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HOPE CREEK GENERATING STATION
PLANT UNIQUE ANALYSIS REPORT
VOLUME 6
TORUS ATTACHED PIPING AND SUPPRESSION CHAMBER PENETRATION ANALYSES

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ABSTRACT

The primary containment for the Hope Creek Generating Station was designed, erected, pressure-tested, and N-stamped in accordance with the ASME Boiler and Pressure Vessel Code, Section III, 1974 Edition with addenda up to and including Winter 1974. These activities were performed for the Public Service Electric and Gas Company (PSE&G) by the Pittsburgh-Des Moines Steel Company. Since then, new requirements which affect the design and operation of the primary containment system have been established. These requirements are defined in the Nuclear Regulatory Commission's (NRC) Safety Evaluation Report, NUREG-0661. The NUREG-0661 requirements define revised containment design loads postulated to occur during a loss-of-coolant accident or a safety-relief valve discharge event which are to be evaluated. In addition, NUREG-0661 requires that an assessment of the effects that these postulated events have on the operation of the containment system be performed.

This plant unique analysis report (PUAR) documents the efforts undertaken to address and resolve each of the applicable NUREG-0661 requirements for Hope Creek. It demonstrates, in accordance with NUREG-0661 acceptance criteria, that the design of the primary containment system is adequate and that original design safety margins have been restored. The Hope Creek PUAR is composed of the following six volumes:

- Volume 1 - GENERAL CRITERIA AND LOADS METHODOLOGY
- Volume 2 - SUPPRESSION CHAMBER ANALYSIS
- Volume 3 - VENT SYSTEM ANALYSIS
- Volume 4 - INTERNAL STRUCTURES ANALYSIS
- Volume 5 - SAFETY RELIEF VALVE DISCHARGE PIPING ANALYSIS
- Volume 6 - TORUS ATTACHED PIPING AND SUPPRESSION CHAMBER PENETRATION ANALYSES

Major portions of all volumes of this report have been prepared by NUTECH Engineers, Incorporated (NUTECH), acting as a consultant responsible to the Public Service Electric and Gas Company. Selected sections of Volumes 5 and 6 have been prepared by the Bechtel Power Corporation (acting as an agent responsible to the Public Service Electric and Gas Company). This volume, Volume 6, documents the evaluation of the torus attached piping and suppression chamber penetrations.

NOTE: Identification of the volume number precedes each page, section, subsection, table, and figure number.

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LIST OF ACRONYMS

ACI	American Concrete Institute
ADS	Automatic Depressurization System
AISC	American Institute of Steel Construction
ASME	American Society of Mechanical Engineers
ATWS	Anticipated Transients Without Scram
BDC	Bottom Dead Center
BWR	Boiling Water Reactor
CDF	Cumulative Distribution Function
CO	Condensation Oscillation
DBA	Design Basis Accident
DC	Downcomer
DLF	Dynamic Load Factor
ECCS	Emergency Core Cooling System
FSAR	Final Safety Analysis Report
FSI	Fluid-Structure Interaction
FSTF	Full-Scale Test Facility
HNWL	High Normal Water Level
HPCI	High Pressure Coolant Injection
IBA	Intermediate Break Accident
I&C	Instrumentation and Control
ID	Inside Diameter
IR	Inside Radius
LCDS	Load Capacity Data Sheets
LDR	Load Definition Report (Mark I Containment Program)
LOCA	Loss-of-Coolant Accident

LIST OF ACRONYMS
(Continued)

LPCI	Low Pressure Coolant Injection
LTP	Long-Term Program
MC	Midcylinder
MCF	Modal Correction Factor
MJ	Mitered Joint
MVA	Multiple Valve Actuation
NEP	Non-Exceedance Probability
NOC	Normal Operating Conditions
NRC	Nuclear Regulatory Commission
NSSS	Nuclear Steam Supply System
NVB	Non-Vent Line Bay
OBE	Operating Basis Earthquake
OD	Outside Diameter
PSD	Power Spectral Density
PSE&G	Public Service Electric and Gas Company
PUA	Plant Unique Analysis
PUAAG	Plant Unique Analysis Application Guide
PUAR	Plant Unique Analysis Report
PULD	Plant Unique Load Definition
QSTF	Quarter-Scale Test Facility
RCIC	Reactor Core Isolation Cooling
RHR	Residual Heat Removal
RPV	Reactor Pressure Vessel

RSEL	Resultant Static-Equivalent Load
SBA	Small Break Accident
SBP	Small Bore Piping
SER	Safety Evaluation Report
SORV	Stuck-Open Safety Relief Valve
SRSS	Square Root of the Sum of the Squares
SRV	Safety Relief Valve
SRVDL	Safety Relief Valve Discharge Line
SSE	Safe Shutdown Earthquake
STP	Short-Term Program
SVA	Single Valve Actuation
TAP	Torus Attached Piping
VB	Vent Line Bay
VH	Vent Header
VL	Vent Line
VPP	Vent Pipe Penetration
ZPA	Zero Period Acceleration

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6-1.0 INTRODUCTION

In conjunction with Volume 1 of the Plant Unique Analysis Report (PUAR), this volume documents the efforts undertaken to address the requirements defined in NUREG-0661 (Reference 1) which affect the Hope Creek torus attached piping (TAP), including large and small bore piping, supports, piping equipment, and suppression chamber penetrations. The torus attached piping PUAR is organized as follows:

- INTRODUCTION
  - Scope of Analysis
- LARGE BORE PIPING
  - Component Description
  - Loads and Load Combinations
  - Analysis Acceptance Criteria
  - Methods of Analysis
  - Analysis Results and Conclusions
- SMALL BORE PIPING
  - Component Description
  - Loads and Load Combinations
  - Analysis Acceptance Criteria
  - Methods of Analysis
  - Analysis Results and Conclusions

- PIPING SUPPORTS
  - Component Description
  - Loads and Load Combinations
  - Methods of Analysis and Acceptance Criteria
  - Analysis Results and Conclusions
- EQUIPMENT AND VALVES
  - Component Description
  - Loads and Load Combinations
  - Methods of Analysis and Acceptance Criteria
  - Analysis Results and Conclusions
- SUPPRESSION CHAMBER PENETRATIONS
  - Component Description
  - Loads and Load Combinations
  - Analysis Acceptance Criteria
  - Methods of Analysis
  - Analysis Results and Conclusions

The introduction contains an overview discussion of the scope of the torus attached piping systems and suppression chamber penetration evaluations. Each of the analysis sections contains a discussion of the loads and load combinations to be addressed, and a description of the piping components or penetrations affected by these loads and load combinations. The sections also contain a discussion of the methodology used to evaluate the effects of the loads and load

combinations, the evaluation results, the acceptance limits to which the results are compared, and the conclusions derived from the evaluations performed.

6-1.1 Scope of Analysis

The general criteria presented in Volume 1 are used as the basis for the Hope Creek torus attached piping and suppression chamber penetration evaluations described in this report. The evaluations include the large and small bore torus attached piping; piping supports; piping components such as flanges, strainers, and expansion joints; related equipment nozzles such as pumps, valves, and turbines; and TAP suppression chamber penetrations. These components are evaluated for the effects of LOCA-related and SRV discharge-related loads discussed in Volume 1, and defined by the NRC's Safety Evaluation Report NUREG-0661 (Reference 1) and by the Mark I Containment Program Load Definition Report (LDR) (Reference 2).

The LOCA and SRV discharge loads used in this evaluation are formulated using procedures and test results which include the effects of the plant unique geometry and operating parameters contained in the Plant Unique Load Definition (PULD) report (Reference 3). Other loads and methodology which have not been redefined by NUREG-0661, such as the evaluation for seismic loads, are taken from the plant's Final Safety Analysis Report (FSAR) (Reference 4).

The evaluation includes performing a structural analysis of the torus attached piping systems and suppression chamber penetrations for the effects of LOCA-related and SRV discharge-related loads to confirm that the design of the torus attached piping and suppression chamber penetrations is adequate. Rigorous analytical techniques are applied in this evaluation, utilizing detailed analytical models and refined methods for computing the dynamic response of the torus attached piping systems, including consideration of the interaction effects of individual piping systems and the suppression chamber.

The results of the TAP structural analysis for each load are used to evaluate load combinations for the piping, piping supports, equipment, and suppression chamber penetrations in accordance with NUREG-0661 and the Mark I Containment Program Structural Acceptance Criteria Plant Unique Analysis Applications Guide (PUAAG) (Reference 5). The analysis results are compared with the acceptance limits specified by the PUAAG and the applicable sections of the American Society of Mechanical Engineers (ASME) Code for Class 2 piping and piping supports, and for Class MC components for the torus penetrations (Reference 6).

Evaluation of the piping for fatigue effects stipulated in Reference 1 has been addressed generically for all Mark I plants by the Mark I Owners Group (Reference 7). Use of the generic fatigue evaluation approach has been permitted by the NRC as described in Reference 8.

6-2.0 LARGE BORE PIPING

An evaluation of each of the NUREG-0661 requirements which affect the design adequacy of the Hope Creek large bore torus attached piping (TAP) is presented in the following sections. The general criteria used in this evaluation are contained in Volume 1.

The component parts of the TAP systems which are analyzed are described in Section 6-2.1. The loads and load combinations for which the piping systems are evaluated are described and presented in Section 6-2.2. The acceptance limits to which the analysis results are compared are discussed and presented in Section 6-2.3. The analysis methodology used to evaluate the effects of the loads and load combinations on the piping systems, including evaluation of fatigue effects, is discussed in Section 6-2.4. The analysis results and conclusions are presented in Section 6-2.5.

6-2.1 Component Description

The large bore TAP for Hope Creek consists of piping systems with 4" and larger nominal diameters, which penetrate or are directly attached to the suppression chamber. This section gives a general description of the large bore TAP systems and their associated components.

Large bore TAP lines range in size from 4" to 24" nominal diameter and have varying piping schedules. Although most of the piping consists of ASTM A-106, Grade B carbon steel material, some pipe segments are ASME SA312 GR. TP304L austenitic stainless steel. Table 6-2.1-1 lists the Hope Creek large bore TAP systems, their associated suppression chamber penetrations, and their essentiality classification. Figure 6-2.1-1 shows the locations of the penetrations on the suppression chamber.

The large bore TAP systems are grouped into two general categories: torus external piping and torus internal piping. An example of a system with only torus external piping is the high pressure coolant injection (HPCI) pump suction line shown in Figure 6-2.1-2. A typical system having both internal and external piping is the HPCI turbine exhaust line shown in Figure 6-2.1-3.

Table 6-2.1-1

IDENTIFICATION OF LARGE BORE TORUS ATTACHED PIPING SYSTEMS AND ASSOCIATED PENETRATIONS

PENETRATION NUMBER	SYSTEM DESCRIPTION	ESSENTIAL (E)/ NON-ESSENTIAL (NE) SYSTEM CLASSIFICATION
P201	HPCI Turbine Exhaust	E
P202	HPCI Pump Suction	E
P203	HPCI Minimum Return	NE
P204	HPCI & RCIC Vacuum Breaker	NE
P207	RCIC Turbine Exhaust	E
P208	RCIC Pump Suction & Discharge	E
P209	RCIC Minimum Return	NE
P211A	RHR Pump Suction "D"	E
P211B	RHR Pump Suction "B"	E
P211C	RHR Pump Suction "A"	E
P211D	RHR Pump Suction "C"	E
P212A	RHR Torus Water Clearing	E
P212B	RHR Torus Water Clearing	E
P213A	RHR Relief to Torus	NE
P213B	RHR Relief to Torus	NE
P214A	RHR to Torus Spray Header	E
P214B	RHR to Torus Spray Header	E
P216A	Core Spray Pump Suction "B"	E
P216B	Core Spray Pump Suction "D"	E
P216C	Core Spray Pump Suction "C"	E
P216D	Core Spray Pump Suction "A"	E
P217A	Core Spray Test to Torus	NE (1)
P217B	Core Spray Test to Torus	NE (1)
P219	Torus Vacuum Relief & Purge Outlet	NE
P220	Torus Vacuum Relief & Purge Inlet	E
P222	Torus Water Cleanup Return	NE
P223	Torus Water Cleanup Supply	NE

NOTE:

1. Systems include both essential and non-essential segments.

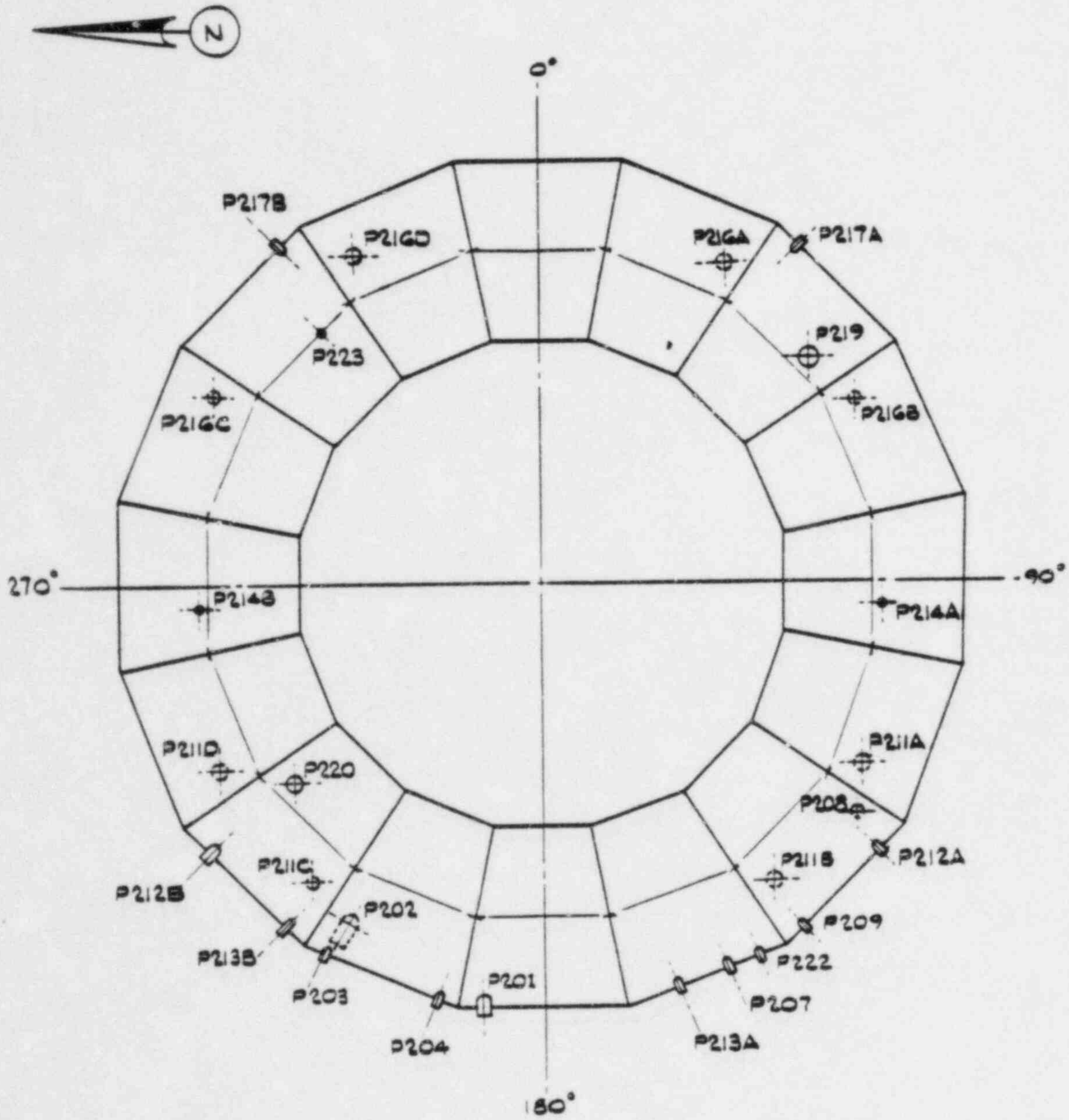

Figure 6-2.1-1

LARGE BORE TAP PENETRATION LOCATIONS ON SUPPRESSION CHAMBER - PLAN VIEW

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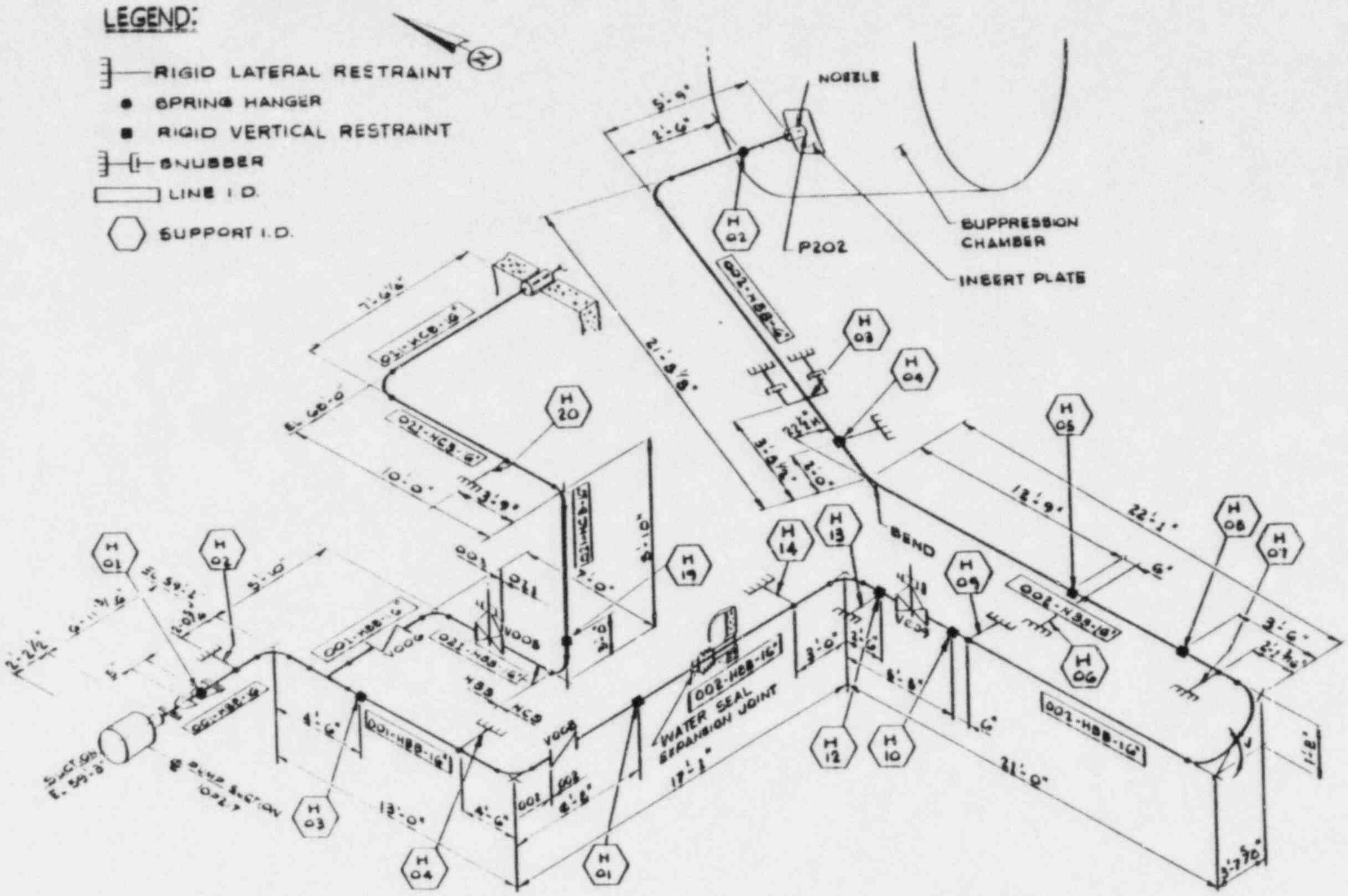

