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SECTION 6A.1

INTRODUCTION

6A.1.1 Purpose

The purpose of the Design Assessment Report for Hydrodynamic Loads (DAR) is to present the completed design assessment of the Nine Mile Point Nuclear Station - Unit 2 (Unit 2) for hydrodynamic loads associated with safety/relief valve (SRV) discharge and the postulated loss-of-coolant accident (LOCA) in a boiling water reactor (BWR) Mark II containment.

For the design basis assessment, the methods used to define, apply, and combine the loads are in compliance with the following Nuclear Regulatory Commission (NRC) documents:

1. NUREG-0487, Supplements 1 and 2
   Mark II Containment Lead Plant Program Load Evaluation and Acceptance Criteria

2. NUREG-0808
   Mark II Containment Program Load Evaluation and Acceptance Criteria

3. NUREG-0802
   Safety/Relief Valve - Quencher Loads Evaluation Reports - BWR Mark II and III Containments

4. NUREG-0783 (Draft)
   Suppression Pool Temperature Limits for BWR Containments

5. NUREG-0763
   Guidelines for Confirmatory Inplant Tests of Safety-Relief Valve Discharges for BWR Plants

The basic supporting document for the Unit 2 design assessment is the Mark II Containment Dynamic Forcing Functions Information Report (DFFR), Revision 4(1). Additional references will be cited where the methods are different from those described in DFFR Revision 4, or where a particular loading condition was not addressed in DFFR Revision 4.

NOTE: The DAR for Unit 2 that was submitted in July 1976 has been superseded in its entirety by this appendix. Appendix 6A is the DAR.

6A.1.2 Scope

NRC letters(2,3) to Niagara Mohawk Power Corporation (NMPC) discussed the SRV and LOCA hydrodynamic load phenomena associatedwith the BWR Mark II containment. Specific requests for additional information included with each letter formed the initial basis for the Unit 2 design assessment. In the course of investigating the Mark II hydrodynamic phenomena, the requirements for design assessment have been refined, and are now contained in the NUREGs referenced in Section 6A.1.1. In this appendix, the Mark II acceptance criteria are addressed item by item to document the compliance identified in Section 6A.1.1.

6A.1.3 Summary of Design Assessment

A design assessment has been performed on structures, equipment, and piping subjected to loads resulting directly or indirectly from suppression pool hydrodynamic phenomena. These are as follows:

1. Reactor building basemat and structures and primary containment structures.
2. Primary containment internal structures including the reactor pressure vessel (RPV) pedestal and drywell floor.
3. Primary containment basemat, wall, and pedestal liners.
4. Downcomers.
5. Auxiliary structures such as platforms, ladders, and support frames in the primary containment.
6. Safety-related piping and pipe supports located within the primary containment and reactor building.
7. Safety-related equipment located within primary containment and reactor building.
8. RPV, RPV internals, and associated equipment.
9. Recirculation piping and floor- and pipe-mounted equipment.
10. Control and instrumentation equipment.

Section 6A.2.1 provides a general description of the suppression pool hydrodynamic loading phenomena. Sections 6A.3 and 6A.4 provide more detail for the SRV and LOCA loads, respectively. Load combinations, acceptance criteria, and the methods of combining peak dynamic responses are given in Section 6A.2.2. Other dynamic loads with which hydrodynamic loads must be combined are identified in Section 6A.2.3.

Section 6A.2.4 describes the approach used in performing the Unit 2 design assessment for each of the three following classifications of loading functions:

1. Submerged Structure/Pool Swell Loads Loads directly applied by suppression pool hydrodynamic phenomena to wetwell internal structures and the drywell floor.

2. Building Response Loads Suppression pool hydrodynamic loads applied directly to the suppression pool boundaries (primary containment shell, basemat, and RPV pedestal) and then indirectly to structures, piping, and equipment in the drywell and reactor building due to building dynamic response.

3. Related Effects Other design assessment activities related to suppression pool hydrodynamic phenomena but not included in the above classifications, such as suppression pool temperature response and downcomer/SRV discharge line (SRVDL) fatigue evaluations.

Sections 6A.5 through 6A.9 provide the results of the Unit 2 design assessment. Detailed results of the nuclear steam supply system (NSSS) piping and major safety-related equipment evaluations are presented in Sections 3.9 and 3.10.

Section 6A.5 covers the dynamic responses of the primary structures and provides the amplified response spectra (ARS) used in the NSSS and balance-of-plant (BOP) piping and equipment evaluations, the results of which are presented in Section 6A.9.

Section 6A.6 presents the design assessment results for the primary structures; Section 6A.7, the results for the primary containment liner; and Section 6A.8, the results for the reactor building. Section 6A.10 describes the suppression pool temperature response to plant transients involving SRV discharge, and describes the pool temperature monitoring system.

T-quenchers are used as the SRV discharge devices, and the design assessment is based upon vendor design information(4). The design assessment has demonstrated that sufficient design margins exist in plant structures and components to withstand the effects of the hydrodynamic loads.

The discussion presented in the following Appendix represents the basis for the original Design Assessment Report (DAR) for Hydrodynamic Loads. In support of the Extended Power Uprate (EPU) project to increase plant licensed power to 3988 MWt, an evaluation of the impact of the power increase on this hydrodynamic loads assessment was performed as documented in Reference 6. That evaluation addressed the potential impact of EPU on the following Loads Definitions:

1. Pre-Vent Clearing Jet Loads

2. Pool Swell Loads

3. Condensation Oscillation Loads

4. Chugging Loads (including chugging duration)
5. SRV Actuation Loads

Based upon that evaluation, it was concluded that the above loads at EPU remain bounded by the original loads described in this Appendix.

Similarly, evaluation of the potential effects for MELLLA+ operation has been completed. It was concluded that the above loads at MELLLA+ remain bounded by the original loads described in this Appendix.

6A.1.4 General Arrangement of Suppression Pool Structures

Figures 6A.1-1 through 6A.1-3 show the general arrangement of the suppression chamber, internal structures, and drywell floor penetrations.

6A.1.5 References

1. Mark II Containment Dynamic Forcing Functions, GE Report NEDO-21061, Rev. 4, November 1981.
2. NRC letter to Niagara Mohawk Power Corporation dated April 18, 1975.
3. NRC letter to Niagara Mohawk Power Corporation dated April 21, 1975.
4. Nine Mile Point Unit 2, Thermo Hydraulic Quencher Design of the Safety Relief System, Kraftwerk Union Technical Report No. KWU/R/14/21/1979.
5. Pennsylvania Power & Light Company, Susquehanna Steam Electric Station Units 1 and 2, Docket Nos. 50-387 and 50-388, Design Assessment Report, April 1978.
6. GEH Report 0000-0081-8438-R2, Nine Mile Point Nuclear Station Unit 2 - Extended Power Uprate, Task T0400: Containment System Response, April 2009.

SECTION 6A.2

LOADS AND LOAD COMBINATIONS

6A.2.1 Load Description - Suppression Pool Hydrodynamic Loads and Related Effects

The sequences of hydrodynamic events that occur during a SRV actuation and a postulated LOCA are described in this section. The objective is to describe potential load-producing conditions used in design evaluations.

6A.2.1.1 Safety/Relief Valve Actuation

SRVs are utilized to provide pressure relief during certain reactor transients. SRV actuation may occur:

1. In response to a reactor system transient pressure increase (pressure actuation).
2. As the result of planned Operator actuation (manual operation).
3. As the result of a failure or error affecting one SRV (inadvertent) opening.
4. As part of the automatic depressurization system (ADS).

Both inadvertent and manual operation involves a single SRV. Pressure actuation involves the sequential opening of from one to all SRVs during vessel pressure rise. The opening sequence depends on the SRV pressure setpoints. ADS valves are actuated simultaneously in response to intermediate break accident (IBA) conditions (Section 6A.2.1.2.2). Steam discharged through the valves is routed through discharge lines to be condensed into the suppression pool. The end of each discharge pipe is fitted with a quencher to promote heat transfer between the air-steam mixture and the water in the suppression pool.

Prior to a typical actuation, the SRV discharge piping contains ambient air and a column of water. The height of the column is determined by the submergence of the SRVDL in the suppression pool, and the difference in the drywell and suppression chamber overpressure. Upon SRV actuation, steam compresses the air in the discharge piping resulting in a pressure buildup which forces the water column through the quencher. Water and air from the SRV line is expelled followed by steady-state steam discharge. This is called the line-clearing phase of the SRV discharge. Loads associated with line clearing are transient SRV pipe pressure and thermal loads, pipe reaction forces from transient pressure wave, and fluid motion in the pipe. The line-clearing loads are discussed in Section 6A.3.4.

Following water clearing, the compressed air is formed into high-pressure air bubbles as it accelerates into the suppression pool. The bubbles undergo several oscillating expansions and contractions as they rise to the pool surface. The oscillating air bubbles interact with the suppression pool water producing an oscillating pressure field. The oscillating pressure field exerts a load on the primary containment submerged boundaries. This is referred to as SRV air-clearing load (Section 6A.3.4.7). The water jet and air bubbles also exert drag loads on submerged structures. The submerged structure loads during SRV actuations are discussed in Section 6A.3.4.8.

Following the air-clearing phase, steady steam discharge flow is established and continues until the SRV is closed or the reactor is depressurized. Test data indicate that stable steam condensation exists and the steam is condensed completely in the vicinity of the quencher(1). Analysis of the suppression pool temperature is presented in Section 6A.10. While there is no appreciable suppression pool boundary and submerged structure load during steam condensation, some pipe reaction and thrust forces do act on the quencher body and its support. These loads are discussed in Sections 6A.3.4.4 through 6A.3.4.6. The event-time relationship for a typical SRV discharge is shown on Figure 6A.2-1.

6A.2.1.2 Loss-of-Coolant Accidents

A spectrum of postulated LOCAs is considered to assess the design adequacy of the primary containment system. The hypothetical events and accident conditions are described in this section.

6A.2.1.2.1 Design Basis Accident

The design basis accident (DBA) utilized in the DAR is defined as the LOCA that results in the highest drywell pressure. Usually this is either a double-ended break of a recirculation pump suction line or a main steam line (MSL). The mass and energy release from the break causes rapid pressurization of the drywell and expulsion of the water initially in the downcomers. During the downcomer-clearing process, the water exiting the downcomers forms submerged jets in the suppression pool. The water jets cause impingement and drag loads on structures near the paths of the jets as well as pressure loads on the submerged boundaries. The water jet loads are presented in Sections 6A.4.2 and 6A.4.9.

Following downcomer clearing, air purged from the drywell forms bubbles at the downcomer exits. As the flow of air and steam from the drywell continues, the LOCA bubbles expand with the bubble pressure nearly equal to the drywell pressure. The expanding bubbles create a pressure field in the suppression pool that results in loads on submerged structures and on the pool boundaries. LOCA air bubble loads are discussed in Sections 6A.4.3 and 6A.4.9.

The continued injection of drywell air and the resultant expansion and coalescence of air bubbles produces a rapid rise in the suppression pool surface. This is called the suppression pool swell phase. Any structures close to the suppression pool surface experience impact loads as the rising suppression pool surface strikes the lower surface of the structures, followed by drag loads as the suppression pool surface continues past the structure. In addition, the rising water compresses the suppression chamber air and produces an upward force on the drywell floor. The rising water is eventually stopped by the compressed air in the suppression chamber. The air bubbles break through the surface and gravity-induced suppression pool fallback begins, settling the water back in the suppression pool. The impact and drag loads on any structures along the path of suppression pool swell and fallback, as well as the drywell floor uplift load, are presented in Sections 6A.4.4 and 6A.4.9.

After the suppression pool swell transient, a period of high steam flow rate through the downcomer occurs, followed by a decreasing flow rate as the blowdown continues. Test data show that the steam is entirely condensed in the downcomer exit region. The condensation process is influenced by the downcomer flow rate and the fraction of air flow. At high downcomer flow rates, the steam-water interface oscillates outside the downcomer exit. This phenomenon, referred to as condensation oscillation, produces oscillatory pressure loads on the suppression pool boundaries and submerged structures. Condensation oscillation is discussed in Section 6A.4.5 and the associated submerged structure load in Section 6A.4.9.

At lower steam flow rates, the steam bubbles at the downcomer exit alternately grow and collapse. This unsteady condensation process is referred to as chugging. Chugging also generates pressure oscillation loads on the suppression pool boundaries and submerged structure loads. In addition, the steam bubbles collapse may be asymmetric and produce lateral loads on the downcomer itself. Lateral loads are discussed in Section 6A.4.7. Chugging loads on suppression pool boundaries and submerged structures are presented in Sections 6A.4.6 and 6A.4.9, respectively.

The event-time relationship for a DBA is shown on Figure 6A.2-2. No SRV actuation is mechanistically possible during the DBA due to the associated rapid depressurization of the reactor vessel.

6A.2.1.2.2 Intermediate Break Accident

An IBA is defined as a liquid line break of approximately 0.1 sq ft. The break size is small enough that rapid depressurization of the RPV does not occur. However, the reactor inventory loss is sufficiently rapid to cause a reduction in reactor water level. Consequently, the ADS depressurizes the RPV and allows the low-pressure emergency core cooling system (ECCS) pump to reflood the vessel. The ADS actuates on a level 1 reactor water level signal, coincident with level 3 reactor water level signal, and at least one low-pressure ECCS pump running. A timer in the ADS logic delays actuation until approximately 105 sec (assumed) after the time of coincident initiation signals. When activated, the ADS mechanically actuates the ADS valves, overriding any pressure-actuated valve discharges.

The drywell pressurization rate resulting from an IBA is significantly less than that from a DBA. The downcomer clearing load is less than that resulting from a DBA and there is no significant suppression pool swell. The resulting IBA loads on suppression pool boundaries, submerged structures and equipment are bounded by the corresponding load from a DBA.

For intermediate size breaks, the steam flow rate through the downcomers may be insufficient to cause condensation oscillations. However, chugging loads will occur until the reactor vessel blowdown is reduced to a flow rate where chugging becomes insignificant. To cover the whole spectrum of events, a low downcomer mass flux condensation oscillation load is still defined and used in combination with the ADS load. The event-time relationship for an IBA is shown on Figure 6A.2-3.

6A.2.1.2.3 Small Break Accident

A small break accident (SBA) is defined as an event in which the fluid loss rate from the reactor system is insufficient to depressurize the reactor or result in a decrease of reactor water level. A typical SBA is a 0.01-sq ft steam line break. Following the break, the drywell pressure slowly increases until the high drywell pressure scram setting is reached. The reactor scrams, but the main steam isolation valves (MSIVs) may not close immediately. By conservatively postulating that the MSIVs do close immediately, the reactor system experiences a pressure increase when an isolation transient occurs and SRVs actuate to control system pressure.

Drywell pressure continues to increase at a rate dependent on the size of the break. The pressure increase depresses the water level in the downcomer until the water is expelled and air and steam enter the suppression pool. The air flow rate is such that the air bubbles through the suppression pool without causing suppression pool swell. The steam condenses and drywell air passes to the suppression chamber air space. The suppression chamber gradually pressurizes at a rate dependent upon the air carryover rate. Eventually, all the drywell air is carried over to the suppression chamber and the suppression chamber pressurization rate is controlled by the suppression pool heatup rate.

Vacuum breakers are provided on the drywell floor to vent air back to the drywell when the blowdown is over.

The steam flow rate through the downcomers for a SBA is insufficient to cause condensation oscillations. There may be sufficient steam flow to cause chugging. As the reactor vessel depressurizes and cools down, the downcomer steam mass flux decreases so that the downcomers may not remain cleared. Steam condensation can occur at the water interface inside the downcomers and on the walls of the downcomer pipe.

As a result of a postulated MSIV closure, the SRVs initially discharge for reactor vessel pressure relief in response to the isolation transient. Following the initial discharge, SRV cycling may occur based upon reactor coolant boundary pressure and valve setpoint. When the suppression pool temperature reaches the Technical Specification limit of 120°F, the Operator (following procedures) begins a controlled shutdown depressurization at the rate of 100°F/hr using manual operation of the SRVs if MSIVs are closed, or using the main condenser if MSIVs are open. The event-time relationship for a typical SBA is shown on Figure 6A.2-4.

6A.2.2 Load Combinations and Acceptance Criteria

The suppression pool hydrodynamic loads, as well as the mechanistic relationships between SRV and LOCA loads, are described in Section 6A.2.1. These relationships form the basis for Mark II load combinations.

Design load combinations resulting from this basis are presented in Table 6A.2-1. Following are several important features of the design load combinations:

1. All combinations of SRV and LOCA loads could occur with or without an operating basis earthquake (OBE)/safe shutdown earthquake (SSE).

2. Without a LOCA event, SRV actuation could occur with or without a seismic event.

3. Without SRV actuation, a LOCA event could occur with or without a seismic event.

The appropriate designation of acceptance criteria for structures and components is to be evaluated as important as the identification of design load combinations. Once acceptance criteria are associated with design load combinations, it becomes evident that many simplifications to Table 6A.2-1 can be made, while still retaining all appropriate combinations. The resulting design basis load combinations and acceptance criteria will vary for different types of structures and components, since different design procedures and codes are applicable. These are discussed in detail in the following sections.

6A.2.2.1 Reinforced Concrete Structures

The load combinations and acceptance criteria for the Unit 2 reinforced concrete structures, including the basemat, pedestal, and primary containment, are presented in Table 6A.2-2. This is consistent with Table 5-1 of the DFFR, Rev. 4(2). As discussed there, the factored load philosophy of the strength design method is employed for the assessment of Mark II hydrodynamic loads. This is consistent with the original factored load design in accordance with ACI-318-77, Building Code Requirements for Reinforced Concrete.

Load combinations 1 and 2 (Table 6A.2-2) for normal operation with and without thermal effects are based on ACI-318-77, Paragraphs 9.2.1 and 9.2.7. Load combinations 3 through 7a cover the same combinations of events as ASME Section III, Division 2, with SRV actuations also included. With the inclusion of SRV loads, load factors are adjusted to provide consistent safety margins.

It is noted that substantial simplification from Table 6A.2-1 has been achieved by two means. First, SBA and IBA effects are grouped together. This is reasonable since their effects are generally comparable and both can occur with the same possible SRV actuation cases. Second, the various SRV actuation cases are not called out separately. For design assessment purposes, the most severe SRV actuation case possible should be considered. For Unit 2, the maximum results from any SRV actuation case, including an all-valve discharge, are conservatively used in combinations with SBA and IBA events as well as in combinations without LOCA events.

6A.2.2.2 Steel Structures

Load combinations and acceptance criteria for steel structures in Unit 2 are presented in Table 6A.2-3 (steel structures are not addressed in the DFFR(2)). Table 6A.2-3 contains the same event combinations as Table 6A.2-2; however, unfactored loads are used with stress allowables that reflect the probability of occurrence of each load combination. The stress allowables are in accordance with the AISC Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings. This approach is identical to that used in the original design with the dynamic effects of SRV and LOCA loads now included.

6A.2.2.3 Piping and Equipment

Load combinations and acceptance criteria for BOP and NSSS piping and equipment are presented in Tables 6A.2-1a and 6A.2-1b, respectively. This is consistent with Table 5-2 of DFFR Rev. 4(2) and NUREG-0800(3).

The load combination methods are described in Section 6A.2.2.5 and are consistent with NUREG-0800(3). The applicable load cases and the dynamic analysis procedures used for Unit 2 are consistent with NUREG-0800(3) as follows:

SEB-2 and MEB-4	Use ±15 percent peak broadening of ARS.
SEB-3 and MEB-5	Use Regulatory Guide (RG) 1.92 to combine modal responses.
MEB-2	Use OBE damping for normal/upset conditions; use design basis earthquake (DBE) damping for emergency/faulted conditions.
MEB-7(a)	Annulus pressurization effects are combined with SSE.
MEB-7(b)	OBE plus SRV is treated as an upset condition on an evaluation basis.
MEB-8	Criteria to assure functional capability for all essential components are in conformance with NUREG/CR-0261 and consistent with NUREG-0800(3).

6A.2.2.4 Reactor Pressure Vessel and Internals

Load combinations and acceptance criteria for the RPV and internals are presented in Table 6A.2-1b.

6A.2.2.5 Combination of Dynamic Responses

For all the mechanical systems, components, and supports in Tables 6A.2-1a and 6A.2-1b, the dynamic responses to the dynamic loads such as LOCA, SRV, and OBE/SSE are combined by the square root of the sum of squares (SRSS) method(4). The NRC topical report evaluation(5) and Revision 1 of NUREG-0484(6) accept the SRSS method for the Mark II load combinations.

Various dynamic loads for applicable Category I structures such as LOCA, SRV, and OBE/SSE are combined by the absolute sum method for designing structural components.

6A.2.3 Other Dynamic Loads

The Unit 2 design basis loads are defined in or are derived from information presented in the appropriate sections of the Final Safety Analysis Report (FSAR). The major design loads, in addition to normal operating conditions, result from LOCA and seismic events.

The design basis LOCA loads include the quasi-static pressure and temperature transients in the primary containment, pipe rupture loads, annulus pressurization, and hydrodynamic loads in the suppression chamber and the drywell. The quasi-static pressure and temperature transients are defined in FSAR Section 6.2. Pipe rupture loads are described in FSAR Section 3.6A. Annulus pressurization is discussed in Section 6A.4.8. Hydrodynamic loads are specified in Section 6A.4.

The Unit 2 DBE ground response spectra are defined in FSAR Section 3.7A. One special subset of seismic loads not discussed in the FSAR is referred to as seismic sloshing and is described below.

Sloshing is a term used to describe the dynamic response of the suppression pool water due to the movement of its boundary walls, these boundaries being the primary containment, pedestal, and basemat. The sloshing response of water will generate hydrodynamic pressure loads on the boundary walls and drag loads on structures submerged in the suppression pool. These loads have been determined for both the OBE and the SSE and included in appropriate acceptance criteria for plant structures.

The formulation of the seismic sloshing problems in annular and circular tanks can be found in NUREG/CR-1083(7) and a technical paper(8). The solution consists of solving the Laplace equation to derive a velocity potential. Ground motion is introduced into the solution through the boundary conditions which are time dependent. The associated eigen-value problem is solved to determine the natural frequencies and mode shapes of the sloshing movements. Water displacements, velocities, and dynamic pressures are derived from the potential function. Drag loads are calculated for velocity drag, acceleration drag, and lift with corrections for unsteady flow and interference from neighboring structures.

Free surface deflection time history due to SSE ground motion at r=14.167 ft (pedestal outer radius), θ=0 degrees for the suppression pool, is given on Figure 6A.2-5. The extreme values of the free surface deflection are -3.02 ft and 3.02 ft for the outer suppression pool and -2.05 ft and 2.05 ft for the inner suppression pool. In this analysis two horizontal components and one vertical component of the earthquake are acting simultaneously. Each horizontal component has maximum value of acceleration of 0.15 g (SSE). The vertical component of acceleration conservatively meets the requirements of RG 1.60 as discussed in Section 3.7A.

The maximum dynamic pressure caused by SSE ground motion on pedestal, primary containment wall, and basemat occurs at approximately 9.25 sec. The distribution in the x-z plane for θ =0 degrees and θ=180 degrees is given on Figures 6A.2-6 and

6A.2-7, respectively. The maximum dynamic pressure acting on the primary containment wall is +2.58 psi and -2.63 psi. The maximum dynamic pressure acting on the pedestal wall occurs on the inside diameter and is +1.88 psi and -2.09 psi. The maximum responses for OBE are one-half of SSE.

Submerged structure load time histories were calculated on structures listed in Table 6A.4-3. Sensitivity studies were made to locate the structures that had the maximum response to sloshing. A typical OBE load time history for a 1.25-ft section of quencher arm for SRV line SVV-012-67-3 is given on Figures 6A.2-8 through 6A.2-10.

Other design loads include wind, flood, and missiles as described in FSAR Sections 3.3, 3.4, and 3.5, respectively.

6A.2.4 Approach Used for Design Assessment

Section 6A.2.4 describes the manner in which the Unit 2 design assessment for suppression pool hydrodynamic loads has been accomplished. Section 6A.2.4.1 describes the direct loads considered in the Unit 2 design assessment. Indirect loading due to building response is discussed in Section 6A.2.4.2. Section 6A.2.4.3 covers hydrodynamic load considerations not appropriate for Sections 6A.2.4.1 or 6A.2.4.2.

6A.2.4.1 Submerged Structure/Suppression Pool Swell Loads

The hydrodynamic loads described in Section 6A.2.1 act on the submerged boundaries of the suppression pool and on structures within the suppression pool. During suppression pool swell, hydrodynamic loads also act on the suppression chamber airspace boundary and the drywell floor, as well as structures in the suppression pool swell zone above the suppression pool. Figures 6A.2-11 through 6A.2-26 describe the time relationships of hydrodynamic loads acting on the following structures:

1. Drywell floor (Figure 6A.2-11).
2. Downcomers (Figures 6A.2-12 through 6A.2-15).
3. Suppression chamber walls above water level (Figure 6A.2-16).
4. Submerged suppression chamber (Figures 6A.2-17 through 6A.2-20).
5. Submerged structures (Figures 6A.2-21 through 6A.2-24).
6. Structures above suppression pool, below breakthrough (Figure 6A.2-25).
7. Structures above breakthrough (Figure 6A.2-26).

Section 6A.3 discusses the suppression pool boundary loads due to SRV discharge.

Section 6A.4 discusses the LOCA-related suppression pool boundary loads due to downcomer clearing, condensation oscillations, and chugging as well as the vertical and lateral chugging loads on the downcomers. Section 6A.4 also describes the methods used to calculate the bulk suppression pool swell transient; loads on submerged structures within the suppression pool due to SRV discharge, downcomer clearing, condensation oscillations, and chugging; and loads on structures in and above the suppression pool due to pool swell. SRV discharge and LOCA-related suppression pool boundary loads affect structures and components outside the suppression pool by exciting the primary containment and the reactor building. The methods used to calculate these building response loads are described in Section 6A.2.4.2.

6A.2.4.2 Building Response Load

To determine the dynamic response of the containment structures when subjected to SRV discharge and LOCA loads, a finite element-based computer program, Dynamic Stress Analysis of Axisymmetric Structures under Arbitrary Loading, developed by S. Ghosh and E. Wilson and modified by Stone & Webster Engineering Corporation (SWEC) (Appendix 3A), was utilized.

Mathematical models are developed which model the mat, the primary containment, the shield wall, the reactor pedestal, and the reactor building. The stiffening effects of the RPV stabilizer and star truss are also included. The major dimensions of the structures and identification of their general arrangement are illustrated on Figures 1.2-12, 3.8-11, and 3.8-20.

Figure 6A.5-1 depicts the structural model used to represent the complete reactor building and supporting rock. Solid axisymmetric elements are used to represent the rock to a radius and depth of approximately 3 mat radii, with axisymmetric thin shell elements representing the structures. The external dimensions of the rock were selected to preserve free-field motions. The boundary conditions for the rock, at a radius of approximately three times the mat radius, are fixed at the base of the rock and simply supported along the height of the rock.

Figure 6A.5-1 shows a relatively uniform element spacing in the area of the primary containment with varying element size in the reactor building areas. This spacing has been used because the loads are applied to the pool boundaries within this area and a precise definition of internal loads is required.

The equations of motion are solved numerically by direct integration. The effects of structural damping have been included in the dynamic analysis, unless otherwise noted. The Rayleigh damping technique is utilized in which the damping matrix is assumed to be linearly proportional to the mass and stiffness matrix of the structure. The constants of proportionality are chosen to obtain maximums of 4- and 7-percent damping values for reinforced concrete structures under normal operating conditions for SRV loads and LOCA-related loads, respectively, for frequencies between 10 and 60 Hz. These limits were selected in order to conservatively encompass the range of frequencies in which significant dynamic response occurs.

The SRV and LOCA load definitions are defined in Sections 6A.3 and 6A.4. In general, the pressure loads on the suppression pool boundaries due to a SRV discharge or LOCA event vary both circumferentially and meridionally with time. At any point in time, this pressure field can be represented meridionally by a discretization into zones and circumferentially by a Fourier series at each of the meridional zones. Therefore, the spatial and time-wise variation of pressure can be represented by pressure time histories at each zone for each Fourier series term.

The equations of motion are solved numerically by direct integration and the acceleration time histories at selected locations are computed. ARS are developed from the resultant structural acceleration time histories. These ARS are used as input to evaluate the adequacy of the piping systems and other equipment.

6A.2.4.3 Related Effects

The Unit 2 design assessment for hydrodynamic loads is not limited to suppression pool load definition and plant response. In the case of SRV steam discharge, the conditions of concern are simultaneous high mass flux and high suppression pool temperature in the vicinity of the SRV discharge device. The local temperature/mass flux limit for the KWU T-quencher device is discussed in Sections 6A.3.2 and 6A.10.2. The maximum temperature difference between the mass average (bulk) suppression pool temperature and that in the vicinity of the quencher is discussed in Section 6A.10.2. Section 6A.10.2 provides a description of the suppression pool bulk temperature transients for various events involving SRV discharge. The bulk suppression pool temperature transients are compared against the local temperature limit for the device. Section 6A.10.1 describes the Unit 2 suppression pool temperature monitoring system which alerts the Operator to take certain actions to mitigate suppression pool temperature transients. These actions are consistent with the Technical Specifications.

6A.2.5 References

1. Tests of T-Quencher Jets Discharging into a Pool at Uniform

Temperatures Up to Saturation, SAI Technical Report, July 1979.

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5. USNRC Staff Evaluation of GE Technical Report NEDE-24010-P and Supplements 1 through 3, Letter from R. J. Mattson (NRC) to H. Chou (Mark-II Owners Group), June 25, 1980.

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8. Three-Directional Fluid Pool Seismic Sloshing Analysis, ASME Journal of Pressure Vessel Technology, Vol. 103, February 1981.

9. Functional Capability Criteria for Essential Mark II Piping, NEDO-21985, September 1978.

10. USNRC Memo from J. P. Knight, Division of Engineering, to R. L. Tedesco, Division of Licensing, dated July 17, 1980.

TABLE 6A.2-1

DESIGN LOAD COMBINATIONS AND ACCEPTANCE CRITERIA

Load Combination	Acceptance Criteria
$N + SRV_{ALL}$	Upset
$N + OBE$	Upset
$N + SSE$	Faulted
$N + (OBE+SRV_{ALL})$	Upset
$N + (SSE+SRV_{ALL})$	Faulted
$N + (SBA_{CHUG}+SRV_{ALL})$	Emergency
$N + (IBA_{CO1}+SRV_{1})$	Emergency
$N + (IBA_{CO2}+SRV_{ADS})$	Emergency
$N + (IBA_{CHUG}+SRV_{ADS})$	Emergency
$N + (SBA_{CHUG}+SRV_{ADS})$	Emergency
$N + (SBA_{CHUG}+SRV_{ADS}+SSE)$	Faulted
$N + (SBA_{CHUG}+SRV_{ADS}+OBE)$	Emergency
$N + (IBA_{CO1}+SRV_{1}+SSE)$	Faulted
$N + (IBA_{CO1}+SRV_{1}+OBE)$	Emergency
$N + (IBA_{CO2}+SRV_{ADS}+SSE)$	Faulted
$N + (IBA_{CO2}+SRV_{ADS}+OBE)$	Emergency
$N + (IBA_{CHUG}+SRV_{ADS}+SSE)$	Faulted
$N + (IBA_{CHUG}+SRV_{ADS}+OBE)$	Emergency
$N + (SSE+AP)$	Faulted
$N + (DBA_{CO1}+SRV_{1}+SSE)$	Faulted
$N + (DBA_{CO1}+SRV_{1})$	Faulted
$N + DBA_{CO1} + SSE$	Faulted

TABLE 6A.2-1 (Cont'd.)

Load Combination	Acceptance Criteria
N + DBA_{CHUG} + SSE	Faulted
N + OBE + RHR_B	Emergency

KEY:

N = Normal operating loads
SRV_{ALL} = Actuation of any number of SRVs (envelopes)
SRV_1 = Actuation of one SRV
SRV_{ADS} = Actuation of ADS valves
OBE = Operating basis earthquake
SSE = Safe shutdown earthquake
CHUG = Chugging due to SBA/IBA/DBA
CO_2 = Condensation oscillation with ADS
CO_1 = Basic condensation oscillation
AP = Annulus pressurization
SBA = Small break accident
IBA = Intermediate break accident
DBA = Design basis accident
RHR_B = Actuation of RHR heat exchanger relief valve

TABLE 6A.2-1a

DESIGN LOAD COMBINATIONS AND ACCEPTANCE CRITERIA BOP COMPONENTS, PIPING, AND EQUIPMENT

Load Combination	Acceptance Criteria
$N + SRV_{ALL}$	Upset
$N + OBE$	Upset
$N + SSE$	Faulted
$N + (OBE+SRV_{ALL})$	Upset
$N + (SSE+SRV_{ALL})$	Faulted
$N + (SBA_{CHUG}+SRV_{ALL})$	Emergency$^{(1)}$
$N + (IBA_{CO1}+SRV_{1})$	Emergency$^{(1)}$
$N + (IBA_{CO2}+SRV_{ADS})$	Emergency$^{(1)}$
$N + (IBA_{CHUG}+SRV_{ADS})$	Emergency$^{(1)}$
$N + (SBA_{CHUG}+SRV_{ADS})$	Emergency$^{(1)}$
$N + (SBA_{CHUG}+SRV_{ADS}+SSE)$	Faulted
$N + (SBA_{CHUG}+SRV_{ADS}+OBE)$	Emergency$^{(1)}$
$N + (IBA_{CO1}+SRV_{1}+SSE)$	Faulted
$N + (IBA_{CO1}+SRV_{1}+OBE)$	Emergency$^{(1)}$
$N + (IBA_{CO2}+SRV_{ADS}+SSE)$	Faulted
$N + (IBA_{CO2}+SRV_{ADS}+OBE)$	Emergency$^{(1)}$
$N + (IBA_{CHUG}+SRV_{ADS}+SSE)$	Faulted
$N + (IBA_{CHUG}+SRV_{ADS}+OBE)$	Emergency$^{(1)}$
$N + (SSE+AP)$	Faulted
$N + (DBA_{CO1}+SRV_{1}+SSE)$	Faulted
$N + (DBA_{CO1}+SRV_{1})$	Faulted
$N + DBA_{CO1} + SSE$	Faulted

TABLE 6A.2-1a (Cont'd.)

Load Combination	Acceptance Criteria
N + DBA_{CHUG} + SSE	Faulted
N + OBE + RHR_{B}	Emergency

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(1) Higher stress limits than the level specified in this table may be used provided functional capability is ensured. Piping functional capability is ensured in accordance with NEDO-21985 (Reference 9) and the NRC evaluation of this report (Reference 10).

KEY:

N = Normal operating loads
SRV_{ALL} = Actuation of any number of SRVs (envelopes)
SRV_{1} = Actuation of one SRV
SRV_{ADS} = Actuation of ADS valves
OBE = Operating basis earthquake
SSE = Safe shutdown earthquake
CHUG = Chugging due to SBA/IBA/DBA
CO_{2} = Condensation oscillation with ADS
CO_{1} = Basic condensation oscillation
AP = Annulus pressurization
SBA = Small break accident
IBA = Intermediate break accident
DBA = Design basis accident
RHR_{B} = Actuation of RHR heat exchanger relief valve

TABLE 6A.2-1b

LOAD COMBINATION AND ACCEPTANCE CRITERIA FOR ASME CODE CLASS 1, 2 AND 3 NSSS PIPING, EQUIPMENT, AND SUPPORTS

Load Combination	Acceptance Criteria	Service Level
N + SRV_{ALL}	Upset	B
N + OBE	Upset	B
N + OBE + SRV_{ALL}(3)	Upset	B
N + SSE + SRV_{ALL}	Faulted	D(1)
N + SBA + SRV	Emergency	C(1)
N + IBA + SRV	Faulted	D(1)
N + SBA + SRV_{ADS}	Emergency	C(1)
N + SBA/IBA + OBE + SRV_{ADS}	Faulted	D(1)
N + SBA/IBA + SSE + SRV_{ADS}	Faulted	D(1)
N + LOCA(2) + SSE	Faulted	D(1)

Load Definition Legend:

N = Normal loads (e.g., weight, pressure, temperature, etc.)

OBE = Operating basis earthquake loads

SSE = Safe shutdown earthquake loads

SRV = Safety/relief valve discharge induced loads from two adjacent valves

SRV_{ALL} = Loads induced by actuation of all safety/relief valves

SRV_{ADS} = Loads induced by the actuation of all automatic depressurization system valves during the postulated small or intermediate size pipe rupture

TABLE 6A.2-1b (Cont'd.)

LOCA = Loss of coolant accident associated with the postulated pipe rupture of large pipes (e.g., main steam, feedwater, recirculation piping)

$LOCA_1$ = Pool swell drag/fallback loads on piping and components located between the main vent discharge outlet and the suppression pool water upper surface

$LOCA_2$ = Pool swell impact loads on piping and components located above the suppression pool water upper surface

$LOCA_3$ = Oscillating pressure induced loads on submerged piping and components during condensation oscillations

$LOCA_4$ = Building motion induced loads from chugging

$LOCA_5$ = Building motion induced loads from main vent air clearing

$LOCA_6$ = Vertical and horizontal loads on main vent piping

$LOCA_7$ = Annulus pressurization loads

SBA = Transients loads associated with a small break accident

IBA = Transients loads associated with an intermediate break accident

(1) All ASME Code Class 1, 2, and 3 piping that are required to function for safe shutdown under the postulated events are designed to meet the functional capability criteria described in NEDO-21985.

(2) The most limiting case of load combinations under $LOCA_1$ through $LOCA_7$.

(3) OBE + SRV is treated as an upset event on an evaluation basis without fatigue.

TABLE 6A.2-2

LOAD COMBINATIONS - CONCRETE DESIGN

Equation	Load Condition	D	L	F	P_o	T_o	R_o	E_o	E'_o	P_b	P_a	T_a	R_a	R_r	SRV SEQ	SRV ADS	SRV ASY	SRV SNGL
1.1	Normal without temperature	1.4	1.7	1.0	1.0	-	-	-	-	-	-	-	-	-	1.5	-	-	-
1.2	Normal without temperature	1.4	1.7	1.0	1.0	-	-	-	-	-	-	-	-	-	-	-	1.5	-
2.1	Normal with temperature	1.0	1.3	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	1.3	-	-	-
2.2	Normal with temperature	1.0	1.3	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-	-	1.3	-
3.1	Severe environmental	1.0	1.0	1.0	1.0	1.0	1.0	1.25	-	-	-	-	-	-	1.25	-	-	-
3.2	Severe environmental	1.0	1.0	1.0	1.0	1.0	1.0	1.25	-	-	-	-	-	-	-	-	1.25	-
4.1	Abnormal	1.0	1.0	1.0	-	-	-	-	-	1.25	-	1.0	1.0	-	-	1.25	-	-
4.2	Abnormal	1.0	1.0	1.0	-	-	-	-	-	1.25	-	1.0	1.0	-	-	-	1.25	-
4A.1	Abnormal	1.0	1.0	1.0	-	-	-	-	-	-	1.25	1.0	1.0	-	-	-	-	1.0
5.1	Abnormal severe environmental	1.0	1.0	1.0	-	-	-	1.1	-	1.1	-	1.0	1.0	-	-	1.1	-	-
5.2	Abnormal severe environmental	1.0	1.0	1.0	-	-	-	1.1	-	1.1	-	1.0	1.0	-	-	-	1.1	-
5A.1	Abnormal severe environmental	1.0	1.0	1.0	-	-	-	1.1	-	-	1.1	1.0	1.0	-	-	-	-	1.0
6.1	Extreme environmental	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	-	-	-	-	-	1.0	-	-	-
6.2	Extreme Environmental	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	-	-	-	-	-	-	-	1.0	-

TABLE 6A.2-2 (Cont'd.)

Equation	Load Condition	D	L	F	P_o	T_o	R_o	E_o	E'_o	P_b	P_a	T_a	R_a	R_r	SRV SEQ	SRV ADS	SRV ASY	SRV SNGL
7.1	Abnormal extreme environmental	1.0	1.0	1.0	-	-	-	-	1.0	1.0	-	1.0	1.0	1.0	-	1.0	-	-
7.2	Abnormal extreme environmental	1.0	1.0	1.0	-	-	-	-	1.0	1.0	-	1.0	1.0	1.0	-	-	1.0	-
7A.1	Abnormal extreme Environmental	1.0	1.0	1.0	-	-	-	-	1.0	-	1.0	1.0	1.0	1.0	-	-	-	1.0

KEY TO LOADS:

D = Dead loads
L = Live loads
F = Prestressing loads
P_o = Operation pressure loads
T_o = Operating temperature loads
R_o = Operating pipe reactions
E_o = Operating basis earthquake
E'_o = Safe shutdown earthquake
P_b = SBA or IBA pressure loads (including effect of chugging or condensation oscillation)
P_a = DBA (LOCA) pressure load (including effect of chugging or condensation oscillation)
T_a = Pipe break temperature loads
R_a = Pipe break temperature reaction loads
R_r = Reaction forces, jet forces, and pipe whip forces associated with pipe break
SRV = Safety/relief valve discharge
SEQ = Sequential (all valves)
ADS = Automatic depressurization system (7 valves)
ASY = Asymmetric (3 valves)
SNGL = (1 valve)

NOTE: No live load (L) will be considered when determining equivalent static loads occurring from earthquake (OBE or SSE), SRV, chugging, or condensation oscillation. The only contributor to mass is the dead load (D). (Applicable to platform el 222'-6" and 223'-4" only.)

