APPENDIX 5A

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APPENDIX 5A

DESIGN BASES FOR STRUCTURES, SYSTEMS AND EQUIPMENT

1 GENERAL

The design bases for structures for normal operating conditions are governed by the applicable building codes. The design bases for specific systems and equipment are stated in the appropriate PSAR Section. The basic design criterion for the design basis accident and seismic conditions is that there be no loss of function if that function is related to public safety.

The design of structures and facilities conforms but is not limited to the applicable codes and specifications listed below.

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 Iron and Steel Institute (AISI) "Specification for the Design of Light Gage Cold-formed Steel Structural Members" - 1961 Edition.

4. American Concrete Institute (ACI) "Building Code Requirements for Reinforced Concrete" - (ACI-318-63 and ACI-318-70). 8

5. American Welding Society (AWS) "Standard Code for Arc and Gas Welding in Building Construction" - (AWS D1.0-66 and AWS D12.1-61)

6. API Specification No. 620 & 650 for Welded Steel Storage Tanks.

7. American National Standards Institute, B 96.1 - 1967 "Specification for Aluminum Alloy Tanks". 3

8. ASME Boiler and Pressure Vessel Code, Section III, Nuclear Vessels, Class B, governs the design and fabrication of the containment vessel and penetrations.

9. AEC Publication TID 7024 "Nuclear Reactor and Earthquakes" - governs the seismic design of all Class I structures.

10. American Society of Civil Engineers (ASCE) Paper No. 3269, "Wind Forces on Structures" - governs wind design requirements.

11. American Association of State Highway Officials (AASHO) "Standard Specifications for Highway Bridges" - Ninth Edition 1965.

12. Nuclear Energy Property Insurance Association - Mutual Atomic Energy Reinsurance Pool (NEPIA - MAERP), Basic Fire Protection for Nuclear Power Plants.

13. American Concrete Institute (ACI) "Specification For the Design and Construction of Reinforced Concrete Chimneys" - (ACI-307-69). 3

2 CLASSES OF STRUCTURES, SYSTEMS AND EQUIPMENT

CLASS I

Class I structures, systems and equipment are those whose failure could cause uncontrolled release of excessive amounts of radioactivity or those essential for immediate and long-term operation following a design basis accident. When a system as a whole is referred to as Class I, portions not associated with loss of function of the system are designated as Class II.

The following is a table of Class I structures, their seismic analysis classification and loadings:

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Structures	*General Type of Seismic Analysis	Loadings		
		Earthquake	Tornado	Missile
CONTAINMENT BUILDING				
Shield Building	Type I and II	X	X	X
Containment Vessel	Type I and II	X		X
Containment Penetrations	Type II	X		X
Containment Interior Structures	Type I and II	X		X
AUXILIARY BUILDING				
Exterior Structure	Type I	X	X	X
Interior Structures	Type I	X		X
Penetration Rooms	Type I and II	X	X	X
Station Control Room	Type I and II	X	X	X
Spent Fuel Storage Pool	Type I	X	X	X
Transfer Tubes	Type I and II	X		
Cable Spreading Room	Type I	X		
Switchgear Rooms	Type I	X	X	X
Diesel Generator Rooms	Type I	X	X	X
Station Battery Room	Type I	X	X	X
Class I Equipment Supports	Type II	X		

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INTAKE STRUCTURE					
Concrete Substructure	Type I and II	X		X	
Service Water Pumps Enclosure	Type I	X		X	
Service Water Pipe Tunnel	Type I	X			5
Class I Equipment Supports	Type II	X			
YARD STRUCTURES					
Borated Water Storage Tank	Type I	X			
Tank Foundation	Type I and II	X**	X		
Diesel Fuel Storage Tank	Type I	X			
Tank Foundation	Type I and II	X**	X		
Condensate Storage Tank Foundation	Type I	X**			

*Earthquake Analysis
Type I - Response Spectrum Analysis
Type II - Time History Response Spectrum Analysis

**Only 50% of Tornado Forces on Tank Shells

The following are Class I equipment and systems:

Reactor vessel and internals including control rods and control rod drives.

