September 27, 2007

Mr. Michael A. Balduzzi
Sr. Vice President & COO
Regional Operations, NE
Entergy Nuclear Operations, Inc.
440 Hamilton Avenue
White Plains, NY 10601

SUBJECT: PILGRIM NUCLEAR POWER STATION - RELIEF REQUEST FOR THE REACTOR CORE SHROUD STABILIZER ASSEMBLIES (TAC NO. MD4918)

Dear Mr. Balduzzi:

By letters dated March 22, 2007 (Agencywide Documents and Management System (ADAMS) Accession No. ML070870132), and April 29, 2007 (ML071280519), and supplemental letters dated April 10, 2007 (ML071080222), April 20, 2007 (ML071210250), April 24, 2007 (ML071210254), and May 3, 2007 (ML071310083), Entergy Nuclear Operations, Inc. (the licensee) requested authorization under the provisions of Title 10 of the *Code of Federal Regulations* (10 CFR) 50.55a(a)(3)(i) to modify the core shroud stabilizer assemblies (tie rods) for the Pilgrim Nuclear Power Station (Pilgrim). The Pilgrim core shroud was repaired in 1995 by the installation of four tie rod assemblies. However, recent industry experience identified the potential for high peak surface stress existed for the Pilgrim tie rod design. This high peak stress reduces the design life of the tie rod upper support. The licensee has determined that the most prudent course of action and the best long-term economic solution is preemptive replacement of the tie rod upper support assembly with a modified upper support design with a temporary verbal authorization for an alternative during refueling outage 16 (RFO-16) in April of 2007.

The March 22, 2007, letter proposed to replace all four core shroud upper support assemblies with a modified design and install clamps on the four upper horizontal spring torsional arm bolts. The April 29, 2007, letter modified the request to replace the upper support assemblies and to install torsional arm bolt clamps on the tie rods at the 45° and 225° azimuthal locations. An allowance to operate for one fuel cycle with the existing (unmodified) upper support assemblies and without torsional arm bolt clamps on the tie rods at the 135° and 315° azimuthal locations was also requested. The upper support assemblies and torsional arm bolt clamps at the 135° and 315° azimuthal locations were not installed due to difficulties encountered with the tooling.

The NRC staff verbally authorized the alternative configuration of two modified core shroud stabilizer assemblies and two unmodified core shroud stabilizer assemblies for one operating cycle in a conference call on May 3, 2007. The modification to the upper support assemblies and installation of torsional arm bolt clamps on the tie rods at the 45° and 225° azimuthal locations were implemented during RFO-16.

Based on the information provided by the licensee, the NRC staff has concluded that the proposed modification of the Pilgrim core shroud is acceptable for one operating cycle and will provide an acceptable level of quality and safety. The results are provided in the enclosed safety evaluation.

If you have any questions regarding this approval, please contact the Pilgrim Project Manager, James Kim, at 301-415-4125.

Sincerely,

/RA/

Mark G. Kowal, Chief
Plant Licensing Branch I-1
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-293

cc: See next page

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

REQUEST FOR AUTHORIZATION FOR MODIFICATION OF THE CORE SHROUD TIE RODS

ENTERGY NUCLEAR OPERATIONS, INC.

PILGRIM NUCLEAR POWER STATION

DOCKET NO. 50-293

1.0 INTRODUCTION

By letters dated March 22, 2007 (Agencywide Documents and Management System (ADAMS) Accession No. ML070870132), and April 29, 2007 (ML071280519), and supplemental letters dated April 10, 2007 (ML071080222), April 20, 2007 (ML071210250), April 24, 2007 (ML071210254), and May 3, 2007 (ML071310083), the licensee requested authorization under the provisions of Title 10 of the *Code of Federal Regulations* (10 CFR) 50.55a(a)(3)(i) to modify the core shroud stabilizer assemblies (tie rods) for the Pilgrim.

The March 22, 2007, letter proposed to replace all four core shroud upper support assemblies with a modified design and install clamps on the four upper horizontal spring torsional arm bolts. The April 29, 2007, letter modified the request to replace the upper support assemblies and to install torsional arm bolt clamps on the tie rods at the 45° and 225° azimuthal locations. An allowance to operate for one fuel cycle with the existing (unmodified) upper support assemblies and without torsional arm bolt clamps on the tie rods at the 135° and 315° azimuthal locations was also requested. The upper support assemblies and torsional arm bolt clamps at the 135° and 315° azimuthal locations were not installed due to difficulties encountered with the tooling. The licensee proposed to implement the modification to the upper support assemblies and to install torsional arm bolt clamps on the tie rods at the 45° and 225° azimuthal locations during RFO-16 in the spring 2007.