TABLE 6A.2-3

LOAD COMBINATIONS - STEEL DESIGN

Equation	Load Condition	S	D	L	F	P_o	T_o	R_o	E_o	E'_o	P_b	P_a	T_a	R_a	R_r	SRV SEQ	SRV ADS	SRV ASY	SRV SNGL
1.1	Normal without temperature	1.0	1.0	1.0	-	1.0	-	-	-	-	-	-	-	-	-	1.0	-	-	-
1.2	Normal without temperature	1.0	1.0	1.0	-	1.0	-	-	-	-	-	-	-	-	-	-	-	1.0	-
2.1	Normal with temperature	1.0	1.0	1.0	-	1.0	1.0	1.0	-	-	-	-	-	-	-	1.0	-	-	-
2.2	Normal with temperature	1.0	1.0	1.0	-	1.0	1.0	1.0	-	-	-	-	-	-	-	-	-	1.0	-
3.1	Severe environmental	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0	-	-	-	-	-	-	1.0	-	-	-
3.2	Severe environmental	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-	1.0	-
4.1	Abnormal	1.6	1.0	1.0	-	-	-	-	-	-	1.0	-	1.0	1.0	-	-	1.0	-	-
4.2	Abnormal	1.6	1.0	1.0	-	-	-	-	-	-	1.0	-	1.0	1.0	-	-	-	1.0	-
4A.1	Abnormal	1.6	1.0	1.0	-	-	-	-	-	-	-	1.0	1.0	1.0	-	-	-	-	1.0
5.1	Abnormal severe environmental	1.8	1.0	1.0	-	-	-	-	1.0	-	1.0	-	1.0	1.0	-	-	1.0	-	-
5.2	Abnormal severe environmental	1.8	1.0	1.0	-	-	-	-	1.0	-	1.0	-	1.0	1.0	-	-	-	1.0	-
5A.1	Abnormal severe environmental	1.8	1.0	1.0	-	-	-	-	1.0	-	-	1.0	1.0	1.0	-	-	-	-	1.0
6.1	Extreme environmental	1.6	1.0	1.0	-	1.0	1.0	1.0	-	1.0	-	-	-	-	-	1.0	-	-	-
6.2	Extreme Environmental	1.6	1.0	1.0	-	1.0	1.0	1.0	-	1.0	-	-	-	-	-	-	-	1.0	-

TABLE 6A.2-3 (Cont'd.)

Equation	Load Condition	S	D	L	F	P_o	T_o	R_o	E_o	E'_o	P_b	P_a	T_a	R_a	R_r	SRV SEQ	SRV ADS	SRV ASY	SRV SNGL
7.1	Abnormal extreme environmental	2.0	1.0	1.0	1.0	-	-	-	-	1.0	1.0	-	1.0	1.0	1.0	-	1.0	-	-
7.2	Abnormal extreme environmental	2.0	1.0	1.0	1.0	-	-	-	-	1.0	1.0	-	1.0	1.0	1.0	-	-	1.0	-
7A.1	Abnormal extreme environmental	2.0	1.0	1.0	1.0	-	-	-	-	1.0	-	1.0	1.0	1.0	1.0	-	-	-	1.0

KEY TO LOADS:

S = Allowable design strength based on elastic design method
D = Dead loads
L = Live loads
F = Prestressing loads
P_o = Operating pressure loads
T_o = Operating temperature loads
R_o = Operating pipe reactions
E_o = Operating basis earthquake
E'_o = Safe shutdown earthquake
P_b = SBA or IBA pressure loads (including effect of chugging or condensation oscillation)
P_a = DBA (LOCA) pressure loads (including effect of chugging or condensation oscillation)
T_a = Pipe break temperature loads
R_a = Pipe break temperature reaction loads
R_r = Reaction forces, jet forces, and pipe whip forces associated with pipe break
SRV = Safety/relief valve discharge
SEQ = Sequential (all valves)
ADS = Automatic depressurization system (7 valves)
ASY = Asymmetric (3 valves)
SNGL = (1 valve)

NOTE: No live load (L) will be considered when determining equivalent static loads occurring from earthquake (OBE or SSE), SRV, chugging or condensation oscillation. The only contributor to mass is the dead load (D). (Applicable to platform at el 222'-6" and 223'-4" only.)

SECTION 6A.3

SAFETY RELIEF VALVE LOADS

6A.3.1 Introduction

This section discusses the methodology used for the design evaluation of the MSL SRV discharge system of Unit 2.

The discharge system is designed to minimize the loading on components inside the containment during SRV operations. Of particular concern is the avoidance of steam condensation instability associated with SRV discharge of high mass steam flux into a hot suppression pool. This phenomenon can induce high containment excitations that result in severe loading on components(1,2).

Unit 2 utilizes a Kraftwerk Union (KWU) designed T-quencher device connected to the end of the SRVDL in the suppression pool. Through a series of model and in-plant tests(3-8), KWU has shown that quenchers maintain their stable quenching performance even when local pool temperatures approach boiling.

Section 6A.3.2 discusses important plant and operating parameters that influence the thermal hydraulic performance of the quenchers and the associated loads on walls and submerged structures in the suppression pool. Justifications are provided to show that the results of KWU quencher tests, used as a basis for the KWU load specification for T-quenchers, are applicable to Unit 2 and can be used for design. The discussion includes methods for calculating boundary pressure loads, submerged structure loads, and quencher arm, body, and support loads (Section 6A.3.4).

In Section 6A.3.5, key results of the Karlstein quencher tests (KTG)(9,10) are compared with those of the Unit 2 load specification. This comparison shows that the Unit 2 load specification is bounding and hence conservative.

The effects of EPU (to a rated core thermal power of 3,988 MWt) on SRV loads have been evaluated, as documented in Reference 18. NMP2 is equipped with Kraftwerks Union (KWU) T-quencher devices. The methodology to calculate the SRV air-clearing loads employs pressure signatures derived from the KWU T-quencher test program to account for a design reactor pressure of ~1250 psig. This design basis reactor pressure (~1250 psig) for the NMP2 SRV loads definition is greater than the maximum safety setpoint of 1,241 psig established for the EPU. The EPU will not impact on the NMP2 design basis SRV air-clearing loads definition. Therefore, it is concluded that the current SRV loads definition is still applicable to the EPU. The evaluation concluded that Unit 2 SRV load definitions are not impacted by the power uprate for either first or subsequent SRV actuations. This conclusion was also confirmed for MELLLA+ operation.

6A.3.2 Thermal Hydraulic Design Consideration of the Quencher

A short description of the major physical phenomena and a summary of important parameters that influence the pressure oscillation is presented prior to discussing the thermal hydraulic quencher design.

6A.3.2.1 Description of the Physical Phenomena

The Unit 2 SRV discharge system for the MSLs consists of 18 SRVs, whose discharges are individually piped into the suppression pool through the SRVDLs. Inside the suppression pool, each SRVDL is connected to a quencher device that directs the discharge through more than 1,000 small holes.

There are several plant operational transients that can result in a pressure rise in the reactor vessel. During these transients, the SRVs will open as necessary to prevent the pressure from exceeding allowable limits. Following this SRV actuation, steam flows into the discharge line of the relief system. The discharge line is normally filled with air and a column of water at the submerged end. The inertia effect of the water column slows the outflow of the enclosed air volume and causes the discharge line to be pressurized. The increased pressure affects acceleration of the water column that is eventually expelled from the discharge system through the quencher outlet. This phenomenon is known as vent clearing. The vent clearing process induces loads on the discharge line and quencher arms, body, and support. These loads are discussed in Appendix 6D, Sections 6D.3.4.4 through 6D.3.4.6.

The vent clearing of water is followed by the expulsion of the initially enclosed steam-air mixture through the quencher holes. This exhausted pressurized gas (steam-air mixture) forms an oscillating system with the surrounding pool water in which the gas acts as the spring and the water as the mass.

This steam-air bubble coalition continues to oscillate while rising due to buoyancy. KWU tests(3-8) have shown that the oscillating pressure usually becomes negligible before the bubble rises to the water surface.

The bubble pressure oscillation induces flow fields in the suppression pool. As a result, the wetted suppression pool boundary experiences a pressure loading, and the components submerged in the pool experience submerged structure loadings. These are discussed in Appendix 6D, Sections 6D.3.4.7 and 6D.3.4.8.

6A.3.2.2 Vent Clearing Pressure

(Proprietary - See Appendix 6D, Section 6D.3.2.2.)

6A.3.2.3 Major Parameters Influencing Pool Pressure Oscillation

(Proprietary - See Appendix 6D, Section 6D.3.2.3.)

6A.3.2.3.1 Suppression Pool Temperature Limits

With regard to the influence of suppression pool temperature on pool pressure amplitude described in Appendix 6D, Section 6D.3.2.3, Item 2, emergency operating procedures (EOPs) have applied the conclusions of NEDO-30832, "Elimination of Limit on BWR Suppression Pool Temperature for SRV Discharge with Quenchers." The conclusions are that the need for temperature limits on BWRs which use T-quenchers is no longer necessary. It further concludes that the SRV condensation loads are low compared to loads due to other events which are already considered in the containment structural evaluations. However, Technical Specifications establish an operating envelope for suppression pool temperature (110°F reactor scram requirement) and reactor pressure (1052 psig automatic reactor scram) which is more restrictive than the operating envelope defined in Figure 6D.3-1 of Appendix 6D.

6A.3.2.4 Thermal Performance of the Quencher

(Proprietary - See Appendix 6D, Section 6D.3.2.4.)

6A.3.3 Unit 2 SRV Discharge System Description

The Unit 2 SRV discharge system consists of 18 SRVs that are set to open at one of five pressure levels (Table 6A.3-1). Two valves are set at the lowest level and four valves each are set at one of the other four levels. Each of the SRVs discharges into a pipe that directs the steam flow into the suppression pool. The discharge line ends in a vertical run of pipe and is connected through a sliding joint to a KWU-designed T-quencher device (Figure 6A.3-1 and Figure 6D.3-2 of Appendix 6D).

6A.3.3.1 SRV Specification

Unit 2 uses 18 Dikker's direct-acting SRVs for the four MSLs. Each valve has a separate spring-actuated safety setpoint and a pneumatic-actuated relief setpoint (Table 6A.3-1).

6A.3.3.1.1 SRV Flow Rates

The valve steam discharge rate depends on the upstream (MSL) pressure (assuming choked flow through the valve throat). The maximum and minimum mass flux through the valves as a function of upstream pressure are given on Figure 6A.3-2.

6A.3.3.1.2 Valve Opening Time

The valve opening times for typical main steam SRVs are estimated to range from 20 to 150 msec. A recent test(11) has shown that for the Dikker's valve used in Unit 2, the typical valve opening time for steam flow is approximately 50 to 60 msec. Hence, the use of the 20-msec valve opening time yields conservative results for vent clearing analysis.

6A.3.3.1.3 Automatic Depressurization System

The ADS employs 7 of the 18 SRVs to rapidly depressurize the MSL under certain emergency conditions such as IBA. The ADS valves are actuated automatically and simultaneously. The quencher locations associated with these ADS valves are shown on Figure 6A.3-3.

6A.3.3.1.4 SRV Opening Events

There are a number of operational transients that can result in a pressure rise in the reactor vessel. SRVs are actuated as necessary to prevent the pressure from exceeding allowable limits. For most of these events, the SRV will open only once. However, some events can result in a closure of the MSIVs and subsequent cycling of the SRVs. Although a scram occurs simultaneously with the isolation, the reactor continues to generate steam due to core decay heat. Until the residual heat removal (RHR) system becomes available to extract the decay heat, the SRVs are the primary means of controlling pressure in the vessel.

For Unit 2, which is a 251 BWR/5 with motor-driven feedwater pumps, General Electric Company (GE) has estimated that a total of 5,200 valve actuations can occur over the 40-yr plant life (Table 6A.3-2)(12). The cumulative effect of these valve actuations needs to be evaluated on equipment and piping components (Section 6A.3.4.9).

6A.3.3.2 Discharge Line Geometry

The steam discharge from each SRV is piped into the suppression pool through discharge lines of various lengths. The drywell portion of the discharge lines consists of 10-in NPS Schedule 40 pipes while the suppression chamber portion consists of 12-in NPS Schedule 120 pipes. The discharge line geometries for the shortest (152 ft) and longest (224 ft) lines and the anchor points between the in-plant T-quencher and the SRVs are shown on Figures 6A.3-4 and 6A.3-5. The line length, submergence length and length of the first pipe segment between the SRV and the first elbow are provided in Table 6A.3-3. The numerical results of the maximum backpressure and flow rate are based on steady-state steam blowdown results which are calculated from SWEC computer program STEHAM (Appendix 3A). The corresponding line air volumes at high water level for these lines are 74 and 113.6 cu ft, respectively.

Two vacuum breakers in parallel are provided for each line above the drywell floor. The vacuum breakers are used to limit the reflood height of suppression pool water into the SRVDL and the resulting higher loading on subsequent valve actuations. Section 6A.3.4.1 provides a more detailed description of the vacuum breakers' performance.

The discharge line in the suppression pool is connected to the quencher through a sliding joint (Figure 6D.3-3 of Appendix 6D). The sliding joint design allows for an axial thermal expansion of the discharge line.

Tests of the KWU T-quencher design were performed at the Karlstein test facility with discharge line geometries very similar to those of Unit 2(9,10). The results verified the adequacy and performance of the quencher design in meeting design criteria (Section 6A.3.5).

6A.3.3.3 T-Quencher Geometry

(Proprietary - See Appendix 6D, Section 6D.3.3.3.)

6A.3.3.4 Quencher Arrangement in the Suppression Pool

The 18 quenchers associated with the 18 SRVs are arranged in the form of a ring in the suppression pool (Figure 6A.3-3). The quenchers are supported from the basemat of the pool with the center line of the quenchers 3.5 ft above the basemat. The azimuthal locations of the quenchers have been arranged in such a way that quenchers associated with SRVs of the same pressure setpoints are spaced out around the pool to distribute the loads as uniformly as possible.

6A.3.4 SRV-Related Loads

The quencher design has a significant effect on the vent-clearing transient and its associated loads. The loading conditions on the discharge system are described in the following sections. These loading conditions apply to the SRV piping and quencher body, arms, and support.

6A.3.4.1 SRV Backpressure

The maximum SRV backpressure during steady-state blowdown was investigated analytically(13) and by GE computer code RVFOR04(14) for the Unit 2 discharge system. As expected, the longest line yields the highest SRV backpressure. In all cases, the maximum steady-state SRV line pressures are less than the GE-specified design value of 575 psig.

The transient SRV backpressure was also investigated for both the first actuation case and the subsequent actuation case. In the subsequent actuation case, the SRV was assumed to open at peak reflood (as predicted by GE computer code RVR1Z02(15) and assuming only one of the two vacuum breakers was operating). In all cases, the maximum transient SRV line pressures are found to be less than the GE-specified design value of 625 psig.

6A.3.4.2 SRV System Water Clearing Pressure Load

(Proprietary - See Appendix 6D, Section 6D.3.4.2.)

6A.3.4.3 SRV Discharge Line Loads

During water clearing, different portions of the discharge line are subjected to various dynamic loads due to flow changes within the line (pressure and momentum changes). These loads are generated using the SWEC computer code STEHAM (Appendix 3A), which models the discharge line, sliding joint, and quencher.

The impacts of these dynamic loads are analyzed using one of the piping analysis computer programs (Appendix 3A). The resulting stresses are then combined with other loads to evaluate the design adequacy in meeting applicable piping code requirements.

The KWU-specified load on the discharge system due to the sliding joint at the quencher is shown on Figure 6D.3-5 of Appendix 6D.

6A.3.4.4 Quencher Body Loads

(Proprietary - See Appendix 6D, Section 6D.3.4.4.)

6A.3.4.5 Quencher Arm Loads

(Proprietary - See Appendix 6D, Section 6D.3.4.5.)

6A.3.4.6 Quencher Support Loads

(Proprietary - See Appendix 6D, Section 6D.3.4.6.)

6A.3.4.7 Loads on Suppression Pool Wetted Boundaries

(Proprietary - See Appendix 6D, Section 6D.3.4.7.)

6A.3.4.8 Loads on Submerged Structures

(Proprietary - See Appendix 6D, Section 6D.3.4.8.)

6A.3.4.9 Fatigue Load Analysis

GE has estimated that over the 40-yr operating life of a BWR plant, a total of 253 events can occur that would result in the actuation of one or more SRVs(11). Of these events, 169 are isolation-type events that cause a cycling of the SRV and constitute a majority of the estimated total of 5,200 SRV actuations for the low set valves in Unit 2.

The actuation of these SRVs and the associated steam condensation in the suppression pool generate hydrodynamic loads that act on plant components either directly, in the form of hydrodynamic forces on submerged structures, or indirectly in the form of support excitations resulting from the building acceleration response to the suppression pool wetted boundary pressure loading. The cumulative effect of these loads over the 40-yr plant operating life can lead to fatigue on the affected components and must be considered in the design evaluation.

A complete fatigue assessment in accordance with applicable ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, is performed on downcomers, SRVDLs in the wetwell, and Safety Class 1 piping components affected by the SRV-related loads. This evaluation is supplemental to the design loads specified elsewhere in this section. A brief summary of the methods used to perform the fatigue evaluation is presented in the following sections.

6A.3.4.9.1 Event Occurrence Analysis

(Proprietary - See Appendix 6D, Section 6D.3.4.9.1.)

6A.3.4.9.2 Equivalent Number of Load Occurrences

(Proprietary - See Appendix 6D, Section 6D.3.4.9.2.)

6A.3.4.9.3 Equivalent Stress Cycles

(Proprietary - See Appendix 6D, Section 6D.3.4.9.3.)

6A.3.4.9.4 Load Combinations and Fatigue Usage Factors

Piping and equipment in the primary containment are subject to numerous dynamic and hydrodynamic loads from normal, upset, and LOCA-related plant operating conditions. For purposes of fatigue evaluation, all of the following loads are included: 1) cyclic effects due to direct or indirect hydrodynamic loads including SRV actuation, CO, and chugging, 2) significant thermal and pressure transients, and 3) seismic events. The determination of load combinations is explained in Section 6A.2.2.

The affected components are analyzed for the appropriate load combinations. The combined stresses and corresponding equivalent stress cycles are computed to obtain the fatigue usage factors in accordance with applicable ASME III Codes. The cumulative usage factors (CUFs) of these components are then shown to be less than unity.

6A.3.5 Verification of SRV Load Specification

The quencher design for Unit 2 and the load specification on the wetted boundaries of the suppression pool, on the submerged structures, and on the pressure relief system, are based on parametric model test studies and full-scale in-plant test results from a similar quencher design used in KWU BWR plants. In order to verify these load specifications and further verify the quencher's steam-condensing characteristics, full-scale, single-cell tests were conducted at the KWU test facility at Karlstein, West Germany. Appendix 6D, Section 6D.3.5.1, contains a brief description of the test objective, test setup, and test results.

6A.3.5.1 Karlstein Quencher Tests

(Proprietary - See Appendix 6D, Section 6D.3.5.1.)

6A.3.5.2 Applicability of Test Results to Unit 2

(Proprietary - See Appendix 6D, Section 6D.3.5.2.)

6A.3.5.3 Comparison of SRV Load Specification to Test Data

(Proprietary - See Appendix 6D, Section 6D.3.5.3.)

6A.3.5.4 Compliance with NUREG-0763 - Guidelines for Confirmatory In-plant Tests of Safety/Relief Valve Discharges for BWR Plants

Unit 2 uses the same T-quencher designed by KWU as that used in Susquehanna Steam Electric Station (SSES) and tested at Karlstein. The quencher arm, body, and hole pattern are all the same; therefore, the quencher performances are anticipated to be similar. Appendix 6D, Table 6D.3-14, provides a comparison of the discharge line parameters for Karlstein, SSES, and Unit 2. The discharge line parameters, geometry, and vacuum breaker size are very similar to each other. Furthermore, the quencher location and orientation in Unit 2 are similar to the Karlstein test configuration, and the concrete containment which Unit 2 used in its design would preclude any significant fluid structure interaction. Therefore, it is concluded that the Karlstein tests have provided sufficient confirmation of the Unit 2 SRV load specification and that no plant-specific SRV testing is necessary.

Further discussion of the similarity of Unit 2 SRV discharge conditions to those of other plants is provided in the following sections.

6A.3.5.4.1 Introduction

This section presents justification that there is no need to perform plant-specific SRV testing to confirm the adequacy of quencher loads used in the Unit 2 design. NUREG-0763(16) states that in-plant testing is required to substantiate SRV load specifications unless the applicant can demonstrate that discharge conditions in its plant are sufficiently similar to those in previously tested plants. This action precludes the need for additional testing. To date, one U.S. BWR Mark II plant, LaSalle County Station (LSCS), has performed in-plant SRV testing, and SSES has performed full-scale prototypical SRV testing.

The discussion herein compares the critical parameters of Unit 2 with those of the Limerick Generating Station (LGS), LSCS, and SSES projects as outlined in NUREG-0763. NUREG-0763 provides five criteria which must be satisfied to show that existing test data are applicable to a particular plant. These criteria were established to examine the key parameters that affect hydrodynamic loads and pool temperature gradients (and are not concerned with plant parameters that do not affect these loads). Specifically, the criteria address plant similarities for the quenchers, SRVDLs and their configuration, mass flow rates, suppression pool geometries, and structural parameters in the pool region which might influence the loading definition. The criteria do not consider differences in plant parameters which do not affect the loading definition.

The comparison of key parameters demonstrates that the comparison of these plants provides sufficient confirmation of the Unit 2 SRV load specifications. All important quencher, SRVDL, suppression pool geometry, and structural properties at Unit 2 are similar to SSES, LSCS, and LGS; therefore, SSES and LSCS SRV discharge test data provide adequate confirmation for the Unit 2 design loads, and an in-plant SRV discharge test is not required for Unit 2.

6A.3.5.4.2 Evaluation of Criteria

Each of the five criteria in NUREG-0763 is examined to demonstrate that the key conditions affecting SRV loading are similar to previously tested plants. The key parameters affecting the suppression pool hydrodynamic loads have been identified by extensive generic test programs. With this information, the intent is to examine each of the five criteria and demonstrate that similarities exist among LSCS, LMG, SSES, and Unit 2, and that a sound basis exists for the definition of the SRV discharge hydrodynamic loads. The criteria are stated, a comparison is made with the plants, and any differences are discussed.

Criterion 1

This criterion requires that the discharge device be similar to those previously tested.

The T-quencher for LSCS, SSES, LGS, and Unit 2 was designed by KWU. The essential parameters of the quenchers (quencher configuration, arm dimension and spacing, hole pattern and sizes) are the same for each plant.

Criterion 2

This criterion states that discharge line parameters, line length, area and volume, quencher submergence, vacuum breaker size, and available pool area per quencher must be similar to previously tested plants.

A comparison of the SRV line parameters for LSCS, SSES, LGS, and Unit 2 is made in Table 6A.3-4. The SRVDL air volume, submergence, and vacuum breaker size do not differ significantly.

Table 6A.3-4 indicates that the Unit 2 SRVDL air volume is within 5 percent of the SSES air volume and bounded by LSCS.

The influence of the vacuum breakers is primarily on consecutive valve actuation (CVA). Because Unit 2 and SSES have the same vacuum breaker size, the SSES test results will be applicable to Unit 2.

The effect of SRVDL lengths is primarily on SRV backpressure. The longest line length for Unit 2 is 14 percent longer than LSCS's longest SRVDL. The longer SRVDL will increase the line pressure drop due to higher (fl/D) friction losses. This increases the backpressure on the SRV exit and, if permitted to become large enough, will allow the SRV flow to become unchoked, reducing its effectiveness for reactor pressure relief. To address this concern, the SSES DAR reported SRV test backpressures at 319 psi at 1,080 psi reactor pressure of the 625 psi allowable. The Unit 2 frictional losses are greater than those of SSES. The maximum expected backpressure for Unit 2 at the same test conditions would be slightly greater. For Unit 2, the backpressure is 527 psi at 1,535 psi reactor pressure of the 625 psi allowable. Since the longest line length at Unit 2 produces backpressures less than the allowable, line length is not a problem.

In conclusion, the longest Unit 2 SRVDL will produce the predicted pool pressures while ensuring that SRV flow remains choked with line pressures well below the allowable.

The available pool surface area has not been found to affect bubble frequency, but the pressure amplitude tends to decrease with the increase of available pool surface area. It has been found that SSES has approximately the same pool surface area per quencher as Unit 2.

Criterion 3

Criterion 3 states that the flow rate of the steam per unit area of discharge line and the net flow rate of steam through the line may determine the air column dynamics and pool temperature gradients during an extended actuation. These parameters must be similar to those of previously tested plants.

The steam flow rate per unit area of discharge line and the net flow rates for Unit 2, SSES, and LGS are shown in Table 6A.3-4.

During an extended valve actuation test, it is expected that these plants should have similar performances.

Criterion 4

This criterion states that the quencher location and orientation in the pool and pool geometry must show that all features of the pool configuration are similar to previously tested plants.

Table 6A.3-5 compares quencher data among Unit 2, SSES, LSCS, and LGS. Based on the data given, there are no significant differences. The pool depth at Unit 2 is between LSCS and SSES. In order to compare Unit 2 submergence depths, pool widths vary among plants. For Unit 2, the pool width is approximately 10-percent wider than the SSES pool width; however, the pool area per quencher is similar (see Table 6A.3-4). It is further noted that all Unit 2 geometry is very similar to the full-scale prototypical test stand geometry at Karlstein performed by SSES.

Criterion 5

The characteristics of the containment structure may affect peak boundary pressure and frequencies of air bubble oscillation. For example, in-plant tests conducted in a concrete containment will not be considered to have direct application for a freestanding steel containment unless adequate justification for fluid/structure interaction has been demonstrated.

Since SSES, LGS, LSCS, and Unit 2 have similar plant construction, this is adequate justification that similar fluid/structure interaction is prevalent for these three plants. The Unit 2 containment is a concrete structure effectively 5.25-ft thick, with a steel liner 3/8-in thick in the suppression pool area (see Table 6A.3-6); this is slightly thinner than SSES and LGS, but thicker than LSCS.

6A.3.5.4.3 Conclusion

The comparison of key parameters for each of the five criteria presented and addressed in the previous sections demonstrates that discharge conditions are sufficiently similar among Unit 2, LSCS, SSES, and LGS. LSCS has performed an in-plant SRV test. The SSES quencher was verified under full-scale single cell tests conducted at the KWU laboratories in Karlstein, West Germany. The SRVDL characteristics, suppression pool geometry, and structural properties are similar for all three plants. From this comparison, the need is eliminated for in-plant testing to substantiate the SRV load specification at Unit 2. Those items that do differ slightly, such as soil shear wave velocity, do not have a significant effect on SRV loadings. Therefore, Unit 2 meets the criteria established in NUREG-0763 for exemption from in-plant testing.

6A.3.6 References

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TABLE 6A.3-1

SRV AND DISCHARGE LINE PARAMETERS

Line No.	Valve No. SRV	Nominal Relief/ Spring Set Pressures (psig)	Ties to ADS	Line Length (ft)	Quencher Location	
					Deg	Min
1	124	1113/1175		172	149	16
2	125	1123/1185		182	167	16
3	126	1133/1195	Yes	170	131	16
4	127	1143/1205	Yes	170	95	16
5	128	1103/1165		168	113	16
6	120	1123/1185		152	77	16
7	121	1133/1195	Yes	156	41	16
8	122	1123/1185		176	5	16
9	123	1113/1175		170	23	16
10	134	1143/1205	Yes	164	293	16
11	135	1133/1195		224	311	16
12	136	1113/1175		199	329	16
13	137	1143/1205	Yes	223	347	16
14	129	1143/1205	Yes	164	195	00
15	130	1133/1195	Yes	155	239	16
16	131	1113/1175		188	221	16
17	132	1123/1185		157	275	16
18	133	1103/1165		160	257	16

TABLE 6A.3-2

TOTAL NUMBER OF LOW SET SRV ACTUATIONS FOR UNIT 2

Type of Event	No. of Events/ 40-yr Plant Life	SRV Actuations/ Events	Total No. of SRV Actuation/ Event Type
Isolation	169	30	5,070
Other	84	1	84
Total	253	31	5,154*

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* Total number of SRV actuations to be used for design is rounded up to 5,200.

TABLE 6A.3-3

DIMENSIONS FOR SHORTEST AND
LONGEST SRV DISCHARGE LINE

	Longest Discharge Line	Shortest Discharge Line
L1	20.42	20.42
L2	224.00	152.00
L3	9.2	15.2

L1 = Submergence length (ft) (from normal water level to centerline of the T-quencher)

L2 = Line length (ft)

L3 = Length of the first pipe segment between the SRV and first elbow (ft)

TABLE 6A.3-4

COMPARISON OF SRV DISCHARGE LINE PARAMETERS

Parameter	Unit 2	SSES	LGS	LSCS
SRVDL air volume (ft^3)/line length, ft				
Maximum	113.6/224	110.7/158.4	94.8/144.9	147/192
Minimum	74/151.47	77.6/114.47	74.2/116.4	99/131
Pool area/quencher, ft^3	326.3	338.8	355.3	288
Submergence, ft (HWL)	21.5	20.5	20.75	21.5
Vacuum breaker, diameter	2'-6"	2'-6"	NA	NA
Steam flow rate per unit area at 1,150 psig, lb/hr ft^2	1,609,489	1,047,643	1,168,152	-
Net steam flow at 1,262 psig, lb/hr	1,186,000	1,103,040	1,232,043	-

TABLE 6A.3-5

COMPARISON OF QUENCHER DATA

Parameter	Unit 2	SSES	LGS	LSCS
Distance from bottom of drywell floor to centerline of quencher arm, ft	56.3	52.3	56	55.3
Distance from top of basemat to centerline of quencher arm, ft	3.5	3.5	3.5	5.0
Submergence, ft	21.5	20.5	20.75	21.5

TABLE 6A.3-6

COMPARISON OF CONTAINMENT CHARACTERISTICS

Parameter	Unit 2	SSES	LGS	LSCS
Containment material	Concrete	Concrete	Concrete	Concrete
Wall thickness in pool region, ft	5.25	6.0	6.16	5
Basemat thickness, ft	10	8	8	-
Drywell wall thickness, ft	5.25	3.5	3.5	3.5
Pool width, ft	31.34	28.5	25.2	28.5
Pool depth, ft	25	24	24.25	26.6
Pool surface area, ft^2	5,873	5,421	4,974	5,187
Soil shear wave velocity, ft/s	7,700	6,180	5,950	-

SECTION 6A.4

LOCA LOADS

6A.4.1 Introduction

A general description of the LOCA is given in Section 6A.2.1.2. As a result of mass and energy release associated with a LOCA, pressure and temperature transients will be experienced concurrently in the drywell and suppression chamber. Dynamic loading, which is generally termed the dynamic forcing function, will act on the containment system. The drywell and suppression chamber pressure and temperature transients are presented in FSAR Section 6.2.1.

The LOCA Loads discussion presented in the following sections represents the basis for the original DAR for Hydrodynamic Loads. In support of the EPU project to increase plant licensed power to 3,988 MWt, the impact of the power increase on this Hydrodynamic Loads assessment was performed as documented in Reference 29. That evaluation addressed the potential impact of EPU on the following LOCA loads definitions:

1. Pre-Vent Clearing Jet Loads

2. Pool Swell Loads

3. Condensation Oscillation Loads

4. Chugging Loads (including Chugging duration)

Based upon that evaluation, it was concluded that the above LOCA loads at EPU remain bounded by the original loads described in this Appendix. The MELLLA+ evaluation determined that the original loads remain bounding for operation in the MELLLA+ domain.

6A.4.2 LOCA Water Jet

Following a DBA, the drywell will pressurize and expel the water in the downcomers. Due to this downcomer clearing phenomenon, water jets that may produce pressure loads on the containment basemat and the submerged suppression chamber walls are formed in the suppression pool. Additionally, drag loads may be induced on structures in or near the path of the jets. SRVDLs and the quencher devices are the only structures in the suppression pool that are in the vicinity of the jet paths. The drag loads induced by the LOCA water jets on the SRVDL and quencher are presented in Section 6A.4.9. No other structures lie within three radii of a downcomer or one radius below the downcomer elevation, and beyond this region, any drag load that can possibly be produced by the induced flow field of the water jet is negligible and is not considered.

6A.4.2.1 Drag Load on the Downcomer During Downcomer Clearing Phase

A vertically downward load on the downcomer results from the frictional drag forces between the water and the inside wall of the downcomer. These loads are generally very small when compared to other loads on the downcomers.

The vertical drag load due to venting of air following complete water expulsion is 600 lb per downcomer (Section 4.2.3.2 of NEDO-21061(1)). This value is very low; therefore, it is not considered in the structural evaluation of the primary containment.

6A.4.2.2 Submerged Boundary Loads During Downcomer Clearing

The downcomer clearing phenomenon following a LOCA results from the clearing of water from the downcomers due to drywell pressurization. As a result of the phenomenon, pressure loads are produced on the primary containment basemat and the submerged suppression chamber walls. Section 2.1.2.1 of NUREG-0808(2) defines the acceptable load methodology applicable to the downcomer clearing phase of a LOCA as follows: The NRC acceptance criteria(1) stipulate that the overpressure (above local hydrostatic) on the basemat and walls below the downcomer exit is determined as follows:

First, define a parameter:

$$F = (\dot{m}hL)/\left[A_p / A_v)\right]$$

Where:

$\dot{m}$ = Mass flow, 17,363 lb/sec

V_{DW} = Drywell volume, 302,275 ft^3

h = Enthalpy, 169.2 Btu/lb

L = Submergence, 11.68 ft

$\frac{A_p}{A_v}$ = Suppression pool area to downcomer area ratio, 5,800/356.74

F = Plant parameter, Btu/ft^2/sec

Then:

P = 24 when F <55

or

$P = 24 + 0.27 (F-55)$ when $F \geq 55$

Where:

P = Peak overpressure between suppression pool bottom and bottom of downcomer in psi

The value of parameter F is 6.98, which is less than 55; hence, overpressure specification is 24 psi. The duration of this load is 0.79 sec (Table 6A.4-3). Load application for structural assessment is done in the following way: 24 psi overpressure (above local hydrostatic) is applied on the basemat and walls below the downcomer exit. On the walls of the suppression pool between the suppression pool surface and the bottom of the downcomers, the 24-psi overpressure is varied linearly with zero overpressure at the suppression pool surface.

6A.4.3 LOCA Charging Air Bubble

After the water is cleared from the downcomer, the air in the downcomers and the drywell flows into the suppression pool. Air bubbles form at the downcomer exits. The bubble center is assumed to be stationary on the downcomer centerline, one downcomer radius below the downcomer exit. As the bubble is charged from the drywell it continues to expand, establishing acceleration and velocity fields in the pool. The motion of the suppression pool water results in drag loads on submerged structures. The LOCA charging bubble is considered part of bulk suppression pool swell for purposes of suppression pool boundary load assessment. Suppression pool boundary loads due to suppression pool swell are discussed in Section 6A.4.4. Submerged structure loads due to LOCA charging bubble are presented in Section 6A.4.9.

6A.4.4 Suppression Pool Swell and Fallback

In general, structures and components within the suppression chamber may be subjected to impact and drag loads during suppression pool swell and fallback. Suppression pool swell is the term describing the upward movement of the suppression pool water above the exit plane of the downcomers due to the injection of drywell air beneath the pool surface. The suppression pool swell phenomenon occurs immediately after downcomer clearing and after the formation of air bubbles at the downcomer exit plane following a large break accident. As air flow continues from the drywell, the bubbles expand and coalesce; and subsequent suppression pool motion is essentially one-dimensional upward. The continued expansion of the air bubble forces the slug of water above it to accelerate and rise upward causing the suppression pool swell.

The velocity of the suppression pool surface associated with this phenomenon causes impact and drag forces to be exerted on structures that are within the swell zone. Suppression pool swell is eventually terminated due to the compression of air in the suppression chamber free space and the negative acceleration due to gravity. Once the swell is terminated, a communication path is established between the air bubble and the air in the suppression chamber free space which causes a rapid equalization of the bubble and free space pressures. Driven by natural buoyancy, the air bubble percolates through the suppression pool water slug and the suppression pool water slug falls back to the remaining portion of the suppression pool under the force of gravity. This process is defined as suppression pool fallback.

The suppression pool swell analytical model (PSAM) is described in Section 4.2.2 of NEDO-21061(1). Figure 6A.4-1 shows the schematic representation of the pool swell model.

The SWEC computer code, LOCTVS(3), used for predicting primary containment pressure and temperature response following a large break accident, incorporates a suppression pool swell model which is essentially similar to PSAM.

The only significant difference is the estimation of the drywell temperature. LOCTVS code calculates drywell temperature based on complete mixing of air and hot fluid from the break, whereas PSAM calculates the drywell temperature considering adiabatic compression of the air. This results in somewhat milder air bubble pressure for LOCTVS. However, considering a high degree of turbulence under large break conditions, LOCTVS modeling of the drywell temperature is more realistic. Therefore, the Unit 2 suppression pool swell velocity, acceleration, elevation, air bubble pressure, and suppression chamber free space pressure transients are calculated with the LOCTVS code.

Suppression pool fallback velocity and acceleration calculations are based on the free-falling fluid slug, described in Section 4.2.3.6 of NEDO-21061(1).

6A.4.4.1 Pool Swell Loads

Loads resulting from pool swell include both impact on structures above the initial elevation of the suppression pool surface, but below the maximum swell height, and drag on structures. The impact force on a body occurs over a time period; typically, the force versus time profile during this period is such that the force increases to a maximum value during the first half of the time period and then decreases to the value of the drag force during the second half of the period, assuming flow continues around the structure. A typical force profile measured during GE Pressure Suppression Test Facility (PSTF) tests is shown on Figure 4.4-23 of NEDE-21061-P(4). The duration of the force varies from about 7 msec for small structures to about 100 msec for large structures. The drag forces apply as long as the structure is surrounded by the water slug.

In addition to impact/drag loads, suppression pool swell also causes vertical drag loads on downcomers, air bubble (pressure) loads on the primary containment wall and basemat, and an upward differential pressure load across the drywell floor due to suppression chamber free space air compression.

The suppression pool swell phenomenon described earlier is analyzed, based on NUREG-0808(2), using plant parameters listed in Table 6A.4-1.

1. Suppression Pool Swell Elevation

   NUREG-0808 specifies that the maximum suppression pool swell height shall be taken as the greater of Items a or b:

   a. 1.5 times the downcomer submergence.

   b. Elevation corresponding to a drywell floor uplift ΔP = 2.5 psid.* The suppression pool surface elevation corresponding to the maximum suppression chamber air compression will be calculated assuming a polytropic process with an exponent of 1.2. For Unit 2, Item b yields the maximum pool swell height.

2. Suppression Pool Swell Velocity

   NUREG-0808 specifies that the suppression pool swell velocity used to determine impact and drag loads on suppression chamber components shall consist of the velocity predicted by the suppression pool swell analytical model described in NEDE-21544-P(6) multiplied by a factor of 1.1. For Unit 2, the LOCTVS pool swell velocity is multiplied by a factor of 1.1.

3. NUREG-0808 specifies that the air bubble pressure be calculated in a similar way to the pool swell velocity.

4. NUREG-0808 specifies that the suppression chamber air pressure should be consistent with the pool swell elevation analysis.

The DBA for this analysis is the double-ended rupture (DER) of a recirculation pump suction line. The short-term pressure transient includes the effect of inventory in the broken recirculation line. The drywell pressure transient is summarized in Table 6A.4-2.

Table 6A.4-3 lists the results of the suppression pool swell analysis. It is noted that the Unit 2 design basis analysis assumes the suppression chamber air compression exponent of 1.2 (i.e., polytropic process) for all pool swell parameters of interest. The use of the polytropic exponent of 1.2 as opposed to the isentropic value of 1.4 for pool swell velocity is conservative. Figure 6A.4-2 shows the drywell, air bubble, and suppression chamber airspace pressure histories up to the time of maximum swell height. After maximum swell height has been reached, the suppression chamber pressure is taken to be that from the primary containment analysis transient presented in FSAR Section 6.2. Figures 6A.4-3 and 6A.4-4 give the pool swell elevation and velocity as a function of time following the DBA. Figure 6A.4-5 shows suppression pool swell velocity as a function of suppression pool swell elevation.

