COM-02-041-7
Revision 0
May 1983
27.0200.2105

DRESDEN NUCLEAR POWER STATION
UNIT 3
PLANT UNIQUE ANALYSIS REPORT
VOLUME 7
TORUS ATTACHED PIPING AND SUPPRESSION CHAMBER PENETRATION ANALYSES

Prepared for:
Commonwealth Edison Company

Prepared by:
NUTECH Engineers, Inc.
San Jose, California

Approved by:

A. S. Herlekar, P.E. Project Engineer	Dr. T. P. Khatua, P.E. Engineering Manager
E. V. Harlow Project Leader	T. W. Soo Hoo, P.E. Engineering Manager
J. A. Gavula, P.E. Project Engineer	J. D. Muffett, P.E. Engineering Manager
H. L. Gustin, P.E. Project Engineer	Dr. L. C. Hsu Engineering Manager

Issued by:

T. J. Victorine, P.E. Project Manager	R. H. Buchholz Project Director

nutech ENGINEERS

REVISION CONTROL SHEET

TITLE: Dresden Nuclear Power Station Unit 3, Plant Unique Analysis Report, Volume 7

REPORT NUMBER: COM-02-041-7 Revision 0

T. J. Victorine/Project Manager ______ INITIALS

A. G. Brnilovich/Project Manager ______ INITIALS

A. K. Moonka/Project Manager AKM INITIALS

______ INITIALS

______ INITIALS

______ INITIALS

______ INITIALS

EFFECTIVE PAGE(S)	REV	PREPARED	ACCURACY CHECK	CRITERIA CHECK	EFFECTIVE PAGE(S)	REV	PREPARED	ACCURACY CHECK	CRITERIA CHECK
7-ix through 7-xviii 7-1.1 through 7-1.10	0 ↓ 0			AKM ↓ AKM					

QEP-001.4-00

nutech ENGINEERS

REVISION CONTROL SHEET

TITLE: Dresden Nuclear Power Station Unit 3, Plant Unique Analysis Report, Volume 7

REPORT NUMBER: COM-02-041-7 Revision 0

Dr. T. P. Khatua, P.E./Engineering Mgr. TPK
INITIALS

A. S. Herlekar, P.E./Project Manager ASH
INITIALS

M. M. Habib/Consultant I MMH
INITIALS

J. I. Khan/Consultant I JIK
INITIALS

INITIALS

EFFECTIVE PAGE(S)	REV	PREPARED	ACCURACY CHECK	CRITERIA CHECK	EFFECTIVE PAGE(S)	REV	PREPARED	ACCURACY CHECK	CRITERIA CHECK
7-2.1 through 7-2.4	0	MMH	ASH	N/A					
7-2.5	↓	↓	JIK	N/A					
7-2.6	↓	↓	ASH	N/A					
7-2.7 through 7-2.13	↓	↓	JIK	N/A					
7-2.14 through 7-2.30	↓	↓	ASH	TPK					
7-2.31	↓	↓	JIK	TPK					
7-2.32 through 7-2.42	↓	↓	ASH	TPK					
7-2.43	↓	↓	JIK	ASH/TPK					
7-2.44 through 7-2.79	↓	↓	JIK	TPK					
7-2.80	↓	↓	JIK/ASH	TPK					
7-2.81	0	MMH	JIK/ASH	TPK					

QEP-001.4-00

nutech ENGINEERS

REVISION CONTROL SHEET

TITLE: Dresden Nuclear Power Station Unit 3, Plant Unique Analysis Report, Vol. 7

REPORT NUMBER: COM-02-041-7 Revision 0

J. A. Gavula, P.E./Engineer — JAG INITIALS

J. E. Neurauter, P.E./Engineer — JEN INITIALS

________ INITIALS

________ INITIALS

________ INITIALS

________ INITIALS

________ INITIALS

EFFECTIVE PAGE(S)	REV	PREPARED	ACCURACY CHECK	CRITERIA CHECK	EFFECTIVE PAGE(S)	REV	PREPARED	ACCURACY CHECK	CRITERIA CHECK
7-3.1 through 7-3.12	0	JAG	JEN	JEN	1-3.13 through 1-3.21	0	JAG	JEN	JEN

CEP-001.4-00

nutech ENGINEERS

REVISION CONTROL SHEET

TITLE: Dresden Nuclear Power Station, Unit 3, Plant Unique Analysis Report, Volume 7

REPORT NUMBER: COM-02-041-7 Revision 0

T. W. Soo Hoo/Principal Engineer — TWSH INITIALS

E. V. Harlow/Consultant I — E.V.H. INITIALS

G. S. Wallach/Consultant I — GSW INITIALS

INITIALS

INITIALS

EFFECTIVE PAGE(S)	REV	PREPARED	ACCURACY CHECK	CRITERIA CHECK	EFFECTIVE PAGE(S)	REV	PREPARED	ACCURACY CHECK	CRITERIA CHECK
7-4.1	0	E.V.H.	GSW	TWSH					
7-4.2	↓	↓	↓	↓					
7-4.3									
7-4.4									
7-4.5									
7-4.6									
7-4.7									
7-4.8									
7-4.9	0	E.V.H.	GSW	TWSH					

QEP-001.4-00

nutech ENGINEERS

REVISION CONTROL SHEET

TITLE: Dresden Nuclear Power Station Unit 3, Plant Unique Analysis Report, Volume 7

REPORT NUMBER: COM-02-041-7 Revision 0

Dr. T. P. Khatua, P.E./Engineering Mgr. — TPK — INITIALS

A. S. Herlekar, P.E./Project Engineer — ASH — INITIALS

M. M. Habib/Consultant I — MMH — INITIALS

J. I. Khan/Consultant I — JIK — INITIALS

________ — INITIALS

________ — INITIALS

________ — INITIALS

EFFECTIVE PAGE(S)	REV	PREPARED	ACCURACY CHECK	CRITERIA CHECK	EFFECTIVE PAGE(S)	REV	PREPARED	ACCURACY CHECK	CRITERIA CHECK
7-5.1	0	MMH	JIK	ASH/TPK					
7-5.2	↓	↓	↓	↓					
7-5.3									
7-5.4									
7-5.5									
7-5.6									
7-5.7	0	MMH	JIK	ASH/TPK					

QEP-001.4-00

nutech ENGINEERS

REVISION CONTROL SHEET

TITLE: Dresden Nuclear Power Station, Unit 3, Plant Unique Analysis Report, Volume 7

