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3.8.3.3.7 Reaction Due to Pipe Ruptures (Y_r)

The load on a structure generated by the reaction of a ruptured high-energy pipe during the postulated event includes an appropriate dynamic load factor. The time dependent nature of the load and the ability of the structure to deform beyond yield are considered in establishing the structural capacity necessary to resist the effects of Y_r.

3.8.3.3.8 Jet Impingement (Y_j)

The load on a structure generated by the jet impingement from a ruptured high-energy pipe during a postulated event includes an appropriate dynamic load factor. The time-dependent nature of the load and the ability of the structure to deform beyond yield are considered in establishing the structural capacity necessary to resist the effects of Y_j. The dynamic load factor is calculated using a long duration step function for the load. The target resistance is idealized as bilinear elasto-perfectly plastic.

3.8.3.3.9 Impact of Ruptured Pipe (Y_m)

The load on a structure or a pipe restraint resulting from the impact of a ruptured high-energy pipe during the postulated event includes an appropriate dynamic load factor. The type of impact (i.e., plastic, elastic), together with the ability of the structure to deform beyond yield are considered in establishing the structural capacity necessary to resist the impact.

3.8.3.4 Design and Analysis Procedures

Inserts 3.8.3.4(a) and 3.8.3.4(b)

Concrete and steel composites are commonly used in construction because of the inherent benefits of the steel tensile strength in concrete sections. The fundamental difference between the conventional reinforced concrete and SC modular construction is that the reinforcement and formwork of conventional reinforced concrete is replaced by the steel faceplates of the SC. For walls within the US-APWR, additional benefits are realized by providing formwork during construction, improved construction staging and schedule, continuous steel surfaces for welding of field attachments, and impactive/impulsive capacities as applicable. If required to be qualified as radiation shielding, the requirements and recommended practices are maintained in accordance with RG 1.69 (Reference 3.8-20). ~~Assurances that SC modules for interior compartments of the US-APWR meet or exceed the requirements of ACI-349 (Reference 3.8-8) are provided by the following design and analysis procedures.~~ DCD_03.07.02-35

The permanently-placed faceplates act as forms during the placement of concrete. Plate stresses occurring during concrete placement are conservatively assumed simply supported spans between tie bars. Faceplates fabricated from A572 high-strength low-alloy Columbium-Vanadium structural steel provide minimum yield strength of 50 ksi or greater, and maintain out-of-plane plate deflection to within code allowables.

Stresses are induced on faceplates acting as formwork during concrete placement, however, they are not applicable during other load combinations. After concrete curing, the SC module performs as a composite section of concrete with outer faceplates acting as either compression or tension reinforcement. The composite section is designed to

Assurances that SC modules for interior compartments of the US-APWR meet or exceed the strength requirements of ACI-349 (Reference 3.8-8) are provided by the following design and analysis procedures.

allow faceplate yielding prior to the concrete reaching its strain limit of 0.003 in. per in. Under tensile straining, the residual stress that was initiated by concrete placement is naturally relieved. While the formwork is permanently placed, the stresses generated by construction activities are therefore not applicable during other load combinations.

The SC module forms a composite section once the concrete has reached sufficient strength, consisting of steel faceplates that carry in-plane tension or compression from axial loads and out-of-plane bending. Structural behavior of composite sections used as SC modules inside containment is, therefore, similar to conventional concrete reinforced by steel. Research regarding in-plane loading of composite sections consisting of steel faceplates and concrete infill is described in “Experimental Study on Steel Plate Reinforced Concrete Shear Walls with Joint Bars” (Reference 3.8-21) and “A Compression and Shear Loading Test of Concrete Filled Steel Bearing Wall” (Reference 3.8-22). Out-of-plane loading research is provided by “Experimental Studies on Composite Members for Artic Offshore Structures, Steel/Concrete Composite Structural Systems” (Reference 3.8-23), “Strength of Composite System Ice-Resisting Structures, Steel/Concrete Composite Structural Systems” (Reference 3.8-24), “Design and Behaviour of Composite Ice-Resisting Walls, Steel/Concrete Composite Structural Systems” (Reference 3.8-25), and “Tests on Composite Ice-Resisting Walls Steel/ Concrete Composite Structural Systems” (Reference 3.8-26). In addition, “1/10th Scale Model Test of Inner Concrete Structure Composed of Concrete Filled Steel Bearing Wall” (Reference 3.8-27) provides research regarding in-plane loading of composite sections, and supports the conclusion there are significant advantages of SC modules over conventional reinforced concrete, such as high strength, high ductility, and less decrease of stiffness, over reinforced concrete elements of equivalent thickness and reinforcement ratios. Further, "A Study on the Structural Performance of SC Thick Walls" (Reference 3.8-70) reflects the experimental results of a 1/6th scale test which demonstrates the seismic behavior of the primary shield wall.

