October 5, 2001

Mr. Mark E. Warner
Vice President - TMI Unit 1
AmerGen Energy Company, LLC
P.O. Box 480
Middletown, PA 17057

SUBJECT: THREE MILE ISLAND NUCLEAR STATION, UNIT 1 (TMI-1) - ISSUANCE OF AMENDMENT RE: ONCE-THROUGH STEAM GENERATOR (OTSG) SURVEILLANCE FOLLOWING CYCLE 13 (TAC NO. MB0664)

Dear Mr. Warner:

The Commission has issued the enclosed Amendment No. 237 to Facility Operating License No. DPR-50 for TMI-1, in response to your application dated December 6, 2000, as supplemented July 13 and September 6, 2001.

The amendment revises the OTSG surveillance criteria contained in the TMI-1 Technical Specifications to permit certain inside diameter intergranular attack indications to remain in service. The changes also extend the repair criteria from a cycle-to-cycle basis to a permanent basis.

A copy of the related safety evaluation is also enclosed. Notice of Issuance will be included in the Commission's biweekly *Federal Register* notice.

Sincerely,

/RA/

Timothy G. Colburn, Senior Project Manager, Section 1
Project Directorate I
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket No. 50-289

Enclosures: 1. Amendment No. 237 to DPR-50
2. Safety Evaluation

cc w/encls: See next page

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AMERGEN ENERGY COMPANY, LLC

DOCKET NO. 50-289

THREE MILE ISLAND NUCLEAR STATION, UNIT NO. 1

AMENDMENT TO FACILITY OPERATING LICENSE

Amendment No. 237
License No. DPR-50

1. The Nuclear Regulatory Commission (the Commission or NRC) has found that:

   A. The application for amendment by AmerGen Energy Company, LLC (the licensee), dated December 6, 2000, as supplemented July 13 and September 6, 2001, complies with the standards and requirements of the Atomic Energy Act of 1954, as amended (the Act), and the Commission's rules and regulations set forth in 10 CFR Chapter I;

   B. The facility will operate in conformity with the application, the provisions of the Act, and the rules and regulations of the Commission;

   C. There is reasonable assurance: (i) that the activities authorized by this amendment can be conducted without endangering the health and safety of the public, and (ii) that such activities will be conducted in compliance with the Commission's regulations;

   D. The issuance of this amendment will not be inimical to the common defense and security or to the health and safety of the public; and

   E. The issuance of this amendment is in accordance with 10 CFR Part 51 of the Commission's regulations and all applicable requirements have been satisfied.

2. Accordingly, the license is amended by changes to the Technical Specifications as indicated in the attachment to this license amendment, and paragraph 2.c.(2) of Facility Operating License No. DPR-50 is hereby amended to read as follows:

   (2) Technical Specifications

   The Technical Specifications contained in Appendix A, as revised through Amendment No. 237, are hereby incorporated in the license. The AmerGen Energy Company, LLC shall operate the facility in accordance with the Technical Specifications.

3. This license amendment is effective as of its date of issuance and shall be implemented within 30 days of issuance. This includes the licensee's commitment in its September 6, 2001, letter with respect to modifications to Engineering Report ECR No. TM 01-00328.

FOR THE NUCLEAR REGULATORY COMMISSION

/RA/

Lakshminaras Raghavan, Acting Chief, Section 1
Project Directorate I
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Attachment: Changes to the Technical Specifications

Date of Issuance: October 5, 2001

ATTACHMENT TO LICENSE AMENDMENT NO. 237

FACILITY OPERATING LICENSE NO. DPR-50

DOCKET NO. 50-289

Replace the following pages of the Appendix A Technical Specifications with the attached revised pages. The revised pages are identified by amendment number and contain marginal lines indicating the areas of change.

Remove	Insert
4-78	4-78
4-80	4-80
4-81	4-81
4-82	4-82
4-83	4-83
--	4-83a

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO AMENDMENT NO. 237 TO FACILITY OPERATING LICENSE NO. DPR-50

AMERGEN ENERGY COMPANY, LLC

THREE MILE ISLAND NUCLEAR STATION, UNIT 1

DOCKET NO. 50-289

1.0 INTRODUCTION

By letter dated December 6, 2000, as supplemented July 13, and September 6, 2001, AmerGen Energy Company (the licensee) submitted a request to change the technical specifications (TSs) at the Three Mile Island Nuclear Station, Unit 1 (TMI-1). The requested TS changes would allow once-through steam generator (OTSG) tubes to remain in service with indications of inside diameter (ID) intergranular attack (IGA) located below the upper tubesheet (UTS) secondary face. The requested changes also extend the repair criteria from a cycle-to-cycle basis to a permanent basis.

The supplemental letter dated July 13, 2001, provided the licensee's response to a request for additional information (RAI) from the Nuclear Regulatory Commission (NRC) staff, and provided an engineering report, ECR No. TM 01-00328, to support the licensee's request. The supplemental letter dated September 6, 2001, provided additional clarifying information and minor changes to the engineering report and TSs. Per the formal commitment contained in the licensee's September 6, 2001, letter, the NRC staff expects the licensee to incorporate the changes to the engineering report prior to the start of the 14R refueling outage. The July 13 and September 6, 2001, letters provided additional clarifying information which did not change the initial proposed no significant hazards consideration determination or expand the amendment beyond the scope of the original notice. The September 6, 2001, letter also provided camera ready pages of the TSs.