The LOCTVS pool swell results for Unit 2 were benchmarked indirectly against the PSAM predictions in two steps. First, the SWEC equivalent of PSAM called POSHY** was used to model PSAM benchmark case 2 of Section 4.2.3.4, NEDO-21061(28). POSHY results are virtually identical to PSAM results, as shown on Figures 6A.4-50 through 6A.4-53. Secondly, POSHY (equivalent of PSAM) was used to predict the Unit 2 pool swell transient resulting from the input specified drywell pressure transient predicted by LOCTVS. The LOCTVS and POSHY pool swell results are compared on Figures 6A.4-54 through 6A.4-57. These comparisons show favorable agreement between the LOCTVS and POSHY pool swell velocity and pool swell height predictions. The somewhat large difference observed in the bubble pressure predictions is attributed to the use, in LOCTVS, of the drywell homogeneous temperature for the bubble rather than the temperature resulting from the assumption of adiabatic compression as in PSAM. The maximum difference is less than 3.5 psi. As stated in Section 6A.5.2.1, the dynamic response of the primary containment structures due to the pool swell is not significant and is bounded by other LOCA-related loads. The design of safety-related components other than the primary containment structures affected by the air bubble load is generally bounded by other LOCA-related loads. These components have been evaluated and can withstand the additional 3.5 psi air bubble load.

6A.4.4.1.1 Impact Loads on Small Structures Due to Suppression Pool Swell

A small structure upon impact causes the water to flow around it, thereby sustaining impact and drag forces. In this DAR, the term small structure refers to pipes, I-beams, and other similar structures having any one dimension less than or equal to 20 in(1,5).

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* ΔP = 5.5 psid is used to calculate the maximum suppression pool swell elevation. This yields about 1/2 ft of additional pool swell which is conservative.

Impact loads on small structures located above the initial pool surface, but below maximum pool swell height, are discussed and calculated in Section 6A.4.9.

6A.4.4.1.2 Impact Loads on Large Structures from Pool Swell

A structure is considered large if it has both dimensions in the horizontal plane greater than 20 in(1,5). Unit 2 does not have any large structures within the suppression pool swell zone.

6A.4.4.1.3 Drag Load on the Downcomer Due to Suppression Pool Swell

During suppression pool swell, an upward drag load is applied to each downcomer over a constant length of 11.7 ft (Table 6A.4-1).

** This code was previously used for Shoreham Nuclear Power Station plant design assessment report (Appendix H).

The load evaluation is based on the approach presented in Section 4.2.4.2 of NEDO-21061(28), subject to the following acceptance criteria.

<u>Applicable Criteria</u>

Acceptance Criteria A.2 (Pool Swell Velocity) of NUREG-0808(2).

<u>Load Evaluation</u>

Only standard drag is evaluated, since flow is parallel to the downcomer. Based on Section 4.2.4.2 of NEDO-21061(28), the drag force is determined as follows:

$$F_f = \frac{\pi C_f L D \rho (1.1V)^2}{2 g_c} \qquad (6A.4\text{-}1)$$

Where:

F_f = Frictional load, lbf

C_f = Frictional drag coefficient, 0.455/(log Re), 2.58 (0.00243)

= $\left[0.455/(\log \mathrm{Re}_L)^{2.58}\right] = 0.00243$

Re_L = Reynold's No.

L = Maximum downcomer submergence (11.69 ft)

D = Downcomer OD (2 ft)

ρ = Water density (62.11 lbm/ft^3) at 90°F

V = Maximum suppression pool swell velocity predicted by LOCTVS suppression pool swell model (28.3 ft/sec)

g_c = Gravitational constant (32.174 ft-lbm/lbf-sec^2)

The upward drag force per downcomer during suppression pool swell is 167 lbf. This load is insignificant compared to the other loads on the downcomer.

6A.4.4.1.4 Drag Loads on Structures Other Than Downcomers Due to Suppression Pool Swell

During suppression pool swell, structures initially submerged (above the downcomer exit plane) and structures below maximum suppression pool swell elevation (initially not submerged) will experience a drag force in the vertical direction and a lateral force in the horizontal plane.

Load evaluation methodology is discussed in Section 6A.4.9.

6A.4.4.1.5 Loads on Grating Due to Suppression Pool Swell

There is no grating located in the suppression pool swell zone for Unit 2.

6A.4.4.1.6 Suppression Chamber Boundary Loads Due to Suppression Pool Swell

The pressure developed in the air bubble will cause additional loading on the suppression chamber walls. At the same time, the suppression chamber boundaries above the instantaneous suppression pool surface are loaded by the increase in suppression chamber airspace pressure. The maximum value of these pressures is obtained from the LOCTVS suppression pool swell model and applied statically as uniform increases in the suppression pool hydrostatic pressure. This method, as described in Section 4.2.5.1 of NEDO-21061(1), is acceptable to the NRC in accordance with Section III.B.3.b of NUREG-0487(5) and Section 2.1.2.5 of NUREG-0808(2). The loading condition is shown conceptually on Figure 6A.4-6.

The maximum air bubble pressure is taken from Figure 6A.4-2 and the maximum suppression chamber pressure is taken to be the instantaneous drywell pressure (at peak drywell floor upward loading time) plus the maximum uplift differential pressure of 5.5 psid. Suppression pool swell boundary loads are not applied to the pedestal, since there are downcomers within the pedestal, and since the ratios of suppression pool surface to downcomer area for outside pedestal and inside are not significantly different. However, a conservative bounding analysis was done to evaluate the differential pressure loading across the pedestal wall. The outside region has 49 sq ft of pool surface area per downcomer whereas the inside region has 37 sq ft pool area per downcomer. This results in a maximum of 4.3 psid pressure difference (inside to outside) across the pedestal in the bubble region. The analysis was performed in two steps. First, a pool swell analysis was done for the pedestal region considering the appropriate geometry. Next, the pool swell analysis was repeated for the region outside the pedestal. The difference between the predicted bubble pressures for each pool swell transient represents the load on the pedestal. As explained in Section 6A.4.4.1, the LOCTVS code underpredicts the air bubble pressure by about 3.5 psi. However, this underprediction does not affect the 4.3 psid maximum pedestal loading which is based on the difference between two LOCTVS generated bubble pressure transients. The pedestal design was checked for the air bubble load and found to be acceptable. The effect of asymmetric bubble loading equal to 20 percent of maximum air bubble pressure applied to one-half of the submerged boundary, and zero gauge pressure on the other half of the boundary, is also considered.

6A.4.4.1.7 Drywell Floor Loads Due to Suppression Pool Swell

At the end of suppression pool swell, the potential exists for an upward differential pressure to act on the drywell floor due to the increase in suppression chamber air space pressure(1,2). Since there is no significant froth generated in the Mark II containment system as a result of suppression pool swell, no loads due to the froth are specified. Section 2.1.3 of NUREG-0808(2) considers a 5.5-psid upward differential pressure to be conservative and acceptable.

6A.4.4.2 Suppression Pool Fallback Loads

Structures in the suppression pool will experience drag loads during suppression pool fallback. The fallback drag load is computed based on the velocity and acceleration time-histories of the free-falling fluid slug, the standard drag, and acceleration drag equations.

Suppression pool fallback velocity and suppression pool elevation transients are shown on Figure 6A.4-7. These were based on the free-fall equation provided in NEDO-21061(1) for the fallback load calculation. The drag loads for structures other than downcomers are evaluated and shown in Section 6A.4.9.

The drag load on the downcomer during suppression pool fallback is evaluated using the method shown in Section 6A.4.4.1.3. The maximum fallback velocity of 34.6 ft/sec corresponds to a load of 207 lbf downward during suppression pool fallback. This load is insignificant compared to other loads on the downcomer.

6A.4.5 Condensation Oscillation

6A.4.5.1 Loads During Condensation Oscillation

The condensation oscillation (CO) period of a LOCA follows the suppression pool swell transient. During the CO period, both the steam mass flux and air content flowing through the downcomers are decreasing. The steam-water interface at the downcomer exit oscillates as the steam is condensed. The downcomer steam mass flux is sufficient to prevent suppression pool water backflow into the downcomer. The condensation process induces pressure loads on the drywell, downcomer, submerged structures, and suppression pool boundaries. As the downcomer steam mass flux continues to decrease, the steam-water interface can no longer be sustained outside the downcomer, and water reenters the downcomer until it is driven out by the drywell steam. This unsteady condensation phenomenon is commonly referred to as chugging. Loads due to chugging are discussed in Section 6A.4.6.

This section discusses loading conditions on the suppression pool and drywell boundaries. Downcomer lateral loads are discussed in Section 6A.4.7. Submerged structure loads are described in Section 6A.4.9.

6A.4.5.2 Data Base

The condensation phenomenon involves an unsteady, turbulent, two-component flow. The complexity of the phenomenon makes analytical modeling difficult. Consequently, the Mark II Owners Group decided to perform full-scale experiments that cover the range of conditions in Mark II plants.

The data base for the CO loading conditions on the drywell and pool boundaries is the test series TS5200 from GE's Mark II test program. Test series TS5200 is commonly referred to as the Temporary Tall Test Tank-CO (4TCO) tests. The 4TCO test facility was a single downcomer, full-scale model of the Mark II geometry with conservatively-sized suppression pool and drywell volumes. It has a prototypical downcomer length and drywell mounted over suppression chamber. The test series consisted of 28 blowdowns designed to investigate CO phenomena in the Mark II containment. The choice of the initial suppression pool temperature and the break size was made in order to cover the complete range of suppression pool temperatures and steam flow rates expected in Mark II plant LOCAs. The combination of initial temperatures in the range of 70°F to 100°F with 2.125-, 2.5-, 3.0-, and 3.8-in diameter Venturi sizes (in the test facility) covered the complete range of mass flux expected for the Mark II containment.

The results of the 4TCO tests are documented in NEDE-24811-P(7). The NRC reviewed this document and concluded that the 4TCO tests provide an appropriate data base for a conservative load specification for CO(2).

6A.4.5.3 Loading on Pool Boundary and Drywell

The Mark II generic CO load definition is a direct application of the 4TCO data. Two load cases are considered. The first load, basic CO, is a bounding representation of the CO load that may occur during a Mark II LOCA. The second load is for the load combination of CO and actuation of the ADS.

The bounding time intervals that define the basic CO load were selected on the basis of power spectral density (PSD) analysis of the suppression pool bottom pressure data from the entire 4TCO test series. The suppression pool bottom and drywell pressure time-histories corresponding to the bounding time intervals are applied directly to the primary containment structural model. Fluid-structure interaction studies were performed and it was concluded that direct use of the measured 4TCO pressure is conservative for the Mark II application(8).

The CO load for combination with ADS actuation was also defined on the basis of the 4TCO data. However, for reasons described in Section 6A.4.5.3.2, the data base for this load was limited to time periods with low downcomer mass flux from the small liquid break tests. These tests are most representative of Mark II plant conditions when ADS actuation would occur. An extensive description of the CO load definition can be found in NEDE-24288-P(9).

6A.4.5.3.1 Basic CO Load

The basic CO load is a bounding load for any CO condition expected during a hypothetical LOCA in a Mark II plant. It is composed of a group of pressure time-histories from the test data obtained during the 4TCO test program(9). The test data used are the suppression pool bottom center pressure (BCP) measurements and the drywell acoustic pressure measurements.

The CO periods of all the 4TCO test runs were analyzed to determine the bounding time periods. The criterion for the selection of these time periods was to bound the maximum PSD values observed in the BCP throughout the CO period in all runs, in any 2.048-sec block for all frequencies from 0 through 60 Hz in approximately 0.5-Hz increments. The time periods for the 4TCO runs, which compose the basic CO load, CO load for combination with ADS, and the CO duration in these runs, are given in Table 6A.4-4. Samples of suppression chamber bottom center and drywell pressure histories, and the envelope of PSD values observed for CO in 4TCO tests are shown on Figures 2.2, 2.3, and 2.1, respectively, of NEDE-24288-P(9).

6A.4.5.3.2 CO Load for Combination with ADS

The ADS in Unit 2 consists of seven SRVs that will open with coincident level 1 and level 3 low reactor water level signals, and at least one low-pressure ECCS pump running, after a 105-sec delay. The actuation of the ADS when there is downcomer blowdown flow into the suppression pool may lead to the simultaneous occurrence of loadings on the primary containment boundary due to the SRV discharge and the condensation at the downcomer exit.

The 4TCO test data show that the root-mean-square CO load magnitude is significantly lower at low downcomer steam mass flux values. Therefore, the CO load, which could conceivably occur at the time of ADS actuation, will be significantly lower than the basic CO load. Thus it is appropriate to define a second, more representative CO load for combination with the ADS load.

In defining the CO load for combination with the ADS load case, all 4TCO data were screened to determine which data are applicable for combination with ADS. Results of the data screening revealed that the 2.125-in liquid line break tests were appropriate. This is the smallest break size (0.025 sq ft per downcomer) tested in 4TCO. This break size is substantially higher than the range of Mark II plant break sizes (0.013 to 0.021 sq ft per downcomer) that produce maximum downcomer steam mass flux conditions at ADS actuation. Since the 4TCO test data show that, for the small break tested, the root-mean-square BCP decreases with a decrease in break size(7), the 2.125-in liquid line breaks were taken as a conservative data base for the CO load to be combined with the ADS.

Of the break sizes analyzed, which result in ADS actuation, the highest calculated downcomer steam mass flux at ADS actuation for all Mark II plants ranged from approximately 3 to 5 lbm/sq ft-sec. As an added margin, a downcomer steam mass flux of 6 lbm/sq ft-sec was taken as the upper bound value for downcomer steam mass flux at which Mark II plants can experience ADS actuation. The CO time periods in the 2.125-in liquid line break tests with downcomer steam mass flux less than 6 lbm/sq ft-sec are to be used for the CO load for combination with ADS. The time periods and CO durations in these runs are given in Table 6A.4-4.

6A.4.5.4 CO Load Inside Pedestal-Plant Unique Adjustments

The Unit 2 primary containment has downcomers erected in the cylindrical suppression chamber inside the pedestal. Therefore, CO load is also anticipated on the wetted pool boundary inside the pedestal. The procedure Unit 2 adopted to deduce the load specification on the wetted surface of the cylindrical pool is similar to the approach used by LaSalle Station in "Plant Unique Assessment of the 4TCO Data for LaSalle," documented in the "Generic CO Load Definition Report" (NEDE-24288P), and accepted by NUREG-0808.

Downcomers inside the pedestal wall are connected to a common drywell with the downcomers in the annular pool, and they have similar vent lengths. Therefore, the same steam condensation sources are applicable to downcomers in the cylindrical pool.

The only difference is the pool geometry. Since no significant pool modes are observed during CO, pool geometry affects only the CO pressure amplitude. The SWEC computer program ME214, CWL, (FSAR Appendix 3A), which employs the Green's function solution technique for the inhomogeneous wave equation (NEDE-24822P) is used to quantify the geometric effect. Table 6A.4-5 shows the amplitude ratio between the cylindrical pool and the annular pool over the observed CO frequency range. Since the CWL Code is an acoustic model, only the vent harmonic sources need to be input into the computer code. Vent harmonics lie between 0 and 30 Hz; therefore, monochromatic sources in this frequency range are used as the acoustic sources. The average pressure amplitude ratio between the inner and outer pool varies between 1.04 and 1.24. A conservative multiplier of 1.25 is used to define the CO load inside the pedestal. Unit 2 uses the same 19 CO load segments specified in the generic Mark II CO load definition given in NEDE-24288-P(9), which envelops the PSD values observed for CO in the 4TCO tests between 0 and 60 Hz.

The same time-history segments specified in the Mark II generic CO load definition were applied to the wetted surface of the two pools simultaneously.

6A.4.5.5 Load Application Procedure

The evaluation of measured 4TCO boundary pressures from CO showed that the bottom of the suppression pool experienced the highest dynamic pressure magnitudes. The 4TCO bottom center pressure time-history, corresponding to the time interval given in Table 6A.4-4, is applied uniformly over the annular suppression pool boundary below the downcomer exit elevation. The same BCP time-history is applied with the multiplier of 1.25 obtained in Section 6A.4.5.4 over the cylindrical pool up to the downcomer exit elevation. The dynamic pressure time-history is linearly attenuated to zero at the suppression pool surface to match the free surface boundary condition. Figure 6A.4-11 shows the spatial distribution of the dynamic pressure loading on the suppression pool boundaries. The drywell pressure traces for the same time periods are applied uniformly throughout the drywell.

6A.4.6 Chugging

6A.4.6.1 Loads During Chugging

Chugging occurs during periods of low steam flow rate in the latter stage of a LOCA. The condensation process is unsteady during chugging. The steam-water interface cannot maintain a steady position at the downcomer exit; a steam bubble forms and collapses, allowing water to enter the downcomer between chugs. The pressure oscillations during chugging are associated with the rapid collapse of the steam bubble at the downcomer exit and typically exhibit a pressure spike, followed by a damped ringout which has predominant frequency components at the downcomer and suppression pool natural frequencies. Chugging can produce oscillatory pressure loads on the wetted primary containment surfaces, drag loads on submerged structures, and lateral loads on downcomers. Drag loads are discussed in Section 6A.4.9; lateral loads, in Section 6A.4.7.

6A.4.6.2 Chugging Loads on Pool Boundary

The chugging load definition was developed by applying an acoustic methodology to the chugging data base provided by the Mark II 4TCO Test Program(10). The acoustic model is described in NEDE-24822-P(11).

6A.4.6.2.1 Approach to Load Definition

The application of the acoustic methodology to the 4TCO data was governed by four key observations made during the test programs:

1. The chugging load is generated by a rapid steam bubble collapse at each vent which produces a pressure response in the suppression pool and the vent.

2. For fixed system thermal conditions, the strength of the bubble collapse is random in time for single downcomer systems and from downcomer to downcomer in multidowncomer systems, and the frequency content of the response varies from chug to chug.

3. The initiation of the bubble collapse in multidowncomer systems is desynchronized from downcomer to downcomer.

4. Bulk fluid motions during chugging are relatively small and permit the test facility and suppression pools to be modeled as acoustic systems.

The approach to the chugging load definition starts with the identification of steam bubble collapse as the fundamental excitation mechanism. The collapse produces acoustic responses in the suppression pool and the downcomers. The downcomer signals are transmitted across the steam-water interface and contribute to the pool boundary pressure signal. The essential independence and relatively long wavelength of the downcomer and pool responses allow the 4TCO and Mark II suppression pools to be modeled without an explicit representation of the downcomers. Furthermore, the average chug period seen in the test data (approximately 2 sec) is of sufficient length in comparison to the chug duration that chugs may be considered independent. The combined excitation of the suppression pool, from bubble collapse and downcomer response, is characterized as a time-varying volumetric point source at the downcomer exits in the acoustic models.

6A.4.6.2.2 Design Sources

The entire 4TCO chugging data were screened to select the bounding chugs. Seven chugs from the six 4TCO runs that experienced periods of high amplitude chugging were chosen as key chugs. The PSD envelope of these seven chugs is compared to the bounding envelope of all the 4TCO data on Figure 6A.4-12.

A general chug source function is assumed in the form:

$$S(t) = -A_o\,\Lambda\left(\frac{2t}{\tau} - 1\right) + \sum_i A_i e^{-\zeta_v 2\pi f_i t}\sin\left(2\pi f_i t\right) \qquad (6A.4\text{-}2)$$

Where:

Λ (x) = Triangular impulse function defined by

$$\Lambda(x) = \begin{cases} 1 - |x| & for\ |x| \le 1 \\ 0 & for\ |x| > 1 \end{cases}$$

s(t) = Volumetric source value at time t, m^3/sec^2

A_o = Amplitude of triangular impulse function, m^3/sec^2

τ = Duration of the triangular impulse function, sec

A_i = Amplitude of the sinusoidal component, i, m^3/sec^2

ζ_v = Damping parameter that controls decay of the sinusoidal terms, nondimensional

f_i = Frequency of the sinusoidal component, i, Hz

t = Time, sec

This form of the source function accounts for the two elements of chug excitation: 1) impulse bubble collapse, and 2) sinusoidal components, primarily due to downcomer response. The seven key chugs were then sourced so that the calculated BCP response to the source agrees with the observed pressure in 4TCO. To account for multidowncomer source strength variations, each key chug source was averaged with the larger of the two neighboring chugs (one preceding and one succeeding the key chug in the time-history). Multidowncomer source strength variations were observed in Japanese Atomic Energy Research Institute (JAERI) multidowncomer test data(12-17).

To ensure that the design sources include components that can excite high frequency response in the Mark II suppression pool, three key chug sources are added to the set of seven averaged design sources. The additional design sources will be used in the Mark II design basis for containment response above 50 Hz. Detailed sourcing procedures are presented in NEDE-24302-P(18).

Table 2-1 of NEDE-24302-P presents numerical values for the parameters A_o, A_i, τ, f_i, and ζ_v total for the chug design sources.

6A.4.6.3 Load Application

6A.4.6.3.1 Load Transfer Procedure

Since the 4TCO test is a full-scale test that has a conservative and prototypical setup of the Mark II suppression pool geometry and simulates Mark II LOCA blowdown conditions, the chugging sources inferred from the 4TCO data are appropriate for use in the acoustic model of Mark II containments. The acoustic model is based on an inhomogeneous wave equation Green's function solution (IWEGS) with appropriate boundary conditions. The objective of the source-to-wall load transfer procedure is to obtain a pressure load that may be applied to a suitable fluid-structure model of the primary containment to determine structural responses.

The method used by Unit 2 is to obtain pressure load, the so-called flexible wall procedure(11). This method adjusts the design source acoustic speed and damping values to account for differences between 4TCO and Mark II wall flexibility. The computer code used in the source-to-wall load transfer calculation is the SWEC computer program ME214 (FSAR Appendix 3A). Sound speed and damping value adjustment are discussed in Section 6A.4.6.3.2.

The appropriate chugging event for plant design is a "pool chug" where all downcomers are assumed to chug within a time period that is very short compared to the chug duration. This event produces a pressure load at the suppression chamber boundary that integrates the effects of the slightly desynchronized design sources at individual downcomer exits within a specified time window. Downcomer desynchronization has been verified by determining the time delay between individual bubble collapses in the full-scale tests conducted by JAERI. Chug desynchronization and start time selection are discussed further in Section 6A.4.6.3.3.

The load transfer procedure for the cylindrical pool inside the pedestal wall follows the same procedure for the annular pool described above. As is discussed in Section 6A.4.5.4, downcomers inside the pedestal wall are connected to a common drywell with those in the annular pool, and they have similar vent lengths. Therefore, the same steam condensation sources are applicable in the cylindrical pool. However, in the event of chugging, pool modes become significant. To properly account for the pool responses, the same chugging sources were applied to downcomers in both the annular and the cylindrical pools at the same time. Only the sound speeds were adjusted to account for the fluid structure interaction effect in conforming with the flexible wall approach. The resultant pressure time-histories were then applied to the wetted surface simultaneously to evaluate the containment responses.

6A.4.6.3.2 Sound Speed and Damping Values Adjustment

It is shown in NEDE-24822-P(11) that for a locally reacting primary containment the fluid-structure-interaction effect in an acoustic model can be accounted for by adjusting the acoustic speed and damping values. Furthermore, NEDE-24822-P(11) shows that the acoustic suppression pool frequency shift due to wall flexibility can be expressed as:

$$\omega_N = \omega_N^o \left[1 + \frac{2\rho c^2}{\rho_s} \left(\frac{\frac{1}{L}}{h_b \omega_b} + \frac{\frac{1}{a}}{h_s \omega_s} \right) \right] -1/2 \qquad \text{(6A.4-3)}$$

Where:

ω_N = Flexible wall suppression pool frequency, radians/sec

ω_N^o = Rigid wall suppression pool frequency, radians/sec

ρ = Water density, Kg/m^3

ρ_s = Container density, Kg/m^3 (relates to test facilities)

ω_b = Primary container floor vibration frequency, radians/sec

ω_s = Sidewall or shell vibration frequency, radians/sec

L = Nominal water depth, m

a = Tank radius, m

c = Acoustic speed in tank, m/sec

h_b = Primary containment floor thickness, m (relates to test facilities)

h_s = Shell thickness, m

The fundamental eigen frequency calculated by acoustic methodology is:

$$\omega_N = \frac{c}{4L} \tag{6A.4-4}$$

Therefore, we have:

$$c_{4T} = c_o \left[1 + K_{4T}\, c_o^{\,2} \right] -1/2 \tag{6A.4-5}$$

generally

$$c_{NMP2} = c_o \left[1 + K_{NMP2}\, c_o 2 \right] -1/2 \tag{6A.4-6}$$

Where:

c_4T = Effective acoustic speed in 4TCO facility, m/sec

$$K_{NMP}2 \qquad K_{4_T} = \frac{2\rho}{\rho_s} \left(\frac{\frac{1}{L}}{h_b\,\omega_b} + \frac{\frac{1}{a}}{h_s\,\omega_s} \right) = tank\ cons\tan t,\ \sec^2/m^2 \tag{6A.4-7}$$

c = Acoustic speed in rigid tank, m/sec

c_{NMP2} = Effective acoustic speed in Unit 2 containment, m/sec

Table 6A.4-7 summarizes the parameters for the 4TCO facility and its tank constant as calculated from Equation 6A.4-7. The constant K_{NMP2}, on the other hand, is calculated from:

$$K_{NMP2} = \rho\ \delta_{NMP2} \tag{6A.4-8}$$

Where:

δ_{NMP2} = Distensibility of the containment

By definition:

$$\delta = \frac{1}{V}\,\frac{\Delta V}{\Delta p} \tag{6A.4-9}$$

Where:

$\frac{1}{V}\,\frac{\Delta V}{\Delta p}$ = Volume increment due to the applied pressure, m^2/N

Table 6A.4-8 gives the effective sound speeds expected in the Unit 2 suppression pool for the design sources. The design sources are designated GE801 through GE810, following the convention used in NEDE-24302-P(18). The adjusted sound speeds were calculated using Equations 6A.4-5 and 6A.4-6. Additional adjustments were made for design sources GE804, GE805, GE809, and GE810 to simulate the effect of pool stratification. NEDE-24302-P(18) states that a one-fourth standing wave was observed between the downcomer exit and suppression pool bottom instead of the total suppression pool depth for Chug 2 from 4TCO Run 15(10), where Chug 2 stands for the second chug observed in the real-time analogy tape. This requires a factor of 2 adjustment for design sources GE805 and GE810 to simulate a whole suppression pool ringout frequency. Also, stratification is inferred for Chug 2 from Run 25(10), otherwise an unrealistic sound speed exceeding 5,000 ft/sec would result for both the Unit 2 primary containment and the rigid tank for sources GE804 and GE809. The Unit 2 approach is to maintain the dominant pool frequency, thus preserving the loading condition. Since the dominant pool mode is the quarter standing wave, the relationship between sound speed and frequency is:

$$f = \frac{C}{4L}$$

Where:

C = sound speed

L = pool depth

When the pool is stratified acoustically, the stratification interface forms an effect-free surface for the acoustic wave and L would be replaced by l, the distance between pool bottom and the interface. To maintain the loading frequency, one would then use an effective sound speed C_{eff} given by:

$$C_{eff} = C\,\frac{L}{l}$$

Since a quarter standing wave in the whole pool has more energy than that in the half pool, the Unit 2 approach is conservative. Since the effective interface location is unknown, an additional chug source 811 is added to the chugging design source to account for the fluid-structure-interaction uncertainty. The sound speed of source GE811 is deduced from the maximum acoustic speed of 5,000 ft/sec in a rigid tank with a one-fourth standing wave in a stratified suppression pool. The effective sound speed for source 811 is given in Table 6A.4-8. Numerical values for the parameters A_o, A_i, τ, f_i, and ζ_v for source 811 are the same as for source GE809 given in Table 2-1 of NEDE-24302-P.

The damping observed in chugging traces is believed to come from both suppression pool and wall damping. Since a flexible container (4T) is expected to incur more damping than a rigid primary containment, the damping value for the design sources is also adjusted. NEDE-24822-P(11) states that the 4TCO wall damping is about 4.5 percent. Since the minimum damping value in the 0- to 100-Hz range used for the Unit 2 containment is 1.94 percent, the wall damping difference between Unit 2 and the 4TCO facility can be no more than 2.56 percent. The 4TCO chugging design sources are adjusted by 2.56 percent to conservatively bound the data.

6A.4.6.3.3 Chug Start Time Selection

The design sources GE801 through GE810 described in Sections 6A.4.6.2.2 and 6A.4.6.3.2 are applied desynchronized to SWEC computer code ME214, using the set of chug start times having the smallest variance in 1,000 Monte Carlo trials drawn from a uniform distribution of start times within a time window of 50 msec. The chug start time and its assignment pattern are given in Table 6A.4-10 and Figure 6A.4-13, respectively. The same chug start time and assignment pattern is used for both the symmetric and the asymmetric load cases.

Chugging phasing was determined for the annular and cylindrical pool downcomers. One Monte Carlo selection for phasing was used to obtain wall loads during a chugging event, in accordance with NUREG-0808 acceptance criteria. All 121 downcomers were considered for both annular and cylindrical regions of the suppression pool. Justification for using this approach follows:

1. Both the annular and cylindrical pool regions share a common airspace.

2. Four portals located in the pedestal wall interconnect both regions of the suppression pool; therefore, pool chug should occur simultaneously.

3. The random start time (Table 6A.4-10) for the downcomers, which is dictated by the local turbulence and thermo-hydraulic conditions, should be concerned by the same process.

4. A complete set of eight downcomers inside the pedestal wall does not constitute a large statistical sample for two separate time windows.

For chugging phasing, the differential pressure is actually calculated for all nodes on the pedestal wall by the Monte Carlo process. The geometrical effect, i.e., pool area per downcomer, is automatically accounted for in the SWEC Computer Code ME214, called "CWL".

6A.4.6.3.4 Symmetric Load Case

The symmetric chugging load for Unit 2 is obtained by the desynchronized application of each of the design sources, in turn, at every downcomer exit location in the suppression pool. The results of the acoustic model calculations are 11 dependent distributions of suppression pool boundary pressure corresponding to the 11 design sources.

Representative pressure time-histories for each of the design sources are presented on Figures 6A.4-14 through 6A.4-24.

6A.4.6.3.5 Asymmetric Load Case

Since chugging source strength may vary from downcomer to downcomer, an asymmetric load case is also prescribed to account for source asymmetry. The Mark II approach is to use geometrical and statistical considerations. First, a design moment axis is identified based on the geometric consideration of downcomer arrangement.

Any diameter of the suppression pool can be considered a moment axis. The design moment axis is the one that maximizes the summation:

$$\sum_{i=1}^{N} L_i + 0 \qquad (6A.4\text{-}10)$$

Where:

N = Number of downcomers

L_i = Perpendicular distance from the i^{th} downcomer to such a moment axis

The plus and minus sides of the moment axis are chosen to make the summation nonnegative. The design moment axis is the one that maximizes this summation. The design moment axis for the Unit 2 suppression pool is shown on Figure 6A.4-13. The chug source strength is then increased by a factor ∝ on one side of the design moment axis, while decreasing the same factor on the other side of the design moment axis.

The asymmetric factor ∝ is a function of the root-mean-square moment, m_{rms}, and is determined from statistical measure as follows(19):

$$\alpha = \frac{M^*_{rms}}{p^*_{rms}\left(\sum_{i=1}^{N} L_i\right)} \qquad (6A.4\text{-}11)$$

Where:

$$M^*_{rms} = E < M_{rms} > +3.45 \left(V < M_{rms} > \right) 1/2 \qquad (6A.4-12)$$

$$V < M_{rms} > = V < P_{rms} > \sum_{i=1}^{N} L_i^2 \qquad (6A.4-13)$$

$$E < M_{rms} > = E < P_{rms} > \sum_{i=1}^{N} L_i \qquad (6A.4-14)$$

The three parameters:

$$M^*_{rms}$$

$$E < M_{rms} >$$

$$V < M_{rms} >$$

are the expected value, variance, and design values of a statistical measure of chug strength and are determined from statistical analysis of actual data(18). Table 2-2 of NEDE-24302-P presents these statistical parameters. The calculated asymmetric factor ☐-11. for Unit 2 is given in Table 6

The design sources (1+ ☐) S are app
side of the design moment axis and (1-☐) S are applied at downcomer exits to the other side of the axis with the same set of chug start times as the symmetric case, where S stands for each of the 11 chug sources. This results again in 11 independent distributions of suppression pool boundary pressures.

Representative pressure time-histories of the 11 chugs are given on Figures 6A.4-25 through 6A.4-35.

6A.4.6.4 Chugging Fatigue Analysis

6A.4.6.4.1 General

Chugging is characterized by a burst of pressure pulses separated by a quiescent period. As is, it can be described as a series of isolated load histories called occurrences, separated by short periods of zero hydrodynamic activity.

For every pool chug, the associated time-history exhibits random variation in the dominant frequency and amplitude. Hence, it would be overly conservative to perform fatigue analysis by applying the design load (which was derived to conservatively bound all expected loads) with the estimated total occurrence frequency of the chugging downcomer. A more realistic approach is to obtain from a library dynamic loading time-histories with varying amplitudes that will occur during a downcomer load. This result (in terms of an equivalent occurrence factor [EOF]) is then utilized to reduce the total number of loading cycles per downcomer that is used for fatigue analysis.

6A.4.6.4.2 Equivalent Occurrence Factor

The chugging EOF is obtained in the following manner:

1. Tabulate the histogram or the frequency of occurrence of the maximum chug amplitude for each of the six key runs from 4TCO data(10).
2. Normalize the frequency distribution to the maximum amplitude value (ratio frequency distribution).
3. Multiply the probability of value within a given range (occurrence frequency) by its corresponding amplitude ratio raised to the power 4.3(20). For the downcomer evaluation, the magnitude ratio was raised to the power 3.0.
4. Sum all the resulting products of Step 3 and obtain the EOF for each of the six key runs.

Table 6A.4-12 presents the calculated EOF for each of the six key runs. The maximum EOF obtained is 0.12 for 4TCO Run 26 which is rounded up to 0.25(10).

6A.4.6.4.3 Maximum Number of Chugs in a LOCA

The maximum duration of chugging for any postulated LOCA is desired for fatigue load calculations. A LOCA with a small break area results in an extended period of relatively low downcomer steam mass flux, Gv. Although a SBA could last as long as 6 hr, it is not anticipated that chugging would occur throughout the entire period. Examination of available test data reveals that a lower downcomer steam mass flux threshold exists below which chugging would not occur(19).

The lowest Gv observed during chugging in 4TCO tests was 0.7 lbm/sq ft-sec and occurred for the 2.5-in liquid blowdown of Run 25. Most of the lower Gv values were about 1 lbm/sq ft-sec. The lowest Gv at the end of chugging in JAERI was about 0.3 lbm/sq ft-sec.

The threshold of 0.3 lbm/sq ft-sec was then applied to the blowdown transients of a representative Mark II plant(19). This resulted in the expected chugging duration for different break areas tabulated in Table 2.1 of Reference 19. Based on this tabulation, the maximum duration was determined to be less than 2,000 sec.

The mean chug period between two consecutive chugs in 4TCO data was found to be 1.84 sec and in JAERI data, 1.97 sec. It was demonstrated in subscale tests that the chug period increases as the downcomer steam mass flux decreases(21). Thus, the 4TCO mean chug period of 1.84 sec is expected to be shorter than would be encountered in a Mark II plant because the 4TCO blowdown had relatively high downcomer steam mass flux. This is further confirmed by a longer chug period of 1.97 sec in JAERI tests which had lower mass flux chugging than 4TCO.

Since the limiting case for chugging duration is the SBA where the downcomer steam mass flux is even lower for a longer duration than that of the 4TCO and JAERI tests, it is reasonable to use 2 sec as the average chug period.

Based on a 2-sec average chug period and a 2,000-sec chug duration, the maximum number of chugs during a LOCA is 1,000. Multiplying this value by the EOF of 0.25 gives the equivalent number of 250 full-strength chugs which are considered in the chugging fatigue analysis.

6A.4.7 Lateral Loads on Downcomers

Steam condensation tests with vertical downcomers similar to those used in the Mark II containment have shown that significant lateral loading of the downcomers can occur. The load results from random movement of the steam/water interface or steam bubble collapse at the downcomer exit. The 4TCO tests have shown that the lateral load during the CO period is relatively small compared to chugging-induced lateral loads. Therefore, the chugging lateral load was used in design.

The Unit 2 approach is to use the NRC acceptance criteria documented in Section 2.3.3 of NUREG-0808(2). However, only the single-downcomer loads will be used for downcomer evaluation since Unit 2 uses 24-in unbraced downcomers.

Accordingly, separate assessments are made for the following dynamic forces applied at the tip of each downcomer. The mathematical expression for the transient load function is represented by:

$$F_1(t) = A(\tau)\sin\frac{\pi}{\tau}t \ \text{kips};\ o \le t \le 6 \text{ msec} \qquad (6A.4\text{-}15)$$

Where:

$$A(\tau) = (50 - 20\frac{\tau}{3})\ \text{kips};\ 3 \le \tau \le 6 \text{ msec} \qquad (6A.4\text{-}16)$$

The lateral load is an impulsive load. Equation 6A.4-16 prescribes A(τ) = 10 kips at τ = 6 msec, for low-intensity chugs, characterized by a long duration and $A(\tau)$ = 30 kips at τ = 3 msec for the infrequent high-intensity chugs, characterized by a short duration.

For the very high-intensity, low-probability load specification, the following equation is used:

$$F_2(t) = 65 \sin\frac{\pi}{3} t \text{ kips}; o \leq t \leq 3\text{msec}, \tau = 3 \text{ msec} \qquad (6A.4\text{-}17)$$

Since Unit 2 uses unbraced downcomers, the diaphragm (drywell, floor at el 240 ft 0 in) is designed to withstand the moment and shear caused by multivent lateral loads at the junction of the downcomer(s) with the drywell floor.

The following method was used in designing the floor:

1. A dynamic analysis of a single downcomer is performed for the loads defined above. Since the natural frequency of the downcomer is low and since the time-history of the lateral dynamic load is an impulse half-sine loading with a duration of approximately 6 msec, the reactor forces/moments at the drywell floor have predominantly only low frequencies close to the downcomer frequencies. Since the drywell floor frequencies are significantly higher, no dynamic amplification of the reaction forces/moments is expected.

2. The maximum values of forces/moments from the dynamic analysis of a single downcomer in step 1 above are then applied at all downcomers simultaneously as static loads in the same direction. Since the maximum forces do not occur at the same time in the same direction, the procedure is quite conservative.

3. Forces/moments resulting from the analysis in step 2 above are then combined with the forces/moments from other concurrent loads with appropriate load factors, in accordance with the loading combinations of Table 3.8-11, to verify the design adequacy of the drywell floor.

6A.4.8 Annulus Pressurization

Annulus pressurization (AP) refers to the pressurization of the annular space between the RPV and the biological shield wall (BSW) following a rupture of a high-energy line at the safe-end weld to the RPV nozzle.

AP is evaluated for the postulated pipe ruptures that result in significant loads: DER of the feedwater, recirculation suction and discharge, low-pressure coolant injection (LPCI), low-pressure core spray (LPCS), and high-pressure core spray (HPCS) lines at the RPV nozzle. A rupture of a MSL does not result in AP since the steam lines are attached to the RPV above the top of the BSW. Description of the pressure transient is given in FSAR Section 6.2.1.2.

These pressure loads are used to evaluate structural response which is discussed in Section 6A.5.

6A.4.9 Submerged Structure Loads

During a postulated LOCA, the events of water jet, air bubble, pool swell, fallback, and steam COs will induce fluid motion in the Mark II suppression pool. This fluid motion causes loads on structures submerged in the suppression pool. To evaluate these loads, analytical models are used to determine the flow fields; then standard drag, acceleration drag, and lift are calculated from the following rigid structure formulas(22,23):

$$\text{Standard Drag} = F_S = \frac{C_d\, A_x\, \rho\, U\, |U|}{2\, g_c} \tag{6A.4-18}$$

$$\text{Acceleration Drag} = F_A = \frac{C_m\, \rho\, vol\, \dot{U}}{g_c} \tag{6A.4-19}$$

$$\text{Lift} = F_\ell = \frac{C_\ell\, A_x\, \rho\, U\, |U|}{2\, g_c} \tag{6A.4-20}$$

Where:

C_d = Standard drag coefficient, nondimensional

A_x = Structure's area normal to flow direction, ft^2

ρ = Density of water, lbm/ft^3

U = Fluid velocity normal to structural axis, ft/sec

g_c = Acceleration constant = 32.2

C_m = Inertial coefficient, nondimensional

Vol = Structure volume, ft^3

$\dot{U}$ = Fluid acceleration normal to structural axis ft/sec^2

$C\ell$ = Lift coefficient, nondimensional

For the downcomer, the effect of fluid structure interaction is considered. The standard drag acts in phase with the velocity of the flow and the acceleration drag acts in phase with the acceleration of the flow. The lift force exerted on a structure is along the direction perpendicular to the flow velocity. Standard drag and acceleration drag are called in-line forces, whereas the lift force is called a transverse force. The total fluid force on a structure is the vector sum of the in-line and transverse forces. The coefficients used for the load calculation are the steady-state values modified to account for load increases due to structural interferences, unsteady flow, and bubble asymmetry. Long structures are subdivided for load calculations to account for flow field variations along the structure(5,23).