2.0 REGULATORY REQUIREMENTS

The inservice inspection (ISI) of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) Class 1, 2, and 3 components is to be performed in accordance with Section XI of the ASME Code and applicable editions and addenda as required by 10 CFR 50.55a(g), except where specific written relief has been granted by the Commission pursuant to 10 CFR 50.55a(g)(6)(i). 10 CFR 50.55a(a)(3) states in part that alternatives to the requirements of paragraph (g) may be used, when authorized by the Nuclear Regulatory Commission (NRC), if the licensee demonstrates that: (i) the proposed alternatives would provide an acceptable level of quality and safety, or (ii) compliance with the specified requirements would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

The licensee submitted this relief request for the NRC staff's review and approval to use as an alternative repair under the provisions of 10 CFR 50.55a(a)(3)(i).

3.0 TECHNICAL EVALUATION

3.1 ASME Code Requirement

The core shroud tie rod assemblies are not included as a repair under ASME Code, Section XI. However, the licensee's proposed alternative was designed to comply with the requirements of the ASME Code, Section III, Division 1, Subsection NG, 2001 Edition, and 2003 Addenda and Code Case N-60-5, "Materials for Core Support Structures, Section III, Division 1."

3.2 Licensee's Basis for Requesting Relief

Background

Industry experience has shown that boiling-water reactor (BWR) core shroud welds are subject to intergranular stress-corrosion cracking and/or irradiation-assisted cracking (IGSCC/IASCC). As a result, the staff issued Generic Letter (GL) 94-03, "Intergranular Stress Corrosion Cracking of Core Shrouds at Boiling Water Reactors [BWRs]," which led BWR facilities to perform detailed inspections and analyses of the core shrouds to determine susceptibility to this phenomenon. Pilgrim installed core shroud tie rod assemblies in 1995, on a pre-emptive basis in lieu of ultrasonic (UT) inspection of the core shroud horizontal welds. The tie rods functionally replace the shroud horizontal H1 through H10 welds. The General Electric Company (GE) designed and installed the Pilgrim tie rod assemblies. GE provided core shroud repairs using tie rods to many other domestic BWR plants. By letter dated January 16, 1995, Boston Edison Company, the previous licensee, submitted a repair of the Pilgrim core shroud by installation of four tie rods to the NRC staff for review and approval. The staff, in its letter dated May 12, 1995, found the proposed repair acceptable as allowed by the requirements of 10 CFR 50.55a(a)(3)(i). In spring 2006, cracking was discovered in the tie rod upper supports at Hatch Unit 1 during an in-vessel visual inspection (IVVI). The apparent root cause is IGSCC in the Alloy X-750 tie rod upper support material. Alloy X-750 material is susceptible to IGSCC, if subjected to sustained, large peak stress conditions. GE conducted an evaluation to determine if the potential IGSCC in the Alloy X-750 tie rod structural components of other BWR core shroud repairs designed by GE could be a reportable condition under 10 CFR Part 21 (Reference 1). GE used the criterion provided in the BWR Vessel and Internals Project (BWRVIP) Report BWRVIP-84, "BWR Vessel and Internals Project, Guidelines for Selection and Use of Materials for Repairs to BWR Internals, BWRVIP-84," for the IGSCC susceptibility assessment of the Alloy X-750 components in the tie rod vertical load path.

Based on the Hatch Unit 1 finding, GE revised the assessment of the GE tie rod upper support design life and determined that the potential for a high peak surface stress existed for the Pilgrim tie rod design. The potential for high peak stress in the original tie rod upper bracket design at Pilgrim was attributed to the lack of a specified radius at the corner junction between horizontal and vertical legs of the bracket which creates a high stress concentration. This high peak stress reduced the design life of the original tie rod upper support. Tie rod inspections performed during each refueling outage could justify continued operation on a cycle-by-cycle basis. However, the licensee has determined that the most prudent course of action and the best long-term economic solution is pre-emptive replacement of the tie rod upper support with a modified upper support design capable of operation through the end of the renewed operating license term (2032).

GE conducted an extent of condition review to determine if other Alloy X-750 tie rod components had similar potential for high peak stress. GE identified that the root radii of the threads in the tie rod threaded components of the original Pilgrim design may be smaller than the nominal values used in previous design evaluations. Hence, the licensee proposed to include a modified tie rod nut that incorporates an improved locking mechanism. To improve IGSCC resistance, the new tie rod nuts will include a specified root radius sufficient to minimize the peak principle stress to within the same criterion as used for the upper support. In addition, GE has identified that the torsional arm bolt which attaches the torsional arm to the upper spring was susceptible to IGSCC due to excessive preload. The licensee proposed to provide a clamp over the torsional arm bolt to maintain the function of the torsional arm. In these submittals, the licensee addressed the impact of the proposed modification on previously performed analyses and evaluations.

3.3 Technical Evaluation of Modified Tie Rod Assembly

3.3.1 Design Objectives

The objectives of the proposed tie rod repair modifications were to design and install replacement upper support assemblies, tie rod top nuts, and torsional arm bolt clamps that will remain resistant to IGSCC over the remaining plant life (i.e., until 2032) and to ensure that the replacement components interface correctly with the existing shroud repair hardware.