REPORT NUMBER: COM-02-041-7 Revision 0

H. L. Gustin/Engineer — HLG INITIALS

L. C. Hsu/Supervising Engineer — LCH INITIALS

Y. S. Wu/Consultant I — YSW INITIALS

A. Y. Kuo/Consultant I — AYK INITIALS

T. S. Hsu/Associate Engineer — TSH INITIALS

L. K. Chang/Specialist — LKC INITIALS

D. G. Lee/Consultant I — DGL INITIALS

A. K. Rao/Consultant II — AKR INITIALS

EFFECTIVE PAGE(S)	REV	PREPARED	ACCURACY CHECK	CRITERIA CHECK	EFFECTIVE PAGE(S)	REV	PREPARED	ACCURACY CHECK	CRITERIA CHECK
7-6.1 through 7-6.3	0	HLG	YSW	LCH	7-6.19 through 7-6.22	0	HLG	AKR	LCH
7-6.4 through 7-6.8			LKC		7-6.23 through 7-6.25	0	HLG	DGL	LCH
7-6.9 through 7-6.13			TSH						
7-6.14 through 7-6-18	0	HLG	AYK	LCH					

QEP-001.4-00

nutech ENGINEERS

REVISION CONTROL SHEET

TITLE: Dresden Nuclear Power Station, Unit 3 Plant Unique Analysis Report Volume 7

REPORT NUMBER: COM-02-041-7 Revision 0

Dr. T. P. Khatua, P.E./Engineering Mgr. — TPK — INITIALS

A. S. Herlekar, P.E./Project Engineer — ASH — INITIALS

M. M. Habib/Consultant I — MMH — INITIALS

________ INITIALS

________ INITIALS

________ INITIALS

________ INITIALS

EFFECTIVE PAGE(S)	REV	PREPARED	ACCURACY CHECK	CRITERIA CHECK	EFFECTIVE PAGE(S)	REV	PREPARED	ACCURACY CHECK	CRITERIA CHECK
7-7.1	0	MMH	ASH	TPK					
7-7.2	0	MMH	ASH	TPK					

QEP-001.4-00

nutech ENGINEERS

ABSTRACT

The primary containments for the Dresden Nuclear Power Station Units 2 and 3 were designed, erected, pressure-tested, and N-stamped in accordance with the ASME Boiler and Pressure Vessel Code, Section III, 1965 Edition with addenda up to and including Summer 1965 for the Commonwealth Edison Company (CECo) by the Chicago Bridge and Iron Company. Since then new requirements have been established. These requirements affect the design and operation of the primary containment system and are defined in the Nuclear Regulatory Commission's (NRC) Safety Evaluation Report, NUREG-0661. This report provides an assessment of containment design loads postulated to occur during a loss-of-coolant accident or a safety relief valve discharge event. In addition, it provides an assessment of the effects that the postulated events have on containment systems operation.

This plant unique analysis report (PUAR) documents the efforts undertaken to address and resolve each of the applicable NUREG-0661 requirements. It demonstrates that the design of the primary containment system is adequate and that original design safety margins have been restored, in accordance with NUREG-0661 acceptance criteria. The Dresden Units 2 and 3 PUAR is composed of the following seven 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 LINE PIPING ANALYSIS
- Volume 6 - TORUS ATTACHED PIPING AND SUPPRESSION CHAMBER PENETRATION ANALYSES (DRESDEN UNIT 2)

o Volume 7 - TORUS ATTACHED PIPING AND SUPPRESSION CHAMBER PENETRATION ANALYSES (DRESDEN UNIT 3)

This volume documents the evaluation of the torus attached piping and suppression chamber penetrations. Volume 1 through 4 and 6 and 7 have been prepared by NUTECH Engineers, Incorporated (NUTECH), acting as an agent to the Commonwealth Edison Company. Volume 5 has been prepared by Sargent and Lundy (also acting as an agent to Commonwealth Edison Company), who performed the safety relief valve discharge line (SRVDL) piping analysis. Volume 5 describes the methods of analysis and procedures used in the SRVDL piping analysis.

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Concluded)

LIST OF ACRONYMS

ABS	Absolute Sum
ACI	American Concrete Institute
AISC	American Institute of Steel Construction
ASME	American Society of Mechanical Engineers
CECo	Commonwealth Edison Company
CO	Condensation Oscillation
DBA	Design Basis Accident
DBE	Design Basis Earthquake
DLF	Dynamic Load Factor
DOF	Degree of Freedom
DW	Dead Weight
ECCS	Emergency Core Cooling System
FSI	Fluid-Structure Interaction
HPCI	High Pressure Coolant Injection
IBA	Intermediate Break Accident
LBP	Large Bore Piping
LDR	Load Definition Report
LOCA	Loss-of-Coolant Accident
LPCI	Low Pressure Coolant Injection
NEP	Non-Exceedance Probability
NOC	Normal Operating Conditions
NRC	Nuclear Regulatory Commission
OBE	Operating Basis Earthquake
OL	Operating Loads

LIST OF ACRONYMS
(Concluded)

PS	Pool Swell
PUAAG	Plant Unique Analysis Applications Guide
PUA	Plant Unique Analysis
PUAR	Plant Unique Analysis Report
PULD	Plant Unique Load Definition
SAR	Safety Analysis Report
SBA	Small Break Accident
SBP	Small Bore Piping
SRSS	Square Root of the Sum of the Squares
SRV	Safety Relief Valve
SSE	Safe Shutdown Earthquake
TAP	Torus Attached Piping
VCL	Vent Clearing Loads

LIST OF TABLES

LIST OF TABLES
(Concluded)

LIST OF FIGURES

7-1.0 INTRODUCTION AND SUMMARY

In conjunction with Volume 1 of the plant unique analysis report, this volume (Volume 7) documents the efforts undertaken to address the requirements defined in NUREG-0661 (Reference 1) which affect the Dresden Unit 3 torus attached piping (TAP), including large and small bore piping and supports, piping equipment, and suppression chamber penetrations. The torus attached piping Plant Unique Analysis Report (PUAR) is organized as follows:

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

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

The introduction contains an overview discussion of the scope of the TAP and suppression chamber penetration evaluations as well as a summary of the results and conclusions resulting from the evaluations presented in later sections. Each of the analysis sections contains a comprehensive discussion of the loads and load combinations to be addressed, a description of the piping components or penetrations affected by these loads and load combinations, the methodology used to evaluate the effects of the loads and load combinations, and the evaluation results and acceptance limits to which the results are compared to ensure that the design is adequate.

7-1.1 Scope of Analysis

The general criteria presented in Volume 1 are used as the basis for the Dresden Unit 3 TAP and suppression chamber penetration evaluations described in this report. The investigation includes an evaluation of the large and small bore TAP, the related equipment (pumps, valves, turbines), and piping penetrations for the effects of loss-of-coolant accident (LOCA)-related and safety relief valve (SRV) discharge-related loads discussed in Volume 1 of this report, and defined by the Nuclear Regulatory Commission's (NRC) Safety Evaluation Report NUREG-0661 (Reference 1) and the "Mark I Containment Program Load Definition Report" (LDR) (Reference 2). Table 7-1.1-1 lists the large bore TAP systems and the associated penetrations. Figure 7-1.1-1 shows the locations of the penetrations on the torus.