Figure 6-2.1-2

TAP SYSTEM ISOMETRIC AND SUPPORT LOCATIONS -

HPCI PUMP SUCTION LINE (P202)

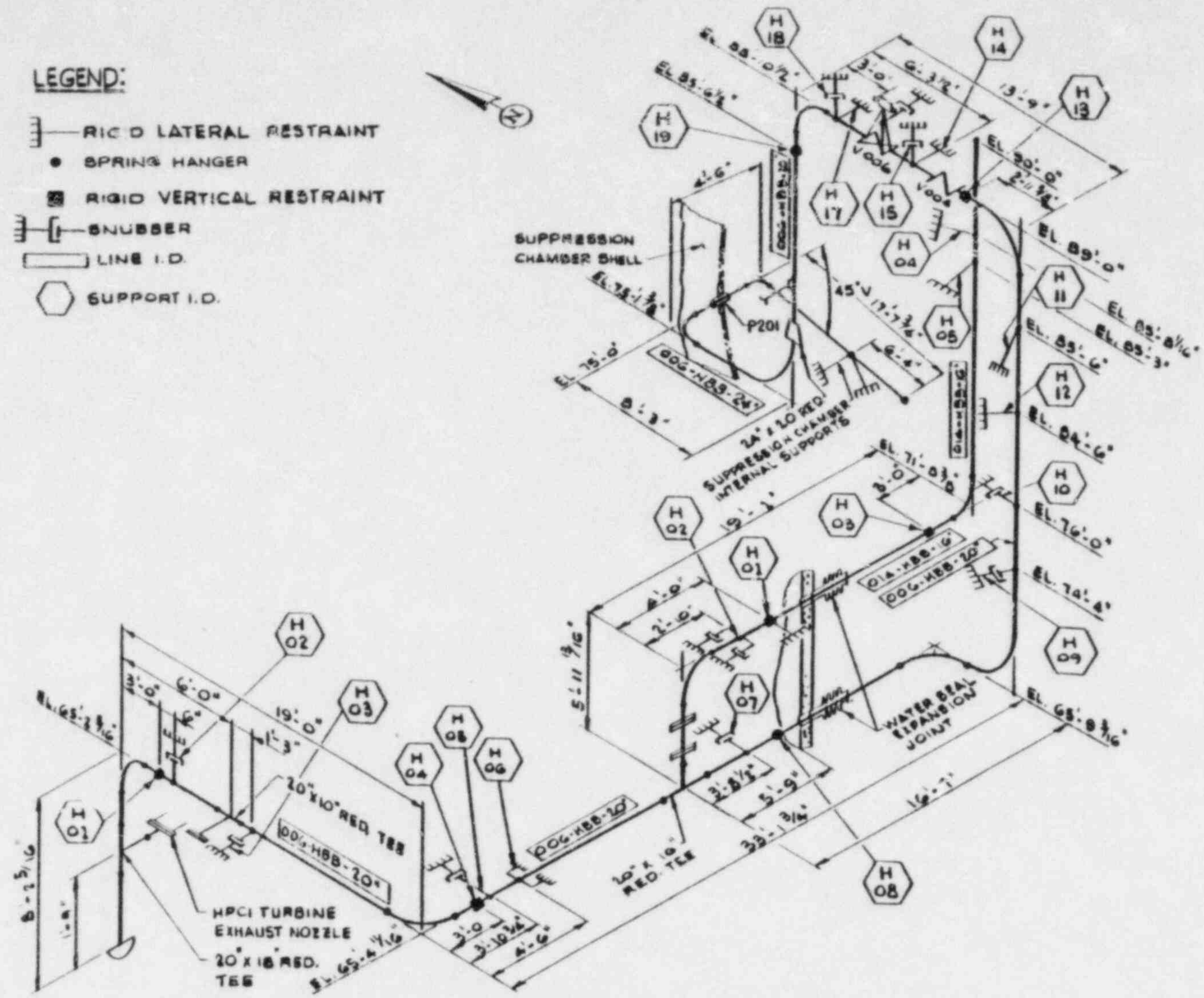

Figure 6-2.1-3

TAP SYSTEM ISOMETRIC AND SUPPORT LOCATIONS -

HPCI TURBINE EXHAUST LINE (P201)

6-2.1.1 Torus External Piping

The torus external piping included in the plant unique analysis (PUA) starts at the suppression chamber penetration nozzles, and terminates for evaluation purposes at anchor supports or equipment within the reactor building. The external piping typically extends from the suppression chamber up to the reactor building floor slab at elevation 77'-0". Some lines extend up to the reactor building floor slab at elevation 102'-0".

The external piping is supported by hangers, rigid restraints, guides, and snubbers attached to reactor building slabs or walls, or to main structural steel in the reactor building. Figures 6-2.1-4 and 6-2.1-5 illustrate typical pipe support configurations outside the suppression chamber. Other components on these lines include valves and standard pipe fittings. The valve types used are gate valves, globe valves, swing check valves, butterfly valves, and relief valves.

Smaller lines branching off the large bore TAP systems are discussed in Section 6-3.0. Piping supports are described in Section 6-4.0. Equipment such as valves, pumps, and turbines are described in Section 6-5.0.

The suppression chamber penetrations are described in Section 6-6.0.

6-2.1.2 Torus Internal Piping

Piping located inside the suppression chamber may be categorized into three basic configurations:

(a) Short, unsupported segments of piping which project inside the suppression chamber. Examples of these types of configurations are the discharge lines which penetrate the upper half of the suppression chamber and the suction lines which penetrate the lower half. Discharge lines are typically open-ended whereas suction lines have a strainer connected to their inner nozzle flange. An example of this type of internal piping configuration is the HPCI Pump Suction Line (P202) shown in Figure 6-2.1.2.

(b) Short segments of piping inside the suppression chamber which are supported by rigid struts attached to the torus shell, the mid-bay girders or to the mitered joint ring girders as shown in Figure 6-2.1-6. The HPCI turbine exhaust line (P201) shown in Figure 6-2.1-3 is an example of this type of piping configuration.

(c) Long lengths of piping running through more than a single torus bay which are supported at intervals by rigid struts connected to the torus shell or ring girders. This type of large bore piping configuration is unique to the RHR to torus spray header lines (P214A and 214B).

Supports for the torus internal piping are discussed in Section 6-4.0. Strainers for the torus internal piping are discussed in Section 6-5.0.

Loads and load combinations which are applied to the large bore TAP systems described above are presented in the following sections.

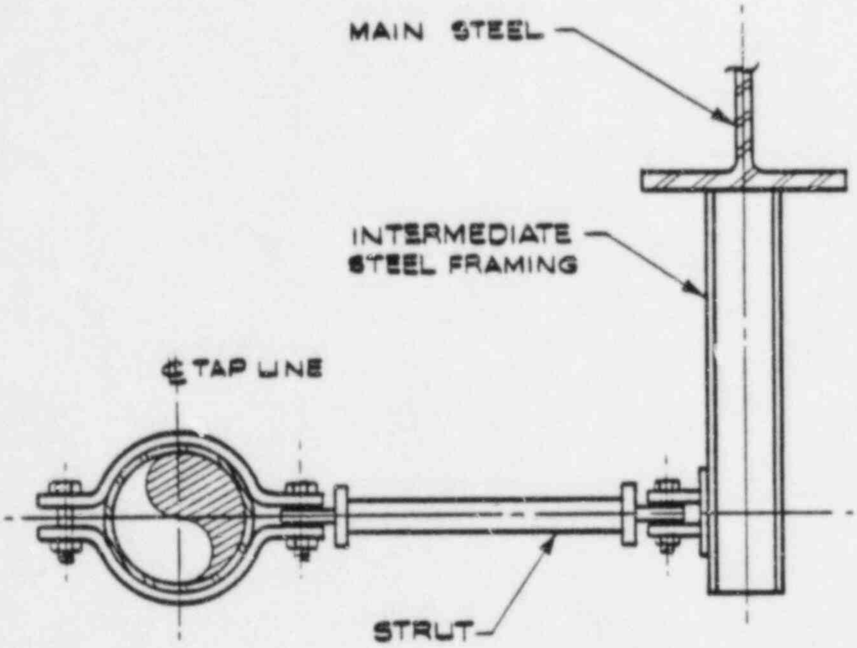

Figure 6-2.1-4

TYPICAL TAP SYSTEM SUPPORT OUTSIDE SUPPRESSION CHAMBER
ATTACHED TO MAIN STEEL

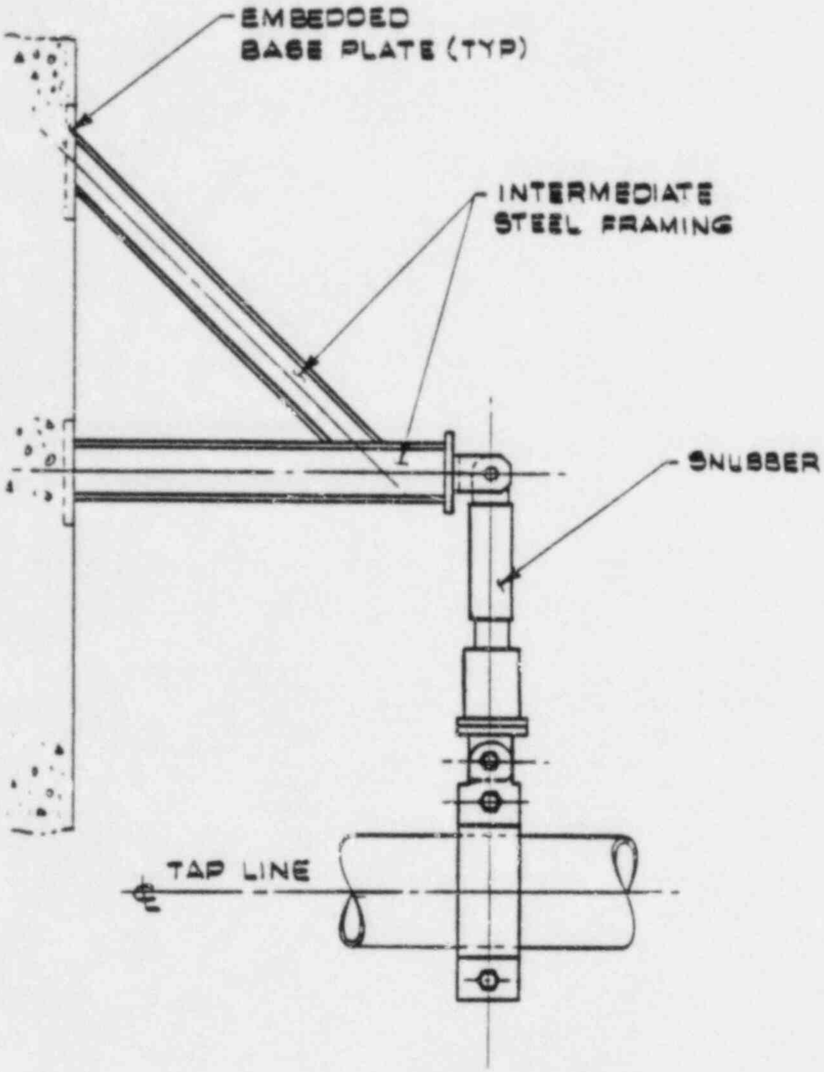

Figure 6-2.1-5

TYPICAL TAP SYSTEM SUPPORT OUTSIDE SUPPRESSION CHAMBER
ATTACHED TO STRUCTURAL CONCRETE

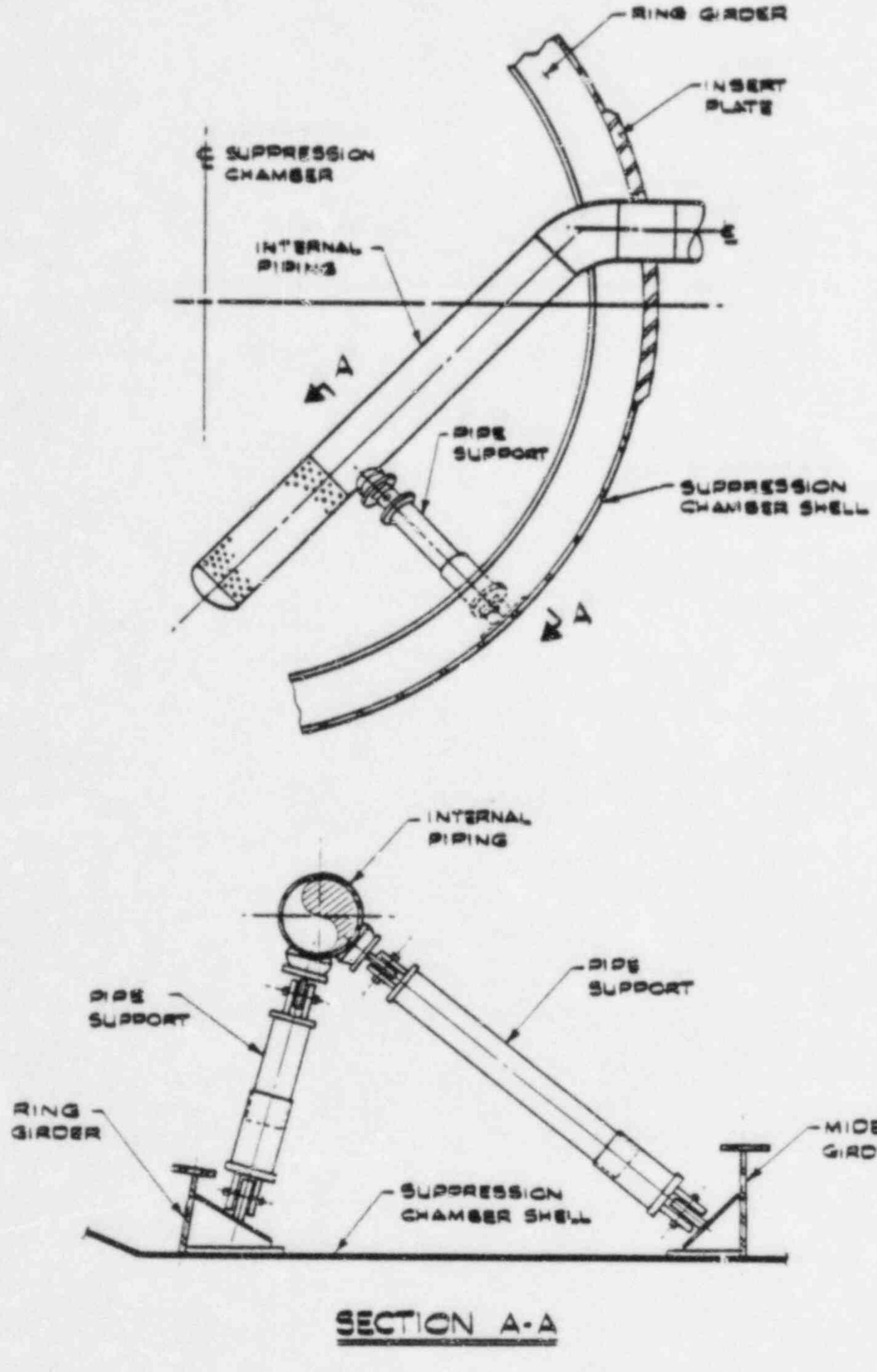

Figure 6-2.1-6

TYPICAL TAP SYSTEM SUPPORT INSIDE SUPPRESSION CHAMBER

6-2.2 Loads and Load Combinations

The loads for which the Hope Creek torus attached piping is designed are defined in NUREG-0661 on a generic basis for all Mark I plants. The methodology used to develop plant unique TAP loads for each load defined in NUREG-0661 is discussed in Section 1-4.0. In addition, the loading event sequences described in Sections 1-3.2 and 1-4.3 include consideration of plant unique operation of the torus attached piping systems. The results of applying the above methodology to develop specific values for each of the controlling loads which act on the piping are discussed and presented in Section 6-2.2.1.

Using the event combinations and event sequencing described in Sections 1-3.2 and 1-4.3, the governing load combinations which affect the torus attached piping are formulated. The load combinations are discussed and presented in Section 6-2.2.2.

6-2.2.1 Loads

The loads acting on the torus attached piping are categorized as follows:

1. Dead Weight
2. Seismic
3. Pressure and Temperature
4. Operating
5. Static Torus Displacement
6. Safety Relief Valve Discharge
7. Vent Clearing
8. Pool Swell
9. Condensation Oscillation
10. Chugging
11. Torus Motion

Loads in Categories 1 through 4 are analyzed in the piping design per the FSAR (Reference 4). The range of pressures and temperatures (Category 3) considered in the analyses include those relating to the time period within the Mark I Program event duration. Loads in Category 5 are displacements resulting from torus internal pressure or water dead weight during both normal and accident conditions. Loads in Category 6 result from SRV discharge events. Loads in Categories

7 through 10 result from postulated LOCA events. Loads in Category 11 consist of torus inertial and displacement responses due to hydrodynamic loads acting on the torus.

Not all of the loads defined in NUREG-0661 and the FSAR need be examined, since some are enveloped by others or have a negligible effect on the torus attached piping. Only those loads which maximize the piping response and lead to controlling stresses are examined and discussed. These loads are referred to as governing loads in the following sections.

Descriptions of the governing loads in each category are provided in the following paragraphs. The corresponding section of Volume 1, where the methodology used to develop the loads are discussed, is provided in Table 6-2.2-1. Loading magnitudes for loads in Categories 6 through 10 are similar to values provided in Volumes 2 and 3. Representative torus motion loads (Category 11) are presented in Section 6-2.4.5.

1. Dead Weight (DW) Loads

These loads are defined as the uniformly distributed weight of the piping and insulation, and the concentrated weight of piping supports, hardware attached to piping, valves, and flanges. Also included is the weight of th contents of the torus attached piping.

2. Seismic Loads

a. OBE Inertia (OBE_I) Loads: These loads are defined as the horizontal and vertical accelerations acting on the TAP systems during an operating basis earthquake (OBE). The loading is taken from the design basis for the piping as documented in the FSAR. Building response spectra at elevations which represent piping attachment points are utilized to develop enveloping response spectra curves for the N-S, E-W, and vertical direction OBE_I inputs, respectively.

b. OBE Displacement (OBE_D) Loads: These loads are defined as the maximum horizontal and vertical relative seismic displacements at

the piping attachment points during an OBE. The loading is taken from the design basis for the piping, as documented in the FSAR.

c. SSE Inertia (SSE_I) Loads: These loads are defined as the horizontal and vertical accelerations acting on the piping during a safe shutdown earthquake (SSE). The loading is taken from the design basis for the piping, as documented in the FSAR. Building response spectra at different elevations which represent the piping attachment points are utilized to develop enveloping response spectra curves for the N-S, E-W, and vertical direction SSE_I inputs, respectively.

d. SSE Displacement (SSE_D) Loads: These loads are defined as the maximum horizontal and vertical relative seismic displacements at the piping attachment points during a SSE. The loading is taken from the design basis for the piping, as documented in the FSAR.

3. Pressure and Temperature Loads

a. Pressure (P_o, P) Loads: These loads are defined as the maximum operating internal pressure (P_o) and design condition pressure (P), in the torus attached piping.

b. Temperature (TE, TE_1) Loads: These loads are defined as the thermal expansion (TE) of the piping associated with temperature changes occurring during normal operating conditions, and the thermal expansion (TE_1) of the piping associated with temperature changes occurring during maximum operating conditions.

