APPENDIX C

STRUCTURAL DESIGN CRITERIA

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STRUCTURAL DESIGN CRITERIA

C.1 CLASSIFICATION OF STRUCTURES

C.1.1 General

Certain station structures must remain functional and/or protect vital equipment and systems, both during and following the most severe natural phenomenon which is postulated to occur at the site. In order to establish the loadings and loading combinations for which each individual structure is to be designed, buildings and their structural systems are separated into the following two seismic classes with respect to aseismic design requirements.

Seismic Class I - Seismic Class I structures and equipment are those whose failure could increase the severity of the design basis accident, and cause release of radioactivity in excess of 10CFR100 limits, or those essential for safe shutdown and removal of decay heat following a LOCA.

Seismic Class II - Seismic Class II structures and equipment are those whose failure would not result in the release of significant radioactivity and would not prevent reactor shutdown. The failure of seismic Class II structures may interrupt power generation.

A structure designated seismic Class II shall not degrade the integrity of any structure designated seismic Class I. Although a structure, as a whole, may be seismic Class I, less essential portions may be considered seismic Class II if they are not associated with loss of function, and their failure does not render the seismic Class I portions inoperable.

Seismic Class II structures are structurally separated from seismic Class I structures by means of expansion joints to provide for unequal deflections associated with independent movements of the structures. The arrangement is such that in the unlikely event that a Class II structure should collapse, it would not impair the safety function of the Class I structure.

The criteria for the relative movements under maximum earthquake loadings require that the clearance provided exceeds the combined movements. The relative movements under these loadings are accommodated by expansion joints at adjoining structures and by built-in flexibility for piping systems. A dynamic analysis has shown that the cumulative maximum displacements of adjoining concrete structures will be about one-half of the clearance provided.

In the case of structures defined as partially Class I and partially Class II rigidly interconnected, the Class I portion is checked to assure it can carry any loads that may be transmitted from the connected Class II structure.

The following list itemizes the structures, equipment, and process systems which fall under the two seismic classes defined above.

C.1.2 Seismic Class I Structures and Systems

Class I Structures

- Drywell, vents, torus, and penetrations
- Reactor building
- Spent fuel pool
- Reactor vessel support pedestal
- Main control room complex (including cable spreading room, emergency switchgear rooms, and battery rooms)
- Radwaste building
- Diesel generator building
- Pump structure (portion containing critical service water pumps)
- Emergency heat sink facility, including cooling tower
- Stack
- Structures required to protect seismic Class I equipment
- Post-LOCA CADS liquid N_2 tank building
- Recombiner building

Class I Equipment and Systems

Nuclear steam supply systems:
- Reactor vessel and internals, including:
  - CRD housing
  - CRD guide tube
  - CRD
  - CRD cap screw
  - Control rod
  - CRD thermal sleeve and key
  - In-core housing
  - Feedwater sparger
  - Jet pump adapter
  - Shroud
  - Top guide

- Core support
- Core support and top guide aligner
- Core plate stud
- Jet pump riser brace
- Jet pump assembly
- Jet pump instrument penetration seal
- Differential pressure and liquid control line
- Core spray line and clamp
- Head cooling spray nozzle (for Unit 2 only)
- Dry tube
- Power range monitor installation hardware
- Power range detector
- Orificed fuel support
- Fuel channel
- Fuel assembly

Reactor vessel supports and stabilizers
Control rod drive system (equipment required for scram operation)
Control rod drive housing supports
Recirculating piping, including valves and pumps
Main steam piping out to second isolation valve
Nuclear boiler system safety valves
Nuclear boiler system relief valves
Piping connections from the reactor vessel, up to and including the first isolation valve external to the drywell

Core standby cooling systems (CSCS)
Standby liquid control system (except for the test tank and test connections)
High pressure service water system
Emergency service water system
Standby gas treatment system
Fuel storage facilities, to include spent fuel and new fuel storage racks
Reactor building crane
Circulating water pump structure crane
Standby power systems:

- Station batteries (except balance-of-plant battery and 24 volt neutron monitoring batteries)
- Standby diesel generators
- Emergency buses and other electrical gear for onsite power supply to engineered safeguards and nuclear safety systems

Instrumentation and controls:

- Reactor level instrumentation
- Reactor manual control system
- Control rod instrumentation (portions)

Post-LOCA CADS

C.1.3 Seismic Class II Structures and Systems

Class II Structures

Turbine building
Shop and warehouse
Administration building
Water treatment building
Pump structure, except for portion affecting critical service water systems
Intake screen structure
Cooling towers and cooling tower pump structures for circulating water
Off-gas filter station
Auxiliary boiler house
Guardhouse
Outdoor electrical switchgear structures
Sewage treatment plant
Radwaste onsite storage facility

Class II Equipment and Systems

Turbine-generator system and transformers
Condensers
Turbine building crane
Feedwater heaters and pumps
Condensate storage tanks and pumps
Refueling water storage tank
Station auxiliary power buses
Offsite AC power system
Radwaste systems
Reactor water cleanup system
Condensate filter-demineralizer system
Compressed air system
Reactor building cooling water system
Turbine building cooling water system
Instrument N_2 system
All other piping and equipment not listed under seismic Class I
24 volt neutron monitoring batteries
Feedwater zinc injection system
Hydrogen Water Chemistry System

C.2 STRUCTURAL DESIGN BASIS

Structures are designed for dead loads, live loads, seismic loads, and wind loads in accordance with applicable codes and as described in the following paragraphs. The loading conditions, and combinations thereof, are determined by the function of the structure and its importance in meeting the station safety and power generation objectives.

