January 16, 2004

MEMORANDUM TO: Michael E. Mayfield, Director
Division of Engineering Technology
Office of Nuclear Regulatory Research

FROM: Ledyard B. Marsh, Director **/RA/**
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

SUBJECT: NRR COMMENTS ON DRAFT NUREG/CR REPORT FROM ARGONNE NATIONAL LABORATORY

As requested in your memorandum, dated November 18, 2003, NRR has reviewed your draft NUREG/CR-xxxx, ANL 03/xx, "Behavior of PWR Reactor Coolant System Components, Other than Steam Generator Tubes, under Severe Accident Conditions - Phase II Final Report." We understand that this report documents the research performed during phase II of the project and serves as the basis for the next phase of the project. Therefore, our review consisted of two parts. The Probabilistic Safety Assessment Branch reviewed the report with respect to the adequacy of the scope of the investigation to support the probabilistic risk assessments that will depend on the results of this study. The Mechanical and Civil Engineering Branch focused on the technical issues involved in the various component stress, heat transfer and failure analyses included in the draft report.

Overall, the report appears to be investigating the appropriate issues to support the probabilistic assessments. It appears to provide an appropriate basis for proceeding to phase III, where we understand that refinements will be made to the models and input data to reduce the uncertainty in the results. We recognize that substantial reduction in the uncertainties in the failure times of the subject components is necessary to understand whether any can be relied upon to fail before the steam generator tubes fail, which would result in a containment bypass.

The attachment provides our technical comments on the draft report. These comments have been discussed with RES and their contractor, Argonne National Laboratory. They have agreed that our comments can be incorporated into the final report.

Thank you for the opportunity to review the progress of this research effort.

Attachment: As stated

CONTACT: Steve Long, NRR/DSSA/SPSB
415-1077

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* See previous concurrence
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NRR Comments on "Behavior of PWR Reactor Coolant System Components, Other than Steam Generator Tubes, under Severe Accident Conditions - Phase II Final Report"

GENERAL COMMENTS

1. The report addresses a set of components that appear to be the appropriate choices for consideration as potentially failing before the steam generator tubes fail.

2. After the RCS components were selected for this study, the thermal-hydraulic model was changed, including the addition of nominal leakage values to the reactor coolant pump (RCP) seals following loss of cooling during station blackout sequences. The result is that the seals are now predicted to experience somewhat higher temperatures as core damage progresses. Although the new seal packages have been designed for "high" temperatures, the new thermal-hydraulic model results indicate the fluid going through these packages would exceed the design temperature. We have not previously addressed how the higher temperatures may affect the nominal leak rates through the seals or their probability of gross failure, with resulting leak rates in the hundreds of gpm. Therefore, we suggest that consideration be given to adding the RCP seal packages to the list of components addressed in the phase III effort.

3. When evaluating the results of the individual failure analyses, two considerations will be important for future use in probabilistic risk assessments. The first is the timing of gross structural failure, sufficient to cause depressurization of the RCS in a manner rapid enough to preclude steam generator tube failure. The current draft properly reflects this consideration. The other consideration is the timing of the onset of substantial leakage, which may alter the thermal-hydraulic analyses. The changes in the thermal-hydraulic conditions in the RCS due to leakage may be beneficial or detrimental to the survival of the tubes, depending on the location of the leak and the flow rate. For example, leakage through the steam generator manway would primarily divert the gas flow between the cooler "return-flow tubes" and the hot-leg. This could cause an increase in the temperatures of the hotter "outflow tubes" by diverting some of the cooler gas that would otherwise mix with the very hot gas entering the inlet plenum from the hot leg before it reaches the tube sheet. So, while rapid failure of the manway, once leakage starts, it would be beneficial, early onset of leakage with slow progression to gross failure of the manway could be detrimental. Thus, it would be most helpful if the phase III work can estimate the leak rate as a function of time. That could also be important to the gross failure calculation, because leakage past the seals would also tend to increase the heating rate and decrease the failure time for the bolts.

4. In the report, the conclusions of the main report seem to be slightly inconsistent with the conclusion in the section on RTD wells and their associated welds and seals. The section conclusions appear to be more certain of the early failure times for the welds than is reflected in the final conclusions.