Different pressure and temperature values are typically applied to specific segments of a piping system for each of the system operating conditions which are evaluated. The pressures and temperatures used in the analyses are in accordance with the FSAR.

Effects of thermal anchor movements at the torus penetrations and at torus support locations are also included in the analysis.

The piping thermal anchor movement loadings are categorized and designated as follows:

1. THAM - Piping thermal anchor movement during normal operating conditions (NOC), and

2. $THAM_1$ - Piping thermal anchor movement during accident conditions.

4. Operating (OL) Loads

These loads are defined as line operating thrust loads due to discharge of piping systems into the torus. The loads are applicable to the HPCI turbine exhaust line (P201), the RCIC turbine exhaust line (P207), the RHR test lines (P212A and 212B), and the core spray test lines (P217A and 217B).

5. Static Torus Displacement Loads

These loads are defined as the torus displacement loads due to the weight of water in the torus and due to normal operating or accident condition pressures.

a. TD - These are the torus displacements due to normal operating pressure and the weight of water in the torus.

b. TD_1 - These are the torus displacements due to torus internal pressure during SBA conditions plus the weight of water in the torus.

c. TD_2 - These are the torus displacements due to torus internal pressure during IBA conditions plus the weight of water in the torus.

d. TD_3 - These are the torus displacements due to torus internal pressure during DBA conditions plus the weight of water in the torus.

6. Safety Relief Valve Discharge (QAB) Loads

The safety relief valve (SRV) discharge loads are defined as the transient pressures which act on the submerged portion of the TAP and supports in the torus during a SRV discharge. The methodology

for developing the loads is discussed in Volume 1. The SRV discharge loads consist of the following components:

a. Water Jet Impingement Loads: During the water clearing phase of a SRV discharge event, the submerged TAP and supports are subjected to transient drag pressure loads. The procedure used to develop the transient forces and spatial distribution of these loads is discussed in Section 1-4.2.4.

b. Air Bubble Drag Loads: During the air clearing phase of a SRV discharge event, transient drag pressure loads are postulated to act on the submerged TAP and supports. The procedure used to develop the transient forces and spatial distribution of these loads is discussed in Section 1-4.2.4.

7. Vent Clearing (VCLO) Loads

These loads are defined as the transient pressure loads acting on the submerged portion of the TAP and supports during the water and air clearing phase of a DBA event.

a. LOCA Water Jet Impingement Loads: During the water clearing phase of a DBA event, the submerged portion of the TAP and supports are subjected to transient drag pressure loads. The procedure used to develop these transient drag forces is discussed in Section 1-4.1.5.

b. LOCA Air Bubble Drag Loads: During the air clearing phase of a DBA event, the submerged portion of the TAP and supports are subjected to transient drag pressure loads. The procedure used to develop these transient drag forces is discussed in Section 1-4.1.6.

8. Pool Swell (PSO) Loads

These loads are defined as the transient pressure loads which act on the portion of the TAP and supports above the minimum torus water level.

a. Impact and Drag Loads: During the initial stages of a DBA event, the TAP and supports within the torus are subjected to transient impact and drag pressures. The procedure used to develop these pressure transients is discussed in Section 1-4.1.4.2.

b. Froth Impingement Loads: During the LOCA pool swell event, the TAP and supports within the torus airspace are subjected to transient pressures. The procedure used to develop these pressure transients is discussed in Section 1-4.1.4.3.

c. Pool Fallback Loads: During the later phase of pool swell, the TAP and supports within the torus are subjected to transient pressures. The procedure used to develop these pressure transients is discussed in Section 1-4.1.4.4.

9. Condensation Oscillation (CO) Loads

During the condensation oscillation phase of a DBA event, the submerged portion of the TAP and supports within the torus are subjected to harmonic velocity and acceleration drag pressures. The procedure used to develop the harmonic drag loads is discussed in Section 1-4.1.7.3. Included are acceleration drag loads due to torus fluid-structure interaction (FSI).

10. Chugging Loads

a. Pre-Chug (PCHUG) Loads: These loads are defined as single harmonic velocity and acceleration drag loads, including acceleration drag loads due to torus FSI effects. They act on the submerged portion of the TAP and supports during the pre-chug phase of a SBA, IBA, or DBA event. The procedure used to develop the pre-chug loads on these components is discussed in Section 1-4.1.8.3.

b. Post-Chug (CHUG) Loads: These loads are defined as harmonic velocity and acceleration drag loads, including acceleration drag loads due to torus FSI effects. They act on the submerged portion of the TAP and supports during the post-chug phase of a SBA, an IBA, or a DBA event. The procedure used to develop the post-chug loads on these components is discussed in Section 1-4.1.8.3.

11. Torus Motion Loads

These loads are defined as the inertia and displacement effects at the TAP attachment points on

the suppression chamber due to loads acting on the suppression chamber shell. The loads are derived from the analysis of the suppression chamber discussed in Volume 2.

a. SRV Torus Motion Loads:

   1. QAB_I - These are the inertia effects of torus motions due to SRV T-quencher discharge loads.

   2. QAB_D - These are the displacement effects of torus motions due to SRV T-quencher discharge loads.

b. Pool Swell Torus Motion Loads:

   1. PSO_I - These are the inertia effects of torus motions due to pool swell loads.

   2. PSO_D - These are the displacement effects of torus motions due to pool swell loads.

c. Condensation Oscillation Torus Motion Loads:

1. CO_I - These are the inertia effects of torus motions due to condensation oscillation loads.

2. CO_D - These are the displacement effects of torus motions due to condensation oscillation loads.

d. Pre-Chug Torus Motion Loads:

1. $PCHUG_I$ - These are the inertia effects of torus motions due to pre-chug loads.

2. $PCHUG_D$ - These are the displacement effects of torus motions due to pre-chug loads.

e. Post-Chug Torus Motion Loads:

1. $CHUG_I$ - These are the inertia effects of torus motions due to post-chug loads.

2. $CHUG_D$ - These are the displacement effects of torus motions due to post-chug loads.

Table 6-2.2-1

TORUS ATTACHED PIPING LOADING
IDENTIFICATION CROSS-REFERENCE

LOAD DESIGNATION		VOLUME 1 SECTION NUMBER
LOAD CATEGORY	LOAD CASE NUMBER	
DEAD WEIGHT	1	1-3.1
SEISMIC	2	1-3.1
PRESSURE AND TEMPERATURE	3	1-3.1, 1-4.1.1
OPERATING	4	1-3.1
STATIC TORUS DISPLACEMENT	5	1-3.1, 1-4.1.1
SRV DISCHARGE	6	1-4.2.4
VENT CLEARING	7	1-4.1.5, 1-4.1.6
POOL SWELL	8	1-4.1.4.2, 1-4.1.4.3, 1-4.1.4.4
CONDENSATION OSCILLATION	9	1-4.1.7.3
CHUGGING	10	1-4.1.8.3
TORUS MOTION	11	1-4.1, 1-4.2

6-2.2.2 Load Combinations

The loads for which the TAP systems are evaluated are presented in Section 6-2.2.1. The general NUREG-0661 criteria for grouping the loads into load combinations are discussed in Sections 1-3.2 and 1-4.3 and summarized in Table 6-2.2-2.

The load combinations specified for each event in Table 6-2.2-2 can be expanded into many more load combinations than those shown, as discussed in Section 2-2.2.2. However, not all load combinations for each event need be examined, since many have the same allowable stresses and are enveloped by others which contain the same plus additional loads. Many of the 27 load combinations listed in Table 6-2.2-2 are actually pairs of load combinations with all of the same loads except for seismic loads. The first load combination in the pair contains OBE loads, while the second contains SSE loads.

Table 6-2.2-3 presents the basis for establishing the governing loading combinations for the TAP systems. The resulting governing load combinations are listed in Table 6-2.2-4. The appropriate ASME Code equations for

the torus attached piping are also provided in Table 6-2.2-4.

Included in the list of governing load combinations are four additional load combinations which do not result from the 27 event combinations listed in Table 6-2.2-2. These are: Load Combination A-1, which relates to the design pressure plus dead weight condition; Load Combinations A-2 and B-1, which include the combination of normal and seismic loads; and Load Combination T-1, which relates to the hydrostatic test condition. Evaluation of Load Combination T-1 is a requirement of the ASME Code (Reference 6). Load Combinations A-1, A-2, and B-1 are consistent with the requirements specified in the FSAR (Reference 4).

The system pressure and temperature loads considered in the loading combinations include those occurring within the range of the Mark I Program event durations, as defined in the LDR (Reference 2).

In performing loading combinations, the dynamic loading components of the structural response are combined using the square root of the sum of the squares (SRSS) method. Use of the SRSS methodology for torus attached piping has been permitted by the NRC as described in Reference 9.

Each of the listed governing load combinations for the torus attached piping as provided in Table 6-2.2-4 has been considered in the analysis methods described in Section 6-2.4.

Table 6-2.2-2

EVENT COMBINATIONS AND ALLOWABLE LIMITS

FOR TORUS ATTACHED PIPING

EVENT COMBINATIONS			SRV	SRV + EQ		SBA IBA		SBA + EQ IBA + EQ				SBA+SRV IBA+SRV		SBA + SRV + EQ IBA + SRV + EQ				DBA		DBA + EQ				DBA+SRV		DBA + SRV + EQ			
							CO, CH			CO, CH			CO, CH			CO,CH		PS (1)	CO, CH	PS		CO, CH		PS	CO, CH	PS		CO, CH	
TYPE OF EARTHQUAKE				O	S			O	S	O	S			O	S	O	S			O	S	O	S			O	S	O	S
COMBINATION NUMBER			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
LOADS	NORMAL (2)	N	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	EARTHQUAKE	EQ		X	X			X	X	X	X			X	X	X	X			X	X	X	X			X	X	X	X
	SRV DISCHARGE	SRV	X	X	X							X	X	X	X	X	X							X	X	X	X	X	X
	THERMAL	T_A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	PIPE PRESSURE	P_A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	LOCA POOL SWELL	P_{PS}																X		X	X			X		X	X		
	LOCA CONDENSATION OSCILLATION	P_{CO}					X			X	X		X			X	X		X			X			X			X	
	LOCA CHUGGING	P_{CH}					X			X	X		X			X	X		X			X	X		X			X	X
STRUCTURAL ELEMENT		ROW																											
ESSENTIAL PIPING SYSTEMS	WITH IBA/DBA	10	B	B (3)	B (3)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	D (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	D (4)
	WITH SBA	11				B (3)	B (3)	B (4)	B (4)	B (4)	B (4)	B (3)	B (3)	B (4)	B (4)	B (4)	B (4)	-	-	-	-	-	-	-	-	-	-	-	-
NONESSENTIAL PIPING SYSTEMS	WITH IBA/DBA	12	B	C (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)
	WITH SBA	13				C (5)	C (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	-	-	-	-	-	-	-	-	-	-	-	-

Table 6-2.2-2

(Concluded)

Notes:

1. Where a drywell-to-wetwell pressure differential is normally utilized as a load mitigator, an additional evaluation shall be performed without SRV loadings but assuming the loss of the pressure differential. Service Level D limits shall apply for all structural elements of the piping system for this evaluation. The analysis need only be accomplished to the extent that integrity up to and including the first pressure boundary isolation valve is demonstrated. If the normal plant operating condition does not employ a drywell-to-wetwell pressure differential, the listed service level assignments will be applicable. Since Hope Creek does not utilize a drywell-to-wetwell differential pressure, the listed service limits are applied.

2. Normal loads (N) consist of dead loads (D).

3. As an alternative, the 1.2 S_h limit in equation 9 of NC-3652.2 may be replaced by 1.8 S_h, provided that all other limits are satisfied. Fatigue requirements are applicable to all columns, with the exception of 16, 18, 19, 22, 24 and 25.

4. Footnote 3 applies except that instead of using 1.8 S_h in equation 9 of NC-3652.2, 2.4 S_h is used.

5. Equation 10 of NC-3650 will be satisfied, except that fatigue requirements are not applicable to columns 16, 18, 19, 22, 24 and 25 since pool swell loadings occur only once. In addition, if operability of an active component is required to ensure containment integrity, operability of that component must be demonstrated.

Table 6-2.2-3

BASIS FOR GOVERNING LOAD COMBINATIONS - TORUS ATTACHED PIPING

EVENT COMBINATION NUMBER(1)	GOVERNING LOAD COMBINATIONS (2)	DISCUSSION	EVENT COMBINATION GOVERNING BASIS
1	B-2,	SECONDARY STRESS BOUNDED BY EVENT COMBINATION NUMBER 3.	(3)
2	C-1a, A-3	N/A	N/A
3	C-1b, A-3	N/A	N/A
4,5	N/A	IBA BOUNDED BY EVENT COMBINATION NUMBER 15 AND SBA BOUNDED BY EVENT COMBINATION NUMBER 11.	(3)
6,8,12	N/A	BOUNDED BY EVENT COMBINATION NUMBER 14.	(3)
7,9,13	N/A	BOUNDED BY EVENT COMBINATION NUMBER 15.	(3)
10	N/A	IBA BOUNDED BY EVENT COMBINATION NUMBER 15 AND SBA BOUNDED BY EVENT COMBINATION NUMBER 11.	(3)
11	C-2, C-3 A-4, A-5	FOR SBA ONLY. IBA BOUNDED BY EVENT COMBINATION NUMBER 15.	(3)
14	D-1, D-2 A-4, A-5	PER SECTION 1-4.1.7.1, FOR IBA, CHUGGING USED IN LIEU OF CO; FOR SBA, CO LOADS NOT SPECIFIED	N/A
15	D-1, D-2 A-4, A-5	PER SECTION 1-4.1.7.1, FOR IBA, CHUGGING USED IN LIEU OF CO; FOR SBA, CO LOADS NOT SPECIFIED	N/A
16,18,22	N/A	BOUNDED BY EVENT COMBINATION NUMBER 24.	(3)
19	N/A	BOUNDED BY EVENT COMBINATION NUMBER 25.	(3)
17,20,23	N/A	BOUNDED BY EVENT COMBINATION NUMBER 26.	(3)
21	N/A	BOUNDED BY EVENT COMBINATION NUMBER 27.	(3)
24	D-3, A-6	N/A	N/A
25	D-3, A-6	N/A	N/A
26	D-4, A-7	FOR CO ONLY, DBA CHUGGING BOUNDED BY EVENT COMBINATION NUMBER 14.	(3)
27	A-8, A-9	DBA CHUGGING BOUNDED BY EVENT COMBINATION NUMBER 15. EVALUATE FOR SECONDARY STRESS ONLY.	(3)

Table 6-2.2-3

(Concluded)

Notes:

1. Event combination numbers refer to the numbers used in Table 6-2.2-2.
2. Governing load combinations are listed in Table 6-2.2-4.
3. The governing event combination contains more loads while the allowable limits are the same.

Table 6-2.2-4

GOVERNING LOAD COMBINATIONS - TORUS ATTACHED PIPING

NUREG-0661 LOAD COMBINATION NUMBER	LOAD COMBINATIONS (1,5,6)	ASME (2) CODE EQUATION
A-1	P + DW + OL	8
A-2	TE + THAM + TD + OBE_D	10 (3)
A-3 (7)	TE + THAM + TD + QAB_D + SSE_D	10 (3)
A-4	TE_1 + $THAM_1$ + TD_1 or TD_2 + $PCHUG_D$ + QAB_D + SSE_D	10 (3)
A-5 (9)	TE_1 + $THAM_1$ + TD_1 or TD_2 + $CHUG_D$ + QAB_D + SSE_D	10 (3)
A-6 (9)	TE_1 + $THAM_1$ + TD_3 + PSO_D + QAB_D + SSE_D	10 (3)
A-7 (4)	TE_1 + $THAM_1$ + TD_3 + CO_D + OBE_D	10 (3)
A-8	TE_1 + $THAM_1$ + TD_3 + $PCHUG_D$ + QAB_D + SSE_D	10 (3)
A-9	TE_1 + $THAM_1$ + TD_3 + $CHUG_D$ + QAB_D + SSE_D	10 (3)
B-1	P_O + DW + OBE_I + OL	9
B-2	P_O + DW + QAB + QAB_I + OL	9
C-1a	P_O + DW + QAB + QAB_I + OBE_I + OL	9
C-1b	P_O + DW + QAB + QAB_I + SSE_I + OL	9
C-2	P_O + DW + PCHUG + $PCHUG_I$ + QAB + QAB_I + OL	9
C-3	P_O + DW + CHUG + $CHUG_I$ + QAB + QAB_I + OL	9
D-1 (7)	P_O + DW + PCHUG + $PCHUG_I$ + QAB + QAB_I + SSE_I + OL	9
D-2 (7)	P_O + DW + CHUG + $CHUG_I$ + QAB + QAB_I + SSE_I + OL	9
D-3 (7)	P_O + DW + PSO + PSO_I + VCLO + QAB + QAB_I + SSE_I + OL	9
D-4 (4)	P_O + DW + CO + CO_I + OBE_I + OL	9
T-1 (8)	1.25P + DW	8

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Table 6-2.2-4

(Concluded)

Notes:

1. See Section 6-2.2.1 for definition of individual loads.

2. Equations are defined in subsection NC-3650 of the ASME Code (Reference 6).

3. As an alternate, meet equation 11 of the ASME Code (Reference 6).

4. For the DBA condition, SRV discharge loads need not be combined with CO and chugging loads.

5. See Section 6-2.2.2 for combination of dynamic loads.

6. Only governing load combinations from Table 6-2.2-3 are considered here.

7. The larger of OBE or SSE is used.

8. Hydrostatic test condition. DW for all lines shall be with lines full of water at 70° F.

9. The larger of TD_1, TD_2, or TD_3 is used in load combinations A-5 and A-6.

6-2.3 Analysis Acceptance Criteria

The acceptance criteria defined in NUREG-0661 on which the Hope Creek TAP analysis is based are discussed in Section 1-3.2. In general, the acceptance criteria follow the rules contained in the ASME Code, Section III, Division 1 up to and including the 1977 Summer Addenda for Class 2 piping (Reference 6). The corresponding service level limits, allowable stresses, and essentiality classification are also consistent with the requirements of the ASME Code and NUREG-0661. The torus attached piping is analyzed in accordance with the requirements for Class 2 piping systems contained in Subsection NC of the Code. The NUREG-0661 service level limits and corresponding ASME Code allowable stresses for essential and non-essential classifications have been applied in the piping system analyses. Tables 6-2.3-1, and 6-2.3-2 list the applicable ASME Code equations and stress limits for each of the governing load combinations for the essential and non-essential piping systems, respectively. Functionality requirements for the TAP as defined in NUREG-0661 are addressed by meeting the ASME code stress allowable limits.

Table 6-2.3-1

APPLICABLE ASME CODE EQUATIONS AND
ALLOWABLE STRESSES FOR ESSENTIAL TORUS ATTACHED PIPING

STRESS TYPE	ASME CODE EQUATION NUMBER	SERVICE LEVEL	STRESS LIMIT	ALLOWABLE VALUE (ksi) (1)	GOVERNING LOAD COMBINATION NUMBER (2)
PRIMARY	8	DESIGN	1.0 S_h	15.0/15.7	A-1, T-1
PRIMARY	9	B	1.2 S_h	18.0/18.84	B-1, B-2
PRIMARY	9	B	1.8 S_h	27.0/28.26	C-1a THROUGH C-3
PRIMARY	9	B	2.4 S_h	36.0/37.68	D-1 THROUGH D-4
SECONDARY	10	B	1.0 S_a	22.5/23.55	A-2 THROUGH A-9
PRIMARY AND SECONDARY	11	B	S_h+S_a	37.5/39.25	(3)

Notes:

1. Carbon steel (SA-106 GR. B)/stainless steel (SA312 GR. TP 304L).
2. Governing load combination numbers are listed in Table 6-2.2-4.
3. See ASME Code, Section III, Subsection NC, paragraph NC-3652.3 (Reference 6) for combination of loads.