C.2.1 Dead and Live Loads

The structures in the power plant complex are designed for the dead loads and live loads to which the structures will be subjected. Roofs of all the structures are designed for a snow load of 30 psf.

C.2.2 Seismic Loads

The design of seismic Class I structures is based on a dynamic analysis using the spectrum response curves developed for the site. The design of seismic Class I equipment is based on a dynamic analysis using either acceleration spectrum response curves or acceleration time histories developed at points of attachment, the method of analysis being dependent on the nature of the equipment.

The list of Class I (seismic design) structures, equipment, and systems is presented in paragraph C.1.2. All structures listed in this table as Class I structures were seismically analyzed by the response spectra method, except the portion of the pump structure containing critical service water pumps was seismically analyzed by the time-history method.

The structures are analyzed for the following magnitudes of ground acceleration:

a. Design earthquake considers a maximum horizontal ground acceleration of 0.05g. Under this condition, stresses due to the earthquake combined with stresses due to other operational loadings are limited to the working stress levels of the materials used in the structures except as noted in paragraph C.2.6.3. The customary increase in normal allowable working stress due to earthquake is not used.

b. Maximum credible earthquake (MCE) considers a horizontal ground acceleration of 0.12g. Under this condition, stresses due to the earthquake combined with stresses due to other operational loadings are allowed to approach the yield strength of the materials and are limited to 90 percent of yield stress (fy) for the steel and 85 percent of ultimate compressive stress (f'c) for the concrete. In addition, all items required for safe shutdown will not lose their function.

Proof of design adequacy is accomplished by showing the criteria stated for steel and concrete for the MCE condition are not exceeded and thus the structures comply with the definition of seismic Class I in paragraph C.1.1. Structural deformations and deflections calculated are well within the linear-elastic range and cause only low stresses.

c. Vertical ground accelerations associated with the design earthquake and MCE are 67 percent of the corresponding horizontal acceleration spectrums; namely, 0.033g for the design earthquake and 0.08g for the MCE.

Table C.2.1 shows the damping factors which are used for excitations associated with the design earthquake and the MCE.

Vertical seismic stresses are not severe because they represent only a fractional increase in the dead load which the structure carries. Since the frequencies of the modes associated with vertical motion are normally large, it is sufficient to design the vertical elements for the maximum vertical ground acceleration without a detailed dynamic analysis of the structure.

The reactor building is nearly symmetrical about both perpendicular axes. The lack of symmetry is not sufficient to significantly alter stresses and may be safely ignored. However, to account for so-called "accidental" torsion, after evaluating the worst cases an arbitrary conservative allowance of 20 percent was made on all forces.

Parametric studies were carried out to determine the relative influence of the numerous variables involved which verified the adequacy of the assumption.

The vertical seismic response can be divided into two categories. The first category is the general building motion involving primarily the column or wall elements and the second category is the local response of various beam and slab elements oriented parallel to the ground.

In general, for a building founded on a rigid foundation the building response will be small compared to the dead load since the building frequencies will be higher than the primary frequencies of the earthquake spectrum.

The beams, slab, equipment, and systems may respond differently than the overall building since their frequencies may correspond to the primary frequencies of the earthquake spectrum.

All Class I equipment and structural elements including columns, walls, beams, and slabs are analyzed and designed to resist the vertical seismic forces together with any other loads as defined in the design criteria. Beams and floors are analyzed to determine their maximum response and frequency. The equipment and systems are designed to resist any amplified beam and floor accelerations.

The seismic Class II radwaste on-site storage facility structure is designed for seismic loadings corresponding to the maximum ground acceleration of 0.05g selected for the Operating Basis Earthquake (OBE). A model analysis using a lumped mass model of the facility was performed using the criteria and methodology described in USNRC Regulatory Guide 1.143. American Concrete Institute standard ACI 318-77, "Building Code Requirements for Reinforced Concrete" was used in the design of the concrete structures. For steel structure design, American Institute of Steel Construction "Specification for the Design, Fabrication and Erection of Structural Steel for Buildings," November 1978 was used. The one-third allowable stress increase was included for steel structures for load combinations involving earthquakes or wind loads. The building foundation is discussed in UFSAR section 2.7.6.4.