The licensee proposed to revise TS 4.19 to allow steam generator (SG) tubes to remain in service with indications of ID IGA in the area of the tube defined by the bottom of the UTS completely to the top of the lower tubesheet. In Amendment Nos. 206 and 209 dated October 16, 1997, and April 13, 1999, respectively, the NRC approved one-cycle license amendments for TMI-1 which allowed SG tubes to remain in service with ID IGA indications in this defined area. The licensee proposed to incorporate by reference in the TSs the Volumetric ID IGA Management Program contained in the Amergen Engineering Report, ECR No. TM 01-00328. This program defines how the licensee will ensure that the SG tubes will meet the repair criteria and the leakage criteria at the time of inspection and the end of the next cycle of operation, and includes the acceptance criteria.

The licensee's license amendment request proposed to eliminate the one-cycle restriction, and provided the information cited in the October 16, 1997, and April 13, 1999, safety evaluations that is necessary to support issuance of a permanent amendment.

2.0 BACKGROUND

2.1 Previous TMI OTSG ID IGA License Amendment History

In November 1981, while performing reactor coolant system hydrostatic testing with the reactor shut down, primary-to-secondary system leakage was detected in both OTSGs. Subsequently, eddy current testing (ECT) examinations revealed many defective tubes. Metallographic examination of portions of removed tubes confirmed that the tube degradation initiated from the primary side of the tubes in the form of circumferential stress-assisted intergranular cracks. The active chemical impurity causing the corrosion was sulfur in reduced forms, which had been inadvertently introduced into the reactor coolant system. The vast majority (approximately 95%) of the defects occurred within the top 2 to 3 inches of the 24-inch thick UTS. The corrosion attacks most rapidly at the air/water interface and during lay up. The air/water interface was located in the UTS during a significant portion of the post-hot-functional shutdown period. To repair the defective OTSG tubes within the UTS, the licensee applied a kinetic (explosive) expansion repair technique. The NRC staff previously reviewed and approved the licensee's repair of the OTSG tubing in NUREG-1019, "Safety Evaluation Report Related to Steam Generator Tube Repair and Return to Operation -- Three Mile Island Nuclear Station, Unit No. 1," dated November 1983.

The kinetic expansion repair technique applied in the early 1980's addressed the existence of defects located in tubes in the UTS. However, a limited population of tubes in the TMI-1 OTSGs contained degradation located below the UTS secondary face that could not be repaired by the kinetic expansion technique. Because of the uncertainty in sizing the depth of ID IGA degradation that was not previously repaired, the NRC staff and the licensee agreed during a meeting held in Rockville, Maryland, on July 15, 1997, that the tube repair criteria in the TMI-1 TSs should be amended to address tubes identified with this mode of degradation.

Subsequently, the licensee proposed TS repair criteria to be used through the Cycle 12 operating cycle, which addressed ID IGA below the UTS. For the first time, the licensee was to implement a 100-percent bobbin probe examination with follow-up motorized rotating pancake coil (MRPC) probe examinations of all the ID IGA flaws identified by the bobbin probe. By enlarging the scope of their examination in this way, the licensee could perform a more robust growth rate evaluation of the ID IGA flaws present in the SGs. In previous outages, the licensee had performed a less than 100-percent examination of all ID IGA flaws with the MRPC probe which limited the growth analyses that could be performed to evaluate if the degradation mode was still active.

The ID IGA repair criteria for Cycle 12 supplemented the existing TS depth-based tube repair limit (i.e., 40-percent through-wall (TW)) with ECT voltage-based and length-based repair limits. The length-based repair limits did not account for flaw growth over the cycle because the licensee had concluded that the ID IGA flaws were inactive. In addition to the proposed repair limits, the licensee proposed modifications to the reporting requirements for SG tube inspections to include the submission of a summary of SG inspections and results to the NRC within 90 days following completion of the inspections and repair. The proposed TS repair criteria were reviewed and approved for Cycle 12 in Amendment No. 206 as discussed in the related NRC staff safety evaluation dated October 16, 1997.

The licensee subsequently submitted a request to the NRC to continue the TS repair criteria through the next cycle, through the end of Cycle 13. The request was again limited to one cycle because the licensee and NRC staff recognized that more data were required before a permanent amendment would be approved by the NRC. Outage 13R would be the second of two consecutive outages in which a very large number of ID IGAs would have been examined using the same ECT scope and techniques (i.e.,100-percent bobbin probe examination with follow-up MRPC probe examinations of all the ID IGA flaws identified by the bobbin probe). The results of the two outages were to provide a significant amount of ECT flaw length data with which to analyze the growth rate of the ID IGA flaws. This analysis would provide a basis for a permanent ID IGA repair criteria amendment.

The staff's evaluation of the repair criteria for Cycle 13 evaluated the leakage and structural integrity margins, growth rate analysis of ID IGA indications, and the capability of the ECT techniques to reliably implement the length-based repair criteria. The proposed TS changes to allow the use of the ID IGA repair criteria through the end of Cycle 13 were approved by the NRC staff in a safety evaluation dated April 13, 1999.

In the safety evaluation dated April 13, 1999, the NRC staff encouraged the licensee to pursue the development of a qualified ECT technique which could reliably depth-size ID IGA in accordance with the original 40-percent tube repair limit. The NRC staff also noted areas of weakness in the licensee's growth rate study. Although some of these factors were addressed in the Cycle 13 TS change request, the NRC staff asked the licensee to ensure that all areas of weakness were completely addressed in any subsequent submittals. These areas were: (1) bobbin probe wear, (2) calibration practices and standards, (3) differences in data acquisition hardware, and (4) data analyst uncertainty.