Table 6-2.3-2

APPLICABLE ASME CODE EQUATIONS AND ALLOWABLE STRESSES FOR NON-ESSENTIAL TORUS ATTACHED PIPING

STRESS TYPE	ASME CODE EQUATION NUMBER	SERVICE LEVEL	STRESS LIMIT	ALLOWABLE VALUE (ksi) (1)	GOVERNING LOAD COMBINATION NUMBER (2)
PRIMARY	8	DESIGN	1.0 S_h	15.0/15.7	A-1, T-1
PRIMARY	9	B	1.2 S_h	18.0/18.84	B-1, B-2
PRIMARY	9	C	1.8 S_h	27.0/28.26	C-1a
PRIMARY	9	D	2.4 S_h	36.0/37.68	C-1b, C-2, C-3 D-1, thru D-4
SECONDARY	10	B	1.0 S_a	22.5/23.55	A-2, thru A-9
PRIMARY AND SECONDARY	11	B	S_h+S_a	37.5/39.25	(3)

Notes:

1. Carbon steel (SA-106 GR. B)/stainless steel (SA312 GR. TP 304L).
2. Governing load combination numbers are listed in Table 6-2.2-4.
3. See ASME Code, Section III, Subsection NC, paragraph NC-3652.3 (Reference 6) for combination of loads.

6-2.4 Methods of Analysis

This section describes the methods of analysis used to evaluate the large bore (4" in diameter and larger) piping and supporting systems attached to the torus both internally and externally, for the effects of the governing loads as described in Section 6-2.2.

The methodology used to develop the structural models of the TAP systems is presented in Section 6-2.4.1. The methodology used to obtain results for the governing load combinations and to evaluate the analysis results for comparison with the acceptance limits is discussed in Sections 6-2.4.2 through 6-2.4.5. The approach used to address fatigue effects is presented in Section 6-2.4.6.

A standard, commercially available piping analysis computer code, PISTAR, is used in performing the piping system analyses. The PISTAR computer code is based on the well known SAP computer code, and has been verified using ASME benchmark problems. The PISTAR program performs static, modal extraction, uniform response spectra, multiple response spectra, and dynamic time-history analyses of piping systems. It also performs ASME Code piping evaluations.

6-2.4.1 Analytical Modeling

The structural models used in the analysis of the large bore TAP systems fall into the following two categories: piping models which represent systems with only torus external piping, and piping models which include both torus internal and torus external piping. Figures 6-2.4-1 and 6-2.4-2 show representative torus internal and external piping system models.

Twenty-two separate piping system models are utilized to represent the twenty-seven piping systems listed in Table 6-2.1-1. Five of the systems (P216A, P216D, P216B, P211C, and P211D) are not modeled since they are essentially identical to systems P216C, P211A, and P211B which are modeled.

The piping systems are modeled as multi-degree of freedom, finite element systems consisting of straight and curved beam elements using a lumped mass formulation. A sufficient amount of detail is used to accurately represent the dynamic behavior of the piping systems for the applied loads. Flexibility and stress intensification factors based on the ASME Code, Section III, Class 2 piping requirements are included in the model formulations. Mass, flexibility and stiffness

properties, as appropriate, for piping components such as in-line valves, strainers, flanges, and expansion joints are also included in the piping system structural models.

Torus external piping supports included in the models consist of snubbers, struts, spring hangers, and their supplemental steel. Snubbers are modeled as active in seismic and other dynamic load cases, while spring hangers and struts are active in all load cases. Spring hanger preloads, are modeled as active in the dead weight load case only. The effects of the mass of supports and connecting hardware attached to the piping are included in the piping models when the effective support mass attached to the piping exceeds 5% of the mass of both adjacent pipe spans.

Stiffness values at a piping support location are established considering the combined effects of the snubber or strut and its supplementary steel.

For piping models which include torus internal piping, the entire piping system including the internal supports connected to the torus is modeled. The hydrodynamic mass acting on submerged portions of the piping and supports is also included in the models.

Boundary conditions for the piping models at the torus consist of the torus penetration and attachment points for the torus internal piping supports. The local stiffness of the torus is included at these locations in the form of six degree-of-freedom linear springs for all analyses except the coupled torus motion analyses described in Section 6-2.4.4. These local stiffnesses are represented by the torus modal characteristics when performing the coupled torus motion analyses of the piping systems.

Model boundary conditions at the torus external piping termination points consist of rigid anchors at physical restraint locations. Examples of physical restraints are structural anchors, equipment (pumps, turbines), anchors at building penetrations, etc. Rigid stiffness values are specified in the models at these locations.

Branch lines are included in the piping models unless they meet uncoupling criteria based on the relative outside diameters (OD) of the branch line and main line. An OD ratio of 3 to 1 is used for this purpose. These criteria ensure that omission of the branch line will not influence the behavior of the main line. The evaluation of the omitted branch lines has been considered in Section 6-3.0.

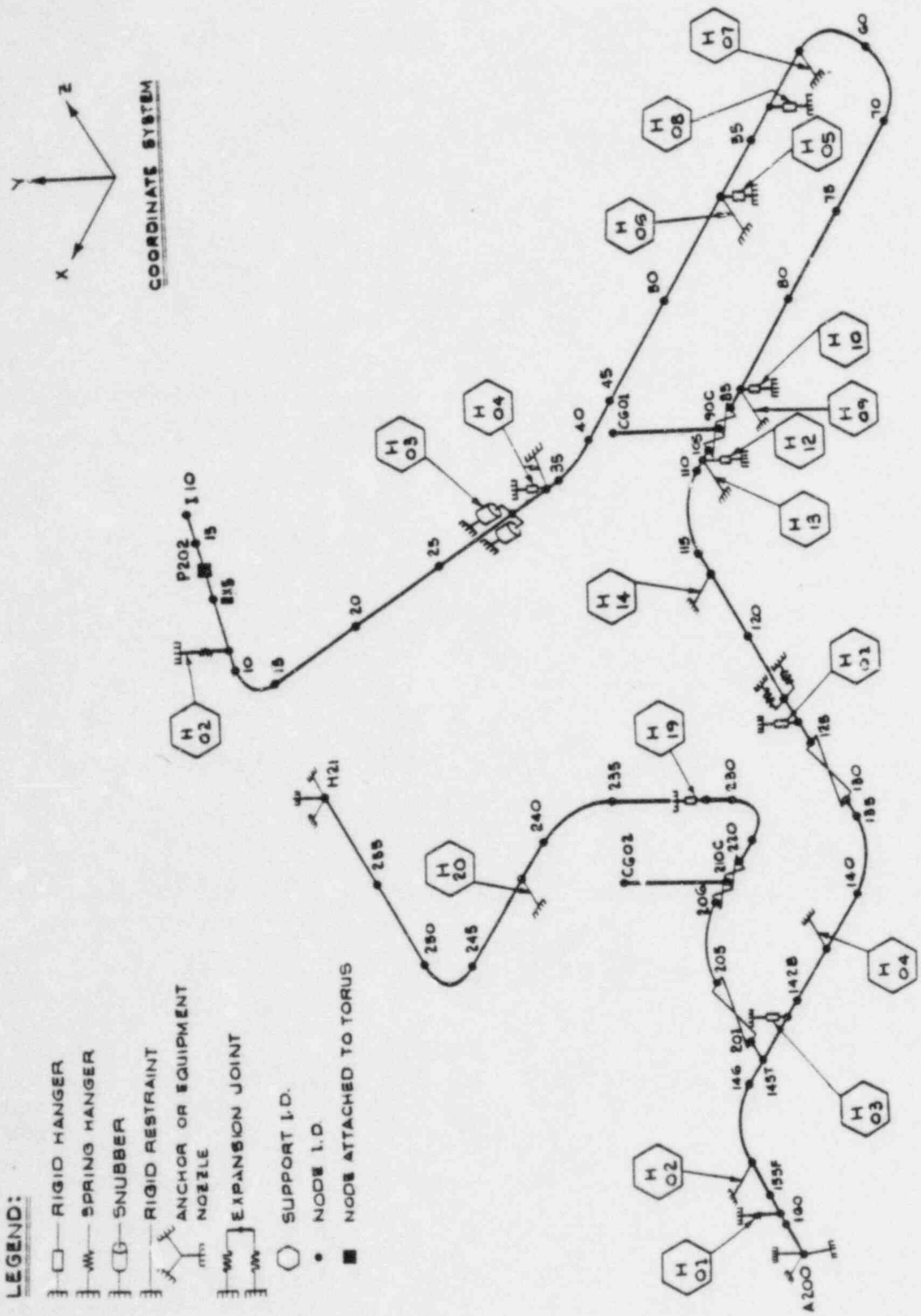

Figure 6-2.4-1

TAP SYSTEM STRUCTURAL MODEL (LINE P202)

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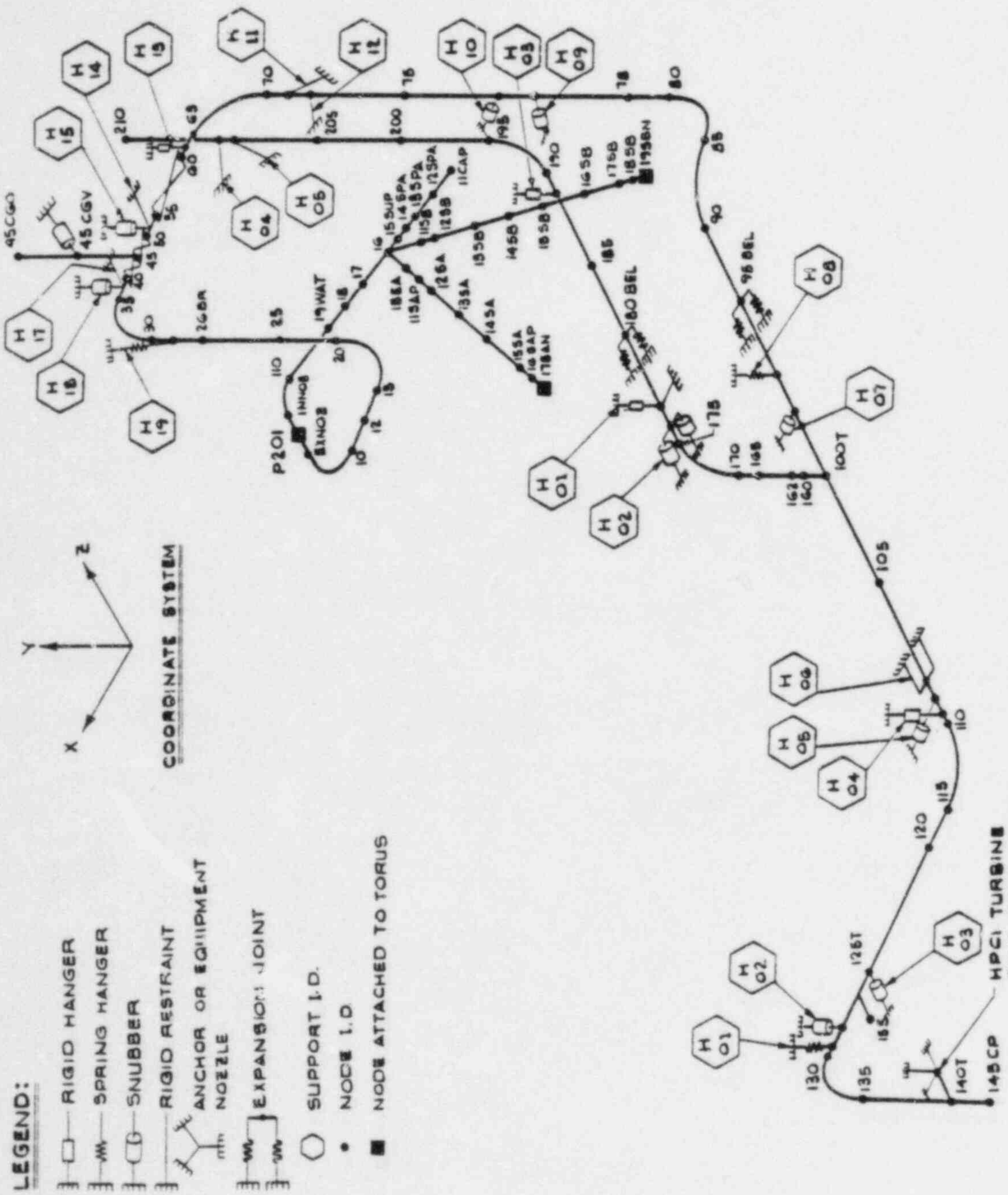


Figure 6-2.4-2

TAP SYSTEM STRUCTURAL MODEL (LINE P201)

6-2.4.2 Methods of Analysis for FSAR and Static Torus Displacement Loads

The following loads, which . e described in Section 6-2.2.1, represent the FSAR and static torus displacement loads for which the TAP systems are analyzed.

1. Dead Weight
2. Seismic
3. Pressure and Temperature
4. Operating
5. Static Torus Displacement

The methods used to analyze the piping systems for the above loads are described as follows:

1. Dead Weight (DW) Loads

   A static analysis is performed for the uniformly distributed and concentrated weight loads, including insulation and pipe contents, applied to the TAP systems.

2. Seismic Loads

a. OBE Inertia (OBE_I) Loads: A dynamic analysis is performed independently for each of the three orthogonal directions (N-S, E-W, and vertical) using the uniform response spectra method. Critical damping is in accordance with the FSAR. All modes up to 33 hertz are considered in calculating the peak response of the piping system. System frequencies above 33 hertz are also considered in the analyses to account for high-frequency rigid range response of the piping system.

b. OBE Displacement (OBE_D) Loads: A static analysis is performed independently for each of the three orthogonal directions. Relative anchor displacements are applied to the piping systems in accordance with the Hope Creek FSAR. Horizontal displacements at the torus penetration and reactor building slabs and walls are considered to be in-phase. Vertical displacements at the penetration, building slabs and walls are considered to be out of phase.

c. SSE Inertia (SSE_I) Loads: A dynamic analysis is performed independently for each of the three orthogonal directions using the uniform response spectra method. Critical damping is in accordance with the FSAR. All modes up to 33 hertz are considered in calculating the peak response of the piping systems. System frequencies above 33 hertz are also considered as described in Load Case 2a.

d. SSE Displacement (SSE_D) Loads: A static analysis is performed independently for each of the three orthogonal directions. The relative anchor displacements are applied in the horizontal and vertical directions as described in Load Case 2b.

The methodology used to combine modal responses and spatial components in the seismic analysis is defined in NRC Regulatory Guide 1.92 (Reference 10). The individual modal responses are grouped by frequencies (within 10%) and the modal responses within each group are combined by absolute sum. The responses of each group are then combined by the SRSS method. The seismic analysis is performed independently for each of

the two horizontal directions and for the vertical direction. The resulting peak responses obtained for each of the three directions are combined by the SRSS method.

3. Pressure and Temperature Loads

a. Pressure Loads: The effects of maximum operating pressure (and design pressure (P) are evaluated util the techniques described in Subsection NC-3650 of the ASME Code, Section III (Reference 6).

b. Temperature Loads: A static thermal expansion analysis is performed for the piping temperature cases TE and TE_1 using the temperatures discussed in Section 6-2.2.1. A static analysis is performed for anchor movement loads (THAM and $THAM_1$) at the torus supports and penetrations, as described in Section 6-2.2.1.

4. Operating (OL) Loads

Operating loads as described in Section 6-2.2.1 are included in the TAP system analyses.

5. Static Torus Displacement Loads

The static displacements of the suppression chamber at the TAP penetration locations due to normal (TD) and accident (TD_1, TD_2, TD_3) condition torus pressures and torus dead weight are applied to each piping system as an applied displacement load case.

6-2.4.3 Methods of Analysis for Hydrodynamic Loads

Portions of TAP systems internal to the torus are subjected to hydrodynamic drag loads as a result of SRV discharge and LOCA events, as discussed in Section 6-2.2.1. The methods used to analyze the piping for these loads are described as follows:

6. Safety Relief Valve Discharge (QAB) Loads

   a. Water Jet Impingement Loads: Water jet pressure loadings are evaluated by multiplying the drag pressures by the appropriate submerged piping projected areas and converting them to piping nodal forces. An equivalent static analysis is performed by multiplying the forces by a value of 2.0, which is the maximum dynamic load factor (DLF) for the rectangular pulse loading.

   b. Air Bubble Drag Loads: An equivalent static analysis of the piping systems is performed to evaluate the acceleration drag and standard drag forces imparted to the submerged portions of piping. The applied equivalent static loads include a DLF of 3.0

if the natural frequency of the internal structure is below 20 hz and 2.0 if the natural frequency is above 20 hz. The DLF values have been established based on test results as discussed in Section 1-4.2.4.

7. Vent Clearing (VCLO) Loads

a. LOCA Water Jet Impingement Loads: An equivalent static analysis method is used to apply the LOCA jet loads to submerged portions of the piping models. For a given jet loading time-history, the peak DLF for the structure within the load frequency range (1 to 50 hertz) is determined. The equivalent static load applied to each segment of piping is equal to the product of the peak jet load section force and the appropriate DLF.

b. LOCA Air Bubble Drag Loads: An equivalent static analysis is performed to evaluate the acceleration drag and standard drag forces imparted to the submerged portions of the piping. The loading profiles for LOCA air bubble loads may be enveloped by a rectangular pulse loading. Accordingly, a

DLF value of 2.0 is applied in performing the equivalent static analyses.

As described in Section 6-2.4.5 the vent clearing (VCLO) loading is bounded by other loadings. The VCLO loads have been evaluated only for a typical piping system used to demonstrate that the load is enveloped by other loads.

8. Pool Swell (PSO) Loads

The method of equivalent static loads is used in analyzing the piping systems for the effects of pool swell loads. The applied equivalent static piping section forces are equal to the peak section forces multiplied by their corresponding DLF's. These section forces are converted into nodal forces for application to the piping models.

a. Impact and Drag Loads: Horizontal torus internal piping above the elevation of the downcomers is subjected to pool swell impact and drag loads. The impact and drag pressure transients are distributed uniformly over the affected piping surface. The load is applied in the upward direction most critical to the

piping within the specified load directional range. The impact plus drag loading transient consists of a sharp triangular impulse followed by a rectangular drag loading. The combined DLF value for this transient is 1.7. In some cases where the impact load component does not exist, a DLF of 2.0 is utilized to account for the drag load component.

b. Froth Impingement Loads: The pool swell froth loading time-history is a rectangular pulse which has a maximum DLF value of 2.0. Froth impingement loads are applied to piping located within the suppression chamber, as defined in Section 1-4.1.4.3.

c. Pool Fallback Loads: Following the pool swell transient, the pool water falls back to its original level, creating drag loads on piping inside the torus. The fallback loading is a triangular pulse and is applied statically to the piping using a DLF value of 1.25.

As described in Section 6-2.4.5 the pool swell (PSO) loading is bounded by other loadings.

9. Condensation Oscillation (CO) Loads

As discussed in Section 6-2.2.1, the CO drag force is composed of both velocity and acceleration drag components. The drag forces are determined based on the summation of 50 harmonic loading functions. A detailed description of the harmonic loading functions as well as the procedures used in applying the loads are discussed in Section 1-4.1.7.

An equivalent static analysis method is applied utilizing peak structural dynamic load factors. Once the amplitudes of the drag forces for a given piping system have been determined, they are converted to the piping coordinate system and applied as piping nodal forces.