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~~Metho[...] concrete. Table 3.8.3-3 summarizes the modeling and analytical methods used for SC modules inside containment. The determination of section properties are in accordance with ACI-349 (Reference 3.8-8). For all loads, the analyses use the monolithic (uncracked) stiffness of each concrete element. For thermal loads, design forces are calculated by multiplying the reduction ratio α, considering the reduction of stiffness by cracking to the result values of above analysis. The reduction ratio α is set to 0.5 as the reduction ratio of flexural stiffness caused by cracking for the typical member. For example, the flexural stiffness of cracked section for 48 in. wall with 0.5 in. plates assuming zero tensile strength of concrete is 22.2 by 10^9 lbs-in.^{2}/in., and the reduction ratio calculated by this value and elastic flexural stiffness (47.5 x 10^9 lbs-in.^{2}/in.) is 0.47.~~

~~Table 3.8.3-4 summarizes axial, in-plane shear and out-of-plane flexural stiffness properties of the 56-in., 48-in. and 39-in. walls based on a series of different assumptions. The stiffnesses are expressed for unit length and height of each wall.~~

~~Case 1 assumes monolithic behavior of the steel plate and uncracked concrete. This stiffness is the basis for the stiffness of the SC modules in the seismic analyses and the stress analysis.~~

~~Case 2 assumes that the concrete in tension has no stiffness. For the flexural stiffness this is the conventional stiffness value used in working stress design of reinforced~~

concrete sections. The containment internal structure is unique among the RB complex structures in that it is comprised of a number of different structural types. The structural types include composite SC walls of varying thickness, massive reinforced concrete sections, and reinforced concrete slabs. These structures experience varying levels of stress and resultant concrete cracking under the seismic and accident thermal loading applied to the containment internal structure. Each structural type exhibits unique stiffness and damping characteristics before and after cracking. Thus, it is not appropriate to apply a uniform stiffness reduction to the entire containment internal structure for the SSI analyses of the RB complex. Each structural component is assigned stiffness and damping values appropriate for its construction type and estimated cracking levels. This assignment is simplified by grouping structural components into six structural categories with common behavior. Stiffness and damping values are then defined for each category under two basic loading conditions that encompass the full range of stresses and resultant cracking anticipated for the containment internal structure seismic response. DCD_03.07.02-35

The six structural categories defined for stiffness and damping characterization are described below and summarized in Table 3.8.3-4. The values are derived from supporting experimental data for the SC modules and from industry standards for reinforced concrete structures. Plan and elevation views illustrating the use of each of the six structural categories are presented in Figures 3.8.3-12 through 3.8.3-18.

Overall thickness of the single-celled SC walls vary from 36” to 67”, while the multi-celled primary shielding walls have overall thickness in excess of 9’-11”. The range of experimental data establishing the composite stiffness characteristics of SC walls is applicable to sections with overall thickness less than or equal to 56” and steel plate reinforcement ratio (ρ) greater than 1.5%.

$$\rho = 2 \cdot t_p / T > 0.015$$

Where

t_p = plate thickness,

T = overall wall thickness

The SC walls are separated into three categories, as follows:

Category 1: All walls with T ≤ 56” in the containment internal structures meet the criteria above and are thus classified as ‘SC’.

Category 2: Non-primary shielding walls with T > 56” (e.g. the 67”-thick single-celled walls) are to be treated as concrete walls with no additional stiffness imparted by the steel plates.

Category 3: The primary shielding walls below elevation 35’-11” are not only too thick to be considered as composite SC walls but also have a unique multi-celled arrangement consisting of inner and outer face plates, a mid-thickness longitudinal plate and numerous transverse plates. These walls are to be treated as concrete structures, but with different stiffness conditions for thermal loading than those applied to the Category 2 walls.

Move to Section 3.8.3.4 as "Insert 3.8.3.4(a)"

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Non-SC structural components are separated into three categories, as follows:

Category 4: Reinforced concrete slabs.

Category 5: Massive reinforced concrete that supports the steam generators and reactor coolant pumps, extending from the top of the mat at elevation 3'-7" to elevation 25'-3" and bounded by the primary and secondary shielding walls.

Category 6: Walls or slabs formed by steel plates and/or shapes with non-structural concrete fill provided for shielding purposes.

Move to Section 3.8.3.4 as "Insert 3.8.3.4(b)"

~~Discussion of~~ The ~~conditions:~~

~~As stated above, the~~ containment internal structure seismic analysis must consider the stiffness and damping levels appropriate for two basic loading conditions:

Condition A: Seismic + Operating Thermal. The normal operating thermal loading involves ambient temperatures of 105°F to 120°F, which are not anticipated to cause cracking that would significantly reduce the stiffness of the SC modules or any of the reinforced concrete structures. The operating temperature of the reactor cavity is 150°F, such that a linear temperature distribution is postulated through the nominally 10-ft thickness of the primary shielding walls, varying from 150°F at the interior face to 105-120°F at the exterior face. This shallow linear gradient is not anticipated to cause significant cracking of the primary shielding walls. Thus, the stiffness for Condition A is estimated by evaluating stresses resulting from the seismic loading condition only.

Condition B: Seismic + Accident Thermal. The accident thermal condition postulated involve initial temperatures of 580°F on the pipe-rupture side of a given wall, with a nearly immediate increase of temperature on the opposite face to 300°F. Within approximately 1000 seconds (17 minutes) the two face temperatures equilibrate to 300°F, which sets up a parabolic (U-shaped) temperature distribution through the thickness of the SC walls.

This distribution will cause through-thickness cracks in the SC walls. These cracks will reduce the in-plane shear stiffness, cause overall thermal deformations and out-of-plane flexural cracking at restraints.