2.2 Proposed TMI ID IGA License Amendment

The licensee has proposed the continuation of the TS repair criteria, as previously approved in Cycles 12 and 13, in a permanent license amendment. A public meeting was held on April 25, 2001, between the licensee and NRC staff to discuss the information that the licensee had submitted for the proposed license amendment. On the basis of NRC staff comments provided during the meeting, the licensee revised its submittal to include details of a formal "Management Program for Volumetric Inside Diameter Intergranular Attack in the Once-Through Steam Generators," described in an AmerGen Engineering Report, ECR No. TM 01-00328, provided subsequent to the meeting. The TSs for the proposed license amendment were changed to reference the new engineering report. The report summarizes the licensee's experience with ID IGA at TMI-1 and the technical basis for the license amendment. In addition, the report adds statistical tests and acceptance criteria for evaluating the validity of the growth assessments.

The NRC staff's evaluation of this proposal continues, as with the evaluation for Cycle 13, to consider the ECT technique capability of reliably implementing the repair criteria, structural and leakage integrity margins, and growth rate analysis of ID IGA indications. The NRC staff evaluated the information provided by the licensee to respond to open issues that had previously restricted NRC approval for this alternate repair criteria to one-cycle amendments. The evaluation is provided below.

3.0 EVALUATION

3.1 Inservice Inspection of SG Tubes

The licensee has proposed to utilize on a permanent basis the same scope of SG tube inspection that was used for Cycles 12 and 13. Specifically, during each outage in which the volumetric ID IGA management program is utilized, a 100-percent bobbin coil inspection of the bottom of the upper tubesheet completely to the top of the lower tubesheet of inservice tubes will be conducted in accordance with the TMI-1 SG TSs. All ID indications of tube degradation identified as a result of this bobbin coil inspection will then be inspected with an MRPC probe.

If the morphology of an indication as determined by the MRPC probe is characterized as:

- ID-initiated and volumetric, then the indication will be treated as volumetric ID IGA;
- outside diameter (OD)-initiated, or crack-like, or mixed mode, then the indication will be treated as a mechanism other than volumetric ID IGA and will be repaired; or
- no defect, then it will be assumed that the bobbin or MRPC probe indication is not a defect.

As requested by the NRC staff in the April 13, 1999, safety evaluation, the licensee specifically addressed (1) bobbin probe wear, (2) calibration practices and standards, (3) differences in data acquisition hardware, and (4) data analyst uncertainty in its new engineering report and in response to an NRC staff RAI. The revised submittal described the ECT equipment and calibration techniques used in outages 11R, 12R, and 13R, and how consistent use of the above mentioned probes would ensure that measurement error would be minimized.

Specifically, TMI-1 uses the following ECT examination coils for examination of volumetric ID IGA in the SG tubes:

- 0.510" bobbin is used as a general screening coil
- 0.540" bobbin is used for evaluating ID Volumetric IGA indications
- 0.080" high frequency (shielded coil) pancake coil on an MRPC probe is used for axial and circumferential extent measurement
- 0.115" pancake coil on an MRPC probe is used for axial and circumferential extent measurement for comparison to previous 0.115" coil measurements, if available
- Plus-point coil on an MRPC probe is used for determination of surface of initiation and volumetric morphology

TMI-1 has used the 0.540" bobbin coil probe for evaluating its volumetric ID IGA indications in all outages since 1985. This probe serves as a benchmark with which past ECT data for a given indication may be compared with more current data. All ID flaw indications found with a 0.510" bobbin coil probe are given an additional examination with the 0.540" bobbin coil probe.

Two new practices were implemented by the licensee in outage 12R to provide enhanced consistency. Bobbin coil wear is now being monitored for examinations where ID IGA is being evaluated, by requiring that all 0.540" probes show a voltage change of not more than 15 percent in response to holes in a calibration standard. Data obtained from probes not meeting the wear standard voltage requirement are voided and the affected tubes are reexamined.

In addition, a Babcock and Wilcox Owners Group American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section XI, “mother standard” is being utilized for calibrations (versus individual calibration standards) in order to eliminate subtle voltage differences between calibration standards. The use of a mother standard over consecutive outages allows for a more accurate assessment of voltage changes for a given indication, such as those performed for growth studies.

Some of the volumetric ID IGA indications are given depth-size estimates using the bobbin coil probe, which is discussed in the next section. To ensure the reliability of these depth-size measurements, the TMI-1 site-specific eddy current analyst test for TMI-1 has required that all resolution analysts estimate ID IGA depth within 10 percent TW root mean square error with respect to the test’s truth answers. A minimum of 16 flaws were used in these analyst tests.

Prior to the 12R and 13R outages in 1997 and 1999, respectively, the licensee performed a study to quantify the expected acquisition, analysis, and technique errors expected during the MRPC probe examinations of the ID IGA indications. For the 0.080" high frequency pancake coil (the coil used by TMI-1 to measure the extents of the ID IGA indications), the acquisition standard deviations were 0.0114" for axial length and 0.0084" for circumferential length. The analysis standard deviations were 0.022" for axial length and 0.031" for circumferential length. Technique variabilities were obtained by comparing the results of the ECT analysis to the actual metallurgy of the flaws. The technique standard deviations were 0.039" for axial length and 0.033" for circumferential length. The average technique errors were a 0.124" overestimate of the axial extent and a 0.127" overestimate of circumferential extent. The licensee concluded from the above studies that the rotating coil techniques have demonstrated that axial and circumferential extents are consistently overestimated, and the acquisition and analysis errors are minimal compared to the overestimation that results from use of the MRPC probe. Further, even when analysis and technique/equipment variability are applied at a 95-percent confidence level, the extents measured by ECT are larger than the actual extents.

The licensee discussed differences between outages and the expected effects on the ECT data and growth rate analysis, and concluded the differences would not adversely affect flaw growth studies because procedures were implemented to assure consistency.