During the suppression pool swell and fallback, direct hydrodynamic loads also occur on structures above the normal suppression pool water level that are within the suppression pool swell zone. These structures not only experience the aforementioned drag and lift loads but also experience loading due to the impact of the water surface on the structure. The calculation of this impact is based on the method specified in NUREG-0487(5).

Section 6A.4.9.1 presents the methodologies used to determine the flow fields for the various downcomers. Section 6A.4.9.2 addresses interference effects, unsteady flow, and segmentation of structures for the calculation of the loads(5). Section 6A.4.9.3 presents load and time-histories on typical structures for each downcomer.

6A.4.9.1 Flow Field Methodologies

6A.4.9.1.1 LOCA Water Jet

After a postulated LOCA the drywell space is pressurized by a steam and air mixture. This rise in pressure results in expulsion of a water jet from each of the downcomers. The ejection of these jets induces hydrodynamic loads on submerged structures that are below the downcomer exit plane. There are no structures in the direct path of any jet; therefore, the jet is modeled as a rigid sphere moving at the jet front velocity. The flow fields around these spheres are used to calculate the drag load on the structure(4,5).

The sphere's volume is assumed equal to the initial volume of the water in the downcomer. The location of the front of the sphere's penetration at any instant in time is the farthest distance that any particle exiting the downcomer would have traveled. The velocity of the sphere is the velocity of this particle. The particle velocities at the downcomer exit are calculated by the suppression pool swell analytical model of the LOCTVS program(3) (Section 6A.4.4). These velocities are not attenuated for calculating penetration distances. The flow field at a given point P(R,x), due to the flow around a single sphere of radius a, traveling at a velocity of U, can be determined from potential theory by the following equations (Figure 6A.4-36):

$$\phi(R,x) = -\frac{a^3U}{2}\frac{(x-b)}{\left[(x-b)^2+R^2\right]^{3/2}}$$

$$v_x = \frac{\partial\phi}{\partial x} = \frac{a^3U\,[2(x-b)^2-R^2]}{2r^5}$$

$$v_R = \frac{\partial\phi}{\partial R} = \frac{3\,a^3\,U\,(x-b)\,R}{2r^5}$$

$$\dot{v}_x = \frac{\partial v_x}{\partial t} = v_x\left[\frac{1}{U}\frac{dU}{dt}+\frac{5\,U\,(x-b)}{r^2}\right] - \frac{2\,a^3\,(x-b)\,U^2}{r^5}$$

$$\dot{v}_R = \frac{\partial v_n}{\partial t} = v_R\left[\frac{1}{U}\frac{dU}{dt}+\frac{5\,U\,(x-b)}{r^2}\right] - \frac{3\,a^3\,RU^2}{2\,r^5}$$

(6A.4-21)

Where:

a = Radius of sphere, ft

b = Vertical distance between center of sphere and downcomer exit, ft

r = Distance between center of sphere and point P(R,x), ft

R = Horizontal distance between center of sphere and point P(R,x), ft

U = Velocity of sphere, ft/sec

x = Vertical distance from downcomer exit to point P(R,x), ft

ϕ R,x) = Potential function given in R,x coordinates, ft^3/sec

V_R = Velocity in R direction, ft/sec

V_x = Velocity in X direction, ft/sec

$\dot{V}_R$ = Acceleration in R direction, ft/sec^2

$\dot{V}_x$ = Acceleration in X direction, ft/sec^2

The total flow field at the given point P(R,x) is the vector sum of the combinations of all the jets. It is assumed that at any instant in time all spheres are at the same vertical location.

6A.4.9.1.2 LOCA Air Bubble

After the water jet clears the downcomers, the drywell air is expelled into the suppression pool. This air forms a bubble below each downcomer exit. The formation of these bubbles causes velocity and acceleration flow fields in the suppression pool, resulting in loads on all structures submerged in the suppression pool. This load terminates when the bubbles coalesce and suppression pool swell starts.

Potential flow theory is used to calculate the flow fields(24). Disturbances in the pool are modeled as point sources and the method of images (MOI) is used to satisfy the pool boundary conditions. The MOI is applicable to plane boundaries; therefore, the annular and cylindrical portions of the suppression pool are approximated as rectangular boxes (Figures 6A.4-37 and 6A.4-38). The application of this potential theory also requires the finite air bubbles to be modeled as point sources. The modeling is accomplished by solving the LOCA air bubble equations to obtain a spherical potential source(24) which is used at each bubble location. These sources are then adjusted to equivalent point so that the pressure boundary condition on each bubble surface is satisfied(24,25).

The LOCA air bubble equations are solved for the suppression chamber and drywell pressure time-histories given in Section 6A.4.3. The initial radius is equal to the radius of the downcomer, and the initial radial expansion is equivalent to the last water particle velocity exiting the downcomer. The solution was obtained from an IBM Continuous System Modeling Program III (CSMP III) simulation using a fourth order Runge-Kutta integration technique.

The SSLOAD program (FSAR Appendix 3A) adjusts the spherical sources to point sources and calculates the velocity and acceleration flow fields. The loads are presented in Section 6A.4.9.3.

6A.4.9.1.3 LOCA Suppression Pool Swell and Fallback

The suppression pool swell occurs after the LOCA air bubbles coalesce to form an air pocket in the suppression pool. This air pocket forces the water above the downcomer exit upward as a slug. The velocity of the water slug varies with time and approximates a half sine wave during the swell. As the maximum height of the slug is reached, the air breaks through the slug and the water falls under gravity.

The water slug velocities and accelerations during suppression pool swell are calculated by the LOCTVS suppression pool swell model (Section 6A.4.4). These calculated velocities are increased 10 percent in accordance with NUREG-0487(5). The fallback acceleration is set equal to gravity (-32.2 ft/sec^2), and the fallback velocity is determined from:

$$V(t) = -32.2\ (t - 1.79) \qquad (6A.4\text{-}22)$$

Where:

V(t) = Fallback velocity, ft/sec

t = Time after start of suppression pool swell, sec

1.79 = Time of maximum suppression pool swell, sec

6A.4.9.1.4 LOCA Steam Condensation Oscillations

COs occur after the drywell air has carried over into the suppression pool and there is a medium-to-high steam mass flow through the downcomer. At this flow rate a steam bubble forms outside the exit of the downcomer where the steam is condensed on the surface of this bubble by the suppression pool. The size of these bubbles oscillates as the steam is condensed and recharged. This oscillation causes fluid accelerations and velocities in the suppression pool that result in loads on structures submerged in the suppression pool.

The method used to calculate these flow fields is similar to that used for the LOCA air bubble case. A point source is first defined to match the CO source definition. The source is located below the exit of each downcomer and the SSLOAD program is used to determine the potential flow field. Unlike the air bubble, each source in the suppression pool is not normally assigned the same value but is assigned the peak negative or positive value so as to maximize the load on the target structure.

The source strengths are determined from the following equations(11,26) from the 4TCO pressure time-histories discussed in Section 6A.4.5:

$$S = \int \dot{S} dt \, ; \dot{S} = \frac{P_{wall}}{\rho\ f(r)} \qquad (6A.4\text{-}23)$$

Where:

S = Volumetric flow source, ft^3/sec

$\dot{S}$ = Derivative of volumetric flow source, ft^3/sec^2

P_{wall} = 4TCO wall pressure, lbf/ft^3

ρ = Density of water, $slugs/ft^3$

$f(r)$ = Suppression pool transfer factor for point source in 4T suppression pool based on the MOI = 2.82 ft^{-1}

The integration for the volumetric flow source was accomplished by use of fourth-order Runge-Kutta numerical technique.

6A.4.9.1.5 LOCA Chugging

Chugging occurs when there is a low steam mass flow so that condensation of the steam cannot be maintained outside the downcomer. There is a rapid collapse of the water-steam interface into the downcomer, after which the pressure builds up due to the reduced condensation area and forces the interface out. This unsteady collapse and expulsion causes acceleration and velocity flow fields in the suppression pool resulting in loads on structures submerged in the suppression pool. The method for calculating the flow field for these loads is the same as for CO except for locating the sources at the downcomer exit and the source definition.

The source is modeled as a point with the following flow source definition(11,18):

$$S = - A_0 \Lambda \left[\frac{2t}{\tau} - 1 \right] + \sum_i A_i e^{\alpha \omega_i t} \sin \omega_i t$$

$$S = \int \dot{S} dt \qquad (6A.4\text{-}24)$$

Where:

$-A_o$ = Amplitude of impulse, ft^3/sec

A_i = Amplitude of sinusoidal contributions, ft^3/sec

∞ = Downcomer damping coefficient, nondimensional

Λ [arg] = Triangular impulse function

$$\Lambda [\text{arg}] = \left\{ \begin{array}{ll} 1 \underset{0}{-} |\text{arg}| & |\text{arg}| \langle | \\ & |\text{arg}| \rangle | \end{array} \right\}$$

t = Time, sec

τ = Impulse duration, sec

ω_i = Frequency of sinusoidal contribution (i), radians/sec

$\dot{S}$ = Derivative of volumetric flow rate, ft^3/sec^2

S = Volumetric flow rate, ft^3/sec

The sources used were the 800 series key chugs(18).

6A.4.9.2 Drag Load Coefficients

Loads on a structure are determined by calculating the velocity and acceleration at points in the fluid model that correspond to intervals along the centerline of the structure and then applying the drag and lift equations. The coefficients for these equations are modified to account for unsteady flow and the effects of interfering structures. The criteria for segmenting the structure and the method for determining the drag coefficients were presented with technical justifications in the Zimmer FSAR(23). Because the majority of the available data for unsteady flow have been developed for a cylinder, the discussion is focused on cylinders. The structures in the Unit 2 suppression pool are all analyzed as cylinders. An equivalent diameter is used for noncylindrical structures. For typical noncylindrical structures such as I-beams and box frames, the equivalent diameter is determined by a circumscribing circular cylinder. For highly-perforated ECCS suction strainers which resemble the shape of a finned cylinder, a multiplier is introduced to account for the perforation and the spacing between fins. This reference was accepted with minor changes to coefficients for noncylindrical structures by Supplement 1 of NUREG-0487(5). This section lists the methods and criteria(2,23) that were used for calculating the loads.

6A.4.9.2.1 Equivalent Uniform Flow Velocity and Acceleration

Structures are segmented into small sections so that:

$$L/D \le 1.5 \qquad (6A.4\text{-}25)$$

Where:

L = Segment length

D = Diameter of the structure

The velocity and acceleration are calculated at the geometric center of each segment. Loads normal to the axis of the structure are calculated at each section based on the normal flows at that section. Loads parallel to the axis of the structure are calculated based on the maximum flow along the axis or by wall pressures if the structure intersects the wall.

6A.4.9.2.2 Interference Effects on Acceleration Drag

When submerged structures are closely located in a flow field, they can interfere with one another, affecting acceleration drag. Structures are considered close when they are within three characteristic distances of each other, where the characteristic distance is defined as the equivalent circular cross-section diameter of the largest interfering structure. The method to account for this interference is presented in the Zimmer FSAR(23) and is given by the following equations:

$$\sum \Delta F_{\ell n} = \Delta C_m \, \rho \pi a_\ell^2 \left| \dot{U}_{\infty N} \right| + C_v \rho a_\ell \left| U_{\infty N} \right|^2$$

$$\Delta Cm = \sum_n \left\{ (C_{1n} - 1) e^{i\alpha_1} - C_{2n} e^{i(2B_{\ln} - \alpha_1)} \right\}$$

$$Cv = \sum_n \left\{ (C_{3n} + C_{4n}) e^{iB_{\ell n}} - C_{5n} e^{i(3B_{\ln} 2\alpha_2)} - C_{6n} e^{i(2\alpha_2 - B_{\ell n})} \right\} \qquad \text{(6A.4-26)}$$

Where:

a_ℓ = Radius of the cylinder on which the interference effects are being calculated, ft

C_{kn} = Coefficient C from Section G.3.1 of the Zimmer FSAR(25) for interfering cylinder n, nondimensional

$\Delta F_{\ell n}$ = Change in load on cylinder due to interfering cylinder n per unit length of cylinder (lbf/ft)

n = Number of interfering cylinders

∞_1 = Angle of acceleration measured in the plane normal to the axis of the structures, radians

∞_2 = Angle of velocity measured in the same manner as ∞_1 radians

i = $\sqrt{-1}$

$\dot{U}_{\infty n}$ = Normal acceleration calculated at geometric center of ∞ cylinder, ft/sec^2

$\dot{U}_{\ell n}$ = Normal acceleration calculated at geometric center of ℓ cylinder, ft/sec^2

$B_{\ell n}$ = Angle between ℓ cylinder and interfering cylinder, radians

The values for ΔC_M and C_v are dependent on flow directions ∞_1 and ∞_2. For the load calculations these values were maximized with respect to these angles by the following equations:

$$\left|\Delta C_M\right|_{\max} = \left[P + \left(v^2 + R^2\right)\right]^{1/2} \qquad (6A.4\text{-}27)$$

Thus for a circular cylinder:

$$\left|C_M\right|_{\max} = C_M + \left|\Delta C_M\right|_{\max} = 2 + \left[P + \left(v^2 + R^2\right)^{1/2}\right] \qquad (6A.4\text{-}28)$$

Where:

$$P = \left[\sum_n c_{1n} - 1\right]^2 + \sum_i \sum_j C_{2i}\, C_{2j} \cos 2\left(B_{\ell i} - B_{\ell j}\right)$$

$$v = -2\left[\sum_n \left(C_{1n} - 1\right)\right]\left[\sum C_{2n} \cos 2\, B_{\ell n}\right]$$

$$R = -2\left[\sum_n \left(C_{1n} - 1\right)\right]\left[\sum C_{2n} \sin 2\, B_{\ell n}\right] \qquad (6A.4\text{-}29)$$

For C_v we have:

$$\left|c_v\right| = \left(p_1 + p_2 \cos 2\alpha_2 + p_3 \sin 2\alpha_2 + p_4 \cos 4\alpha_2 + p_5 \sin 4\alpha_2\right)^{1/2} \qquad (6A.4\text{-}30)$$

The maximum of this value has been approximated by:

$$\left|c_v\right|_{\max} \approx \left\{p_1 + \left[p_2^2 + p_3^2\right]^{1/2} + \left[p_4^2 + p_5^2\right]^{1/2}\right\}^{1/2} \qquad (6A.4\text{-}31)$$

Where:

p_1 = $A^2 + D^2 + 1/2\ (B^2 + C^2 + E^2 + F^2)$

p_2 = $2\ (A \cdot B + D \cdot E)$

p_3 = $2\ (A \cdot C + D \cdot F)$

$$p_4 = 1/2\ (B^2 - C^2 + E^2 - F^2)$$

$$p_5 = B \cdot C + E \cdot F$$

$$A = \sum_n \left(C_{\cdot 3n} + C_{4n}\right) \cos B_{\ell n}$$
$$B = -\sum_n C_{\cdot 5n} \cos 3 B_{\ell n} - \sum_n C_{6n} \cos B_{\ell n}$$
$$C = -\sum_n C_{5n} \sin 3 B_{\ell n} - \sum_n C_{6n} \sin B_{\ell n}$$
$$D = \sum_n \left(C_{3n} + C_{4n}\right) \sin B_{\ell n}$$
$$E = -\sum_n C_{5n} \sin 3 B_{\ell n} + \sum_n C_{6n} \sin B_{\ell n}$$
$$F = \sum_n C_{5n} \cos 3 B_{\ell n} - \sum_n C_{6n} \cos B_{\ell n} \qquad (6A.4\text{-}32)$$

The SSLOAD program calculates the values for C_m and C_v, and typical values for structures in the suppression pool are given in Table 6A.4-14. The convective drag term C_v was combined by the SRSS method with the standard drag term C_d for calculating the total in-line velocity drag.

When a structure is located close to the suppression pool boundary wall, the interference effect on the acceleration drag is determined by the method of images (MOI); that is, the boundary is replaced by an imaginary mirror structure on the other side of the boundary. Interference effects from multiple structures and boundary are combined in accordance with Eq. 6A.4-26. Alternately, when boundary proximity is the primary contributor to the interference effect on the acceleration drag coefficient, a conservative formula derived from bounding experimental and theoretical results is used to determine the modified acceleration drag coefficient. This formula meets the acceptance criterion discussed in NUREG-0487 and is the recommended formula described in NUREG-0661. The alternate formula calculates the multiplier $(1+A_w)$ to the acceleration drag coefficient. The increment to the acceleration drag coefficient is A_w and is obtained as a bounding expression that envelops theoretical and experimental data. The value of A_w is given as a function of χ_w ($\chi_w = r/D - 1/2$, where r is the distance from the center of the structure to the boundary) and is:

$$A_w = 0.05/\chi_w \text{ when } 0.05 \leq \chi_w < 1.0$$

and

$$A_w = 1.0 \text{ for } \chi_w < 0.05$$

The resultant acceleration drag coefficient C_M is:

$$C_M = (1+A_w)\ C_{M\infty}$$

Where:

$C_{M\infty}$ = the acceleration drag coefficient in the free flow field

6A.4.9.2.3 Interference Effects on Standard Drag

Changes to standard drag and lift coefficients are calculated by the methods presented in the Zimmer FSAR(23). These values are dependent on flow direction so the maximum values were used as input for the load calculation. Table 6A.4-15 lists values for typical small structures in the suppression pool.

Interference effects on the standard drag coefficient due to the proximity effect of suppression pool boundary are considered by replacing the wall as a plane reflector and calculated using the MOI. Alternately, when boundary proximity is the primary contributor to the interference effect on the standard drag coefficient, a conservative formula derived from bounding experimental and theoretical results is used to determine the modified acceleration drag coefficient. This formula meets the acceptance criterion discussed in NUREG-0487 and is the recommended formula described in NUREG-0661. The alternate formula calculates the multiplier $(1+D_w)$ to the standard drag coefficient. The increment, D_w, is determined from values that bound theory and experimental results and is given as a function of χ_w (χ_w = r/D - 1/2, where r is the distance from the center of the structure to the boundary).

$$D_w = 0.12/\chi_w \text{ when } 0.05 \le \chi_w < 1.0$$

and

$$D_w = 2.4 \text{ for } \chi_w < 0.05$$

The resultant standard drag coefficient C_d is:

$$C_d = (1+D_w)\ C_{d\omega}$$

Where:

$C_{d\omega}$ = the standard drag coefficient in the free flow field

6A.4.9.2.4 Determination of Drag and Lift Coefficients for Unsteady Flow

Unsteady effects may increase the steady-state values of standard drag and acceleration drag coefficients and may increase or add lift to the structure. NUREG-0808(2) presents a methodology based on experimental data to account for these effects. This methodology is used to increase the loads as applicable. The loads are first calculated with the drag and lift coefficients adjusted for interference. These loads are then adjusted for unsteady flow by multiplying by the ratio of the coefficient for unsteady flow to the steady-state coefficient without interference. Lift due to unsteady flow was added separately to the calculated loads. Section 6A.4.9.3 discusses the calculated loads and adjustments for unsteady flow if required.

6A.4.9.2.5 Bubble Asymmetry

NUREG-0487(5) recommends a 10-percent increase on acceleration drag and a 20-percent increase on standard drag to account for LOCA bubble asymmetry. These increases are applied for all load cases.

6A.4.9.3 Loads and Time-Histories

This section presents the calculated submerged structure loads and time-histories. Table 6A.4-16 lists and Figure 6A.4-39 shows the location of structures located in the pool. Table 6A.4-17 lists the structures in and above the suppression pool that are subject to suppression pool swell and fallback loads.

6A.4.9.3.1 LOCA Water Jet

Water jet loads are calculated on the SRVDLs and quenchers since they are in the vicinity of the jet path. Loads are calculated at 29 time points spanning the jet transient. A sensitivity study shows the load contribution from 32 jets surrounding the structure is sufficient for load convergence. The highest loads are on the quencher arms. These loads are dominated by acceleration drag which increases with time until the downcomer terminates. Steady-state values for inertia and standard drag coefficients are used. Lift forces are not considered because the load due to the velocity term is only about 1 percent of the acceleration. Figures 6A.4-40 and 6A.4-41 show the normal force time-histories for a typical 1.25-ft quencher arm segment.

6A.4.9.3.2 LOCA Air Bubble

LOCA air bubble loads are calculated for structures listed in Table 6A.4-17. Because of the large number of downcomers, only critical loads on selected downcomers are calculated. This selection is based on the downcomer's radial location and the distribution of bubbles around it. Since the bubbles are in phase, downcomers with an asymmetrical distribution of bubble sources would have the highest horizontal loads. At least one such downcomer for each of the five radial locations is chosen.

The loads are calculated for 8 time points covering the air bubble transient. A typical normalized time-history for a downcomer segment without bubble engulfment is given on Figure

6A.4-42. The drag load on a segment goes to zero when a bubble engulfs the segment. Figure 6A.4-43 shows the peak load distribution for the downcomer located at 76.5 deg and radius 19.5 ft (from the suppression pool centerline) which has the highest calculated load. The steady-state values of C_m and C_v, modified for interference, are used for this constantly accelerating flow (Section 6A.4.9.3.1). No adjustments are made to lift since the velocity drag is only about 1 percent of the acceleration drag load.

6A.4.9.3.3 Suppression Pool Swell and Fallback

Suppression pool swell and fallback loads are calculated for structures listed in Table 6A.4-17. Impact loads are calculated with methods given in NUREG-0487(5). Drag and lift loads are based on acceleration and velocity flow fields presented in Section 6A.4.9.2.3. Adjustments are made for interference and unsteady flow. Since loading is dependent on structure location, each structure is evaluated separately. Figures 6A.4-44 and 6A.4-45 show a typical load evaluation for a horizontal section of piping (2ICS-012-75-2).

6A.4.9.3.4 Condensation Oscillation Loads

CO loads are calculated for structures listed in Table 6A.4-16. As in the case of LOCA air bubble, only critical loads on selected downcomers are calculated. The selection is also based upon the radial location of the downcomer in the suppression pool and the distribution of sources around it. However, downcomers having the highest number of sources closely surrounding them are chosen since the sources are phased to maximize the load. Phasing for submerged structures is accomplished by using the MOI, SWEC computer code ME-229 (SSLOAD). The resulting velocity and acceleration fields are used to determine the drag loads. The MOI is only applicable to straight boundaries. Since the annular pool has curved sides, the annular geometry is approximated by three methods described in Section 6A.4.9.1.2. The structure is located at the center of the box for each case. Peak segment loads are calculated by using in-phase and out-of-phase analyses. In-phase loads are most critical for the radical component of the structure. Out-of-phase loads where peak positive sources coincide with peak negative sources on opposite sides of the structure produce the highest value for the tangential load component. Corrections for interference and unsteady flow are made. The correction for unsteady flow required a calculation of a period parameter (Keulegan Carpenter number) which is based on the dominant frequency of the flow for each of the 17 sources considered. Velocity drag loads are insignificant, usually less than 1 percent of the load, so load time-history follows the acceleration time-history. From potential flow theory this time-history is the 4TCO wall pressure time-history that is applied to the primary containment (Section 6A.4.5). Figures 6A.4-46 and 6A.4-47 show a typical load time-history and peak load distribution. In particular, they show the time-history for CO which is from GE 4TCO RUN 12 and the peak load distribution on the downcomer located at 18 deg and radius 34.5 ft (from suppression pool centerline). This downcomer has the highest calculated loads.

6A.4.9.3.5 Chugging Loads

Chugging loads are calculated for the submerged structures listed in Table 6A.4-16, including pool boundary loads.

Peak segment submerged structure loads were calculated using the MOI model, as described in Section 6A.4.9.1.2. Phasing was introduced into analysis and described in Section 6A.4.9.3.4.

Peak segment submerged structure loads were also calculated using an acoustical wave model. The acoustical wave model accounts for additional physical parameters (i.e., pool and wall damping fluid sound speed, etc.) and produces a load reduction, as compared with the MOI model. Phasing is introduced into analysis by allowing a time delay between sources on both sides of pool. Computer Code ME242, called "SSLAM," was developed for chugging submerged structure loads. A typical peak load distribution on the downcomer located at radius 24 ft from suppression pool centerline and 18 deg for Key Chug 801 is shown on Figure 6A.4-48. Figure B-4 of NEDE-24302-P(18) shows the load time-history for this chug. This downcomer has the highest calculated load.

Pool boundary loads were calculated using an acoustical wave model. Phasing is introduced into the analysis, as described in Sections 6A.4.6.3.2 through 6A.4.6.3.5. Computer Code ME214, called "CWL", was developed for chugging wall loads, as described in Sections 6A.4.6.2.2 through 6A.4.6.3.5.

6A.4.10 References

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TABLE 6A.4-1

UNIT 2 DATA FOR DOWNCOMER CLEARING AND SUPPRESSION POOL SWELL ANALYSIS

Drywell	
Free air volume (up to downcomer exit)	302,275 ft^3(3)
Initial temperature	135°F
Initial pressure	15.45 psia
Relative humidity	40%
Suppression Chamber	
Free air volume (at high pool level)	194,530 ft^3(3)
Water volume (at high pool level)	150,470 ft^3(3)
Initial temperature	90°F(2)
Initial pressure	15.45 psia
Relative humidity	100%(2)
Break Area	
DBA - recirculation suction line break (pipe inventory considered)	4.235 ft^2
Vapor Suppression System	
Downcomer size (ID)	23.25 in
No. of downcomers	121
Downcomer submergence (at high water level)	11.0 ft(1)
Downcomer loss factor (entrance, pipe friction and exit)	2.36
Suppression pool surface area (net)	5,800 ft^2
Drywell Pressure Transient	
See Table 6A.4-2	

---

(1) After downcomers have cleared, downcomer submergence is 11.69 ft.

(2) The maximum suppression chamber air space temperature is changed to 122°F. This change does not affect the pool swell analysis.

(3) These values differ slightly from actual physical values to accommodate downcomer submergence.

TABLE 6A.4-2

UNIT 2 DRYWELL PRESSURE HISTORY FOLLOWING DBA*

Time After DBA (sec)	Drywell Pressure (psia)
0.00	15.45
0.79	32.31
0.90	34.13
1.00	35.25
1.20	36.59
1.40	37.34
1.60	37.52
1.80	37.65
2.00	38.83

---

* Drywell pressure used for pool swell analysis is higher than FSAR Figure 6.2-4.

TABLE 6A.4-3

RESULTS OF DOWNCOMER VENT CLEARING AND SUPPRESSION POOL SWELL ANALYSIS FOR UNIT 2

1.	Downcomer vent clearing time*, tc	0.79 sec
2.	Downcomer vent clearing velocity at tc	53.75 ft/sec
3.	Suppression pool swell velocity at tc	3.31 ft/sec
4.	Maximum suppression pool swell velocity	28.30 ft/sec
5.	Maximum suppression pool swell acceleration	74.40 ft/sec^2
6.	Maximum suppression pool swell height, H_{max} (above initial suppression pool level)	19.24 ft
7.	H_{max}/initial submergence	1.75
8.	Drywell floor maximum upward pressure differential	5.5 psi
9.	Time* to reach H_{max}	1.79 sec
10.	Maximum air bubble pressure	34.41 psia
11.	Maximum suppression chamber air space pressure (at breakthrough)	43.07 psia
12.	End of suppression pool fallback*	2.86 sec
13.	Maximum velocity during fallback	34.57 ft/sec

---

* Times are from time of LOCA initiation.

TABLE 6A.4-4

4TCO TIME PERIODS FOR BASIC CO LOAD AND CO LOAD WITH ADS

	Run Number	Time Segment Specified for Basic CO Load* (sec)	Time Interval of CO Observed in Test (sec)
Basic CO Load	3	13 to 15	5 to 29
	4	10 to 12	5 to 29
	5	19 to 21	5 to 38
	8	5 to 7	5 to 28
	9	10 to 23	5 to 38
	10	28 to 30	5 to 41
	12	21 to 25	5 to 48
	14	25 to 31	5 to 59
	15	31 to 48	5 to 50
	22	13 to 21	5 to 32
	23	5 to 7	5 to 28
	24	12 to 14	5 to 30
	25	32 to 42	5 to 29 32 to 44
	26	16 to 24, 32 to 36	5 to 24 29 to 37
	27	16 to 34	5 to 40
	28	17 to 19	5 to 36
CO Load with ADS	13	50 to 59	5 to 60
	24	50 to 59	5 to 59

---

* These segments contain the maximum PSD between 0 and 60 Hz in applicable test conditions. Selection criteria are discussed in Sections 6A.4.5.3.1 and 6A.4.5.3.2.

TABLE 6A.4-5

AVERAGE PRESSURE AMPLITUDE RATIO BETWEEN THE CYLINDRICAL AND THE ANNULAR POOL AS CALCULATED FROM ACOUSTIC THEORY

Vent Source Frequency (Hz)	Sound Speed (M/S)	Average Pressure Amplitude*
8	365.8	1.21
12	365.8	1.23
16	365.8	1.24
22	365.8	1.05
30	365.8	1.05
5	1,275.9	1.21
15	1,275.9	1.22
25	1,275.9	1.21

---

* The pressure amplitude ratio calculated from acoustic model varies slightly from point to point.

TABLE 6A.4-6

THIS TABLE HAS BEEN DELETED

TABLE 6A.4-7

NOMINAL 4T STRUCTURE AND FLUID PROPERTIES USED IN THE VERIFICATION OF THE ACOUSTIC FLUID-STRUCTURE INTERACTION METHODOLOGY

a = 1.0668 m (3.5 ft) = tank radius

L = 7.0104 m (23 ft) = nominal water depth

= 6.2484 m (20.5 ft) = water depth for Anamet test

h_b = 101.6 mm (4 in) = base plate thickness

h_s = 15.875 mm (5/8 in) = shell thickness

ω_b = 1,185.6 S^{-1} = base plate vibrational frequency(1)

= 1,373.6 S^{-1}(2)

= 674.1 S^{-1}(3)

ω_s = 4,913.8 S^{-1} = shell vibration frequency

ρ_s = 7,700 kgm^{-3} (470.7 lbm ft^{-3}) = steel density

Y = 19.5 (10^{10}) Pa (28.3 Mpsi) = steel elastic modulus

μ = 0.28 = Poisson's ratio for steel

ρ = 1,000 kgm^{-3} (62.4 lbm ft^{-3}) = water density

c_c = 1,036 m/s (3,400 fps) = acoustic speed

inner pool - 1.923×10^{-9} per psf

outer pool - 1.943×10^{-9} per psf

NMP2 (inner pool) - $4.017 \times 10^{-8} \quad \frac{s^2}{m^2}$

NMP2 (outer pool) - $4.057 \times 10^{-7} \quad \frac{s^2}{m^2}$

TABLE 6A.4-7 (Cont'd.)

---

(1) Observed in Anamet 4T FSI study.

(2) $$\omega_b = \frac{1}{a}\left[\frac{Y}{\rho_s}\left(1 - \mu^2\right)^{-1}\right]^{1/2} \quad (\textit{clamped plate})$$

(3) $$\omega_b = (4.99)\,\frac{h_b}{a^2}\left[\frac{Y}{12\,\rho_s}\left(1 - \mu^2\right)^{-1}\right]^{1/2} \quad (\textit{simply supported plate})$$

TABLE 6A.4-8

EFFECTIVE SOUND SPEEDS
USED FOR CHUGGING EVALUATION

Source	Acoustic Speed (m/s)	Source	Acoustic Speed (m/s)	Source	Acoustic Speed (m/s)
GE 801	(Inner pool) 549.4 (Outer pool) 521.4	GE 805	(Inner pool) 1578.8 (Outer pool) 1424.8	GE 809	(Inner pool) 1243.4 (Outer pool) 1164.0
GE 802	(Inner pool) 878.9 (Outer pool) 776.2	GE 806	(Inner pool) 975.4 (Outer pool) 840.2	GE 810	(Inner pool) 1578.8 (Outer pool) 1424.8
GE 803	(Inner pool) 1255.2 (Outer pool) 1000.0	GE 807	(Inner pool) 871.5 (Outer pool) 771.0	GE 811	(Inner pool) 1808.0 (Outer pool) 1356.0
GE 804	(Inner pool) 1339.4 (Outer pool) 1241.4	GE 808	(Inner pool) 1414.7 (Outer pool) 1075.1		

TABLE 6A.4-9

THIS TABLE HAS BEEN DELETED

TABLE 6A.4-10

RANDOM START TIMES

Time Window - 50 x 10^{-3}s
Number of downcomers - 127
MEAN - 0.025
MIN VAR - 0.0015736

Downcomer Index Number	Start Times ($x10^{-3}s$)	Downcomer Index Number	Start Times ($x10^{-3}s$)
1	6	68	12
2	46	69	36
3	30	70	14
4	18	71	18
5	32	72	20
6	34	73	14
7	14	74	12
8	16	75	36
9	22	76	12
10	42	77	6
11	10	78	22
12	24	79	36
13	8	80	16
14	20	81	22
15	50	82	36
16	26	83	10
17	8	84	48
18	12	85	42
19	8	86	26
20	42	87	22
21	26	88	40
22	28	89	48
23	36	90*	30
24	16	91	48
25	22	92	24
26	38	93	16
27	30	94	28
28	36	95	26
29	42	96	2
30	24	97	32
31	10	98	20
32	48	99	26
33	50	100**	28
34	20	101	36
35	18	102	14
36	28	103*	10
37	12	104	36
38	22	105	14
39	18	106	16

TABLE 6A.4-10 (Cont'd.)

Downcomer Index Number	Start Times ($x10^{-3}s$)	Downcomer Index Number	Start Times ($x10^{-3}s$)
40	14	107	26
41	22	108	2
42	4	109	30
43	14	110	10
44	8	111	2
45	10	112	16
46	46	113**	28
47	34	114	32
48	30	115	28
49	30	116	38
50	8	117*	26
51	28	118	10
52	38	119	28
54	8	121	44
55	36	122	14
56	36	123	40
57	48	124	6
58	14	125	30
59	40	126	26
60	22	127	36
61	18		
62	8		
63	26		
64	40		
65*	46		
66	24		
67	20		

---

* These downcomers have been capped (vacuum breaker relocations) but were included in the analysis as open downcomers. However, due to the random nature of start times, it is not expected that the resultant chugging loads will be affected by these downcomers.

** These downcomers have been capped (RHR heat exchanger relief valve discharge quencher interference at these locations) but were included in the analysis as open downcomers. However, due to the random nature of start times, it is not expected that the resultant chugging loads will be affected by these downcomers.

TABLE 6A.4-11

CHUG STRENGTH ASYMMETRIC FACTORS

Source	Asymmetric Factor (α)
801	0.1267
802	0.1341
803	0.1349
804	0.1246
805	0.1391
806	0.1329
807	0.1445
808	0.1236
809	0.1058
810	0.1369
811*	0.1058

---

* The statistical values of source 811 are approximated by those of source 809, since it is derived from 809 with a modified sound speed (see Section 6A.4.6.3.2).

TABLE 6A.4-12

EOF FOR THE SIX 4TCO KEY RUNS

4TCO Run No.	EOF
1	0.06
15	0.06
16	0.07
20	0.09
25	0.06
26	0.12

TABLE 6A.4-13

THIS TABLE HAS BEEN DELETED

TABLE 6A.4-14
MODIFIED VALUES OF C_M C_V DUE TO INTERFERENCE

DOWNCOMER 99	CM=2.2581, CV=0.3476
DOWNCOMER 99 WITH SVV-012-64-3	CM=2.0843, CV=0.1159
DOWNCOMER 63 WITHOUT SVV-012-64-3	CM=2.0558, CV=0.0544
DOWNCOMER 63 WITH SVV-012-64-3	CM=2.1491, CV=0.1146
DOWNCOMER 46 WITHOUT SVV-012-64-3	CM=2.1556, CV=0.0502
DOWNCOMER 46 WITH SVV-012-64-3	CM=2.1442, CV=0.1346
DOWNCOMER 64 WITHOUT SVV-012-64-3	CM=2.1400, CV=0.0380
DOWNCOMER 64	CM=2.1909, CV=0.0688
DOWNCOMER 104	CM=2.0846, CV=0.1094
DOWNCOMER 105	CM=2.1173, CV=0.0889
DOWNCOMER 106	CM=2.1695, CV=0.1001
LINE 2-RHS-018-166-2	CM=2.2952, CV=0.6105
LINE 2-CSL-020-2-2/2CSL*STR1	CM=2.22/2.5, CV=*
LINE 2-RHS-003-253-2 WITH 2-CSL-020-2-2	CM=2.3422, CV=0.1075
LINE 2-RHS-003-253-2 W/O 2-CSL-020-2-2	CM=2.1197, CV=0.0260
LINE 2-RHS-012-175-2	CM=2.5565, CV=0.8807
LINE 2-RHS-012-175-2 W/O 2-CSL-020-2-2	CM=2.4888, CV=0.9188
LINE 2-RHS-012-175-2 W/O 2-RHS-024-1-2	CM=2.5417, CV=0.9011
LINE 2-RHS-012-175-2 W/O 020-2 & 024-1	CM=2.4694, CV=0.9403
LINE 2-RHS-024-1-2/2RHS*STR1A	CM=2.3/2.36, CV=*
LINE 2-RHS-024-167-2/2RHS*STR1B	CM=2.3/2.36, CV=*
LINE 2-RHS-024-167-2 W/O 2-RHS-006-211-2	CM=2.0980, CV=0.1642
LINE 2-RHS-024-167-2 W/O 2-RHS-012-204-2	CM=2.0860, CV=0.1932
LINE 2-RHS-024-167-2 W/O 6-211 & 12-204	CM=2.0858, CV=0.1514
LINE 2-RHS-006-211-2	CM=2.3152, CV=0.1884

TABLE 6A.4-14 (Cont'd.)

LINE SVV-012-64-3	CM=2.2459, CV=0.1433
LINE SVV-012-71-3	CM=2.0726, CV=0.2697
DOWNCOMER 121	CM=2.1039, CV=0.1564
DOWNCOMER 26	CM=2.1496, CV=0.0982
LINE 2-RHS-024-169-2/2RHS*STR1C	CM=2.23/2.36, CV=*
LINE 2-RHS-003-257-2 WITH 2-RHS-024-169-2	CM=2.7421, CV=0.3972
LINE 2-RHS-003-257-2 W/O 2-RHS-024-169-2	CM=2.1197, CV=0.0260
LINE 2-RHS-012-204-2	CM=2.6066, CV=0.8454
LINE 2-RHS-204-2 W/O 2-RHS-024-167-2	CM=2.5962, CV=0.8638
LINE 2-RHS-012-204-2 W/O 2-RHS-024-169-2	CM=2.4888, CV=0.9188
2-RHS-12-204-2 W/O 2-RHS-24-(167,169)-2	CM=2.4694, CV=0.9403
LINE 2-ICS-002-74-2	CM=2.1240, CV=0.0204
LINE 2-ICS-006-76-2 STRAINER	CM=2.1746, CV=0.1608
LINE 2-ICS-006-76-2 PIPE	CM=2.1721, CV=0.0949
LINE 2-ICS-012-75-2	CM=2.2796, CV=0.3959
LINE 2-CSH-020-13-2/2CSH*STR1	CM=2.24/2.5, CV=*
LINE 2-RHS-003-253-2, HORIZONTAL	CM=2.1137, CV=0.0493
LINE 2-RHS-012-175-2, HORIZONTAL	CM=2.0090, CV=0.0135

NOTE: Downcomer numbering is that given on Figure 6A.4-13.

* C_V values are included in the standard drag coefficient in Table 6A.4-15.

TABLE 6A.4-15

TYPICAL VALUES FOR C_D DUE TO INTERFERENCE ON STANDARD DRAG

Pipeline	C_D Max
2-ICS-002-74-2	1.353
2-ICS-006-76-2	1.413
2-ICS-012-75-2	1.537
2-CSH-020-13-2	1.44
2-CSH*STR1	1.92
Downcomer 110	1.333
2-RHS-024-169-2	1.443
2-RHS*STR1C	1.724
2-RHS-003-257-2	2.28 Vertical segment 1.268 Horizontal segment
2-RHS-012-204-2	1.959
Downcomer 114	1.44
2-RHS-024-167-2	1.459
2-RHS*STR1B	1.724
2-RHS-006-211-2	1.594
2-RHS-018-166-2	1.538
2-CSL-020-2-2	1.44
2-CSL*STR1	1.92
2-RHS-003-253-2	1.709 Vertical segment 1.268 Horizontal segment
2-RHS-012-175-2	1.983
2-RHS-024-1-2	1.453

NOTE: Downcomer numbering is that given on Figure 6A.4-13.

TABLE 6A.4-15 (Cont'd.)

