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July 30, 1999

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U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555

Ladies and Gentlemen:

Subject: Three Mile Island Nuclear Station, Unit 1 (TMI-1)
Operating License No. DPR-50
Docket No. 50-289
GPU Nuclear Response to NRC Requests Regarding the OTSG Kinetic Expansion Region Inspection Acceptance Criteria for 12R Examinations

Attached is the GPU Nuclear response to the NRC's June 17, 1999 request regarding the Once Through Steam Generator (OTSG) kinetic expansion region inspection acceptance criteria that was used for dispositioning indications during the Cycle 12 Refueling (12R) Outage.

For the Cycle 13 Refueling (13R) Outage[1] kinetic expansion examinations, GPU Nuclear intends to use the same methods and criteria as those used for disposition of indications during the 12R Outage. We are aware of the analyses currently under development by Framatome Technologies, Inc. (FTI) using a different structural analysis model to calculate the OTSG axial tube loads and tubesheet bore dilations under Main Steam Line Break (MSLB) accident conditions. However, until such time that the results of the FTI revised tube load and tubesheet dilation analyses for TMI-1 are available, reviewed and accepted by GPU Nuclear, the structural repair criteria developed for the 12R Outage remain valid.

We no longer anticipate any changes from the 12R kinetic expansion region examination acceptance criteria for the 13R inspections. We also note that in the absence of ASME Boiler and Pressure Vessel Code provisions for inside diameter initiated flaws in the tubesheets of straight tube steam generators, these criteria do not appear to us to represent alternatives to10 CFR 50.55a requirements necessitating

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[1] The TMI-1 13R Outage is scheduled to begin on September 10, 1999.

formal NRC approval. However, we remain committed to fully informing the NRC of these criteria and their use at TMI-1. If any additional information is needed, please contact Mr. Major R. Knight, GPU Nuclear TMI Licensing at (717) 948-8554.

Sincerely,

M J Ross for

James W. Langenbach
Vice President and Director, TMI

/MRK
Attachment
cc: Administrator, Region I
TMI-1 Senior Project Manager
TMI-1 Senior Resident Inspector
File No. 99119

GPU Nuclear Response to NRC Request For Additional Information Regarding 12R Outage OTSG Kinetic Expansion Region Inspection Acceptance Criteria

NRC Question No. 1

The axial once-through steam generator (OTSG) tube loads used in the structural assessment were considered without including a factor of safety. The staff has identified that the use of nominal, thermally-induced loads may not yield conservative results in situations involving large thermal displacements imposed on flawed steam generator tubes. In addition, the staff has been informed that the limiting OTSG tube loads applicable to TMI-1 are currently being evaluated by Framatome Technologies, Incorporated (FTI). Preliminary results from FTI's analyses indicate that the loads considered in MPR-1820, Revision 0 (proprietary), are greater than the peak axial loads applicable to OTSG tubing. However, it is unclear if the loads considered by the licensee bound those that will result from FTI's study when considering additional factors of safety. Discuss whether the structural repair criteria developed for the 12R outage remain valid considering the revised tube load analyses conducted by FTI and the application of factors of safety to these loads. Provide the technical bases for any safety factors considered in this assessment.

TMI-1 Response to Question No. 1

The purpose of the 12R kinetic expansion structural flaw acceptance criteria was to conservatively disposition tubing expansions that might theoretically part or slip under TMI-1 license basis conditions. We will discuss, below, the conservatisms that were part of our 12R criteria as regards the "no-part" condition. Also, we will discuss why factors of safety that could have been used as part of the "no-slip" condition were not necessary.

The principal conservatism within the "no-part" condition was that the peak axial tube load that was derived for the peripheral tube locations was applied to tubes at all radial locations within the tube bundle. It is known that there is a substantial difference in axial tube load between the periphery and the center of the unit; the loads at the periphery are much larger. No credit was taken for the actual load differences because the peak load was used throughout for the analysis of the "no part" criteria. Also, it was conservatively assumed that any circumferential indication that could potentially part the tube within a joint was located at the bottom of the expansion region where the axial load is at its maximum. At higher elevations within the expansion region, part of the axial load is transmitted to the tubesheet by the frictional restraining force, thereby reducing the axial load in the tube wall at the location of the indication. No credit was taken for the reduction in applied tube load within the expansion due to friction. This assumption provides even more conservative results for defects that may be located within the expanded zone.