Reactor coolant system components (steam-generators, pressurizer, pumps, etc.) and interconnecting piping and supports.

All piping and connections to the primary system to and including the second isolation valve.

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Containment isolation valves and penetrations

Main steam and feedwater piping from generator to and including the isolation valve

Atmospheric dump and main steam safety valves and associated piping

Auxiliary feedwater pumps and system

Fuel storage facilities including spent fuel and new fuel storage equipment

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Diesel generator system

Containment vessel crane (unloaded condition)

Station battery system

Emergency buses and other electrical gear to and including power equipment required for safe shutdown

Service water system, parts which service Class I systems

Component cooling water system serving vital NSS heat exchange equipment

Containment spray system

Containment air recirculation and cooling units

Low pressure injection and residual heat removal system

Core flooding system 2

Makeup system 2

High-pressure injection system

Condensate storage tank (except tornado, turbine missiles and collapse of Class II structures).

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NOTE: The figures showing the interfaces between the Class I and II systems have been submitted in answer to the question 1.3. These figures show the components of the systems and the seismic class to which they are designed.

CLASS II

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

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Class I equipment and systems located in Class II structures have reinforced concrete enclosures designed to withstand the loads for Class I structures.

3 DESIGN BASES

All steel structures are designed by the Working Stress Method. All major reinforced concrete structures are designed by the Ultimate Strength Method.

4 NOTATIONS

U = Required ultimate load capacity.

D = Dead load of structure and equipment plus any other permanent loads contributing stresses, such as soil or hydrostatic loads. An allowance is also made for future permanent loads.

L = Live load and piping loads.

R = Force or pressure on structure due to rupture of any one pipe.

T_o = Thermal loads due to temperature gradient through wall under operating conditions.

H_o = Force on structure due to thermal expansion of pipes under operating conditions.

T_A = Thermal loads due to temperature gradient through wall under accident conditions.

H_A = Force on structure due to thermal expansion of pipes under accident conditions.

E = "Maximum Probable (Smaller) Earthquake" resulting from ground surface acceleration of 0.08g. 2

E' = "Maximum Possible (Larger) Earthquake" resulting from ground surface acceleration of 0.15g.

W = Wind load. (Wind velocity 90 mph at 30 ft above ground.) See ASCE 3269 for increase due to gusts and height.

W' = Tornado load including differential pressure.

Ø = Capacity reduction factor. (Defined in ACI-318-63 Code, Section 1504.) See Appendix 5D for discussion.

f_s = Allowable stress for structural steel. (Defined in AISC, Section 1.5)

F_y = Yield strength for steel.

5 SEISMIC ANALYSIS

For seismic loads, Class I structures and components are designed using the "Response Spectrum Curves" shown in Figures III-5 and III-6 of Appendix 2C. Seismic accelerations are determined on the basis of dynamic analysis.
6 When structures or components are adequately represented by a single degree of freedom model the maximum value of the response curve for the appropriate damping factor may be used in lieu of performing a dynamic analysis.

Complex structures and components which require multi-degree of freedom analysis for adequate representation will be analyzed by modal techniques similar to those described in Section 5.2.2.3.8.

Damping factors to be used in determining response acceleration as shown in Table 5A-1.

