A peak recording accelerograph is installed on a representative Class I item to verify the seismic response determined analytically.

The seismic instrumentation locations and measurement ranges are discussed in Section 2.5.4.4.

The time history of ground motion and resultant vibrating response will be recorded and taped. An annunciation system consisting of audio and visual signs will be energized at a preset seismic acceleration for the triaxial sensor unit attached to the reactor building base mat.

5.2 REACTOR BUILDING

The reactor building is a concrete structure with a cylindrical wall, a flat foundation mat, and a shallow dome roof. The foundation slab is reinforced with conventional mild-steel reinforcing. The cylinder wall is prestressed with a post-tensioning system in the vertical and horizontal directions. The dome roof is prestressed utilizing a three-way post-tensioning system. The inside surface of the reactor building is lined with a carbon steel liner to ensure a high degree of leak tightness during operating and accident conditions. Nominal liner plate thickness is 3/8 inch for the cylinder and dome and 1/4 inch for the base.

The foundation mat is bearing on competent bearing material and is 12-½ feet thick with a 2 feet thick concrete slab above the bottom liner plate. The cylinder portion has an inside diameter of 130 feet, wall thickness of 3 feet 6 inches, and a height of 157 feet from the top of the foundation mat to the spring line. The shallow dome roof has a large radius of 110 feet, a transition radius of 20 feet 6 inches, and a thickness of 3 feet. The reactor building is shown in Figure 5-2, penetration details in Figure 5-3, and personnel and equipment access opening details in Figure 5-4.

The reactor building has been designed to contain radioactive material which might be released from the core following a Loss-of-Coolant Accident (LOCA). The prestressed concrete shell ensures that the structure has an elastic response to all loads and that the structure strains within such limits so that the integrity of the liner is not prejudiced. The liner has been anchored to the concrete so as to ensure composite action with the concrete shell.

The design and construction of the reactor building has been given a thorough re-evaluation subsequent to the discovery on April 14, 1976, of a delaminated condition in the dome. The upper part (approximately 12 inches thick) of the 3 feet design concrete thickness separated from the lower part of the dome structure parallel to the membrane over an approximate diameter of 105 inches. Extensive analytical and field investigations were conducted to establish an acceptable repair program. This repair program included removal of the upper part of the dome, placement of non-prestressed reinforcing steel mats, installation of radial reinforcement, and placement of concrete to restore the dome to a thickness of 3 feet. Details of the delaminated condition of the dome, re-evaluations of the dome, and the dome repair program are described in the report: "Final Report - Reactor Building Dome Delamination," December 10, 1976.

In several instances, the design criteria and/or construction methods related to the repair program have superseded those contained in Chapter 5. In all such cases, the above referenced report is the preferenced authority applied to the dome repair.

5.2.1 STRUCTURAL DESIGN PARAMETERS

The reactor building is a Class I structure with an internal free volume of at least 2.00 x 10^6 cubic feet. It was designed for an internal pressure of 55 psig and a temperature of 281°F (accident condition); an internal pressure (external pressure drop) of 3 psig during a tornado; and an external pressure (internal pressure drop) of 2.5 psig

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during normal operation of the plant. Due consideration was given to the dead load, live load, temperature gradients, and effects of penetrations at accident and working conditions.

The design criteria for the reactor building are covered in Section 5.2.3.

5.2.1.1 DESIGN LEAKAGE RATE

The reactor building has been designed to limit the leakage rate to 0.25% by weight of contained atmosphere in 24 hours at the design pressure and temperature.

5.2.1.2 DESIGN LOADS

The design loads for the reactor building have been determined based on operating and accident requirements, as specified below, in addition to the loads as required by applicable codes.

Scaled plots of stress resultants, stress couples, shear, and deflections for the individual loads are shown in Figure 5-5 through Figure 5-9, and Figure 5-12.

5.2.1.2.1 LOSS-OF-COOLANT ACCIDENT (LOCA)

a. Postulated Accident Conditions

The reactor building encloses the reactor and the Reactor Coolant System (RCS) and is designed to ensure that an acceptable upper limit of leakage of radioactive material will not be exceeded under the maximum LOCA as described in Chapter 14. The accident is based on a double-ended pipe break in the RCS and produces pressures and temperatures that are influenced by the reactor coolant blowdown energy release rates, reactor building heat sinks, and Engineered Safeguards (ES) Systems operation. This is described in Chapters 6 and 14.