3.3.2 Design Criteria

The modified upper supports, tie rod top nuts, and torsional arm bolt clamps comply with the criteria delineated in the BWRVIP-02-A, "BWR Vessel and Internals Project, BWR Core Shroud Repair Design Criteria, Revision 2," and the BWRVIP-84 reports with no exceptions taken. The original codes and design standards used for construction of the original tie rod assemblies were delineated in GE Specification, which was included in the January 16,1995, core shroud repair submittal. The original codes and design standards remain applicable to the proposed modifications, as well as other more recent standards (e.g., BWRVIP-84).

3.3.3 Description of Repair Components and Design Features

The geometry of the upper support replacement hardware (upper support, tie rod nut, and other associated upper support components) is shown on Figure 1 of the GE Stress Analysis Report GE-NE-0000-0061-6306-R4-P (Attachment 4 to March 22, 2007, letter). The torsional arm clamp consists of the guide bolt, locking spring and the capture cover. The torsional arm clamp is shown on Figure 2 of the GE Stress Analysis Report GE-NE-0000-0066-0380-R1-P (Attachment 1 to April 10, 2007, letter). These newly-designed components incorporate features that improve their ability to resist IGSCC. These features include: (1) a large fillet radius at the corner of the upper support arm; (2) increased width and thickness of the upper support; (3) sharp edges eliminated; (4) a larger root radius of the tie rod nut threads; and (5) modification of the upper support spring torsional arm to prevent failure. The original tie rod installation required that cutouts be made in the shroud head flange to accommodate the upper support arm, which hang over the shroud flange. The dimensions of the cutouts will not be changed for installation of the modified upper supports.

The original design analysis was submitted by the licensee on January 16, 1995, and the NRC staff, in a letter dated May 12, 1995, approved this design analysis. The licensee claimed that the proposed current modification has an insignificant affect on the following attributes that were evaluated in the original design analysis:

(1) Seismic model

(2) Dynamic analysis

(3) Bypass flow

(4) Load case and load combinations

(5) Shroud deflections

(6) Effect of the tie rod modification on reactor pressure vessel stress analysis

(7) Effect of the tie rod modification on core shroud shell, shroud head and shroud support plate

(8) Loose parts considerations

(9) Flow induced vibration

(10) Radiation Effects

(11) Down comer Flow Evaluation

3.3.4 Structural Evaluation

Finite element analysis (FEA) and/or manual calculations were used to structurally analyze the modified upper support assembly components. The original FEA of the upper support brackets used the COSMOS finite element code. The mesh size in the original model was coarse and not suitable for capturing peak stresses. A revised FEA of the replacement upper support bracket with refined mesh sizes has been performed using the ANSYS computer program. Details of the analysis, such as input criteria, applied loading, material properties, boundary conditions, and analysis methods are described in the stress analysis report (Attachment 4 to March 22, 2007, letter). The licensee also contracted Structural Integrity Associates, Inc. (SIA) to perform an independent third party review of the GE upper support FEA. SIA developed a separate ANSYS model and their results compared favorably to the GE results for the maximum principle tensile stress. The ANSYS program is qualified for use on safety-related components.

The replacement hardware components (upper support, tie rod nut, and other tie rod components) were evaluated for their susceptibility to IGSCC. The design goal established by the licensee was to maintain sustained peak stress below 0.8 times the minimum yield stress

(Sy) for all new Alloy X-750 upper support components, Alloy X-750 tie rod nuts, and Alloy X-750 locking springs in the torsional arm clamp, thereby providing margin to the criteria in BWRVIP-84.

The replacement hardware components were also evaluated against ASME Code allowable stresses. The design stress intensity (Sm) and Sy values for Alloy X-750 material were specified in accordance with Code Case N-60-5. This is consistent with BWRVIP-84. The membrane and bending stresses were calculated for these components and shown to meet the ASME Code allowable stress limits.

3.3.5 Materials and Fabrication

For the proposed modification, the licensee used the following materials:

(1) Alloy X-750—Tie rod upper support main load path bearing parts and miscellaneous smaller parts that are not in main load path

(2) Alloy X-750—Tie rod nuts

(3) Type 316 stainless steel-----Tie rod upper support dowel pins

(4) Type XM-19 stainless steel—Upper support torsional arm bolt retainer clamps and bolting

(5) Type X-750—Upper support torsional arm retainer ratchet springs

The above-listed materials have been used for many other reactor internal components and have demonstrated good resistance to stress-corrosion cracking in laboratory testing and long-term service experience in the non-welded and low sustained operating stress condition. Nickel-based Alloy X-750 and Type 316 and XM-19 austenitic stainless steels are acceptable per the BWRVIP-84 report and Section III of the ASME Code. The proposed materials for the replacement parts are consistent with those used in the original Pilgrim tie rod design, which was found acceptable by the NRC staff as documented in the Safety Evaluation (SE) dated May 12, 1995.