Pipeline	C_D Max
2-RHS*STR1A	1.724
2-SVV-012-62-3	1.589
2-SVV-012-68-3	1.807
2-SVV-012-74-3	1.838

TABLE 6A.4-16

STRUCTURES SUBJECT TO AIR BUBBLE, CONDENSATION OSCILLATION, AND CHUGGING

Item	Structure	Quantity/Description
1	Downcomers	121
2	SRV vent lines	18
3	Suction lines and associated strainers and supports	2-ICS-006-76-2 2-RHS-024-1-2 2-RHS-024-167-2 2-RHS-024-169-2 2-CSL-020-2-2 2-CSH-020-13-2
4	Discharge lines and associated supports	2-ICS-002-74-2 2-ICS-012-75-2 2-RHS-003-257-2 2-RHS-003-253-2 2-RHS-006-211-2 2-RHS-012-175-2 2-RHS-012-204-2 2-RHS-018-166-2 2-RHS-018-178-2
5	SRV lines and quenchers	18

TABLE 6A.4-17

STRUCTURES SUBJECT TO SUPPRESSION POOL SWELL AND FALLBACK

Item	Structure	Description
1	Suction lines and associated strainers and supports	2-ICS-006-76-2 2-RHS-024-1-2 2-RHS-024-167-2 2-RHS-024-169-2 2-CSL-020-2-2 2-CSH-020-13-2
2	Discharge lines and associated supports	2-ICS-002-74-2 2-ICS-012-75-2 2-RHS-003-257-2 2-RHS-003-253-2 2-RHS-006-211-2 2-RHS-012-175-2 2-RHS-012-204-2 2-RHS-018-166-2 2-RHS-018-178-2
3	Other miscellaneous piping and associated supports	2-CPS-002-6-2 2-HCS-003-17-2 2-DER-004-18-2 2-DFR-006-65-2 2-CPS-012-17-2
4	Bracing for platform at elevation 222'-6"	

SECTION 6A.5

DYNAMIC RESPONSE OF PRIMARY STRUCTURES

Dynamic response of primary structures is described in two parts. Section 6A.5.1 describes the response to SRV loads, while Section 6A.5.2 describes the response to hydrodynamic loads related to LOCA events.

6A.5.1 Structural Response to SRV Loads

The SRV discharge loads that are the basis for the design assessment are defined in Section 6A.3. Responses to these loads consist of ARS at various points on the structure, and internal forces and moments in the structure. The ARS are used for the evaluation of piping and equipment and the forces and moments are used for structural design.

The following SRV load cases are considered:

1. <u>Simultaneous Actuation of All Valves (Symmetric Loading Condition)</u> This load results from the simultaneous actuation of all valves. The resulting pool boundary pressures are assumed to be axisymmetric.

2. <u>Simultaneous Actuation of Three Adjacent Valves (Asymmetric Loading Condition)</u> This load results from the simultaneous actuation of three adjacent valves. The circumferential distribution of the pool boundary pressures is depicted on Figure 6D.3-34 of Appendix 6D.

3. <u>Automatic Depressurization System (ADS) Discharge</u> This load case results from the simultaneous actuation of the seven ADS valves. The circumferential distribution of the pool boundary pressure is shown on Figure 6D.3-35 of Appendix 6D.

4. <u>Single Valve Discharge</u> This load case assumes that a single SRV actuates. The circumferential distribution of pool boundary pressure is shown on Figure 6D.3-33 of Appendix 6D.

As described in Section 6A.3.3 for the T-quencher load definition, the entry of air bubbles into the suppression pool is assumed to be simultaneous and in phase for all load cases considered. Three pressure traces from Brunsbuttel are selected for plant assessment. The frequency content of the time-histories is varied by stretching or compressing the time-history traces into a longer or shorter duration by factors varying from 1.8 to 0.9. The amplitudes of the pressure traces are multiplied by 1.5. Figures 6D.3-32 through 6D.3-35 of Appendix 6D show the meridional variation of pressure along the pool boundary for all SRV load cases.

Once the loads are defined, the structural response calculations are performed using an axisymmetric finite element model of the containment structure. The finite element program GHOSH, which is described in Appendix 3A, is used for the analysis. The model used is shown on Figure 6A.5-1.

The fluid in the suppression pool was not modeled in the structural model used for hydrodynamic analysis. The basemat and containment are sufficiently rigid to preclude any fluid-structure interaction effects.

The pressure time-histories are converted to equivalent nodal force and moment time-histories. Nonaxisymmetric values are represented by an appropriate number of Fourier terms. The results of these analyses are acceleration time-histories at selected nodal points, and force and moment time-histories in the finite elements. The acceleration time-histories are used to generate ARS.

For each case, a total of 15 analyses has been completed. Each of the three traces has five factors applied to the time scale (0.9, 1.0, 1.2, 1.4, and 1.8). The ARS from each of these analyses are enveloped to give the conservative design ARS for that load case.

For structural design, the analysis which produces the most severe effects on the structure is used.

6A.5.1.1 Response to All Valve Discharge

Structural response to SRV discharge is developed for all three pressure traces, each with five time scale factors. Enveloped ARS are developed from the 15 individual ARS. Representative vertical ARS are presented on Figures 6A.5-2 and 6A.5-3 at the top of the pedestal and at the primary containment at the elevation of the star truss. Since the loading is symmetrical, the horizontal response to this event is exclusively in shell radial vibration modes.

Radial response at the same structural locations is presented on Figures 6A.5-4 and 6A.5-5.

Maximum values of internal loads at critical locations (Figure 6A.5-6) in the basemat region and the superstructure region are listed in Tables 6A.5-1 and 6A.5-2, respectively. These structural forces are used in Section 6A.6 for structural evaluation. Figure 6A.5-7 indicates the various internal loads and defines the corresponding sign convention for the basemat and superstructures.

6A.5.1.2 Response to Three Adjacent Valve Discharge

Structural response to this asymmetric event has also been determined. Enveloped ARS of vertical, radial, and tangential responses are presented on Figures 6A.5-8 through 6A.5-13 for the top of the pedestal and the primary containment at the elevation of the star truss. Tables 6A.5-3 and 6A.5-4 list the maximum values of internal loads at critical locations in the regions of substructure and superstructures of the reactor building.

6A.5.1.3 Response to ADS Discharge

Structural response to the ADS discharge event has been determined. Enveloped ARS of vertical, radial and tangential responses are presented on Figures 6A.5-14 through 6A.5-19 for the top of the pedestal and the primary containment at the elevation of the star truss. Maximum values of internal loads at the critical locations are calculated and found to be enveloped (bounded) by the all-valve case (Section 6A.5.1.1). Therefore, the results from the all-valve case (Tables 6A.5-1 and 6A.5-2) are used in place of these loads for the purpose of designing the structure.

6A.5.1.4 Response to Single Valve Discharge

Structural response to the single valve discharge event has been determined. Enveloped ARS of vertical, radial, and tangential responses are presented on Figures 6A.5-20 through 6A.5-25 for the top of the pedestal and the primary containment at the elevation of the star truss. Maximum values of internal loads at the critical locations are calculated and found to be enveloped (bounded) by the three-valve case (Section 6A.5.1.2). Therefore, the results from the three-valve case (Tables 6A.5-3 and 6A.5-4) are used in place of these loads for the purpose of designing the structure.

6A.5.2 Structural Response to LOCA Loads

This section describes the behavior of the containment structures when subjected to dynamic LOCA loads. The LOCA loads are described in detail in Section 6A.4.

The LOCA loads which cause dynamic responses in the containment structures are downcomer clearing, which include air pressure and pool swell, chugging, CO, and annulus pressurization.

Internal loads are computed for the basemat, reactor support pedestal, primary containment, and other structures. ARS were generated for the dynamic events and are used for the assessment of piping systems and equipment.

Results of this section are used in the assessment of primary structures as required by the load combinations discussed in Section 6A.6.

6A.5.2.1 Response to Vent Clearing

The transient pressure loads described in Section 6A.4.4 are applied to the same structural model described in Section 6A.5.1, and the dynamic response was determined. One Fourier series term is used to represent this axisymmetric event.

Since the loads due to vent clearing occur before the wetwell pressurization and do not have to be considered in conjunction with the loads due to wetwell pressurization, this load case is not significant for design, and is bounded by other LOCA events.

Selected ARS of resulting accelerations are presented on Figures 6A.5-26 through 6A.5-29. As can be seen, there is little dynamic response to vent clearing loads.

6A.5.2.2 Response to Condensation Oscillation Loads

The dynamic response of the structure from the CO load was determined. The CO load is defined in Section 6A.4.5. These loads are applied to the structural model described in Section 6A.5.1, and resulting structural responses are found. The ARS are enveloped for all cases of the basic CO loading, and also for the cases of CO loadings associated with ADS actuation. Figures 6A.5-30 through 6A.5-37 show enveloped ARS for both the basic case and the ADS case.

Internal moments and forces used for structural evaluation are the worst case of all CO loadings. Tables 6A.5-5 and 6A.5-6 present maximum values for primary structures in the region of the suppression pool.

6A.5.2.3 Response to Chugging Loads

The dynamic response of the containment structures to the oscillatory chugging loads was determined. The loading is described in Section 6A.4.6. These loads are applied to the structural model described in Section 6A.5.1. The loads are not axisymmetric, and had to be represented by a total of nine Fourier coefficients (symmetric terms plus four odd and four even terms). The resulting ARS for each load case are enveloped for evaluation of piping and mechanical systems. Examples of these enveloped radial, vertical, and tangential responses are shown on Figures 6A.5-38 through 6A.5-43.

The internal forces and moments used for design are the maximum values resulting from all the cases. They are given for locations near the suppression pool listed in Tables 6A.5-7 and 6A.5-8.

6A.5.2.4 Structural Response To Annulus Pressurization Loads

Annulus pressurization (AP) refers to the dynamic asymmetric pressurization of the annular space between the RPV and the shield wall following a DER of a high-energy line at the safe-end weld to the RPV nozzle. As stated in Section 6A.4.8, AP loads are described and discussed in Section 6.2.1 of the Unit 2 FSAR.

This section contains a description of the method used to calculate the dynamic structural response to AP loads. Representative ARS of the resulting building accelerations were generated for postulated pipe rupture events that result in significant AP loads. These are pipe ruptures of systems such as the recirculation suction lines at the RPV nozzle with the LPCI lines flow diverters and the feedwater lines without flow diverters. A rupture of a MSL does not result in AP loads since it is attached to the RPV above the top of the shield wall.

The AP dynamic model is a combined horizontal and vertical centerline beam model consisting of concentrated masses interconnected by linear beam and spring elements. The mass matrix is characterized by non-zero off-diagonal terms corresponding to hydrodynamic masses representing fluid structure interaction in the RPV and internals. The AP dynamic model is identical to the uncracked seismic model described in Section 3.7 of the Unit 2 FSAR. The model represents the RPV, shield wall, star truss and stabilizer, pedestal, primary containment, reactor building, and basemat.

The forcing functions applied to the AP dynamic model consist of five components which are simultaneously applied to the model. The components include pressure transients distributed over the boundary surfaces of the annular region and the drywell, pipe whip restraint embedment loads, RPV jet reaction force (RPV blowdown), jet impingement on RPV, and pipe impact on shield wall penetration (feedwater analysis only). The annulus pressure has a time-varying spatial distribution. Therefore, at each time step of the calculated pressure transient, the pressures are integrated over the surface areas under evaluation to obtain the unbalanced forces acting on the RPV and shield wall, respectively. These integrated pressure loads are then applied to the appropriate nodal points on the AP dynamic model simultaneously with the four other load components.

The dynamic solution is obtained by time-history modal analysis. Since AP is a faulted condition, the structural damping values used are those prescribed for a SSE. The dynamic solution consists of ARS of building accelerations generated using an exact analytical solution (Section 6A.2.4.2) for the hydrodynamic loads.

Results of the dynamic analysis indicate significant horizontal accelerations in the immediate vicinity of the applied loads, i.e., on the RPV and shield wall. The response is very localized, and substantially attenuated at the base of the RPV and shield wall (top of the pedestal). Response of the primary containment is not significant while the reactor building is unaffected. No significant vertical response occurs.

ARS of horizontal accelerations at points of maximum response in the RPV, shield wall, and pedestal will be presented in an amendment. These ARS represent envelopes of the greatest responses, from the feedwater, LPCI, or the recirculation suction line break.

A complete set of ARS curves including vertical responses were generated at points throughout the reactor building (including the primary containment) for both the recirculation suction and feedwater line breaks. These results are utilized in the evaluation of all plant piping and equipment components.

TABLE 6A.5-1

MAXIMUM VALUES OF DYNAMIC LOADS IN THE BASEMAT FROM AN ALL VALVE SRV DISCHARGE

Radius (ft)	M_{SS} (ft-k/ft)	M_{TT} (ft-k/ft)	N_{SS} (k/ft)	N_{TT} (k/ft)	Q_S (k/ft)
8.08	12.90	5.16	3.53	3.49	10.10
12.125(I)	17.90	8.35	2.62	3.05	3.60
12.125(O)	108.00	14.20	10.70	3.24	26.40
14.13	33.10	4.29	4.84	2.35	9.90
45.50	78.75	13.40	7.57	3.82	19.25
48.13(I)	140.00	29.40	7.85	4.14	23.70
48.13(O)	107.00	11.40	6.99	1.81	12.30
57.25	4.36	1.76	5.74	1.75	10.30

NOTE: All values are ±.

M_{SS}	Radial (longitudinal) bending moment (ft-k/ft) positive (+) when causing tension on top of mat and inside surface of superstructure.
M_{TT}	Tangential (hoop) bending moment (ft-k/ft) positive (+) when causing tension on top of mat and inside surface of superstructure.
N_{SS}	Axial (longitudinal) force (k/ft) positive (+) when causing tension in mat and superstructure.
Q_S	Radial (transverse) shear (k/ft) positive (+) when acting upward on outer face of mat and radially outward on superstructure.
N_{TT}	Tangential (hoop) force (k/ft) positive (+) when causing tension in mat and superstructure.
Q_T	Tangential (hoop) shear (k/ft).
N_{ST}	In-plane membrane shear (k/ft).

TABLE 6A.5-2

MAXIMUM VALUES OF DYNAMIC LOADS IN THE SUPERSTRUCTURES FROM AN ALL-VALVE SRV DISCHARGE

Elevation (ft)	M_{SS} (ft-k/ft)	M_{TT} (ft-k/ft)	N_{SS} (k/ft)	N_{TT} (k/ft)	Q_S (k/ft)
Pedestal					
176.00	58.75	9.35	13.70	1.77	13.50
180.80	11.30	3.60	10.50	15.90	13.70
190.40	12.60	5.62	10.30	20.80	4.90
195.20	6.60	5.07	10.30	12.40	1.82
224.00	0.38	0.07	9.14	0.44	0.12
230.50(B)	1.26	0.20	9.14	0.94	0.34
230.50(T)	1.36	0.25	8.67	0.82	0.58
238.00(B)	6.40	0.97	8.67	3.26	1.40
238.00(T)	9.84	1.55	8.53	3.37	2.36
242.76	2.09	0.28	8.53	3.20	0.99
259.38	2.76	0.52	7.41	0.24	0.55
266.54	4.92	0.92	7.41	3.20	0.26
Primary Containment					
176.00	100.00	16.80	7.35	4.46	18.40
180.80	11.60	20.15	7.32	13.45	13.71
185.60	34.20	5.58	7.29	26.30	10.20
190.40	41.20	6.65	7.11	33.60	4.23
195.20	31.00	4.95	7.11	33.90	1.42
231.44	6.67	1.08	5.92	3.77	1.26
238.00(B)	5.53	0.94	5.92	2.06	0.96
238.00(T)	2.56	0.47	5.64	2.05	0.38
243.33	2.16	0.42	5.74	1.45	0.37
248.67	2.74	0.49	5.85	1.80	0.35
259.33	2.59	0.44	5.52	1.97	0.38
264.67	2.32	0.41	5.63	2.52	0.40
296.67	2.34	0.40	3.21	1.47	0.51
302.00	4.23	0.69	3.01	1.18	0.66
306.36	2.04	0.52	2.98	1.41	0.77
315.25	4.40	0.49	1.46	2.24	0.68
326.83	0.16	1.30	0.85	9.61	1.65

TABLE 6A.5-2 (Cont'd.)

Drywell Floor

Radius (ft)	M_{SS} (ft-k/ft)	M_{TT} (ft-k/ft)	N_{SS} (k/ft)	N_{TT} (k/ft)	Q_S (k/ft)
Elevation 230.5 ft					
6.06	0.96	0.62	1.09	1.00	0.18
Elevation 238 ft					
12.13	23.80	4.69	4.08	2.98	5.10
19.32	3.33	2.13	2.87	2.92	1.42
40.93	3.78	0.57	1.63	2.45	0.74
48.13	5.31	1.03	1.74	2.31	0.63

Secondary Containment

Elevation (ft)	M_{SS} (ft-k/ft)	M_{TT} (ft-k/ft)	N_{SS} (k/ft)	N_{TT} (k/ft)	Q_S (k/ft)
175.0	0.47	0.04	1.90	0.15	0.15
198.0	0.37	0.04	1.98	0.81	0.09

NOTE: All values are ±.

TABLE 6A.5-3

MAXIMUM VALUES OF DYNAMIC LOADS IN THE BASEMAT FROM A THREE ADJACENT VALVE SRV DISCHARGE

Radius (ft)	M_{SS} (ft-k/ft)	M_{TT} (ft-k/ft)	M_{ST} (ft-k/ft)	N_{SS} (k/ft)	N_{TT} (k/ft)	N_{ST} (k/ft)	Q_S (k/ft)	Q_T (k/ft)
8.08	7.50	3.32	0.80	2.81	1.78	2.02	5.12	0.41
12.125(I)	17.90	8.35	0.41	2.62	3.05	1.00	3.60	0.60
12.125(O)	108.00	14.20	0.41	10.70	3.24	8.76	26.40	8.07
14.13	50.60	15.40	7.50	10.50	2.07	6.31	22.40	3.30
45.50	63.40	10.40	1.38	7.63	2.74	1.86	19.90	0.73
48.13(I)	110.00	22.80	1.24	7.34	2.98	1.74	18.90	1.35
48.13(O)	91.40	10.60	1.24	8.19	1.98	3.64	10.60	1.39
57.25	4.45	1.97	2.44	7.47	1.25	2.13	8.96	0.09

NOTE: All values are ±.

TABLE 6A.5-4

MAXIMUM VALUES OF DYNAMIC LOADS IN THE SUPERSTRUCTURES
FROM A THREE ADJACENT VALVE SRV DISCHARGE

Elevation (ft)	M_{SS} (ft-k/ft)	M_{TT} (ft-k/ft)	M_{ST} (ft-k/ft)	N_{SS} (k/ft)	N_{TT} (k/ft)	N_{ST} (k/ft)	Q_S (k/ft)	Q_T (k/ft)
Pedestal								
176.00	56.10	9.35	3.55	13.70	3.17	14.60	13.50	4.50
180.80	9.14	3.60	4.01	7.89	9.85	15.50	13.70	1.33
190.40	12.60	5.62	0.62	5.66	20.80	6.90	4.89	1.66
195.20	6.60	5.07	2.36	7.14	12.40	4.59	1.82	1.03
224.00	1.80	0.91	0.57	9.51	1.01	4.87	0.77	0.21
230.50(B)	2.93	0.43	0.47	8.91	1.58	4.84	0.80	0.19
230.50(T)	3.05	0.97	1.01	8.53	1.60	5.35	1.36	0.23
238.0(B)	10.90	2.38	1.84	7.94	2.84	4.93	2.05	0.78
238.0(T)	18.20	3.99	2.82	9.03	3.03	2.70	3.12	1.60
242.76	6.21	2.69	0.82	8.66	3.43	3.35	1.78	0.62
259.38	4.95	4.31	1.22	6.78	1.31	2.60	0.60	0.70
266.54	6.78	3.40	2.15	6.46	3.15	2.84	0.83	0.63
Primary Containment								
176.00	111.00	18.70	0.70	5.95	2.96	8.67	19.90	2.83
180.80	16.65	3.10	6.11	5.94	11.30	8.81	14.89	0.51
185.60	34.70	6.91	6.03	5.84	24.70	8.16	11.00	0.84
190.40	43.80	9.11	3.85	5.64	32.90	6.29	4.14	1.12
195.20	34.30	8.18	2.16	5.72	34.00	4.85	1.51	1.02
231.44	7.67	1.83	3.20	5.11	4.83	5.31	1.66	0.16
238.0(B)	11.50	2.05	1.85	4.62	5.36	4.81	1.85	0.48
238.0(T)	12.90	2.28	2.02	3.76	5.41	2.97	1.38	0.41
243.33	6.90	1.34	0.86	3.86	5.33	2.45	1.06	0.23
248.67	3.96	1.14	0.83	4.03	4.64	1.94	0.69	0.13
259.33	3.24	1.47	0.69	4.00	3.71	1.83	0.42	0.12
264.67	3.39	1.73	0.51	4.22	3.13	1.74	0.37	0.15
296.67	2.27	0.89	1.03	2.57	1.92	1.79	0.44	0.06
302.00	2.95	1.26	0.97	2.35	2.86	1.58	0.58	0.08
306.36	2.64	1.70	1.00	2.23	3.11	1.52	0.64	0.11
315.25	4.69	2.33	1.27	0.81	2.68	1.26	0.50	0.20
326.83	0.15	6.27	3.07	0.62	9.29	0.43	1.73	0.48

TABLE 6A.5-4 (Cont'd.)

Drywell Floors Radius (ft)	M_{SS} (ft-k/ft)	M_{TT} (ft-k/ft)	M_{ST} (ft-k/ft)	N_{SS} (k/ft)	N_{TT} (k/ft)	N_{ST} (k/ft)	Q_S (k/ft)	Q_T (k/ft)
Elevation 230.5 ft								
6.06	0.96	0.62	0.24	1.09	0.99	0.82	0.18	0.19
Elevation 238 ft								
12.13	23.80	4.69	1.10	4.08	2.45	6.68	5.10	1.70
19.32	4.32	2.22	2.06	3.98	2.95	3.13	2.95	0.18
40.93	2.40	2.03	1.66	3.10	3.94	2.30	2.13	0.12
48.13	13.20	1.73	0.96	3.03	4.14	2.19	1.80	0.29

Secondary Containment Elevation (ft)	M_{SS} (ft-k/ft)	M_{TT} (ft-k/ft)	M_{ST} (ft-k/ft)	N_{SS} (k/ft)	N_{TT} (k/ft)	N_{ST} (k/ft)	Q_S (k/ft)	Q_T (k/ft)
175.0	0.40	0.08	0.01	1.17	0.19	0.33	0.04	0.00
198.0	0.53	0.07	0.02	1.06	0.65	0.35	0.09	0.00

NOTE: All values are ±.

TABLE 6A.5-5

MAXIMUM VALUES OF DYNAMIC LOADS IN THE BASEMAT
FROM CONDENSATION OSCILLATION

Radius (ft)	M_{SS} (ft-k/ft)	M_{TT} (ft-k/ft)	N_{TT} (k/ft)	N_{SS} (k/ft)	Q_S (k/ft)
4.04	16.00	13.10	2.30	2.30	2.80
8.08	10.60	11.30	2.25	2.24	3.25
12.125(I)	11.60	8.52	2.22	2.19	3.42
12.125(O)	24.10	8.39	2.20	2.55	7.04
14.13	12.33	7.53	2.19	2.58	4.72
19.35	10.80	8.44	2.15	2.50	2.47
40.27	19.20	4.92	5.33	11.60	22.80
45.50	123.00	22.30	6.17	11.50	28.35
48.125(I)	212.00	45.70	6.55	11.80	34.50
48.125(O)	173.00	17.60	2.99	11.40	19.60
57.25	5.71	2.95	1.98	9.30	16.40
75.50	5.02	0.91	1.57	1.62	0.65
84.625(I)	8.08	1.06	1.50	1.53	0.58
84.625(O)	4.12	0.75	1.40	1.39	0.60
91.50	0.00	0.60	1.32	1.32	0.55

TABLE 6A.5-6

MAXIMUM VALUES OF DYNAMIC LOADS IN THE SUPERSTRUCTURES FROM CONDENSATION OSCILLATION

Elevation (ft)	M_{SS} (ft-k/ft)	M_{TT} (ft-k/ft)	N_{SS} (k/ft)	N_{TT} (k/ft)	Q_S (k/ft)
Pedestal					
176.00	4.06	0.61	11.20	3.60	1.56
180.80	1.68	0.23	11.20	3.28	1.31
190.40	1.62	0.17	10.20	4.35	0.98
195.20	0.68	0.04	10.20	2.75	0.47
224.00	1.83	0.28	8.17	1.53	0.44
230.50(B)	5.34	0.89	7.43	2.79	0.79
230.50(T)	3.88	1.15	7.95	3.06	1.98
238.00(B)	25.50	3.66	7.95	14.70	7.14
238.00(T)	24.00	3.71	7.22	14.20	7.06
242.76	5.34	0.75	7.94	11.22	2.43
259.38	6.14	1.13	10.58	0.80	0.88
266.54	8.32	1.57	10.58	6.69	0.81
Primary Containment					
176.00	168.00	28.20	10.50	6.94	29.40
180.80	36.00	6.15	10.50	22.60	23.60
185.60	62.70	10.20	10.40	46.30	19.90
190.40	87.00	14.10	9.86	61.40	8.91
195.20	72.60	11.70	9.86	64.10	4.85
231.44	29.70	4.79	9.77	20.35	6.40
238.00(B)	21.10	3.60	8.88	10.50	4.38
238.00(T)	11.30	2.03	8.16	10.50	2.33
243.33	17.82	3.08	9.30	8.50	2.49
248.67	20.24	3.31	9.58	7.69	2.23
259.33	16.50	2.72	9.09	8.09	2.44
264.67	15.73	2.66	9.14	9.91	2.48
296.67	14.30	2.38	6.88	5.30	1.46
302.00	16.61	2.59	7.21	5.81	2.95
306.36	9.24	2.46	6.68	6.49	3.04
315.25	22.66	3.15	3.81	10.37	2.59
326.83	0.00	6.14	2.47	36.85	6.51
Drywell Floor					
Radius (ft)	M_{SS} (ft-k/ft)	M_{TT} (ft-k/ft)	N_{SS} (k/ft)	N_{TT} (k/ft)	Q_S (k/ft)
Elevation 230.5 ft					
6.06	2.45	3.18	2.54	2.54	0.31

TABLE 6A.5-6 (Cont'd.)

Drywell Floor

Radius (ft)	M_{SS} (ft-k/ft)	M_{TT} (ft-k/ft)	N_{SS} (k/ft)	N_{TT} (k/ft)	Q_S (k/ft)
Elevation 238 ft					
12.13	32.89	6.62	13.20	14.30	6.68
19.32	7.98	4.44	13.53	13.86	4.19
40.93	11.44	2.38	6.93	11.11	1.90
48.13	19.25	4.38	7.50	10.45	1.62

Secondary Containment

Elevation (ft)	M_{SS} (ft-k/ft)	M_{TT} (ft-k/ft)	N_{SS} (k/ft)	N_{TT} (k/ft)	Q_S (k/ft)
175.00	0.58	0.07	2.05	0.51	0.07
198.00	0.41	0.05	2.05	0.60	0.08

TABLE 6A.5-7

MAXIMUM VALUES OF DYNAMIC LOADS IN THE BASEMAT FROM CHUGGING

Radius (ft)	M_{SS} (ft-k/ft)	M_{TT} (ft-k/ft)	M_{ST} (ft-k/ft)	N_{SS} (k/ft)	N_{TT} (k/ft)	N_{ST} (k/ft)	Q_{S} (k/ft)	Q_{T} (k/ft)
4.04	10.80	10.10	2.66	5.08	5.75	2.56	4.64	0.65
8.08	10.30	5.50	2.25	5.40	6.23	2.31	8.01	0.66
12.125(I)	42.60	16.50	0.35	5.65	6.22	2.28	8.39	1.63
12.125(O)	83.00	10.90	0.35	9.00	6.52	6.80	19.60	5.54
14.13	37.25	9.98	5.08	8.15	4.40	4.62	13.80	2.55
19.35	16.60	6.94	4.12	6.81	2.75	3.30	7.84	1.14
40.27	12.70	5.57	3.50	7.64	4.33	1.93	10.00	0.68
45.50	84.10	15.10	2.36	8.77	4.90	1.80	19.85	0.75
48.125(I)	146.00	31.40	1.00	9.11	5.17	1.88	24.30	1.41
48.125(O)	131.00	14.20	0.94	10.30	4.06	2.96	15.30	1.26
57.25	6.98	3.10	2.36	7.38	1.78	1.79	6.87	0.21
75.50	4.33	1.15	1.06	2.72	1.25	1.09	0.70	0.07
84.625(I)	5.70	1.14	0.36	2.11	1.32	0.87	0.73	0.18
84.625(O)	5.49	0.92	0.36	1.47	1.37	0.68	0.82	0.11
91.50	0.00	0.51	0.35	1.38	1.27	0.58	0.76	0.00

TABLE 6A.5-8

MAXIMUM VALUES OF DYNAMIC LOADS IN THE SUPERSTRUCTURES FROM CHUGGING

Elevation (ft)	M_{SS} (ft-k/ft)	M_{TT} (ft-k/ft)	M_{ST} (ft-k/ft)	N_{SS} (k/ft)	N_{TT} (k/ft)	N_{ST} (k/ft)	Q_S (k/ft)	Q_T (k/ft)
Pedestal								
176.00	51.95	8.17	2.58	8.50	4.64	9.89	12.00	3.54
180.80	12.60	4.90	4.87	7.73	16.50	11.60	9.63	1.10
190.40	16.95	11.30	2.50	9.21	28.50	6.80	6.06	3.09
195.20	11.50	9.50	3.19	10.00	17.80	7.80	4.06	2.31
224.00	9.42	5.47	2.59	9.75	4.88	7.25	2.34	1.48
230.50(B)	10.30	1.87	2.47	12.10	3.75	6.78	3.02	0.99
230.50(T)	9.55	3.92	4.33	12.40	4.35	9.18	5.11	0.83
238.00(B)	28.30	6.55	3.54	13.40	7.73	9.77	6.57	3.04
238.00(T)	23.80	7.01	3.97	14.90	7.15	8.39	4.37	2.53
242.76	11.30	5.35	2.20	13.20	5.60	8.95	2.75	1.49
259.38	16.20	11.30	3.98	10.85	5.70	6.26	2.48	2.62
266.54	19.90	13.00	4.28	10.10	10.80	7.70	3.44	3.21
Primary Containment								
176.00	138.00	22.20	0.50	6.94	4.78	5.57	26.75	2.85
180.80	28.70	5.56	6.75	6.38	14.30	5.72	18.40	0.80
185.60	46.50	10.50	6.54	6.20	30.30	5.40	9.62	1.51
190.40	61.40	15.00	5.50	5.90	40.20	4.90	7.30	1.97
195.20	55.60	15.00	7.15	5.60	40.70	5.15	6.90	1.90
231.44	25.20	7.80	6.50	4.80	11.30	5.35	6.13	1.12
238.00(B)	34.90	6.02	5.34	4.58	9.06	5.77	7.19	1.08
238.00(T)	23.30	4.57	5.42	5.22	9.28	3.55	2.43	0.59
243.33	18.50	4.13	4.11	5.20	8.66	3.60	2.35	0.65
248.67	15.80	4.21	3.08	5.50	8.60	3.35	2.30	0.68
259.33	14.40	3.74	2.72	6.00	8.60	2.65	2.25	0.60
264.67	14.10	3.79	2.51	6.20	8.53	2.80	2.20	0.58
296.67	10.20	3.83	1.87	5.09	6.58	3.45	1.80	0.61
302.00	10.60	3.05	2.51	4.75	6.60	3.60	1.60	0.38
306.36	8.50	3.50	2.90	4.15	6.70	3.80	2.10	0.75
315.25	14.00	4.60	2.51	2.72	6.20	3.80	2.15	1.42
326.83	0.60	12.00	10.10	1.74	26.30	1.12	5.80	0.00

TABLE 6A.5-8 (Cont'd.)

Drywell Floor Radius (ft)	M_{SS} (ft-k/ft)	M_{TT} (ft-k/ft)	M_{ST} (ft-k/ft)	N_{SS} (k/ft)	N_{TT} (k/ft)	N_{ST} (k/ft)	Q_S (k/ft)	Q_T (k/ft)
Elevation 230.5 ft								
6.06	2.96	1.84	0.61	4.10	3.20	3.50	0.88	0.58
Elevation 238 ft								
12.13	30.50	5.32	1.60	11.70	6.10	11.50	6.69	2.63
19.32	7.14	4.10	3.04	11.80	7.20	7.25	3.30	0.74
40.93	11.40	2.24	2.04	9.30	6.91	5.35	2.35	0.47
48.13	19.50	4.31	2.52	9.00	6.69	3.11	2.26	0.73

Secondary Containment Elevation (ft)	M_{SS} (ft-k/ft)	M_{TT} (ft-k/ft)	M_{ST} (ft-k/ft)	N_{SS} (k/ft)	N_{TT} (k/ft)	N_{ST} (k/ft)	Q_S (k/ft)	Q_T (k/ft)
175.00	0.58	0.00	0.02	1.65	0.46	0.60	1.10	0.00
198.00	0.40	0.05	0.02	1.50	0.55	0.53	0.08	0.00

SECTION 6A.6

PRIMARY CONTAINMENT STRUCTURES ASSESSMENT

6A.6.1 Introduction

This section presents an evaluation of the design adequacy of the primary containment structures for loading conditions, which include the effects of SRV discharge and LOCA. The primary structures defined in this section consist of the primary containment, reactor pedestal, drywell floor, and foundation basemat. The general arrangement of the reactor building is shown on Figures 1.2-11 and 1.2-12. These structures are evaluated in terms of their capability to sustain the loads, as defined by the factored load combinations discussed in Section 6A.2.2.1 and Table 6A.2-2.

Section 6A.5 provides a description of the dynamic behavior of the primary containment structures when subjected to the effects of SRV and LOCA loads. As discussed in Section 6A.5, the structural assessment for SRV loads is based on the four cases of the T-quencher load definition described in Section 6A.3, with simultaneous air bubble entry into the suppression pool. Margins of safety for the primary containment structures have been calculated and are presented here.

6A.6.2 Description of Structures

The primary containment is a reinforced concrete structure. It is composed of a conical section, the drywell (located above a cylindrical section), and the suppression chamber, each separated by a 4-ft thick reinforced concrete drywell floor. A cylindrical pedestal that supports the BSW and the RPV extends up from the base of the primary containment and protrudes through the drywell floor. The primary containment and pedestal are supported on a reinforced concrete foundation mat, 10 ft thick, that also supports the reactor building.

The containment, internal structures, and foundation mat are further described in Sections 3.8.1, 3.8.3, and 3.8.5 of the FSAR and shown on Figures 3.8-1 through 3.8-3, 3.8-3a, 3.8-11, 3.8-14, 3.8-20, 3.8-22, and 3.8-23.

6A.6.3 Design Criteria and Loads

6A.6.3.1 Design Criteria

The primary containment structures are designed to accommodate the effects of environmental conditions associated with normal operation, transient conditions, seismic events, and postulated pipe rupture accidents. The structures also have sufficient capacity to sustain the effects of SRV discharge and LOCA loads when combined with the normal and abnormal load events, as delineated in Table 6A.2-2 and in Section 3.8.1.3 of the FSAR.

To ensure the integrity of the structures under the postulated events, the strength capacity of the members under tension, flexure, and compression includes a capacity reduction factor in accordance with the requirements of ACI-318-77.

The maximum absolute value of the dynamic responses due to SRV and LOCA, along with seismic and AP loadings, are used for the assessment of the primary containment structures.

The material and strength properties of the primary containment structures are given in Section 3.8.4 of the FSAR.

6A.6.3.2 Loads

All appropriate loads, including hydrodynamic loads, have been considered in the design assessment.

For a SBA and IBA, the suppression pool temperature and pressure are defined in Section 6A.2.1.

The SRV discharge loading (obtained from Section 6A.3), normalized pressure time-history, and corresponding pressure profile are shown on Figures 6D.3-32 through 6D.3-35 of Appendix 6D.

In addition to the quasi-static LOCA pressures and temperatures defined in Section 6.2 of the FSAR, the LOCA loads defined in Section 6A.4 have been considered.

6A.6.3.3 Load Combinations

Section 6A.2.2 provides a set of loading conditions and factored load combinations used for evaluating the structural integrity of the containment structures. These load combinations and corresponding load descriptions are shown in Table 6A.2-2.

6A.6.4 METHOD OF ANALYSIS

The method of analysis for assessing the primary containment structures under the effects of the suppression pool loads is described in Section 6A.2.4. The results of the analysis in terms of primary containment structure response are described in Section 6A.5, including maximum values of structural internal loads (moments, shears, axial loads). Resulting concrete and steel stresses and strains are evaluated by nonlinear stress analysis of the reinforced concrete sections.

6A.6.5 Summary, Design Margins, and Conclusions

6A.6.5.1 Containment Internal Loads

The foundation basemat, reactor pedestal, drywell floor, and primary containment were evaluated for the factored load combinations, including the hydrodynamic loads given in Table 6A.2-2.

The predominant structural internal loads are longitudinal bending moment, axial load, and transverse shear at the junctures of the reactor pedestal and primary containment with the foundation mat. Figure 6A.5-6 identifies those locations on the primary containment structures that are most heavily stressed but below allowable.

Tables 6A.5-1 and 6A.5-2 show the maximum values of bending moment, transverse shear, and axial load at selected positions within the suppression pool for an axisymmetric (all valve) discharge. Tables 6A.5-3 and 6A.5-4 provide the maximum results for the asymmetric adjacent valve discharge load.

The internal loads due to the all-valve simultaneous discharge are larger than the 3-valve asymmetric discharge and are used in load combination Equations 1, 2, 3, and 6 of Table 6A.2-2.

For a description of nomenclature and positive sign convention for internal loads, refer to Table 6A.5-1 and Figure 6A.5-7.

The internal loads resulting from the SRV and LOCA events have been combined with the corresponding internal loads from the other individual events in accordance with Table 6A.2-2. The summed values for internal loads, Equations 1 through 7a, are shown in Table 6A.6-1 for the basemat and in Table 6A.6-2 for the pedestal and primary containment. In each of these load equations, the directions of the maximum SRV load and other transient internal loads are assumed in such a manner as to produce the most critical conditions for stress calculations.

6A.6.5.2 Design Margins

The critical locations for each structure, in terms of design margin, have been found to be at the base of the reactor pedestal, at the base of the primary containment, and just outside the pedestal and primary containment for the foundation basemat.

6A.6.5.3 Conclusions

An evaluation of the structural capacity of the foundation basemat, reactor support pedestal, and primary containment to sustain the load combinations, including SRV discharge and LOCA transient loads, indicates an adequate design margin.

TABLE 6A.6-1

BASEMAT DESIGN INTERNAL LOADS

Equation No.	M_{SS} (k-ft/ft)	N_{SS} (k/ft)	Q_S,Q_T (k/ft)	M_{TT} (k-ft/ft)	N_{TT} (k/ft)	N_{ST} (k/ft)
<u>In the Vicinity of the Pedestal</u>						
1.1, 1.2	-409	-45	126	-185	16	-
2.1, 2.2	-1,232	165	140	-1,055	67	-
3.1, 3.2, 6.1, 6.2	-2,281	69	196	-2,021	80	-
4.1, 4.2, 4a.1, 5.1, 5.2, 5a.1	-2,899	104	212	-2,261	176	-
7.1, 7.2, 7a.1	-3,041	110	245	-2,427	168	-
<u>In the Vicinity of the Primary Containment</u>						
1.1, 1.2	-477	-2	132	-101	9	-
2.1, 2.2	-1,162	71	156	-375	139	-
3.1, 3.2,	-1,180	72	245	-394	164	-
6.1, 6.2				-569	-114	
4.1, 4.2, 4a.1, 5.1, 5.2, 5a.1	-1,738	1	252	+810	142	-
7.1, 7.2,	-1,721	11	293	+864	137	-
7a.1				-649	30	

NOTES:
1. Refer to Table 6A.2-2 for load combination equations.
2. The individual load events have been superimposed in such a way as to produce the most critical conditions for design calculations.
3. Maximum shear listed herein envelops shear in both horizontal directions.
4. In-plane membrane (torsional) shear is negligible.