Move to Section 3.8.3.4.1.1 as "Insert 3.8.3.4.1.1"

~~Estimated stiffness for each category and loading condition:~~

Category 1, Condition A: An assessment of the maximum seismic in-plane shear demands in each SC wall of the containment internal structures indicated that these demands were generally lower than the cracking threshold for in-plane shear. Thus, the best estimate in-plane shear stiffness for Condition A is that of the uncracked composite section.

Note that the cracking threshold for SC walls was assumed at a concrete stress of $2\sqrt{f'_c}$. Typically the cracking threshold for concrete is related to concrete stress of $4\sqrt{f'_c}$, but the limit for SC walls is reduced to account for shrinkage and other effects, as described in Reference 3.8-67. This reduction is also corroborated by experimental data (Reference 3.8-61). In addition, the uncracked stiffness estimated for this condition takes into account the recommendation to increase calculated secant stiffness values by a factor of 1.25 to

Move to Section 3.8.3.4.1.2 as "Insert 3.8.3.4.1.2(a)"

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obtain effective in-plane shear stiffness values appropriate for use in an equivalent linear model (Reference 3.8-62).

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. This is

Experimental data indicates there is little to no uncracked out-of-plane flexural stiffness manifest in SC walls due to effects of shrinkage cracking and partial composite action resulting from the discrete nature of the shear connectors (studs) between the face plates and the concrete core (Reference 3.8-59). Instead, the stiffness ($E_c I_{ct}$) associated with the cracked-transformed section is exhibited very early during the application of out-of-plane moments to SC walls.

where

E_c = modulus of elasticity of concrete

I_{ct} = cracked-transformed moment of inertial of concrete

Category 1, Condition B: The through-thickness temperature gradient resulting from the accident thermal loading can cause significant cracking that reduces the in-plane shear stiffness of the SC walls. An empirical relationship providing a best-estimate of secant in-plane shear stiffness of cracked SC walls is as follows (Reference 3.8-59):

$$K_{cr} = 0.5(\bar{\rho}^{-0.42})G_s A_s$$

where

$$\bar{\rho} = \frac{A_s F_y}{\sqrt{f'_c} A_c}$$

G_s = shear modulus of steel

A_s = 2·(face plate thickness)

F_y = yield strength of steel plates

f'_c = specified compressive strength of concrete

A_c = unit area of conrete core

Category 2, Condition A: Stress evaluation indicates these thick walls remain uncracked for Condition A. Thus, uncracked stiffness values of the concrete section shall be used; i.e. $G_c A_c$ for in-plane shear and $E_c I_c$ for out-of-plane flexure.

where

G_c = shear modulus of concrete

A_c = gross area of concrete

Move to Section 3.8.3.4.1.2 as "Insert 3.8.3.4.1.2(b)"

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E_c = modulus of elasticity of concrete

I_c = moment of inertial of concrete

Category 2, Condition B: Stiffness of these walls shall account for cracking due to accidental thermal loading. Stiffness values of $0.5G_cA_c$ and $0.5E_cI_c$ are assigned per the recommendations for cracked concrete walls (Reference 3.8-60).

Category 3, Condition A: The linear temperature gradient through the primary shield walls for normal operating conditions is not anticipated to cause significant cracking, and seismic demands on these walls are limited. Thus the primary shield wall stiffness shall be modeled as that of uncracked concrete (G_cA_c and E_cI_c). No credit is taken for the stiffness of the steel plates.

Category 3, Condition B: The accident thermal loading conditions is anticipated to cause only localized cracking in the thick primary shielding walls, which are largely enclosed by the mass concrete (Category 5) at the base of the containment internal structures. Thus, the stiffness for this condition is the same as that assigned for Condition A (uncracked).

Category 4, Condition A: In-plane shear stiffness of the reinforced concrete slabs shall be that of the gross concrete section (G_cA_c, in accordance with Reference 3.8-60). Out-of-plane flexural stiffness is equal to that of the gross concrete section (E_cI_c), as seismic-induced moments in the slabs are shown to be less than cracking moments (M_{cr}):

$$M_{cr} = f_r \cdot S$$

where

S = gross section modulus

f_r = modulus of rupture, taken equal to $7.5\sqrt{f'_c}$

Category 4, Condition B: In-plane shear stiffness of the reinforced concrete slabs for this condition shall also be that of the gross concrete section (G_cA_c). Out-of-plane flexural stiffness is taken as $0.5E_cI_c$ (Reference 3.8-60).

Category 5 (both conditions): No significant cracking is anticipated in the massive reinforced concrete at the base of the structure as a result of either seismic or accident thermal loading. Thus, the stiffness is taken to be equal to that of uncracked concrete for both loading conditions.

Category 6 (both conditions): The stiffness of in-fill concrete provided for shielding purposes is not modeled for either loading condition; only the mass of these sections is included. For the pressurizer support platform, which is comprised of a grillage of steel shapes with in-fill concrete, only the stiffness of the steel members is modeled.

