R. E. GINNA NUCLEAR POWER PLANT

IPSAR SECTION 4.17.1

CONTAINMENT LINER INSULATION

I. INTRODUCTION

The staff's final safety evaluation for SEP Topic III-7.B for the R. E. Ginna Nuclear Power Plant was issued on April 21, 1982 (Reference 1). The Safety Evaluation Report concluded that further analysis of the containment liner is required to demonstrate liner integrity during postulated accident loads. This topic evaluation provided input to the Integrated Plant Safety Assessment Report (NUREG-0821, Reference 2). That report stated that the licensee would provide an analysis to resolve the issue. By letter dated April 28, 1983 (Reference 3), the licensee provided the required analysis to address the concern described in Section 4.17.1 of the IPSAR.

II. EVALUATION

The analysis provided by the licensee addresses the integrity of the containment liner under postulated pressure and thermal loads created by a LOCA or a main steamline break. The concern is that the thermal load induces compressive stresses in the liner which could induce differential forces on the studs that attach the liner to the concrete and possibly destroy the leak-tight integrity of the liner should the studs fail. The analysis addresses this concern in the Insulation Termination Region (ITR) of the containment and in the general dome away from the ITR.

The analysis was performed by first excluding the effects of internal pressure and then, more realistically, including this load. Before the analysis was performed, an extensive review was undertaken to ascertain the types and locations of the studs. This was done by reviewing drawings and pictures taken during construction and through discussions with personnel associated with the project during construction. Upon establishing the size and location of the studs, the analysis was performed considering possible variations in computed liner buckling stresses and in the strength of the 5/8" diameter studs.

The conclusions of the analysis are given below for the various conditions.

A. Insulation Termination Region

1. Without Internal Pressures - The maximum stud displacement ranges from 84% to 99% of the ultimate stud displacement and most likely ranges from 84% to 95% of the ultimate value. This indicates that there will be no separation of the stud from the liner; however, in light of the large displacements and the sensitivity to changes in limiting liner stresses, some of the studs located near the insulation termination may fail.

2. With Internal Pressure - The effect of internal pressure in this region is to prevent liner buckling and thus increase the differential force on the studs. This effect would increase the possibility of stud failure in this region.

B. General Dome

1. Without Internal Pressure - For the 5/8" diameter studs located in this region, the stud displacements range from 68% to 102% of their ultimate value. Based on this it is possible that some studs located in this region may fail. Based on stud displacements that are 11% of the ultimate value for the 3/4" studs located in this region, failure of the 3/4" studs in this region is unlikely.

2. With Internal Pressure - The internal pressure prevents the liner from buckling in the region where the 5/8" diameter studs are located and thus prevents a differential force on the stud. Therefore, it is unlikely that these studs will fail.

   For the region where the 3/4" studs are located, the internal pressure prevents buckling of the liner for the first 2.15 hours, and therefore, the 3/4" studs are not expected to fail during this time. However, after 2.15 hours, the pressure has reduced sufficiently and the liner is expected to buckle. When the liner buckles, it is predicted that 45 ksi compressive stress exists in the unbuckled portion adjacent to the panel that buckles. This results in an unbalanced shear force large enough to cause stud failure.

The staff believes that the conclusions which include the effects of internal pressure are considered most representative of the actual physical situation. The conclusions for this condition are that some 5/8" diameter studs are expected to fail in the insulation termination region and that some 3/4" diameter studs in the general dome region can be expected to fail. Thus, the concern is that failure of the studs may cause tearing of the liner in the process. To demonstrate that the liner will remain leak-tight and not tear, reference is made to a technical paper by G. G. Goble entitled "Shear Strength of Thin Flange Composite Specimens" (Reference 4). The paper describes the result of tests that were performed to determine the failure mode of studs welded to plates and subject to shear. Various size studs welded to flanges of various thicknesses were subject to shear and the failure mode was observed. The main conclusion of the paper is that the shift in failure mode from stud shear to flange pull-out occurs at a stud diameter to flange thickness ratio of about 2.7. In other words, if the ratio is less than 2.7, the failure mode will most likely be stud shear. The ratios for the cases occurring at Ginna are 1.17 for the 5/8" diameter studs and 2.0 for the 3/4" diameter studs. Since these ratios are substantially less than 2.7, the licensee concluded that liner tearing will not occur.