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 Safety Analysis Report (SAR) (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 verify that the design of the torus attached piping and suppression chamber penetrations is adequate. Rigorous analytical techniques are used in this evaluation, utilizing detailed analytical models and refined methods for computing the dynamic response of the torus attached piping and penetrations, including consideration of the interaction effects of each piping system 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 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 containment structures (Reference 6).

Evaluation of the piping for fatigue effects stipulated in Volume 1 has been addressed generically for all Mark I plants by the Mark I Owners Group (Reference 7).

Table 7-1.1-1

IDENTIFICATION OF LARGE BORE TORUS ATTACHED PIPING SYSTEMS AND ASSOCIATED PENETRATIONS

SYSTEM	PENETRATION NUMBER	DESIGNATION OF LINE ATTACHED TO PENETRATION
ECCS SUCTION HEADER	X-303A,B,C,D	3-1501-24"
VACUUM RELIEF	X-304	3-1601-20"-LX
LPCI TEST LINE AND SPRAY HEADER DISCHARGE FROM PUMPS 3A/3B	X-310A	3-1517-14"-LX
	X-311A	3-1516-6"-LX
LPCI TEST LINE AND SPRAY HEADER DISCHARGE FROM PUMPS 3C/3D	X-310B	3-1522-14"-LX
	X-311B	3-1521-6"-LX
HPCI TURBINE EXHAUST	X-317	3-2306-16"-LX
PRESSURE SUPPRESSION	X-318	3-1603-18"-LX
CORE SPRAY 3A DISCHARGE	CONNECTING TO LPCI TEST LINE WITH PENETRATION X-310A	3-1406-8"-LX
CORE SPRAY 3B DISCHARGE	CONNECTING TO LPCI TEST LINE WITH PENETRATION X-310B	3-1409-8"-LX
LPCI PUMP 3A/3B SUCTION	CONNECTING TO ECCS SUCTION HEADER	3-1502-24"-LX
LPCI PUMP 3C/3D SUCTION	"	3-1507-24"-LX
CORE SPRAY 3A SUCTION	"	3-1401-16"-LX
CORE SPRAY 3B SUCTION	"	3-1402-16"-LX
HPCI PUMP SUCTION	"	3-2302-16"-LX

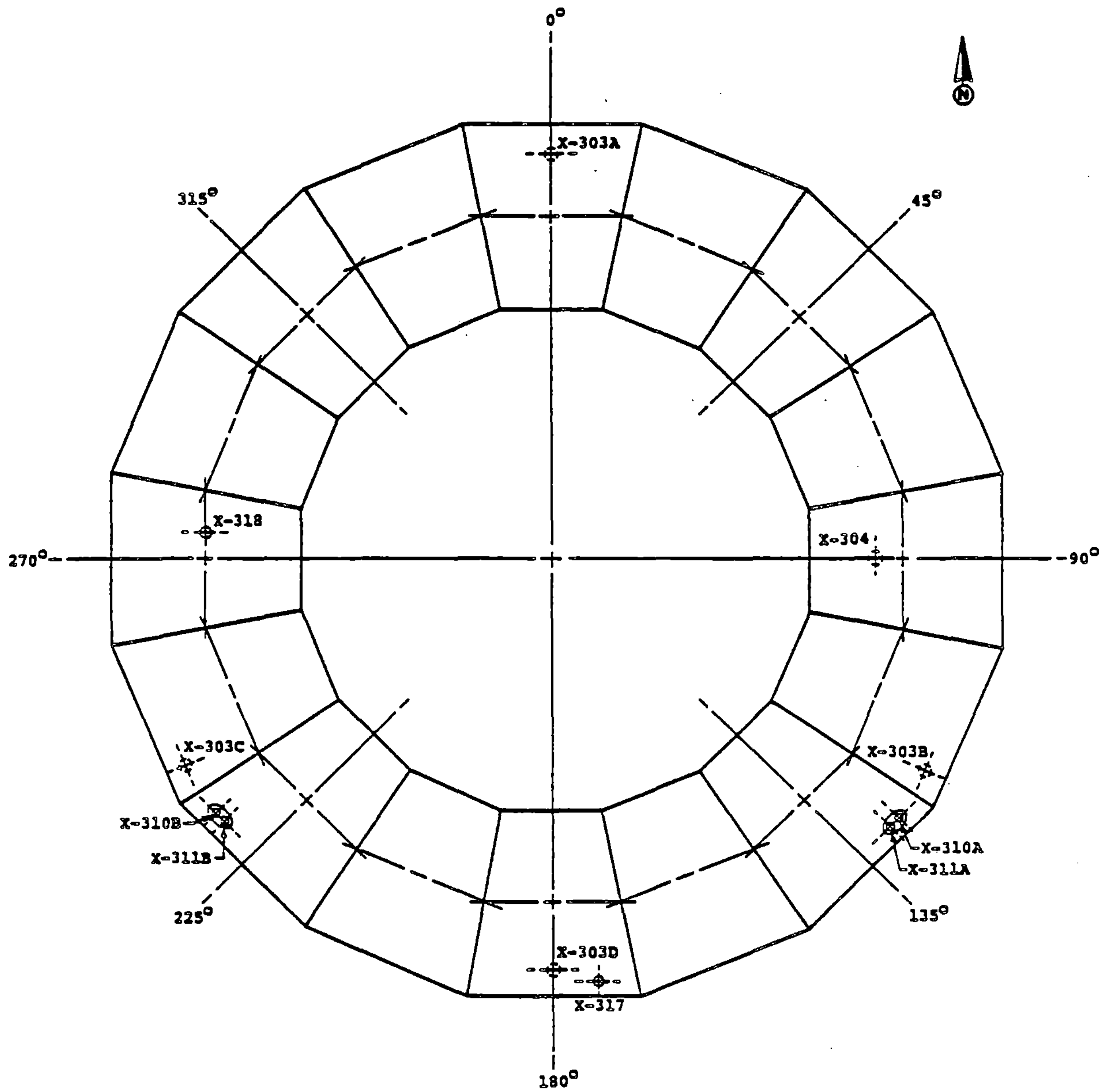


Figure 7-1.1-1

LARGE BORE TAP PENETRATION LOCATIONS IN TORUS - PLAN VIEW

7-1.2 Summary and Conclusions

An evaluation of the Dresden Unit 3 large and small bore torus attached piping, piping supports, equipment and valves, and suppression chamber penetrations has been performed for the systems as described in Sections 7-2.1 through 7-6.1.

The loads considered in the evaluation are described in Sections 7-2.2, 7-3.2, 7-4.2, 7-5.2, and 7-6.2. They include original loads as documented in the SAR plus additional loadings which are postulated to occur during small basis accident (SBA), intermediate basis accident (IBA) or design basis accident (DBA) LOCA-related events, and during SRV discharge events as defined in Volume 1.