~~Damping for Containment Internal Structures:~~

Move to Section 3.8.3.4.1.2 as "Insert 3.8.3.4.1.2(c)"

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Damping values are assigned to each structural category based on the estimated level of cracking. A damping value of 4% is assigned to composite SC walls with uncracked conditions (Condition A), and 5% when significant cracking is anticipated (Condition B). This is based on the results of the 1/10th scale test discussed in Technical Report MUAP-11005-P (Reference 3.8-63). For walls and slabs modeled as reinforced concrete structures, 4% damping is specified in Regulatory Guide 1.61 (Reference 3.8-64) for the limited levels of cracking associated with the OBE, while 7% damping is specified for cracked response exhibited during SSE loading. Finally, the massive concrete in the containment internal structures (Category 5) is not expected to exhibit significant cracking, such that 4% damping is considered appropriate in all cases. Given the similarity in the damping ratios specified for the uncracked response of SC and reinforced concrete components, and recognizing that the amplified seismic response of the containment internal structure is dominated by the response of the SC walls, constant damping ratios of 4% for Condition A and 5% for Condition B are used for the seismic response analyses (See Table 3.8.3-4). DCD_03.07.02-35

Move to Section 3.8.3.4.1.3 as "Insert 3.8.3.4.1.3"

The report "1/10th Scale Model Test of Inner Concrete Structure Composed of Concrete Filled Steel Bearing Wall" (Reference 3.8-27) provides damping of the SC modules based on the cyclic load tests of an containment internal structure model. The SC module exhibited 5 % equivalent viscous damping at the design load level. This remained nearly constant up to the load level where yielding was reached in the steel plate. Therefore, dynamic analyses as described in Subsection 3.7.1 are performed using 7 % damping for the reinforced concrete and 5 % for the SC modules. DCD_03.07.02-35

3.8.3.4.1 SC Module Stress Analyses

The design forces and moments for each member of the containment internal structure are calculated by the stress analysis using a three-dimensional FE model. The model is shown in Figure 3.8.3-10. The SC modules are simulated within the FE model using three-dimensional shell plate bending elements. Equivalent elastic stiffnesses of the SC modules are computed as shown below. The application of more detailed FE analysis is acceptable for qualifying modules subject to extreme conditions such as high accident temperatures. The shell element properties are computed using the combined concrete section and the steel faceplates of the SC modules. This representation models the composite behavior of the steel and concrete. The axial, shear and bending stiffness values are subject to the application guidance described in MUAP-10001 and MUAP-11013 (References 3.8-69 and 3.8-68). Refer to Table 3.8.3-4 for a summary of stiffness used in analysis. DCD_03.07.02-35

Appendix A

3.8.3.4.1.1 Basic Loading Conditions to Determine Stiffness and Damping Levels

- Axial and Shear Stiffnesses of SC Modules:

Insert 3.8.3.4.1.1

$$\Sigma EA = E_c A_c + E_s A_s, \quad \Sigma GA = G_c A_c + G_s A_s$$

3.8.3.4.1.2 Estimated Stiffness for Each Category and Loading Condition

$$A_c = L(t - 2t_s),\ A_s = 2Lt_s,\ G_c = E_c/2(1+\nu_c),\ G_s = E_s/2(1+\nu_s)$$

- Bending Stiffness of SC Modules:

Inserts 3.8.3.4.1.2(a), 3.8.3.4.1.2(b), & 3.8.3.4.1.2(c)

~~$\Sigma EI = E_c I_c + E_s I_s$~~

3.8.3.4.1.3 Damping for SC modules and RC structures of the Containment Internal Structure

~~$I_c = L(t - 2t_s)^3/12,\ I_s = Lt^3/12 - I_c$~~

Insert 3.8.3.4.1.3

~~where:~~

~~E_c or E_s = modulus of elasticity for concrete or steel~~

~~ν_c or ν_s = Poisson's ratio for concrete or steel~~

~~L = length of SC module~~

~~t = thickness of SC module~~

~~t_s = thickness of plate on each face of SC module~~

3.8.3.4.2 Hydrodynamic Analyses

The vertical and lateral pressures of liquids inside containment are treated as dead loads. Structures supporting fluid loads during normal operation and accident conditions are designed for the hydrostatic as well as hydrodynamic loads as discussed in Subsection 3.7.3.9. The hydrodynamic analyses take into account the flexibility of walls in considering fluid-structure interaction. Sloshing height, however, is calculated using a conservative simplified assumption of a rigid tank shell in accordance with guidance provided in ASCE 4-98 (Reference 3.8-34), Subsection 3.5.4.3.

3.8.3.4.3 Thermal Analyses

The RWSP water and containment operating atmosphere's temperature is considered stable. The operating thermal load for each concrete member is calculated as the average and gradient based on this condition. The stress analysis is carried out by inputting these loads into the corresponding part of R/B whole FE model. The normal thermal stresses for design are calculated in accordance with Appendix A of ACI 349 (Reference 3.8-8). The analysis reduction factor and modeling methods are shown in Table 3.8.3-3 and Table 3.8.3-4. For thermal effects on dynamic response, see Subsection 3.8.3.4. DCD_03.07.02-35

The RWSP water and containment atmosphere are subject to temperature transients in the event of a LOCA as described in Subsection 3.8.3.3. The accident temperature transients result in a nonlinear temperature distribution within the members. Temperatures within the concrete members are calculated in a unidimensional heat flow analysis. The accident thermal load (average and equivalent linear gradients) is calculated from this analysis, at selected times during the transient.