TABLE 6A.6-2

REACTOR PEDESTAL AND PRIMARY CONTAINMENT DESIGN INTERNAL LOADS

Equation No.	M_{SS} (ft-k/ft)	N_{SS} (k/ft)	Q_{S} (k/ft)	M_{TT} (ft-k/ft)	N_{TT} (k/ft)	Q_{T} (k/ft)	N_{ST} (k/ft)
Base of Pedestal							
1.1, 1.2	126	-223	-28	17	-8	8	45
2.1, 2.2	356	-176	-81	25	-84	7	42
3.1, 3.2	378	-111	-84	27	-82	8	46
4.1, 4.2, 4a.1	757	-99	-194	69	-133	12	56
5.1, 5.2, 5a.1	762	-46	-194	68	-130	11	54
6.1, 6.2	375	-69	-85	24	-80	7	43
7.1, 7.2, 7a.1	776	4	-199	66	-130	11	58
Base of Primary Containment							
1.1, 1.2	409	-112	-62	39	-5	5	33
2.1, 2.2	589	-61	-93	-134	-105	4	36
3.1, 3.2	752	67	-109	-143	-94	4	102
4.1, 4.2, 4a.1	2,402	242	-342	-120	-194	8	39
5.1, 5.2, 5a.1	2,121	289	-300	-138	-192	7	94
6.1, 6.2	787	111	-104	-137	-92	5	122
7.1, 7.2, 7a.1	1,893	288	-244	-133	-73	8	134

NOTES:
1. Refer to Table 6A.2-2 for load combination equations.
2. Refer to Table 6A.6-1 for internal load definitions.
3. The individual load events have been superimposed in such a way as to produce the most critical conditions for design calculations.

SECTION 6A.7

PRIMARY CONTAINMENT LINER ASSESSMENT

6A.7.1 Liner Assessment for Hydrodynamic LOCA Loads

The primary containment liner is assessed in two parts, the basemat liner (Section 6A.7.2) and the wall liner (Section 6A.7.3). The wall liner anchorage system is assessed with the liner plate and welds.

The design loads acting on the primary containment liner, other than loads resulting from hydrodynamic transient events, are defined in FSAR Section 3.8.1.3. Hydrodynamic SRV and LOCA loads are described in Sections 6A.3 and 6A.4, respectively. The liner assessment for SRV loads is based on evaluation of all SRV load cases.

The liner in the suppression chamber is fabricated from carbon steel, SA-537, Class 2 and is clad with stainless steel, except at embedments or penetrations, which are completely stainless steel. The liner is designed, fabricated, and constructed in accordance with the ASME Boiler and Pressure Vessel Code, Section III, 1971 Edition, with Addenda through Summer 1973.

6A.7.2 Basemat Liner

The basemat liner is constructed of flat 1/4-in thick carbon steel plates with their edges welded to each other in an array as shown on Figure 3.8-2. The maximum size plates are approximately 15 by 7 ft, with several cutouts in the plates for embedments. The plates are attached to each other at their edges by a continuous full penetration weld with test channel, as shown on Figure 3.8-2, which also illustrates the weld detail at the junction of the basemat liner and the suppression pool liner. A 12-in thick slab of insulation concrete is installed over the basemat liner to protect it from the LOCA thermal effects and to minimize the corresponding loads on the concrete primary containment wall. A 1/8-in thick, stainless steel additional liner is provided over the insulation concrete to serve as a waterproof membrane for that concrete.

6A.7.2.1 Load Sources and Design Criteria

6A.7.2.1.1 Load Sources

The loads on the primary containment basemat liner caused by the SRV discharge and LOCA transients are described in Sections 6A.3 and 6A.4, respectively.

6A.7.2.1.2 Design Criteria

The design criteria and load combinations for the primary containment basemat liner, including the effects of the SRV discharge, are shown in FSAR Section 3.8.1.5. The basemat liner is also evaluated using the load combinations from FSAR Table 3.8-1. The combined strains are compared with the respective allowables given in Table CC-3720-1 of ASME Boiler and Pressure Vessel Code, Section III, Division 2.

A fatigue analysis of the basemat liner is performed to verify that the CUF is less than 1.0 (Reference Section 6A.7.3.2). The fatigue analysis uses the load combination given in FSAR Table 3.8-1 and methods prescribed by ASME Section III, Division 1, Subparagraph NB-3222.4(e).

6A.7.2.2 Load Combinations

The basemat liner is evaluated using the design criteria stated in Section 6A.7.2.1.2. In the evaluation of the basemat liner, strains generated by the various effects were combined to yield the greatest tensile or compressive value and were then compared to their respective allowables of Table CC-3720-1 of ASME Section III, Division 2.

In the fatigue evaluation, the strains to be used in evaluating the basemat liner will be converted to stresses and multiplied by a stress concentration factor to account for peak stress effects. The stress concentration factor is described in Section 6A.7.2.3. The fatigue analysis is performed using the cyclic data shown in Table 6A.7-1 and methods of Subparagraph NB-3222.4(e).

6A.7.2.3 Basemat Liner Analytical Methods

The basemat liner is analyzed in accordance with FSAR Section 3.8.1.4.2. A summary of the maximum computed stress and strain governing the design of the primary containment liner and the allowable values is shown in Table 6A.7-2.

6A.7.2.3.1 Stress Concentration Factors

Concentration of the secondary membrane stresses in the mat liner occurs at each weld. The details of these welds to the various types of mat embedments are shown on Figure 3.8-2. For the fatigue analysis, a stress concentration factor of 3.0 is used to represent the local increase in secondary stresses at the weld.

6A.7.2.3.2 Basemat Liner Analyses

The 1-ft concrete cover slab is in contact with the basemat liner. The liner will follow the motion of the basemat and will not lift during a SRV event. Results of the dynamic analysis performed in Section 6A.5 have indicated that accelerations generated by the oscillatory loads at the basemat are not of sufficient magnitude to cause the covering concrete and the basemat liner to separate. Displacements and rotations from the basemat analysis can be used as described in FSAR Section 3.8.1.4.2 for a static analysis of the basemat liner.

6A.7.2.3.3 Basemat Liner Anchorage System

The basemat liner anchorage has been evaluated for shear loads resulting from load combinations presented in FSAR Table 3.8-1. These loads are less than the allowables given in Table CC-3730-1.

6A.7.2.4 Basemat Liner Summary and Design Margin

This section summarizes the resultant stress and strain levels calculated and combined in this evaluation.

6A.7.2.4.1 Strains and Stress from SRV Loads

Evaluation of the basemat liner response to symmetric SRV discharge effects shows that the radial strains resulting from the radial displacements are negligible (approximately 3.58×10^{-6} in/in). This analysis shows that the maximum mat liner strain from SRV effects is 8.96×10^{-6} in/in, which corresponds to a uniaxial stress of 260 psi. The stress and strain levels for SRV loads are negligible compared to the corresponding magnitudes of the respective ASME Section III, Division 2 allowables.

6A.7.2.4.2 Operating Stress Range Comparison in Accordance with ASME Section III, Division 1

In evaluating the operating stress ranges resulting from the load combinations in FSAR Table 3.8-1, the highest stress intensity range is 3,000 psi. This range is almost negligible when compared with the $3\ S_m$ operating stress range allowable of 66,000 psi. Therefore, an adequate design margin is provided.

6A.7.2.4.3 Strain Evaluation in Accordance with ASME Section III, Division 2

In evaluating the strain levels resulting from the load combinations in FSAR Table 3.8-1, the maximum positive and negative normal/severe environmental condition strains are 3.39×10^{-5} in/in and -4.74×10^{-5} in/in. From ASME Section III, Division 2, Table CC-3720-1, the normal membrane strain allowables are 0.001 in/in and -0.002 in/in, respectively. There is no tensile strain for the abnormal load categories, and the highest compressive strain is -1.37×10^{-4} in/in, for which the strain allowable is -0.005 in/in. This analysis, therefore, shows that the strain allowables of Table CC-3720-1 are much greater than the calculated strains obtained from all load combinations.

6A.7.2.4.4 Fatigue Analysis

FSAR load combination Table 3.8-1 will be used in conjunction with stress cycle Table 6A.7-1 to perform a fatigue analysis. Based on fatigue analyses, it is assumed that the CUF will be negligible when compared to the allowable usage factor of 1.0.

6A.7.3 Wall Liner and Anchor System

The suppression pool wall liner is a 45-ft 6-in radius cylinder, 3/8-in thick, carbon steel clad with stainless steel. The liner plates are attached to the concrete by closely spaced 5/8-in diameter anchor studs. The studs are welded to the liner in a diamond pattern. On the suppression chamber liner of the wall the horizontal distance between studs is a nominal 12 in, and the vertical distance between rows of studs is a nominal 14 in. The diamond pattern is a staggered arrangement of studs which helps to stiffen the liner plates against independent deflection, vibration, or buckling away from the concrete.

6A.7.3.1 Load Sources and Design Criteria

6A.7.3.1.1 Load Sources

The wall liner is subjected to the same load combinations as the basemat liner (Section 6A.7.2.1.1) and FSAR Section 3.8.1.3.

6A.7.3.1.2 Design Criteria

<u>Wall Liner Criteria</u>

The wall liner design criteria are the same as those described in Section 6A.7.2.1.2.

<u>Wall Liner Anchor Criteria</u>

The allowable anchor loads or anchor displacements are taken from Table CC-3730-1 of ASME Section III, Division 2.

6A.7.3.2 Load Combinations

Because of the need to obtain a maximum stress intensity range for the 3 S_m comparison, the load combinations in FSAR Table 3.8-2 are evaluated.

A fatigue analysis of the basemat liner is performed at the most critical element of the liner system (i.e., wall-mat junction of the liner), using the procedures described in Section 6A.7.2.1.2 and Section 6A.7.2.2.

The CUF of the liner element obtained from this analysis is substantially lower than the allowable value of 1.0.

6A.7.3.2.1 Stress Concentration Factor

For the small discontinuity caused by a weld between an anchor stud and the liner, a stress concentration factor of 3 is assumed. Thus, all peak stresses are calculated by multiplying the secondary stresses by 3. This assumption is based on the analogous case of a girth fillet weld to socket weld fitting using K_1 of Table NB-3683.2-1 (ASME Section III, Summer 1973 Addenda).

6A.7.3.3 Wall Liner Analytical Methods

6A.7.3.3.1 SRV Load

The liner is analyzed for the SRV discharge oscillating pressure and the dynamic nature of the containment wall in response to the SRV actuation.

The displacement and force profiles obtained from the dynamic response of the primary structures described in Section 6A.5 are used to obtain the axial and hoop strains of the liner plate. The strains of the liner are computed as described in FSAR Section 3.8.1.4.2.

The normal oscillating forces that act on the liner are the SRV, including hydrostatic pressure, and the acceleration from the concrete wall vibration. The mass of the liner per square inch is multiplied by the maximum acceleration of the primary containment wall to obtain this load per square inch on the liner. This pullout load is negligible and is never sufficient to exceed the SRV plus hydrostatic pressure, which always pushes the liner against the concrete.

Each SRV event is estimated to produce, at most, 10 stress cycles during which the amplitude of the oscillating response dampens out. In the fatigue analysis, 10 stress cycles with equal maximum amplitude are conservatively assumed for each SRV event. The number of stress cycles per event is based on the enveloped responses of a family of single degree-of-freedom oscillators subjected to a number of time-history forcing functions.

The anchors were evaluated for both shear and pullout force. The shear resulting from an unbalanced load from the liner plate was determined. The pullout force at locations above the suppression pool was determined to be negligible.

6A.7.3.3.2 Condensation Oscillation and Chugging Loads

The liner is analyzed for LOCA CO and chugging loads in a manner similar to the SRV loads as described in Section 6A.7.3.3.1.

6A.7.3.4 Wall Liner Summary and Design Margin

6A.7.3.4.1 Strain from SRV Loads

The SRV produces a maximum strain of ±7.15 x 10^{-5} in/in.

6A.7.3.4.2 Operating Stress Range Comparison in Accordance with ASME III, Division 1

The maximum stress intensity range was obtained with the load combinations, normal without temperature and abnormal/extreme environmental. The calculated range is 48,000 psi. This satisfies the 3 S_m allowable of 66,000 psi.

6A.7.3.4.3 Strain Evaluation in Accordance with ASME Section III, Division 2

Load Condition	Maximum Strain (in/in)	Strain Allowables in Accordance with Table CC-3720-1 (in/in)
(6) Normal/ extreme environmental	-0.0012 0.00086	-0.002 0.001
(7a) Abnormal/ extreme environmental	-0.0021 0.0011	-0.005 0.003

Other load conditions are less severe. All load conditions satisfy the strain allowables of ASME Section III, Division 2.

6A.7.3.4.4 Fatigue Analysis

The fatigue usage factor is based on stress cycles in Table 6A.7-1 and the load combinations in FSAR Table 3.8-2. Conservative peak stress ranges are used in the fatigue analysis procedure to obtain the partial usage factors.

6A.7.3.4.5 Wall Anchorage Summary

The maximum pullout load in response to hydrodynamic loads occurs in an area above the water level. This load is caused by the effects of the wall accelerating during SRV blowdown. For all load combinations, the anchor studs are subjected to shear and axial loads that are less than the allowable anchor force (1/3 F μ) of Table CC-3730-1.

TABLE 6A.7-1

STRESS CYCLIC DATA FOR FATIGUE ANALYSIS

Event	Stress Cycle
LOCA (DBA, IBA, SBA)	
1 event*/40 yr	-
Seismic	
1 SSE event/40 yr	20 cycles/event
5 OBE events/40 yr	20 cycles/event
SRV	
5,200 events/40 yr	10 cycles/SRV event
Operating Temperature	
400 events/40 yr	1 cycle/event
Operating Pressure	
100 events/40 yr	1 cycle/event

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* One event consists of:

1,000 chugs - 10 cycles/chug
3 min of condensation oscillation - 500 cycles for CO

TABLE 6A.7-2

SUMMARY OF PRIMARY CONTAINMENT LINER STRESSES AND STRAINS

Stress/ Strain	Loading Condition	Computed Value	Allowable Value	Factor of Safety
Stress (primary +secondary +bending)	Emergency	42.5 ksi	66.0 ksi	1.55
	Faulted	48.0 ksi	66.0 ksi	1.38
Stress (membrane)	Test	19.7 ksi	51.0 ksi	2.59
Strain (membrane +bending)	Abnormal/ severe environmental	-2.10×10^{-3} in/in	-0.014 in/in	6.67
	Test	0.681×10^{-3} in/in	0.001 in/in	1.47

SECTION 6A.8

ASSESSMENT OF THE REACTOR BUILDING AND OTHER STRUCTURES

6A.8.1 Introduction

This section addresses the effects of hydrodynamic suppression pool loads on the reactor building and other structures inside the primary containment and reactor building. The effects of suppression pool hydrodynamics on the primary containment are shown in Section 6A.6, and the effects on the reactor building appear to be negligible and will be considered in the design. The manner in which these loads affect each of these structures and the methods of assessing their effects are described in this section. All of the suppression pool loads considered are described in detail in Sections 6A.3 and 6A.4 for SRV and LOCA loads. Load combinations and acceptance criteria for reinforced concrete structures and structural steel are discussed in Section 6A.2 and presented in Tables 6A.2-2 and 6A.2-3, respectively.

6A.8.2 Reactor Building

The reactor building structure has been adequately designed for hydrodynamic loads. The assessment includes the effects of hydrodynamic loads on the reactor building external wall, floor systems, roof structure, miscellaneous internal structures, and all integral elements. There are no direct loads on the reactor building due to the suppression pool phenomena. Effects are transmitted to the reactor building only through basemat excitations. These load effects have been applied through the use of equivalent static loads.

6A.8.3 Drywell Structural Steel

All drywell structural steel has been adequately designed for the effects of hydrodynamic loads. The effects of the suppression pool hydrodynamic phenomena on piping have been evaluated and structural steel floor framing has been designed to accommodate the effects of this loading.

6A.8.4 Platforms, Ladders, and Walkways (Inside Primary Containment)

The two means by which these structures are affected by hydrodynamic loads are through building vibrations due to SRV and LOCA loads and by pool swell impact and drag loads in the pool swell zone in the suppression pool air space. The effects of building vibrations are assessed by means of equivalent static loads determined from building ARS. The methodology for assessing impact and drag loads is described in Section 6A.4.

Platforms, ladders, and walkways have been designed to accommodate the effects of hydrodynamic loads. All platform grating and supporting structural members are located such that they are not impacted by pool swell. There are no ladders in the pool swell zone; therefore, pool swell loads are not a factor in the design of these items in the suppression pool.

The analysis and design of structural steel components are discussed in FSAR Section 3.8.4.4.

6A.8.5 Cable Tray and Conduit Supports

Cable tray and conduit supports have been adequately designed for hydrodynamic loads. These structures have been assessed for these effects by means of equivalent static loads based on ARS.

The analysis and design of cable tray and conduit supports are discussed in FSAR Section 3.10. The load combinations and acceptance criteria applicable to these supports are presented in Table 6A.2-3.

SECTION 6A.9

PLANT PIPING, COMPONENTS, AND EQUIPMENT ASSESSMENT

6A.9.1 Balance-of-Plant Piping and Equipment

6A.9.1.1 Piping System

6A.9.1.1.1 Evaluation Procedures

Scope

All safety-related piping and supports, and that piping which could affect safety-related equipment, in the Unit 2 reactor building are evaluated to the Mark II hydrodynamic loads. Load combinations and acceptance criteria are described in Section 6A.2.

Procedures

The piping and components are evaluated in accordance with the load combinations and acceptance criteria delineated in Section 6A.2. The piping and components are designed for the system normal loads, seismic loads, and hydrodynamic loads which are briefly summarized as follows:

1. Weight The sustained load consisting of the weight of the pipe, its fluid contents and piping insulation, and any pipe-mounted equipment.
2. Thermal A secondary, self-limiting load resulting from the constraint of the free end displacement of the piping system during a temperature transient including imposed thermal displacements at restraint locations where applicable.
3. Seismic A dynamic load caused by the vibratory motion of the piping during an earthquake event, including the effects of relative anchor displacements.
4. Pressure Stress induced in the pipe due to the internal pressure.
5. Flow Transient A fluid dynamic load on applicable piping system due to the sudden changes of the flow rate and/or pressure.
6. Seismic Sloshing A dynamic load on applicable systems due to suppression pool water motion during an earthquake event.

7. Mark II Suppression Pool Hydrodynamic Mark II suppression pool hydrodynamic loads are identified and discussed in detail in Section 6A.2. SRV loads are described in Section 6A.3. LOCA loads are described in Section 6A.4. However, as far as piping stress analysis is concerned, the SRV and LOCA loads can be divided into two categories. The first category is the system transient vibratory motion and anchor movements due to the associated building responses.

   The second category is the direct loads imposed on the system as the result of suppression pool fluid motion during the postulated dynamic event. The piping and components in the suppression pool, such as downcomers, ECCS suction/discharge lines, and quencher devices are subjected to direct drag loads during SRV discharge and LOCA. The piping and components above the suppression pool surface, but within the suppression pool swell zone, are subjected to direct loads due to suppression pool swell impact and drag loads during LOCA. This group of components is analyzed for the direct suppression pool dynamic loads as well as the vibratory motion and anchor movement effect resulting from the associated building responses. The vast majority of piping and components outside the suppression chamber are not subjected to any direct loads during SRV discharge and LOCA. This group is analyzed for the vibratory motion and anchor movement effect only.

Static and dynamic analyses are performed to generate stresses at the system nodal points. The stresses are calculated in accordance with ASME Section III and evaluated against limitations set by the code. The evaluation of the piping design is in accordance with the load combinations and acceptance criteria delineated in Section 6A.2.

6A.9.1.1.2 Analytical Techniques

Vibratory Loads

The vibratory motion of piping systems and components is generally analyzed by the ARS method. The mathematical procedures of the ARS method are described in FSAR Section 3.7 and reviewed in this section.

The basic method of piping system analysis is the finite element stiffness method. The continuous piping is mathematically idealized as an assembly of elastic structural members connecting discrete nodal points. System loads such as weights, equivalent thermal forces, and dynamic forces are applied at the nodal points. Member stiffnesses are modeled to account for component characteristics as well as ASME Code flexibility factors.

The static equations of equilibrium for the idealized system are written in matrix form and solved by one of the piping analysis computer programs in Appendix 3A. The nodal displacements are then applied to the individual members, and the member stiffnesses are used to find the internal forces. The nodal displacements at the support location are also used along with support stiffnesses to determine the support reactions.

For dynamic analysis, the mathematical model is described as a lumped mass, multiple degree-of-freedom system. The equation of equilibrium is solved to obtain the system natural frequencies and mode shapes. Then, the uncoupled modal equation is solved by the response spectrum method or by step-by-step integration to obtain the system response in each mode, and the individual modal results are combined to determine the total system dynamic response.

ARS data are developed by performing dynamic analysis of the building structures applying the time-history dynamic load on the applicable buildings. ARS curves are available for selected locations throughout the buildings.

An additional conservatism is provided to the piping design by the following procedures utilized in the piping analysis for dynamic loads; ARS acceleration peaks are broadened ±15 percent in accordance with RG 1.122 and modal responses are combined by the grouping method in accordance with RG 1.92. OBE damping values, as defined in RG 1.61, are used for hydrodynamic loads specified as normal and upset condition loads.

The SSE damping values are used for hydrodynamic loads specified as emergency and faulted condition loads.

Direct Loads

Direct loads (or drag and impact loads) are described in detail in Sections 6A.3 and 6A.4. These include LOCA water jet, LOCA bubble, suppression pool swell, chugging drag, and CO drag as well as SRV water clearing, air clearing, SRV bubble, and SRV drag loads. Submerged piping affected by these loads includes the 18 SRVDLs, 121 downcomers, 17 other large bore lines (ECCS piping), and several small bore lines (drain lines).

Direct dynamic loads are analyzed either by time-history dynamic analysis, or by equivalent static analysis with appropriate dynamic load factor (DLF) applied.

The loads due to the initial LOCA pool swell impact and subsequent drag and fallback loads are applied to the exposed area of the piping as dynamic time-history loads. Alternatively, these loads are multiplied by a dynamic load factor of 2.0 and applied as static forces to exposed piping. The piping is adequately supported so that the pool swell impact stresses, in combination with SSE and SRV stresses, meet the ASME Level D allowables. The design of supports includes pool swell and fallback impact loads on piping, as well as directly on the support structure.

Fatigue

Unit 2 Safety Class 1 piping is designed to sustain the cumulative fatigue effects resulting from the normal and upset loads including dynamic, pressure, and thermal transients. In addition, SRVDL and downcomer fatigue assessments will be performed in accordance with Safety Class 1 rules, using Mill Certification material properties as necessary.

DFFR Revision 4(1), Section 5.2.1, provides the number of SRV actuations in Table 5-4 for various transient events. It concludes that several transients will initiate and actuate more than one SRV. Also, several transients that involve reactor isolation at power will induce a large number of subsequent actuations, and the SRV having the lowest setpoint will actuate 5,154 times over plant lifetime.

For a reactor isolation event at power, the reactor overpressure attenuation time-histories (FSAR Section 15A.1) are used to establish the number of SRVs actuated during the subsequent actuations by comparing the reactor pressure and SRV setpoints. Piping responses (stress values) corresponding to the number of valves actuated are determined for typical piping components. These stress values are used to convert the number of equivalent stress cycles for various numbers of valves actuated by using a fatigue damage formula.

The equivalent fatigue damage formula is constructed in such a way that an identical fatigue usage factor would be obtained from the ASME Section III Design Fatigue Curve, with the consideration of alternating stresses at a piping component.

Functional Capability

All ASME Code Class 1, 2, and 3 piping systems that are required to function for safe shutdown under the postulated events are designed to meet the functional capability criteria of Reference 3. The functional capability of essential piping systems is evaluated to assure their fluid-flow capability. This capability will be maintained if significant reductions in cross-section area do not occur under any service condition.

Equation 9 of ASME Section III, Paragraph NB-3652, modified in accordance with Table 6A.9-1, is used for this evaluation. Results indicate that Unit 2 representative essential systems meet the functional capability requirements.

6A.9.1.1.3 Special Topics

Downcomers

The downcomers are modeled as lumped-mass, multidegree-of-freedom, cantilever beams fixed at the drywell floor. Two conditions are evaluated: 1) Where the submerged portion of the downcomer is filled with water, and 2) During a LOCA, when steam/air occupies the entire length of the downcomer. The appropriate static, seismic, and hydrodynamic loads are combined and show all stresses below allowable limits. The downcomers are also analyzed for fatigue cycles resulting from seismic, SRV, and LOCA, and for functional capability. Results show that the 113 downcomers outside the suppression pool pedestal are controlling (the eight downcomers inside the pedestal are shorter in length and are not subjected to the SRV air bubble load) and are within allowable limits. The governing cases are shown in Tables 6A.9-2a and 6A.9-2b.

SRV Piping in the Suppression Pool

A Safety Class 1 fatigue analysis is performed for the SRV piping penetration through the drywell floor. Although the SRV piping system is Safety Class 3, these additional requirements are considered for additional assurance that steam bypass across the drywell floor will not occur. Additionally, since the highest loads occur at the penetration, this serves to increase the confidence in the overall system.

6A.9.1.1.4 Results

Summary of Results

All Unit 2 piping and supports are being evaluated for the effects of the dynamic loads. All load combinations and acceptance criteria described in Section 6A.2 are addressed. The following three load combinations are found to be controlling:

Load Case	Load Combination
2	N + SRV + OBE
5	N + SRV + OBE + IBA/SBA
7	N + SSE + AP/basic CO

It is noted that margins of safety actually exist due to the conservative analytical approaches. The following is a listing of the significant conservatisms used:

1. ARS is used instead of time-history.

2. The responses of SRV symmetric, asymmetric, ADS, and single valve ARS were enveloped to provide a bounding load case.

3. ARS for radial and tangential directions are enveloped to generate a bounding ARS for X (E-W) and (N-S) Z directions.

Typical Piping Examples

Three Safety Class 1 piping subsystems are selected for the demonstration of the assessment results. The piping routings are shown on Figures 6A.9-1 through 6A.9-3. Responses from dynamic loads are combined by the SRSS method. Flow transient responses on applicable systems are also included. Tables 6A.9-3 through 6A.9-5 present the primary stress intensities as calculated by Equation 9 of ASME Section III, Paragraph NB-3652, at typical piping nodes. Table 6A.9-6 presents results of the required stress check for functional capability.

Typical Submerged Piping Examples

The RHR discharge line 2RHS-018-166-2 is anchored at the primary containment wall at el 206 ft. It extends radially toward the reactor center and turns vertically downward with a 90-deg elbow. The pipe is terminated at el 198 ft.

Submerged structure loads in accordance with Unit 2 submerged structure criteria (Section 6A.4.9) are generated and applied to the RHR submerged pipe. Inertia stresses corresponding to seismic, SRV, and LOCA building vibrations are analyzed. Load combinations and acceptance criteria are in accordance with those prescribed in Section 6A.2.

Table 6A.9-7 presents stresses at the elbow, a highly-stressed component for all direct and vibratory loads acting on the pipe as well as for the three potentially controlling load combinations. Actual stresses are below the allowable stress for all applicable acceptance criteria.

6A.9.1.2 Equipment

6A.9.1.2.1 Summary

Safety-related equipment is evaluated for the combined effects of seismic and hydrodynamic loads. Results of this evaluation show that a new qualification plan is required for equipment located in the primary containment. The summary of results for equipment affected by the combined effects of seismic and hydrodynamic loads is provided in the appropriate tables in FSAR Sections 3.9 and 3.10.

6A.9.1.2.2 Dynamic Loads and Stress Limits

Hydrodynamic loads consist of high-acceleration magnitudes, frequency content beyond the seismic frequency range, and a large number of events of long durations for which equipment must be qualified through its design life. These hydrodynamic loads are postulated to combine with seismic and normal loads.

Controlling load combinations for the upset and faulted conditions and stress allowables for both ASME Code and non-ASME Code items are defined in FSAR Section 3.9.

Response Spectra and Loads for Line-Mounted Equipment

In addition to obtaining the required response spectra (RRS) for the upset and faulted load combinations, the RRS associated with the following hydrodynamic events are also obtained:

SRV	Envelope of all valve actuation, asymmetric, ADS, and single subsequent actuation cases
LOCA	Envelope of AP, CO, and chugging

The response spectra due to the pool swell or the vent-clearing effects of a LOCA are negligible. The AP loading produces local effects only, and therefore does not have a significant influence on equipment located inside the reactor building. The SRV and LOCA spectra are obtained to address the fatigue cycle requirements of the hydrodynamic loads that are discussed as follows.

The response spectra are obtained in three orthogonal directions by time-history analyses of the structural model (see Section 6A.2.4.2). The radial and tangential spectra are enveloped for each load, and the enveloped response spectrum is used in each of two horizontal axes. The radial and tangential spectra can also be developed separately if required.

In addition, the response spectra generated after proper combinations and enveloping are peak broadened ±15 percent in accordance with FSAR Section 3.7.

Equipment damping value allowed for the upset and SRV RRS is 2 percent, and 3 percent for the faulted and LOCA RRS. RRS for other damping values are also obtained and used when required by RG 1.61.

For line-mounted equipment, especially valves with extended structures, the loads are obtained directly from the piping analysis. Maximum accelerations at the operator center of gravity are obtained in each of the X (horizontal), Y (vertical), and Z (horizontal) directions for each dynamic load. The restraint configurations to the piping are optimized to maintain maximum accelerations from the hydrodynamic loads below certain levels.

Number of Events and Cycles

Hydrodynamic loads consist of a large number of events postulated over the design life of the plant. Each event produces many stress cycles. The stress cycles per event are obtained by analyzing the response and enveloping the data of a number of single degree-of-freedom systems for a large number of time-histories. Since all events of the same load may not occur at the design amplitude, EOF are obtained by analyzing test pressure data. The total number of stress cycles due to a load is, therefore, a product of the number of events, the EOF, and the stress cycles per event.

When qualification is performed by analysis, stress cycles are used to demonstrate that the CUF is less than unity. This information is also used to specify test durations and the number of tests required when the equipment is qualified by testing.

6A.9.1.2.3 Qualification Acceptance Criteria

The acceptance criteria for qualification to the combined effects of seismic and hydrodynamic loads are the same as those identified in FSAR Sections 3.9A.2.2.1, 3.9A.2.2.2 and 3.10A.1. The ability to perform a safety-related function is demonstrated during and after the Upset, Faulted, and LOCA plant conditions, as applicable. In addition, the CUF due to the fatigue effects of the land is maintained below unity.

6A.9.1.2.4 Qualification Procedures

Qualification procedures are classified into two categories: new qualification and reevaluation of equipment already qualified for seismic loads. For both categories, design specifications for equipment in the reactor building (mainly primary containment) are revised to reflect the addition of the hydrodynamic loads.

Reevaluation Procedures

Reevaluation is made to determine whether sufficient design margins exist to accommodate the effects of the combined seismic and hydrodynamic loads. If the equipment fails to meet the new requirements, the requalification process is implemented.

Qualification by Analysis

Certain equipment can be qualified by using the static or dynamic analysis method. The maximum stress is computed in each of the three orthogonal directions and combined using the SRSS method. When reevaluation is required, a comparison is made of the original design margin with respect to the increased loads. If it is not evident that the margin is sufficient, reanalysis is performed to calculate the new design margin.

Static Coefficients for Floor-Mounted Equipment

For equipment that is qualified by analysis, the conservative and simple static analysis method is predominantly used. An equivalent static force is imposed at the center of gravity of the equipment or distributed over the whole equipment so that the resultant of the forces passes through the center of gravity.

This force is equal to the mass multiplied by a static coefficient, which is 1.5 times the peak acceleration of the ARS curve corresponding to the equipment location. In this case, determination of the natural frequency of the equipment is not necessary. This factor is for beam/frame-type structures.

Dynamic Analysis

When dynamic analysis is performed for qualification, all significant modes of the equipment in the frequency range of the loading are considered in the analysis. This accounts for the high frequency content of the hydrodynamic loads. In addition to determining stresses and deflections, analysis is also performed to determine fatigue usage factors. Usage factors for SRV, upset condition, faulted condition, and LOCA loads are obtained, and it is demonstrated that the sum is less than unity.

Qualification by Testing

Dynamic qualification is accomplished by testing, generally the preferred method for Class 1E electrical equipment. Floor-mounted equipment and certain line-mounted equipment (MSIVs) are qualified using random, multifrequency, multiaxis motions in which the test response spectra (TRS) envelop the RRS. For most line-mounted equipment (valve operators), additional random-motion tests and single-frequency sine beat tests are also performed.

For equipment already tested for seismic loads, the TRS are compared to the new RRS, which include the hydrodynamic loads. If the RRS are justifiably enveloped by the TRS, the test time-histories are analyzed to determine the equivalent stress cycles at magnitudes corresponding to the zero period acceleration (ZPA) of the RRS. The equivalent stress cycles from all the dynamic loads are also evaluated at the same magnitudes. If the test motions yield higher cycles than those calculated for the postulated loads, no further testing is required.

New testing is performed using the random, multifrequency, multiaxis method for the SRV, upset, faulted, and LOCA loads in this sequence. Five tests of a 30-sec duration each are used for the Upset condition. One 30-sec duration test is used for the

Faulted condition loads. Determination of durations for the SRV and LOCA tests is based on the consideration that the expected fatigue cycles from these tests will exceed the stress cycles of the postulated hydrodynamic loads. Testing for line-mounted equipment is also performed for the loads mentioned above in the same sequence. However, in addition to random testing, a multitude of sine beat tests at test frequencies representative of the frequency content of the dynamic loads are also used. The input motions correspond to acceleration magnitudes obtained from the piping analysis and also correspond to the number of stress cycles of the dynamic loading.

6A.9.1.2.5 Pump and Valve Operability Program

No active pumps in the BOP scope of work are affected by hydrodynamic loads. For safety-related active valves, the operability program is the same as that stated in FSAR Section 3.9A.3.2.2 and the qualification procedures of DAR Section 6A.9.1.2.4. In addition, accelerations that keep the stresses and deflections within allowable limits are established and reconciled with accelerations from piping dynamic analysis, and an adequate margin of safety is demonstrated. The operability testing of the valve assembly and the dynamic testing of the actuator and other safety-related electric components are also performed using the accelerations determined from piping analysis, with adequate margins.

6A.9.2 NSSS Piping, Components, and Equipment

6A.9.2.1 Structural Systems Response

Safety-related NSSS piping and equipment located within the containment are subjected to pool hydrodynamic loads due to SRV and LOCA effects. The NSSS piping and equipment are evaluated to confirm their adequacy to withstand these hydrodynamic loads in combination with seismic and other applicable loads in accordance with the load combinations given in Table 6A.2-1b.

The structural system responses to the SRV and LOCA suppression pool hydrodynamic phenomena are generated using defined forcing functions. These responses are in the form of 1) broadened responses spectra, and 2) acceleration time-histories at the pedestal-to-diaphragm floor intersection and at the stabilizer evaluation.

The response spectra for piping attachment points on the RPV, shield wall, and pedestal complex (above the pool area) are based upon the acceleration time-histories using a detailed lumped mass beam model for the vessel internals, including a representation of the adjoining structures. This leads to the assessment of force and moment on the vessel support and internals. For floor-mounted equipment, the broadened response spectra are used.

The structural system response to the LOCA-induced asymmetric pressure in the annular region between the BSW and the RPV is based on pressure time-histories. These pressure time-histories are combined with jet reaction, jet impingement, and pipe whip restraint loads in the analysis to yield acceleration, force, and moment time-histories, as well as response spectra at the piping attachment points on the RPV, shield wall, pedestal, vessel supports, and internal components.

6A.9.2.2 Fuel Assemblies

The fuel assemblies(2) were evaluated for design adequacy to withstand the seismic, SRV, and LOCA loadings. Loading combination criteria were used to determine the maximum combined fuel acceleration profiles for all event categories. The fuel assembly horizontal loadings combined with the appropriate vertical loadings were shown to be less than the generic capability for BWR/2-5 fuel for all events. The dynamic analysis(2) for vertical loadings showed that no loss of lateral support occurred between the fuel assembly and the orificed fuel support (OFS) due to vertical movement of the fuel.

The fuel assembly fatigue analysis was performed for the limiting SRV case and the OBE + SRV load combination. Fatigue capability of the fuel assembly components was determined by exchanging the previously evaluated capability of 10 to 150 cycles of peak SSE loading for a larger quantity of cycles of the lower OBE or SRV loads as allowed by the material curves. The SRV loads are small enough such that negligible fatigue will occur to any of the fuel assembly components. Each component of the fuel assembly was shown to be capable of withstanding a number of cycles sufficiently in excess of the expected number of cycles of peak OBE + SRV loading. The assemblies were demonstrated to have adequate fatigue capability to withstand the loadings resulting from multiple SRV actuation and the OBE + SRV event.

6A.9.2.3 Piping System

6A.9.2.3.1 Piping

The NSSS piping stress analyses consider the dynamic responses from 1) the original design basis loads including seismic vibratory motions, 2) the structural system feedback loads from the suppression pool hydrodynamic events, and 3) the LOCA-induced AP event.

Lumped mass models are developed for the recirculation piping systems. These lumped mass models include the snubbers, hangers, pipe-mounted valves, and major branch piping connected to the recirculation system. ARS for all attachment points within the piping system are applied; i.e., distinct acceleration excitations are specified at each piping support and anchor point. The detailed models are analyzed to determine the piping response to:

1. Design basis loads including pressure, temperature, weight, seismic events, etc.

2. Bounding suppression pool hydrodynamic event.

3. AP effects on unbroken piping system.

Additionally, the end reaction forces and accelerations for the pipe-mounted equipment (valve and nozzles) are simultaneously calculated.

The piping stresses due to each of the above load events are combined in accordance with the load combinations delineated in Section 6A.2.2. These stresses are calculated at geometrical discontinuities and compared to ASME Code allowable stresses (ASME Boiler and Pressure Vessel Code, Section III, NB-3650) for the appropriate loading condition. Computer codes used to perform the NSSS piping stress analysis are described in FSAR Section 3.9B.1.2. Fatigue is calculated for all operating and upset events and summed to ensure that the cumulative fatigue usage factor is less than 1.0.

6A.9.2.3.2 Valves and Other Pipe-Mounted Equipment

The reaction forces and accelerations acting on the pipe-mounted equipment, when combined in accordance with the required load combinations, are used to assess the valve design adequacy. The reactor coolant pressure boundary (RCPB) valves are qualified for operability during seismic and hydrodynamic loading events by both analysis and test.

6A.9.2.4 RPV Supports and Internal Components

The loads from bounding load combinations at each service level are compared to the design basis loads. When the calculated bounding loads are less than the design basis loads, the component design is deemed adequate. When the calculated loads are greater than the design basis loads, the calculated stresses are compared to the Code allowable stresses to demonstrate the component design adequacy. In certain cases, component test results are used in conjunction with analyses to assess component adequacy.

Fatigue evaluations of the RPV supports and internal components are also calculated for SRV cyclic duty loads. The SRV fatigue usage factors are added to all other upset condition usage factors to obtain a cumulative fatigue usage factor.

Computer programs used to conduct RPV component analyses are described in Section 3.9B.1.2.

6A.9.2.5 Floor-Mounted Equipment

Design adequacy of the floor-mounted equipment is assessed by dynamic test or analysis. The choice depends upon function, type, size, shape, and complexity of the equipment. In general, the requirements outlined in IEEE-344-1975 are followed for the qualification of equipment. The analysis and test procedures are described as follows.

6A.9.2.5.1 Dynamic Analysis Procedure

Dynamic analysis of various equipment is divided into three groups in accordance with the relative rigidity of the equipment as determined by the magnitude of their fundamental natural frequency.

1. Structurally simple equipment comprises the equipment that can be adequately represented by a one-degree-of-freedom system.
2. Structurally rigid equipment comprises the equipment whose fundamental frequency is:
    a. Greater than 33 Hz for the consideration of seismic loads.
    b. Greater than the high-frequency asymptote (ZPA) of the RRS for the consideration of hydrodynamic loads.
3. Structurally complex equipment comprises the equipment which cannot be classified as structurally simple or structurally rigid.

The appropriate response spectra for specific equipment are obtained from the response spectra for the floor, on which the equipment is mounted, in a building for OBE, SSE, and hydrodynamic loads. This includes the vertical as well as both the N-S and E-W horizontal directions.

For structurally simple equipment, the dynamic loading consists of a static load corresponding to the equipment weight times the acceleration selected from the appropriate response spectrum. The selected acceleration corresponds to the equipment's natural frequency. If the equipment's natural frequency is not known, the selected acceleration corresponds to the maximum value of the response spectra, which is then multiplied by a static coefficient of 1.5 to take into account the effects of both multifrequency excitation and multimode response.

For structurally rigid equipment, the seismic loading consists of a static load corresponding to the equipment weight times the acceleration at 33 Hz selected from the appropriate response spectrum. The hydrodynamic loading consists of a static load corresponding to the equipment weight times the ZPA at the floor attachment point selected from the appropriate response spectrum.

The analysis of structurally complex equipment utilizes an idealized mathematical model which includes the dynamic properties of the equipment. An acceptable alternative is a static analysis for frame-type structures that can be represented by a simple model. No determination of natural frequencies is made and the response of the equipment is assumed to be the peak of the response spectrum. This response is then multiplied by a static coefficient to take into account the effects of both multifrequency excitation and multimode response. This static coefficient is in compliance with RG 1.100.

6A.9.2.5.2 Testing Procedure

Dynamic adequacy for some equipment is established by dynamic test data instead of performing dynamic analysis. Such data must conform to one of the following:

1. Performance data of equipment subjected to dynamic loads, considering appropriate frequency rating, equal to or greater than those expected under the specific dynamic loading conditions.