Based on (1) the scope of inspection implemented since outage 12R; (2) consistent use of the same probes to evaluate degradation growth; and (3) improvements to the licensee’s inspection practices discussed above, the NRC staff has determined that the inspection program is acceptable for monitoring the ID IGA in the locations covered under this license amendment request.

3.2 Structural Integrity Assessment

The primary method of ensuring structural integrity of ID IGA flaws has been the application of the TS length-based repair criteria, which were determined based on structural analyses of flawed SG tubing assuming TW defects of the limiting length. That is, the limiting axial length criterion of 0.25" was based on the NRC Regulatory Guide (RG) 1.121 analysis performed for the Crystal River Unit 3 Nuclear Generating Plant’s OTSGs and accepted for use at TMI-1 in the October 16, 1997, safety evaluation for use of an ID IGA alternate repair criteria at TMI-1.

This length was based upon the RG 1.121 analysis which assumed a 100-percent TW axial flaw of 0.25" extent was present in a tube.

The existing repair criteria specify that tubes shall be repaired or removed from service when degradation exists within the tube that measures equal to or greater than 40 percent of the nominal tube wall thickness. TW depth is estimated from the bobbin coil data. The 0.540" bobbin coil ID flaw indications ($\leq$30 degrees and $\geq$5 degrees) are assigned a percent TW depth estimate if their measured signal is $\geq$0.4 volts and has a signal-to-noise ratio of $\geq$3:1. ID flaw indications measuring <0.4 volts and <3:1 signal-to-noise ratio are not assigned an estimated TW extent due to insufficient signal. In addition, the repair criteria provide additional limits on the dimensional extent of volumetric ID IGA indications. Specifically, the measured circumferential and axial lengths of ID IGA tube degradation are limited to less than or equal to 0.52 and 0.25 inches, respectively. This repair criteria has been implemented since Cycle 12.

In order to demonstrate continued structural integrity, the licensee completed in-situ burst testing, during the 12R outage, of SG tubes with bounding ID IGA indications. In addition, supplemental laboratory burst tests were performed on pulled tubes in order to effectively simulate both peak hoop and axial stresses which might be applied to tubes containing volumetric flaws during a postulated main steam line break. None of the indications tested in-situ or in the laboratory burst when subjected to test pressures simulating up to three times the normal SG tube operating differential pressure. In fact, the burst pressures of the tube sections containing ID IGA that were tested in the laboratory were above 10,000 pounds per square inch gauge (psig). This indicates that substantial structural margin exists for these flaws since the burst pressure for tubes with no defects averages 11,216 psig. The defects that have been left in service to this point are bounded by the burst tests that have been performed in previous outages and laboratory testing.

The licensee has provided site-qualification data for the bobbin coil from the Appendix H qualification for depth sizing ID IGA indications. This TMI-1-specific qualification was based on two laboratory produced crack specimens and 28 flaws from TMI-1-pulled tubes with the sodium thiosulfate-induced damage. Since the tubes were pulled from the TMI-1 SGs, the tube geometry, signal-to-noise ratios, deposits, and other parameters affecting ECT are similar to the inservice tubes. This qualification has been reviewed by independent Qualified Data Analysts as required by the Electric Power Research Institute Pressurized Water Reactor Steam Generator Examination Guidelines, Revision 5. The data set contains both intergranular stress corrosion cracks (IGSCC) and ID IGA.

The NRC noted that out of 30 indications in the qualification data set, only five indications were ID IGA flaws that exhibited voltage signals large enough to be depth sized. Seven additional indications were listed as ID IGA flaws in the qualification data set, but were not depth sized by ETC. The rest of the flaws listed in the data set were IGSCC flaws.

The NRC staff does not agree that this data set is robust in demonstrating the ability of the technique to depth size IGA flaws. The NRC staff believes that the data comparing ECT depth size to destructive examination flaw depth size are better correlated for IGSCC than for IGA, when the data are plotted separately. Nonetheless, based on the improvement to the ID IGA management program represented by the statistical analyses of the licensee's data, and comparison of the analyses to conservative acceptance criteria, the NRC staff believes that the limitations of the depth-sizing technique should not impede the licensee's ability to assess

growth from cycle to cycle. If the hypothesis of no growth of the ID IGA flaws is substantiated by the statistical evaluations of the data, the tubes would be expected to retain their structural integrity with respect to the ID IGA degradation based on the tests described in the previous discussion. The statistical analyses contained in the licensee's ID IGA management program are described in Section 3.4 of this safety evaluation, titled "Analysis of Growth Rate for IGA Degradation."

ID volumetric indications are evaluated with respect to the TS criteria whether they are detected by the bobbin coil probe and confirmed by MRPC probe or if they are detected only by the MRPC probe. The bobbin coil depth (when assigned), MRPC axial extent, and MRPC circumferential extent limits are applied separately, and, if any one of the three limits is exceeded, the tube must be repaired. These length-based repair limits for the ID IGA degradation are based on structural analyses of flawed SG tubing, assuming it contains 100-percent TW defects of the limiting length. The licensee concludes that tubes with defects at these repair limits would retain their structural integrity (i.e., assuming a TW defect, the defect would be stable) under normal operating and postulated Main Steam Line Break (MSLB) accident loads. These length-based repair limits are unchanged from the previously approved one-cycle license amendment.

The licensee will continue, as necessary, to conduct additional in-situ pressure testing of a sample of SG tubes containing ID IGA indications to supplement the in-situ tests results obtained during prior outages. Tubes selected for testing will include the most significantly degraded tubes (i.e., the lowest expected burst pressure) as determined by an assessment of ECT signal characteristics. The licensee will consider indication voltage, dimensional lengths, and depth measurements to choose potential candidates for in-situ testing. If the tested tubes retain their structural and leakage integrity throughout the test, there is additional assurance that tubes with less significant degradation will have adequate margins for tube integrity during a postulated MSLB accident.