Analysis of other seismic Class II structures is based on the design criteria established for the structures in Zone I of the seismic zones as defined by the Uniform Building Code, 1967 Edition.

Class II structures, such as the turbine building, which adjoin Class I structures are arranged and designed in such a way that the possible failure of the Class II building will not endanger the function of any Class I building or system.

Additionally, in the case of the 1997 re-analysis of the Recirculation system piping and the Residual Heat Removal and Reactor Water Clean-up piping inside primary containment for Peach Bottom NCR 97-02267, the seismic analysis was based on NRC Regulatory Guide 1.60 (Design Response Spectra for Seismic Design of Nuclear Power Plants) with modal combination and spatial components in accordance with Reg. Guide 1.92 (Combining Modal Responses and Spatial Components in Seismic Response Analysis). These regulatory guides were used because they are required by Regulatory Guide 1.84 when using ANSI Code Case N-411-1 (Alternative Damping Values for Response Spectra Analysis of Class 1, 2, and 3 Piping Section III, Division 1).

C.2.3 Wind Loads

The methods used in determining the wind pressures for the radwaste on -site storage facility are in accordance with ANSI A58.1-1972, "Building Code Requirements for Minimum Design Loads in Buildings and other Structures". The storage facility structures are designed to withstand a maximum windspeed of 90 miles per hour. The wind is assumed to occur 30 feet above ground and has a 100-year mean recurrance interval.

The wind loads used in the design of other portions of this plant are derived from Paper 3269, entitled "Wind Forces on Structures," published by the American Society of Civil Engineers, Transactions, Volume 126, Part II, 1961, as applied to the Peach Bottom site. The total wind pressures, listed in Table C.2.2, include positive and negative pressures and gust factors.

C.2.4 Tornado Loads

Tornado winds traversing the site could damage the reactor building superstructure, turbine building, condensate storage tanks, stack, and incoming power lines. However, the ability to shut down the reactor, the integrity of primary containment, and the capability of essential heat removal systems would not be impaired.

Components which directly affect the ultimate safe shutdown of the plant are located either in reinforced concrete structures or underground for tornado protection. These components include the following:

Reactor primary system

CRD hydraulic equipment, excluding feed pumps

Standby gas treatment system

Standby liquid control system

Primary containment and isolation valves

HPCIS

RCICS

RHRS

Emergency service water system

High pressure service water system

Station batteries

Standby diesel-generators and associated switchgear

Controls and instrumentation for above systems

Main control room complex

Intake structure (portions essential to systems listed above)

Where failure could affect the operation and function of the primary containment, the reactor primary system, or other safeguards equipment, the following tornado effects are considered in the design of these structures:

1. External wind forces resulting from a tornado having a horizontal peripheral tangential velocity of 300 mph maximum, which includes the tangential and translational components.

2. Differential pressure of 3 psi between inside and outside of fully enclosed areas. Blowout panels are included where necessary in the design of the structure to limit pressure differentials.

3. Missiles equivalent to a 4 in thick x 12 in wide x 12 ft long wood plank traveling end-on at 300 mph; or a 4,000-lb passenger auto flying through the air at 50 mph, at not more than 25 ft above ground, with a contact area of 20 sq ft.

4. A torsional moment resulting from applying the wind specified in item 1 acting on one-half the length of a building.

Walls of all open compartments were designed to withstand the differential pressure which occurs during the tornado depressurization. Blowout panels are provided to relieve excess positive pressure in all essential parts of the structure.

Building structures housing safeguards equipment are designed to withstand a tornado-induced depressurization rate of 1 psi/sec for 3 sec. To accomplish this objective, all compartments that are essentially leaktight are checked to verify that they are capable of withstanding a differential pressure of 3 psi.

Seismic Class I equipment and/or structures either protected by a tornado resistant structure, or whose loss of function during a tornado would not violate the safety requirements of the plant, are not designed against tornado effects.

The structural steel frame of the reactor building upper superstructure is designed to withstand the force of a 300-mph wind without exceeding the yield stress. The reactor building siding and roof decking, however, is designed for the normal wind loading. When this design wind loading is appreciably exceeded, portions of the siding and decking are expected to be lost. Connectors for the siding are designed to fail at stress levels associated with tornado loading to assure that the siding will blow away. However, to ensure an adequate load carrying capacity of the structural members, the individual members were designed to take the full load of the tornado if the siding directly affecting that member remained intact. However, the reinforced concrete structure of the reactor building protects the equipment necessary for the safe shutdown of the reactor, the primary containment, and the essential heat removal equipment from the effects of a tornado. Tornado effects on the spent fuel pool are discussed in General Electric Topical Report APED-5696. On the sides, the fuel pool is protected against low trajectory missiles by thick concrete walls between the turbine and the pool.

C.2.5 Special Loadings

The structures housing critical equipment required for safe shutdown of the plant are designed for special loadings.

