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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO CORE SHROUD STABILIZER DESIGN

PEACH BOTTOM ATOMIC POWER STATION, UNIT NOS. 2 AND 3

FACILITY OPERATING LICENSE NOS. DPR-44 AND DPR-56

PECO ENERGY COMPANY

DOCKET NUMBERS 50-277 AND 278

1.0 BACKGROUND

In Boiling Water Reactors (BWRs) the core shroud is a stainless steel cylinder within the reactor pressure vessel (RPV) that provides lateral support to the fuel assembly. The core shroud also serves to partition feedwater in the reactor vessel's downcomer annulus region from cooling water flowing through the reactor core. The RPV, core shroud and other RPV internals are designed to accomplish three basic safety functions:

- provide a refloodable coolant volume for the reactor core to assure adequate core cooling in the event of a nuclear process barrier breach;
- limit deflections and deformation of internal safety-related RPV components to assure that control rods and Emergency Core Cooling Systems can perform their safety functions during anticipated operational transients and/or design basis accidents;
- assure that the safety functions of the core internals are satisfied with respect to safe shutdown of the reactor and proper removal of decay heat.

In 1991, cracking of the core shroud was visually observed in a foreign BWR. The crack in this BWR was located in the heat-affected zone of a circumferential weld in the mid-core shroud shell. The General Electric Company (GE) reported the cracking found in the foreign reactor in Rapid Information Communication Services Information Letter (RICSIL) 054. GE identified the cracking mechanism as intergranular stress corrosion cracking (IGSCC).

A number of domestic BWR licensees have recently 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 experience. The combined industry experience from plants which have performed inspections to date indicates that both axial and circumferential cracking can occur in the core shrouds of GE designed BWRs, and that extensive cracking can occur in circumferential welds located both in the upper and lower portions of BWR core shrouds. The cracking reported in the Brunswick Unit 1 core shroud was particularly significant since it was the first time that extensive 360° core shroud cracking had been reported by a licensee in a domestic BWR. The 360° core shroud crack at Brunswick Unit 1 was located at weld H3 which joins the top guide support ring to the mid-core shroud shell. Information Notice 93-79 was issued by the NRC on September 30, 1993, in response to the observed cracking at Brunswick Unit 1.

The cracks reported by the Commonwealth Edison Company (ComEd) in the Dresden Unit 3 and Quad Cities Unit 1 core shrouds were of major importance, since they signified the first reports of 360° cracking located in lower portions of BWR core shrouds. These 360° cracks are located at core shroud weld H5, which joins the core plate support ring to the middle core shroud shell in both the Dresden and Quad Cities Units. Information Notice 94-42 and its Supplement were issued by the NRC on June 7, and July 19, 1994, to alert other licensees of the core shroud cracking discovered at Dresden Unit 3 and Quad Cities Unit 1.

On July 25, 1994, the NRC issued Generic Letter (GL) 94-03 (Reference 1) 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 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 core shroud welds, and which delineates the examination methods to be used for the inspections of the core 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.

By letters dated August 24, 1994 (Reference 2), September 16, 1994 (Reference 3), September 26, 1994 (Reference 4), February 14, 1995 (Reference 5), and June 22, 1995 (Reference 6), PECO responded to GL 94-03 by submitting the details of the contingency repair of the Peach Bottom, Units 2 and 3 core shrouds. Additional information in response to NRC staff questions was provided in a submittal dated August 17, 1995 (Reference 7), and revisions to some of the repair design details were submitted on August 28, 1995, and on September 5, 1995 (References 8 and 9). PECO also provided an additional analysis of the core spray piping on September 19, 1995 (Reference 10). Part of the licensee's response included PECO's plans for inspection of the Peach Bottom core shroud during the upcoming refueling outage and plans for a contingency repair that involves a permanent modification. Additional details regarding the pre-modification inspection were provided on September 27, 1995 (Reference 15). PECO advised the staff that the modification will encompass the entire set of circumferential welds in the core shroud and will involve the installation of four (4) restraint assemblies in the annulus region around the core shroud.

2.0 EVALUATION

2.1 Scope of the Modification Design

The scope of this safety evaluation (SE) focuses on the circumferential welds in the core shroud, since the only significant cracking of BWR core shrouds has been associated with these welds. The staff is currently not aware of any extensive cracking of vertical seam welds in BWR core shrouds. Cracking in these welds has been limited to relatively small lengths (less than 3 inches with one exception, where a 15-inch crack was observed.)

The Peach Bottom core shroud repair has been designed to restrain the core shroud head, the top guide support ring, the core and core plate support ring, and to prevent upward displacement of the core shroud during postulated accident conditions. The modification has been designed as an alternative to the requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code pursuant to Title 10 of the Code of Federal Regulations, Part 50.55a(a)(3)(i). It is designed to structurally replace the circumferential welds from the H1 weld at the top of the core shroud to the H7 weld at the bottom of the core shroud (see Figure 1 for identification of the core shroud welds). The Peach Bottom core shroud repair design therefore provides structural integrity for, and takes the place of, all circumferential welds which are subject to cracking in the Peach Bottom core shrouds. PECO has also stated that the repair is designed for a life equal to the remaining design life of the plant plus possible life extension beyond the current operating license.

Details of the modification are contained in a number of GE proprietary and non-proprietary reports which were reviewed by the staff. These are contained in References 3 through 9.