Detailed analytical models are developed and utilized in calculating the response of the piping systems and the suppression chamber penetration loads. A combination of static, dynamic, and equivalent static analyses are performed and the results appropriately combined in accordance with NUREG-0661. For piping system components, the dynamic load responses have been combined using either the absolute sum (ABS) of the square root of the sum of the squares (SRSS). Results of the analyses are compared to the NUREG-0661 criteria as discussed in Volume 1.

The evaluation results show that the piping, piping supports, equipment, and suppression chamber penetration loads and stresses meet the requirements of NUREG-0661.

7-2.0 LARGE BORE PIPING

An evaluation of each of the NUREG-0661 requirements which affect the design adequacy of the Dresden Unit 3 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 components of the TAP systems which are analyzed are described in Section 7-2.1. The loads and load combinations for which the piping systems are evaluated are described and presented in Section 7-2.2. The acceptance limits to which the analysis results are compared are discussed and presented in Section 7-2.3. 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 7-2.4. The analysis results are presented in Section 7-2.5.

7-2.1 <u>Component Description</u>

The large bore TAP for Dresden Unit 3 consists of 4" and larger nominal diameter piping, which penetrates or is 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 schedules. Most of the piping consists of ASTM A106, Grade B carbon steel material. Some pipe segments are ASTM A358M TP304 stainless steel. Table 7-1.1-1 lists the Dresden Unit 3 large bore TAP systems along with their associated penetrations. Figure 7-1.1-1 shows the locations of penetrations on the torus.

Large bore TAP may be grouped into two general categories: torus external piping and torus internal piping. An example of a system with only torus external low pressure coolant injection (LPCI) piping is the pressure suppression system line. Typical systems having both torus external and internal piping are the high pressure coolant injection (HPCI) turbine exhaust line and the LPCI test line. Figure 7-2.1-1 shows an isometric view of a typical TAP system for Dresden Unit 3.

In addition to the large bore systems described above, one small diameter piping system (the HPCI pot drain line) is included in this section since it has been analyzed using the same methods applied to the large bore piping analyses.

The large bore piping suppression chamber penetrations evaluated for Dresden Unit 2 are numbered and located as shown in Figure 7-1.1-1. The principal components of the penetrations are the nozzles, the insert plates, and the "spider" reinforcements. The nozzle extends from the outer circumferential pipe weld through the insert plate to the inner circumferential pipe weld or flange. The insert plate and "spider" provide local reinforcement of the suppression chamber shell near the penetration.

Each penetration modification is designed to allow the penetrations to sustain TAP reaction loads produced by suppression chamber motions due to normal loads and hydrodynamic loads, while keeping component stress intensities below the specified allowable values. Sufficient similarities exist in the penetrations diameters, geometries, locations on the suppression chamber, reinforcements, and loadings to allow some grouping for analysis.

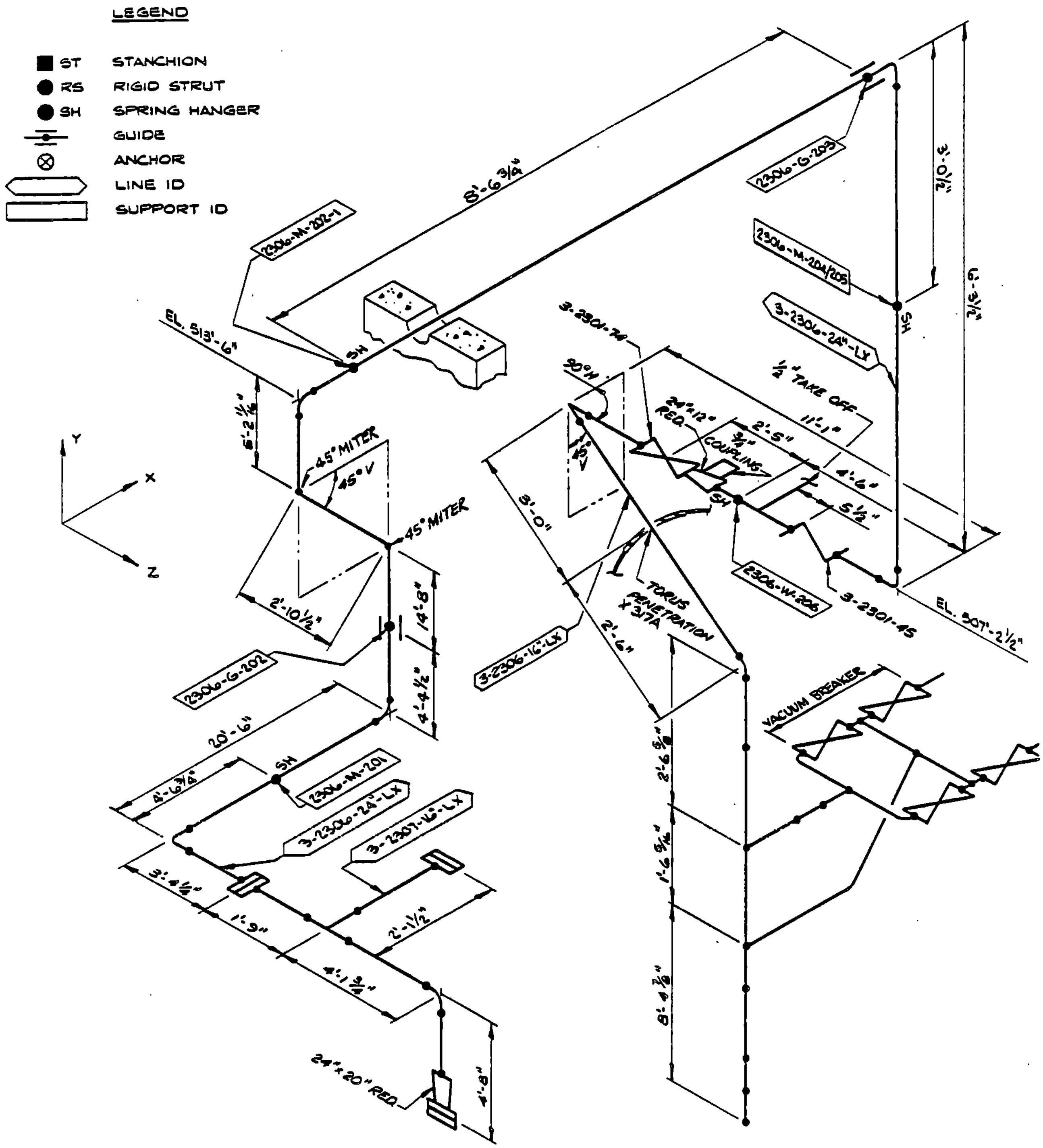


Figure 7-2.1-1

TAP SYSTEM ISOMETRIC AND SUPPORT LOCATIONS -

HPCI TURBINE EXHAUST LINE (X-317)

7-2.1.1 Torus External Piping

The torus external piping initiates at the penetration nozzles which are connected to the torus shell through insert plates, and terminates at anchor supports or equipment within the reactor auxiliary building. From the torus, the lines typically extend up to the building slab at an elevation of 517'-6". However, some lines extend up to slabs at elevations of 545'-6" and 588'-0".