C.2.5.1 Turbine Missiles

The turbine missile probability will be maintained to less than 1×10^{-5} per year, and the probability of damaging a critical target will be maintained less than 1×10^{-7}. This is consistent with Sections 3.5.13 and 2.2.3 of the Standard Review Plan. Section 11.2.4 includes the basis for determining probabilities and the inspection program that has been instituted to maintain the probability of turbine missile generation within acceptable limits.

Missiles from the RCIC turbine were also investigated to assure that they would not damage any critical piping in the vicinity of the turbine. The possibility of this type of missile is very remote.

C.2.5.2 Tornado-Generated Missiles

Tornado-generated missiles are discussed in paragraph C.2.4. The concrete shield plug above the drywell is capable of resisting missiles generated in a tornado. The large equipment openings of the diesel generator building have missile-proof doors. The personnel access doors are shielded from such missiles by baffle walls. This concept is used throughout the project to protect large openings against effects of tornado winds, depressurization, and tornado-generated missiles.

C.2.5.3 Temperature Loads

For each seismic Class I structure, temperature loads considered to be significant were included in the design. For example, the biological shield was designed for the normal operating loads listed in Table C.4.5; the reactor pressure vessel pedestal was designed for the loading conditions listed in Table C.4.4; the primary containment shell was designed for the accident conditions listed in Tables M.3.5 and M.3.6; the fuel pool walls were designed for normal allowable stresses. A check under loss-of-fuel pool coolant (i.e., boiling water) indicated that stresses would be still below normal allowable limits.

Higher temperatures than LOCA condition were not considered for other than process equipment normally encountering higher temperatures; however, an examination of the stress level contained in subsection C.4 will show that they are sufficiently low to be able to tolerate a short duration increase in temperature to 305°F and still be within the allowable limits.

Transient stresses do not significantly affect concrete stresses. However, transients were considered at the point of embedment of the shell. The design basis for this plant was a LOCA temperature of 281°F. The changes in the reactor vessel conditions with power rerate result in the expected peak drywell gas temperature exceeding the shell design temperature by approximately 11°F at the beginning of a LOCA. However, the peak drywell gas temperature exceeds the shell design temperature for only a short time (less than 20 seconds). This temperature excursion does not present a threat to the drywell structures due to the short duration of the excursion and the long time that it takes for the drywell shell to heat up. All drywell equipment required to be operable in accordance with 10CFR50.49 has been qualified to at least 297°F which provides sufficient margin to envelop the increase in peak drywell gas temperature associated with power rerate.

C.2.5.4 Flood Loads and Flood Protection

Structures required for safe shutdown of Units 2 and 3 in the event of the probable maximum flood (PMF), (causing an estimated wave runup to Elevation 136.9 ft (C.D.) assuming no accident occurs concurrently, are:

- Reactor building
- Main control room complex
- Diesel generator building
- Pump structure (portion containing critical service water pumps)
- Emergency heat sink facility, including cooling tower

Components required for safe shutdown of Units 2 and 3 are:

- Reactor vessel and internals
- CRDS (portion essential for scram)
- Recirculation piping system
- RCICS
- RHRS
- High pressure service water system
- Emergency cooling system
- Emergency service water system
- Standby power systems
- Instrumentation and controls:
  - Reactor level instrumentation
  - Reactor pressure instrumentation

For description of wave runup superimposed on the PMF refer to subsection 2.4.

For drawings of structures and components listed above see Figures 12.1.1 through 12.1.7, 12.2.1, and 12.2.2. The emergency heat sink structure is shown in Figure C.2.1.

Watertight doors are provided at all structures; waterproofing is installed to Elevation 135.0 ft (C.D.) and any penetration in the exterior walls is sealed to ensure leaktightness necessary to plant safety.

The integrity of the waterproofing on the external surfaces of vertical walls below grade cannot be checked since such surfaces are inaccessible. Accessible joints are visually inspected and caulked as required on a periodic basis as part of regular plant maintenance.

Plastic waterstops are used at all construction joints to maintain the integrity of joints. Penetrations and conduits in exterior walls are sealed with approved, pre-tested seal details and material which assure leaktightness against ground or flood water. Penetration seals are installed in accordance with approved specifications and procedures and are inspected to assure proper installation.

C.2.6 Loading Combinations

The following paragraphs describe the loading combinations used for the design of the seismic Class I structures. Loads and loading combinations for Class II structures are in accordance with the Uniform Building Code and normal design practice for power plants. Loading combinations used for the design of the primary containment are discussed in Appendix M.

D = Dead load of structure and equipment plus any other permanent loads contributing stress, such as soil or hydrostatic loads, operating pressures, and live loads expected to be present when the plant is operating. 50 psf is considered normal operating live load.

W = Design wind loading conditions.

W' = Loads due to tornado.

R = Jet force on structure due to rupture of any one pipe.

H = Force on structure due to thermal expansion of pipes under operating conditions. The effect of this loading was considered on individual members where required.

E = Design earthquake load.

E' = MCE load.

T = Temperature load.

F = Flood loading (flood level at Elevation 135 ft 0 in).