For selected piping systems, in order to reduce conservatisms in the analysis, a dynamic time-history analysis is performed as follows. Given the harmonic nodal force time-histories for acceleration and standard drag as well as the results of a piping mode-frequency analysis for each piping system, a steady-state response

calculation is carried out using the modal superposition method.

The torus FSI effects are also considered in performing the CO load analyses.

10. Chugging Loads

a. Pre-Chug (PCHUG) Loads: As described in Section 6-2.2.1, the pre-chug load definition is a single harmonic velocity and acceleration drag loading. The defined loading amplitude is ±2 psi, and the loading frequency is in the 6.9 to 9.5 hertz range. In reviewing the pre-chug loading amplitudes and frequencies, it has been determined that the effects of this loading are bounded by post-chug loads (Case 10b). Therefore the post-chug loading has been used in the analyses in lieu of pre-chug.

b. Post-Chug (CHUG) Loads: The post-chug loading definition is similar to that for CO loads. The piping analysis procedures for post-chug loads are the same as for the CO loads described above.

6-2.4.4 Methods of Analysis for Torus Motion Loads

11. Torus Motion Loads

Torus motion loads, as discussed in Section 6-2.2.1, are considered for the analysis of all large bore torus attached piping systems. This section describes the methods of analysis for the following torus motion load cases:

a. SRV Torus Motion (QAB_I, QAB_D)

c. Condensation Oscillation Torus Motion (CO_I, CO_D)

e. Post-Chug Torus Motion ($CHUG_I$, $CHUG_D$)

As described in Section 6-2.4.3, the effects of pre-chug loadings are bounded by post-chug loads. Therefore, analyses are not performed for the pre-chug torus motion loads, (Case 11d).

As described in Section 6-2.4.5, the pool swell torus motion (PSO_I, PSO_D) loading is bounded by other loadings. Accordingly, no analyses are performed for pool swell torus motion loads, (Case 11b).

Analyses performed for condensation oscillation and post-chug torus motion loads include the summation of fifty harmonic loadings using a random phasing technique as discussed in Section 1-4.1.7.1.

The methods of analysis for the above torus motion load cases are described in the following paragraphs.

Coupling Analysis

The conventional method for performing dynamic analyses of piping systems attached to and excited by structures such as containment vessels is to perform independent uncoupled dynamic analyses of the containment and of the supported piping. This method of analysis is termed an uncoupled analysis because the dynamic models of the containment vessel and the piping are never directly coupled or combined.

Conventional uncoupled analyses tend to overestimate the response of the supported piping. This overestimation of piping response may be corrected by performing a coupled analysis in

which a single dynamic model including both the containment (torus) and the piping is used. However, a coupled analysis of this type is not practical for the majority of the torus attached piping systems. For these systems, a computer program based on CMDOF (Reference 11) has been developed which is used to incorporate the coupling effects into the results of the uncoupled torus and piping analyses.

Since the coupling program is formulated in the time domain, it is not directly applicable for LOCA-related loads such as CO and chugging, which are defined in the frequency domain. It is also impractical for performing analyses for loads with a wide range of frequencies or a large number of separate load cases that must be considered such as SRV discharge loads.

Transfer Function Approach

In order to facilitate application of the coupling methods for CO, chugging, and SRV loads, a transfer function approach is utilized in conjunction with the coupling program. This method provides for determination of the critical coupled

response frequencies of the piping systems. The critical piping system frequencies are then utilized to select loading frequencies for the analyses which will yield the maximum system response.

The basic steps involved in performing the coupled/transfer function TAP analysis are shown in the flow chart provided in Figure 6-2.4-3.

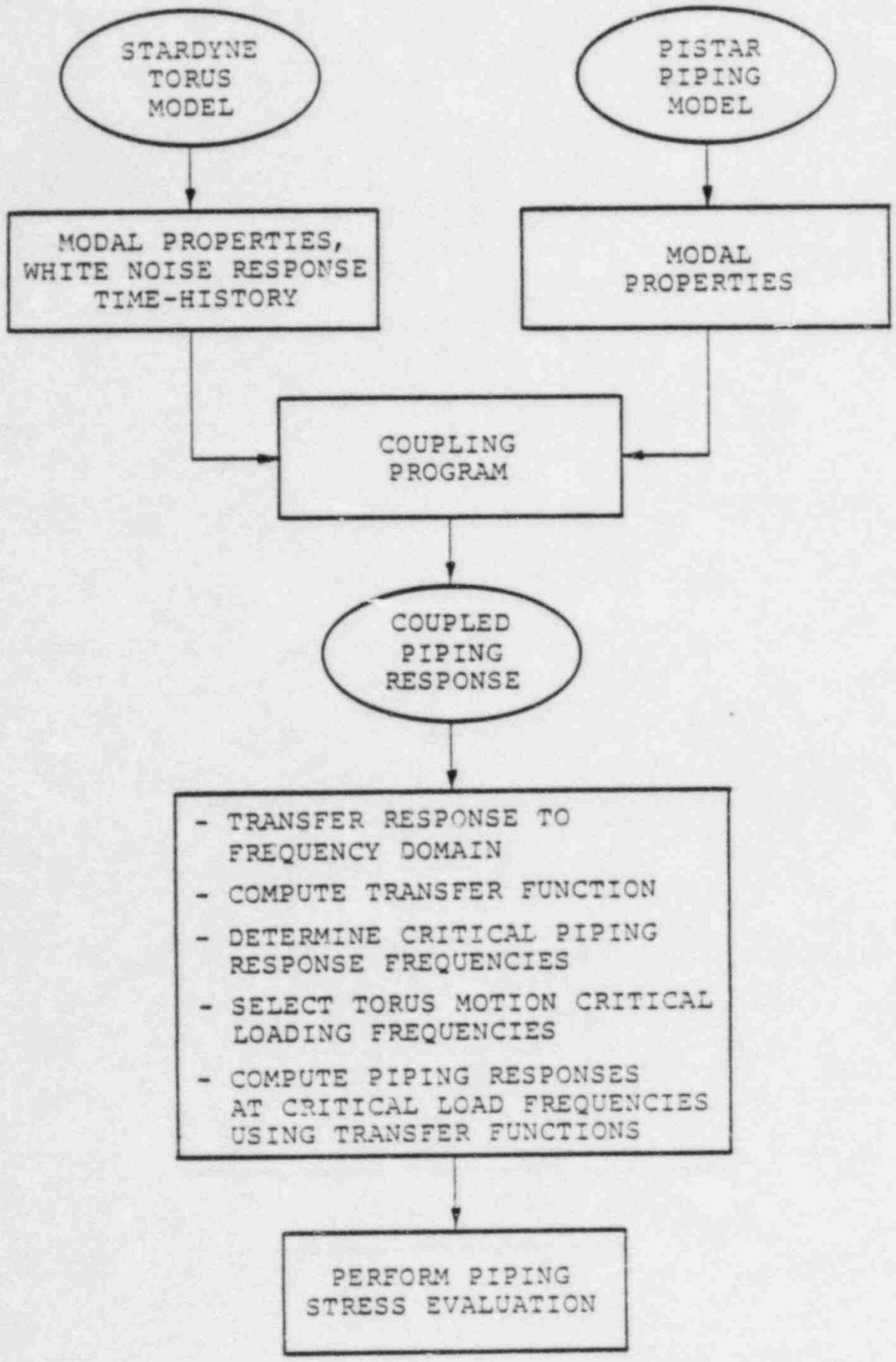


Figure 6-2.4-3

TAP COUPLED/TRANSFER FUNCTION ANALYSIS PROCEDURE

6-2.4.5 Enveloping of Loading Combinations A-6 and D-3

As discussed in Sections 6-2.4.3 and 6-2.4.4, specific analyses for selected loadings are not performed for the TAP systems since they are bounded by other loadings. On this basis, Loading Combinations A-6 and D-3 which contain pool swell and vent clearing loads are eliminated from the TAP analysis of each system. Details of the loading combination enveloping are described in the following paragraphs.

As can be seen by inspection of Table 6-2.2-4, Load Combination A-6 is similar to Load Combination A-5 except that A-6 contains pool swell torus motion displacement loads (PSO_D) in place of the chugging torus motion displacement loads ($CHUG_D$) in A-5. In addition, the SRV discharge torus motion displacement loads (QAB_D) for Load Combination A-5 correspond to a multiple SRV actuation, while those for Load Combination A-6 correspond to a single SRV actuation. The individual displacements for each torus motion load case are shown in Table 6-2.4-1.

Combining the displacements shown in Table 6-2.4-1 in accordance with Load Combinations A-5 and A-6 from Table 6-2.2-4 reveals that the displacements for Load

Combination A-5 envelope those of Load Combination A-6. These results are shown in Table 6-2.4-2. Therefore the displacement effects due to Load Combination A-5 are evaluated for each TAP system in lieu of those for Load Combination A-6.

A similar conclusion can be drawn by comparing Load Combinations D-2 and D-3. These combinations are similar except that Combination D-2 includes chugging hydrodynamic and torus motion loads (CHUG and $CHUG_I$) whereas D-3 includes hydrodynamic and torus motion loads associated with pool swell (PSO, VCLO, and PSO_I). Also, the SRV discharge loads (QAB and QAB_I) included in the combinations relate to different discharge conditions (i.e., single versus multiple SRV discharge).

The displacement effects of Load Combinations D-2 envelop those of Load Combination D-3 as shown in Tables 6-2.4-1 and 6-2.4-2. The inertia effects of torus motion acceleration loads in D-2 are also considered to bound those due to Load Combination D-3. This can be demonstrated by examining the characteristics of the pool swell (PSO_I), chugging ($CHUG_I$), and SRV discharge (QAB_I) loadings. The pool swell torus shell loading transient is a low frequency

(2.5 Hz) single pulse loading. Chugging is a harmonic loading with loading components throughout a frequency range of 0 to 50 Hz. SRV discharge loads are sinusoidal in nature and have maximum frequencies of 11.0 Hz and 15.0 Hz for the DBA single and IBA/SBA multiple valve discharge cases, respectively. Evaluation of piping analysis results shows that the TAP response due to torus motion loadings is driven by the dominant suppression chamber frequency of 16.1 Hz. Since the pool swell and single SRV discharge loading frequencies are removed from the dominant suppression chamber frequency while the multiple SRV discharge and chugging load frequencies are close to or span the dominant suppression chamber frequency, the dynamic amplification effects of chugging plus multiple SRV discharge are more severe than those of a single SRV discharge plus pool swell. The inertia effects of Load Combination D-2, therefore, envelop those of Load Combination D-3.

In order to verify that the hydrodynamic loading components contained in Load Combination D-2 envelop those of Load Combination D-3, a typical piping system (P212A) is analyzed by applying hydrodynamic loads associated with each combination. The SRV discharge hydrodynamic loads are conservatively assumed to be the

same for both combinations. Therefore, only the remaining hydrodynamic loads are included in the load combination comparisons. The results of the two combination analyses, as shown in Table 6-2.4-3, demonstrate that the hydrodynamic loads contained in Combination D-2 significantly bound those in Load Combination D-3. Thus it is demonstrated that both the hydrodynamic and the inertial torus motion loads in Combination D-2 bound similar loads contained in D-3.

Based on the above conclusions, Loading Combinations A-5 and D-2 are evaluated for each TAP system in lieu of combinations A-6 and D-3.

Table 6-2.4-1

INDIVIDUAL TORUS MOTION LOAD DISPLACEMENTS

FOR LOADING COMBINATIONS A-5 AND A-6

ITEM		SINGLE SRV DISCHARGE	MULTIPLE SRV DISCHARGE	PRE-CHUG	POST-CHUG	DBA CO	POOL SWELL
TORUS SHELL RESULTANT DISPLACEMENTS AT QUARTER BAY (IN.)	BDC	0.1769	0.2621	0.0101	0.0486	0.1732	0.0776
	OUTSIDE 45^{O} ABOVE BDC	0.1548	0.2319	0.0064	0.0497	0.2060	0.0436
	OUTSIDE EQUATOR	0.1225	0.1758	0.0096	0.0377	0.1540	0.0980
	OUTSIDE 45^{O} ABOVE EQUATOR	0.0725	0.1069	0.0016	0.0364	0.1230	0.0142

Note:

1. Results taken from analysis documented in Section 3-2.4.

Table 6-2.4-2

COMBINED TORUS MOTION DISPLACEMENTS FOR LOADING COMBINATIONS A-5, A-6 D-2 AND D-3

ITEM		MULTIPLE SRV + CHUGGING (1)	SINGLE SRV + POOL SWELL (1)
TORUS SHELL RESULTANT DISPLACEMENTS AT QUARTER BAY (IN.)	BDC	0.27	0.19
	OUTSIDE 45° ABOVE BDC	0.24	0.16
	OUTSIDE EQUATOR	0.18	0.16
	OUTSIDE 45° ABOVE EQUATOR	0.11	0.07

Note:

1. Displacements combined by SRSS.

Table 6-2.4-3

TYPICAL LINE ANALYSIS RESULTS
FOR HYDRODYNAMIC LOADS CONTAINED IN
COMBINATIONS D-2 AND D-3

LINE P212A (INTERNAL) LOCATION	COMPONENT STRESS (ksi)	
	PSO + VCLO (L.C. D-3)	CHUG (W/FSI) (L.C. D-2)
PENETRATION NOZZLE	1.82	6.32
ELBOW	2.07	6.33
PIPING SEGMENT MID-SPAN	1.86	5.99
PIPING STRUT	1.64	2.06

6-2.4.6 Fatigue Evaluation

Section 4.3.3.2 of NUREG-0661 (Reference 1) requires that a fatigue evaluation of the torus attached piping be performed for all loading conditions except pool swell.

The Mark I Owners Group prepared and submitted a generic fatigue evaluation report (Reference 7) to the NRC on November 30, 1982. The report addressed fatigue on a generic basis using actual piping analysis results from essentially all Mark I plants. The resulting cumulative usage factors are below 0.5, demonstrating that further plant unique fatigue evaluations are not warranted. Use of the generic fatigue evaluation approach has been approved as described in Reference 8. Therefore, the Hope Creek TAP is adequate for fatigue based on this generic evaluation.

6-2.5 Analysis Results and Conclusions

The analytical results and conclusions for the large bore TAP evaluation are summarized in this section.

The maximum piping stresses resulting from governing load combinations for locations on each large bore TAP line are presented in Table 6-2.5-1. The maximum stresses for each Service Level are listed along with the associated ASME Code equations.

Fatigue evaluations for the TAP lines have been performed generically as described in Section 6-2.4-6. The Hope Creek torus attached piping is qualified for fatigue effects based on this generic evaluation.

The analysis results show that the design of the large bore torus attached piping systems is adequate for the loads, load combinations and acceptance criteria limits specified in NUREG-0661 (Reference 1) and in the PUAAG (Reference 5).

Table 6-2.5-1

ANALYSIS RESULTS FOR LARGE BORE TORUS ATTACHED PIPING STRESS

PENETRATION NUMBER	MAXIMUM STRESS (ksi)				
	DESIGN (1)	LEVEL B (2)	LEVEL C (2)	LEVEL D (2)	SECONDARY (3)
P201	5.92	10.90	11.14	11.30	15.34
P202	3.56	9.50	10.64	13.62	6.00
P203	5.26	18.00	24.51	24.52	9.50
P204	1.91	15.80	18.94	26.87	22.25
P207	9.41	13.45	16.22	17.34	12.77
P208	2.21	18.00	21.00	36.00	10.30
P209	4.64	15.24	30.16 (5)	34.32	11.40
P211A	3.56	15.44	15.90	16.22	19.85
P211B	3.33	15.77	20.00	20.00	21.08
P211C	3.33	15.77	20.00	20.00	21.08
P211D	3.56	15.44	15.90	16.22	19.85
P212A	6.19	14.66	15.27	15.32	18.11
P212B	5.87	17.38	23.56	27.42	10.81 (4)
P213A	6.47	18.00	25.61	25.32	28.81
P213B	8.61	16.65	17.50	17.82	26.24 (4)
P214A	4.80	8.39	8.92	10.70	35.95 (4)
P214B	2.73	4.92	6.38	6.39	20.90
P216A	2.41	10.55	11.67	15.06	8.64
P216B	2.41	10.55	11.67	15.06	8.64
P216C	2.41	10.55	11.67	15.06	8.64
P216D	2.41	10.55	11.67	15.06	8.64
P217A	14.56	16.75	17.00	18.20	34.40 (4)
P217B	13.04	16.30	20.40	20.40	19.03
P219	3.04	14.30	16.94	16.98	11.26
P220	2.40	16.42	17.00	17.20	15.30
P222	3.75	11.70	13.36	19.98	16.51
P223	1.86	7.69	8.08	8.20	5.20

Notes:

1. ASME Code, Section III, Subsection NC-3650, Equation 8.
2. ASME Code, Section III, Subsection NC-3650, Equation 9.
3. ASME Code, Section III, Subsection NC-3650, Equation 10.
4. ASME Code, Section III, Subsection NC-3650, Equation 11.
5. Non-essential piping system-level D allowable.

6-3.0 SMALL BORE PIPING

An evaluation of each of the NUREG-0661 (Reference 1) requirements which affect the design adequacy of the Hope Creek small bore piping (SBP) is presented in the following sections. The general criteria used in this evaluation are contained in Volume 1.

The components of the SBP which are examined are described in Section 6-3.1. The loads and load combinations for which the SBP are evaluated are described and presented in Section 6-3.2. The acceptance limits to which the analysis results are compared are discussed and presented in Section 6-3.3. The analysis methodologies used to evaluate the effects of the loads and load combinations on the SBP are discussed in Section 6-3.4. The analysis results and conclusions are presented in Section 6-3.5.

6-3.1 Component Description

The SBP lines for the Hope Creek plant unique analysis (PUA) consist of the following configurations.

1. Cantilevered lines
2. Torus attached external SBP lines
3. Torus attached internal SBP lines.
4. Other small bore lines attached to large bore TAP

Of the 139 small bore lines evaluated, approximately 29 lines are cantilevered from the torus or from large bore TAP systems. These cantilevered lines function as vents, drains, and test lines.

Seventeen small bore lines are attached directly to the torus. These small bore internal and external TAP lines include torus instrument lines and vacuum breaker test lines. The lines range in size from 1" to 2" diameter.

Ninety-three small bore lines are attached to large bore torus attached piping. These branch lines are typically 1" to 2" in diameter and may be several feet in length. The branch systems normally include one or

two isolation valves and terminate at anchors, equipment, or other large bore lines.

6-3.2 Loads and Load Combinations

The loads for which the Hope Creek SBP is designed are defined in NUREG-0661 on a generic basis for all Mark I plants. The methodology used to develop plant unique loads for each load defined in NUREG-0661 is discussed in Section 1-4.0. The results of applying the methodology to develop specific values for each of the controlling loads which act on the SBP are discussed and presented in Section 6-3.2.1.

Using the event combinations and event sequencing defined in NUREG-0661 and discussed in Sections 1-3.2 and 1-4.3, the governing load combinations which affect the SBP are formulated. The load combinations are discussed and presented in Section 6-3.2.2.

6-3.2.1 Loads

The loads acting on the SBP are the same as the large bore TAP loads defined in Section 6-2.2.1 except as described below. All large bore TAP loads except Load Case 4 (Operating Loads) and Load Cases 6, 7, 9, and 10 (LOCA and SRV discharge submerged structure hydrodynamic loads) are applied in the SBP analyses.

Torus response due to LOCA-induced and SRV discharge-induced loadings directly affect the small bore piping attached to the torus. These loads also indirectly affect small bore piping attached to large bore TAP lines.

Not all of the loads defined in NUREG-0661 need to be evaluated, since some are enveloped by others or have a negligible effect on the piping. Only those loads which maximize the piping response and lead to controlling stresses are examined and discussed. These loads are referred to as governing loads in subsequent discussions.