The damping values associated with a stress level of "0.5 times yield point" will be used in analysing the structures, components and equipments. The damping values 2% and 4% for the maximum probable and maximum possible
6 earthquake will be used in reinforced concrete structures and 1% and 2% damping values will be used for the pipings and welded steel respectively. The damping values associated with 0.25Fy and 1.0Fy will not be used in the analysis

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TABLE 5A-1

PERCENTAGE OF CRITICAL DAMPING FACTORS

Stress Level	Type and Condition of the Structure							
	Vital Piping	Piping	Welded Steel	Bolted and/or riveted steel	Reinforced Concrete Max. Prob. Earthquake	Reinforced Concrete Max. Poss. Earthquake	Prestressed Concrete Max. Prob. Earthquake	Prestressed Concrete Max. Poss. Earthquake
Below 0.25 times yield point	0.5	0.5	1.0	1.0 (no joint slip)	1.0 (no cracking)		1.0	
About 0.50 times yield point	1.0	1.0	2.0	5.0	2.0 (slight cracking)	4.0 (considerable cracking)	2.0 (slight cracking)	
At or just below yield point	2.0	2.0	5.0	10.0	7.0	10.0	5.0 (Partial prestress left)	7.0 (no prestress left)
Beyond yield point		5.0	7.0	20.0	10.0	15.0	10.0	15.0

Class II structures are designed in accordance with design methods of referenced codes and standards, with prudent engineering practice, and in accordance with applicable codes. The area is in Seismic Zone No. 1 (UBC-1967).

6 DESIGN PROCEDURES

6.1 CLASS I STRUCTURES, SYSTEMS AND EQUIPMENT

6.1.1 DURING NORMAL OPERATION

For loads encountered during normal station operation, Class I structures, systems and equipment are designed in accordance with design methods of referenced codes and standards. Seismic design is in accordance with Section 5.

6.1.1.1 Concrete

Reinforced concrete structures are designed for ductile behavior, whenever possible; that is, with steel stresses controlling.

Design of concrete structures shall satisfy the most severe loading combinations, based on the load factors shown below:

$$U = 1.5\ D + 1.8\ L$$

$$U = 1.25\ (D + L + H_o + E) + 1.0\ T_o$$

$$U = 1.25\ (D + L + H_o + W) + 1.0\ T_o$$

$$U = 0.9\ D + 1.25\ (H_o + E) + 1.0\ T_o$$

$$U = 0.9\ D + 1.25\ (H_o + W) + 1.0\ T_o$$

In addition, for ductile moment resisting concrete space frames, shear walls and braced frames:

$$U = 1.4\ (D + L + E) + 1.0\ T_o + 1.25\ H_o$$

$$U = 0.9\ D + 1.25\ E + 1.0\ T_o + 1.25\ H_o$$

For structural elements carrying mainly earthquake forces, such as equipment supports:

$$U = 1.0\ D + 1.0\ L + 1.8\ E + 1.0\ T_o + 1.25\ H_o$$

6.1.1.2 Yield Capacity Reduction Factors

The yield capacity of all load carrying structural elements will be reduced by a yield capacity reduction factor (Ø) as given below. The justification

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for these numerical values is given in Appendix 5D. This factor will provide for the possibility that small adverse variations in material strengths, workmanship, dimensions, control, and degree of supervision while individually within required tolerance and the limits of good practice, occasionally may combine to result in undercapacity.

Yield Capacity Reduction Factors:

ϕ = 0.90 for concrete in flexure.

ϕ = 0.85 for diagonal tension, bond, and anchorage in concrete.

ϕ = 0.75 for spirally reinforced concrete compression members.

ϕ = 0.70 for tied compression members.

ϕ = 0.90 for fabricated structural steel.

ϕ = 0.90 for reinforcing steel in tension (excluding splices).

ϕ = 0.90 for reinforcing steel in tension with mechanical splices.