For Class I structures, code allowable stress values are modified since structures of this class must sustain much more severe loads and be more accurately proportioned than structures normally considered under building codes. However, the same codes will still furnish guidance.

The criteria for seismic Class I structures with respect to stress levels and load combinations for the postulated events are noted in the following paragraph.

C.2.6.1 Reactor Building and All Other Seismic Class I Structures

1. D+E — Normal allowable code stresses (AISC for structural steel, ACI for reinforced concrete). The customary increase in normal design stresses, when earthquake loads are considered, is not permitted.

2. D+E' — Maximum allowable stresses are as follows:
   Steel - 0.9 F_y (yield strength of steel);
   Concrete - 0.85 f'_c (compressive strength of concrete);
   Reinforcement - 0.9 F_y (yield strength of reinforcement).

3. D+W — Maximum allowable working stresses may be increased one-third above normal code allowable stresses.

4. D+W' — Maximum allowable stresses are as follows:
   Steel - 0.9 F_y;
   Concrete - 0.85 f'_c;
   Reinforcement - 0.9 F_y.

5. D+E+T — Normal allowable code stresses. The customary increase in normal design stresses when earthquake is considered is not permitted.

6. D+E'+T — Maximum allowable stresses are as follows:
   Steel - 0.9 F_y;
   Concrete - 0.85 f'_c;
   Reinforcement - 0.9 F_y.

7. D+F — Maximum allowable stresses are as follows:
   Steel - 0.9 F_y;
   Concrete - 0.85 f'_c;
   Reinforcement - 0.9 F_y.

C.2.6.2 Reactor Vessel Pedestal

1. D+T+E — Normal allowable code stresses (AISC

for structural steel, ACI for reinforced concrete). The customary increase in normal design stresses, when earthquake loads are considered, is not permitted.

2. D+T+R — Maximum allowable stresses are as follows:
Steel - 0.9 Fy;
Concrete - 0.85 f'C;
Reinforcement - 0.9 Fy.

3. D+T+E' — Maximum allowable stresses are as follows:
Steel - 0.9 Fy;
Concrete - 0.85 f'C.
Reinforcement - 0.9 Fy.

C.2.6.3 Spent Fuel Pool

The spent fuel pool has been reevaluated structurally for additional loading due to the high density fuel racks and increased number of fuel elements. This reevaluation was performed in accordance with the applicable codes and standards identified in Section C.2.7.1.

All loading combinations required by USNRC Regulatory Guide 1.142, USNRC Standard Review Plan 3.8.4, ACI and AISC were evaluated. The number of combinations to be analyzed were reduced by eliminating combinations governed by others. Final governing equations for the spent fuel pool structure are shown below for concrete structures using strength design methods and for structural steel using plastic design methods.

Load Combinations

Reinforced Concrete

1. $U = 1.4D + 1.4F + 1.7T_0$
2. $U = 1.4D + 1.4F$
3. $U = 1.4D + 1.4F + 1.7L + 1.9E$
4. $U = D + F + L + E' + T_a$
5. $U = D + F + L + E'$
6. $U = 1.05D + 1.05F + 1.3L + 1.43E + 1.3T_0$

Structural Steel

7. $Y = 1.7D + 1.7F + 1.7L + 1.7E$
8. $Y = 1.3D + 1.3F + 1.3L + 1.3E + 1.3T_0$
9. $Y = 1.1 (D + F + L + E' + T_a)$

Where: L = Live Load
T_0 = Operating Temperature
T_a = Accident Temperature

Loading Assumptions:

The dead load includes the weight of the spent fuel racks, stored fuel, spent fuel pool, and the contributing weight of the adjacent floor slabs, roof, and walls.

The live load includes the roof snow load, the distributed live loads on the adjacent floor slabs, crane loads and a buoyant weight of a loaded spent fuel storage cask.

Hydrostatic loads consist of vertical and lateral water pressures exerted on the spent fuel pool slab and walls, respectively.

Thermal loads are based on the pool water temperatures resulting from a full core discharge under normal operating conditions, and saturation temperatures for accident conditions. In all cases, a conservative Reactor Building indoor ambient temperature of 68°F is used. A stress free temperature of 70°F is used.

C.2.7 Governing Codes and Regulations

The design of all structures and facilities conforms to the applicable general codes or specifications listed below except where specifically stated otherwise.

Each structure was analyzed by methods appropriate for its configuration; this furnished a measure of the stresses the structure would experience under the postulated conditions. Referenced codes were used as guides to establish reasonable allowable stresses.

1. Uniform Building Code (UBC). 1967 Edition.

2. American Institute of Steel Construction (AISC), "Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings," Sixth Edition.

3. American Concrete Institute (ACI), "Building Code Requirements for Reinforced Concrete," (ACI 318-63) and "Code Requirements for Reinforced Concrete Chimneys," ACI 307 (1969).