6-3.2.2 Load Combinations

The loads for which the SBP are evaluated are presented in Section 6-3.2.1. The general NUREG-0661 criteria for grouping these loads into load combinations are discussed in Sections 1-3.2 and 1-4.3.

Load combinations specified for the SBP are the same as those specified for the large bore TAP in Table 6-2.2-4. The hydro-test load combination (T-1) is not evaluated since these loadings have a negligible effect on the small bore piping. Also, as discussed in Section 6-2.4.5, load combinations A-6 and D-3 have not been evaluated since they are enveloped by other combinations. The remaining load combinations listed in Table 6-2.2-4 have been considered in the SBP analytical methods described in Section 6-3.4.

6-3.3 Analysis Acceptance Criteria

The acceptance criteria defined in NUREG-0661 on which the Hope Creek SBP analysis is based are discussed in Volume 1. The acceptance criteria follow the rules contained in the ASME Code, Section III, Division 1, 1977 Summer Addenda for Class 2 piping (Reference 6). The corresponding service level limits and allowable stresses are also consistent with the requirements of the PUAAG (Reference 5) and the ASME Code (Reference 6).

6-3.4 Methods of Analysis

The governing load combinations for which the Hope Creek SBP is evaluated are discussed in Section 6-3.2.2. The methodology used to evaluate the SBP for the effects of these loads is described in the following paragraphs.

The SBP systems are evaluated for the effects of the loads discussed in Section 6-3.2.1 using several different methods, depending on the type of system configuration. A description of the methods of analysis used for each type of configuration follows.

a. Cantilevered Test Lines and Vents: A beam model of the cantilevered system is used to calculate the natural frequency using standard beam formulations. A dynamic load factor is calculated based upon the calculated system natural frequency and the predominant loading frequency. An equivalent static analysis is performed using the loads and load combinations defined in Sections 6-3.2.1 and 6-3.2.2.

b. Small Bore Torus Attached Lines: A multiple response spectra or time-history dynamic analysis

is performed for the SBP torus attached lines using the loads and load combinations defined in Sections 6-3.2.1 and 6-3.2.2.

The type of dynamic analysis used for a particular TAP line is initially based upon the piping system natural frequencies. If system frequencies are near the dominant suppression chamber and load frequency, a time-history analysis is performed. If system frequencies are outside of this loading frequency range, a multiple response spectra analysis is performed.

c. Other Small Bore Lines Attached to Large Bore TAP: Initially, a number of the SBP branch lines are excluded from specific evaluations for LOCA and SRV discharge induced loadings since the large bore piping branch connection locations are far removed from the suppression chamber and as a result stresses are significantly below allowables. Lines which are not excluded on this basis are specifically evaluated using the multiple response spectra analysis technique.

The treatment of each load in each load category identified in Section 6-3.2.1 is discussed in the following paragraphs.

1. Dead Weight (DW) Loads

   A static analysis is performed for the uniformly distributed and concentrated weight loads including the weight of water contained inside the small bore piping.

2. Seismic Loads

   a. OBE Inertia (OBE_I) Loads: A dynamic analysis is performed independently for each of the horizontal and vertical directions using the uniform response spectra method.

   b. OBE Displacement (OBE_D) Loads: A static analysis is performed for the horizontal and vertical OBE displacements as defined in the FSAR.

   c. SSE Inertia (SSE_I) Loads: A dynamic analysis is performed independently for each of the

horizontal and vertical directions using the uniform response spectra method.

d. SSE Displacement (SSE_D) Loads: A static analysis is performed for the horizontal and vertical SSE displacements as defined in the FSAR.

3. Pressure and Temperature Loads

a. Pressure (P_o, P) Loads: The effects of these loads on the SBP are evaluated by using the ASME Code piping equations. The design pressure is conservatively applied to the SBP analysis.

b. Temperature (TE, TE_1) Loads: A static thermal expansion analysis is performed with the load applied uniformly to the small bore piping.

An additional static analysis is performed for the effects of thermal anchor movements at the attachment of the SBP to the suppression chamber for normal operating and accident conditions.

4. Safety Relief Valve Discharge (QAB_I, QAB_D) Loads

A dynamic time-history analysis or multiple response spectra analysis is performed for the loads defined in Section 6-3.2.1.

5. Pool Swell (PSO_I, PSO_D) Loads

As discussed in Section 6-2.4.5, the pool swell load is bounded by other loads. Accordingly, no analysis of the SBP is performed for this load.

6. Condensation Oscillation (CO_I, CO_D) Loads

A dynamic time-history analysis or multiple response spectra analysis is performed for the loads defined in Section 6-3.2.1.

7. Chugging Loads

   a. Pre-Chug ($PCHUG_I$, $PCHUG_D$) Loads: As discussed in Section 6-2.4.3, pre-chug loads are bounded by post-chug loads (Case 7b). Therefore, no analysis is performed for pre-chug loads.

b. Post-Chug ($CHUG_I$, $CHUG_D$) Loads: The post-chug loading definition is similar to that for CO loads. The SBP analysis procedures for post-chug loads are the same as for the CO loads described above.

6-3.5 Analysis Results and Conclusions

The component descriptions, loads and load combinations, acceptance criteria, and analysis methods used in the evaluation of the Hope Creek SBP are presented and discussed in the preceding sections. The results from the evaluation of the SBP are presented in the following paragraphs.

Table 6-3.5-1 shows maximum stresses for representative torus attached, branch, and cantilever SBP lines resulting from application of ASME Code piping equations for the controlling load combinations.

In summary, the results show that the small bore piping is adequate for the loads, load combinations, and acceptance criteria specified in NUREG-0661 (Reference 1) and the PUAAG (Reference 5).

Table 6-3.5-1

REPRESENTATIVE SMALL BORE PIPING STRESSES FOR CONTROLLING LOAD COMBINATIONS

SYSTEM TYPE	DESIGN(1)	LEVEL B(2)	LEVEL C(2)	LEVEL D(2)	SECONDARY(3)
	ALLOWABLE STRESS (ksi)				
	15.00	18.00	27.00	36.00	22.50
	MAXIMUM STRESS (ksi)				
CANTILEVER	0.70	5.20	15.20	23.60	0.00
TORUS ATTACHED PIPING	1.97	10.41	14.51	14.58	9.25
BRANCH PIPING	1.99	12.50	12.65	12.67	20.87

Notes:

1. ASME Code, Section III, Subsection NC-3650, Equation 8.
2. ASME Code, Section III, Subsection NC-3650, Equation 9.
3. ASME Code, Section III, Subsection NC-3650, Equation 10.

6-4.0 PIPING SUPPORTS

An evaluation of each of the NUREG-0661 (Reference 1) requirements which affect the design adequacy of the Hope Creek piping supports is presented in the following sections. The general criteria used in this evaluation are contained in Volume 1.

The piping supports which are examined are described in Section 6-4.1. The loads and load combinations for which the piping supports are evaluated are described and presented in Section 6-4.2. The acceptance limits to which the analysis results are compared and the analysis methodologies used to evaluate the effects of the loads and load combinations on the piping supports are discussed in Section 6-4.3. The analysis results and conclusions are presented in Section 6-4.4.

6-4.1 Component Description

External TAP lines are supported by spring hangers, rigid struts, guides, and snubbers attached to reactor building walls or slabs using frames and base plates, or directly to the main structural steel in the reactor building. Figures 6-2.1-4 and 6-2.1-5 show typical TAP supports outside the suppression chamber.

Torus internal piping is generally supported by rigid struts attached directly to the torus shell or ring girders, as shown in Figure 6-2.1-6.

6-4.2 Loads and Load Combinations

The loads for which the Hope Creek TAP supports are designed are defined in NUREG-0661 on a generic basis for all Mark I plants. The methodology used to develop plant unique TAP loads for each load defined in NUREG-0661 is discussed in Volume 1.

The loads acting on the piping supports outside the suppression chamber are caused by the response of the piping systems to the loads defined in Sections 6-2.2.1 and 6-3.2.1. Piping supports inside the suppression chamber experience these same loads, with the addition of hydrodynamic impact and drag loads as defined in Section 6-2.2.1.

Using the event combinations and event sequencing defined in NUREG-0661 and discussed in Volume 1, the governing load combinations which affect the piping supports are formulated. Table 6-4.2-1 presents the governing load combinations. Loads on the piping supports resulting from dynamic events have been combined using the SRSS method in accordance with Reference 9.

Table 6-4.2-1

GOVERNING LOAD COMBINATIONS - PIPING SUPPORTS

LOAD COMBINATION NUMBER	LOAD COMBINATION [5]
A-1 [3]	DW_T+OL
B-1	DW+OBE_I+OL
B-2	DW+QAB+QAB_I+OL
B-3 [4]	OBE_I+OBE_D+DW+TE+THAM+TD+OL
B-4 [4]	QAB+QAB_I+DW+TE+THAM+TD+OL
C-1 [1]	DW+QAB+QAB_I+SSE_I+OL
C-2	DW+QAB+QAB_I+CHUG+$CHUG_I$+OL
C-3 [2][4]	QAB+QAB_I+CHUG+$CHUG_I$+DW+TE_1+$THAM_1$+TD_1+OL
C-4 [1][2][4]	QAB+QAB_I+SSE_I+SSE_D+DW+TE_1+$THAM_1$+TD_1+OL
D-1 [1]	DW+QAB+QAB_I+SSE_I+CHUG+$CHUG_I$+OL
D-2 [1][2][4]	QAB+QAB_I+SSE_I+SSE_D+CHUG+$CHUG_I$+DW+TE_1+$THAM_1$+TD_1+OL
D-3	DW+CO+CO_I+OBE_I+OL
D-4 [2][4]	CO+CO_I+OBE_I+OBE_D+DW+TE_1+$THAM_1$+TD_1+OL
D-5	DW+QAB+QAB_I+SSE_I+PSO+PSO_I+VCLO+OL
D-6 [2][4]	DW+QAB+QAB_I+SSE_I+SSE_D+PSO+PSO_I+VCLO+TE_1+$THAM_1$+TD_1+OL

Notes:

1. Use OBE or SSE whichever is greater.
2. Use TD_1 or TD_2 or TD_3 whichever is the greatest value.
3. Applicable to non-water lines only (hydrotest load).
4. The most severe combination of static loads must be considered.
5. See Section 6-2.2.2 for combination of dynamic loads.

6-4.3 Methods of Analysis and Acceptance Criteria

Pipe supports are evaluated using standard linear elastic structural analysis methods, which include hand calculations and standard structural analysis computer programs. The resultant component forces and/or stresses are compared to their respective allowable values.

Design procedures used in the analysis of component supports are described in Subsection NF-3130 of ASME III, Division I, 1974 edition with addenda through Winter of 1975. All component supports are categorized into three separate types; plate and shell type supports, linear type supports, and component standard supports.

Component standard supports defined per Section NF-1214 are catalogue items. Load Capacity Data Sheets (LCDS) developed by ITT Grinnell Pipe Hangers Division, Corner & Lada, and NPS are being used for acceptance of hardware. Methods of analysis/design procedure are indicated in the LCDS.

Most of the supports are linear type component supports acting under essentially a single component of direct

stress which may be subjected to shear stresses. Elastic analysis based on maximum stress theory in accordance with the rules of NF-3230 of Appendix XVII - 2000 is used for the design of Class 1, 2, and 3 linear type supports.

The nationally recognized computer program, ICES STRUDL II, on the UNIVAC SYSTEM (Bechtel Documentation CE-901) is used to perform static linear elastic frame analyses for linear type supports, e.g., beams and columns (subjected to axial force and bending), trusses and frames. Long hand calculations are performed at times using standard beam formulae. Standard formulae are available in various text books and other reference books such as Frame Formulas by Kleinloggl, Beam Formulas by Griffel, and the AISC Manual. Stresses calculated are compared against allowable values given in Table 6-4.3-1. These allowables are calculated according to Appendix XVII - 2000; however, Appendix XVII - 2211(c) and NF-3392.1(b) are not applicable to welding. Allowables for weld stresses are based on NF-3292. Plate and shell type supports are analyzed per NF-3132.2 and the resultant component stresses are compared against allowables for Class 1, 2, and 3 given in NF-3200, NF-3320, and NF-3400 respectively.

Table 6-4.3-1

ALLOWABLE STRESS LIMITS FOR PIPING SUPPORTS

MATERIAL	TYPE OF STRESS	NORM/ UPSET (ksi)	EMERGENCY (ksi)	FAULTED (ksi)	REMARKS
SA-36 STEEL	TENSION	19.1(.6 Sy)	25.5(1.33x.6 Sy)	31.9	S_y = YLD. STR. @ 300°F = 31.9 KSI
	BENDING	19.1	25.5	31.9	
	SHEAR	12.8 (.4 Sy)	17.0(1.33x.4 Sy)	19.1(1.5x.4 Sy)	
	COMPRESSION	Refer SFPSM (1) 3.10.1 (Fa)	1.25xFa	1.25xFa	
E-70 ELECTRODE	WELD	(NF-3292-1.1) 18.0	24.0(=1.33x18)	30.6(=1.7x18)	

Notes:

1. San Francisco Power Pipe Support Design Manual.
2. Allowable stresses for linear type nuclear pipe supports, ASME Code, Section III, Subsection NF.

6-4.4 Analysis Results and Conclusions

The loads, load combinations, acceptance criteria and analysis methods used in the evaluation of piping supports are discussed in the preceding sections.

The results from the evaluation of the supports for the governing load combinations are presented in this section. Supports are evaluated for large and small bore (less than 4 inch diameter), torus attached piping and branch lines (attached to large bore piping). The results of large bore pipe support evaluations are shown in Table 6-4.4-1. For each line, the table identifies the penetration number, corresponding isometric drawing number, number of existing and new supports evaluated, and number of existing supports requiring modification. Results indicate that relatively few modifications to existing supports or additional supports are required because the original design included some preliminary hydrodynamic loads.

The analysis results confirm that all supports in their final configuration meet the acceptance criteria specified in References 1 and 5.

Table 6-4.4-1

SUMMARY OF LARGE BORE PIPE SUPPORT MODIFICATIONS

ISOMETRIC DRAWING	PENETRATION NUMBER	NUMBER OF SUPPORTS		
		EXISTING	NEW	MODIFIED
P-FD-01	P-201	23	1	1
P-BJ-01 & P-AP-01	P-202	17	0	4
P-BJ-01	P-203	8	0	2
P-BC-06	P-204	16	5	3
P-FC-01	P-207	21	1	2
P-BD-01 & P-AP-01	P-208	18	0	1
P-BC-04	P211A	18	2	2
P-BC-04	P211B	12	2	1
P-BC-04	P211C	13	2	3
P-BC-04	P211D	18	2	2
P-BC-01	P212A	24	1	4
P-BC-03	P212B	21	4	0
P-BC-01	P213A	47	5	4
P-BC-03	P213B	51	0	12
P-BC-01	P214A	8	0	0
P-BC-03	P214B	10	0	0
P-BE-01	P216A	15	0	0
P-BE-01	P216B	20	0	2
P-BE-02	P216C	14	0	2
P-BE-02	P216D	15	0	0

Table 6-4.4-1
(Concluded)

ISOMETRIC DRAWING	PENETRATION NUMBER	NUMBER OF SUPPORTS		
		EXISTING	NEW	MODIFIED
P-BE-01	P-217A	60	0	2
P-BE-02	P-217B	52	0	6
P-GS-01	P-219	13	2	0
P-GS-01	P-220	39	0	4
P-EE-01	P-222	5	4	0
P-EE-01	P-223	5	0	0

6-5.0 EQUIPMENT AND VALVES

As an integral part of the TAP analysis, the Hope Creek equipment and valves associated with the piping have been evaluated in accordance with the criteria established in NUREG-0661 (Reference 1).

The components, equipment, and valves which are examined are described in Section 6-5.1. The loads and load combinations for which the equipment, components, and valves are evaluated are described and presented in Section 6-5.2. The acceptance limits to which the analysis results are compared and the analysis methodologies used to evaluate the effects of the loads and load combinations on the equipment and valves are discussed in Section 6-5.3. Analysis results and conclusions are presented in Section 6-5.4.

6-5.1 Component Description

The equipment evaluated for TAP loads includes pump and turbine nozzles which act as termination points, pipe mounted valves, flanges, water seal expansion joints, and suction strainers.

The TAP systems which terminate at equipment consist of the RHR, core spray, HPCI, and RCIC systems. Valves that have been evaluated are included in the piping structural models described in Sections 6-2.4.1 and 6-3.4. The types of valves represented consist of gate, globe, check, relief, and butterfly valves. Valves are generally equipped with motor or air operators. Suction strainers are attached to eleven of the torus internal piping systems and are included in the piping system evaluation.

6-5.2 Loads and Load Combinations

The loads acting on the valves, valve operators, flanges, water seal expansion joints, strainers, and equipment nozzles are caused by the response of the piping systems to the loads defined in Sections 6-2.2.1 and 6-3.2.1. Strainers are also subjected to direct application of the hydrodynamic loads described in Section 6-2.2.1. The results of the component evaluations are used to establish compliance with the operability and functionality criteria of NUREG-0661.

Equipment nozzle connections are modeled as rigid anchors in the piping system analyses, as described in Section 6-2.4.1. Reaction loads at the nozzles are computed using the governing load combinations listed for the piping supports in Table 6-4.2-1 (excluding operating loads (OL) which have a negligible effect on the nozzles). These loads are used in the evaluation of the equipment, as described in Section 6-5.3.

Valve accelerations are calculated using the governing load combinations listed for the piping system analyses in Table 6-2.2-4. The acceleration components obtained from the piping analysis are used in the evaluation of the valves and valve operators, as described in Section 6-5.3.

Accelerations and hydrodynamic loads on strainers are also calculated using the governing load combinations listed for the piping system analyses in Table 6-2.2-4. The acceleration components obtained from the piping analysis and the directly applied strainer hydrodynamic loads are used in the evaluation of the strainers as described in Section 6-5.3.

In accordance with the original design criteria, equipment nozzles, valves and associated valve operators, flanges, expansion joints, and strainers have been designed and qualified by the manufacturers for load, displacement, and acceleration magnitudes defined in the Hope Creek FSAR. These limits have been used in evaluating equipment operability and functionality.

6-5.3 Methods of Analysis and Acceptance Criteria

The equipment described in Section 6-5.1 is evaluated for the loading combinations described in Table 6-4.2-1. Nozzle loads are evaluated by comparison with the nozzle allowables specified by the equipment manufacturers for the specified Service Levels.

The valves located in TAP systems are classified as ASME Code, Section III, Class 2 components. In performing the valve evaluations, the resultant horizontal and vertical accelerations have been determined from the piping analyses in the direction of the weak axis of the valve. The resultant valve accelerations from individual loads are combined in accordance with Table 6-2.2-4. The valve acceleration allowables listed in Table 6-5.4-1 which are used in the evaluations have been derived from the valves' original design criteria.

The strainers described in Section 6-5.1 are evaluated for acceleration and hydrodynamic loadings contained in loading combination Table 6-2.2-4. Strainer loads are evaluated by comparison with strainer allowables developed in accordance with the original strainer design bases.

Flanges are evaluated for the loading combinations contained in Table 6-2.2.4. To qualify the flanges, resultant loadings at the flange locations are compared to ASME code flange allowables.

The water seal expansion joints are evaluated by comparing maximum displacements from the piping analyses at expansion joint locations to manufacturer's allowable displacements.

6-5.4 Analysis Results and Conclusions

The results of the equipment and component evaluations conducted concluded that the acceptance criteria as described in Section 6-5.3 have been satisfied.