The external piping is supported by hangers, rigid restraints, guides, and snubbers attached to building slabs or walls, or to main structural steel in the building. Figures 7-2.1-2 and 7-2.1-3 illustrate typical pipe supports outside the torus. Other components on these lines are valves and standard pipe fittings. Valve types are gate valves, swing check valves, and nozzle type relief valves.

Smaller lines branching off the large bore TAP are discussed in Section 7-3.0. Piping supports are described in Section 7-4.0. Equipment such as valves, pumps, and turbines are described in Section 7-5.0. The suppression chamber penetrations are described in Section 7-6.0.

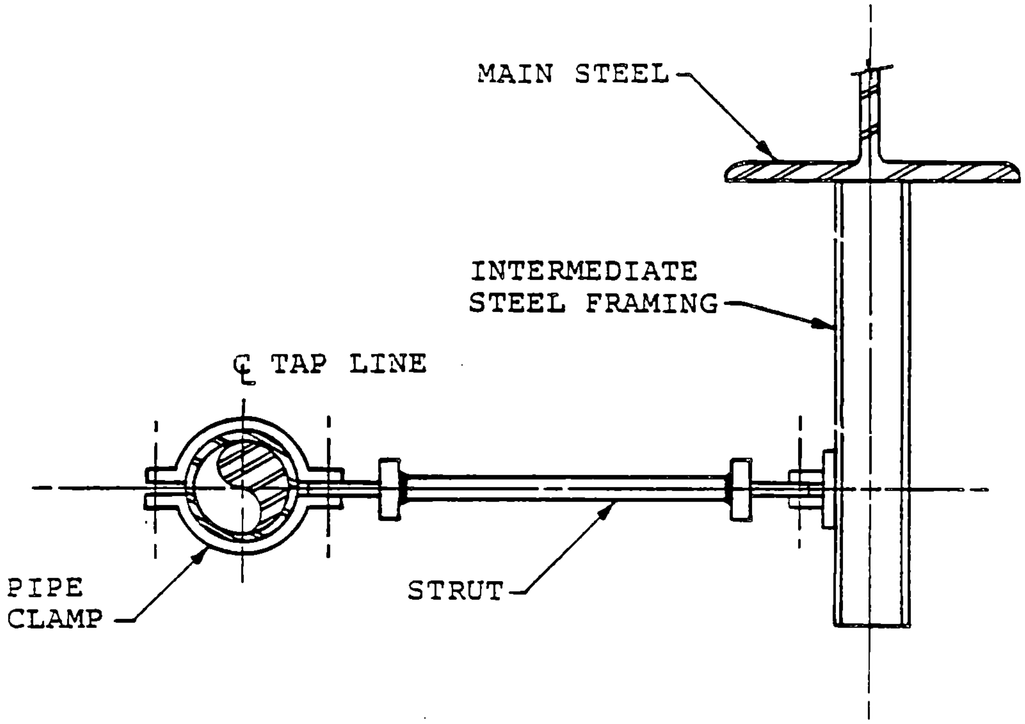


Figure 7-2.1-2

TYPICAL TAP SYSTEM SUPPORT OUTSIDE TORUS

ATTACHED TO MAIN STEEL

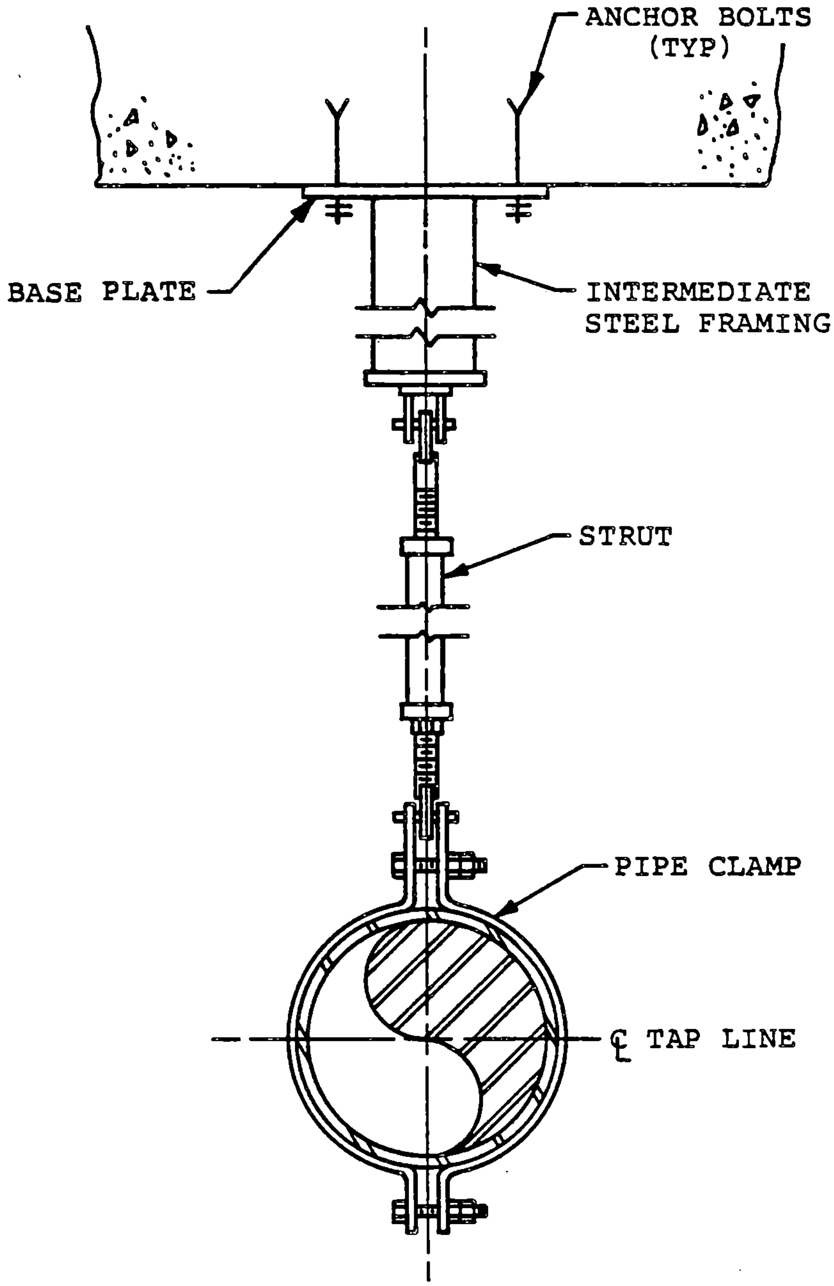


Figure 7-2.1-3

TYPICAL TAP SYSTEM SUPPORT OUTSIDE TORUS

ATTACHED TO CONCRETE WALL OR SLAB

7-2.1.2 Torus Internal Piping

Piping internal to the torus may be categorized into three basic configurations:

a) Short penetration nozzles projecting inside the torus. Typical example of this type of configuration is the suction header which penetrates the lower half of the torus. The suction header has a strainer connected to its inner nozzle flange. Figure 7-2.1-4 shows a typical suction header penetration and strainer.

b) A short segment of piping inside the torus, supported by rigid struts attached to the torus shell or to the ring girders (Figure 7-2.1-5).

c) A long length of pipe running through more than a single torus bay and supported at intervals by rigid struts connected to the torus shell or ring girders (Figure 7-2.1-6).