Before discussing the conservatisms that were incorporated in the development of the "no-slip" portion of the tube repair criteria, it is important to note that the ASME Code does not provide guidance as regards factors of safety for mechanical integrity of cold formed tube-to-tubesheet joints. The ASME Code provides criteria for prevention of ductile failure as part of the design basis of pressure boundary components in Section III and for prevention of both ductile and non-ductile failure of in-service pressure boundary components in Section XI. There is no basis to conclude that the most conservative factors of safety that are used in the ASME code for pressure boundary integrity when considering primary stresses only for either normal operation or hypothetical faulted conditions must be used for mechanical integrity of cold formed tube-to-tubesheet joints. It is important to note that as part of the design basis criteria for the pressure boundary under normal operating conditions that the factor of safety is equal to 1.0 when considering both primary and secondary stresses together. Prevention of tube slippage within the tube-to-tubesheet joint, with the pressure boundary intact since the expansion zone that resists pull-out remains in contact with the tubesheet, satisfies the condition that is necessary to ensure mechanical integrity of the joint. It is reasonable to provide mechanical integrity of the joint using a factor of safety equal to 1.0 when considering both primary and secondary loads together because the axial tube load that occurs as a result of the hypothetical MSLB is predominantly thermally-induced, or secondary. This was the approach that was used for the preparation of the kinetic expansion inspection criteria that were used during the 12R Outage. It is also important to note that thermal displacement-induced loads are "self-limiting" so that the axial membrane stress will not exceed the material yield strength. Using Appendix F of Section III as guidance, this would result in a factor of safety equal to 1.4 with respect to 0.7 S_u[1] for the peak load condition when using 0.5 S_u as the material yield strength. The practical conservatism is that the axial tube load is predominantly secondary so that slip of the tube within the joint, if it occurs, relieves the applied load. Even if slip were to occur, the tube would not come out of tubesheet but would rather re-attach to the tubesheet at a lower elevation.

There were additional factors that contributed conservatism to the "no-slip" portion of the tube repair criteria. The capacity of the joint to resist axial tube load without slipping was developed using conservative assumptions, particularly regarding the impact of potential circumferential defects. Each defect, regardless of its measured circumferential surface extent, was assumed to locally relieve the tube-to-tubesheet contact pressure to the same extent as a 360 degree circumferential defect. Therefore, the relief of contact pressure due to any acceptable circumferential defect was overestimated and the actual pull-out capacity would be higher than that calculated. Also, the analysis of joint mechanical integrity assumed that all defects, both circumferential and axial, were 100% through-wall. The difference between actual

[1] S_u - ultimate tensile strength

depth and assumed 100% through-wall extent represents additional conservatism. For the "no slip" and "no part" portions of the analyses the entire circumferential or axial extent of the indications, as measured by eddy current, was assumed to influence the joint. No credit was taken for the conservative overestimation of actual flaw lengths by the rotating Eddy Current Test (ECT) probe, although the ID volumetric indication axial and circumferential length were confirmed to have been overestimated by the 12R destructive examinations (tube pulls).

Also, the practical implementation of the inspection acceptance criteria introduced another conservatism. The acceptance criteria were applied from the point of full expansion at the bottom of the expansion and above. The analytical model representation of the six-inch kinetically expanded region included the transition where it was less than fully expanded. The load carrying capacity given by the analytical model was based on a reduction to the six inch qualification length equal to the length of the transition region (about 0.5"). The analysis model results depend on about 0.5" less than the full qualification length as contributing to the pull-out capacity due to the presence of this transition. Therefore, the implementation of the acceptance criteria required approximately 0.5" more defect free expanded tube length than was required analytically.

Additional factors of safety that could be used as part of the "no-slip" conditions are not necessary. While there was no single factor of safety applied on the design basis loads, as discussed above, there were numerous conservatisms that were applied over the whole course of the evaluation.

We are aware of the analyses currently under development by Framatome Technologies, Inc. (FTI) using a different structural analysis model to calculate the OTSG axial tube loads and tubesheet bore dilations under Main Steam Line Break (MSLB) accident conditions. However, until such time that the results of the FTI revised tube load and tubesheet dilation analyses for TMI-1 are available, reviewed and accepted by GPU Nuclear, the structural repair criteria developed for the 12R Outage remain valid.

NRC Question No. 2

Section 3.6.1 of MPR-1820, Revision 0, states that the inspection acceptance criteria for tubes at any location can be determined by interpolating between the results for the center, mid-radius, and peripheral locations. The staff notes that this approach may result in non-conservative flaw sizes for 22-inch expansions for tubes within a relative radii between 0.707 and 1. Provide additional information to explain how the repair criteria remain conservative in this situation.