2.2 Core Shroud Repair Modification Description

The design of the Peach Bottom Units 2 & 3 core shroud repair consists of four (4) tie rod stabilizer assemblies, which are installed 90° apart in the core shroud/reactor vessel annulus, between attachment points at the top of the core shroud flange and toggle support assemblies attached to the core shroud support plate. Each tie rod stabilizer assembly consists of upper and lower spring assemblies and a mid span tie rod support connected by a solid tie rod. The rod provides the vertical load transfer from the core shroud head flange to the core shroud support plate attachment and supports the spring assemblies. The upper spring assembly provides lateral load support at the top guide elevation from the core shroud to the RPV. The lower spring assembly provides lateral support from the core shroud at the core plate support ring elevation to the RPV. The mid span tie rod support provides lateral support for the mid sections of the core shroud and increases the natural frequency of the tie rod stabilizer to reduce flow induced vibration. Each cylindrical section of the core shroud between welds H1 through H7 is prevented from unacceptable lateral motion by these tie rod stabilizer assemblies.

The upper spring assemblies of the tie rod stabilizer assemblies are attached to the core shroud head flange by means of brackets which are installed into slots machined in the flange. The lower end of the tie rod stabilizer assemblies are attached to pins in toggle assemblies which are bolted into holes cut into the core shroud support plate. Hook devices on the lower spring assemblies allow attachment to the toggle assemblies. The tie rod stabilizer assemblies provide vertical restraint to the core shroud. The springs limit the lateral displacements of the core shroud during horizontal dynamic loading in the postulated event of a 360° through-wall failure of one or more of the circumferential welds, so as to ensure control rod insertion. Together, the tie rod stabilizer assemblies and the lateral restraints resist both vertical and lateral loads resulting from normal operation and design accident loads, including seismic loads and postulated pipe ruptures.

The tie rod stabilizer assemblies are installed with a small vertical preload such that the core shroud is in compression during cold shutdown conditions. The coefficients of thermal expansion of the components of the tie rod stabilizer are smaller than those of the core shroud such that the compressive preload on the core shroud increases as the reactor reaches operating conditions. The combined spring constant of the tie rod stabilizer assemblies and the core shroud together was designed to provide a total vertical preload at operating conditions which will assure no separation of any or all failed circumferential welds from H1 through H7 during normal plant operation. Vertical separation for any and all welds is precluded except for the postulated design event consisting of a main steam line break loss of coolant accident combined with a design basis earthquake, since excessive preload would be required to prevent any separation for this event. Similarly, the upper and lower spring assemblies are installed with a small preload during cold shutdown. During normal operation, the lateral expansion of the core shroud and the spring assemblies due to thermal growth is greater than that of the RPV, providing additional preload and support for the core shroud. This preload will restrict the lateral core shroud displacements during postulated accident conditions within acceptable limits, and assure prompt rod insertion during these conditions.

2.3 Structural Evaluation

2.3.1 Core Shroud and Tie Rod Stabilizer Assemblies

The repair of the core shroud using the tie rod stabilizer assemblies have been designed to the structural criteria specified in the Peach Bottom Updated Final Safety Analysis Report (UFSAR) (Reference 11). The seismic analyses were performed in accordance with the methods described in the UFSAR. All of the loads and load combinations specified in the UFSAR which are relevant to the core shroud were included in the design. The tie rod stabilizer assemblies were designed using the ASME Code Section III, 1989 Edition, Subsections NB and NG as a guide (Reference 12). The original ASME Code Section III (1965 Edition and Addenda through Winter 1965) for the design and construction of the RPV did not have design requirements for core support structures. The additional loads placed on the RPV by the stabilizer assemblies have been evaluated to the original design Code.

PECO evaluated all load combinations required by the UFSAR for normal, upset, emergency, and faulted conditions which include normal (dead weight (DW) plus normal operating temperature), thermal upset, Design Basis Earthquake (DBE), Maximum Credible Earthquake (MCE), Main Steam Line Break (MSLB) Loss of Coolant Accident (LOCA), and Recirculation Line Break (RLB) LOCA loads. All loads including those due to the faulted load combination of MCE plus LOCA were combined by absolute summation. A three-dimensional finite element analysis model was developed for the stress analysis of the core shroud and the tie rod stabilizer assemblies (References 6 and 7). The analysis was performed using the commercial finite element program ANSYS. The use of ANSYS for modelling of the core shroud and the tie rod stabilizer assemblies is acceptable to the staff. PECO evaluated the dynamic nature of the DBE, MCE, RLB and MSLB LOCA loads on the repaired core shroud structure. The RLB LOCA lateral loading fluctuates with time, but the initial acoustic loading has an input frequency much greater than the core shroud frequency content such that there is very little response due to the initial acoustic loading. PECO determined that the portion of the RLB loading following the acoustic portion is relatively constant which would result in a static load with no amplification, and that the RLB loads were bounded by the MSLB loads for the design of the stabilizer.