3.3 Leakage Integrity Assessment

3.3.1 In-Situ Pressure Testing to Demonstrate Leakage Integrity

The existing depth-based repair criteria, as well as the length-based alternate repair criteria used during Cycles 12 and 13, have been established to ensure SG tubes have adequate leakage integrity with appropriate margins of safety under normal operating and postulated accident conditions. The licensee will rely on previously completed in-situ pressure testing of SG tubes with ID IGA indications and a statistical assessment of ID IGA growth to demonstrate a low leakage potential for tubes containing this mode of degradation. The statistical tests to measure the growth rate of OD IGA indications performed by the licensee each outage must conclude that there is a low likelihood that the ID IGA degradation grew during the previous cycle of operation in order for the licensee to use the in-situ pressure test results obtained in previous outages. Detection of flaw growth will necessitate the performance of additional in-situ pressure testing in future outages to reassess tube leakage integrity margins, as well as require a license amendment request from the licensee to address its proposed growth analysis.

In-situ pressure testing subjects degraded tubes to conditions that are conservative with respect to internal pressure loadings postulated to occur under accident conditions. Internal pressure within the tube during the test induces axial and circumferential stresses within the tube wall.

The purpose of the testing is to assess whether the degraded tubes exposed to these elevated stresses are capable of withstanding the test conditions while retaining leakage and structural integrity.

3.3.2 Prior In-Situ Tests and Laboratory Results

In order to demonstrate leakage integrity margins, the licensee completed in-situ pressure testing, during the 12R outage, of SG tubes with the bounding ID IGA indications to demonstrate that tubes containing this mode of degradation had a low leakage potential. Six volumetric ID IGA indications were in-situ tested, and no leakage was detected during any of the tests. The tubes were pressurized to a representative normal operating primary-to-secondary differential pressure, MSLB differential pressure, and 3 times the normal operating primary-to-secondary differential pressure.

In addition, 13 volumetric ID IGA indications were leak tested (and burst tested) from a tube pulled in 1997. Given that six volumetric ID IGA indications were in-situ leak tested during the 12R outage, and 13 indications leak tested in the laboratory after the 12R outage, the total number of volumetric ID IGA indications that have successfully undergone leak testing is 19.

In addition, supplemental laboratory leak tests were performed on pulled tubes in order to effectively simulate both peak hoop and axial stresses which might be applied to tubes containing volumetric flaws during a postulated main steam line break (the in-situ test equipment used during the 12R outage was not able to fully simulate these stresses on SG tubes). None of the indications tested in-situ or in the laboratory leaked at pressures simulating up to three times the normal operating differential pressure. Therefore, the licensee concluded that no increase in accident-induced leakage would be expected due to the presence of ID IGA flaws.

During the 13R outage in 1999, no additional in-situ tests were performed on ID IGA indications. However, indications with circumferential extents, axial extents, and percent TW depth estimates exceeding those of the volumetric ID IGA population were tested with no leakage during the previous 12R outage.

3.3.3 Leakage Integrity Methodology for Proposed License Amendment

As discussed in the previous section, no TMI-1 volumetric ID IGA indications leaked under any of the pressurized water conditions tested in laboratory leak tests or in-situ pressure tests. Pressures in excess of 10,000 psig have been necessary to burst the flaws tested in laboratories. Based on the data showing an absence of leakage in field-tested and lab-tested tubes with ID IGA degradation, the NRC staff has concluded that ID IGA patches are unlikely to leak in their current state.

For indications in the defined region, TMI-1 must provide assurance that the potential primary-to-secondary leakage rate during the limiting accident condition for leakage (MSLB) does not exceed 1 gallon-per-minute (gpm) for the affected SG. Larger amounts of leakage have been analyzed for theoretical leakage from flaws in the kinetic expansions. This criteria will be met each outage through the SG program requirements/procedures. A portion of the 1 gpm limit is designated for the volumetric ID IGA. The other degradation mechanisms are addressed

separately under the SG program requirements and are combined with the volumetric ID IGA leakage value to ensure the design requirements are met.

To provide a reasonable assurance that the leakage rate, 1 gpm, will not be exceeded, MSLB primary-to-secondary leak rates must be determined for the population of ID IGA flaws left in service. Since the volumetric ID IGA indications have not leaked in service, it is necessary to predict some leakage condition to be used to assess the SGs' tubing for hypothetical leakage from these flaws. Crack formation must be assumed to occur if a volumetric ID IGA defect is assumed to leak.

The licensee's evaluation of the normal operating conditions concluded that leakage from an axial crack is more probable than leakage from a circumferential crack. This is based on the fact that the OTSG tubes are in compression during steady-state operation, which inhibits the formation of a circumferential crack, and hoop stresses caused by primary-to-secondary pressure differential favor the formation of an axial crack.

From destructive analysis of TMI-1 SG tubes containing ID IGA, the licensee has concluded that the volumetric ID IGA has a generally elliptical profile. For purposes of predicting a leak path length, the elliptical profile will be assumed to be maintained as a flaw theoretically grows to a depth necessary to initiate an axial crack. Some fraction of a flaw's length must be assumed to completely penetrate the tube wall in order for leakage to occur. When calculating theoretical population leak rates for this program, the assumed individual indication leak rates will be conservatively calculated based on a 100-percent TW crack which has a length of 33 percent of the total axial extent of the IGA patch measured by MRPC probe. This 33-percent term is based on the pulled-tube analysis results illustrating that, as previously described, axial extents of the patches measured by MRPC probe are approximately 3 to 5 times larger than the actual extent of the patches.

