December 16, 2005

MEMORANDUM TO: Luis A. Reyes
Executive Director for Operations

FROM: Carl J. Paperiello, Director ***/RA/***
Office of Nuclear Regulatory Research

SUBJECT COMPLETION OF GENERIC SAFETY ISSUE 188, "STEAM GENERATOR TUBE LEAKS OR RUPTURES CONCURRENT WITH CONTAINMENT BYPASS FROM MAIN STEAM OR FEEDWATER LINE BREACHES"

The Office of Nuclear Regulatory Research (RES) has completed its technical assessment of Generic Safety Issue (GSI)-188, "Steam Generator Tube Leaks or Ruptures Concurrent with Containment Bypass from Main Steam or Feedwater Line Breaches." This assessment resulted in the enclosed NUREG-series report, which the RES staff will publish and make publicly available. The NRC developed GSI-188 as a result of a memorandum, dated June 27, 2000, from J. Wiggins (OEDO) to A. Thadani (RES), related to a staff member's concern regarding the potential for resonance vibrations of steam generator (SG) tubes during a main steam line break (MSLB) event (Ref. 1). In accordance with Management Directive 6.4, "Generic Issues Program," the staff screened the issue and classified it as GSI-188 on May 21, 2001 (Ref. 2). The principal assertion of GSI-188 was that the dynamic loads induced in SG tubes from MSLB or other secondary side breaches could lead to growth of cracks and increased SG tube leakage or ruptures outside the range of analyses and experiments performed by the staff. The technical work conducted to address this issue leads to its closure with no changes to existing regulations or guidance.

GSI-188 indicated that two events had not been fully addressed. The first event questions whether a steam line break or other secondary side break could lead to significantly increased SG tube leakage or ruptures as a result of the dynamic loads imposed by the secondary side blowdown. The second event questions whether multiple SG tube leaks or ruptures could cause the secondary side to over-pressurize and cause a steam line break that could then result in additional SG tube leaks or ruptures. GSI-188 also referred to a relationship with GSI-163, "Multiple Steam Generator Tube Leakage."

A revised SGAP transmitted to the NRC's Executive Director for Operations (EDO) on May 11, 2001 (Ref. 3), included Task 3.1, which addressed the research needed to resolve the principal assertion of GSI-188. The staff developed the revised SGAP to include the research work and activities needed to address the conclusions and recommendations in NUREG-1740, "Voltage-Based Alternative Repair Criteria" (Ref. 4), in which the NRC's Advisory Committee on Reactor Safeguards (ACRS) reviewed and evaluated a staff member's differing professional opinion. On October 18, 2001, the ACRS concluded that the revised SGAP, including the research to be conducted under Task 3.1, was technically sound and adequately responded to the ACRS recommendations (Ref. 5).

In its technical assessment of GSI-188, RES performed thermal-hydraulic (TH) calculations and sensitivity studies using the TRAC-M computer code to assess the pressure loads acting on the tube support plates (TSPs) and SG tubes during an MSLB and a feedwater line break (FWLB). The assessment also included sensitivity studies on code and model parameters including solution methods. The resultant TH report (Ref. 6) provided a conservative estimate of loads and evaluations, with a comparison against similar analyses, and included a TH assessment of flow-induced vibrations during an MSLB and an FWLB. Using the TH conditions calculated during the transient, the staff developed a conservative estimate of flow-induced vibration displacement and frequency assuming steady-state behavior. The TH results showed a single main pressure pulse, and no significant resonance vibrations occurred. The results also showed that the MSLB produced the highest pressure drop. These results agreed with earlier results obtained by Westinghouse, and the staff provided the results of these studies to Argonne National Laboratory (ANL) for use in its tube integrity analyses.

ANL used the pressure loads and displacements from the TH analyses to evaluate loads on SG tubes and determine the integrity of flawed tubes (Ref. 7). ANL conducted its integrity analyses for MSLB loads because they produced the highest pressure drops across the TSPs and the highest lateral pressure on the tubes. The analysis found that the lateral pressures are too low to cause significant bending stress in the tubes. Bending stresses are undesirable because they impose bending loads on cracks in steam generator tubes and, if the loads are high enough or the cracks are large enough, the cracks can propagate and the tubes may leak or rupture.

Vertical motion of the TSPs relative to the tubes as a result of the pressure pulse associated with an MSLB may transfer loads to the tubes if they are locked to the TSP by corrosion products. If the tubes are not locked to the TSPs, no loads will be transferred. In addition, if the locked tubes are cracked, the transferred loads may contribute to crack growth. Calculations were conducted over a range of conditions to determine the influence of the pressure pulse causing vertical motion of the TSPs as a function of the number of tubes locked to the TSPs. The results showed that axial cracks do not grow under the dynamic loads imposed by an MSLB; however, there is a potential for circumferential cracks to grow. The results also showed that if only one or two tubes per quadrant are locked to the TSPs, the stresses induced on the tubes by an MSLB can be greater than the yield strength, creating a potential for short, throughwall circumferential cracks to grow. However, as more tubes become locked to the TSPs, longer throughwall circumferential cracks can be tolerated. The results show that when only 10 tubes per quadrant in the SG are locked to the TSPs, throughwall circumferential cracks up to 180E can be tolerated; if all tubes are locked to the TSPs, throughwall circumferential cracks up to 300E are stable. Field examinations and tube pull-out force results indicate that in steam generators experiencing significant degradation at the TSPs, a majority of the tubes are locked in place. In addition, tubes with extensive circumferential cracks would have been taken out of service.