The stress analysis is carried out by inputting the accident thermal load into the corresponding part of R/B whole FE model, as well as other parts. The stresses of containment are used for containment design. Though the stresses of containment internal structure are also obtained at the same time, since these self-limiting stresses are

released in ultimate condition under such as extreme and abnormal load conditions, they are not taken into account in calculation of required reinforcement steel.

Thermal transients for the DBAs are described in Section 6.3.

3.8.3.4.4 Design Procedures

Replace with Insert 3.8.3.4.4

~~The concrete members of the containment internal structure are designed by the strength method, as specified in the ACI "Code Requirements for Nuclear Safety-Related Structures", ACI 349 (Reference 3.8-8).~~ DCD_03.07.02-35

The primary and secondary shield walls, RWSP, refueling cavity, and other structural walls are designed using SC modules. ~~SC modules are designed as reinforced concrete structures in accordance with the requirements of ACI 349 (Reference 3.8-8), as supplemented in the following paragraphs.~~ SC modules are described in Technical Report MUAP-11013 (References 3.8-68) and Technical Report MUAP-10001 (References 3.8-69). DCD_03.07.02-35

Floor slabs of reinforced concrete are designed as reinforced concrete structures in accordance with ACI-349 (Reference 3.8-8). The floors of elevation 76 ft, 5 in. (Operating floor) and elevation 50 ft, 2 in. are supported by structural steel framing.

Methods of analysis used are based on accepted principles of structural mechanics and are consistent with the geometry and boundary conditions of the structures.

The safe shutdown earthquake loads are determined from the results of seismic response analysis described in Section 3.7.

The determination of pressure and temperature loads due to pipe breaks is described in Subsections 3.6.1 and 6.2.1.2. Subcompartments inside containment containing high energy piping are designed for pressurization loads of 2 to 39 psi.

Determination of RCL support loads is described in Subsection 3.9.3. Design of the RCL supports are in accordance with ASME Code, Section III, Division 1, Subsection NF (Reference 3.8-2) as described in Subsections 3.9.3.

Computer codes used are general purpose codes. The code development, verification, validation, configuration control, and error reporting and resolution are according to the Quality Assurance requirements of Chapter 17.

3.8.3.4.5 SC Modules Design and Analysis

The SC modules are designed for dead, live, thermal, pressure, and safe shutdown earthquake loads. The RWSP walls are also designed for the hydrostatic head due to the water in the pit and the hydrodynamic pressure effects of the water due to the safe shutdown earthquake loads. The walls of the refueling cavity are also designed for the hydrostatic head due to the water in the refueling cavity.

Replace with Insert 3.8.3.4.5

Figure 3.8.3-7 shows the typical design details of the SC modules, typical configuration of the SC modules, typical anchorages of the SC modules to the reinforced base concrete, and connections between adjacent walls. ~~SC modules are designed as reinforced~~ DCD_03.07.02-35

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concrete structures in accordance with the requirements of ACI 349 (Reference 3.8-8), as supplemented in the following paragraphs. The faceplates are considered as the reinforcing steel, bonded to the concrete by headed studs. The design of critical sections is described in Subsection 3.8.3.5. DCD_03.07.02-35

3.8.3.4.5.1 Design for Axial Loads and Bending

Replace with Insert 3.8.3.4.5.1

Design for axial load (tension and compression), in-plane bending, and out-of-plane bending is in accordance with the requirements of ACI 349, Chapters 10 and 14 (Reference 3.8-8)described in Technical Report MUAP-10001 (Reference 3.8-69) and Technical Report MUAP-11013 (Reference 3.8-68). DCD_03.07.02-35

ThisThe design approach recognizes behavior of the SC module is similar to that of reinforced concrete. The steel plate is similar to standard tensile reinforcement in each of 2 designing orthogonal directions, as concluded by the test results of References 3.8-21 through 3.8-27.

3.8.3.4.5.2 Design for In-Plane Shear

Replace with Insert 3.8.3.4.5.2

Design for in-plane shear is in accordance with the requirements of ACI 349, Chapters 11 and 14 (Reference 3.8-8)described in Technical Report MUAP-10001 (Reference 3.8-69) and Technical Report MUAP-11013 (Reference 3.8-68). The steel faceplates are treated as reinforcement for the concrete, and satisfy the requirements of Section 11.10 of ACI 349 (Reference 3.8-8). DCD_03.07.02-35

ThisThe design approach is based on behavior of the SC module that is similar to reinforced concrete, which is supported by the test results of References listed in Subsection 3.8.3.4. The steel plate acts as shear reinforcement in each of 2 designing orthogonal directions, similar to that of standard concrete reinforcement.

3.8.3.4.5.3 Design for Out-of-Plane Shear

Replace with Insert 3.8.3.4.5.3

Design for out-of-plane shear is in accordance with the requirements of ACI 349, Chapter 11 (Reference 3.8-8)described in Technical Report MUAP-10001 (Reference 3.8-69) and Technical Report MUAP-11013 (Reference 3.8-68). DCD_03.07.02-35

The design approach is based on the premise that the behavior against out-of-plane shear and the effect of shear reinforcement of the SC module are similar to those of reinforced concrete. This methodology is supported by the test results of References listed in Subsection 3.8.3.4.