TMI-1 Response to Question No. 2

MPR-1820 was revised prior to completion of the 12R Outage to correct Figure 3-20. The actual radial location at which the load resisting capacity of the 22" expansion is in equilibrium with the applied axial tube load is at 0.73R, and not at 0.707R as shown in MPR-1820, Rev. 0. Even with this correction, no credit was taken for any load carrying capacity for the 22" expansion until a radial location of 0.79R. Starting at this radial location, three concentric rings were used to conservatively determine the tube repair criteria. For each ring, the inboard or most limiting result was used to conservatively represent the tube repair criteria throughout the ring. For the first ring beyond the mid-radius location (47.01" - 50.70"), the tube repair criteria for 47.01" was used throughout. For the second of three rings (between 50.71" and 54.30"), the tube repair criteria for 50.71" was used throughout, and so on. The field and step-wise approximation in implementation of the 12R kinetic expansion acceptance criteria did depend upon a combination of interpolation and step-wise approximation to obtain intermediate results between 0.707R and 1.0R for the 22 inch expansions. The corrected guidance of MPR-1820, Rev. 1, was used in 12R which resulted in the proper and conservative application of flaw repair criteria. MPR-1820, Rev. 1 will be used in 13R and will be provided for NRC information in reviewing this response.

NRC Question No. 3

The structural acceptance criteria included in Table 3-5 was determined by analyses that assumed a primary-to-secondary differential pressure of 2500 psi acting simultaneously with the peak axial tube loads. This assumption appears to be invalid considering the sequence of the thermal and pressure loads of Topical Report #116, Revision 0, submitted by the licensee on November 26, 1997. Including a pressure load of 2500 psi in the analyses will result in higher than expected tube to tubesheet contact pressure due to pressure effects at the moment when axial tube loads are at their greatest. As a result, the defect length criteria may be non-conservative. Discuss the technical basis for assuming an applied differential pressure of 2500 psi in conjunction with the largest axial tube loads in the development of the acceptance criteria.

TMI-1 Response to Question No. 3

Including a primary-to-secondary differential pressure equal to 2500 psi simultaneously with the peak axial tube load in the development of the kinetic expansion inspection acceptance criteria is consistent with the prescriptive conditions for developing the applied tube load that are found in Reference 2.1.5 of our August 8, 1997 submittal (i.e., "Determination of Minimum Required Tube Wall Thickness for 177-FA Once Through Steam Generators," Babcock and Wilcox No. BAW-10146, April 1980). The conservative 3140 lb. axial tube load could not occur without including a 2500 psi primary-to-secondary differential pressure. The differential pressure contributes directly to the magnitude of the axial tube loads in two ways. First, there is a reaction to the primary pressure that is divided between the OTSG shell and the tube bundle in proportion to the axial stiffness of each. Second, there is an internal reaction in the tubes to primary pressure due to Poisson contraction since the tube ends are fixed. It would not be consistent to use a total, mechanical plus thermal, axial load of 3140 lbs without, at the same time, including a primary-to-secondary differential pressure of 2500 psi. In addition, maximizing the primary-to-secondary differential pressure results in the largest possible tubesheet deflection and, therefore, the largest possible tubesheet hole dilation. Residual contact pressure in the tube-to-tubesheet joint and, hence, joint pull-out resistance is substantially reduced as the tubesheet hole dilation increases. The capacity of the joint is found using a primary-to-secondary differential pressure equal to 2500 psi because the factors affecting the joint (i.e., the applied axial tube load as well as the tubesheet hole dilations) were also calculated using the 2500 psi primary-to-secondary differential pressure. The challenge to tubesheet kinetic expansion joint integrity is maximized by considering the peak axial tube load acting concurrently with the 2500 psi primary -to secondary differential pressure.

NRC Question No. 4

It was stated in the submittal dated November 26, 1997, that the leakage assessment would only consider potential leakage from flaws with a measured through-wall depth greater than 67.4 percent. The staff is unaware of any qualified depth sizing technique for the degradation of interest in the TMI-1 OTSGs. Provide the technical basis for assuming that flaws with a measured through-wall depth less than 67.4 percent will not leak during a main steam line break accident.