The staff has reviewed the analysis presented by the licensee and concludes that the analysis presented is a reasonable prediction of the physical response of the structure. The main conclusion is that both 5/8" diameter and 3/4" diameter studs may fail in various regions of the containment and at various times; therefore, it is important to assure that the liner will not tear during stud failure. The results of testing performed by Goble indicate that failure will most likely be by shearing of the stud shank if the ratio of stud diameter to plate thickness is less than 2.7. The testing performed by Goble utilized ASTM A36 steel, whereas, the liner material at Ginna is ASTM A442 Gr. 60.

Firstly, although Goble concluded that the failure mode shifts from flange pull-out to stud shear at a stud diameter to flange thickness ratio of about 2.7, it cannot be concluded that failure will always be by stud shear for specimens having values less than 2.7. This is because Goble obtained two specimens where the ratios were 2.03 and 2.33 and failure was by a partial flange pull-out; he also obtained one specimen whose ratio was 2.45 and failure was by flange pull-out. However, all specimens tested by Goble whose ratios were 2.0 or less failed by stud shear and not flange pull-out.

Regarding the material differences, the minimum specified yield stress for A36 steel is 36 KSI and the ultimate is 58-80 KSI; for A442 Gr. 60, the minimum specified yield stress is 32 KSI and ultimate is 60-80 KSI. The ultimate stress is approximately the same for both steels; however, the minimum specified yield stress for A442 Gr. 60 is less. The actual yield stress of flange material tested by Goble ranged from 36.0 KSI to 63.7 KSI with an average value of 44 KSI.. The specimens that failed by stud shear had flange material whose yield stress ranged from 36.0 KSI to 50.1 KSI. There were a number of specimens with a stud diameter to plate thickness ratio of 1.7 to 2.0 for which the actual flange yield stress ranged from 36 KSI to 39 KSI and the failure mode was stud shear. Based on NUREG/CR-2569 (Reference 5), ASTM A442 Gr. 60 steel used at Zion has an actual median yield stress of 48.4 KSI with a standard deviation of 2.3 KSI. Therefore, at Ginna, it is expected that even though the minimum specified yield stress is 32 KSI, actual values will most likely be substantially higher and in the range of values tested by Goble. Tensile elangation requirements are the same for the two materials. Therefore, the staff concludes that the test results obtained by Goble are applicable to the liner and stud materials at Ginna.

In a technical paper by Doyle and Chu (Reference 6), a maximum ratio of 2 was suggested for design, since this is thought to be a reasonable ratio to use in the design of containment liners in order to assure that any failures will not rupture the liner. Given these facts, it is the staff's judgement that any stud/liner failure will most likely occur by shearing of the stud shank and that tearing of the liner is unlikely.

III. CONCLUSION

The licensee has analyzed the containment liner for the postulated loading conditions and concluded that stud failure is possible but that the liner will retain its leak-tight integrity. The staff has reviewed the analysis and concludes that it is unlikely that any stud failure will result in tearing of the liner at Ginna and, therefore, the liner will retain its leak-tight integrity during the postulated loading conditions. This conclusion is based on testing of studs loaded in shear by Goble and the fact that additionally, the maximum stud diameter to plate thickness ratio at Ginna is the same as the maximum suggested for use in design in a technical paper on the same subject by Doyle and Chu. Goble obtained no plate failures for specimens that had a stud diameter to plate thickness ratio of 2.0 or less, which encompasses the values at Ginna.

IV. REFERENCES

1. Letter from D. M. Crutchfield (NRC) to J. E. Maier (RG&E), dated April 21, 1982.

2. NUREG-0821, Integrated Plant Safety Assessment Final Report, R. E. Ginna Nuclear Power Plant, December 1982.

3. Letter from J. E. Maier (RG&E) to D. M. Crutchfield (NRC), dated April 28, 1983.

4. G. G. Goble, "Shear Strength of Thin Flange Composite Specimens," AISC Engineering Journal, pp. 62-65, April 1968.

5. NUREG/CR-2569, Response of the Zion and Indian Point Containment Buildings to Severe Accident Pressures, May 1982.

6. J. M. Doyle and S. L. Chu, "Some Structural Considerations in the Design of Nuclear Containment Liners," Nuclear Engineering and Design, 1971.