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Dear Howard:

In the CRBRP Safety Evaluation Report (SER)[1,2] two items related to structural response during faulted conditions and Beyond Design Base (BDB) accidents were identified that need additional analyses and tests before the present designs can be proven acceptable. One item involves the response of cell liners during large liquid metal spills (Level D, faulted conditions) and during the TMBDB scenario when hot liquid sodium can be present in lined cells (see Ref. 1, Sec. 3.8A). The other item involves determining the capability of the reactor vessel head for absorbing sodium slug kinetic energy during a Hypothetical Core Disruptive Accident (HCDA) (see Ref. 2, Secs. A.3.4 and A.3.5). In the remainder of this letter I will summarize the current status, from my viewpoint, of resolving these two structural concerns.

Cell Liners

At the beginning of the Construction Permit (CP) review the applicants provided the NRC staff limited test data and some analyses to show that the cell liners could survive induced temperature increases from large spills of liquid sodium. The test data came from a large-scale sodium spill test.[3] Because of failure of several stud-to-cell liner welds in this test, the liner was understressed and we do not believe the test was valid for exhibiting an acceptable cell liner design.

Analyses presented by the applicant were not valid because the finite element meshes and boundary conditions chosen did not allow the liners to buckle into the expected lowest energy buckling mode. Also, the meshes were far too coarse, especially at the stud/liner interface, to accurately predict expected stresses and strains. Subsequent to first stages of the CP review, the applicants refined some of the analyses and obtained more accurate predictions of the stress and strain fields, except at the stud/liner interface where failure would be expected to occur.

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Another issue that came to light during the review was the selection of appropriate failure criteria. The only precedent in existing codes seemed to be criteria suggested in the ASME Boiler and Pressure Vessel Code for steel liners inside concrete nuclear containment buildings.[4] It became obvious, after reviewing the applicants' early analyses, that these criteria could not possibly be met and may not be appropriate for stress and strains from secondary loads. Because the bulk of the predicted liner stress arises from secondary, thermal loads, the applicant proposed a less restrictive set of criteria for within design base loads. Since these criteria had not been previously applied to a licensing situation we suggested they not be applied until proven acceptable through an experimental program. One issue that the proposed criteria do not address is the possibility of creep rupture at the stud/liner interface. Available data[5] show that, under expected maximum stresses at the stud/liner interface (as high as 40 Ksi), the liner could rupture within one to four hours. The high stresses are from secondary loads, but, because of the stress concentration at the stud/liner interface. the bulk of the liner will remain elastic and an elastic follow-up phenomenon is possible. Currently proposed criteria do not address stress rupture or elastic follow-up so an indepth test/analysis program was suggested to address not only the cell liner design, but also the needed failure criteria.

In March of 1983 the applicants proposed a cell liner design validation program[6] that included both analysis and tests of the cell liner design. After attempting to analyze the problem, the applicants determined that they had neither the technology nor the funds necessary to perform the analysis. They, therefore, verbally proposed a program relying solely on experiments. This experimental program was never presented in enough detail to comment on its acceptability. However, in the following paragraph I will discuss some of the elements that I believe should be included.

Because liner failure is expected to occur first at a stud/liner interface, the experiments must accurately model the details of this interface. It is also important that the complex loading at the critical point of interest be accurately simulated. This loading requirement means that the stud will have to be simultaneously loaded in shear, bending, and tension at temperatures up to maximum DBA and BDBA conditions. The liner buckling pattern should also be simulated as accurately as possible. Because of discontinuities in the cell liners (penetrations, corners, reinforcements, etc.) all of the studs will not be equally loaded. Analyses performed by the applicants during the review period should be sufficient for choosing the critical location to be simulated during the experiments. Enough structural detail needs to be included in the experimental cell liner model to ensure that the possibility of creep rupture can be investigated.

Reactor Vessel Head

Review of reactor vessel head analyses and tests performed prior to the CP review resulted in the conclusion that neither was appropriate for exhibiting the vessel head capability for resisting a sodium slug generated during an HCDA. The head models used during the dynamic tests, SM-4 and SM-5, were found to be "overstiff" because of the method used for attaching the under-head shielding plates. Also, the models were not loaded with the scaled equivalent of the vessel head component margin requirement (a sodium slug impacting the

head with 75 MJ of kinetic energy). Computational models used for analyzing the vessel head were found to be overstiff and, therefore, inappropriate for proving vessel head capability.

Further hydrostatic tests performed during the CP review, SM-7 and SM-8, indicated that the vessel head may not be capable of resisting a slug with 75 MJ of kinetic energy. The applicants then proposed changes to the vessel head[7] and started into a test program[8] to show that, if the original head design could not sustain the required loads, the modified head would be acceptable. The first test in this series, a hydrostatic test designated SM-10, was performed but data were not reduced before funding was cut off.

Based on the experimental plan developed by the applicants,[7,8] we believe that successful completion of the experimental program would result in an acceptable head design. The key element in the experimental program involves ensuring that a representative model of the final head design is loaded with the scaled equivalent of 75 MJ of kinetic energy. Also critical to the program is the use of a well modeled vessel/head interface (vessel flange). Identification of the eventual failure mode for the vessel head should be pursued, probably in the hydrostatic portion of the program. If the expected mode of failure is fracture of any of the head or flange components, a more detailed investigation is recommended to determine whether the failure mode scales as expected.

Recommendations

The cell liner test program details have not been addressed. However, I believe an acceptable program could be designed using models that include all of the essential features of geometry, boundary conditions, and loads. The test program for addressing the capability of the vessel head has been well planned and should provide the necessary licensing information.

The weak point in both the cell liner and vessel head test program is the lack of planned analytical support. I recommend that the applicants and NRC staff both develop analytical models to support the experimental efforts. These models, when benchmarked, can be invaluable for predicting the effects of limited design changes, changes in loads, and other parametric and sensitivity studies. Development of such analytical models could preclude the need for additional tests beyond those planned.

I trust that this summary letter will be of value for future LMFBR licensing reviews. If you need further information please feel free to contact me.

References:

1. "Safety Evaluation Report Related to the Construction of the Clinch River Breeder Reactor Plant," Vol. 1, Main Report, NUREG-0968, March 1983.

2. "Safety Evaluation Report Related to the Construction of the Clinch River Breeder Reactor Plant," Vol. 2, Appendix, NUREG-0968, March 1983.

3. L. D. Simmons and R. W. Wierman, "Large-Scale Liner Sodium Spill Test, LT-1," Hanford Engineering Development Laboratory report TME 79-35, December 198C.

4. American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section III, Subsection CC, paragraph CC-3700, 1980 edition.

5. M. G. Cowgill, B. C. Gowda, and K. C. Thomas, "Final Report on Base Materials Test for Cell Liner Steels," Westinghouse Electric Corporation report WARD-D-0252, January 1980.

6. Letter from J. R. Longenecker to J. N. Grace, on cell liner design validation program, HQ-S:83:231, March 4, 1983.

7. Letter from J. R. Longenecker to J. N. Grace, on reactor closure head capability to meet margin requirements, HQ-S:83:222, February 14, 1983.

8. C. M. Romander, "Test Plan for Static Testing of 1/20-Scale Models of the Clinch River Breeder Reactor Closure Head," SRI International report under Contract No. DE-AT03-82-SF11670, July 1983.

Sincerely,

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