6.1.1.3 Structural Steel

Steel structures shall satisfy the following loading combinations without exceeding the specified stresses:

a. D + L....................................Stress Limit = f_s

b. D + L + T_o + H_o + E....................Stress Limit = 1.25 f_s

c. D + L + T_o + H_o + W.....................Stress Limit = 1.33 f_s

In addition, for structural elements, carrying mainly earthquake forces, such as struts and bracings:

D + L + T_o + H_o + E......................Stress Limit = f_s

6.1.2 DURING ACCIDENT AND MAXIMUM POSSIBLE (LARGER) EARTHQUAKE CONDITIONS

The Class I structures, systems and equipment are in general proportioned to maintain elastic behavior when subjected to various combinations of dead loads, thermal loads, seismic and accident loads. The upper limit of elastic behavior is considered to be the yield strength of the effective load-carrying structural materials. The yield strength F_y for steel (including reinforcing steel) is considered to be the guaranteed minimum given in appropriate ASTM specifications. The yield strength for reinforced concrete structures is considered to be the ultimate resisting capacity as calculated from the "Ultimate Strength Design" portion of the ACI-318-63 code.

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6.1.2.1 Concrete

Concrete structures shall satisfy the most severe of the following loading combinations:

$$U = 1.0\ D + 1.0\ L + 1.25\ E + 1.0\ T_A + 1.0\ H_A + 1.0\ R$$

3 $$U = 1.0\ D + 1.25\ E + 1.0\ T_A + 1.0\ H_A + 1.0\ R$$

$$U = 1.0\ D + 1.0\ L + 1.0\ E' + 1.0\ T_o + 1.25\ H_o + 1.0\ R$$

$$U = 1.0\ D + 1.0\ L + 1.0\ E' + 1.0\ T_A + 1.0\ H_A + 1.0\ R$$

$$U = 1.0\ D + 1.0\ L + 1.0\ W' + 1.0\ T_o + 1.25\ H_o$$

6.1.2.2 Structural Steel

Steel structures shall satisfy the most severe of the following loading combinations without exceeding the specified stresses:

a. $D + L + R + T_o + H_o + E'$..................Stress Limit* = $1.5\ f_s$

b. $D + L + R + T_A + H_A + E'$..................Stress Limit* = $1.5\ f_s$

c. $D + L + I + T_o + H_o$......................Stress Limit* = $1.5\ f_s$

*Maximum allowable stress in bending and tension is $0.9\ F_y$. Maximum allowable stress in shear is $0.5\ F_y$.

Stress in some of the materials may exceed yield strength. If this is the case, an analysis shall be made to determine that the energy absorption capacity of the structure exceeds the energy input. The resulting deflection or distortion shall be reviewed. The containment structure and engineered safety features system components are protected by barriers from all credible missiles which might be generated from the primary system. Local yielding or
1 erosion of barriers is permissible due to jet or missile impact, provided there is no general failure.

The final design of the missile barrier and equipment support structures inside the containment will be reviewed to assure that they can withstand applicable pressure loads, jet forces, pipe reactions and earthquake loads without loss of function. The deflections or deformations of structures and supports will be checked to assure that the functions of the containment and engineered safety features equipment are not impaired.

6.2 CLASS II STRUCTURES, SYSTEMS AND EQUIPMENT

6.2.1 CONCRETE

1 Load factors and combinations as specified shall apply. All other design, except load factors and combinations, shall be as specified in the ACI Standard 318-63. Significant thermal loads shall be included. The following load factors and combinations shall be used for ductile moment resisting space frames and shear walls:

$$U = 1.4\ (D + L + E) + 1.0\ T_o + 1.25\ H_o$$

$$U = 0.9\ D + 1.25\ E + 1.0\ T_o + 1.25\ H_o$$

6.2.2 STRUCTURAL STEEL

Steel structures shall satisfy the following loading combinations without exceeding the specified stresses:

a. $D + L$ ....Stress Limit = f_s

b. $D + L + T_o + H_o + E$ ....Stress Limit = $1.33\ f_s$

c. $D + L + T_o + H_o + W$ ....Stress Limit = $1.33\ f_s$

6.3 CLASS I SYSTEMS AND EQUIPMENT DESIGN

All Class I systems and equipment are designed to the standards of the applicable Code. The loading combinations which are employed in the design of Class I systems and equipment are given in Table 5A-2.