ATTACHMENT

SPECIFIC COMMENTS

5. On page xxviii, it may be helpful to evaluate how the Zion-specific results can be more generically applied, or the limitations in doing so.

6. On pages 12, section 5, provide a discussion about how the ABAQUS code has been verified for the stated purposes.

7. On page 19-21, section 6.1.2, in general, for all of the materials of interest, do we know how existing creep data were developed? Are we confident that compressive stresses produce negative creep equal and opposite to the amount for tensile stresses?

8. On page 20 and page 226, section 6.1.2 and Appendix E, the report indicates that the SG manway bolts undergo significant creep strain at only 450 ^{0}C (842 ^{0}F). This temperature appears to be too low for significant creep to occur. The report indicates that there is insufficient data to perform a good estimate of the creep performance, but that a limited set of data was used for the analysis. It would be helpful to include a table of the data which was used for the SG manway bolts in the report. As background for this comment, the estimate of SG manway failure at a temperature of about 1160 ^{0}F reported in NUREG-1570 was based on estimates of the Larson-Miller parameter as a function of stress for a material somewhat similar to A 193 B7 bolt material. The data points used were:

Stress, psi	PLM = T(20-log(r)), where T is in ^{0}R and r is in % per hour
2700.	39000.
8500.	36000.
22000.	33000.
45000.	30000.

Recently, another reference, “Steels for Elevated Temperature Service,” US Steel, December 1974 was found which provides the following “typical creep property” data for A 193 B7 bolt material.

Test Temperature, ^{0}F	Stress for a Creep Rate of 0.00001% per hour
800.	44000.
900.	18000.
1000.	6000.

This data allows the computation of the following Larson-Miller parameter values:

Stress, psi	PLM = T(20-log(r)), where T is in ^{0}R and r is in % per hour
6000.	35040.
18000.	32640.
44000.	30240.

9. On page 21, figure 6.2, isn't "fitted" derived from "test?" Why show fitted vs. test? Is it to show confidence? Why show this only for bolts?

10. On page 42, section 7.1.2, it is stated that creep tends to relax the stresses and keep them below the yield strength of the material. This holds true for secondary and bending deformation, but for membrane stress (e.g., pressure), would not creep add to the plastic strain? Do we know that the model applies creep properly in this regard?

11. On page 79-81, section 8.2, provide a discussion of the assumed gasket loading and unloading characteristics. Would a variation of these properties significantly affect the results?

12. On page 83, figures 8.6 and 8.7, why is there significant nonuniformity of deformation and stress in the manway cover from pretensioning? Are not all bolts pretensioned the same?

13 On page 98-99, section 8.5, the criteria for the SG manway failure are dependent on the opening amount of the joint. In addition to bolt testing, should there be follow-up testing of a gasketed test flange to better estimate heat transfer phenomena and gasket response?

14. On page 98-99, section 8.5, for additional testing of bolts, should consideration be given to applying tension and bending to the bolts, since this is what would occur (versus simpler heated pull testing)? This would address the effects of stress nonuniformity.

15. On page 102, section 9.2, it is stated that axial constraint was not applied in the RTD weld failure analysis. However, axial loading is expected to be considerable in the hot leg. Does the sensitivity analysis bound the effects of the large axial loading?

16. On page 105, figure 9.10a, it would be helpful to explain why the maximum and minimum points represent the failure times.

17. On page 128 and 134, sections 11.6 and 12.6, can we say that the PORV seats appear to be able to cycle as required during the accident? Are there other possible aspects of the valves which should be evaluated? For the 17-4 PH material, should we also address high temperature (>700 ^{0}F) hardening, distortion, and cracking effects?

18. On page 135, section 12.7, should we include testing of 17-4 PH material?

19. On page 135, section 12.7, it is stated that creep properties of manway gaskets are needed to determine springback behavior. Should we also include testing for tearing or blowout (to determine if this occurs prior to gasket unloading) and/or ablation effects (to determine if the discharge area increases very quickly)?

20. In general, should we study the thermal-hydraulic coupling effects? For example, should we analyze if and how SG tubes may be even hotter as a result of failure of the RED welds or the SG man ways?