The functionality and operability assessment of the valves concluded that all valves met the acceptance criteria as described in Section 6-5.3.

Table 6-5.4-1 provides the resultant valve accelerations derived from the piping system analyses along with the allowable accelerations.

The results of the strainer, equipment nozzle, flange, and expansion joint evaluations conducted concluded that the acceptance criteria as described in Section 6-5.3 have been satisfied.

Table 6-5.4-1

ANALYSIS RESULTS FOR VALVE ACCELERATIONS

PENETRATION NUMBER	VALVE I.D.	MAXIMUM ACCELERATION FOR ALL EVENT COMBINATIONS (g)	ALLOWABLE ACCELERATION (g)
P201	V006	7.5	7.50
P202	V009	4.2	6.00
P203	V016	2.1	6.00
P204	V256 V010 V007	5.5 5.2 4.3	5.65 6.00 6.00
P207	V005	4.0	6.00
P208	V003	3.7	6.00
P209	V007	2.1	6.00
P211A	V001	3.1	6.00
P211B	V006	3.2	6.00
P211C	V103	3.2	6.00
P211D	V098	3.1	6.00
P212A	V028	2.7	6.00
P212B	V214 V131 V128	2.3 5.5 2.2	6.00 5.53 6.00

Table 6-5.4-1

(Concluded)

PENETRATION NUMBER	VALVE I.D.	MAXIMUM ACCELERATION FOR ALL EVENT COMBINATIONS (g)	ALLOWABLE ACCELERATION (g)
P213A	V255	3.4	5.60
	V010	4.0	6.00
P213B	V253	3.8	5.60
	V107	4.1	6.00
P216A	V019	1.4	6.00
P216B	V020	1.4	6.00
P216C	V018	1.4	6.00
P216D	V017	1.4	6.00
P217A	V026	2.3	6.00
P217B	V025	3.8	6.00
	V035	4.1	6.00
P220	V022	1.7	6.00
P222	V001	6.0	6.00
	V002	6.0	6.00
P223	V003	4.2	6.00
	V004	2.9	6.00

6-6.0 SUPPRESSION CHAMBER PENETRATIONS

An evaluation of the NUREG-0661 requirements which affect the design adequacy of the Hope Creek torus attached piping (TAP) penetrations is presented in the following sections. This evaluation includes both small bore and large bore penetrations. The general criteria used in this evaluation are contained in Volume 1.

The components which are analyzed are described in Section 6-6.1. The loads and load combinations for which the penetrations are evaluated are described and presented in Section 6-6.2. The acceptance limits to which the analysis results are compared are discussed and presented in Section 6-6.3. The analysis methodology used to evaluate the effects of the loads and load combinations on the penetrations, including consideration of fatigue effects, is discussed in Section 6-6.4. The analysis results and conclusions are presented in Section 6-6.5.

6-6.1 Component Description

The large bore piping suppression chamber penetrations evaluated in this section are numbered and located as shown in Figure 6-2.1-1. The principal components of the penetrations consist of the nozzles and the insert plates, as shown in Figure 6-6.1-1. The nozzle extends from the outer circumferential pipe weld through the insert plate to the inner circumferential pipe weld or flange. The insert plate provides local reinforcement of the suppression chamber shell near the penetration. Additional reinforcement is provided for several of the penetrations, as shown in Table 6-6.1-1 and Figures 6-6.1-2 through 6-6.1-4.

There are two general types of penetration reinforcements. Several of the penetrations are reinforced by the addition of 3/4" thick plates welded to the inner or outer penetration nozzles as shown in Figure 6-6.1-2. A second type of penetration reinforcement is used for penetrations P212A and B. This type of penetration reinforcement as shown in Figures 6-6.1-3 and 6-6.1-4 consists of an arrangement of plates located inside and outside the suppression chamber. The external reinforcement includes two 1" thick saddle plates welded to the penetration nozzle and six

reinforcing arms which extend to the suppression chamber shell. The reinforcing arms are connected to pad plates on the suppression chamber shell or are directly attached to the penetration insert plate. The internal reinforcement consists of four 3/4" thick stiffener plates attached to the insert plate and to the penetration nozzle.

Each penetration is designed to resist TAP reaction loads produced by suppression chamber motions due to normal loads and hydrodynamic loads, and due to normal and hydrodynamic loads acting directly on the piping system.

Table 6-6.1-1

PENETRATION REINFORCEMENT SCHEDULE

PENETRATION NUMBER	PENETRATION SIZE (NOM. DIA)	REINFORCEMENT TYPE	REFERENCE FIGURE
P213A	10"	NOZZLE PLATES	FIGURE 6-6.1-2 (1)
P213B	10"	NOZZLE PLATES	FIGURE 6-6.1-2 (1)
P217A	10"	NOZZLE PLATES	FIGURE 6-6.1-2 (1)
P217B	10"	NOZZLE PLATES	FIGURE 6-6.1-2 (1)
P222	8"	NOZZLE PLATES	FIGURE 6-6.1-2 (1)
P208	6"	NOZZLE PLATES	SIMILAR TO FIGURE 6-6.1-2 (2)
P212A	18"	SUPPORT ARMS AND STIFFENERS	FIGURES 6-6.1-3 & 4
P212B	18"	SUPPORT ARMS AND STIFFENERS	FIGURES 6-6.1-3 & 4

Notes:

1. Four reinforcement plates on inner penetration nozzle.
2. Two reinforcement plates on outer penetration nozzle.

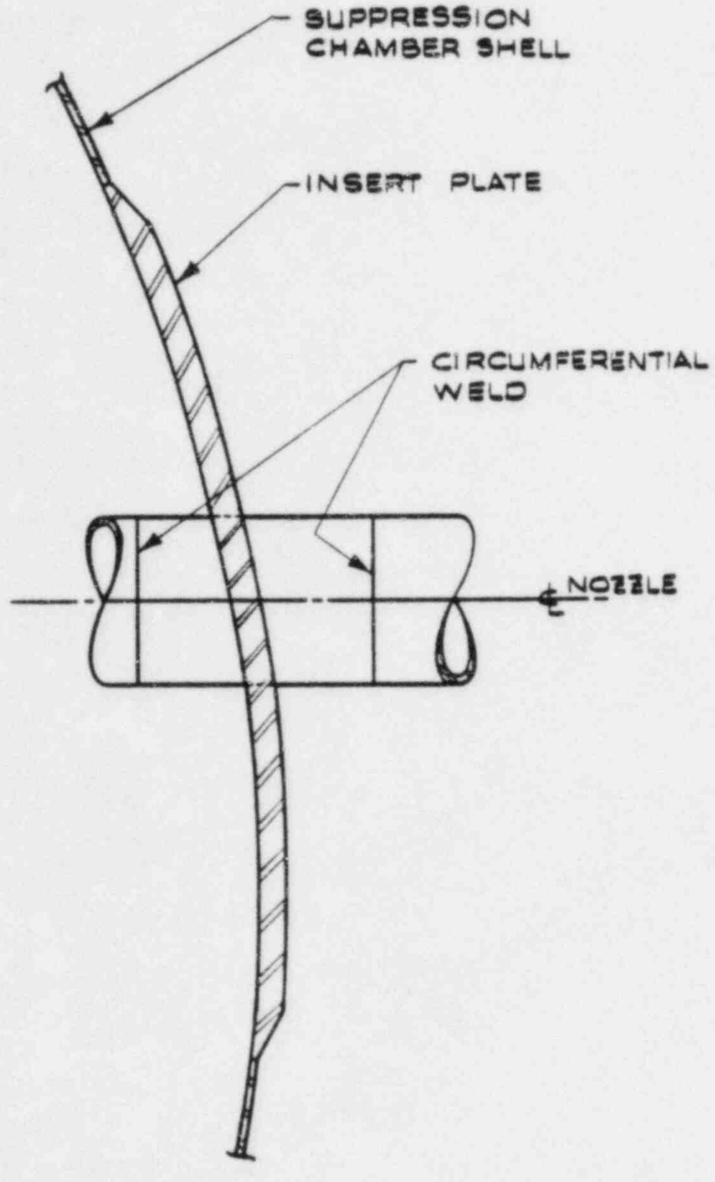
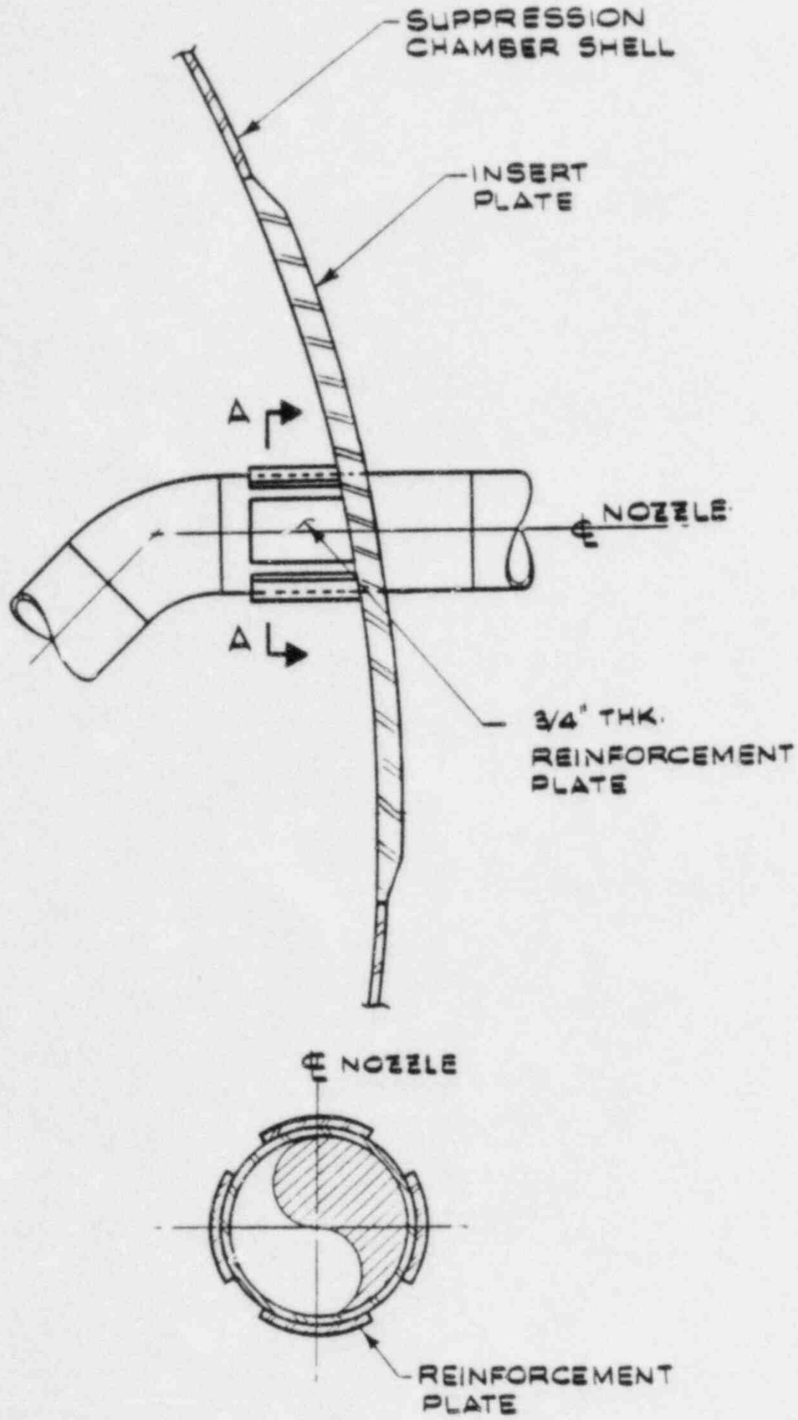


Figure 6-6.1-1

TYPICAL UNREINFORCED PENETRATION



SECTION A-A

Figure 6-6.1-2

TYPICAL PENETRATION WITH
NOZZLE REINFORCEMENT ONLY

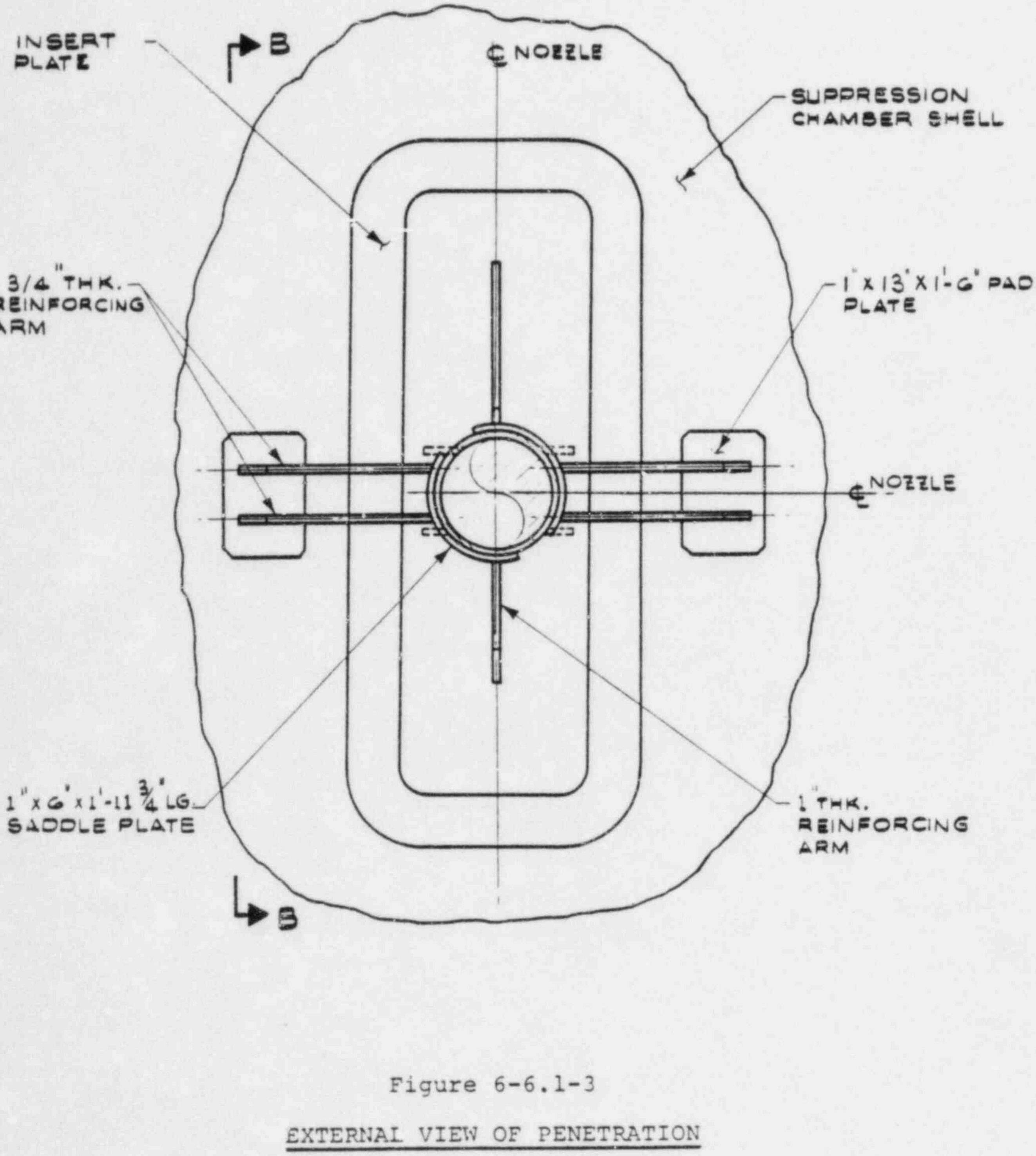


Figure 6-6.1-3

EXTERNAL VIEW OF PENETRATION
P212A AND B REINFORCEMENT

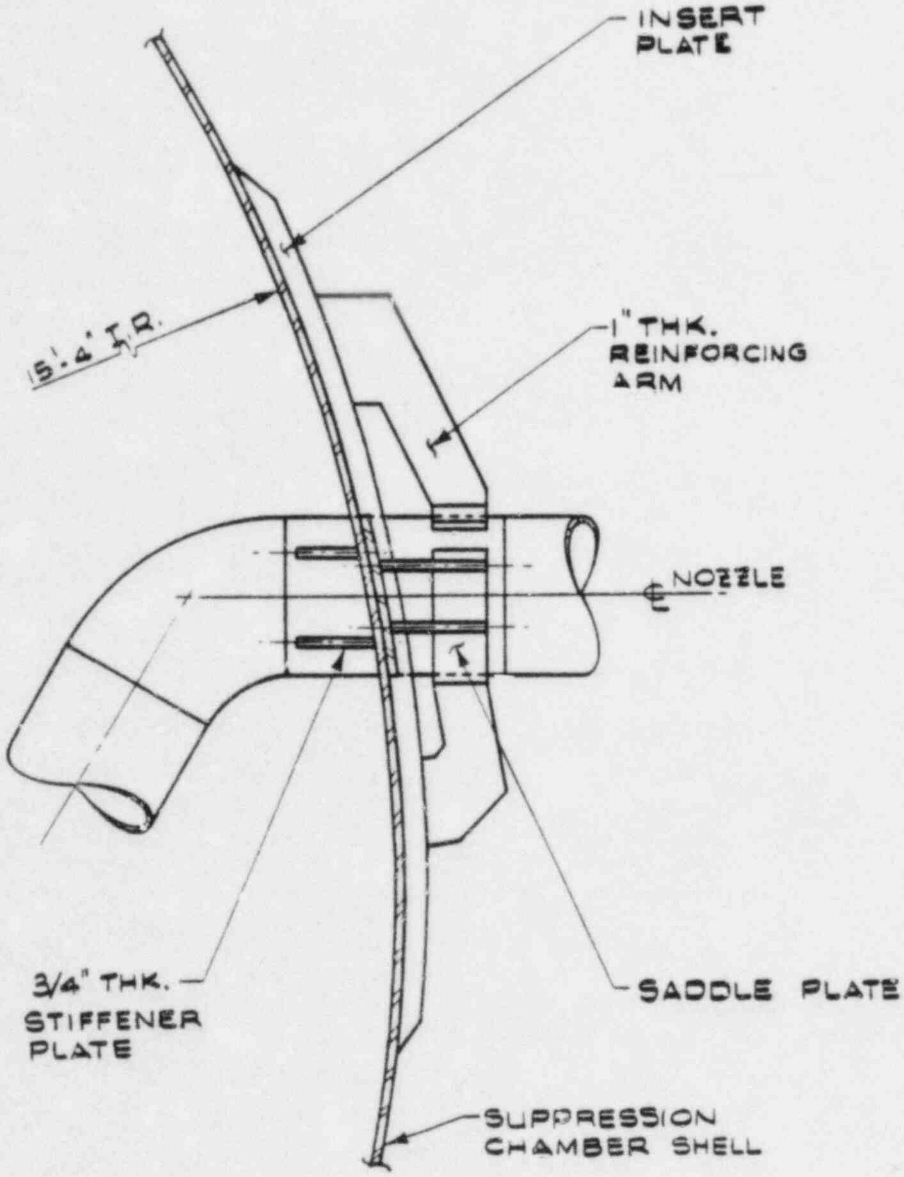


Figure 6-6.1-4

REINFORCEMENT DETAILS FOR PENETRATION P212A AND B

6-6.2 Loads and Load Combinations

The loads for which the Hope Creek suppression chamber penetrations are evaluated are defined in NUREG-0661 on a generic basis for all Mark I plants. Torus attached piping reaction loads for each penetration are derived from the piping analyses described in Sections 6-2.4 and 6-3.4. The controlling reaction loads which act on the penetrations are discussed in Section 6-6.2.1.