Additional energy will be available for release to the reactor building atmosphere from the following sources:

1. Stored heat in the reactor
2. Reactor decay heat
3. Stored heat in the RCS
4. Metal-water reaction
5. Fission products in the core

The energy released from these sources is discussed in Chapter 14. The energy contribution from the secondary steam system is not included in the calculations for the reactor building design pressure and temperatures. The supports and restraints for the RCS components are designed to withstand the forces associated with a break in the RCS pipe. A rupture in the secondary system will not be considered to act simultaneously with a RCS pipe break.

b. Internal Pressure

The design internal pressure for the reactor building is 55 psig. The building was designed for an internal pressure equal to 3 psig above external pressure during a tornado. The building was also designed for an internal pressure equal to 2.5 psig below external pressure to withstand an accidental actuation of the

Reactor Building Spray System. Additionally, a total negative pressure of 6 psig has been evaluated to address the suction on containment liner, which may result from accidental actuation of building spray throughout the range of normal operating pressures. Following completion of construction, the reactor building was pressure tested at 63.3 psig.

c. Accident Temperature

The winter accident temperature profile is shown in Figure 5-10. This profile was obtained from Reference 28, for a nuclear generating station located in the northern United States, which has a more severe winter climate than Crystal River Unit 3. Thus, the use of these profiles for Crystal River Unit 3 is considered to be conservative.

5.2.1.2.2 DEAD LOAD

The dead load consists of the weight of the complete structure as shown in Figure 5-2.

5.2.1.2.3 PRESTRESS LOAD

The concrete shell has been prestressed sufficiently to eliminate tensile stresses due to membrane forces from design loads. Membrane tension due to factored loads is as described in Section 5.2.3.3.1. The prestress load applied to the reactor building is divided into three groups:

a. Local effect due to temporary jacking force equal to 80% of the minimum guaranteed ultimate capacity of the wires. In addition, stresses in the concrete such as bearing stresses, bursting stresses, and spalling stresses were checked.

b. Initial prestress force equal to 70% of ultimate capacity when locked off (shimmed in place). The supporting concrete and anchorage reinforcement has been analyzed and designed for this load.

c. Final prestress force at the end of plant life (40 years). This load takes into account time dependent losses such as shrinkage, creep, and steel stress relaxation.

5.2.1.2.4 LIVE LOAD

Applicable loads on the reactor building shell due to normal operation and factored loads are:

		During Operation	**Factored Loads**
a.	Pipe penetration	Normal reactions	Pipebreak & earthquake
b.	Pipe supports	Normal reactions	Pipebreak & earthquake
c.	Polar crane	Normal reactions	Earthquake

5.2.1.2.5 WIND LOAD

The wind velocity, as a function of height and drag coefficients, has been established on the basis of ASCE Paper No. 3269 (Ref 2).

The basic wind velocity (wind 30 feet above grade) has been based on the fastest mile of wind with a 100 year period of recurrence. The Crystal River site has been classified as a coastal area and the wind velocity as a function of height is expressed as:

$$\boxed{V_z = V_{30}\left(\frac{z}{30}\right)^X}$$

where:

V_z	=	velocity at height z above grade
V_{30}	=	fastest mile of wind at 30 feet above grade
z	=	height above grade
X	=	exponent for Ekman spiral (ranges from 0.3 to 0.118)

For the Crystal River site, the following values have been used:

V_z	=	179 mph
V_{30}	=	110 mph
z	=	166 feet (the pressure at this elevation was considered for the entire height of the cylinder)
X	=	0.285

The wind force has been applied in the vertical plane. The wind pressure can then be defined as:

$$\boxed{q = \frac{1}{2} PV_z^2}$$

For standard air at 0.07651 lb/cu feet and V_z^2 in mph:

$$\boxed{q = 0.002558\ V_z^2\ \text{psf} = 0.0000177\ V_z^2\ \text{psi}}$$

Or:

$$\boxed{q = 0.568\,\text{psi}}$$

The wind pressure distribution in the horizontal plane is defined by the Fourier series:

$$\boxed{\begin{aligned} f(x) = &-0.3145 + 0.1568\cos x + 0.4864\cos 2x + 0.2158\cos 3x \\ &-0.0263\cos 4x + 0.0071\cos 5x + 0.0348\cos 6x - 0.0044 \\ &\cos 7x - 0.0263\cos 8x - 0.0065\cos 9x \end{aligned}}$$

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5.2.1.2.6 TORNADO LOAD

The reactor building has been designed to withstand short term tornado loadings, including tornado generated missiles. The tornado design requirements are:

a. Tangential wind velocity of 300 mph.
b. An external pressure drop of 3 psig.
c. Missile equivalent to a utility pole 35 feet long, 14 inches in diameter, density of 50 lb./cu.ft. and traveling at 150 mph.
d. Missile equivalent to a one ton automobile traveling at 150 mph.