Consistent with the fabrication requirements specified in the BWRVIP-84 report, the licensee proposed to not utilize any avoidable crevices in the upper bracket design. If the crevices are inherently present, the licensee proposed to implement the following requirements:

(1) the design of crevice will not have any sensitized areas and only IGSCC resistant materials will be used, and

(2) to the extent practical, stagnant conditions will be minimized.

The licensee stated that there are no welds in the replacement upper support assemblies, and they will be procured and processed to prevent sensitized material by meeting the requirements of BWRVIP-84.

3.4 Technical Evaluation of Tie Rod Assembly with Two Modified Core Shroud Stabilizer Assemblies and Two Unmodified Core Shroud Stabilizer Assemblies

3.4.1 Background

During Refueling Outage (RFO-) 16, the licensee replaced the upper supports and installed torsional arm clamps on the 45^0 and 225^0 azimuthally located core shroud stabilizer assemblies. However, the upper supports of the 135^0 and 315^0 azimuthally located core shroud stabilizer assemblies were not replaced due to difficulties encountered with tooling. Thus, these tie rods and stabilizer assembly upper supports remain in the configuration reviewed and accepted by the NRC in its May 12, 1995, SE.

The modifications to the 45^0 and 225^0 tie rod stabilizer assemblies conform to the requirements of the core shroud repair criteria provided in BWRVIP-02-A and BWRVIP-84. The 135^0 and 315^0 core shroud stabilizer assemblies remain in the configuration previously reviewed by the NRC in its May 12, 1995, SE.

3.4.2 Design Objectives

The objective is to operate for one cycle with two (2) core shroud stabilizer assemblies with unmodified upper supports and two (2) core shroud stabilizer assemblies with the modified upper supports.

3.4.3 Description of Repair Components and Design Features

The repair components and design features are discussed in subsection 3.3.3 of this SE.

3.4.4 Structural Evaluation

The difference in the net combined stiffness of the four original core shroud stabilizer assemblies as compared to the proposed arrangement is negligible. Therefore, the thermal preload, which is a function of the stiffness, remains unaffected. It is a requirement that adequate compression be maintained by the core shroud stabilizer assemblies in the shroud welds to prevent separation during normal operation. Since the design basis preload is maintained, adequate clamping force is available to preclude weld separation during normal operation, consistent with the original analysis.

At the 135^0 location, an attempt was made to de-torque the tie rod nut and remove the original upper support in order to install the replacement. This attempt was aborted due to field difficulties with tooling. However, there was no discernable rotation of the tie rod nut based on detailed visual examinations between the as found and as-left conditions. Thus, there was no degradation of the tightness of 135^0 core shroud stabilizer assembly. Also, the inspections verified that there is no looseness in the vertical load path in any of the four core shroud stabilizer assemblies.

Therefore, it is concluded that adequate preload and shroud compression is maintained with the proposed arrangement.

Since the stiffness of the core shroud stabilizer assemblies with the unmodified and modified upper supports are equivalent, there is no impact on the operating loads such as pressure, thermal, seismic, and loss-of-coolant accident (LOCA), due to the proposed configuration. In addition, the operating preload remains unaffected.

Since the preload, as well as the operational loads remain unaffected, the structural adequacy of the components in the modified and unmodified core shroud stabilizer assemblies remains consistent with the design bases.

3.4.5 Justification of Using the Unmodified Upper Support Brackets for One Additional Fuel Cycle

In their April 29, 2007, and May 3, 2007, letters, the licensee indicated that the original upper support brackets may be used for one additional fuel cycle because inspection results from the two upper supports removed from service at Pilgrim and the results from inspection of tie rods assemblies in the BWR fleet indicates that there is reasonable assurance that the unmodified upper support brackets are not flawed.

The original Pilgrim Alloy X-750 upper support brackets have operated for 12 years. The Pilgrim upper supports removed from operation were inspected on the exterior and interior surfaces. The two upper supports being left in service were inspected on the exterior surfaces. No indications of IGSCC were observed.

Table 1 in the licensee's April 29, 2007, letter lists the stresses associated with the nine BWR plants that have inspected the supports and the years of operation following installation of the tie rod repair. These inspections were performed using enhanced visual test (EVT-1) inspection methods. Except for the plant discussed in Reference 4, none of those inspections have detected any crack indications. The upper supports at two plants received additional inspections of the hidden interior surface that also revealed no cracking. The peak stresses in the Pilgrim supports are significantly lower than the stresses in the supports that exhibited IGSCC after 12 years of operation and are lower than one other plant that has operated for 12 years with an installed tie rod repair and has not observed any IGSCC in its Alloy X-750 upper support brackets.

