APPENDIX 5B

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REACTOR BUILDING PRESSURE TESTS

The basic purpose of a structural pressure test is to substantiate that the reactor building will safely carry the loads as predicted by the design analysis. By testing the reactor building to an overpressure, a pressure greater than the design level by some margin, it can be demonstrated that failure would not be incipient under dead load plus design pressure. In addition, a correlation of predicted shell strains versus measured strains can show that the original prestress level has not been reached or exceeded.

The overall structural integrity of the reactor building depends primarily upon the integrity of the prestressing tendons. Therefore, it is appropriate that the test pressure at least creates a stress in the tendons equivalent to the stress due to dead load and design accident pressure. Most previous steel and reinforced concrete reactor buildings and a number of the European prestressed concrete reactor buildings have been tested to 115 percent of design pressure. Therefore, in order to conform to past practices, it has been decided to test the reactor building at 115 percent of design pressure. At the test pressure, there is still compressive stress in the reactor building liner and there is no concern that it will develop a crack during the test.

The safety margin of the prestressed structure at test, compared to ultimate, can be compared to a steel vessel by reviewing safety margins on various types of stresses and the significance of the stresses in the failure mode of the respective structures.

The prestressed structure relies upon the tensile strength of the tendons for its ultimate strength. The secondary stresses of the structure are isolated from the tendons. At ultimate capacity of the vessel, the secondary stresses and the thermal stresses have been relieved by local cracking of the concrete and the tendons are subjected to internal pressure and dead load only. Dead load stresses are insignificant and tend to reduce the tendon stresses.

The engineered margin of safety for ultimate structural integrity of a steel vessel is based on the ultimate stress as related to stress at test pressure for various combinations of stresses. The margin of safety for a steel vessel is as follows:

FACTOR OF SAFETY TO ULTIMATE FOR A STEEL VESSEL
(Based on ASME Boiler and Pressure Vessel Code, Section III)

Type of Stress	Stress at Test (1.25 x Allowable, S_m)	Margin of Safety
Membrane	21,900	3.2
Membrane Plus Bending	32,800	2.13

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Type of Stress	Stress at Test (1.25 x Allowable, S_m)	Margin of Safety
Membrane Plus Bending Plus Secondary	65,600	0.92

The prestressed reactor building has various material elements contributing to the structural integrity of the structure. The margin of safety at test pressure of the tendons, which are the most critical elements of the structure, is 1.90. This margin of safety for the prestressed reactor building is lower than that of a steel reactor building when it is based on a comparison of membrane stresses. However, the margin of safety of 3.2 shown for membrane stress in a steel vessel neglects the effect of secondary and thermal stresses and their ability to propagate failure. Since the membrane integrity at ultimate strength is controlled by the secondary stress concentrations, the margin of safety for this case forms a more reasonable basis for comparison with the reactor building. Certainly the margin of safety at ultimate failure is larger than 0.92 and must lie between 0.92 and 2.13, depending on the significance of the secondary stresses. An exact value for the margin of safety for a steel vessel would be virtually impossible to evaluate. On this basis, the margin of safety of a steel vessel and the prestressed reactor building are roughly comparable.

The prestressed reactor building is a ligament type vessel where the failure of a single ligament would result in a load redistribution to adjacent ligaments. This type of gradual progressive failure of isolated ligaments gives ample warning of distress during tests rather than a possible sudden catastrophic failure of a biaxially stressed steel membrane.

The selected test pressure cannot be considered as proof of individual tendon strength, but rather the safe design of the integrated components of the structure, mainly the collective tendon system and the concrete and, to some limited extent, the reactor building liner. The design accident pressure is not considered to act before thermal stresses have been developed in the shell. There are some regions of the reactor building where the test pressure produces higher stresses than the combined thermal and accident pressure stresses, thereby requiring design specifically for the test pressure. It is for this reason that a test pressure above 115 percent of the design accident level is not advisable.

The pressure test does not duplicate the stress distribution which would be caused by accident pressure and temperature. The membrane stresses caused by the pressure test with prestress acting are approximately uniformly distributed across the concrete section. These concrete stresses are generally the maximum. However, the strains of the reactor building liner and interior one-third of the concrete thickness due to accident temperature would reduce the prestress in the outer two-thirds of concrete thickness.

Indirectly, verification of structural integrity is also possible with observations during post-tensioning since, if deformations are similar to those predicted by analysis, inferences can be drawn that the analysis also provides reasonable predictions of structural integrity for other load conditions.