3.8.3.4.5.4 Evaluation for Thermal Loads

The acceptance criterion for the load combination with normal thermal loads, which includes the thermal transients described in Subsection 3.8.3.4, is that the overall stress in general areas of the steel plate be less than yield. In local areas where the stress may exceed yield, the total stress intensity range is less than twice yield. This evaluation of thermal loads is based on the ASME Code philosophy for Level A service loads given in

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ASME Code, Section III (Reference 3.8-2), Subsection NE, Paragraphs NE-3213.13 and NE-3221.4.

3.8.3.4.5.5 Design of Tie Bar

The tie bars provide a structural framework for the SC modules with faceplates, maintain the separation between the faceplates, support the SC modules during transportation and erection, and act as "form ties" between the faceplates when concrete is being placed. After the concrete has cured, the tie bars are not required to contribute to the strength or stiffness of the completed SC modules. However, they do provide additional shear capacity between the steel plates and concrete as well as additional strength similar to that provided by stirrups in reinforced concrete. The tie bars are designed as “form ties” ~~according to the requirements of AISC-N690 (Reference 3.8-9)~~ and designed as out-of-plane shear reinforcement ~~according to the requirements of ACI 349 (Reference 3.8-8)~~as described in Technical Report MUAP-10001 (Reference 3.8-69) and Technical Report MUAP-11013 (Reference 3.8-68). DCD_03.07.02-35

Replace with Insert 3.8.3.4.5.3

3.8.3.4.5.6 Design of Shear Studs

The SC modules are designed as reinforced concrete elements, with the faceplates serving as reinforcing steel. Since the faceplates do not have deformation patterns typical of reinforcing steel, shear studs are provided to transfer the forces between the concrete and the steel faceplates. The shear studs make the concrete and steel faceplates interact compositely. In addition, the shear studs permit anchorage for piping and other items attached to the walls.

3.8.3.4.6 Floor Slab

The floor slab of reinforced concrete is analyzed and designed according to ACI 349 (Reference 3.8-8) considering the same loads as for the SC modules. The floor design does not rely on composite action with supporting structural steel beams.

3.8.3.4.7 Structural Steel Design and Analysis

Structural steel framing within the interior of the PCCV is primarily for support of floor slabs, equipment, distribution systems, and access platforms. Design and analysis procedures, including assumptions on boundary conditions and expected behavior under loads, are in accordance with the allowable stress design (ASD) method in AISC-N690 (Reference 3.8-9). Analysis methods are generally simple calculations using seismic accelerations obtained from Section 3.7 methodologies in load combinations. Frame connections are detailed for simply-supported beams unless otherwise analyzed and detailed.

3.8.3.4.8 RCL Supports

The RCL piping and support system is analyzed for the dynamic effects of a SSE. A coupled model of the containment internals and the RCS is dynamically evaluated using a time-history integration method of analysis. Appendix 3C provides additional information regarding the qualification of RCL supports.

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Insert 3.8.3.4.4 (Markup Page 3.8-47)

The reinforced concrete members of the containment internal structure are designed by the strength method, as specified in the ACI "Code Requirements for Nuclear Safety Related Structures," ACI 349 (Reference 3.8-8).

The primary and secondary shield walls, RWSP, refueling cavity, and other structural walls are designed using SC modules. SC modules are designed using the methodology of reinforced concrete structures in accordance with ACI 349 (Reference 3.8-8), as supplemented in Technical Report MUAP-11013 (Reference 3.8-68).

Insert 3.8.3.4.5 (Markup Page 3.8-47)

Figure 3.8.3-7 shows the typical design details of the SC modules, typical configuration of the SC modules, typical anchorages of the SC modules to the reinforced concrete basemat, and connections between adjacent walls. SC modules are designed using the methodology of reinforced concrete structures in accordance with ACI 349 (Reference 3.8-8), as supplemented in Technical Report MUAP-11013 (Reference 3.8-68). The faceplates are considered as the reinforcing steel, bonded to the concrete by headed studs. The design of critical sections is described in Subsection 3.8.3.5.

Insert 3.8.3.4.5.1 (Markup Page 3.8-48)

Design for axial load (tension and compression), in-plane bending, and out-of-plane bending is in accordance with the methodology of ACI 349 (Reference 3.8-8) Chapters 10 and 14, as supplemented by Technical Report MUAP-11013 (Reference 3.6-68).

Insert 3.8.3.4.5.2 (Markup Page 3.8-48)

Design for in-plane shear is in accordance with the methodology of ACI 349 (Reference 3.8-8) Chapters 11 and 14, as supplemented by Technical Report MUAP-11013 (Reference 3.8-68). The steel faceplates are treated as reinforcement for the concrete which satisfy the provisions of Section 11.10 of ACI 349 (Reference 3.8-8).

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Insert 3.8.3.4.5.3 (Markup Page 3.8-48)

Design for out-of-plane shear is in accordance with the methodology of ACI 349 (Reference 3.8-8) Chapter 11, as supplemented by Technical Report MUAP-11013 (Reference 3.8-68).

Insert 3.8.3.4.5.5 (Markup Page 3.8-49)

according to the requirements of AISC N690 (Reference 3.8-9) and designed as out-of-plane shear reinforcement according to the requirements of ACI-349 (Reference 3.8-8), as supplemented by MUAP-11013 (Reference 3.8-68).