In summary, two factors provide a strong basis that the existing tie rod supports are acceptable. First, the peak stresses in the Pilgrim supports are significantly lower than the stresses in the supports that exhibited IGSCC after 12 years of operation. Secondly, the specific inspections performed including the thorough inspections of the two upper supports that were removed from service provide confirmation that no IGSCC has occurred to date in the two unmodified upper support assemblies.

3.4.6 Justification for Not Installing the Torsional Arm Clamp on the Unmodified Core Shroud Stabilizer Assemblies

The torsional arm clamp's design function is to eliminate the possibility of loose parts from the torsional arm connection and to replace the function of the torsional arm bolt. The torsional arm clamp serves as a capture device for the torsional arm, torsional arm bolt, and a pin. The licensee indicates that the upper stabilizer assembly design is not adversely affected by not installing the torsional arm clamp for one cycle. If the function of the torsional arm was lost:

1. The resulting rotation of the upper spring and the impact on interfacing components in the upper spring bracket yield stresses within acceptable limits.

2. Reactor safety is not impacted by the release of loose parts.

The detailed analysis supporting these conclusions is described in Section 3.2 of the April 29, 2007, letter from the licensee.

3.5 Loose Parts Analysis

The potential loose parts as a result of IGSCC of the torsional arm bolt are the torsional arm, torsional arm bolt, and a pin. The licensee evaluated a number of different pathways for loose parts and determined the effects of having loose parts in the reactor. The evaluation determined the impact of the possible loose parts on the potential for fuel bundle flow blockage and fuel damage due to overheating of the fuel cladding, interference with control rod operation, corrosion or adverse chemical reaction with other reactor materials, interference with Reactor Water Cleanup (RWCU) or Residual Heat Removal (RHR) isolation valves or bottom head drain, interference with instrumentation, and impairment of recirculation system performance. The evaluation concluded that reactor operations would not be compromised with the presence of the potential loose parts in the reactor vessel. There is no design concern for flow blockage to the fuel bundles (fuel debris filter), interference with the control rod scram function (fuel debris filter and guide tubes), or corrosion or adverse chemical reaction with other reactor materials. Also, no significant damage to reactor pressure vessel (RPV) internals, interference with neutron monitoring instrumentation (no flow), interference with the RWCU or RHR isolation valves (single failure proof), or significant plugging of the bottom head drain will result.

3.6 Inspection Results of the As-Found Core Shroud Stabilizer Assemblies

The inspections were performed in accordance with BWRVIP requirements (References 2 and 3). The examinations included the following:

1) EVT-1 inspections of the four core shroud stabilizer assemblies to ensure there was no cracking in the upper support area similar to that observed at another BWR.

2) The tie rod upper support top surface was inspected for wear contact and cracking of all four core shroud stabilizer assemblies. This inspection was by EVT-1 with no indications of cracking.

3) The 45^0 and 225^0 upper support contact areas (underside) were inspected by EVT-1 with no indications of cracking. Since the 135^0 and 315^0 core shroud stabilizer assemblies were not disassembled this inspection could not be performed on those upper supports.

4) An EVT-1 examination of high stress locations identified in GE Part 21 Notification letter (Reference 5) was completed for all four core shroud stabilizer assemblies.

5) The torsional arm bolt was inspected by EVT-1 on all four core shroud stabilizer assemblies with no indications of cracking.

6) An ASME Code general visual (VT-3) inspection of the entire tie rod assembly was performed on all four core shroud stabilizer assemblies with no indications of cracking.

7) An ASME Code examination to detect discontinuities and imperfections (VT-1) inspection of the Lower Support engagement onto the gusset pin from both sides on all four core shroud stabilizer assemblies was performed with no indications of cracking.

8) The tie rod nut and tie rod threads were inspected by EVT-1 with no indications of cracking for the 45^0 and 225^0 core shroud stabilizer assemblies. Since the 135^0 and 315^0 core shroud stabilizer assemblies were not disassembled this inspection could not be performed on those tie rod nuts and threads.

9) Gusset inspections were performed on all four core shroud stabilizer assemblies by EVT-1 with no indications of cracking. The gusset area has been protected by hydrogen water chemistry (HWC) since approximately 1991 and will be protected in the future by HWC nobel metal chemical addition (NMCA). However, no credit is being given to HWC/NMCA for the upper portion of the tie rod near the H-1 weld.

The core shroud stabilizer assemblies have been inspected in accordance with BWRVIP-76, “BWR Vessel and Internals Project, BWR Core Shroud Inspection and Flaw Evaluation Guidelines,” requirements and vendor recommendations. The gussets have been inspected in accordance with BWRVIP-38, “BWR Vessel and Internals Project, BWR Shroud Support Inspection and Flaw Evaluation Guidelines,” requirements.

3.7 Post-Installation Inspection Results

Post-modification inspections were performed for the 45^0 and 225^0 core shroud stabilizer assemblies. These inspections included a general post-maintenance visual inspection and recording of the fit of the shroud support hardware onto the shroud to confirm that there were no interferences at the support locations and that the installation was in accordance with the requirements of the modification drawings and the GE installation specification 26A7096.

