Criteria for the Peach Bottom Unit-2 Shroud," Rev. 0, (GENE-523-276-1093) dated December 13, 1993.

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