The limiting upset loading condition event which PECO evaluated is the cold feedwater transient. During this transient, due to injection of cold feedwater into the core shroud annulus, a maximum temperature difference of 133°F between the hot core shroud and the cooler tie rod stabilizer assembly components could exist. This would cause an increase in the tensile load on the stabilizer and an increase in the compressive load on the core shroud. PECO evaluated this condition and determined that the stresses in the stabilizer and in the core shroud for this condition would be both less than the ASME Code upset allowable stress and less than the material yield stress, thus preventing permanent deformation, which is acceptable. PECO also determined that this event is the only case which produces any fatigue in need of consideration. For this event, the maximum calculated fatigue usage was found to be insignificant compared to the allowable usage and is, therefore, acceptable.

PECO has also investigated the effects of radiation on the repair design. Specifically, PECO determined that the fast flux levels on the stabilizer are low compared to levels which could degrade material properties. Further, the service temperature for this application has no significant effect on the degradation of the repair materials.

The NRC staff has reviewed the methodology and results of the stress analysis of the core shroud and tie rod stabilizer assembly and has determined it meets the appropriate criteria to assure core shroud structural integrity and, therefore, is acceptable.

2.3.2 Evaluation of Postulated Critical Weld Failures

PECO evaluated an enveloping combination of postulated cracked/uncracked welds to define the worst case for the core plate and top guide displacements to ensure control rod insertion and safe shutdown during the assumed normal, upset, emergency and faulted conditions required by the UFSAR. Each postulated through-wall cracked weld was modeled as a hinge or roller to determine the limiting displacement. In References 6 and 7, PECO provided the maximum allowable transient and permanent displacements of the core plate and top guide. The staff agrees that these maximum displacements are reasonable and therefore acceptable. The predicted worst case lateral transient deflection of the core plate support ring is 0.88 inches for a load combination of an MCE plus an MSLB LOCA with the H7 weld cracked. This is less than the allowable limit of 1.50 inches. The worst lateral transient displacement of the top guide support ring is 2.24 inches during a DBE which is less than the allowable limit of 4.8 inches.

The limiting loads in the tie rods and the limiting loads in the upper and lower springs occur for different postulated core shroud crack combinations. The limiting loads in the tie rods occur under the MCE plus operating pressure combination, assuming a through-wall crack in weld H7 when it behaves as a hinge. The limiting loads in the radial direction on the upper springs occur under the MCE plus operating pressure combination where it is assumed that all horizontal welds in the core shroud are cracked and represented as hinges. The limiting loads in the radial direction on the lower springs occur under the MCE plus MSLB LOCA combination where it is assumed that weld H7 in the core shroud is cracked and represented as a roller. The mid span support is designed to prevent radial deflections of the core shroud from exceeding acceptable limits. The upper and lower springs are similarly designed to prevent the radial deflection of the top guide support ring and the core plate support ring from exceeding acceptable limits. The maximum deflection of any part of the shroud that is not directly supported by the upper or lower springs is limited by mechanical limit stops to approximately 1.0 inches which is equal to one half of the shroud thickness. This results in overlapping of the shroud sections by at least 1.0 inches.

The tie rod stabilizer assembly preload prevents the vertical separation of the core shroud at all potential crack locations during normal operation. The critical cracked weld locations are for H2 and H3 since the failure of these welds has a significant effect on the vertical stiffness of the core shroud due to the greater deflections in the top guide support ring when vertical loads are applied. PECO also included the effect of a postulated failure of the H5 and H6 welds on the vertical core shroud stiffness. The most severe consequences are determined to occur if these welds are postulated to be initially intact but fail subsequently in operation. For this scenario, PECO's calculations indicate that there is sufficient preload to prevent weld separation due to the change in rigidity of the core shroud structure. PECO determined that the tie rod stabilizer assembly cold preload could be reduced a substantial amount due to the application of the core shroud head weight when it is installed if the core shroud stiffness is reduced the maximum amount. However, since the mechanical cold preload is only a small part of the total hot operating preload, there will be no separation at any welds during normal operation. The staff has reviewed PECO's evaluation and finds it reasonable and acceptable.

In References 6 and 7, PECO reported that the maximum expected vertical separation of the H6 weld would be 0.30 inches for the postulated MCE plus dead weight plus MSLB LOCA load combination. This displacement is momentary since the tie rod stabilizer assemblies and the weight of the core shroud and the internals will close the gap once the event is over. PECO also determined that this motion would not place any loading on the control rod guide tubes because they are designed to accommodate a 0.5 inch vertical motion. The staff finds these results reasonable and acceptable.

2.3.3 Seismic Analysis

The licensee's seismic model for analyzing the core shroud and repair stabilizers included a determination of the natural frequencies and mode shapes of the RPV and building system for the East-West and North-South directions and computations of the dynamic response to the DBE and MCE time histories including shears, moments, and displacements. The model was a two-dimensional linear elastic dynamic analysis consistent with the original design model in the UFSAR, and the synthetic DBE and MCE time histories used are based on the UFSAR response spectra. The 1871 Wilmington, Delaware, earthquake is the design basis MCE. The peak ground accelerations for the DBE and MCE are 0.05g and 0.12g respectively. With the exception of the nuclear core and the core shroud (including the repair hardware), these models were identical to the original seismic models. The nuclear cores of Units 2 and 3 were updated to the projected Cycle 11 and Cycle 10 configurations respectively. The seismic models incorporated the tie rod stabilizer assemblies and the core shroud with postulated 360° through-wall cracks. The tie rod stabilizer assemblies were modeled as an equivalent rotational spring and incorporated into the stick model, and these were assumed to resist the horizontal seismic loading acting on the core shroud. However, due to the postulated cracked welds, the structural behavior of the core shroud is non-linear, with different mass and stiffness characteristics causing the dynamic properties of the core support shroud and the tie rod stabilizer assemblies to vary, depending on the particular load combination and the postulated cracked weld configuration. To permit the application of linear elastic analysis, the core shroud was represented by a number of stick models, in which the critical cracked welds were represented by hinges or rollers. The seismic analyses were performed considering these loading conditions and core shroud models as bounding cases. These analyses were performed using the GE proprietary computer program SAP4G07 (Reference 6) that has been accepted for this application. The material damping ratios used in the seismic analyses were the same as for the original design analysis and are consistent with those in the UFSAR. Values used for the nuclear core and control rod drive housings were 3.5 and 7.0 percent of critical damping, respectively.