3.8 Inspections During Subsequent Refueling Outages

In the first refueling outage following installation of the modified tie rod upper supports, the licensee will inspect the tie rod assemblies in accordance with the requirements defined in BWRVIP-76, Section 3.5, Option 1 or 2. The licensee will also repeat the post-installation inspections described in Section 7.2.1 of the licensee’s submittal dated March 22, 2007.

3.9 Conclusion

Based on the technical justification, the licensee concludes that the proposed modification provides an acceptable level of quality and safety for one additional fuel cycle, pursuant to the requirements specified in 10 CFR 50.55a(a)(3)(I).

4.0 STAFF EVALUATION

4.1 Safety Evaluation of the Modified Tie Rod Assembly

4.1.1 Structural and Design Evaluation

The design analysis indicated that the licensee used the following aspects of the design criteria for the modification of the upper shroud support, tie rod nuts, and torsional arm clamp:

(A) Maximum tensile principal stress due to sustained normal conditions loads for IGSCC evaluation of Alloy X-750 materials

(B) Stress intensities for the upper shroud support for ASME Code compliance

In the current modification, the licensee used a criterion for IGSCC susceptibility of Alloy X-750 materials which specifies a maximum threshold stress limit that is more conservative than the existing value specified in the BWRVIP-84 Report. By creating a upper core shroud support fillet radius, the maximum principal stress is reduced significantly in the upper support which ultimately reduces the susceptibility to IGSCC. The NRC staff reviewed the maximum principal stress values of all the Alloy X-750 materials that are used in the current modification, and concludes that these principal stress values comply with IGSCC design criterion.

The licensee used the ASME Code design criteria that are specified in the ASME Code, Section III, Subsection NG, Core Support Structure, 2001 Edition through and including the 2003 Addenda for the current core shroud tie rod modifications. All the stress intensity values of the components that are used in the current core shroud tie rod modifications comply with the ASME Code, Section III, Subsection NG design criteria. Therefore, the NRC staff concludes that the licensee's current core shroud tie rod modifications are structurally qualified to meet the ASME Code, Section III design criteria, and this design is consistent with the original design basis of the tie rod modification.

To determine the principle stress for the design analysis, GE used the computer code ANSYS for performing FEA. The stress analysis modeled the bearing interface of the horizontal arm of the upper support with that of the flange using contact elements with a coefficient of friction specified in Section 5.3.1 of Attachment 4 to the March 22, 2007, letter. In the April 20, 2007, letter the licensee evaluated the impact of the coefficient of friction on the analysis. The licensee indicates:

> Pilgrim Replacement Upper Support Stress Analysis (Pilgrim Report GE-NE-000-0061-6304-R4-P) used a friction factor of 0.3 between the bearing interface of the horizontal arm of the upper support and the shroud flange, which is a typical value for such applications, and is also consistent with GE standard design specification for Core Support Structures. This value is within the range used for wetted steel in engineering references. However, a sensitivity study was performed to assess the effect of different friction coefficient values on the upper support stress. The friction coefficients of 0.2, 0.3, and 0.4 were used in the sensitivity analyses. The results of these analyses showed that stress increased with increased friction coefficients, the change in the Pm+Pb+Q+F stress in the upper support due to the above friction coefficients is negligible (< 1%) and, as a result, the design is insensitive to the friction coefficient used. Hence, resistance of the upper support to IGSCC is not impacted.

Based on the licensee's response and sensitivity analysis, the NRC staff concludes that licensee's stress analysis has adequately modeled the interaction of the horizontal arm of the upper support and the shroud flange.

The NRC staff requested that the licensee identify analyses that users have performed to qualify the ANSYS computer code for use on safety-related components and identify staff SEs that approved the use of this code to perform FEA to determine the total stress on safety-related components.

In the April 20, 2007, letter the licensee indicated that GE has used ANSYS for several RPV internals evaluations (e.g., Clinton Power Station Unit 1 - Core Shroud Repair, Docket No. 50-461). In addition, ANSYS applicability and validity was demonstrated by running a series of verification cases (over 200) that exercise the elements and options used in the finite element code. The verification cases were extracted from textbooks in which classical or theoretical solutions are published.

Since GE has validated the ANSYS computer code, its use for determining principle stresses in the safety analysis is acceptable.

In its design review of the current tie rod modification, the NRC staff compared the load cases and load combinations that were used in the original analysis (licensee's submittal dated January 16, 1995) with that of the current modification.

The original analysis included loading conditions for normal operation; two upset conditions; three faulted conditions, and three emergency conditions. However, the licensee used load cases representing one emergency condition and one faulted condition for the current modification.

The licensee in its response dated April 20, 2007, stated that the stress analysis for the replacement upper support was performed for the bounding (largest) load for the faulted and emergency conditions, and this analysis is consistent with that of the original design. The NRC staff finds this response acceptable because the licensee used bounding analysis and this methodology is consistent with the original design analysis.