To provide a reasonable assurance that the leak rate will not be exceeded, MSLB primary-to-secondary leak rates must be determined as a function of the axial extent of the assumed crack. PICEP, a computer code that estimates leakage from pre-determined crack sizes, was used to calculate the fluid flow rates through axial cracks in OTSG tubes subjected to bounding MSLB conditions. The crack opening displacement was calculated based on the Electric Power Research Institute (EPRI)/ZAHOOR Model. The MSLB conditions assumed in this analysis were a primary-to-secondary pressure differential of 2575 psid, and the tube and primary fluid temperatures were assumed to be 600 °F. Based on these conditions, leak rates are calculated as a function of 100-percent TW crack length.

The NRC staff notes that there is a high level of uncertainty inherent in using PICEP for this application, i.e., predicting leak rates from pre-determined crack sizes. There is a large amount of scatter in the data used to benchmark this code. In addition, the EPRI/ZAHOOR Model was not specifically benchmarked against leakage from this type of degradation (ID IGA). Nonetheless, the NRC staff recognizes the difficulty in modeling leakage from ID IGA degradation due to the paucity of data for ID IGA patches that have grown TW. The NRC staff finds that the licensee's approach is acceptable because of the conservative assumption that all indications would leak. Other conservatisms exist, such as the over-estimation of the linear extent of the indications based on the use of the MRPC probe for extent measurements.

To implement the program, a maximum number of volumetric ID IGA indications that might theoretically leak in an SG, and still meet the leakage criterion, will be evaluated. This maximum number will then be used to determine a number of in-situ pressure tests, with no leaks, that must be performed to statistically demonstrate that remaining indications will not leak in excess of the allowable leakage limit. This will be performed by analysis of the eddy current data for the volumetric ID IGA indications, evaluating the theoretical leak rate of those indications, and comparing that summed leak rate to the leakage limit. This will be performed by determining a leak rate for each indication, assuming that 33 percent of each indication's measured axial extent was 100 percent TW. An average leak rate per indication per SG was calculated by dividing the total leak rate by the number of indications in each SG. The maximum allowable number of indications that might theoretically leak may then be calculated by dividing the leak rate limit for volumetric ID IGA by the average leak rate per indication. In-situ pressure tests will be performed as necessary to demonstrate that fewer than the maximum allowable number of indications, as described above, are present in the TMI-1 OTSGs.

TMI-1 will in-situ pressure test a sufficient number of volumetric ID IGA indications to demonstrate that potential leakage from indications remaining in service will be less than the allowable limit. After each inspection, a statistical assessment will be used to determine the number of in-situ tests. A hypergeometric distribution will be used to determine the number of in-situ tests that must be performed, with no leaks, to be statistically certain (95-percent one-sided confidence interval) that the allowable number of untested indications remaining in service will leak less than the allowable leakage limit. The detected population is defined as all indications characterized by ECT to be volumetric ID IGA during the current inspection.

The NRC staff has determined that the licensee's method of estimating the total leak rate for the total population of ID IGA flaws in the faulted OTSGs for the upcoming cycles is conservative. This is based on the NRC staff's finding that the ID IGA indications are no longer experiencing significant growth (discussed in the next section) and the NRC staff's finding that the licensee's estimate of the number of ID IGA flaws that may leak during postulated accidents is conservative. Based on the lack of any leakage during the historical leak testing and lack of any significant reduction in structural strength during in-situ tests, the NRC staff believes that this approach is appropriate and will provide conservative leakage predictions.

3.4 Analysis of Growth Rate for IGA Degradation

The number of bobbin indications that are confirmed volumetric ID IGA, plus any additional volumetric ID IGA indications not reported by the bobbin examinations but detected by the MRPC probe examinations are considered to make up the detected population for each SG each outage. The licensee will analyze the growth rate of this population for all future outages based on the TMI-1 Management Program for Volumetric ID IGA in Once-Through Steam Generators.

For the previous license amendment (Amendment No. 209), the licensee had demonstrated from data gathered in previous cycles that ID IGA degradation was not an active degradation mechanism at TMI-1. This was demonstrated through comparisons of nondestructive examination data from several outages. This is a significant aspect of the technical basis supporting this amendment request because the length-based repair criteria that were developed for Cycles 12 and 13 were based on the assumption of zero flaw growth. Therefore, the NRC staff has a heightened sensitivity to the ongoing results of the licensee's growth rate

analyses. The licensee's previous growth rate analyses were based on a review of ECT data and metallurgical and chemical analyses performed on the 12R outage pulled tubes and are discussed in the following paragraphs.

The licensee performed assessments of volumetric ID IGA growth rates based on changes in bobbin coil voltage, MRPC probe-indicated axial length and MRPC probe-indicated circumferential length. The repair criteria for measured circumferential and axial lengths of ID IGA tube degradation are set to less than or equal to 0.52 and 0.25 inches, respectively.

When the 12R outage bobbin coil voltages were compared to previous voltage responses at the same location, a 0.04 volt average increase was observed. When the 13R outage bobbin coil voltages were compared to 12R outage voltage responses at the same location, a 0.005 volt average increase was observed. These voltage changes are comparable with voltage variations from seven previous outages and indicate no statistically significant growth.

MRPC probe-indicated axial and circumferential length measurements were made for all ID IGA indications detected during the 12R and 13R outages. These values were compared to measurements from examinations performed during the previous two outages, when available. The licensee determined that there was essentially no change in axial or circumferential dimensions for the outages compared. The dimensions used for this comparison were obtained using the same type of ECT probe for all four outages.