2. Test data from comparable equipment previously tested under similar conditions with test loading equal to or greater than those the equipment are expected to experience.

3. Testing of equipment in operating conditions simulating the actual installation on the required loadings and load combinations.

6A.9.3 References

1. Mark II Containment Dynamic Forcing Functions, GE Report NEDO-21061, Rev. 4, November 1981.

2. GE 11 Compliance with Amendment 22 of NEDE-24011-P-A (GESTAR II), NEDE-31917P, General Electric Company, April 1991; and for GE 14, NEDE-32868P Revision 1, General Electric Company, September 2000, NEDE-31152P Revision 8, General Electric Company, April 2001, and NE-DE-0000-0016-5640-00, General Electric Company, March 2004; for GNF2, 003N2003 Revision 1, GE Hitachi Nuclear Energy, February 2016 and NEDC-33270P Revision 5, May 2013.

3. Functional Capability Criteria for Essential Mark II Piping, GE NEDO-21985, September 1978.

TABLE 6A.9-1

LOAD COMBINATIONS FOR EQUATION 9*

Service Level	Load Set	Load Combinations For Eq. 9
Design	1	$P_D + W + OBE_I$
A and B - Normal and Upset	1 2	$P_P + W + [OBE_I^2 + SRV_I^2 + FT^2]^{1/2}$
C - Emergency	1	$P_P + W + [OBE_I^2 + SRV_I^2 + FT^2 + CHUG_I^2]^{1/2}$
	2	$P_P + W + [OBE_I^2 + SRV_I^2 + FT^2 + COND_I^2]^{1/2}$
D - Faulted	1	$P_P + W + [SSE_I^2 + SRV_I^2 + FT^2 + CHUG_I^2]^{1/2}$
	2	$P_P + W + [SSE_I^2 + SRV_I^2 + FT^2 + COND_I^2]^{1/2}$
	3	$P_P + W + [SSE_I^2 + SRV_1^2 + BASIC\ COND_I^2]^{1/2}$
	4	$P_P + W + [SSE_I^2 + AP^2]^{1/2}$

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* Excluding suppression pool submerged piping.

KEY:

P_D = Design pressure
W = Deadweight
OBE_I = Operating basis earthquake
P_P = Peak pressure
SRV_I = Safety/relief valve actuation
FT = Fluid transient
$CHUG_I$ = LOCA chugging
$COND_I$ = LOCA condensation oscillation with ADS
BASIC $COND_I$ = Basic condensation oscillation
SSE_I = Safe shutdown earthquake
SRV_1 = Single safety/relief valve actuation
AP = Annulus pressurization

TABLE 6A.9-2

THIS TABLE HAS BEEN DELETED

TABLE 6A.9-2a

DOWNCOMER ASME CODE CLASS 2 STRESS SUMMARY
(GOVERNING CASES)

Load Condition	Stress (ksi)	Allowable (ksi)
Faulted		
SSE + SRV + LOCA (CO_1)	26.44	40.13
Emergency		
OBE + SRV + LOCA (CHUG)	25.24	29.66
Upset		
OBE + SRV	16.50	21.36

TABLE 6A.9-2b

DOWNCOMER FUNCTIONAL CAPABILITY STRESS SUMMARY (GOVERNING CASES)

Load Condition	Stress (ksi)	Allowable (ksi)
Faulted		
SSE + SRV + LOCA (CO_1)	25.18	31.26
Emergency		
OBE + SRV + LOCA (CHUG)	24.04	30.17
Upset		
OBE + SRV	15.72	34.35

TABLE 6A.9-3

LOAD ASSESSMENT

Component: Feedwater Piping (Figure 6A.9-1)

Service Level	Acceptance Criteria	Actual Stress or CUF (psi)	Allowable Stress or CUF (psi)	Actual/ Allowable	Location Component (Node)
Normal and Upset	EQ 9≤1.5 S_m	26,367	26,718	0.987	Elbow (540)
	EQ 12≤3.0 S_m	56,082	58,170	0.964	Sweepolet (125)
	EQ 13≤3.0 S_m	47,622	58,170	0.819	Sweepolet (125)
	CUF <1.0	0.1891	1.0	0.1891	Sweepolet (125)
	EQ 12≤2.4 S_m*	31,808	64,080	0.496	Run Pipe (285)
	EQ 13≤2.4 S_m*	18,877	47,842	0.395	Elbow (267)
	CUF <0.1*	0.0984	0.10	0.984	Run Pipe (267)
Emergency	EQ 9≤2.25 S_m	28,021	43,628	0.642	Sweepolet (175)
Faulted	EQ 9≤3.00 S_m	34,876	58,170	0.600	Sweepolet (125)

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* In break exclusion region.

EQ = Equation
CUF = Cumulative Usage Factor

TABLE 6A.9-4

LOAD ASSESSMENT

Component: Reactor Core Isolation Cooling Piping (Figure 6A.9-2)

Service Level	Acceptance Criteria	Actual Stress (psi)/CUF	Allowable Stress (psi)/CUF	Actual/ Allowable	Location Component (Node)
Normal and Upset	EQ 9<1.5 S_m	22,132	26,790	0.826	Elbow (35)
	EQ 12<3.0 S_m	15,291	53,580	0.285	Branch (31)
	EQ 13<3.0 S_m	51,946	53,580	0.970	Branch (31)
	CUF<1.0	0.975	1.000	0.975	Branch (31)
Emergency	EQ 9<2.25 S_m	39,344	40,185	0.979	Elbow (35)
Faulted	EQ 9<3.0 S_m	40,623	53,580	0.758	Elbow (35)

NOTES: EQ = Equation
CUF = Cumulative Usage Factor

TABLE 6A.9-5

LOAD ASSESSMENT

Component: Reactor Water Cleanup Piping (Figure 6A.9-3)

Service Level	Acceptance Criteria	Actual Stress psi/CUF	Allowable Stress psi/CUF	Actual/ Allowable	Location Component (Node)
Normal and Upset	EQ 9<1.5 S_m	20,903	21,222	0.985	Tee (397)**
	EQ 12<3.0 S_m	48,297	54,204	0.891	Elbow (282)
	EQ 13<3.0 S_m	51,905	54,204	0.958	Tee (230)
	CUF <1.0	0.269	1.000	0.269	Tee (235)
	EQ 12<2.4 S_m*	15,682	43,363	0.362	Branch (522)
	EQ 13<2.4 S_m*	38,783	43,363	0.894	Branch (522)
	CUF <0.1*	0.048	0.100	0.480	Branch (522)
Emergency	EQ 9<2.25 S_m	26,538	31,347	0.847	Tee (397)**
Faulted	EQ 9<3.0 S_m	32,300	41,796	0.773	Tee (397)**

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* In break exclusion zone.

** Material: SA 312 TP316L. Material at remaining locations is SA106 GR B.

EQ = Equation

CUF = Cumulative usage factor

TABLE 6A.9-6

FUNCTIONAL CAPABILITY EVALUATION

Piping System	Component	Results Per EQ 9 (psi)	Allowable Stress (psi)
Feedwater	Sweepolet (125)	30,435	43,598(1)
Reactor Core Isolation Cooling	Elbow (35)	26,439	40,110(1)
Reactor Water Cleanup	Tee (397)	23,841(3)	30,864(2)

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(1) 1.5 S_y per functional capability criterion (NEDO-21985).

(2) 2.0 S_y per functional capability criterion for tees (NEDO-21985).

(3) Based on B_1 and B_2 indices prescribed by NEDO-21985.

TABLE 6A.9-7

SUBMERGED RHR PIPING[1]

Load/Combination	Stress at Elbow (psi)	Allowable (psi)
Normal(N) - Deadweight + Pressure	3,190	16,368
OBE	3,889	NA
SSE	4,921	NA
SRV	932	NA
SRV-bubble	2,508	NA
LOCA[2]	2,201	NA
LOCA - bubble	1,247	NA
Pool swell	3,857	NA
CO - drag	1,413	NA
Chug - drag	4,515	NA
$N+(OBE^2+SRV^2+SRV\ BUBBLE^2)^{1/2}$	7,910	19,642
$N+(OBE^2+SRV^2+SRV\ BUBBLE^2+LOCA^2+DRAG^2)^{1/2}$	10,083	19,642[3]
$N+(SSE^2+SRV^2+SRV\ BUBBLE^2+LOCA^2+DRAG^2)^{1/2}$	10,714	19,642[3]

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[1] 2RHS-018-166-2

[2] Maximum of condensation oscillation (basic), chugging, and annulus pressurization inertia loads.

[3] With emergency and faulted conditions meeting upset condition allowables for a pipe with D/t 48<50, functional capability requirements of NEDO-21985 are met.

DRAG = Maximum of LOCA bubble, pool swell, CO drag, or chug drag.
NA = Not applicable.

SECTION 6A.10

CONDENSATION INSTABILITY DURING SRV DISCHARGE

6A.10.1 Suppression Pool Temperature Monitoring System

6A.10.1.1 Purpose

The suppression pool temperature monitoring system monitors pool temperature to provide the Operator with the information necessary to prevent excessive pool temperature during transient or accident. Temperatures are indicated and alarmed in the main control room.

6A.10.1.2 General System Description

Suppression pool temperature is monitored at 14 monitoring stations, each consisting of two platinum resistance temperature detectors operating on separate electrical divisions. Temperature sensors are mounted 10 in to 3 ft below the normal suppression pool water level. Normal pool monitors are located within 30 ft line-of-sight of the interstices of each SRV T-quencher discharge. Ten of the sensors in each division provide temperature signals to associated temperature switches and to a temperature selector switch that controls the input to a control room temperature indicator. At high temperature, the temperature switches actuate to energize a control room annunciator and computer point. The other four elements of each division provide temperature signals to an emergency response facility (ERF) computer and to a control room temperature recorder. An unweighted average of these signals is also sent to the containment integrity display (see Figure 18.2-9). In addition, 20 elements (10 in each division) which are wired to control room indicators and the control room annunciator are installed as spares.

The monitoring stations are arranged so that each SRV discharge point meets the 30-ft line-of-sight criterion(1) with respect to two stations. A signal from any sensor operating on one electrical division is sufficient to generate an alarm.

The temperature recorded on the control room recorders will be within ±2°F of the actual temperature. All suppression pool temperature monitoring instrumentation is Category I, and energized from onsite emergency power supplies. In addition, temperature sensors located in the suppression pool are designed in accordance with structural loads expected in this location.

6A.10.1.3 Normal Plant Operation

The temperature monitoring system is utilized during normal plant operation to ensure that pool temperature will remain low enough to condense all quantities of steam that may be released in any anticipated transient or postulated accident. During normal plant operation, the system is in continuous operation, recording the suppression pool water temperature with a readout in the main control room. If the pool temperature rises above normal operation temperature, an alarm is actuated in the control room, allowing the Operator to take action to maintain suppression pool temperature below the suppression pool temperature limit (Section 6A.10.2).

6A.10.2 Plant Transients

This section discusses various plant transients that result in SRV discharges to the suppression pool and that could lead to high pool temperatures.

6A.10.2.1 Abnormal Events

Various events that result in energy being discharged to the suppression pool via the SRVs are of short duration and have little effect on the suppression pool temperature. However, the following three events have potential for substantial high energy release to the suppression pool that could result in undesirably high suppression pool temperatures if timely corrective action is not taken:

1. An event that results in the isolation of the plant from the main condenser.

2. Stuck-open SRVs (SORVs).

3. ADS operation.

A brief description of each of these events is given in the following sections.

6A.10.2.1.1 Primary System Isolation

When the primary system is isolated from the main condenser, the reactor is scrammed automatically and the stored energy in the vessel internals, fuel relaxation energy, and decay heat is rejected to the suppression pool. The amount of heat rejected to the suppression pool depends on reactor size, power level, and primary system heat removal capability. This refers to the condensing-type heat exchangers in the RHR system which remove steam directly from the RPV. The RHR heat exchangers have been isolated from removing steam directly from the RPV.

6A.10.2.1.2 Stuck-Open SRV

The steam flow rate through a SRV is a function of the reactor vessel pressure. One method to terminate energy input to the suppression pool is to scram the reactor and depressurize the reactor vessel in the event the relief valve cannot be closed.

During the blowdown, the pool temperature will increase at a rate determined by the RPV pressure, flow capacity of the SRV, primary system heat removal system capability, and suppression pool water heat removal capability.

6A.10.2.1.3 Automatic Depressurization System

Activation of the ADS results in rapid depressurization of the RPV by opening seven SRVs. During this transient, the bulk suppression pool temperature rises. In a typical case, the RPV is depressurized to 170 psia or less in about 10 min.

6A.10.2.2 Transients of Concern

The Mark II Owners Group White Paper, Revision 1(2), and NUREG-0783(5), identified the following cases for analysis by the Mark II plants.

1. SORV at power:
    a. Loss of one RHR heat exchanger.
    b. Spurious closure of MSIV at time = 0.
2. SRV discharge following isolation/scram.
3. SRV discharge following SBA.

6A.10.2.3 Analysis Method

6A.10.2.3.1 Original Rated Power Analysis

The original analysis performed at a core thermal power of 3,467 MWt (104.3 percent of rated) uses the computer code CONSBA(3), which is designed to analyze the reactor and primary containment system transient during normal and abnormal shutdown of the reactor system. The program uses a finite difference technique using input-specified time steps to solve the transient equations. In each time step, the program determines the mass and energy flow across all control volumes and performs thermodynamic state calculations for the reactor vessel, drywell, suppression chamber, and suppression pool, assuming thermodynamic equilibrium conditions.

The reactor coolant is represented by volumes of steam and liquid in thermal equilibrium. The total volume of the coolant (steam and liquid) in the reactor system is assumed constant. The reactor water level is maintained by feedwater, ECCS systems, and control rod drive (CRD) flow throughout the transient. Heat is added to the reactor coolant from thermal mixing with ECCS/feedwater/CRD flow, decay heat, fuel sensible heat, fission energy, and the reactor vessel and internals metal mass. At the beginning of the transient, the reactor vessel, internals, and coolant are assumed to be in thermal equilibrium. With the depressurization of the reactor vessel, the coolant temperature decreases, establishing a heat flow from the reactor vessel and internals to the coolant.

Steam can flow from the reactor coolant steam volume to the drywell, main condenser, or through SRVs into the suppression pool. For the SBA, steam is added directly to the drywell from the break and to the suppression pool through the SRVs. SRV and break flows are calculated using the frictionless Moody flow model.

6A.10.2.3.2 Extended Power Uprate Analysis

The analysis performed for uprated power conditions (core thermal power of 4,068 MWt, 102 percent of uprated power) uses a GEH computer code SHEX. This code uses a coupled RPV and containment model, based on References 9, 10, and 11, to calculate the long-term bulk suppression pool temperature response. This model performs fluid mass and energy balances on the primary system and the suppression pool, and calculates the reactor water level, pressure, and long-term response of the suppression bulk pool temperature. The various modes of all important auxiliary systems such as the SRVs, the MSIVs, the ECCS, the RHR system and feedwater are modelled. The model can simulate actions based on system setpoints, automatic actions and Operator-initiated actions. Consideration of effects due to operation in the MELLLA+ domain has determined that sensible and decay heat do not increase from the EPU basis; these results are valid for that conclusion as well.

6A.10.2.4 General Assumptions and Initial Conditions

A summary of the key inputs to the pool temperature analysis is provided in Table 6A.10-2 (original rated power analysis) and Table 6A.10-2a (EPU analysis).

The following assumptions and initial conditions apply to all pool temperature analysis cases and are in agreement with the guidelines contained in NUREG-0783:

1. Power level and decay heat standard are the same as those used in the FSAR containment analysis.

2. Initial suppression pool volume is the minimum Technical Specification limit for power operation.

3. Initial suppression pool temperature is the maximum Technical Specification limit for continuous power operation without pool cooling, 90°F.

4. Design fouling factors were used in determining RHR heat exchanger effectiveness for the original rated power analysis. However, 82 percent of the design

fouling factors are used for the EPU analysis, which is consistent with RHR heat exchanger performance testing.

5. Reactor water level is maintained by hot feedwater, ECCS, and CRD flow. Feedwater flow is terminated when the enthalpy of the feedwater is less than or equal to the enthalpy of the suppression pool. The feedwater is then replaced by water from the suppression pool.

6. MSIV closure is completed 3.5 sec after the isolation signal for transients where isolation occurs.

7. SRV flow rate is assumed to be 122.5 percent of the ASME-rated flow rate to maximize the flow of steam to the pool.

8. Mass of water contained inside the reactor vessel pedestal is neglected, resulting in a reduction of the heat capacity of the pool and, therefore, is conservative.

9. Offsite power is not available for isolation/scram and small break LOCAs, except that offsite power is available for feedwater pumps.

10. The heat equivalent to 100 percent of the operating RHR pump(s)/ECCS horsepower rating is added directly to the suppression pool and/or to the reactor vessel to maximize energy input to the suppression pool.

11. Reactor cooldown rate for manual depressurization by SRVs is 100°F/hr, and begins after the suppression pool temperature exceeds 120°F, unless the depressurization rate for the event itself (e.g., spurious failure of a SRV in the open position (SORV)) exceeds the required rate at that time. To maintain the 100°F/hr cooldown rate requires the actuation of one or more SRVs, depending upon reactor vessel pressure.

12. Energy absorbed by containment heat sinks is considered in accordance with the approved LOCA analysis methods.

13. RHR pool cooling mode is initiated 10 min for the original rated power analysis and 40 min for the EPU analysis after exceeding the Technical Specification limit for power operation, 90°F.

14. Initial inventory of the reactor vessel includes the recirculation system, main steam piping to the first MSIV, miscellaneous piping, and RHR shutdown piping.

15. Steam flow through piping and valves is assumed to be Moody critical flow.

16. Interruption of RHR pool cooling mode due to a 2-psig high drywell pressure signal is considered.

17. The condensate storage tank (CST) inventory is not available.

18. RHR shutdown cooling mode is assumed to be unavailable following all transients. Operator action is assumed to establish alternate shutdown cooling 1 hr after the reactor pressure permissive of approximately 150 psia is reached.

6A.10.2.5 Case-Specific Assumptions

See Tables 6A.10-3 through 6A.10-6 for case-specific assumptions.

Cases 1a, 1b, 2, and 3 were analyzed using the CONSBA code (Section 6A.10.2.3.1) at 105 percent of the original rated steam flow, corresponding to 3,467 MWt.

These analyses provide the basis for identifying Case 2 as the limiting event and provide a sensitivity of the peak local suppression pool temperature and long-term bulk suppression pool temperature response to the different transients of concern identified in Section 6A.10.2.2.

For EPU, the long-term bulk suppression pool temperature response for the limiting case (Case 2) is calculated using the GE model described in Section 6A.10.2.3.2 at 102 percent of uprated power. This case uses the assumptions given in Table 6A.10-5 for Case 2.

6A.10.2.6 Suppression Pool Temperature Limits

A suppression pool local temperature limit of 200°F was specified in NUREG-0487(4). The revised temperature limit that applies to Unit 2 and other plants with deep quencher submergence, NUREG-0783(5), specifies the following:

1. For steam mass flux (through the quencher) greater than 94 lbm/sq ft-sec, the suppression pool local temperature shall not exceed 200°F.

2. For steam mass flux less than 42 lbm/sq ft-sec, the suppression pool temperature shall be at least 20°F subcooled with respect to the local saturation temperature at the quencher elevation.

3. For steam mass flux greater than 42 lbm/sq ft-sec but less than 94 lbm/sq ft-sec, the suppression pool temperature can be established by linearly interpolating the local temperatures established under Items 1 and 2.

For Unit 2, the minimum quencher submergence is 19.9 ft. Assuming the minimum suppression chamber pressure of 14.2 psia, the local boiling temperature would be 234°F. Considering 20°F of subcooling, the maximum local suppression pool temperature limit would be 214°F.

6A.10.2.7 Results/Conclusions

Original Rated Power Analysis Table 6A.10-1 summarizes the results of the suppression pool temperature transients. Figures 6A.10-2 through 6A.10-9 show the bulk pool temperature and reactor pressure transients for NUREG-0783 transients. It is observed that the peak pool temperature remains below the 212°F design limit in all cases.

Figures 6A.10-10 through 6A.10-13 compare bulk pool temperature as a function of quencher mass flux (reactor vessel pressure) to the local pool temperature limit. The minimum temperature difference between allowable local temperature and the pool bulk temperature ranges from 57°F to 14°F.

EPU Analysis Table 6A.10-1a summarizes the results of the suppression pool temperature transient for Case 2, the limiting event. Figures 6A.10-6a, 6A.10-7a, and 6A.10-12a show the bulk pool temperature, vessel pressure, and bulk pool temperature as a function of quencher mass flux, respectively. The minimum temperature difference between the allowable local temperature and the pool bulk temperature is 14°F, nearly the same as the original rated power analysis.

A maximum local-to-bulk temperature difference on the order of 10°F has been demonstrated by in-plant tests at Caorso(6) and LaSalle(7). This conclusion is supported by the pool thermal mixing analysis described in the following section. For the limiting event (Case 2), the predicted minimum available local to pool bulk temperature difference is 14°F, which provides 4°F margin to the 10°F required margin.

6A.10.2.8 Single Failure Analysis

The Unit 2 RHR system is designed such that any single-active component failure will not disable the pool cooling function and the core decay heat removal function (shutdown cooling mode) simultaneously. The Unit 2 normal shutdown cooling mode of the RHR system could be unavailable as a result of a single failure of the suction line isolation valve inside the drywell. Therefore, the normal shutdown cooling mode was not utilized in the suppression pool temperature transient analysis. In general, following pool heatup transients, the pool cooling mode is actuated. This mode continues to cool the suppression pool until the reactor vessel is sufficiently depressurized to permit initiation of the alternate shutdown cooling mode. This mode is described in Section 15.2.9. In this mode, the suppression pool water is pumped into the reactor vessel through the RHR heat exchanger and is returned to the suppression pool through manually opened SRVs. This mode removes the decay heat from the core and maintains the pool temperature below its design value.

6A.10.3 Suppression Pool Thermal Mixing

6A.10.3.1 Discussion

To preclude the occurrence of condensation instability dynamic loads during SRV discharge events, limitations have been placed on the local temperature of suppression pool water feeding the condensation zone. These limits were discussed in the previous section and are shown on Figures 6A.10-10 through 6A.10-13. However, the bulk or mass average pool temperature is used in plant transient analyses to characterize pool heatup. Accordingly, the difference between the bulk and local values must be specified so that the analysis can demonstrate operation within the prescribed limits.

This analysis demonstrates that the local-to-bulk temperature difference for Unit 2 will be less than 10°F, considering a single SRV discharging and no RHR system flow.

6A.10.3.2 Methodology

The three-dimensional hydrothermal analysis code TEMPEST(8) was used to predict the local temperature transient following a single SRV discharge for Unit 2. The computer code and analytical method initially were benchmarked against the LaSalle in-plant test data(7). Code parameters such as the condensing zone entrainment factor were adjusted parametrically until the code prediction of near field, far field, and surface temperatures agreed with the test data. The model, benchmarked in this fashion, was then applied to the Unit 2 geometry.

6A.10.3.3 Nodalization

The LaSalle extended blowdown test identified in Reference 7 as "SRV-E" was utilized for the comparison. The LaSalle pool geometry is shown schematically on Figure 6A.10-14. The TEMPEST model developed for this pool consists of 390 fluid cells or nodes derived by dividing the annular pool geometry into 13 sectors with each sector containing 30 nodes arranged 6 vertically by 5 radially. The nodal size was established such that the 10-ft tee-quencher is entirely within one cell.

Figure 6A.10-15 shows the Unit 2 pool geometry. By comparison with Figure 6A.10-14, it is observed that the Unit 2 and LaSalle geometries are very similar. Therefore, the same 390-node model was applied in the Unit 2 analysis, with minor changes to reflect the Unit 2 dimensions.

6A.10.3.4 Results

Temperature response data obtained at four sensor locations in the LaSalle SRV-E test are compared with the analytical predictions of the TEMPEST model for the cells representing the sensor locations. These comparisons are presented on Figures 6A.10-16 through 6A.10-19. The sensor locations are shown on Figure 6A.10-14.

Figure 6A.10-20 shows the local-to-bulk temperature difference predicted for Unit 2 as a result of a single SRV blowdown. In this case, the local temperature is the predicted temperature for the fluid cell immediately above the quencher, while the bulk temperature is the mass average temperature. These results indicate that the local-to-bulk temperature difference applicable to Unit 2 is approximately 10°F.

6A.10.4 References

1. Suppression Pool Temperature Monitoring Recommendations, GE Specification 22A4379, November 30, 1978.

2. Assumptions for Use in Analyzing Mark II BWR Suppression Pool Temperature Response to Plant Transients Involving Safety/Relief Valve Discharge, Rev. 1, December 1980 (White Paper, Rev. 1).

3. Stone & Webster Engineering Corporation, Containment Small Break Accident Code (CONSBA), Nu-169.

4. Mark II Containment Lead Plant Program Load Evaluation and Acceptance Criteria, USNRC NUREG-0487, October 1978.

5. Suppression Pool Temperature Limits for BWR Containment, USNRC NUREG-0783, November 1981.

6. NEDE-25127, "CAORSO Thermal Mixing Test Final Report," August 1979.

7. NMPC Letter from C. D. Terry, Manager, Project Engineering, to C. C. Zappile, Project Engineer, Nine Mile Point Nuclear Station - Unit 2, Stone & Webster Engineering Corporation, Transmitting Temperature Data From the Commonwealth Edison Company LaSalle County Station SRV In-plant Test, March 4, 1983.

8. Pacific Northwest Laboratory, A Three-Dimensional Time Dependent Computer Program for Hydrothermal Analysis (TEMPEST), PNL-4348.

9. NEDM-10320, "The GE Pressure Suppression Pool Containment Analytical Model," March 1971.

10. NEDO-20533, "The General Electric Mark III Pressure Suppression Containment System Analytical Model," June 1974.

11. NRC Letter from Ashok Thadani to Gary L. Sozzi, General Electric, Use of SHEX Computer Program and ANSI/ANS 5.1-1979 Decay Heat Source Term for Containment Long-Term Pressure and Temperature Analysis,” July 13, 1999.

TABLE 6A.10-1

SUPPRESSION POOL TEMPERATURE ANALYSIS RESULTS (ORIGINAL RATED POWER ANALYSIS - 82°F UHS)

SRV Discharge Event	Case No.	Peak Bulk Suppression Pool Temperature (°F)	Maximum Bulk Suppression Pool Temperature (°F) During SRV Steam Discharge Phase	Minimum Available Temperature (°F) Difference Between Limiting Local Temperature and Bulk Pool Temperature
Stuck open SRV at power with 1 RHR train	1a	147.8	147.8	56.5
Stuck open SRV at power with spurious isolation	1b	200.0	195.9	18.1
Isolation/scram with 1 RHR train	2	210.7	199.7	14.3
Small break accident with 1 RHR train	3	206.8	193.2	20.8

TABLE 6A.10-1a

SUPPRESSION POOL TEMPERATURE ANALYSIS RESULTS
(EPU ANALYSIS - 84°F UHS)

SRV Discharge Event	Case No.	Peak Bulk Suppression Pool Temperature (°F)	Maximum Bulk Suppression Pool Temperature (°F) During SRV Steam Discharge Phase	Minimum Available Temperature (°F) Difference Between Limiting Local Temperature and Bulk Pool Temperature
Isolation/scram with 1 RHR train	2	210.0	200	14.0

TABLE 6A.10-2

IMPORTANT SYSTEM CHARACTERISTICS USED IN SUPPRESSION POOL TEMPERATURE ANALYSIS (ORIGINAL RATED POWER ANALYSIS)

Minimum suppression pool water volume (w/o pedestal water)	137,110 ft^{3}(5)
Maximum suppression pool temperature	90°F
Reactor coolant system total volume	24,184 ft^{3}(6)
Reactor coolant system liquid volume	13,381 ft^{3}(7)
Initial reactor vessel pressure	1,055 psia
RPV and internals mass	2,823,430 lbm
Initial core power	
Original analysis (104.3% of original rated)	3,467 MWt
Initial steam flow	
105% of original rated	4,170 lbm/sec
Initial CRD flow	14.74 lbm/sec(8)
CRD flow after scram (Prpv = 0 psig)	14.74 lbm/sec(8)
CRD enthalpy (assumed)	168 Btu/lbm
Feedwater ON volume	13,284 ft^{3}
Feedwater OFF volume	13,498 ft^{3}
Vessel permissive pressure for RHR shutdown cooling(1)	150 psia
RHR heat exchanger K factor	240.2 Btu/sec-°F for Case 1a, 3 233 Btu/sec-°F for Case 1b 249 Btu/sec-°F for Case 2
RHR pump heat (per pump)	707 Btu/sec
Service water temperature	82°F(10)
Safety/relief valve effective flow area	0.121 ft^{2}
Effective break area for small steam line break	0.01 ft^{2}

Feedwater Inventory No.	Mass (lbm)	Enthalpy(3) (Btu/lbm)
1	187,816	402.1
2	93,365	370.13
3	194,068	348.00
4	98,007	324.92
5	128,528	271.00
6	75,124	236.00
7	237,869	168.86

TABLE 6A.10-2 (Cont'd.)

Reactor Power Decay

Time (sec)	Fraction of Power[4]	Time (sec)	Fraction of Power
0.0	1.09	4,800	0.01468
0.01	1.08446	6,000	0.01369
0.2	1.07024	7,200	0.01300
0.5	0.96209	9,000	0.01227
0.7	0.91696	10,800	0.01173
1.0	0.8031	12,600	0.01130
3.0	0.7295	14,400	0.01092
5.0	0.5561	16,200	0.01058
7.0	0.4375	18,000	0.01027
10.0	0.3149	19,800	0.009989
20.0	0.1196	21,600	0.009727
30.0	0.0804	23,400	0.009484
60.0	0.04826	36,000	0.008206
90.0	0.04448	54,000	0.007169
180.0	0.03807	72,000	0.006577
390.0	0.03107	90,000	0.006184
600.0	0.02824	259,200	0.004384
1500.0	0.02143	432,000	0.003479
2400.0	0.01862	604,800	0.003006
3600.0	0.01619	1,000,000	0.002470

---

[1] Alternate shutdown cooling assumed 1 hr later.

[2] Deleted.

[3] Includes pipe metal sensible heat.

[4] Where power is normalized to the fraction of initial core power.

[5] The calculated suppression pool water volume is 137,600 ft^3. The analysis used lower volume. This is conservative.

[6] The RCS total volume used in the analysis is 0.3 percent less than the calculated volume. This difference has no significant impact on the suppression pool temperature analysis.

[7] The RCS liquid volume used in the analysis is 5 percent less than the calculated volume. This has no significant impact on the suppression pool temperature analysis.

[8] The CRD flow is used for Case 1A analysis only. The normal flow is 8.89 lbm/sec. The difference of less than 6 lbm/sec flow rate does not significantly affect the analysis.

[9] Deleted.

TABLE 6A.10-2 (Cont'd.)

(10) As a result of an increase in maximum service water design temperature to 84°F, the containment response has been re-evaluated. The resulting suppression pool temperature remains bounded by the current analysis.

(11) Deleted.

TABLE 6A.10-2a

NOTE: ONLY EPU-AFFECTED PARAMETERS ARE SHOWN

IMPORTANT SYSTEM CHARACTERISTICS USED IN SUPPRESSION POOL TEMPERATURE ANALYSIS – CASE 2 (EPU ANALYSIS)

Extended Power Uprate analysis (102% of EPU)	4,068 MWt
Initial steam flow	102% of EPU
Vessel permissive pressure for RHR shutdown cooling(1)	143 psia
RHR heat exchanger K factor	270 Btu/sec-°F
Service water temperature	84°F

Feedwater Inventory No.	Fluid Mass (lbm)	Metal Mass (lbm)	Temperature °F
1	188,000	932,000	443
2	93,000	520,000	384
3	194,000	470,000	376
4	98,000	438,000	321
5	129,000	522,000	211
6	75,000	157,000	134
7	406,154	396,272	121

TABLE 6A.10-2a (Cont'd.)

Reactor Power Decay

Time (sec)	Fraction of Power(2)	Time (sec)	Fraction of Power
0.0	1.0479	7,195	0.01144
0.5	0.84039	14,494	0.00986
3.0	0.60695	36,032	0.00796
10.5	0.40723	54,075	0.00713
20.5	0.15952	100,062	0.00602
30.5	0.14084	245,000	0.00457
60.5	0.08534		
120.0	0.08067		
120.3	0.03216		
180.0	0.02983		
600.0	0.02334		
2401.0	0.01632		
3605.0	0.01429		

---

(1) Alternate shutdown cooling assumed 1 hr later.

(2) Where power is normalized to the fraction of initial core power.

TABLE 6A.10-3

SUPPRESSION POOL TEMPERATURE ANALYSIS ASSUMPTIONS - CASE 1a

A stuck-open relief valve (SORV) at full power, one RHR train available.

SORV at a suppression pool temperature of 90°F.

Manual scram at a suppression pool temperature of 110°F.

Closure of the turbine stop and bypass valves.

One RHR train in pool cooling mode 10 min after high pool temperature alarm (90°F).

Main condenser heat sink reestablished through bypass system 20 min after scram.

No shutdown or alternate shutdown cooling mode considered.

TABLE 6A.10-4

SUPPRESSION POOL TEMPERATURE ANALYSIS ASSUMPTIONS - CASE 1b

A stuck-open relief valve (SORV) at full power, two RHR trains available.

SORV at a suppression pool temperature of 90°F.

Manual scram at a suppression pool temperature of 110°F.

MSIV isolation at scram with 3.5 sec MSIV closure.

Two RHR trains in suppression pool cooling mode 10 min after high pool temperature alarm. Pool cooling mode is interrupted by a high drywell pressure signal for 30 min.

Manual reactor vessel depressurization initiated at a cooldown rate of 100°F/hr when suppression pool temperature is 120°F (unless SORV flow results in a cooldown rate that exceeds 100°F/hr).

At 150 psia reactor vessel pressure, preparation for the alternate shutdown cooling mode is initiated. Within one hour, this mode is fully established.

TABLE 6A.10-5

SUPPRESSION POOL TEMPERATURE ANALYSIS ASSUMPTIONS - CASE 2

Isolation/Scram, one RHR train available.

Isolation/Scram at t=0, at a suppression pool temperature of 90°F.

MSIV closure complete in 3.5 sec.

Original Rated Power Analysis - One RHR train in suppression pool cooling mode 10 min after high suppression pool temperature alarm. Pool cooling mode is interrupted by a high drywell pressure signal for 30 min.

EPU Analysis – One RHR train in suppression pool cooling mode 40 min after the event.

Manual reactor vessel depressurization is initiated at a cooldown rate of 100°F/hr when suppression pool temperature is 120°F.

At ~150 psia reactor vessel pressure, preparation for the alternate shutdown cooling mode is initiated. Within 1 hr, this mode is fully established.

TABLE 6A.10-6

SUPPRESSION POOL TEMPERATURE ANALYSIS ASSUMPTIONS - CASE 3

Small break accident, one RHR train available.

Scram at t = 0 on high drywell pressure.

Isolation at t = 0 with MSIV closure in 3.5 sec.

One RHR train in suppression pool cooling 30 min after the scram.

When T pool = 120°F, begin manual depressurization by opening SRVs as needed. Depressurize with a cooldown rate of 100°F/hr.

At 150 psia reactor vessel pressure, preparation for alternate shutdown cooling mode is initiated. Within one hour, this mode is fully established.

TABLE 6A.10-7

HEAT TRANSFER SUMMARY FOR SUPPRESSION POOL CONTROL VOLUME

(CASE 2 ISOLATION/SCRAM EVENT) ORIGINAL RATED POWER ANALYSIS

	Energy Out of the Pool (Btu)		
	10 min	1 hr	6 hr
To suppression chamber air space (radiation and convection)	1,600	162,600	2,703,000
To pool passive heat sinks (wall and mat)*	531,000	3,324,100	19,691,900
Evaporation from pool surface	24,500	799,700	37,732,700
To service water via RHR heat exchanger	-	29,084,000	458,189,600

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* Heat transfer coefficient between pool water and liner is 150 Btu/ft^2-hr-°F.

APPENDIX 6B

THREED SUBCOMPARTMENT ANALYTICAL MODEL

APPENDIX 6B

THREED SUBCOMPARTMENT ANALYTICAL MODEL

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APPENDIX 6B

THREED SUBCOMPARTMENT ANALYTICAL MODEL

6B.1 FUNCTIONAL DESCRIPTION OF THREED CODE

The THREED computer program is used to calculate the transient conditions of pressure, temperature, and humidity in various subcompartments following a postulated rupture in a moderate- or high-energy pipeline. The results obtained from THREED analyses are used to calculate loads on structures and to define environmental conditions for equipment qualification.

The THREED computer program is similar to RELAP4 and will give the same results as RELAP4 if similar options are chosen(1,2). THREED was formulated to perform subcompartment analyses with capabilities and options extended beyond those available in RELAP4. A significant improvement in THREED is that the homogeneous equilibrium model (HEM) has been extended to include two-phase, two-component flow which is encountered in subcompartment analysis.

6B.2 DESCRIPTION OF THE MODEL

The THREED computer code can be viewed as a numerical integrator for the macroscopic form of the basic field equations describing the conservation of mass, energy, and momentum. The conservation equations, along with the equation of state for the fluid, give a complete solution to the fluid flow phenomena. THREED solves a stream tube form of the field equations based on the assumptions of one-dimensional, homogeneous, thermal-equilibrium flow. Although THREED does not prohibit the use of multidimensional flow paths, the flow paths are modeled to approximate a one-dimensional equation.

Subcompartments are modeled in THREED as a hydraulic network that consists of a series of interconnecting, user-defined nodes (mass and energy control volumes). Nodes are connected by internal junctions (momentum control volumes) with the internodal flow rates determined by the solution of the momentum equation. An internal junction control volume is defined as the composite volume between the centers of adjacent nodes. This difference in control volumes (i.e., a different control volume for momentum than for mass and energy) is illustrated on Figure 6B-1. This "staggered mesh" approximation is necessary for purposes of solving the equations.

Fill junctions are used to simulate flow originating external to the network (i.e., blowdown). These fill junctions are dissimilar to internal junctions in that they have no initial node, and their flow rate is dependent only on the junction area and time. Mathematically, they are treated as boundary conditions.

THREED numerically solves finite difference equations that account for mass and energy flows into and out of a node. Figure 6B-2 summarizes the computational approach used in THREED.

The fluid conservation equations used by THREED can be obtained by integrating the stream tube equations over a fixed volume, V. The mass and energy equations are developed for the generalized i^{th} node, while the momentum equation is developed for the generalized j^{th} internal junction connecting nodes K and L. Neglecting kinetic energy effects, the resulting equations are as follows.

Conservation of Mass The mass equation is(1):

$$\frac{dM_i}{dt} = \sum_j w_{ij} \qquad \text{(6B-1)}$$

Where:

M_i = Total mass of fluid in node i ($M_i = M_{wi} + M_{ai}$)

M_{wi} = Total mass of water in node i

M_{ai} = Total mass of air in node i

W_{ij} = Mass flow rate into node i from junction j

Conservation of Energy The energy equation for homogeneous flow is(1):

$$\frac{dU_i}{dt} = \sum_j w_{ij} \; (h_{ij} + Z_{ij} - \overline{Z_i}) \qquad \text{(6B-2)}$$

Where:

U_i = Total fluid internal energy of water in node i

h_{ij} = Local enthalpy at junction j of the fluid entering or leaving node i

$Z_{ij}-Z_i$ = Elevation change from the center of mass in node i at Z_i to junction j

Conservation of Momentum The incompressible equation for homogeneous flow is(1):

$$I_j \, \frac{dW_j}{dt} = \left(P_K + P_{Kgj}\right) - \left(P_L + P_{Lgj}\right) - F \qquad \text{(6B-3)}$$

Where:

I_j = Geometric "inertia" for junction j

W_j = Mass flow rate in junction j

P_K = Total static pressure in node K (at center)

P_{Kgj} = Gravity pressure differential from the center of node K to junction j

P_L = Total static pressure in node i (at center)

P_{Lgj} = Gravity pressure differential from junction j to the center of node L

F_j = Static pressure change term

Equation of State The functional form of the equation of state is:

$$P_i = f\ (U_i,\ M_{wi},\ M_{ai}) \qquad (6B\text{-}4)$$

Where:

P_i = Total static pressure in node i

The following assumptions are made in deriving the equation of state:

1. The components of water and air form a homogeneous mixture at a uniform temperature.
2. Water, if present, occupies the entire volume. Air, if present, occupies the same volume as the water vapor according to the Gibbs-Dalton Law. Air is assumed to be insoluble in water, and there can be no air present if the volume is filled with water.
3. Air is treated as a perfect gas.
4. If air and water are present, the water vapor is saturated (relative humidity of 100 percent).
5. If air is present, the water conditions are the saturated conditions for P_{wi}. A more accurate model would have liquid at the subcooled conditions corresponding to Pi and Ti. This assumption is made to limit calls to the water property routines to one per iteration.