4.1.2 Materials and Fabrication

With respect to the issue related to materials and their fabrication, the licensee used the guidelines specified in the BWRVIP-84 report. BWRVIP-84 was approved by the NRC staff in a letter dated September 6, 2005. The staff's SE for BWRVIP-84 indicates that the following special surface preparation conditions for cold worked austenitic stainless steel and Alloy X-750 materials should be implemented:

(A) Surface finishing techniques described in Section A.9.2 of BWRVIP-84 shall be implemented on cold worked austenitic stainless steel reactor vessel internal (RVI) components to minimize the susceptibility to IGSCC and fatigue cracking.

(B) Surface finishing techniques described in Section B.8.9 of BWRVIP-84 shall be implemented on cold worked Alloy X-750 RVI components to minimize susceptibilty to IGSCC and fatigue cracking.

(C) Surface examination techniques described in Section 3.6.3 of the staff’s SE shall be implemented for Alloy X-750 RVI components that are fabricated using Electrical Discharge Machining (EDM).

The licensee in its response dated April 20, 2007, stated:

(A) This item is not applicable to the Pilgrim hardware. All 300 series stainless steel components are solution annealed subsequent to the machining operation. No further cold work mitigation is necessary.

(B) Consistent with Section 3.6.2 of the staff's [September 6, 2005] safety evaluation, the surface finish requirements for Alloy X-750 components described in Paragraph B8.9 of BWRVIP-84 have been applied to the replacement hardware.

(C) Consistent with Section 3.6.3 of the staff's [September 5, 2005] safety evaluation, EDM surfaces of Alloy X-750 have demonstrated to be acceptable for BWR service by examination of qualification samples. This examination includes metallographic cross sections to confirm that the surfaces do not contain detrimental surface features (e.g., microfissures).

The NRC staff finds this response acceptable because the licensee’s compliance with these conditions is consistent with the BWRVIP-84 guidelines, and implementation of these conditions ensures adequate mitigation of IGSCC.

4.1.3 Pre-Modification Inspection

In the staff's SE dated May 12, 1995, for the original Pilgrim installation of the four sets of stabilizer assemblies and core plate wedges, the NRC staff indicated that the reinspection plan should include the four gusset plate welds and the core shroud H11 weld because the integrity of these welds is essential to maintaining tie rod preload. The Regulatory Commitments in Attachment 2 to the licensee’s March 22, 2007, letter did not include inspection of the gusset plate welds and core shroud H11 weld. The staff requested that the licensee either include the gusset plate and H11 welds in the reinspection plan or explain why reinspection is not necessary.

In the letter dated April 24, 2007, the licensee indicated that the gusset and gusset welds were inspected by EVT-1 methods during the spring 2007 RFO-16. The licensee indicated that H11 weld integrity is not essential to maintain tie rod preload. Therefore, inspection of the H11 weld was not necessary during RFO-16.

The gussets were previously examined in RFO-11, RFO-12, and RFO-16. No relevant indications were noted in these examinations. In addition, the licensee inspected 100% of the top surface of the H11 weld in RFO-15 with no relevant indications noted.

The licensee indicates future inspections will be performed consistent with the BWRVIP recommendations provided in BWRVIP-38 and BWRVIP-76-A.

Since the licensee has examined the gussets and gusset welds during RFO-16, examined the H11 weld surface during RFO-15, and will perform future inspections in accordance with BWRVIP-38 and BWRVIP-76-A, the licensee has performed sufficient examination of the gussets, gusset welds and H11 weld to assure that these welds are in adequate condition for maintaining tie rod preload.

4.2 Safety Evaluation of Tie Rod Assembly with Two Modified Core Shroud Stabilizer Assemblies and Two Unmodified Core Shroud Stabilizer Assemblies

4.2.1 Structural and Design Evaluation

The torsional arms are attached to both sides of the upper spring by the torsional arm bolt. The torsional arm bolt has been determined to be susceptible to IGSCC (Table 1 in the GE-NE-0000-0064-9392-R2-P Report). The upper ends of the torsional arms fit into slots in the upper spring and are held in place with the torsional arm bolts.

The bottom end of the torsional arm fits into a pocket in the upper spring bracket. When the upper spring is in the radial position, the torsional arms are not loaded. However, if the upper spring starts to rotate during a seismic event, the torsional arms will resist rotation of the upper spring. This tends to keep the upper spring centered within its small range of rotational motion.

The licensee performed an assessment discounting the function of the torsional arm. The assessment evaluated the effect of the potential approximate 5^0 rotation on the upper spring and the interfacing components in the upper spring bracket. This effect was combined with the other applicable operating condition stresses for these components. The calculated stresses were compared to the ASME Code design basis stress limits and were found to be acceptable.