The licensee performed chemical and metallurgical analyses on the 12R outage pulled tube to supplement the growth rate analysis. The following procedures were utilized specifically to investigate the micro chemistry of the volumetric ID IGA (pit-like) degradation found in the pulled tube: X-ray Photoelectron Spectroscopy, Scanning Auger Microprobe and Scanning Electron Microscopy with Energy Dispersive Spectroscopy. The strongest evidence derived from these analyses that supports the historical nondestructive examination record of inactivity of the ID degradation is the absence of aggressive chemical species and the absence of metallographic evidence of any new or different corrosion mechanisms. These analyses did not reveal unusual surface chemistry or reduced forms of sulfur, such as that which caused the original ID damage.

In addition, the analyses did not identify other contaminants in amounts that have been linked to SG tube pitting-type degradation. Microscopic studies of the IGA pits confirmed their volumetric pit-like geometry, which had been characterized during the field ECT exams. The ID IGA defect characterization of the 1997 tubes was similar to that of the ID IGA defects of tubes pulled in 1986. If this IGA were continuing to propagate, as was observed in the 1981 degradation, it would be expected to ultimately develop into stress corrosion cracking (SCC). There was no evidence of ID-initiated SCC at the ID IGA flaw locations examined in the laboratory by metallographic grinding or microscopy.

Beginning with Cycle 14, statistical tests will be conducted on the ECT data gathered during the inspection outages to evaluate growth in the data. Specifically, the licensee will perform sign tests and paired t-tests as required by the report, ECR No. TM 01-00328, that is referenced in the proposed TSs. By comparing the results of the tests with pre-established acceptance criteria, these statistical tests will provide assurance that growth of the volumetric ID IGA indications is not occurring.

The data are first screened with the use of an extreme value test, that will compare the largest growth value with the 5-percent critical value. If the largest growth value is less than the critical value, it will be concluded that the IGA growth data extreme value is not statistically significant. The sign tests will determine if the growth of the ID IGA indications is bounded by the following small, positive reference values between examinations: 0.05V bobbin voltage increase, 1-percent TW bobbin coil probe depth-estimate increase, and 0.01" circumferential extent increase. For the paired t-tests, the mean change in the ID IGA flaws is bounded by the following small, positive reference values between examinations: 0.05V bobbin voltage increase, 1-percent TW bobbin-depth estimate, and 0.01" circumferential extent.

The sign and paired t-tests have been performed by the licensee on data from the “A” SG from the last three TMI-1 refueling outages (11R, 12R, and 13R). The tests were performed using bobbin voltage, bobbin percent TW, and circumferential extent data for the period between outages 12R to 13R. Tests were also performed using bobbin percent TW and circumferential extent data for the period between outages 11R to 13R. The results from these statistical tests have shown that no growth of the volumetric ID IGA indications has occurred. The NRC staff have reviewed the results of these statistical tests, and found the methodology and results acceptable.

Statistical tests were not performed on the axial extent data, because a look-back of historical data indicates far more variability in the axial extent measurements. The licensee believes that this is because the probe travel is more consistent in the circumferential direction than in the axial direction. The licensee believes this to be especially true for locations such as tube expansions and near the tube ends. As discussed in the following section, “Future Considerations”, the licensee plans in the future to apply its ID IGA management program to areas inside the tubesheet that may provide data that are less repeatable in the axial direction. The licensee believes that the growth is equally likely in either direction, and will track the growth by the statistical tests on bobbin voltage and TW measurements. The “A” SG data were chosen for the review of previous data, because that SG had a much larger population of volumetric ID IGA indications than had the “B” SG.

The repair criteria rely on the assumption that the ID IGA degradation growth will not occur during the subsequent operating cycle if growth was not detected in the previous operating cycle. Any changes in the length, voltage, or depth of the flaws will invalidate the results of the leakage assessment. Based on the growth criterion presented in the proposed amendment, the NRC staff concludes that there is reasonable assurance that indicated growth would be expected to trip the criterion, resulting in additional in-situ pressure tests and licensee development of a cycle-specific model of growth for the operational assessment.

To develop the cycle-specific growth model, the licensee will re-verify the analyst-to-analyst variability that is applicable to the field data at hand and evaluate the components of variability so that an accurate model of actual growth can be obtained. Any growth analysis performed using the cycle-specific growth model described here will require a revision to AmerGen Engineering Report, ECR No. TM 01-00328, to include information substantiating the growth conclusions reached and the basis for the conclusions. Per the engineering report, the revised report will be submitted in a license amendment request to the NRC well ahead of the subsequent refueling outage with any proposed actions to address potential growth.

3.5 Future Considerations

The proposed license amendment pertains solely to the area of the tube subject to the TS-defined tube inspection region. That is, the TMI-1 TS requires inspection of the bottom of the upper tubesheet completely to the top of the lower tubesheet of inservice tubes. Requirements for tube inspections inside the upper and lower tubesheets is a topic of ongoing discussion between the licensee and the NRC staff, and this area of the tubes is not currently covered by the TSs. The NRC staff understands that the licensee will resolve the TS issues (i.e., incorporate inspection requirements for the tubesheet region into the TSs) prior to their changeover to the generic TSs that are being developed under the industry initiative, Nuclear Energy Institute 97-06, "Steam Generator Program Guidelines."