TMI-1 Response to Question No. 4

Prior to the 12R Outage, GPUN evaluated the performance of a number of rotating coil eddy current probes/coils for sizing ID-initiated flaws. The work evaluated the primary water stress corrosion cracking (PWSCC) and primary side IGA sizing capabilities of rotating coil examinations in Once Through Steam Generators (OTSGs). The goal of the effort was to confirm the applicability of existing Appendix H PWSCC sizing qualifications for the OTSG's smaller diameter, thinner walled tubing.

The work evaluated the analyst, equipment, and technique variabilities for sizing the PWSCC and primary side IGA defects.

This evaluation was based on laboratory grown and pulled tube PWSCC data included in existing Electric Power Research Institute (EPRI) Appendix H qualifications as well as a series of OTSG tube samples with manufactured defects. The OTSG flaws used in the performance studies were machined EDM notches and pits representing ID IGA. Fifty three (53) machined OTSG flaws were analyzed by five production eddy current analysts and one senior eddy current analyst. The flaw dataset was supplemented with the flaws from the original Appendix H qualifications.

The depth sizing accuracy for the OTSG tubing defects was within previously-defined Appendix H parameters for a qualified technique. The results/errors for the OTSG tubing defect tests were very similar to those in the larger diameter tubing qualification tests; this was expected since the coils on the eddy current probes are surface-riding. The evaluation concluded that the existing Appendix H qualifications for PWSCC were also applicable to OTSG-sized tubing and ID IGA.

In the evaluation, the worst-case error (95% confidence for a single-tailed test) for the eddy current probe used for the TMI-1 kinetic expansion examinations was calculated to be a possible 32.6% underestimate of the through-wall penetration. Technique, analyst and equipment variabilities were included in this worst-case calculation. Thus, an assumed 32.6% through-wall error was applied to conservatively assess which of the eddy current indications might be through-wall and may leak during a postulated MSLB event. Crack-like indications of depths 67% through-wall or greater were assumed to leak over their entire as-called eddy current extent. Volumetric indications of depths 67% through-wall or greater were modeled as both a circumferential and axial crack, both of which were assumed to leak over the entire as-called eddy current circumferential and axial extent, respectively.

For structural evaluations of the eddy current indications within the expansions, depth-sizing was not utilized. For those evaluations, all flaws were assumed to be 100% through-wall over their entire as-called eddy current extent.

NRC Question No. 5

The technical bases for the steam generator tube repair criteria that were submitted to the staff on August 8 and November 26, 1997, indicated that these criteria would be used in the 12R outage. However, the submittals did not indicate whether these criteria would be used in subsequent steam generator tube inspections at TMI-1. Discuss whether the inspection and repair methodology developed to address indications in the kinetic expansions in the 12R outage will be used in subsequent inspections. If the licensee intends to develop new criteria or revise that discussed in previously submitted documents, the staff requests that the licensee submit a description of its technical bases for the new criteria similar to that provided for the 12R inspections for NRC review and approval in accordance with IWB-3630 in Section XI of the ASME Code.

TMI-1 Response to Question No. 5

For the Cycle 13 Refueling (13R) Outage[2] kinetic expansion examinations, GPU Nuclear intends to use the same methods and criteria as those used for disposition of indications during the 12R Outage. We are aware of the analyses currently under development by Framatome Technologies, Inc. (FTI) using a different structural analysis model to calculate the OTSG axial tube loads and tubesheet bore dilations under Main Steam Line Break (MSLB) accident conditions. However, until such time that the results of the FTI revised tube load and tubesheet dilation analyses for TMI-1 are available, reviewed and accepted by GPU Nuclear, the structural repair criteria developed for the 12R Outage remain valid.

We no longer anticipate any changes from the 12R kinetic expansion region examination acceptance criteria for the 13R inspections. We also note that in the absence of ASME Boiler and Pressure Vessel Code[3] provisions for inside diameter initiated flaws in the tubesheets of straight tube steam generators, these criteria do not appear to us to represent alternatives to10 CFR 50.55a requirements necessitating formal NRC approval.

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[2] The TMI-1 13R Outage is scheduled to begin on September 10, 1999.

[3] The 1986 ASME Section XI Code Edition, Subsection IWB-3630 states that the evaluation of cracks, wastage, or intergranular corrosion in steam generator tubes that exceed the allowable flaw standards of IWB-3521 shall be performed by analyses acceptable to the regulatory authority having jurisdiction at the plant site (the NRC). However, Subsection IWB-3521.2, "Allowable Flaws for Straight-Tube Steam Generators," states that these requirements are "in the course of preparation." Therefore, the owner has the responsibility for development of acceptance criteria in addition to those criteria required by the TMI-1 Technical Specifications.