To provide further confidence that a core shroud stabilizer assembly is not compromised by an undetected IGSCC flaws; analytical efforts were also performed to evaluate crack growth of an assumed IGSCC indication hidden from external view in the original supports. The focus of this scoping study was to evaluate the growth and resultant crack depth that would occur over one operating cycle. The crack growth analyses utilize the results from the FEA of the existing Alloy X-750 tie rod upper supports that were generated to better understand the stresses in the tie rod support. The model represented the Pilgrim geometry including the pads on the upper support, plasticity in the stainless steel shroud and X-750 upper support, and contact between the shroud ledge and upper support.

A summary of the analysis approach, assumptions, and results is contained in the May 3, 2007, letter from the licensee. Based on the specific cases evaluated, the resulting predicted crack size present in the support after one cycle was found to be acceptable.

Based on the analyses performed, the impact of IGSCC on the unmodified core shroud stabilizer assemblies has been adequately evaluated.

4.2.2 Materials and Fabrication

The evaluation of materials and fabrication is discussed in subsection (2) in Section 4.1 of this SE.

4.1.3 Loose Parts Evaluation

The licensee performed a loose parts analysis consistent with BWRVIP-06A, Safety Assessment of BWR Reactor Internals, Section 4.1. The evaluation considered if the potential loose parts could represent a safety concern by evaluating if they result in (a) the potential for bundle flow blockage and consequential fuel damage, (b) the potential for interference with control rod operation, or (c) the potential for corrosion and chemical interaction with other reactor materials.

The May 3, 2007, letter from the licensee provided a more detailed evaluation of:

1) the size of loose parts that can be generated with failure of the torsional arm bolt,

2) the locations in the reactor coolant system where the loose parts could migrate, and

3) an explanation of why loose parts are not a safety concern.

Based on the evaluation results from the loose parts analysis, the NRC staff concludes that loose parts from IGSCC-susceptible components in the unmodified core shroud stabilizer assemblies are not a safety concern for operation for one additional cycle with these components.

4.2.4 Inspections During Subsequent Refueling Outages

The NRC staff finds that the licensee’s commitment to perform inspections during subsequent refueling outages is acceptable as it complies with the staff-approved BWRVIP-76 Report. Implementation of the inspection guidelines of the BWRVIP-76 Report provide adequate information regarding the structural integrity of the core shroud modifications.

5.0 <u>CONCLUSIONS</u>

The NRC staff finds that the modified core shroud stabilizer assemblies for Pilgrim are acceptable for the following reasons:

(A) The newly-designed components have wider and thicker upper support arms with no sharp edges and have a larger root radius of the tie rod nut threads. A large fillet radius at the corner of the upper support arm reduces the peak stress and thereby increases resistance to IGSCC.

(B) The licensee’s modified core shroud stabilizer assemblies are structurally qualified to meet the ASME Code, Section III design criteria, and this design is consistent with the original design basis for the tie rod modification.

The NRC staff finds that operation for one additional fuel cycle with two unmodified core shroud stabilizer assemblies without two torsional arm bolt clamps are acceptable for the following reasons:

(A) The upper stabilizer assembly design is not adversely affected and reactor safety is not impacted by the potential release of loose parts due to the postulated failure of the torsional arm bolt by IGSCC.

(B) Based on the inspection results from the Pilgrim upper support assemblies that were removed from service and the inspection results from other operating BWRs with core shroud stabilizer assemblies, there is reasonable assurance that the unmodified core shroud stabilizer assembly upper supports are not flawed.

Based on the above discussion, the NRC staff concludes that the as-left configuration which utilizes two modified core stabilizer assemblies and two torsional arm bolt clamps and two unmodified core shroud stabilizer assemblies, will provide an acceptable level of quality and safety for one additional fuel cycle. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i), the proposed alternative, is authorized for Pilgrim for one additional fuel cycle.

6.0 REFERENCES

1. Letter from J. S. Post (GE) to document Control Desk (NRC), dated October 9, 2006, “Notification: Completion of GE Evaluation on Core Shroud Repair Tie Rod Upper Support Cracking.”

2. Letter from W. Eaton (BWRVIP) to All BWRVIP Committee Members, dated March 29, 2006, “BWRVIP Recommendation to Inspect Core Shroud Tie Rod Repairs.”

3. Letter from R. Dyle/T. Mulford (BWRVIP) to All BWRVIP Committee Members, dated April 3, 2006, “Clarification to BWRVIP Recommendations to Inspect Core Shroud Tie Rod Repairs.”

4. GE Energy - Nuclear, SC 06-07, 10CFR Part 21 Communication, “Core Shroud Repair Tie Rod Upper Support Cracking,” May 12, 2006.

5. Letter from J. S. Post (GE) to document Control Desk (NRC), dated January 5, 2007, GE Part 21 Communication: Potential for Intergranular Stress Corrosion Cracking in Shroud Repair Tie Rod threaded Components.

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