The NRC staff recognizes that the licensee has provided a larger defined region for implementation of the Volumetric ID IGA Management Program in AmerGen Engineering Report, ECR No. TM 01-00328, than the TS-defined inspection region. Specifically, the report defines the following region:

> "During each outage in which the management [above] program is utilized, a 100 % MRPC inspection of the defined region of the lower 5" length of 22" kinetic expansions in in-service tubes at a radial location within the tube bundle of $\leq$47.00" will be conducted in accordance with the requirements of the TMI-1 steam generator tube inspection guidelines. (Bobbin coil probe examinations are not used to detect flaws in the upper tubesheet kinetic expansions since bobbin is not qualified for detection in this area of the tubing. The kinetic expansions are examined with more sensitive, surface-riding MRPC probes.)
>
> During each outage in which this management program is utilized, an MRPC examination of all known volumetric ID IGA indications in the upper tubesheet kinetic expansion transitions will be conducted in accordance with the requirements of the TMI-1 steam generator tube inspection guidelines. (Bobbin coil probe examinations are not used to detect flaws in the upper tubesheet kinetic expansion transitions since the bobbin is not qualified for detection in this area of tubing. The kinetic expansion transitions, like the kinetic expansions themselves, are examined with more sensitive, surface-riding MRPC probes.)"

The NRC staff asked the licensee to clarify the regions inside the tubesheet in which they intend to use the Volumetric ID IGA Program as defined in AmerGen Engineering Report, ECR No. TM 01-00328, as an alternative to the use of the Kinetic Expansion (KE) Repair Criteria, in future submittals related to the KE repair criteria. Through discussions with the licensee in the context of this license amendment review, the licensee has agreed to clarify their intended use of the two different repair criteria in the upper and lower tubesheets.

3.6 Description of Proposed Technical Specification Changes

The following summarizes the proposed changes to the TMI-1 TSs to implement the repair criteria for SG tubes degraded with ID IGA degradation:

(1.) TS 4.19.2.c

A new section is added to the TS to define the inspection requirements for the ID IGA repair criteria which reads as follows:

> "Implementation of the repair criteria for Inside Diameter (ID) Inter-Granular Attack (IGA) requires 100% bobbin coil inspection of all non-plugged tubes in accordance with AmerGen Engineering Report, ECR No. TM 01-00328 during all subsequent steam generator inspection intervals pursuant to Section 4.19.3. ID IGA indications detected by the bobbin coil probe shall be characterized using rotating coil probes, as defined in that report."

(2.) TS 4.19.4.a.3

This section is revised in the definition of a degraded tube, regarding the criteria for ID IGA indications, to delete the restriction of applicability only to Cycle 13. The phrase, "(for operation through Cycle 13 only, ..." is deleted.

(3.) TS 4.19.4.a.6

This section is revised in the definition of "repair limit" to remove the phrase "... For operation through Cycle 13 only, ..." so that the criteria (pertinent to ID IGA indications) are made permanent.

(4.) TS 4.19.4.a.9

This section is revised to replace the words, "a bobbin coil" with the word "an" so that the volumetric ID IGA repair criteria are applied to rotating coil indications in the defined regions (as shown above), and rotating coil indications of volumetric ID IGA are reported to the NRC in a written report to be submitted in accordance with TS 4.19.5.b.

(5.) TS 4.19.5.b.3

This section has been revised to require bobbin coil depth-estimate data, if determined, to be included in the written report submitted 90 days after completion of inspections and repairs. This is an editorial clarification to reflect that not all ID IGA flaws are detected with the bobbin coil.

(6.) TS 4.19.5.b

This section is revised to include the items moved from Section 4.19.5.a. In addition, additional text has been added to the current 4.19.5.a.2 (new TS 4.19.5.b.6) to require that the ID IGA growth assessment be performed in accordance with the AmerGen Engineering Report, ECR No. TM 01-00328.

(7.) TS Bases

Several references to "the 13R Outage" and "Cycle 13 operation" in the Bases are deleted, to remove the wording restricting the use of the ID IGA repair criteria to Cycle 13. In addition, the

words “does not show growth greater than expected ECT repeatability variations” are deleted and replaced with the words “meets the requirements of AmerGen Engineering Report, ECR No. TM 01-00328.” This change is made to incorporate in the Bases the more prescriptive growth assessment requirements required by the report.

3.7 Summary

The NRC staff finds that the implementation of the proposed repair criteria described in the TMI-1 Management Program for Volumetric ID IGA in Once-Through Steam Generators is acceptable. Based on the four criteria discussed above (i.e., leakage integrity, structural integrity, growth-rate analysis, and inservice inspection capability), the NRC staff concludes that extension of the repair criteria to a permanent basis is acceptable and will not adversely affect public health and safety.

The NRC staff has independently assessed the results of the statistical tests performed on ECT data from previous outages, and concurs with the licensee’s finding that the data do not indicate that significant growth has been occurring during the past few cycles. Given the absence of significant growth, the in-situ pressure tests performed in previous outages indicate that the licensee’s estimate of the number of ID IGA indications that may potentially leak during postulated accidents is a conservative upper bound and that the licensee’s estimate of the total accident-induced leakage rate is conservative. Therefore, the proposed changes to the TMI-1 TSs are acceptable to justify allowing tubes with ID IGA indications to remain in service.

4.0 STATE CONSULTATION

In accordance with the Commission's regulations, the Pennsylvania State official was notified of the proposed issuance of the amendment. The State official had no comments.

5.0 ENVIRONMENTAL CONSIDERATION

The amendment changes surveillance requirements. The NRC staff has determined that the amendment involves no significant increase in the amounts, and no significant change in the types, of any effluents that may be released offsite, and that there is no significant increase in individual or cumulative occupational radiation exposure. The Commission has previously issued a proposed finding that the amendment involves no significant hazards consideration, and there has been no public comment on such finding (66 FR 7669). Accordingly, the amendment meets the eligibility criteria for categorical exclusion set forth in 10 CFR 51.22(c)(9). Pursuant to 10 CFR 51.22(b), no environmental impact statement or environmental assessment need be prepared in connection with the issuance of the amendment.

6.0 CONCLUSION

The Commission has concluded, based on the considerations discussed above that (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or to the health and safety of the public.

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