Supports for the torus internal piping are discussed in Section 7-4.0

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

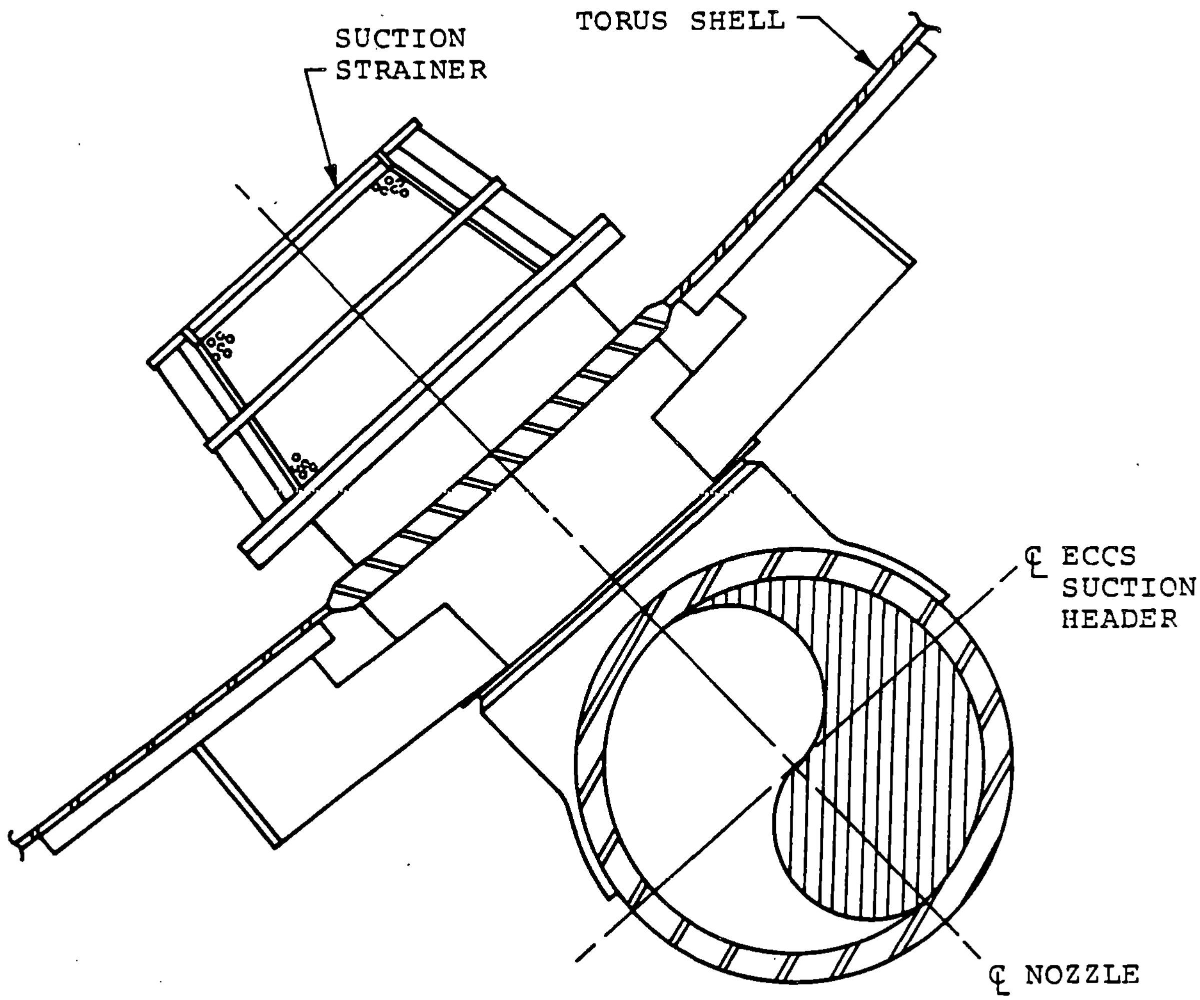


Figure 7-2.1-4

TYPICAL SUCTION STRAINER PENETRATION

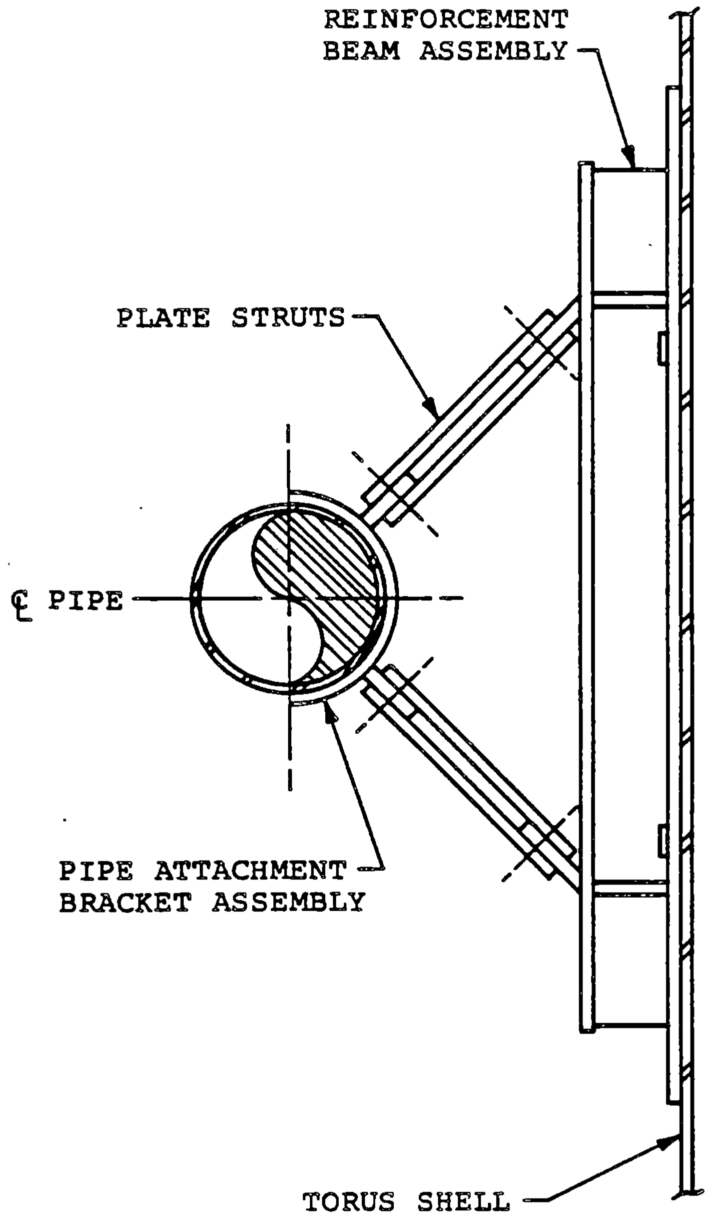


Figure 7-2.1-5

TYPICAL TAP SYSTEM SUPPORT INSIDE TORUS

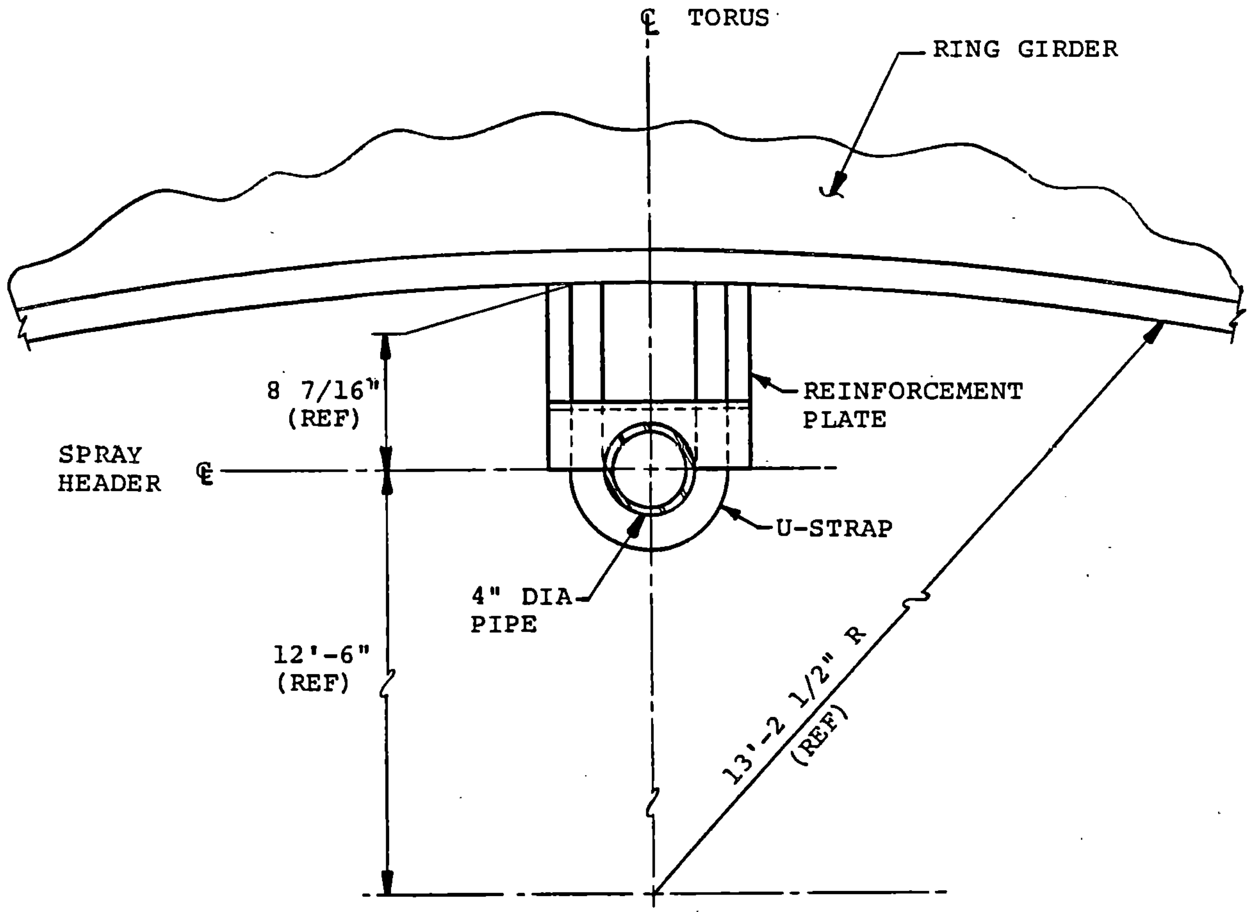


Figure 7-2.1-6

TYPICAL TAP SYSTEM SUPPORT
INSIDE TORUS ATTACHED TO RING GIRDER

7-2.2 Loads and Load Combinations

The loads for which the Dresden Unit 3 TAP 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 Volume 1. The results of applying the methodology to develop specific values for each of the controlling loads which act on the piping are discussed and presented in Section 7-2.2.1.

Using the event combinations and event sequencing defined in NUREG-0661 and discussed in Volume 1, the governing load combinations which affect the torus attached piping are formulated. The load combinations are discussed and presented in Section 7-2.2.2.

7-2.2.1 Loads

The loads acting on the TAP are categorized as follows:

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

Loads in Categories 1 through 4 are considered in the piping design as documented in the SAR (Reference 4). The SAR loads considered in the piping evaluations are those normal loads which are combined directly with Mark I loadings (LOCA and SRV discharge) as well as SAR loads considered for evaluation of system design and test conditions. Loads in Category 5 are displacements resulting from torus internal pressure, weight, and the weight of water during both normal and accident conditions. Loads in Category 6 result from SRV discharge events. Loads in Categories 7 through 10 are hydrodynamic effects of 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 SAR need be examined, since some are enveloped by others or have a negligible effect on the torus attached piping. Only those loads which cause the maximum piping response and lead to controlling stresses are examined and discussed. The loads are referred to as governing loads in the following sections.

The magnitudes and characteristics of the governing loads in each category, obtained using the methodology discussed in Volume 1, are identified and presented in the following paragraphs. The corresponding section of Volume 1 where the loads are discussed is provided in Table 7-2.2-1. The loading information presented in this section is the same as that presented in Volume 1, with additional specific information relevant to the evaluation of the TAP systems.