In order to account for uncertainties in the seismic input and modelling of the core shroud repair, PECO evaluated key input parameters such as the rotational stiffness of the tie rod stabilizer assemblies along with the various crack locations and joint roller or hinge configurations by performing analyses of bounding conditions. Also, the response spectra from both the DBE and MCE time histories envelope the smoothed UFSAR spectra used as a target.

Forces and moments due to vertical seismic loading were calculated as a multiplier of the dead weight in accordance with the UFSAR. The peak horizontal and vertical seismic loads were combined by absolute summation with other loads in the core shroud and the repair hardware analyses.

The staff has reviewed the methodology and results of the seismic analysis of the core shroud and the repair hardware, and has found them to be consistent with the UFSAR criteria and in accordance with current seismic analysis practice, and therefore acceptable.

2.3.4 Evaluation of RPV Components

PECO performed an evaluation (Reference 6) of the core shroud support plate stresses in the vicinity of the tie rod stabilizer bolt attachments with the H8 weld both cracked and uncracked, using a detailed finite element model and the ANSYS code. PECO also computed the effect of the additional loads from the core shroud repair on the original RPV design, including the core shroud support legs. The stresses were evaluated for the combined loading of weight, pressure differential and the tie rod stabilizer loading, resulting from the specified operating, emergency and faulted conditions. The stresses were shown to be within the ASME Code allowable stresses. A fatigue analysis was also performed which showed that the usage factor resulting from the upset thermal condition is minimal. The staff has reviewed these results and finds them reasonable and acceptable.

PECO also addressed the core plate preload clamping force adequacy against lateral sliding relative to the core plate support ring under horizontal MCE seismic forces and resultant vertical loading due to dead weight, buoyancy, vertical MCE and the pressure difference induced by MSLB LOCA (Reference 6). The results indicate that the clamping force is adequate to resist sliding, and that no wedges are needed to prevent sliding. The staff has reviewed these results and finds them reasonable and acceptable.

2.3.5 Evaluation of Core Spray Piping

In Reference 6, PECO analyzed the core spray lines inside the RPV for the seismic loads and anchor movements which result from the assumption of a worst case cracked shroud with the installation of the stabilizer assemblies. The core spray piping was analyzed using the rules for ASME Code Section III Subsection NB Class 1 piping (Reference 12) as a guide. PECO found that the piping meets the allowable stresses for the required service levels, however does not meet the fatigue requirements in one location on Unit 3. Repair brackets were installed in Unit 3 in 1985 after the discovery of cracking in the 240° core spray lines near the connection of the pipe with the tee box at the RPV. The repair brackets and attachment welds to the piping were analyzed in accordance with the requirements of NB-3200. The calculated fatigue usage for one of the two repair brackets was calculated to be 2.0, which is in excess of the Code allowable of 1.0. The main contribution to the calculated fatigue usage was due to the relative displacement of the shroud during only 10 full cycles of a design earthquake (DE) event. The plant design basis of 50 DE cycles therefore could not be accommodated. As a result, PECO initiated Modification P00541 to provide a revised analysis which demonstrates that the brackets are acceptable or to provide replacement brackets to meet the design requirements.

By letter dated September 19, 1995 (Reference 10), PECO submitted an analysis of the core spray piping for Unit 3 which demonstrates that the piping meets the above fatigue requirements. This analysis assumes that the shroud horizontal welds above H8 are only partially cracked, thus reducing the displacement of the shroud during the required 50 DE cycles. The staff finds the Unit 3 analysis acceptable to demonstrate the adequacy of the piping including the tee box, provided PECO verifies that the core shroud is cracked no more than the amount assumed in the analysis. Therefore, PECO should incorporate into the reinspection plan (discussed in Section 2.5 below) inspection of the horizontal core shroud welds necessary to assure that the shroud cracking does not exceed that assumed in the analysis of the core spray piping.

Inspections to date of the Unit 2 core spray RPV penetration tee box have not revealed indications which would require a similar repair. PECO conducts examinations of in-vessel core spray piping pursuant to NRC Bulletin 80-13. Should future inspections reveal additional indications in the core spray piping, PECO may need to update the Reference 6 analyses accordingly.

2.3.6 Potential for Flow-Induced Vibration

PECO also evaluated the potential for flow-induced vibration by calculating the lowest natural frequency of the tie rod stabilizer and the highest vortex shedding frequency due to the water flow in the core shroud annulus. PECO found that the lowest natural frequency of the tie rod stabilizer assemblies is 45.5 Hertz while the maximum vortex shedding frequency is 5.2 Hertz. Therefore, PECO determined that there would be essentially no resulting flow-induced vibration fatigue of any of the tie rod stabilizer assembly components. The staff finds these results reasonable and acceptable.