Table 5A-2 also indicates the stress limits which are used in the design of the listed equipment for the various loading combinations.

To perform their function, i.e., allow core shutdown and cooling, the reactor vessel internals must satisfy deformation limits which are more restrictive than the stress limits shown on Table 5A-2. For this reason the reactor vessel internals are treated separately.

6.3.1 PIPING AND VESSELS

The reasoning for selection of the load combinations and stress limits given in Table 5A-2, is as follows: For the maximum probable (smaller) earthquake, the nuclear steam supply system is designed to be capable of continued safe operation, i.e., for the combination of normal loads and maximum probable (smaller) earthquake loading. Critical equipment needed for this purpose is required to operate within normal design limits.

In the case of the maximum possible (larger) earthquake, it is only necessary to ensure that critical components do not lose their capability to perform their safety function, i.e., shutdown the station and maintain it in a safe condition. This capability is ensured by maintaining the stress limits as shown in Table 5A-2.

For the extremely remote event of simultaneous occurrence of maximum possible (larger) earthquake and reactor coolant system pipe rupture, the design of Class I pipe and components, excluding the broken pipe, is checked for no loss of function, i.e., the capability to contain fluid and allow fluid flow. This is assured by limiting the various stress combinations within the limits shown in line 3 in Table 5A-2.

6.3.2 MOVEMENT OF REACTOR COOLANT SYSTEM COMPONENTS

The criterion for movement of the reactor vessel, under the worst combination of load, i.e., normal plus the maximum possible (larger) earthquake plus reactor coolant pipe rupture loads, is that the radial movement of the reactor vessel will not exceed the clearance between a reactor coolant pipe and the surrounding concrete to prevent excessive shear load on the reactor coolant system pipe, should this limit be more restrictive than those listed in Table 5A-2.

The realtive motions between reactor coolant system components will be controlled by the structures which are used to support the reactor vessel, the steam-generators, the pressurizer and the reactor coolant pumps in such a way that the stresses in the various components and pipes do not exceed the limits as established in Table 5A-2.

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TABLE 5A-2

LOADING COMBINATIONS AND STRESS LIMITS

LOADING CASE	LOADING COMBINATIONS	STRESS LIMITS			
		Vessels (Ref. Section 4.0)	Reactor Vessel Internals	Piping	Supports
CASE I	Design Loads & Maximum Probable (Smaller) Earthquake	$P_m \leq 1.0\ S_m$ $P_l + P_b \leq 1.5\ S_m$	$P_m \leq 1.0\ S_m$ $P_l + P_b \leq 1.5\ S_m$	$P_m \leq 1.2\ S_h$ $P_l + P_b \leq 1.2\ S_h$	Working Stress
CASE II	Design Loads + Maximum Possible (Larger) Earthquake	$P_m \leq 1.2\ S_m$ $P_l + P_b \leq 1.2\ (1.5\ S_m)$	$P_m \leq 2/3\ S_u$ $P_l + P_b \leq 2/3\ S_u$	$P_m \leq 1.2\ S_h$ $P_l + P_b \leq 1.2\ (1.5\ S_h)$	Within Yield
CASE III	Design Loads + Maximum Possible (Larger) Earthquake & Pipe Rupture Loads	$P_m \leq 2/3\ S_u$ $P_l + P_b \leq 2/3\ S_u$	$P_m \leq 2/3\ S_u$ $P_l + P_b \leq 2/3\ S_u$	$P_m \leq 1.2\ S_h$ $P_l + P_b \leq 1.2\ (1.5\ S_h)$	Deflection of supports limited to maintain supported equipment within their stress limits

Where

P_m = primary general membrane stress; or stress intensity

P_l = primary local membrane stress; or stress intensity

P_b = primary bending stress; or stress intensity

S_m = stress intensity value from ASME B & PV Code, Section III

S_h = allowable stress from USASI B31.7 Code for Pressure Piping

S_u = ultimate tensile strength of material at temperature