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The tie bars are designed as "form ties" according to the requirements of AISC N690 (Reference 3.8-9) and designed as out-of-plane shear reinforcement according to the requirements of ACI 349 (Reference 3.8-8).

ASME Code, S... NE-3221.4.

3.8.3.4.5.5 Design of Tie Bar

The tie bars provide a structural framework for the SC modules with faceplates, maintain the separation between the faceplates, support the SC modules during transportation and erection, and act as "form ties" between the faceplates when concrete is being placed. After the concrete has cured, the tie bars are not required to contribute to the strength or stiffness of the completed SC modules. However, they do provide additional shear capacity between the steel plates and concrete as well as additional strength similar to that provided by stirrups in reinforced concrete. ~~The tie bars are designed as "form ties" according to the requirements of AISC-N690 (Reference 3.8-9) and designed as out-of-plane shear reinforcement according to the requirements of ACI 349 (Reference 3.8-8)as described in Technical Report MUAP-10001 (Reference 3.8-69) and Technical Report MUAP-11013 (Reference 3.8-68).~~ DCD_03.07.02-35

3.8.3.4.5.6 Design of Shear Studs

The SC modules are designed as reinforced concrete elements, with the faceplates serving as reinforcing steel. Since the faceplates do not have deformation patterns typical of reinforcing steel, shear studs are provided to transfer the forces between the concrete and the steel faceplates. The shear studs make the concrete and steel faceplates interact compositely. In addition, the shear studs permit anchorage for piping and other items attached to the walls.

3.8.3.4.6 Floor Slab

The floor slab of reinforced concrete is analyzed and designed according to ACI 349 (Reference 3.8-8) considering the same loads as for the SC modules. The floor design does not rely on composite action with supporting structural steel beams.

3.8.3.4.7 Structural Steel Design and Analysis

Structural steel framing within the interior of the PCCV is primarily for support of floor slabs, equipment, distribution systems, and access platforms. Design and analysis procedures, including assumptions on boundary conditions and expected behavior under loads, are in accordance with the allowable stress design (ASD) method in AISC-N690 (Reference 3.8-9). Analysis methods are generally simple calculations using seismic accelerations obtained from Section 3.7 methodologies in load combinations. Frame connections are detailed for simply-supported beams unless otherwise analyzed and detailed.

3.8.3.4.8 RCL Supports

The RCL piping and support system is analyzed for the dynamic effects of a SSE. A coupled model of the containment internals and the RCS is dynamically evaluated using a time-history integration method of analysis. Appendix 3C provides additional information regarding the qualification of RCL supports.

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3.8-63 Research Achievements of SC Structure and Strength Evaluation of US-APWR SC Structure Based on 1/10th Scale Test Results, MUAP-11005-P, Rev. 0, Mitsubishi Heavy Industries, Ltd., January 2011.

3.8-64 Damping Values for Seismic Design of Nuclear Power Plants, Regulatory Guide 1.61, Rev. 1, U.S. Nuclear Regulatory Commission, March 2007.

3.8-65 FEMA 356, Prestandard and Commentary for the Seismic Rehabilitation of Buildings, Federal Emergency Management Agency, November 2000.

3.8-66 Evaluation of the Seismic Design Criteria in ASCE/SEI Standard 43-05 for Application to Nuclear Power Plants, NUREG/CR-6926, Brookhaven National Laboratory, March 2007.

3.8-67 In-Plane Behavior of Concrete Filled Steel (CFS) Elements, Presentation, Enclosure 1 to DCP_NRC_00278, Electronic ADAMS, NRC. Item ID 100130037, Accession Number ML 100050190.

3.8-68 Containment Internal Structure Design and Validation Methodology, MUAP-11013, Rev. ~~0~~ 1, Mitsubishi Heavy Industries, Ltd., ~~June~~ August 2011.

3.8-69 Seismic Design Bases of the US-APWR Standard Plant, MUAP-10001, Rev. 3, Mitsubishi Heavy Industries, Ltd., June 2011.

3.8-70 A Study on the Structural Performance of SC Thick Walls, Annual Conference of Architectural Institute of Japan (Parts 1-3), 2003

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Table 3.8.3-4 Summary of Stiffness and Damping Values for Seismic Analysis

Structural Category	Description	Loading Condition A ($E_{ss} + T_o$)			Loading Condition B ($E_{ss} + T_a$)		
		Shear Stiffness	Flexural Stiffness	Damping	Shear Stiffness	Flexural Stiffness	Damping
1	SC Walls, T ≤ 56"	Uncracked $G_cA_c + G_sA_s$	Cracked-Transformed E_cI_{ct}	4%	Fully Cracked $0.5\,(\rho^{-0.42})A_sG_s$	Cracked-Transformed E_cI_{ct}	5%
2	SC → Walls with T > 56"	Uncracked G_cA_c	Uncracked E_cI_c	4%	Cracked $0.5G_cA_c$	Cracked $0.5E_cI_c$	7%
3	Primary Shielding T = 9'-11" to 15'-4"	Uncracked G_cA_c	Uncracked E_cI_c	4%	Uncracked G_cA_c	Uncracked E_cI_c	4%
4	Rienf. Conc. Slabs T = 16" to 51"	Uncracked G_cA_c	Uncracked E_cI_c	4%	Uncracked G_cA_c	Cracked $0.5E_cI_c$	7%
5	Massive Reinf. Conc. Sections	Uncracked G_cA_c	Uncracked E_cI_c	4%	Uncracked G_cA_c	Uncracked E_cI_c	4%
6	Non-Structural Concrete	No Concrete Stiffness or Damping Applied					