2.3.7 Loose Parts Considerations

PECO stated that all components of the tie rod stabilizer assemblies will be locked in place with mechanical devices and that loose pieces can not occur without the failure of a locking device. Further, PECO determined that if a tie rod stabilizer assembly were to fail during normal operation, the leakage through any through-wall cracks would increase but would not be detectable. If the failed tie rod stabilizer assembly part came completely loose, it could fall onto the core shroud support plate or be swept into the recirculation pump suction line. PECO stated that the consequences of such a loose part would be consistent with other postulated loose parts. As stated in Section 2.5 below, PECO will be required to submit a reinspection plan of the core shroud hardware following restart after the repair is installed. If PECO's tie rod stabilizer assembly inspection results, following the first fuel cycle of operation, indicate that further measures are necessary to assure that the tie rod stabilizer assemblies (or parts thereof) will not become loose or detached during plant operation, PECO will be required to augment the inservice inspection plan to address these additional measures.

In Reference 3, PECO stated that full-scale mock ups, which actually represent the plant core shroud and vessel configuration, have been used to qualify and train personnel for the stabilizer assembly installation task. To install the stabilizer, it is necessary to cut and hone holes in the core shroud support plate and to cut notches in the core shroud head flange using the electric discharge machining (EDM) process. The EDM equipment collects a large portion of the swarf generated during the machining which minimizes the amount of suspended particles required to be removed by the reactor water cleanup (RWCU) system.

2.3.8 PECO 10 CFR 50.59 Safety Evaluation of Core Shroud Repair

In Reference 7, PECO provided its 10 CFR 50.59 Safety Evaluation of the core shroud repair. In accordance with 10 CFR 50.59, PECO determined that no unreviewed safety question will result and no technical specification revision will be involved as a result of the implementation of the core shroud repair. The staff agrees with this determination, and concludes that no license amendment, pursuant to 10 CFR 50.90, is necessary.

2.3.9 Conclusion

PECO has demonstrated that the maximum stresses in the core shroud and the tie rod stabilizer assemblies resulting from operating, upset thermal and emergency and faulted accident conditions meet the corresponding ASME Code-allowable stresses. The staff has reviewed the referenced documents, and has determined that the results are reasonable and in general agreement with design and analysis practices employed in support of other core shroud repairs reviewed by the staff. Based on the foregoing discussion, the staff therefore concludes that the proposed core shroud repair modification is acceptable from a structural standpoint.

2.4 Systems Evaluation

2.4.1 Introduction

PECO provided information in References 6 and 7 to demonstrate that fuel geometry and core cooling would be maintained given the unlikely occurrence of a through-wall failure of any horizontal weld during normal operations and design basis events with the core shroud repair installed. Fuel geometry must be maintained to ensure control rod insertion while core cooling is ensured by proper emergency core cooling system (ECCS) performance. The PECO submittals provided analyses of the principal effects and issues of operating the plant with postulated circumferential core shroud welds cracked and tie rod stabilizer assemblies installed. Some of the conditions analyzed by PECO included tie rod stabilizer assembly induced leakage, core shroud weld crack leakage, downcomer flow characteristics, lateral displacement of the core shroud, and vertical separation of the core shroud. The staff has reviewed these portions of the PECO submittals and is providing the following evaluation of PECO's findings.

2.4.2 Tie Rod Stabilizer Assembly System Induced Leakage

As discussed above, the installation of the tie rod stabilizer assemblies requires the machining of four holes through the core shroud support plate using the Electrical Discharge Machining (EDM) process. PECO estimates that a small amount of core flow leakage will occur through the clearance slots. The total calculated leakage from the installation of the tie rod stabilizer assemblies was estimated to be 0.17% of core flow (525 gpm) at 110% rated power and 87% to 110% rated core flow. The staff does not consider this leakage rate to be significant with regards to total core flow and therefore, it is acceptable.

The installation of the tie rod stabilizer assemblies also requires the machining of eight slots into the core shroud head flange in order to install the long upper supports. The core shroud head flange is located above the H1 weld which is the uppermost weld on the core shroud and is above the top guide. At this location, core flow is considered to be two-phase flow. Leakage at this location does not bypass the core, and therefore, is acceptable.

At Peach Bottom, the ECCS consists of the single-train high pressure coolant injection (HPCI) system, the automatic depressurization system (ADS), the two-train core spray (CS) system, and the two-train low pressure coolant injection (LPCI) system. The staff notes that the leakage from the core shroud support plate and the core shroud head flange to the downcomer annulus does not affect the performance of the above systems. Therefore, the ECCS performance is not affected by the physical installation of the tie rod stabilizer assembly system.

2.4.3 Core Shroud Weld Crack Leakage

The tie rod stabilizer assemblies are installed with a cold preload to ensure that no vertical separation of any or all cracked horizontal welds will occur during normal operations. Vertical separation, if sufficiently large, could compromise fuel geometry and control rod insertion. For most plants, a maximum vertical separation of 13 to 15 inches is required for the top guide to clear the top of the fuel channels. The staff notes that, with the repair, the estimated vertical separation during normal operations will not affect the fuel geometry, and therefore, control rod insertion is not precluded.