   If no water is present in the volume ($M_w = 0$), the detailed form of the equation of state is:

$$U_i = M_{ai} C_{va} T_i \tag{6B-5}$$

$$P_i = \frac{M_{ai} R_a T_i}{V_i} \tag{6B-6}$$

Where:

C_{va} = Constant volume heat capacity of air

T_i = Temperature in node i

R_a = Gas constant of air

V_i = Volume of node i

If water is present in the volume ($M \neq O$), the detailed form of the equation of state is:

$$V_{wi} = M_{wi} / V_i \tag{6B-7}$$

$$U_i = M_{wi} U_{wi} (T_i, V_{wi}) + M_{ai} C_{va} T_i \tag{6B-8}$$

$$P_{ai} = \frac{M_{ai} R_a T_i}{X_i M_{wi} V_{gi} (T_i, V_{wi})} \tag{6B-9}$$

$$P_i = P_{wi} (T_i, V_{wi}) + P_{ai} \tag{6B-10}$$

Where:

V_{wi} = Specific volume of water in node i

U_{wi} = Specific internal energy of water in node i

P_{ai} = Partial pressure of air in node i

X_i = Quality in node i

V_{gi} = Specific volume of water vapor in node i

P_{wi} = Partial pressure of water in node i

The internal code calculations are done in SI units. The reference temperature used for the calculation of the internal energy of air is 0°K. The properties of steam are based on the 1967 ASME formulation of the properties of steam.

Fill Junctions These are normally used to input blowdown (mass and energy release) into a node(s). Their functional form is:

$$W_j = f(t) \tag{6B-11}$$

$$h_{ij} = f(t) \tag{6B-12}$$

Fan Junctions These junctions may be used to model ventilation fan operation in situations where such modeling is appropriate. Their functional form is:

$$W_j = f(H_j) \tag{6B-13}$$

Where:

H_j = Head difference across the fan junction

Choked Flow Options For Internal Junctions Since an incompressible flow model has no mechanism to restrict flow through a junction to the maximum allowable (choked) flow rate, it is necessary to use a separate calculation to restrict the flow rate. To determine if the flow is choked, the momentum equation 6B-3 is solved using a forward finite difference approximation and compared with a calculated choked flow (HEM or Moody). The lesser flow is selected as the junction flow rate for the time step.

Both the HEM and the Moody flow models are based on stagnation properties. Since it is not usually possible to calculate the velocity in a node, it is assumed that the static and stagnation properties in a node are the same (i.e., neglect kinetic energy effects). This may result in an underprediction of the choked flow rate, which is conservative in most cases.

Homogeneous Equilibrium Model The HEM is approximated in THREED using an "ideal gas" approximation. That is, the choked isentropic ideal gas flow equation is used and the isentropic exponent is modified to accommodate two-phase, two-component flow. The isentropic exponent is defined as:

$$\gamma_i = -\frac{V_{wi}}{P_i}\left(\frac{\partial P_i}{\partial V_{wi}}\right)_s \tag{6B-14}$$

Where:

γ_i = Isentropic exponent in node i

The equation used by THREED to calculate the HEM is:

$$W_j = 12\, A_j \left(\frac{2}{\gamma_i + 1}\right)^b \left(g_c \gamma_i \frac{P_{ai}}{V_{ai}}\right)^{1/2} \tag{6B-15}$$

Where:

b = $(\gamma_i + 1)/2\,(\gamma_i - 1)$

A_j = Flow area of junction j, sq ft

γ_i = Isentropic exponent of source node i

g_c = Proportionality constant - 32.174, ft-lbm/lbf-sec^2

P_{ai} = Stagnation pressure in source node i, psia

V_{ai} = Stagnation specific volume of air in source node i, cu ft/lbm

W_j = Mass flow in junction j, lbm/sec

<u>Moody Choked Flow Model</u> The Moody flow model, used in THREED, is based on the interpolation of tables from RELAP4/MOD5(1,3). The model is for one-component flow and, when air is present, the tables are accessed with the total pressure and average enthalpy of the node.

<u>Junction Check Valves</u> A valve may be modeled in any nonfan internal junction as follows:

Normally closed - trips open instantaneously

Normally open - trips closed instantaneously

<u>Time Step Control</u> If the automatic time step control option is selected, the maximum time step will be limited by the following calculation, based on the nodal conditions(1):

$$DT = \min\left\{0.01\left|\frac{P_i}{\dot{P}_i}\right|\right\} \qquad (6B\text{-}16)$$

Where:

i = 1,...,n

DT = Time step size

P_i = dP/dt

6B.3 ASSUMPTIONS EMPLOYED IN THREED

The following assumptions are employed in THREED:

1. Lumped parameter (control volume) approach utilized.
2. Adiabatic process.

3. Independent inflow (blowdown).
4. Thermodynamic equilibrium in each node.
5. One-dimensional formulation.
6. Staggered mesh for the conservation equations.
7. Homogeneous flow, unless the Moody choking option is chosen.
8. Incompressible form of the momentum equation.
9. Kinetic energy effects neglected.
10. For choked flow models, static properties in the nodes considered to be stagnation properties.
11. Valves open or close instantaneously.

6B.4 REFERENCES

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2. Moore, K. V. and Rettig, W. H. RELAP4 - A Computer Program for Thermal Hydraulic Analysis. Report ANCR-1127 Aerojet Nuclear Company, August 1974.

3. Moody, L. J. Maximum Flow Rate of a Single Component, Two-Phase Mixture. Journal of Heat Transfer, Trans ASME, Vol. 87, 1965, pp 134-142.

APPENDIX 6C

HUMPHREY CONCERNS

APPENDIX 6C

HUMPHREY CONCERNS

A Nuclear Regulatory Commission (NRC) letter dated January 10, 1984, from A. Schwencer (NRC) to G. Rhode (Niagara Mohawk Power Corporation [NMPC]), identified safety issues involving Mark II containments. The following responses are provided for each of the concerns found in the letter.

1.0 EFFECTS OF LOCAL ENCROACHMENTS ON POOL SWELL LOADS

Response

1.1 through 1.7 are not applicable to a Mark II containment.

2.0 SAFETY RELIEF VALVE DISCHARGE LINE (SRVDL) SLEEVES

Response

2.1 through 2.3 are not applicable to a Mark II containment.

3.0 EMERGENCY CORE COOLING SYSTEM (ECCS) RELIEF VALVE DISCHARGE LINES BELOW THE SUPPRESSION POOL LEVEL

3.1 The design of the Standard Reactor Island Design (STRIDE) plant did not consider vent clearing, condensation oscillation (CO), and chugging loads which might be produced by the actuation of these relief valves.

NOTE: The steam-condensing mode of RHR has been abandoned in place. References to steam condensing are for historical information only. Relief and safety valves associated with the steam-condensing mode of RHR are no longer operational.

Response

Nine Mile Point Nuclear Station - Unit 2 (Unit 2) will install T-quenchers to condense the steam discharged from the residual heat removal (RHR) relief valve actuation. These quenchers will be installed before the RHR system is allowed to be operated in the steam-condensing mode and are of the same design as those on the main steam SRVDLs. Tests have shown satisfactory thermohydraulic performance of this device and its capability to mitigate vent clearing and steam condensation loads. Since the relief capacity of the RHR relief valves is considerably smaller than that of the main steam SRV, less than one-half the set pressure and one-third the steam-relieving capacity, no separate load consideration is necessary.

3.2 The STRIDE design provided only 9 in of submergence above the RHR relief valve discharge lines at low suppression pool levels.

Response

Humphrey Concern 3.2 is relative to the condensation effectiveness of the RHR relief valve discharge lines at low suppression pool level. The Humboldt Bay pressure suppression test investigated condensation effectiveness by comparing the measured and calculated pressures in the suppression chamber air space. The calculated pressure is based on the complete condensation of the steam in the pool. Complete condensation of the steam, based on the small difference between measured and calculated pressures, was accomplished for the Humboldt Bay conditions shown in Table 6C-1. The Unit 2 conditions also are shown.

Since the Unit 2 conditions fall within the Humboldt Bay test envelope, complete condensation of steam from the RHR relief valve discharge lines at low suppression pool levels can be expected.

3.3 Discharge from the RHR relief valves may produce bubble discharge or other submerged structure loads on equipment in the suppression pool.

Response

Unit 2 used the differential pressure concept developed by Kraftwerk Union (KWU) to calculate the submerged structure loads* (Section 6A.3.4.8). All structures in the pool have been designed to withstand the bubble discharge loads from the quencher. Since Unit 2 uses the same quencher on both the RHR relief valve and the main steam SRVDLs, the submerged structure loads produced by bubble discharge have been properly considered.

3.4 The RHR heat exchanger relief valve discharge lines are provided with vacuum breakers to prevent negative pressure in the lines when discharging steam is condensed in the pool. If the valves experience repeated actuation, the vacuum breaker sizing may not be adequate to prevent drawing slugs of water back through the discharge piping. These slugs of water may apply impact loads to the relief valve or be discharged back into the pool at the next relief valve actuation and apply impact loads to submerged structures.

Response

The reflood analysis has been performed for the RHR heat exchanger relief valve discharge. The vacuum breakers installed in the discharge line limit the reflood to below the vacuum breaker locations. Subsequent analyses have been performed which demonstrate the adequacy of the piping system.

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* The RHR bubble loads on the ECCS strainers are calculated using the same location method as discussed in Appendix 6D, Section 6D.3.4.8, for the SRV bubble loads on ECCS strainers.

3.5 The RHR relief valves must be capable of correctly functioning following an upper pool dump, which may increase the suppression pool level as much as 5 ft, creating higher backpressure on the relief valves.

Response

Not applicable to Mark II containment, since upper pool dump is a design feature specific to Mark III containments.

3.6 If the RHR heat exchanger relief valves discharge steam to the upper levels of the suppression pool following a design basis accident (DBA), they will significantly aggravate suppression pool temperature stratification.

Response

This issue has significance when the RHR heat exchangers are communicating with the reactor vessel, either in the shutdown cooling mode or the steam-condensing mode. The steam-condensing mode is used to maintain the reactor vessel in the hot standby condition whenever the reactor vessel is isolated from the main condenser and, therefore, would not be applicable to an accident situation. The shutdown cooling mode is used only when the reactor vessel has been depressurized below 128 psig. Under this condition it would not be possible for the system to exceed the relief valve setpoint of 500 psig. Therefore, there will be no flow from the RHR relief valves to the suppression pool.

3.7 The concerns related to the RHR heat exchanger relief valve discharge lines should also be addressed for all other relief lines that exhaust into the pool.

Response

Table 6C-2 lists all of the relief lines that discharge into the suppression pool. These are used either as thermal reliefs or relief valves discharging water. In either case, the dynamic loads resulting from the actuations of these valves are insignificant compared with those from the RHR heat exchanger relief valve addressed in Sections 3.1, 3.3, and 3.4. The waterhammer loads due to water discharge have been considered in the piping design.

4.0 SUPPRESSION POOL TEMPERATURE STRATIFICATION

4.1 The present containment response analyses for drywell break accidents assume that the ECCS systems transfer a significant quantity of water from the suppression pool to the lower regions of the drywell through the break. This results in a pool in the drywell which is essentially isolated from the suppression pool at a temperature of approximately 135°F. The containment response analysis assumes that the drywell pool is thoroughly mixed with the suppression pool. If the inventory in the drywell is assumed to be isolated and the remainder of the heat is discharged to the suppression pool, an increase in bulk pool temperature of 10°F may occur.

Response

The maximum collectible volume of water on the drywell floor is less than 2 percent of the suppression chamber pool volume at low water level for Unit 2. The increase in the bulk pool temperature for Unit 2 is estimated to be about 1°F as a result of isolating the drywell pool at 135°F.

4.2 The existence of the drywell pool is predicated upon continuous operation of the ECCS. The current emergency procedure guidelines (EPGs) require the Operators to throttle ECCS operation to maintain the vessel level below Level 8. Consequently, the drywell pool may never be formed.

Response

This issue is not applicable to Unit 2.

4.3 All Mark III analyses presently assume a perfectly mixed, uniform suppression pool. These analyses assume that the temperature of the suction to the RHR heat exchangers is the same as the bulk pool temperature. In actuality, the temperature in the lower part of the pool where the suction is located will be as much as 7.5°F cooler than the bulk pool temperature. Thus, the heat transfer through the RHR heat exchanger will be less than expected.

Response

Unit 2 RHR pumps take suction near the top of the pool (approximately 10 ft below the normal pool level with a pool depth of 25 ft); therefore, this is not an issue for Unit 2. RHR heat exchanger inlet temperature will be very close to bulk pool temperature as assumed in the pool temperature analysis.

4.4 The long-term analysis of containment pressure/temperature response assumes that the wetwell airspace is in thermal equilibrium with the suppression pool water at all times. The calculated bulk pool temperature is used to determine the airspace temperature. If pool thermal stratification were considered, the temperature of the surface, which is in direct contact with the airspace, would be higher; therefore, the airspace temperature (and pressure) would be higher.

Response

In a Mark II containment, the post-LOCA peak pressure is established in the short term by the blowdown dynamics, rather than in the long term by pool airspace heatup. Therefore, pool stratification is not significant for containment peak pressure analysis.

The maximum suppression chamber airspace temperature, which is used for the equipment qualification, is determined from the steam bypass analysis. The steam bypass analysis does not assume the airspace and pool are in thermal equilibrium.

4.5 A number of factors may aggravate suppression pool thermal stratification. The chugging produced through the first row of horizontal vents will not produce any mixing from the suppression pool layers below the vent row. An upper pool dump may contribute to additional suppression pool temperature stratification. The large volume of water from the upper pool further submerges RHR heat exchanger effluent discharge, which will decrease mixing of the hotter, upper regions of the pool. Finally, operation of the containment spray eliminates the heat exchanger effluent discharge jet which contributes to mixing.

Response

Unit 2 does not have horizontal vents or upper pool dump; therefore, the first three issues are not applicable. Drywell spray water returns to the pool via widely dispersed downcomers at a lower elevation than the RHR discharge jet. This arrangement promotes mixing as hot water is rising in the entire pool. Therefore, this issue is not a concern for Unit 2.

4.6 The initial suppression pool temperature is assumed to be 95°F while the maximum expected service water temperature is 90°F for all Grand Gulf Nuclear Station (GGNS) accident analyses, as noted in Table 6.2-50. If the service water temperature is consistently higher than expected, as occurred at Kuosheng, the RHR system may be required to operate nearly continuously in order to maintain suppression pool temperature at or below the maximum permissible value.

Response

Unit 2 maximum service water temperature is 81°F, which is 9°F below the Technical Specification limit of 90°F for suppression pool. Therefore, only intermittent operation of RHR system is required to cool the suppression pool below its Technical Specification limit; thus, this is only a plant availability concern and not a safety concern.

4.7 All analyses completed for the Mark III are generic in nature and do not consider plant-specific interactions of the RHR suppression pool suction and discharge.

Response

There will not be adverse interaction of the Unit 2 RHR suppression pool suction and discharge flows. The RHR pool cooling suction and discharge arrangement is shown on Figure 6C-1. All suction and discharge points are located near the pool wall with suction taken approximately 14 ft above the pool floor, and discharge at 22 ft above the floor and vertically downward. Loop A suction and discharge are separated circumferentially by 140 deg of arc length (chord length 80 ft), and Loop B suction and discharge are 139 deg apart. This arrangement precludes interaction with one RHR loop operating in pool cooling mode. It should be noted that one loop operating is the worst case for maximum suppression pool temperature. In the case of two-loop operation, separation of 40 deg of arc length (chord distance of 29 ft) exists between Loop A discharge and Loop B suction.

4.8 Operation of the RHR system in the containment spray mode will decrease the heat transfer coefficient through the RHR heat exchangers due to decreased system flow. The Final Safety Analysis Report (FSAR) analysis assumes a constant heat transfer rate from the suppression pool even with operation of the containment spray.

Response

The RHR heat exchanger design is based on the shutdown cooling mode. The corresponding flow rate is 7,450 gpm. The containment spray flow rate is 7,500 gpm. Therefore, essentially the same heat transfer coefficient would be applicable for both modes of RHR operation, and use of the design point heat transfer characteristic in the spray mode is justified for Unit 2.

4.9 The effect on the long-term containment response and the operability of the spray system due to cycling the containment sprays on and off to maximize pool cooling needs to be addressed. Also, provide and justify the criteria used by the Operator for switching from the containment spray mode to pool cooling mode and back again.

Response

For Unit 2, cycling of the containment sprays to achieve maximum pool cooling is not required. The criterion for containment spray is discussed in Sections 6.2.1 and 6.2.2.

4.10 Justify that the current arrangement of the discharge and suction points of the pool cooling system maximizes pool mixing.

5.0 DRYWELL TO CONTAINMENT BYPASS LEAKAGE

5.1 The worst case of drywell-to-containment bypass leakage has been established as a small break accident (SBA). An intermediate break accident (IBA) actually will produce the most significant drywell-to-containment leakage prior to initiation of containment sprays.

Response

Unit 2 steam bypass analysis identified the limiting case as a steam line break of approximately 0.4 sq ft, as shown in Section 6.2.1, Figure 6.2-28. This is an IBA.

Initiation of containment sprays is 30 min after the break.

5.2 Under Technical Specification limits, bypass leakage corresponding to $A/\sqrt{K}$ = 0.1 sq ft constitutes acceptable operating conditions. Smaller-than-IBA-sized breaks can maintain break flow into the drywell for long time periods, however, because the reactor pressure vessel (RPV) would be depressurized over a 6-hr period. Given, for example, a SBA with $A/\sqrt{K}$ = 0.1, projected time period for containment pressure to reach 15 psig is 2 hr. In the latter 4 hr of the depressurization, the containment would presumably experience ever-increasing overpressurization.

Response

Current Unit 2 steam bypass analysis considers a full spectrum of break sizes. The containment spray initiation is based on this analysis.

Containment overpressurization will not occur due to containment heat sinks and sprays.

5.3 Leakage from the drywell to containment will increase the temperature and pressure in the containment. The Operators will have to use the containment spray to maintain containment temperature and pressure control. Given the decreased effectiveness of the RHR system in accomplishing this objective in the containment spray mode, the bypass leakage may increase the cyclical duty of the containment sprays.

Response

See response to Concerns 4.8, 4.9, and 5.2.

5.4 Direct leakage from the drywell to the containment may dissipate hydrogen outside the region where the hydrogen recombiners take suction. The anticipated leakage exceeds the capacity of the drywell purge compressors.

5.4 Direct leakage from the drywell to the containment may dissipate hydrogen outside the region where the hydrogen recombiners take suction. The anticipated leakage exceeds the capacity of the drywell purge compressors. This could lead to pocketing of hydrogen which exceeds the concentration limit of 4 percent by volume.

Response

This issue is not applicable to Unit 2 because Unit 2 has an inerted design which makes hydrogen control relatively unimportant.

With regard to the use of recombiners for the purpose of oxygen control, Unit 2 recombiners can take suction from either the suppression chamber or the drywell and return gas to the suppression chamber. The oxygen concentrations in the drywell and wetwell are monitored and displayed independently. Any bypass leakage from the drywell and wetwell would have no effect on the system operation.

5.5 Equipment may be exposed to local conditions which exceed the environmental qualification envelope as a result of direct drywell to containment bypass leakage.

Response

All equipment in the wetwell airspace is qualified for a temperature of 270°F. Local conditions will not exceed this limit.

5.6 The test pressure of 3 psig specified for the periodic operational drywell leakage rate tests does not reflect additional pressurization in the drywell which will result from upper pool dump. This pressure also does not reflect additional drywell pressurization resulting from throttling of the ECCS to maintain vessel level which is required by the current EPGs.

Response

Not applicable to Mark II containments.

5.7 After upper pool dump, the level of the pool will be 6 ft higher, and drywell-to-containment differential pressure will be greater than 3 psi. The drywell H_2 purge compressor head is nominally 6 psid. The concern is that after an upper pool dump, the purge compressor head may not be sufficient to depress the weir annulus enough to clear the upper vents. In such a case, H_2 mixing would not be achieved.

Response

Not applicable to Mark II containments.

5.8 The possibility of high temperatures in the drywell without reaching the 2 psig high-pressure scram level because of bypass leakage through the drywell wall should be addressed.

Response

A transient analysis was performed for the abnormal event of loss of function of all unit coolers in the drywell. The normal heat load, the normal leakage from the reactor coolant system (RCS), passive heat sinks, and 10 percent of the allowable steam bypass $\left(A/\sqrt{K}\right)$ resulted in the 2 psig drywell pressure scram in about 1 hr. The peak temperature for this incident was predicted to be 204°F. This temperature is considerably below the drywell structural design temperature of 293°F and drywell equipment qualification temperature of 340°F.

6.0 RHR PERMISSIVE ON CONTAINMENT SPRAY

6.1 General Electric Company (GE) had recommended that the drywell purge compressors and the hydrogen recombiners be activated if the reactor vessel water level drops to within 1 ft of the top of active fuel (TAF). This requirement was not incorporated in the EPGs.

Response

Rapid hydrogen generation from the degraded core event is mitigated by the inerted containment design. GE has not made any such recommendation for Unit 2. In addition, Unit 2 emergency operating procedures (EOP) for primary containment control provide guidance for when it is appropriate to place hydrogen recombiners in service.

6.2 GE has recommended that an interlock be provided to require containment spray prior to starting the recombiners because of the large quantities of heat input to the containment. Incorrect implementation of this interlock could result in the inability to operate the recombiners without containment spray.

Response

As stated, such an interlock could, if it failed, prevent the use of an otherwise operable recombiner. Therefore, Unit 2 has not implemented an interlock which would require containment spray initiation prior to starting the recombiners. However, the Unit 2 EOPs do specify when it is appropriate to spray the drywell and/or suppression chamber based upon hydrogen and oxygen concentrations. NMP2 recombiners are not adversely affected by primary containment temperature conditions postulated during Updated Safety Analysis Report (USAR) analyzed accidents and do not require that containment sprays be placed in service prior to their operation.

The addition of heat into the primary containment as a result of recombiner operation is addressed by a combination of EOP actions and recombiner design provisions. Drywell temperature control is effected using N2-EOP-PC, Section DWT. This procedure addresses the use of drywell unit coolers, drywell sprays, and emergency RPV depressurization for drywell atmosphere temperature control.

Additionally, in order to minimize containment heatup due to operation of the recombiners, an aftercooler is provided to cool exhaust process gas. The cooling supply for this is service water.

6.3 The recombiners may produce "hot spots" near the recombiner exhausts which might exceed the environmental qualification envelope or the containment design temperature.

Response

Rockwell recombiners such as those used at Unit 2 contain an aftercooler which precludes an excessively high recombiner exhaust temperature. The maximum return gas temperature is 250°F. Equipment in the wetwell airspace is qualified to a temperature of 270°F and that in the drywell is qualified to 340°F.

6.4 For the containment air monitoring system furnished by GE, the analyzers are not capable of measuring hydrogen concentration at volumetric steam concentrations above 60 percent. Effective measurement is precluded by condensation of steam in the equipment.

Response

Heat tracing is present on the lines to and from the hydrogen and oxygen analyzers. The heat tracing is designed to be available after a loss-of-coolant accident (LOCA) to maintain the temperature of the inlet gases higher than the saturation temperature for containment pressures after a LOCA. The analyzers utilize electrochemical cells that serve as hydrogen and oxygen sensors. The cells are not affected by the presence of moisture in the containment sample. Therefore, the oxygen and hydrogen analyzers will not be adversely affected by volumetric steam concentrations of 60 percent or more.

6.5 Discuss the possibility of local temperatures due to recombiner operation being higher than the temperature qualification profiles for equipment in the region around and above the recombiners. State what instructions, if any, are available to the Operator to actuate containment sprays to keep this temperature below design values.

Response

Unit 2 design incorporates redundant external recombiners located in diametrically opposite areas of the reactor building. The local area temperature is calculated to be below the environmental qualification profile considering the recombiner operation.

7.0 CONTAINMENT PRESSURE RESPONSE

7.1 The containment is assumed to be in thermal equilibrium with a perfectly mixed, uniform temperature suppression pool. As noted in Issue No. 4, the surface temperature of the pool will be higher than the bulk pool temperature. This may produce higher than expected containment temperatures and pressures.

Response

See response to Concern 4.4.

7.2 The computer code used by GE to calculate environmental qualification parameters considers heat transfer from the suppression pool surface to the containment atmosphere. This is not in accordance with the existing licensing basis for Mark III environmental qualification. Additionally, the bulk suppression pool temperature was used in the analysis instead of the suppression pool surface temperature.

Response

For Unit 2, the airspace temperature is generally assumed in containment analysis to be the same as that of the bulk pool. However, the environment qualification parameters for equipment in the wetwell airspace are based on the steam bypass analysis in which steam is injected directly into the wetwell airspace and a credit is taken for any heat transfer to the pool surface. Therefore, pool thermal stratification will not affect environmental qualification temperature for the wetwell airspace.

7.3 The analysis assumes that the containment airspace is in thermal equilibrium with the suppression pool. In the short term this is nonconservative for Mark III due to adiabatic compression effects and finite time required for heat and mass to be transferred between the pool and containment volumes.

Response

The Unit 2 containment LOCA analysis was performed with the Stone & Webster Engineering Corporation (SWEC) proprietary LOCTVS code which assumes thermal equilibrium between the suppression pool and suppression chamber airspace. The assumption of adiabatic compression of the suppression chamber airspace in the short term due to pool swell and drywell air purge has been evaluated for Unit 2 and the results indicate that suppression chamber pressure and temperature will increase in the short term during the drywell air purge phase of the transient. The LOCTVS results show that 99 percent of the initial drywell air mass is purged to the suppression chamber airspace within 30 sec after the postulated recirculation line break. Therefore, the suppression chamber pressure and temperature were estimated at 30 sec considering adiabatic compression and are compared to the LOCTVS results at 30 sec.

Containment parameter	LOCTVS	Adiabatic compression
DW pressure (psig)	33.17	37.6
SC pressure (psig)	26.85	31.3
SC temperature (°F)	115.1	247

From the above table it is observed that the drywell and suppression chamber pressure due to adiabatic compression effect is approximately 4.5 psi higher than that calculated by the LOCTVS at 30 sec. However, these pressures are below the LOCTVS calculated peak pressure (shown in the following table) and considerably below the design pressure of 45 psig.

	Peak Pressure (psig)		
	LOCTVS prediction	Adiabatic compression	Design
Drywell	40.6 at 261 sec	37.6 at 30 sec	45.0
Suppression chamber	34.6 at 620 sec	31.3 at 30 sec	45.0

The suppression chamber temperature of 247°F due to adiabatic compression is significantly higher than the short-term temperature calculated by the LOCTVS code and is also above the peak calculated suppression chamber temperature. However, the above temperature is still well below the design suppression chamber environment temperature of 270°F.

It should be noted that the increase in temperature, due to adiabatic compression, will be reduced rapidly by increased heat transfer to the suppression chamber walls and the pool surface. Mark II pressure suppression tests have shown an approximate 50°F/min temperature reduction rate following complete purging the drywell air. Thus, the suppression chamber temperature would equalize with the pool temperature in a short period of time.

8.0 CONTAINMENT AIR MASS EFFECTS

8.1 This issue is based on consideration that some Technical Specifications allow operation at parameter values that differ from the values used in assumptions for FSAR transient analyses. Normally, analyses are done assuming a nominal containment pressure equal to ambient (0 psig) and a temperature near maximum operating (90°F) and do not limit the drywell pressure equal to the containment pressure. The Technical Specifications' operation under conditions such as a positive containment pressure (1.5 psig), temperatures less than maximum (60 or 70°F), and drywell pressure can be negative with respect to the containment (-0.5 psid). All of these differences would result in a transient response different from the FSAR descriptions.

<u>Response</u>

The pressure and temperature prediction is generally based on conservative analysis and is below the design limit; therefore, nominal values present no safety consequences. However, a LOCA analysis was performed based on the worst combination of initial conditions allowed by the Technical Specification. Even for the worst combination of initial conditions, the peak drywell pressure is below the design limit. Additionally, the primary containment minimum pressure design is also based on the worst combination of initial conditions.

8.2 The draft GGNS technical specifications permit operation of the plant with containment pressure ranging between 0 and -2 psig. Initiation of containment spray at a pressure of -2 psig may reduce the containment pressure by an additional 2 psig, which could lead to buckling and failures in the containment liner plate.

<u>Response</u>

Containment spray cannot be initiated below 2 psig due to a pressure interlock permissive in the Unit 2 RHR control logic. Therefore, this concern is not applicable to Unit 2. However, for design evaluation, the maximum negative containment differential pressure was calculated assuming inadvertent spray actuation at the Technical Specification allowable minimum pressure of -0.5 psig as described in Section 6.2.1.

8.3 If the containment is maintained at -2 psig, the top row of vents could admit blowdown to the suppression pool during a SBA without a LOCA signal being developed.

Response

Unit 2 vents will not clear until a differential pressure exists of approximately 4.1 psid between the drywell and the wetwell. The Unit 2 proposed Technical Specification limits the maximum drywell-wetwell pressure difference to no more than 1.5 psi; hence, this concern is not applicable to Unit 2.

8.4 Describe all of the possible methods, both before and after an accident, of creating a condition of low air mass inside the containment. Discuss the effects on the containment design external pressure of actuating the containment sprays.

Response

The design basis event for external or negative containment pressure is the inadvertent actuation of the containment spray mode of the RHR system assuming worst-case minimum air (noncondensable) mass and minimum spray water temperature. This event produces a maximum negative pressure differential of -2.84 psid, compared to the design value of -10 psid described in Section 6.2.1.1.1.

In response to this concern, additional analyses were conducted to consider other scenarios that could create a condition of low air mass inside containment. These analyses focused on events occurring during periodic containment venting or purging operations which would allow noncondensables to escape from the containment volume prior to containment isolation and cooldown to negative pressure conditions.

Events such as pipe breaks or loss of drywell cooling during purging operations are not limiting because noncondensables are supplied to the containment from pressurized sources to make up for the purge exhaust. Also, a nonsafety-related pressure control valve automatically isolates the exhaust line leading to the standby gas treatment system (SGTS) filters when pressure increases in this line.

The drywell and/or wetwell may be vented periodically through a 2-in diameter line to relieve pressure buildup from noncondensable leakage inside containment and to maintain Technical Specification limits on gas concentrations and pressure. This study considered a spectra of LOCA pipe break sizes occurring during venting and found that small size breaks have the greatest potential for depleting air mass because containment isolation at 2 psig drywell pressure is delayed longer due to the smaller blowdown rate. This results in a longer period of leakage with more noncondensables exhausted for small breaks. A 0.01 ft^2 steam break was analyzed assuming the 2-in diameter vent open until drywell isolation occurs at 2 psig. The initial suppression pool temperature was conservatively assumed to be 33°F to ensure a minimum spray water temperature.

The resulting maximum negative pressure differential was -2.84 psid, which is bounded by the design basis event described in Section 6.2.1.1.3.

9.0 FINAL DRYWELL AIR MASS

9.1 The current FSAR analysis is based upon continuous injection of relatively cool ECCS water into the drywell through a broken pipe following a DBA. The EPGs direct the Operator to throttle ECCS operation to maintain reactor vessel level at about Level 8. Thus, instead of releasing relatively cool ECCS water, the break will be releasing saturated steam, which might produce higher containment pressurizations than currently anticipated. Therefore, the drywell air which would have been drawn back into the drywell will remain in the containment, and higher pressures will result in both the containment and the drywell.

Response

For Mark II containment, short-term dynamics, not long-term effects, establish the peak containment pressure. The Unit 2 bypass analysis does not assume that ECCS injection or spillage from the break will terminate reactor steaming.

In addition, analyses were performed for a large main steam line (MSL) break assuming continuous steam blowdown with and without suppression pool steam bypass. In all cases, the results show that manual actuation of the containment spray within 30 min after the break will limit containment peak pressure to less than the design value. Therefore, this concern is of no consequence to Unit 2.

9.2 The continuous steaming produced by throttling the ECCS flow will cause increased direct leakage from the drywell to the containment. This could result in increased containment pressures.

Response

See Section 9.1.

9.3 It appears that some confusion exists as to whether SBAs and stuck-open-SRV (SORV) accidents are treated as transients or DBAs. Clarify how they are treated, and indicate whether the initial conditions were set at nominal or licensing values.

Response

The Unit 2 pool temperature transient analysis has been conducted in accordance with draft NUREG-0783, as described in Appendix 6A.

The initial conditions were set at licensing values as required by the NUREG.

10.0 DRYWELL FLOODING CAUSED BY UPPER POOL DUMP

Response

These issues are related to the upper pool dump in a Mark III containment. They are not applicable to a Mark II containment.

11.0 OPERATIONAL CONTROL OF DRYWELL-TO-CONTAINMENT DIFFERENTIAL PRESSURES

Mark III load definitions are based upon the levels in the suppression pool and the drywell weir annulus being the same.

Response

For Unit 2, the drywell floor vacuum breakers have a setpoint of 0.25-psi differential. This amounts to a potential 7-in increase in the water level in the downcomers. Such an increase would have a negligible effect on vent clearing and drywell pressure.

A depression of the initial downcomer water level (as was done on an interim basis in the Mark I hydrodynamic loads program) has a beneficial effect on the drywell pressure and associated pool dynamics.

12.0 SUPPRESSION POOL MAKEUP LOCA SEAL-IN

Response

Not applicable to Mark II containments.

13.0 NINETY-SECOND SPRAY DELAY

Response

Not applicable to Mark II containments.

14.0 RHR BACKFLOW THROUGH CONTAINMENT SPRAY

A failure in the check valve in the LPCI line to the reactor vessel could result in direct leakage from the pressure vessel to the containment atmosphere. This leakage might occur as the low-pressure coolant injection (LPCI) motor-operated isolation valve is closing and the motor-operated isolation valve in the containment spray line is opening. This could produce unanticipated increases in the containment spray.

Response

The Unit 2 containment spray system is a manual system that is operated in accordance with specific procedures. The drywell and suppression chamber spray isolation valves are all interlocked such that they cannot be opened unless the corresponding LPCI injection valve is fully closed whenever a LOCA signal is present. If a LOCA signal does not exist, the two isolation valves on each drywell spray line are interlocked such that they cannot both be opened at the same time. The suppression chamber spray isolation valves (one on each line) are not interlocked with the LPCI injection valves if no LOCA signal is present. However, these valves are only opened for testing purposes while the reactor is operating. The Operator is instructed to ensure that the corresponding LPCI injection valve is fully closed prior to opening a suppression chamber spray isolation valve.

In addition, the following should be noted:

1. The check valve in question is a testable check valve and is periodically exercised to ensure its operability; therefore, the likelihood of a check valve failure is remote.

2. The LPCI injection valves close fairly rapidly (19.5 sec from fully open to fully closed).

Based upon administration control and these considerations, this issue is not considered a concern for Unit 2.

15.0 SECONDARY CONTAINMENT VACUUM BREAKER PLENUM RESPONSE

The STRIDE plants had vacuum breakers between the containment and the secondary containment. With sufficiently high flows through the vacuum breakers to containment, a vacuum could be created in the secondary containment.

Response

Unit 2 does not have primary to secondary containment vacuum breakers; therefore, this concern is not applicable.

16.0 EFFECT OF SUPPRESSION POOL LEVEL ON TEMPERATURE MEASUREMENT

Some of the suppression pool temperature sensors are located (by GE's recommendation) 3 to 12 in below the pool surface to provide early warning of high pool temperature. However, if the suppression pool is drawn down below the level of the temperature sensors, the Operator could be misled by erroneous readings, and required safety action could be delayed.

Response

The Unit 2 suppression pool temperature monitoring system has 40 temperature sensors located at el 199 ft 2 in and 8 sensors located at el 197 ft 0 in. The minimum post-LOCA drawdown level is at el 197 ft 8 in, which was calculated by assuming that the pool is initially at the minimum Technical Specification level prior to the LOCA. Therefore, the pool level will always be above at least the lower set of temperature sensors.

17.0 EMERGENCY PROCEDURE GUIDELINES

The EPGs contain a curve which specifies limitations on the suppression pool level and the RPV pressure. The curve presently does not adequately account for upper pool dump. At present, the Operator would be required to initiate automatic depressurization when the only action required is the opening of one additional SRV.

Response

The Unit 2 emergency procedures direct the Operator to either maintain the reactor pressure and pool level within a region of acceptable values (below the SRV tail pipe level limit) as defined in the procedure or actuate the automatic depressurization system (ADS). During the operational training program, Operators are thoroughly instructed on how to avoid the suppression pool load limit; the manual operation of one or more SRVs is one of several control actions available to the Operator.

18.0 EFFECTS OF INSULATION DEBRIS

18.1 Failures of reflective insulation in the drywell may lead to blockage of the gratings above the weir annulus. This may increase the pressure required in the drywell to clear the first row of drywell vents and perturb the existing load definitions.

Response

In the Mark II design, the initial pressurization event, during which blockage of the downcomers could be of concern, is over in about 30 to 200 sec. This is insufficient time for any insulation debris to transit to and block the downcomers. Subsequent to the initial pressurization, any minor blockage that might occur would have an insignificant effect (see response to Issue 18.2 for a discussion of the effects of insulation debris on suction strainers).

18.2 Insulation debris may be transported through the vents in the drywell wall into the suppression pool. This debris then could cause blockage of the suction strainers.

Response

Potential sources of insulation debris that might clog the suction strainers are the metal reflective insulation panels and the stainless steel encapsulated Temp-Mat and Min-k insulation sections installed on piping and equipment in the drywell. As discussed in Section 6.2.2.2, it is highly improbable that any dislodged insulation assemblies will be transported to the suppression pool through the downcomers and clog the suction strainers. The suction strainers of the ECCS pumps are designed to sustain 50-percent clogging without affecting system performance.

19.0 SUBMERGENCE EFFECTS ON CHUGGING LOADS

Response

Not applicable to Mark II containments.

20.0 LOADS ON STRUCTURES, PIPING, AND EQUIPMENT IN THE DRYWELL DURING REFLOOD

Response

Not applicable to Mark II containment.

21.0 CONTAINMENT MAKEUP AIR FOR BACKUP PURGE

Regulatory Guide (RG) 1.7 requires a backup purge H_2 removal capability. This backup purge for Mark III is via the drywell purge line, which discharges to the shield annulus, which in turn is exhausted through the SGTS. The containment air is blown into the drywell via the drywell purge compressor to provide a positive purge. The compressors draw from the containment; however, without hydrogen-lean air makeup to the containment, no reduction in containment hydrogen concentration occurs. It is necessary to assure that the shield annulus volume contains a hydrogen-lean mixture of air to be admitted to the containment via containment vacuum breakers.

Response

The Unit 2 containment purge system (CPS) is operated in conjunction with the primary containment inerting system to aid in post-accident cleanup within the primary containment. The inerting system supplies nitrogen directly to the primary containment.

22.0 MISCELLANEOUS EMERGENCY PROCEDURE GUIDELINE CONCERNS

The EPGs currently in existence have been prepared with the intent of coping with degraded core accidents. They may contain requirements conflicting with DBA conditions. Someone needs to carefully review the EPGs to assure that they do not conflict with the expected course of the DBA.

Response

The Unit 2 EOPs are reviewed to ensure consistency with the Unit 2 DBA conditions. Any deviations identified are reconciled between the USAR and EOPs.

TABLE 6C-1

STEAM CONDENSATION DATA

	Humboldt Bay	NMP2
Vent submergence (ft)	12.5 to -2*	4++
Vent pipe size (nominal - in)	14	12
Initial pool temperature (°F)	55 to 138	90 (max)
Steam mass flux (lbm/ft^2/sec)	50 to 250	146**

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* 2 ft above initial pool water level.
** This number corresponds to 500 psig relief valve setting.
++ With respect to minimum pool level under normal reactor operation.

TABLE 6C-2

RELIEF LINES THAT DISCHARGE INTO SUPPRESSION POOL

System	Relief Valve	Set Pressure (psig)	Function
Residual Heat Removal (RHS)			
	2RHS*RV20A	470*	Thermal Relief
	2RHS*RV20B	470*	Thermal Relief
	2RHS*RV20C	470*	Thermal Relief
	2RHS*RV61A	200	Thermal Relief
	2RHS*RV61B	200	Thermal Relief
	2RHS*RV61C	105	Thermal Relief
	2RHS*RV110	200	Thermal Relief
	2RHS*RV139	220	Thermal Relief
	2RHS*RV108	125	Safety Relief
	2RHS*RV56A	500	Thermal Relief
	2RHS*RV56B	500	Thermal Relief
High-Pressure Core Spray (CSH)			
	2CSH*RV113	100	Thermal Relief
	2CSH*RV114	1575	Thermal Relief
Low-Pressure Core Spray (CSL)			
	2CSL*RV123	46	Pressure Relief
	2CSL*RV105	498	Pressure Relief

NOTE: All RV discharge fluid is water.