4. American Welding Society (AWS), "Standard Code for Arc and Gas Welding in Building Construction," (AWS-D.1.0).

5. American Petroleum Institute (API), "Specification No. 650 for Welded Steel Storage Tanks."

6. ASME Boiler and Pressure Vessel Code, "Section III, Class B (governs the design and fabrication of the drywell and suppression chamber), 1965 Edition, with applicable addenda published to April, 1967.

7. U.S. Army Corp of Engineers (Regulations with respect to dredging and construction).

8. American Society of Civil Engineers Paper No. 3269, "Wind Forces of Structures."

9. American Iron and Steel Institute (AISI), "Specification for the Design of Light Gage Cold-formed Steel Structural Members."

10. Commonwealth of Pennsylvania Department of Labor and Industry "Building Regulations for Fire and Panic."

11. Electric Power Research Institute (EPRI) "Visual Weld Acceptance Criteria," EPRI Report No. NP-5380 Volume 1: Visual Weld Acceptance Criteria for Structural Welding at Nuclear Power Plants (NCIG-01, Revision 2), September 1987

C.2.7.1 Spent Fuel Pool Reevaluation

The spent fuel pool has been evaluated structurally for additional loading due to the increased number of fuel elements and high density fuel storage racks in accordance with the following codes and standards:

1. American Concrete Institute (ACI), "Building Code Requirements for Reinforced Concrete," (ACI 318-83) and "Code Requirements for Nuclear Safety Related Structures," (ACI 349-80)

2. American Institute of Steel Construction (AISC), "Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings," 1978

3. U.S. Nuclear Regulatory Commission, "Standard Review Plan 3.8.4, 'Other Seismic Category I Structures,'" Revision 1, NUREG-0800, July 1981

4. U.S. Nuclear Regulatory Commission, letter from B.R. Grimes to All Power Reactor Licensees, April 14, 1978, with enclosure entitled "OT Position for Review and Acceptance of Spent Fuel Storage and Handling Applications," including Supplement, dated January 18, 1979

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TABLE C.2.1

DAMPING FACTORS

	Percent of Critical Damping	
	Design Earthquake	Maximum Credible Earthquake
Reinforced concrete structures	2.0	5.0
Steel framed structures	2.0	5.0
Welded steel assemblies	1.0	2.0
Bolted and riveted assemblies	2.0	5.0
Seismic Class I piping systems *	0.5	0.5

* 1997 Re-analysis of the Recirculation system piping, and the Residual Heat Removal and Reactor Water Clean-up piping inside primary containment for Peach Bottom NCR 97-02267 and ASME Code Case N-411-1 as shown below:

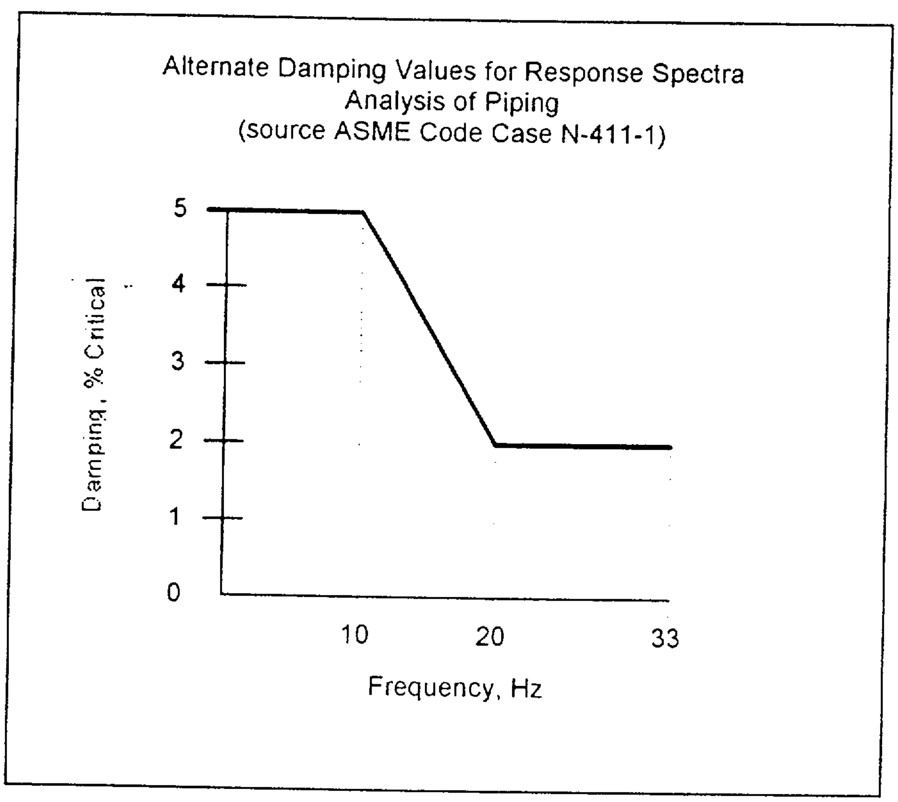

TABLE C.2.2

WIND LOADS

Height-Feet	Pressure (q) - (psf) Class I Structures - 100-Yr Recurrence	Class II Structures - 50-Yr Recurrence
0-50	25	20
50-150	35	25
150-400	45	30
Over 400	55	40

C.3 ANALYSIS OF CLASS I STRUCTURES

C.3.1 Scope

The loads, loading combinations, and allowable limits described in this appendix apply only to seismic Class I structures and components. The criteria in this appendix are intended to supplement applicable industry design codes where necessary to provide design safety margins which are appropriate to extremely reliable structures and components when account is taken of rare events associated with an MCE or postulated LOCA or a combination thereof.