However, a small leakage path could exist due to existing through-wall core shroud weld cracks. PECO conservatively modeled the crack to provide a 0.001 inch leakage path per weld, H1 through H8. PECO estimated that the total leakage from all welds, H1 through H8, having postulated 360° through-wall cracks was approximately 170 gpm (0.04% of core flow) at 110% rated power and 87% to 110% rated core flow. Although core shroud crack leakage is unlikely due to the preload on the tie rod, PECO concluded that there are no consequences associated with the repair installed based on these small leakages during normal operations. The staff acknowledges that the total leakage is insignificant and will not affect the performance of the ECCS.

2.4.4 Downcomer Flow Characteristics

PECO analyzed the available flow area in the downcomer with the four tie rod stabilizer assemblies installed. PECO stated that the size of the tie rod stabilizer assemblies are small compared to the size of the jet pump assemblies and thus, the tie rod stabilizer assemblies are not expected to significantly affect the flow characteristics in the downcomer. However, since the downcomer annulus is smaller at the top of the core shroud with other existing obstructions such as the core spray lines, PECO evaluated the flow blockage area of the upper core shroud restraint of the tie rod stabilizer assembly located between welds H1 and H3. PECO's analysis demonstrated that the installation of the tie rod stabilizer assemblies will decrease the as-built available downcomer flow area by approximately 6 percent. The staff reviewed the downcomer flow calculation which accounted for the core spray piping, miscellaneous bolts, lugs, and brackets, and the upper support and spring of the tie rod stabilizer assemblies. Based on PECO's analyses, the staff concluded that the installation of the tie rod stabilizer assemblies will not have a significant impact on the downcomer flow characteristics.

Additionally, PECO provided the corresponding pressure drop to the decrease in downcomer flow area. PECO demonstrated that the increase in pressure drop due to the installation of tie rod stabilizer assemblies is approximately 0.1 percent which is considerably less than the system pressure drop during normal operations. Based on this information and information from other reviews of similar core shroud repairs, the staff concluded that the increase in the pressure drop is insignificant. Therefore, the staff agrees with PECO that the installation of the tie rod stabilizer assemblies should not affect the recirculation flow of the reactor.

2.4.5 Potential Lateral Displacement of the Core Shroud

PECO also evaluated the maximum lateral displacement of the core shroud at the core plate and top guide under normal operations and load combinations such as MCE, MSLB, and RLB, assuming 360° through-wall cracks at any weld location. Lateral displacement of the core shroud could damage core spray lines and could produce an opening in the core shroud, inducing core shroud bypass leakage and complicating recovery. Maximum permanent displacements of the core shroud are limited to approximately 1.0 inches by mechanical limit stops. This lateral displacement is equal to half the thickness of the shroud, and accordingly, the separated portions of the shroud would remain overlapped during worst case conditions. Additionally, the maximum permanent lateral displacement of the top guide or core plate will not significantly increase the scram time as demonstrated in Reference 7. Therefore, the staff has concluded that the maximum lateral displacement of the core shroud would not result in significant leakage from the core to the downcomer region following an accident scenario and the ability to reflood the core to 2/3 core height would not be precluded.

2.4.6 Potential Vertical Separation of the Core Shroud

PECO evaluated the maximum vertical displacement of the core shroud assuming 360° through-wall cracks at any weld above or below the core plate during an MSLB, MCE, and an MSLB plus MCE. These postulated events would result in a large upward load on the core shroud which could impact the ability of the control rods to insert and the ability of the core spray system to perform its safety function. As stated above, a maximum vertical separation of 13 to 15 inches is required for the top guide to clear the top of the fuel channels. With the repair installed, the maximum vertical separation during an MSLB plus the MCE is limited to 0.30 inches at the H6 location. This separation is limited by the tie rod stabilizer assemblies and should not impact the core spray system. Therefore, based on this assessment, the staff concluded that postulated separation during an MSLB, MCE or an MSLB plus MCE event would not preclude any of the systems from performing their safety functions.

2.4.7 Conclusion

The staff has evaluated PECO's evaluation of the consequences of the proposed core shroud repair. The staff has found that the proposed repair should not impact the ability to insert control rods, the performance of the ECCS, particularly the core spray system, or the ability to reflood and cool the core. The staff concluded that the proposed repair does not pose adverse consequences to plant safety, and therefore, plant operation is acceptable with the proposed core shroud repair installed.

2.5 Materials, Fabrication and Inspection Considerations

2.5.1 Materials and Fabrication

PECO stated in Reference 6 that Type 316 or 316L austenitic stainless steel, Type XM-19 stainless steel and nickel-based (Ni-Cr-Fe) alloy X-750 materials were selected for the fabrication of core shroud tie rod stabilizer components. These materials have been used for a number of other components in the BWR environment and have demonstrated good resistance to stress corrosion cracking by laboratory testing and long-term service experience. Welding is not used in the fabrication and the installation of the core shroud tie rod stabilizer, thereby minimizing its susceptibility to intergranular stress corrosion cracking (IGSCC). The springs, supports and some connecting components were made from alloy X-750. The alloy X-750 material was selected for these components because of the requirements of higher material strength and lower coefficient of thermal expansion than that of the core shroud material (Type 304 stainless steel). The tie rods in the stabilizer assemblies were made of Type XM-19 stainless steel in a solution annealed condition with a carbon content less than 0.04%. The remaining connecting components in the tie rod stabilizer assemblies were made from either Type 316 or 316L austenitic stainless steel with a carbon content not more than 0.02%.

