PDR

CT-1255A

Franklin Research Center
A Division of The Franklin Institute

May 30, 1980

Mr. H. Alderman
Advisory Committee on Reactor Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Re: Detroit Edison Company, FERMI-II.
Capability of Biological Shield to Withstand Double-Ended Pipe Break at Safe Ends of Reactor Vessel

Dear Mr. Alderman:

As requested in your letters of October 23 and December 4, 1979 (Refs. 1 and 2) I have completed the review of the analyses evaluating the capability of the biological shield of Fermi Unit 2 to withstand asymmetric loadings resulting from double ended pipe break at the reactor vessel nozzle safe ends. Documents utilized during this review are listed in the List of References.

Although a number of shortcomings have been identified in the analyses as indicated below, I judge that the adequacy of the sacrificial shield to withstand the specified loadings has been demonstrated by the analyses.

This conclusion is partially supported by the computed stress levels substantially below the allowable limits, providing adequate margin to cover simplifying assumptions, not always known to be conservative. The data presented in the reports listed under References are assumed to be authentic as presented.

The following discussion pertains to the loadings, acceptance criteria, structural modelling and computer analysis and serves as additional basis for the acceptance of the analysis of the sacrificial shield.

Load combinations summarized in Tables 1 and 2 of Ref. 2, cover abnormal/severe and abnormal/extreme environments. These loadings correspond closely to the factored loads of ASME, Section III, Div. 2, Table CC-3230-1 as well as to the GE Specification No. 22A2652, Page No. E8, as reproduced in Reference 9, Page 3. Accordingly, Tables 1 and 2 represent an acceptable set of factored loads* for the sacrificial shield.

*In its review of Ref. 2, Structural Engineering Branch made reference to Document B as the basis for requiring factors 1.25 on both $A_p$ and $A_o$ loadings. Sargent & Lundy responded to this comment indicating that sacrificial shield is actually a steel structure, hence by the same document, load factors should be 1.0. Subsequent conversation with the NRC indicated that the Document B is no longer used. It was the design basis for the AEC (long time ago), prior to issuance of the ASME, Section III, Div. 2.

Allowable stresses for the sacrificial shield are given in Tables 3, 4 and 5 of Ref. 3. These correspond to 1.6 times those given in AISC Specifications for steel and weldments and comply with the ACI 318-71 requirements for reinforcing steel and concrete. It is also noted that these allowables correspond to those given in GE Specification No. 22A267, Rev. 0, pages E8 and E9 as reproduced in Reference 9, Page 4. Similarly, the allowable stresses for concrete and reinforcing steel given in ASME, Section III, Div. 2, Table CC-3421-1 are identical to those used by Detroit Edison, Ref. 3. It is concluded that the allowable stress limits are in compliance with the governing codes and with the normal industry practice.

Principal load governing the sacrificial shield is the annulus pressurization load due to postulated break of 12-inch feedwater line at the reactor vessel safe end weld. This rupture results in the largest pressure differential across the sacrificial shield wall at highest elevation above the reactor pedestal. The larger break of 28-inch recirculation line discharges mostly into the drywell because the flow area into annulus is restricted by the structure surrounding the safe end of 28-inch recirculation line.

Annulus pressurization analysis, Ref. 10, was performed using COMPARE code with some modifications to account for insulation movement and flow area changes. Nodalization sensitivity study was also performed for feedwater line break and the adequacy of the base case was demonstrated. Forty two (42) annulus nodes (assuming 180° symmetry), four (4) drywell nodes and one (1) break node were used to model the annulus pressurization analysis. COMPARE code calculates transient pressure response in a connected system of volumes. Each volume is assumed to be a homogeneous mixture of steam, water and air. The analysis results indicate that the maximum lateral force overturning moment and pressure differential in the annulus are due to the feedwater line break. The plots and tabulations given in Ref. 10 confirm the above conclusion. The annulus pressurization analysis, Ref. 10, is deemed adequate by this reviewer.

Structural analysis of the sacrificial shield is performed by using different models for different loadings. Seismic analysis is discussed in SL-2682, Ref. 8. As it is done by most A/E, the analysis is performed by using separate models for horizontal and vertical components of seismic input. Industry appears to be reluctant to use 3-D modelling, claiming that the overall nuclear power plant structure is too complex to be analyzed by 3-D finite elements in a cost effective manner. Use of separate analysis for horizontal and vertical components of seismic loading is associated with need for justification of simplifications introduced and the neglect of coupling between the horizontal and vertical motions. The analysis, Ref. 8, is thus typical of what one finds in other applications. As far as the sacrificial shield is concerned, there is little concern about the coupling, since critical seismic component is the horizontal one. The sacrificial shield is modelled with frame elements and 3 mass points above the 2 mass point reactor pedestal frame model in horizontal dynamic model (Exhibit 7, Ref. 8). This model of the sacrificial shield is rather simplistic and will only be able to provide beam type bending results in the lowest mode of motion.