Seismic Class I components are not always designed by application of the criteria using analytical techniques. Rather, the design of some components may be based upon test results, empirical evidence, or by comparison with similar items.

The seismic Class I concrete and steel structures are designed considering three inter-related primary functions for the design loading combinations described in paragraph C.2.6. The first consideration is to provide structural strength equal to or greater than that required to sustain the combination of design loads and provide protection to other seismic Class I structures and components. Design code allowable stresses appropriate for the elastic design techniques were used as a guide for all stress limitations under normal design conditions. Higher stresses approaching yield for steel and ultimate for concrete were permitted under the MCE and similar conditions and as noted in paragraph C.2.6.3. Typical stresses under various conditions have been tabulated in Tables C.4.1 through C.4.5, and when these are compared with ultimate strengths, safety factors are readily apparent. The second consideration is to maintain structural deformations within such limits that seismic Class I components and/or systems will not experience a loss of function. Deformations experienced by structures under the loss of function criteria were checked and found, by elastic analysis, to be of such a small magnitude as to assure the structure would function as required. Typical deformations of the reactor building are shown in Figures C.3.8 and C.3.9. The third consideration is to limit excessive containment leakage by preventing excessive deformation and cracking where containment integrity is required.

Structural design and construction were performed in such a way as to prevent concrete cracking insofar as possible by mix design, pour limitation, and curing precautions. The stress limits in the code should result in very limited cracking on the order of a few hundredths of an inch. Such cracking would not significantly affect the leak resistance of the structure.

C.3.2 <u>Structural Analysis</u>

In general, the structural analysis is performed utilizing the "Working Stress Design" method as defined in "ACI Standard Building Code Requirements for Reinforced Concrete" (ACI 318-63), and in the AISC Manual of Steel Construction (Sixth Edition). "Finite element stress analysis" and other techniques are also used where applicable or necessary.

Load combinations and allowable limits on stresses are as shown in paragraph C.2.6. The maximum permissible calculated concrete compression is limited to 0.85 f' (design compressive strength of concrete) and the maximum permissible calculated concrete shear is as given in ACI 318-63, Chapter 17, for loading involving R and E'.

Concrete structures designed for no loss of function criteria have been proportioned so as not to exceed 0.9 f' tension in the reinforcing steel and 0.85 f' compression in the concrete. For bending, stresses have been determined on a straight line stress distribution assumption. This yields maximum allowable moments less than the ultimate strength moment as calculated by ACI-318-63 Code Section 1601. For bending every section is "under reinforced" so that the reinforcing steel reaches its allowable stress before the concrete, thus assuring ductility and reserve strength against structural collapse.

For both reinforcing steel and concrete the design criteria is: normal allowable stresses were not increased when considering operating loads with design earthquake loads except as noted in paragraph C.2.6.3. No loss of function criterion as listed in paragraph C.2.2 was used for MCE, tornado loads, flood loads, or pipe rupture jet loads when combined with normal loads.

Bond and anchorage for reinforcing steel is treated as required by ACI 318-63.

There are no loading conditions such as pressure which would cause net tension across a section resulting in biaxial and triaxial tension when combined with other loads, and thus reduce the shear strength, bond, and anchorage strength of reinforcing bars. However, there are loading conditions which produce biaxial stresses on certain members, similar to that experienced by a two-way slab. This condition is covered by ACI code allowable stresses which were used in the design except for no loss of function criteria loadings. For these criteria, reinforcing bar lap lengths and anchorage lengths that were used to develop the bars for their maximum code allowable stress are adequate to develop the higher stresses produced.

The allowable shear stresses for the no loss of function criteria are presented in Tables C.4.1, C.4.2, and C.4.4

Structural steel members designed for failure criteria have been proportioned so as not to exceed 0.9 f_y in bending and tension, 0.5 f_y in shear, and 1.5 F_a as defined in the AISC-63 code, subsection 1.5.1. Thus, the minimum factors of safety become 1.11 for bending and tension, 1.15 for shear, and from 1.11 to 1.28 for axial compression.