PECO selected Type XM-19 instead of Type 304 or 316 stainless steel for the fabrication of tie rods in the stabilizer assemblies because Type XM-19 material has higher resistance to sensitization, higher allowable stress and a slightly lower coefficient of thermal expansion which would increase the thermal pre-load. PECO stated that Type XM-19 was extensively tested in the mid-1970's, with the results published in Reference 13. The test results showed that Type XM-19 material has good resistance to sensitization and IGSCC. The solution annealed Type XM-19 material has been used in BWR environments with successful experience for over 20 years. The material was used for piston or index tubes in the control rod drive mechanisms and in a number of other applications.

Type 316 or 316L austenitic stainless steel and solution annealed alloy Type XM-19 are acceptable ASME Code Section III materials. The alloy X-750 was procured to American Society for Testing and Materials (ASTM) Standard B637, Grade UNS N07750 material (bars and forging) requirements. The heat treatment of alloy X-750 includes solution annealing at 1975°F ±25°F for 60 to 70 minutes, followed by forced air cooling, and age hardening at 1300°F ± 15°F for a minimum of 20 hours, followed by air cooling. The equalization heat treatment at 1500°F to 1800°F was prohibited because this heat treatment will produce a microstructure that would make the alloy X-750 material susceptible to IGSCC.

Type 316 or 316L austenitic stainless steel was procured to ASTM A-479, A-182 or A-240 with a maximum carbon content of 0.020%. The procured materials were water quenched from solution annealing at 2000°F ±100°F. Some Type 316 or 316L components were re-solution annealed after final machining to improve its resistance to IGSCC.

The Type XM-19 stainless steel materials were procured to ASTM specification A182, A240, A412 or A479. The materials were solution annealed at 1950°F to 2050°F, followed by forced air cooling to a temperature below 500°F in 20 minutes or less. The staff finds that the process of air-cooling from the solution annealing temperature is not consistent with the Boiling Water Reactor Vessel and Internals Project (BWRVIP) guidelines as provided in Reference 14, where water quenching from the solution annealing temperature is recommended. PECO stated in Reference 6 that due to the straightness requirement in the fabrication of the tie rods, it is necessary to air cool the XM-19 materials from the solution annealing temperature, because water quenching will cause excessive distortion in the materials. The staff had reviewed the sensitization and stress corrosion test data performed on XM-19 materials and has determined that the air cooling rate specified for the fabrication of tie rods will not cause any sensitization in the XM-19 material. Therefore, the staff concludes that the subject air cooled XM-19 material is acceptable for use in the BWR environment.

All procured XM-19 and Type 316/316L stainless steel materials were tested for sensitization in accordance with ASTM Standard A262, Procedures A or E, to ensure the materials were not sensitized. These materials were also sensitization tested after high temperature annealing during fabrication. The maximum hardness of the procured materials and completed parts was specified in the GE Fabrication Specification (25A5601, Rev. 2) (Reference 9). The threaded areas of Type XM-19 tie rod stabilizer assembly components were re-solution annealed after final machining to remove the surface cold work effect. The cold work resulting from machining is known to promote IGSCC. PECO stated that the re-solution annealing was carried out by induction heating at a frequency of approximately 8 khz, and that the induction heating process was qualified using heat treated 316L stainless steel threaded sections. GE has performed metallographic examination of the induction heated pieces. The result of the examination showed that a very thin machined skin layer on the threads was completely recrystallized and that a limited grain growth from an original grain size of 9 to 7.5 to 6 had occurred.

To preclude intergranular attack (IGA) as a result of high temperature annealing, PECO required IGA testing per GE E50YP11 specification to be performed for each heat and heat treat lot of materials after annealing or pickling. In lieu of IGA testing, a minimum of 0.03 inches may be removed from all surfaces after the last exposure to high temperature annealing as a control of IGA.

PECO indicated that tie rod stabilizer assembly components are generally rough machined to within 0.10 inches of final size and skim passes are used to achieve the final dimensions. Coolant and sharp tools were used in the machining. The final machined surface finish is generally specified to be 125 root mean square or better. PECO also indicated that a Nickel-Graphite antiseize thread lubricant (D50YP5B) will be used in the installation of tie rod stabilizer assemblies. Controls of lubricant impurities were provided in the GE Specification (D50YP12), where impurities limits were specified for halogens, sulfur and nitrates. PECO stated that machined components that were not solution annealed after machining, were metallography and microhardness evaluated on test samples to verify that the surface condition after final machining has very shallow cold work depth.

The staff has reviewed PECO's submittal regarding the proposed core shroud repair and concludes that the selected materials and fabrication methods for the tie rod stabilizer assemblies are acceptable.

2.5.2 Pre-modification and Post-modification Inspection

PECO's pre-modification inspection plan (References 3 and 15) for Peach Bottom, Units 2 and 3, to support the proposed repair installation consisted of vertical shroud welds, the H9 weld, and repair attachment locations, and was reviewed by the staff. The selection of the welds and the scope and limitation of the inspection are briefly summarized below.