NOTE: Refer to Subsection 3.8.3.4.1.3 for application of damping values

Table 3.7.3-1(a) SSE Damping Values

Welded and friction-bolted steel structures and equipment (%)	4
Bearing bolted structures and equipment (%)	7
Prestressed concrete structures (%)	5
Reinforced concrete structures (%)	7 (4)
Steel-Concrete Modules (%)	5 (4)
Piping systems[1]	4
Full cable trays & related supports (%)	10[2]
Empty cable trays and related supports (%)	7
Full Conduits & related supports (%)	7
Empty conduits & related supports (%)	5
HVAC pocket lock ductwork (%)	10
HVAC companion angle ductwork (%)	7
HVAC welded ductwork (%)	4
Cabinets and panels for electrical equipment (%)	3
Equipment such as welded instrument racks and tanks (impulsive mode) (%)	3[3]
Motors, fans, housings, pressure vessels, heat exchangers, pumps, valve bodies (%)	3

Table 3.7.3-1(b) OBE Damping Values

Welded and friction-bolted steel structures and equipment (%)	3
Bearing bolted structures and equipment (%)	5
Prestressed concrete structures (%)	3
Reinforced concrete structures (%)	4
Steel Concrete Modules (%)	4
Piping systems[1]	3
Full cable trays & related supports (%)	7[2]
Empty cable trays and related supports (%)	5
Full conduits & related supports (%)	5
Empty conduits & related supports (%)	3
HVAC pocket lock ductwork (%)	7
HVAC companion angle ductwork (%)	5
HVAC welded ductwork (%)	3
Cabinets and panels for electrical equipment (%)	2
Equipment such as welded instrument racks and tanks (impulsive mode)(%)	2[3]
Motors, fans, housings, pressure vessels, heat exchangers, pumps, valve bodies (%)	2

Notes for Tables 3.7.3-1(a) and 3.7.3-1(b):

1. As an alternative for response spectrum analyses using an envelope of the SSE or OBE response spectra at all support points (uniform support motion), frequency-dependent damping values shown in the graph below may be used, subject to the following restrictions:

   - Frequency-dependent damping should be used completely and consistently, if at all. Damping values for equipment other than piping are to be consistent with the values in the above table and RG 1.61 (Reference 3.7-15).

   - Use of the specified damping values is limited only to response spectral analyses. Acceptance of the use of the specified damping values with other types of dynamic analyses (e.g., time-history analyses or independent support motion method) requires further justification.

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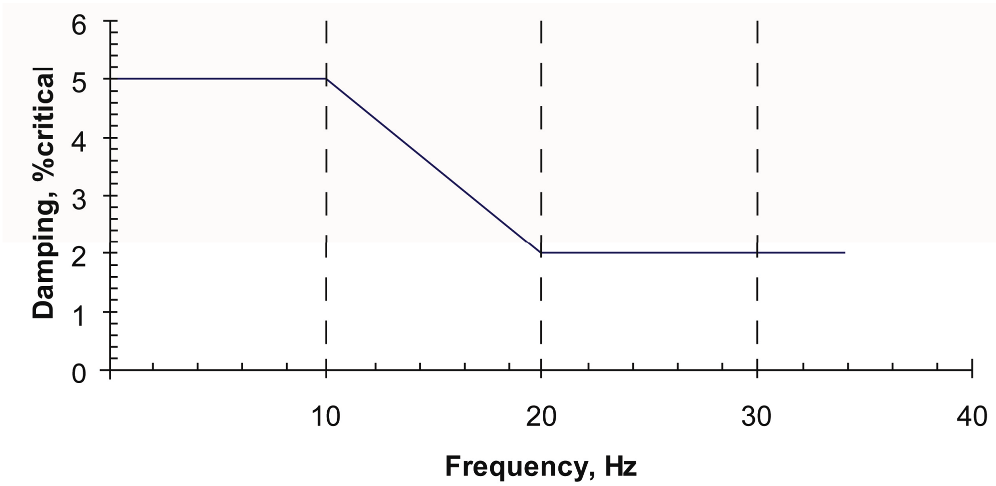
- When used for reconciliation or support optimization of existing designs, the effects of increased motion on existing clearances and online mounted equipment should be checked.
- Frequency-dependent damping is not appropriate for analyzing the dynamic response of piping systems using supports designed to dissipate energy by yielding.
- Frequency-dependent damping is not applicable to piping in which stress corrosion cracking has occurred, unless a case-specific evaluation is provided and reviewed, and found acceptable by the NRC staff.



2. The use of higher damping values for cable trays with flexible support systems (e.g., rod-hung trapeze systems, strut-hung trapeze systems, and strut-type cantilever and braced cantilever support systems) is permissible, subject to obtaining NRC review for acceptance on a case-by-case basis.

3. Use 0.5% damping for sloshing mode for tanks

4. Refer to Table 3.8.3-4 for appropriate damping values of the Containment Internal Structure