C.3.3 Seismic Analysis of Structures

The method used in the seismic analysis consists of the following four steps:

1. Formulation of the mathematical model of the structure or structures to be analyzed.

2. Determination of natural frequencies and mode shapes.

3. Finding the acceleration (g) levels from the response spectra curves.

4. Determination of the response of the structure to the earthquake in terms of moments, shears, and displacements.

The mathematical model of the structure consists of lumped masses and stiffness coefficients. At appropriate locations within the building, points are chosen to lump the weights of the structure. Between these locations, properties are calculated for moments of inertia, cross-sectional areas, and effective shear areas. The properties of the model are utilized in a computer program, applying unit loads at the mass points to obtain the flexibility coefficients of the building.

The natural frequencies and mode shapes of the structures are obtained by a Bechtel computer program, CE617. The program utilizes the flexibility coefficients and lumped weights of the modes. The flexibility coefficients are formulated into a matrix and inverted to form a stiffness matrix. The program then uses the technique of diagonalization by successive rotations to obtain the natural frequencies and mode shapes. Appropriate damping values of individual materials are presented in Table C.2.1.

The basic description of the earthquake is provided by spectrum response curves. Separate curves are used for the design earthquake of 0.05g horizontal acceleration and the MCE of 0.12g horizontal acceleration. These curves are presented in Figures C.3.1 and C.3.2. Additionally, 1997 re-analysis of the Recirculation system piping, and the Residual Heat Removal and Reactor Water Clean-up piping inside primary containment for Peach Bottom NCR 97-02267 used Figure C.3.1a and C.3.2a as required by NRC Regulatory Guide 1.60 (Design Response Spectra for Seismic Design of Nuclear Power Plants). This regulatory guide was used because it is required by Regulatory Guide 1.84 when using ASME Code Case N-411-1 (Alternative Damping Values for Response Spectra Analysis of Class 1, 2, and 3 Piping Section III, Division 1). The response of the structure to the earthquake is obtained by using the spectrum response technique. Appropriate acceleration levels are read from the earthquake spectrum curve corresponding to the natural frequencies of the structure. The mode shapes and lumped weights are utilized to calculate an effective weight associated with each mode.

These effective weights and the spectrum curve acceleration levels are utilized to obtain an effective force for each mode. Then, the mode shapes are used again to distribute the effective modal forces of each mode throughout the structure in order to obtain forces at each point for each mode. These forces, on a modal basis, are used as separate loading conditions to obtain the response of the structure. The individual response values per mode at different points for shear moments and displacements are combined on an absolute basis. All mode shapes of the structural system which have natural frequencies below 30 Hz are used or a minimum of four modes.

The response spectrum specified for the site design earthquake and time-history spectrum of the July 12, 1952 Taft, California S69E Earthquake normalized for the 5 percent design earthquake are compared in Figure C.3.12 for 2 percent of critical damping since only this was used for developing floor spectrum curves. The response spectrum for the 1997 Re-analysis of the Recirculation system piping and Residual Heat Removal and Reactor Water Clean-up piping inside primary containment for Peach Bottom NCR 97-02267 is compared to the site design earthquake in Figure C.3.12A.

To obtain floor spectrum curves for the MCE, the values obtained from the 2 percent damping design earthquake are multiplied by 2.4 (0.12/0.05). Since the higher damping for the MCE is thus not considered, values employed are very conservative.

The time-history technique is used to develop spectrum curves at selected points on the structure for use in equipment analysis.

Since some of the points from the time-history spectrum fall below the site response spectrum, the ratio of the accelerations obtained by the spectrum response technique to the accelerations from the time-history analysis was used as a multiplying factor to increase the time-history spectrum for the Class I structures as appropriate.

Figure C.3.3 shows the mathematical model used for the seismic analysis of the coupled system of the reactor building, reactor vessel pedestal with sacrificial shield, and the reactor vessel. The model of the reactor vessel used in this coupled system was approximate and was used to study its effect on the reactor building. Figure C.3.3A shows the mathematical model used to generate response spectra curves for the 1997 re-analysis of the Recirculation system piping, and the Residual Heat Removal and Reactor Water Clean-up piping inside primary containment for Peach Bottom NCR 97-02267. The seismic analysis of the reactor vessel and its internals is discussed in subsection C.5, "Components."

The seismic moments and shears obtained from the analysis were used for the structural design of the buildings with particular emphasis on the seismic overturning, connections of the members, and arrangement of the reinforcing in the concrete. Figures C.3.4 through C.3.11 show moments, shears, displacements, and accelerations for the reactor building.

These graphs represent the values of moments and shear used in the structural design of buildings. These values were checked from time to time to evaluate the effects of the changes associated with the design development of the project, and to assure that the design values used were always conservative.

To assure the aseismic integrity of equipment, an earthquake time-history is selected whose raw spectrum response curve is greater than or equal to the site design spectrum response curve.

This time-history is applied at the base of the building to generate, at selected elevations, additional time-histories and spectrum response curves. These time-histories and spectrum response curves are then utilized to assure the aseismic integrity of the equipment. Other seismic Class I structures were also dynamically analyzed following the same procedure.