(1) Depending on accessibility, either an enhanced visual examination (VT-1) or an ultrasonic examination (UT) will be performed on four (4) vertical shroud welds (V-3 through V-6) which intersect the mid-core circumferential shroud weld H4. When visual examination is performed, both sides (inner diameter surface and outer diameter surface) of the vertical weld will be inspected. A length of approximately 14 inches of the vertical weld starting from the intersection from the H4 weld will be inspected. The PECO proposed vertical weld examination was based on the recommendations in a General Electric report (GENE-523-A062-0695, Revision 2, September 1995) "Peach Bottom 2/3 Shroud Vertical Seam Welds Evaluation" provided in Reference 8.

(2) An enhanced visual examination (VT-1) will be performed on the H9 weld from the jet pump annulus region at the four repair assembly locations. The H9 weld connects the core shroud support plate to the reactor vessel. Depending on accessibility, a minimum length of 13.5 inches is anticipated to be inspected at each repair location.

(3) An enhanced visual examination (VT-1) will be performed of the accessible areas of the reactor vessel wall and shroud support plates, adjacent to the attachment point for the shroud stabilizer lower support.

PECO will not inspect the segments welds of the core support plate because the results of the stress analysis have shown that there is practically no vertical loading of the repair that would be acting on these welds. PECO stated that there are no segment welds in the top guide support ring and the core plate support ring since each of these rings was made by a one-piece forging.

PECO has not yet finalized its reinspection plan for the core shroud and the tie rod stabilizer assembly components. The staff recommends that PECO's reinspection plan should consider the following: (1) the plant-specific repair design requirements, (2) the extent and the results of the baseline inspection performed during pre-modification inspection, (3) the threaded areas and the locations of crevices and stress concentration in the tie rod stabilizer assemblies, (4) BWRVIP reinspection guidelines when they are established, and (5) the inspection of the core shroud necessary to demonstrate the adequacy of the core spray piping. The NRC staff will review PECO's reinspection plans when submitted. To allow for adequate time for NRC staff to perform review and resolve comments with PECO, PECO is requested to submit the reinspection plan for the core shroud and repair assemblies within 6 months from the restart of the respective Peach Bottom Units. Since the core shroud and the tie rod stabilizer assemblies are generally classified as ASME Code Class B-N-2 components (core structural support), the reinspection plan will be required to be incorporated into the plant in-service inspection (ISI) program.

The staff has reviewed PECO's pre-modification inspection plan and concludes that the pre-modification inspection plan is acceptable to support the proposed core shroud repair.

3.0 CONCLUSION

The proposed core shroud repair has been designed as an alternative to the requirements of the ASME Boiler and Pressure Vessel Code, Section XI, pursuant to Title 10 of the Code of Federal Regulations, Part 50.55a(a)(3)(i). Based on a review of the core shroud modification hardware from structural, systems, materials, and fabrication considerations, as discussed above, the staff concludes that the proposed modifications of the Peach Bottom, Units 2 and 3, core shrouds are acceptable and will not result in any increased risk to the public health and safety.

Principal Contributors: C. Hammer
K. Kavanagh
W. Koo
L. Dudes

Date: October 16, 1995

REFERENCES

1. Generic Letter 94-03, "Intergranular Stress Corrosion Cracking of Core shrouds in Boiling Water Reactors," U.S. NRC, July 25, 1994.

2. Letter of August 24, 1994, from G. A. Hunger, Jr., PECO Energy Company (PECO) to the U.S. NRC Document Control Desk, with attachments.

3. Letter of September 16, 1994, from G. A. Hunger, Jr., PECO Energy Company (PECO) to the U.S. NRC Document Control Desk, with attachments.

4. Letter of September 26, 1994, from G. A. Hunger, Jr., PECO Energy Company (PECO) to the U.S. NRC Document Control Desk, with attachments.

5. Letter of February 14, 1995, from G. A. Hunger, Jr., PECO Energy Company (PECO) to the U.S. NRC Document Control Desk, with attachments.

6. Letter of June 22, 1995, from G. A. Hunger, Jr., PECO Energy Company (PECO) to the U.S. NRC Document Control Desk, with attachments.

7. Letter of August 17, 1995, from G. A. Hunger, Jr., PECO Energy Company (PECO) to the U.S. NRC Document Control Desk, with attachments.

8. Letter of August 28, 1995, from G. A. Hunger, Jr., PECO Energy Company (PECO) to the U.S. NRC Document Control Desk, with attachment.

9. Letter of September 5, 1995, from G. A. Hunger, Jr., PECO Energy Company (PECO) to the U.S. NRC Document Control Desk, with attachments.

10. Letter of September 19, 1995, from G. A. Hunger, Jr., PECO Energy Company (PECO) to the U.S. NRC Document Control Desk, with attachment.

11. Peach Bottom Atomic Power Station, Units 2 & 3, Updated Final safety Analysis Report (UFSAR), Revision 12.

12. American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code, Section III, 1989 Edition.

13. GE Document NEDE-21653-P, "XM-19 Materials Qualification Report," July 1977, (Proprietary).

14. Boiling Water Reactor Owners Group, Vessels and Internals Project (BWROG-VIP) Document BWROG-VIP-9410, "BWR Core Shroud Repair Design Criteria," Section 5.10.7, August 18, 1994.

15. Letter of September 27, 1995, from G. A. Hunger, Jr., PECO Energy Company (PECO) to the U.S. NRC Document Control Desk, with attachment.