Using the event combinations, and the event sequencing defined in NUREG-0661 and discussed in Volume 1, the governing load combinations which affect the penetrations are formulated. The load combinations are discussed and presented in Section 6-6.2.2.

6-6.2.1 Loads

The loads acting on the suppression chamber penetrations are categorized as follows:

1. Dead Weight
2. Seismic
3. Pressure and Temperature
4. Operating
5. Static Torus Displacement
6. Safety Relief Valve Discharge
7. Vent Clearing
8. Pool Swell
9. Condensation Oscillation
10. Chugging
11. Torus Motion

Loads in the above categories include those acting on torus attached piping discussed in Section 6-2.2.1 and those acting on the torus shell discussed in Volume 2. Loads acting directly on torus attached piping systems result in reaction loads on the penetrations. Loads acting directly on the torus shell result in suppression chamber motions. The suppression chamber motions excite the attached piping systems, which produce additional reaction loads on the penetrations. In

addition, loads acting directly on the torus shell produce stresses in the shell and insert plate, which are included in the evaluation as discussed in Section 6-6.4.

The reaction loads used in the suppression chamber penetration evaluation for each load category are taken from the TAP system evaluation described in Section 6-2.4. The components of these reaction loads at the penetrations, as shown in Figure 6-6.2-1, consist of the forces and moments acting on the penetration nozzle both inside and outside the suppression chamber.

Design pressures and temperatures used for the piping systems and the suppression chamber penetration evaluation include those relating to the time period within the Mark I Program event duration. The piping system pressures and temperatures defined in Section 6-2.2.1 are applied to the nozzle portion of the penetrations whereas pressures and temperatures defined for the suppression chamber in Volume 2 are considered in evaluating the insert plate and torus shell portions of the penetration.

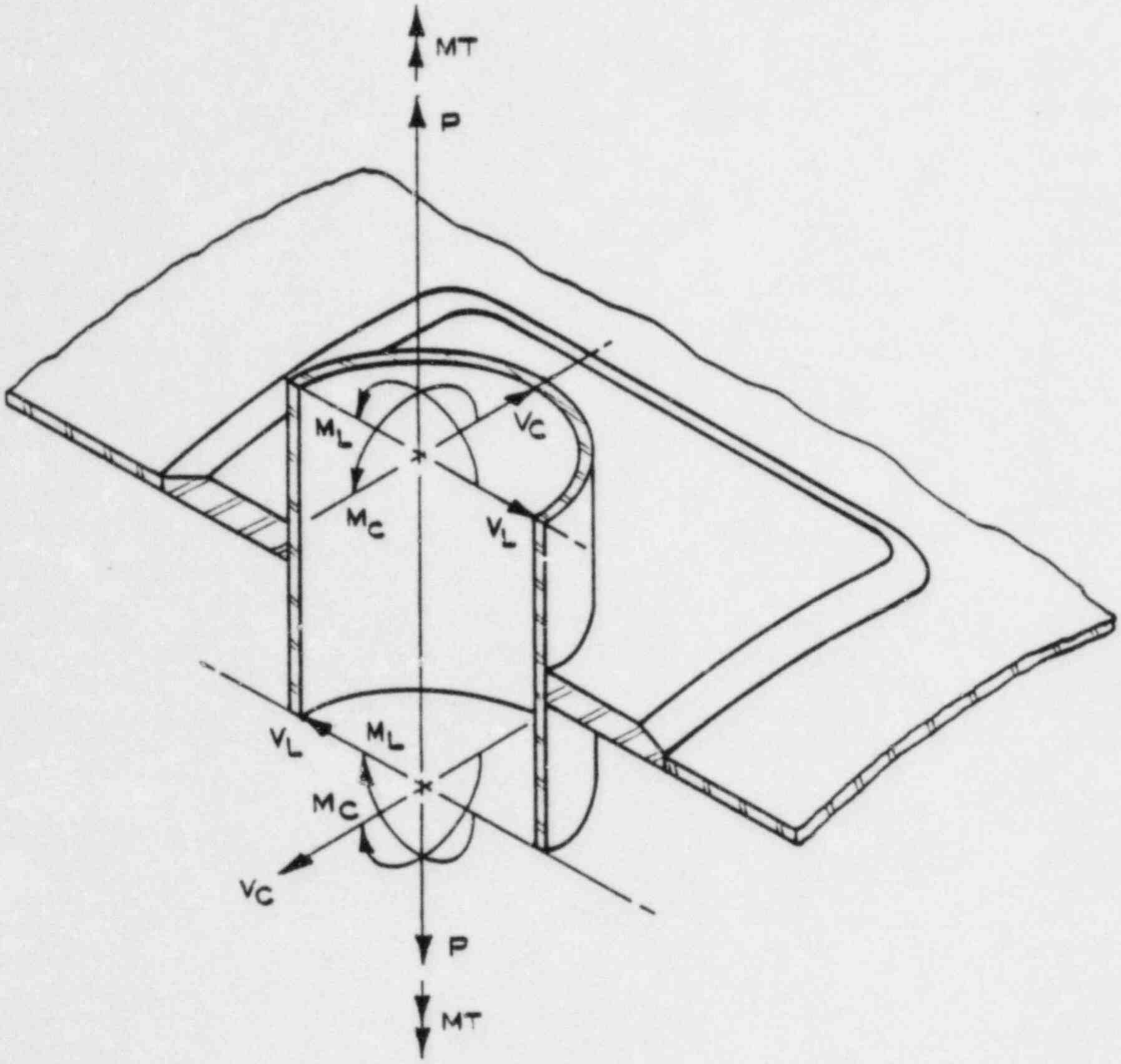


Figure 6-6.2-1

TYPICAL TAP LOADS ON PENETRATION

6-6.2.2 Load Combinations

The loads for which the suppression chamber penetrations are evaluated are presented in Section 6-6.2.1. The general NUREG-0661 criteria for grouping the loads into load combinations are discussed in Volume 1. Not all load combinations for each event are examined, since many have the same or higher allowable stresses and are enveloped by others which contain the same or additional loads. Table 6-6.2-1 shows the governing load combinations evaluated for the suppression chamber penetrations. For the controlling load combination considered, the dynamic loads are combined using the SRSS method as described in Reference 9.

Table 6-6.2-1

GOVERNING PENETRATION LOAD COMBINATIONS AND SERVICE LEVELS

LOAD COMBINATION NUMBER	LOAD COMBINATIONS (1,2)	SERVICE LEVEL
CHUG-14	$DW + P_O + TE_1 + THAM_1 + TD + OL + QAB + QAB_I + QAB_D + OBE_I + + OBE_D + CHUG + CHUG_I + CHUG_D$	B
CO-20	$DW + P_O + TE_1 + THAM_1 + TD + OL + OBE_I + OBE_D + CO + CO_I + CO_D$	B

Notes:

1. See Section 6-2.2.1 for definition of symbols used in load combination.

2. Use the governing case of TD_1, TD_2, or TD_3.

6-6.3 <u>Analysis Acceptance Criteria</u>

The acceptance criteria defined in NUREG-0661 on which the Hope Creek suppression chamber penetrations analysis is based are discussed in Volume 1. In general, the acceptance criteria follow the rules contained in the ASME Code, Section III, Division 1, 1977 Edition up to and including the 1977 Summer Addenda (Reference 6). The corresponding service level limits and allowable stresses are also consistent with the requirements of the ASME Code and NUREG-0661.

The suppression chamber penetrations and penetration reinforcements are evaluated in accordance with the requirements for Class MC components and supports contained in the ASME Code. The jurisdictional boundaries for the penetration Class MC components and component supports are defined as follows.

The penetration nozzles, insert plates, reinforcement plates, saddle plates, pad plates, and the suppression chamber shell adjacent to the penetrations are classified as MC components. The associated attachment welds which join the nozzle and reinforcement plates, and the pad plates and torus shell, are classified as Class MC component welds. The attachment welds which

join the internal gussets to the nozzle and insert plate for penetrations P212A and B are also classified as MC components welds. The reinforcing arms and attachment welds to the saddle plates and pad plates for penetrations P212A and B are classified as NF component supports. The internal gusset plates for penetrations P212A and B are also classified as NF component supports. Table 6-6.3-1 shows the allowable stresses for the components of the suppression chamber penetrations. The allowable stresses are determined at the maximum temperature of each component for Service Level B conditions.

Table 6-6.3-1

ALLOWABLE STRESSES FOR PENETRATIONS

ITEM	CODE CLASSIFICATION	TYPE OF STRESS	SERVICE LEVEL B
COMPONENTS	NE (1)	P_m P_L/P_L+P_b P_L+P_b+Q	1.0 S_{mc} 1.5 S_{mc} 3.0 S_{ml}
SUPPORTS	NF (2)	P_m P_m+P_b	0.6 S_y 0.6 S_y
WELDS	NE (1)	PRIMARY SECONDARY	0.55 S_{mc} 0.55x3.0 S_{ml}
	NF (2)	THROAT (3)	21 ksi

Notes:

1. See Reference 6, Subsection NE, Table NE-3221-1 for components and paragraph NE-3356 for welds.
2. See Reference 6, Article XVII-2000 for supports, and Subsection NF, Table NF-3292.1-1 for welds.
3. Allowable weld stress based on tensile stress of material.

6-6.4 Methods of Analysis

The loads for which the suppression chamber penetrations are evaluated are discussed in Section 6-6.2.1. The methodology used to evaluate the penetrations for these loadings is discussed in the following paragraphs.

Penetrations P212A and B which include additional reinforcing arms have been evaluated using finite element model. The small bore, unreinforced large bore, and penetrations with added nozzle reinforcements only are evaluated using methods based on closed-form solutions for nozzle-type attachments to cylindrical vessels.

A single finite element model representing both P212A and B is used. The model consists of the penetration nozzle, the insert plate, a portion of the suppression chamber shell, the reinforcing arms, pad plates, nozzle saddle plates, and internal stiffener plates. Thin plate finite elements are used to model each component explicitly. The analytical model of the penetration is shown in Figure 6-6.4-1.

The entire length of each nozzle is modeled between the inner and outer piping/nozzle circumferential welds nearest to the suppression chamber shell.

The portion of the suppression chamber shell included in the model is chosen to minimize the boundary effects in the region of stress evaluation. Translational restraints are imposed at the boundary nodes on the suppression chamber shell portion of the model. Where pad plates are attached to the suppression chamber, shell element thicknesses are increased to include the pad plate thickness.

Mechanical and thermal reaction loads at the penetrations are taken from the piping system analysis results and applied to the ends of the nozzles. The force and moment components for each reaction load case are conservatively applied to the analytical model in a manner which maximizes penetration stresses.

The temperature differential between the nozzle and the suppression chamber shell is evaluated for those systems defined to be at maximum operating temperatures during the time of peak hydrodynamic loadings. For the remaining systems, the differential temperatures which

occur during the time of peak hydrodynamic loads are negligible.

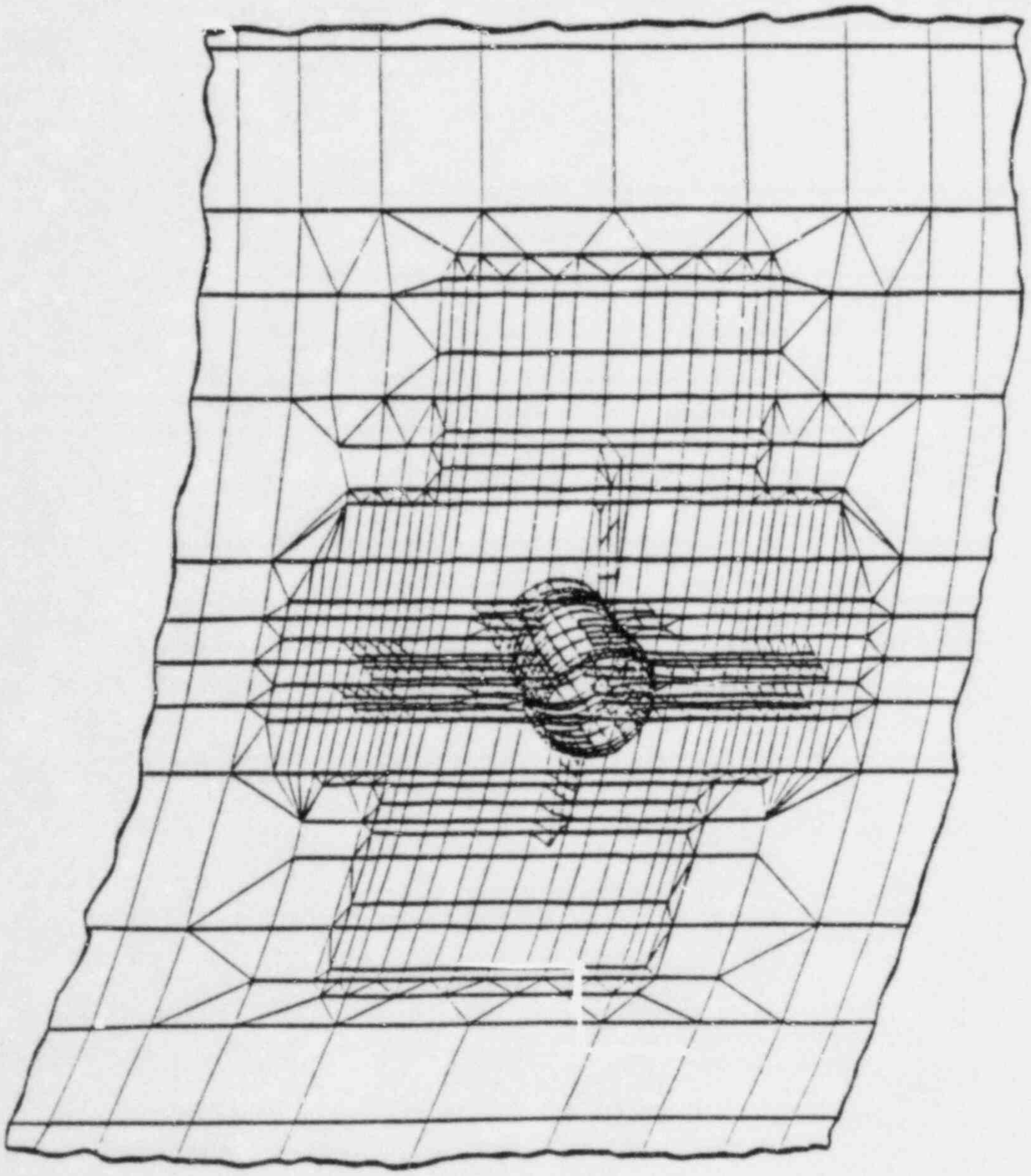
The stresses in the suppression chamber shell and insert plate due to piping reactions are added to the stresses in the suppression chamber shell due to loads acting directly on the suppression chamber as described in Section 6-6.2.1. These stresses are taken from the suppression chamber analysis results discussed in Volume 2.

For the controlling load combination considered, the maximum stress intensities for each penetration component are calculated and compared to allowable stresses listed in Table 6-6.3-1.

The small bore, large bore unreinforced, and nozzle reinforced penetrations are evaluated in a manner similar to the procedure described above. For these penetrations, however, computer codes based on closed-form solutions for nozzle-type attachments to cylindrical vessels is used. The mechanical and thermal loads from the piping analysis are applied to the nozzle ends and to the shell/nozzle intersection. The maximum stress intensities for each penetration

component are calculated and compared to the allowable stresses in Table 6-6.3-1.

Fatigue effects for the penetration with the highest stress levels and maximum loading cycles are evaluated. The number of load cycles for Mark I loads is established using the suppression chamber analysis results presented in Volume 2. The alternating stress intensity for each loading is calculated and fatigue strength reduction factors of 2.0 for major component stresses and 4.0 for component weld stresses are conservatively applied. The governing cumulative fatigue usage factor is determined by calculating fatigue usage for the controlling event combination.



Note:

1. For clarity, only the refined mesh portion of the model is shown.

Figure 6-6.4-1

FINITE ELEMENT MODEL FOR PENETRATIONS P212A AND B

6-6.5 Analysis Results and Conclusions

The geometry, loads and load combinations, acceptance criteria, and analysis methods used in the evaluation of the Hope Creek suppression chamber penetrations are presented and discussed in the previous sections. The results from the evaluation of the penetrations are presented in the following paragraphs.

The unreinforced small bore, large bore and reinforced penetrations are evaluated and found to be within the specified allowable limits. Table 6-6.5-1 presents a comparison of the calculated and allowable stress values for the representative unreinforced and reinforced penetrations.

The cumulative fatigue usage factors for the controlling component and weld are within the allowable fatigue usage factor of 1.0.

The suppression chamber penetrations, therefore, are adequate and all applicable NUREG-0661 requirements have been satisfied.

Table 6-6.5-1

STRESS SUMMARY OF REPRESENTATIVE PENETRATIONS

PENETRATION TYPE	COMPONENT	STRESS TYPE	CALC STRESS (ksi)	ALLOW. (ksi)	CALC. / ALLOW. (ksi)
UNREINFORCED PENETRATION	NOZZLE	PRIMARY	8.93	16.50	0.54
		SECONDARY	44.01	60.00	0.73
	SUPPRESSION CHAMBER SHELL	PRIMARY	22.21	28.95	0.77
		SECONDARY	62.45	69.45	0.90
REINFORCED PENETRATION	NOZZLE	PRIMARY	14.25	16.50	0.86
		SECONDARY	24.80	60.45	0.41
	SUPPRESSION CHAMBER SHELL	PRIMARY	14.72	28.95	0.51
		SECONDARY	58.41	69.45	0.84

6-7.0 LIST OF REFERENCES

1. "Mark I Containment Long-Term Program," Safety Evaluation Report, USNRC, NUREG-0661, July 1980; Supplement 1, August 1982.

2. "Mark I Containment Program Load Definition Report," General Electric Company, NEDO-21888, Revision 2, November 1981.

3. "Mark I Containment Program Plant Unique Load Definition," Hope Creek Generating Station, General Electric Company, NEDO-24579-1, Revision 1, January 1982.

4. Hope Creek Generating Station, Final Safety Analysis Report, Public Service Electric and Gas Company, Amendment No. 2, October 1983.

5. "Mark I Containment Program Structural Acceptance Criteria Plant Unique Analysis Applications Guide," Task Number 3.1.3, General Electric Company, NEDO-24583-1, October 1979.

6. ASME Boiler and Pressure Vessel Code, Section III, Division 1, 1977 Edition with Addenda up to and including Summer 1977.

7. "Mark I Containment Program Augmented Class 2/3 Fatigue Evaluation Method and Results for Typical Torus Attached and SRV Piping Systems," MPR Associates, Inc., MPR-751, November 1982.

8. Letter from D. B. Vassallo (NRC) to H. C. Pfefferlen (GE), "Evaluation of Adequacy of the Existing Mark I Downcomer Chugging Lateral Load Specification and Augmented ASME Class 2/3 Fatigue Evaluation Method for the Mark I Containment Piping Systems," dated November 9, 1983.

9. Letter from D. B. Vassallo (NRC) to H. C. Pfefferlen (GE), "Acceptability of SRSS Method for Combining Dynamic Responses in Mark I Piping Responses," dated March 10, 1983.

10. "Combining Modal Responses and Spatial Components in Seismic Response Analysis," USNRC, Regulatory Guide 1.92, Revision 1, February 1976.

11. Kennedy, R. P. and Kincaid, R. H., "CMDOF (Coupling of Multiple Degrees of Freedom), A Computer Program to Couple the Response of Structures and Supported Equipment for Multiple Degrees of Coupling Using the Results from Uncoupled Structure and Equipment Analysis," Structural Mechanics Associates, Version 1.2.0, December 3, 1982.