The staff presented the technical findings at the 509th meeting of the ACRS Full Committee on February 5, 2004. Prior to that meeting, the ACRS Subcommittees on Thermal-Hydraulics Phenomena and Materials and Metallurgy met with representatives of the RES and contractor staffs on February 3–4, 2004, to review the results in greater detail. The ACRS completed its review of the staff's progress during the Committee's 512th meeting and sent its conclusions to the EDO on May 21, 2004 (Ref. 8). In so doing, the ACRS concluded that “The analyses of the effects of depressurization during an MSLB on tube integrity have been completed, and Item 3.1 is appropriately closed out. However, we recommend that, as a confirmatory measure, a review be performed of the U.S. industry SG tube pullout data and the associated extent of tube locking at the tube support plates in degraded SGs.” In response to that recommendation, the staff completed its review of the available industry data and forwarded the information to the ACRS on August 25, 2004 (Ref. 9). In general, that review of U.S. industry data on the extent of tube pull-out forces was consistent with foreign data presented to the ACRS at the Committee’s 509th meeting.

Other aspects of the original description of GSI-188, involving human reliability in the event that a MSLB or FWLB induces steam-generator tube failures, are moot since the mechanistic analysis demonstrates that the consequential ruptures of the tubes due to dynamic loads are unlikely.

In conclusion, dynamic loads and resonance vibrations following an MSLB are low and have little impact on the growth of existing cracks beyond the effects of differential pressure stress alone. Even when only a small number of tubes are locked to the TSPs, the tubes share the dynamic loads and the effect on the growth of existing cracks is insignificant. The ACRS agreed that the additional dynamic loads do not significantly contribute to the growth of existing cracks, and SGAP Task 3.1 can be closed. Consequently, the staff has concluded that dynamic loads from an MSLB or FWLB do not affect the structural integrity of tubes in service and do not lead to additional leakage or ruptures beyond what would be determined using differential pressure loads alone. Therefore, the principal assertion of GSI-188 is closed, and no changes to existing regulations or guidance are recommended with respect to the dynamic loads induced from a breach of the main steam or feedwater line, as evaluated in Ref. 7. In addition, the dynamic load effects from an MSLB or FWLB need not be taken into account in evaluating the potential for multiple tube ruptures under GSI-163.

For additional information on the issue, please contact James A. Davis at (301) 415-6987 or jad@nrc.gov.

Enclosure:
NUREG-XXXX, “Resolution of Generic Issue 188:
Steam Generator Tube Leaks or Ruptures Concurrent
with Containment Bypass from Main Steam Line or
Feedwater Line Breaches”

References

1. Memorandum from J.T. Wiggins, OEDO, NRC, to A.C. Thadani, Director, RES, Subject: "Staff Member Concern Regarding the Potential for Resonance Vibrations of Steam Generator Tubes During a Main Steam Line Break Event," June 27, 2000.

2. Memorandum from N.C. Chokshi, Chairman, Reactor Generic Issue Review Panel, GSI-188, Thru Farouk Eltawila, Acting Director, Division of Systems Analysis and Regulatory Effectiveness, Subject: "Initial Screening of Candidate Generic Safety Issue 188, "Steam Generator Tube Leaks or Ruptures Concurrent with Containment Bypass from Main Steam Line or Feedwater Line Breaches," May 21, 2001 (ML011410572).

3 Memorandum from S.J. Collins, Director, Office of Nuclear Reactor Regulation, and A.C. Tadani, Director, Office of Nuclear Regulatory Research, to W.D. Travers, EDO, Subject: "Steam Generator Action Plan Revision to Address Differing Professional Opinion on Steam Generator Tube Integrity (WITS Item 2001000026)," May 11, 2001, (ML011300073).

4. U.S. Nuclear Regulatory Commission, NUREG-1740, "Voltage-Based Alternative Repair Criteria," ACRS, March 2001.

5. Memorandum from G.E. Apostolakis, Chairman, ACRS, to The Honorable Richard A. Meserve, Chairman, NRC, Subject: "NRC Action Plan to Address the Differing Professional Opinion Issues on Steam Generator Tube Integrity," October 18, 2001.

6. Krotiuk, W.J., "Pressurized-Water Reactor Steam Generator Internal Loading Following a Main Steam or Feedwater Line Break," SMSAB-02-05, U.S. Nuclear Regulatory Commission, Washington, DC, September 2002.

7. Majumdar, S., et al. (Argonne National Laboratory), "Sensitivity Studies of Failure of Steam Generator Tubes during Main Steam Line Break and Other Secondary Side Depressurization Events," to be published.

8. Letter from M.V. Bonaca, Chairman, ACRS, to Dr. W.D. Travers, EDO, Subject: "Resolution of Certain Items Identified by the Advisory Committee on Reactor Safeguards in NUREG-1740, 'Voltage-Based Alternative Repair Criteria'," May 21, 2004 (ML041450305)

9. Letter from L.A. Reyes, EDO, to M.V. Bonaca, Chairman, ACRS, Subject: "Resolution of Certain Items Identified by the Advisory Committee on Reactor Safeguards in NUREG-1740, 'Voltage-Based Alternative Repair Criteria'," August 25, 2004 (ML0421902671)

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