A 300 mph wind has been applied in accordance with standard wind design practice and utilizing applicable pressures, shape factors, and drag coefficients from ASCE Paper No. 3269. The pressure drop of 3 psig is conservative considering that most measured pressure drops have been in the order of magnitude of 1.5 psig.

The effect of the following tornado-borne missiles was also analyzed:

a. A 4 inch by 12 inch by 12 feet long wooden plank traveling end-on at 300 mph.
b. A missile equivalent to a 3 inch diameter schedule 40 pipe, 10 feet long, traveling end-on at 100 mph.

It is obvious from the following comparison data that they do not have significant effect on the structural integrity of the Class I structures. The spectrum of potential tornado missiles with its kinetic energy and penetration depth is shown in the following data:

Potential Tornado Missiles - Comparison of Kinetic Energy and Penetration

Tornado Missile	**Geometric Properties** **L = Length** **D = Diameter** **A = Minimum Cross Sectional Area**	**Density P(lb/ft^3) or Weight W(lb)**	**Velocity (mph)**	**Kinetic Energy (ft.-lb)**	**Penetration Depth Into Concrete (inches)**
1. Utility Pole	L = 35 feet D = 14 inch	P = 50	150	1,415,000	2.5
2. Compact Auto	A = 6.25 ft^2	W = 2000	150	1,505,000	6.2
3. 3 inch Schedule 40 pipe (piece)	L=10 feet	W = 75.8	100	25,300	0.3
4. Wood Plank	4 in x 12 in L = 12 feet	W = 108	300	325,000	1.3

A comparison of values in the above data indicates that two missiles are critical for design. The 14 inch diameter utility pole is critical because of smaller end dimension with fairly large kinetic energy. The compact auto is critical because of possessing the highest kinetic energy and high penetration depth.

It is predicted that maximum penetration depth for the worst probable missile is 6.2 inches against the exterior concrete wall thickness of safety related structures which is 24 inch minimum. As such, it is concluded that secondary missiles will not be generated within the structure which could damage the safety related equipment and systems.

In the reactor building, the personnel access, equipment access doors, and all penetrations are located inside Class I structures, which are designed for tornado generated missiles.

All access openings in auxiliary, intermediate, diesel generator, and control buildings are located or protected by a missile shield so no damage will be done to safety related equipment from tornado generated missiles.

5.2.1.2.7 EXTERNAL PRESSURE

The reactor building has been designed for an external atmospheric pressure of 2.5 psi greater than that of the internal pressure that could be caused by an accidental discharge from the Reactor Building Spray System. Additionally, a total negative pressure of 6 psig has been evaluated to address the suction on containment liner, which may result from accidental actuation of building spray throughout the range of normal operating pressures.

5.2.1.2.8 OPERATING TEMPERATURE

The normal operating temperature profile is shown in Figure 5-11. This profile was obtained from Reference 28, for a nuclear generating station located in the northern United States, which has a more severe winter climate than Crystal River Unit 3. Thus, the use of these profiles for Crystal River is considered to be conservative.

5.2.1.2.9 EARTHQUAKE LOAD

The site seismology and response spectra are described in Chapter 2.

The seismic design of the reactor building is based on the response to a ground acceleration as described below:

a. Primary steady state stresses, when combined with the seismic stress resulting from the response to a ground acceleration of 0.05g acting horizontally and 0.033g acting vertically and occurring simultaneously, have been maintained within the allowable working stress limits accepted as good practice and, where applicable, set forth in the appropriate design standards, e.g.: ASME Boiler and Pressure Vessel Code (Ref 3), ACI 318-63 (Ref 4), AISC Specification for the Design and Erection of Structural Steel for Buildings (Ref 5), and USAS (ANSI) B31.1 (Ref 6).
b. Primary steady state stress, when combined with the seismic stress resulting from the response to a ground acceleration of 0.10g acting horizontally and 0.067g acting vertically and occurring simultaneously, has been limited so that the function of the structure is not impaired so as to prevent a safe and orderly shutdown of the plant.

The respective vertical and horizontal seismic components at any point on the shell have been added by summing the absolute values of the response (i.e., stress, shear, moment, or deflection) of each contributing frequency due to vertical motion to the corresponding absolute values of the response of each contributing frequency due to horizontal motion.

5.2.1.2.10 GROUNDWATER AND FLOODS

The foundation slab design took into consideration groundwater pressure. Fluctuations in the groundwater due to flood and normal variation have been given due consideration in designing the foundation mat (see Sections 2.4 and 2.5).