Structural Model for analysis of annulus pressurization is shown on Exhibit 2 of Ref. 3. From the point of view of nodalization and completeness of representation of interacting components it is a model of adequate detail. However, the following shortcomings are mentioned:

- o Sacrificial shield has radius to wall thickness ratio R/h = 8.3, just about within reasonable limit for the applicability of thin shell theory.

- o The distribution of steel columns around the circumference is not symmetric. The smallest spacing between the columns is 26°, the largest - 35°15'. When the effective stiffness of columns is smeared out around the circumference, an asymmetric configuration will result. Reference 9 takes this circumstance into account when analyzing for pipe whip reaction loads, but this is not considered in annulus pressurization analysis.

- o The reactor pedestal mean radius to wall ratio varies between R/h = 2.43 to 3.13, well outside the limits of applicability of thin shell theory.

Report, Ref. 3, provides computed stresses at various location only in the combined form (as per factored loads of Tables 1 and 2). Accordingly, there is no information as to the relative contribution of each of the individual loads to the total stress. This makes it difficult to assess the impact of various model shortcomings to the margin of design. However, the experience with such asymmetric pressure loads indicates that the major contributor to the average meridional stress is the unbalanced portion of the pressure (i.e., the first harmonic in even Fourier expansion of surface pressures - beam bending mode). Accordingly, the axial symmetry approximation should be acceptable as a reasonable engineering approach.

Use of thin shell model for the pedestal, however, can only be justified if the non-beamlike bending effects are negligible. Due to the large thickness of the pedestal this is anticipated. Beam type bending of the reactor pedestal will impart rigid body motion to the sacrificial shield and RPV and the only stresses induced in the sacrificial shield due to this motion will be as caused by interaction with primary steel containment through stabilizer truss (see Exhibit 2, Ref. 3). Due to the design of shear lug connecting stabilizer truss to the steel containment, it is further noted that such interaction will restrict relative tangential motion (0.01" clearance, Fig. 1, Amendment 24, June 1979, EF-2-FSAR, E.5.130-8), and hence will hold sacrificial shield top to containment shell at locations ±90° away from the FW line break, causing ovaling of the top portion of the sacrificial shield, hence added circumferential bending (second harmonic of Fourier expanion of the response). Consequently, one would expect highest circumferential bending moment to occur in elements 31 to 34 (Exhibit 2, Ref. 3). Table 8, Ref. 3, lists maximum values of stress resultants, however, only total factored load results are given, hence it is not possible to determine whether the above qualitative conclusions are confirmed in the numerical analysis. It is also noted that the load transferred through the shield lug to containment is of interest but not reported here.

The treatment of asymmetric pressure loading in terms of even Fourier expansion is acceptable and four (4) Fourier term representation is considered adequate. Judging by the time indicated in Table 8 (maximum output at 0.47 sec, pressure history available from Ref. 10 to 0.5 sec), the numerical calculation was carried to the end of available pressure-time history and, possibly, it covered at least one full cycle of lowest structural frequency of the model (Exhibit 2, Ref. 3). Although the direct integration time step used is not indicated in Ref. 3, DYNAX code (originally developed as ASHAD by S. Ghosh and E.L. Wilson) does not use convolution type closed form solution in the time domain (which would allow arbitrary time step size with piecewise linear forcing function) hence, of necessity time steps are small because of the stability requirements. Accordingly, the solution is expected to contain all response peaks of interest.

Very truly yours,

Zenons Zudans
Senior Vice President
Engineering

ces

## References

1. Letter from H. Alderman, dated October 23, 1979.

2. Letter from H. Alderman, dated December 4, 1979.

3. Structural Design Assessment for Safe-End Break Enrico Fermi Power Plant, Unit 2, Sargent & Lundy, SL-3647, Rev. 1, March 22, 1979.

4. Regulatory Guide 1.46 - Protection Against Pipe Whip Inside Containment.

5. USNRC, Standard Review Plan, Section 3.601, Plant Design for Protection Against Postulated Piping Failures in Fluid Systems Outside Containment, NUREG-75/087.

6. USNRC, Standard Review Plan, Section 3.6.2., Determination of Break Location and Dynamic Effects Associated with the Postulated Rupture of Piping, NUREG-75/087.

7. EF-2, FSAR, Section 3.9.1.5, Analysis Method Under Loss-of-Coolant Accident Loading.

8. Seismic Analysis of the Reactor Auxiliary Building Complex, Enrico Fermi Atomic Power Plant, Unit 2, Sargent & Lundy, SL-2682, 1974.

9. Pipe Whip Restraint Support System Design Criteria for Enrico Fermi Atomic Power Plant, Unit 2, Sargent & Lundy, SL-2880, January 10, 1973.

10. Enrico Fermi Unit 2 Reactor Vessel - Sacrificial Shield Annulus Pressurization Analysis, NUS Corp., NUS-312a, May 1978.