1. Dead Weight (DW) Loads

These loads are defined as the uniformly distributed weight of the pipe and insulation, and the concentrated weight of piping supports, hardware attached to piping, valves, and flanges. Also included is the weight of the 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 during an operating basis earthquake (OBE). The loading is taken from the design basis for the piping as documented in the safety analysis report. Horizontal and vertical acceleration coefficients at two different elevations which represent piping attachment points are utilized for the N-S and E-W direction OBE_I inputs.

b. OBE Displacement (OBE_D) Loads: These loads are defined as the maximum horizontal relative seismic displacements at the piping attachment points during an operating basis earthquake. The loading is taken from the design basis for the piping, as documented in the safety analysis report.

c. SSE Inertia (SSE_I) Loads: The horizontal and vertical SSE_I loads specified in the SAR are twice the corresponding OBE_I loads.

d. SSE Displacement (SSE_D) Loads: The horizontal relative seismic displacements at the piping attachment points during a SSE are twice the corresponding OBE_D loads.

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. Table 7-2.2-2 lists values of P_O and P used in the analysis.

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 accident conditions. Table 7-2.2-2 lists pipe temperatures for TE and TE_1 used in the analysis.

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 contents inside the torus. The loads are applicable to the HPCI turbine exhaust, and the LPCI test lines.

5. Static Torus Displacement Loads

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

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

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

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

6. Safety Relief Valve Discharge (QAB) Loads

These 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 SRV discharge loads consist of the following:

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 Volume 1.

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 Volume 1.

   Loads are developed for several possible patterns of air bubbles for both single and multiple T-quencher discharge cases. The results are evaluated to determine the controlling loads.

7. Vent Clearing Loads

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

a. Vent Clearing (VCL) Loads with $\Delta P = 1.0$ psi

1. 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 impact and drag pressure loads. The procedure used to develop these transient drag forces is discussed in Volume 1.

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

b. Vent Clearing (VCLO) Loads with $\Delta P = 0.0$ psi

1. Loca Water Jet Impingement Loads: These loads are the same as Load Cases 7.a.1, except the ΔP is equal to 0.0 psi.

2. LOCA Air Bubble Drag Loads: These loads are the same as Load Case 7.a.2, except the ΔP is equal to 0.0 psi.

8. Pool Swell Loads

These loads are defined as the transient pressure loads which act on the portion of the TAP and supports internal to the torus.

a. Pool Swell (PS) Loads with $\Delta P = 1.0$ psi

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

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

3. 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 Volume 1.

b. Pool Swell (PSO) Loads with $\Delta P = 0.0$ psi

1. Impact and Drag Loads: These loads are the same as Load Case 8.a.1, except the ΔP is equal to 0.0 psi.

2. Froth Impingement Loads: These loads are the same as Load Case 8.a.2, except the ΔP is equal to 0.0 psi.

3. Pool Fallback Loads: These loads are the same as Load Case 8.a.3, except the ΔP is equal to 0.0 psi.

9. Condensation Oscillation (CO) Loads

During the CO phase of a DBA event, the submerged portion of the TAP and supports within the torus are subjected to harmonic drag pressures. The procedure used to develop the harmonic drag loads is discussed in Volume 1. 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 drag loads, including acceleration drag loads due to torus FSI effects, acting on the submerged portion of the TAP and supports during the pre-chug portion of a SBA, an IBA, or a DBA event's chugging cycle. The procedure used to develop the pre-chug loads on these components is discussed in Volume 1.

b. Post-Chug (CHUG) Loads: These loads are defined as harmonic drag loads, including acceleration drag loads due to torus FSI effects, acting on the submerged portion of

TAP and supports during the post-chug phase of a SBA, an IBA, or a DBA event's chugging cycle. The procedure used to develop the post-chug loads on these components is discussed in Volume 1.

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.

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. Pool Swell (PS) Loads with $\Delta P = 1.0$ psi

a. PS_I - These are the inertia effects of torus motions due to pool swell loads.

b. PS_D - These are the displacement effects of torus motions due to pool swell loads.

2. Pool Swell (PSO) Loads with $\Delta P = 0.0$ psi

a. PSO_I - These loads are the same as Load Case 11.b.1.a, except the ΔP is equal to 0.0 psi.

b. PSO_D - These loads are the same as Load Case 11.b.1.b, except the ΔP is equal to 0.0 psi.

c. Condensation Oscillation Torus Motion Loads:

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

2. CO_D - These are the displacement effects of torus motions due to CO 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 7-2.2-1

TORUS ATTACHED PIPING LOADING IDENTIFICATION

CROSS-REFERENCE

LOAD DESIGNATION		REFERENCE 1 SECTION NUMBER
CATEGORY	CASE NUMBER	
DEAD WEIGHT	1	1-3.1
SEISMIC	2a,2b,2c,2d	1-3.1
PRESSURE AND TEMPERATURE	3a,3b	1-3.1, 1-4.1.1
NORMAL OPERATING	4	1-3.1
STATIC TORUS DISPLACEMENT	5a,5b,5c,5d	1-3.1, 1-4.1.1
SRV DISCHARGE	6a,6b	1-4.2.2, 1-4.2.4
VENT CLEARING	7a,7b,7c,7d	1-4.1.5, 1-4.1.6
POOL SWELL	8a,8b,8c,8d, 8e,8f	1-4.1.4.2, 1-4.1.4.3, 1-4.1.4.4
CONDENSATION OSCILLATION	9	1-4-1.7.3
CHUGGING	10a,10b	1-4.1.8.3
TORUS MOTION	11a,11b,11c, 11d,11e	1-4.1, 1-4.2

Table 7-2.2-2

LARGE BORE PIPING SYSTEM DESIGN DATA

SYSTEM	NORMAL OPERATING TEMPERATURE (°F)	MAXIMUM OPERATING CONDITIONS		DESIGN CONDITIONS		CONTENTS
		PRESSURE (psig) (P_o)	TEMPERATURE (°F)	PRESSURE (psig) (P)	TEMPERATURE (°F)	
ECCS SUCTION HEADER	90	35	165	65	285	WATER
VACUUM RELIEF	90	35	165	65	285	AIR
LPCI TEST LINES AND SPRAY HEADER DISCHARGE FROM PUMPS 3A/3B AND 3C/3D	90	180	150	350	350	WATER
HPCI POT DRAIN CONDENSATE	145	60	145	65	285	WATER
HPCI TURBINE EXHAUST	245	50	295	150	360	SATURATED STEAM
PRESSURE SUPPRESSION	90	35	165	65	285	AIR
CORE SPRAY 3A AND 3B DISCHARGE	90	290	165	350	350	WATER
LPCI PUMP 3A/3B AND 3C/3D SUCTION	90	45	165	65	285	WATER
CORE SPRAY 3A AND 3B SUCTION	90	45	165	65	285	WATER
HPCI PUMP SUCTION	90	45	165	65	285	WATER

7-2.2.2 Load Combinations

The loads for which the TAP systems are evaluated are presented in Section 7-2.2.1. The NUREG-0661 criteria for grouping the loads into load combinations are discussed in Volume 1.

Table 7-2.2-3 shows that the load combinations specified in NUREG-0661 for each event can be expanded into many more load combinations than those shown. 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 or additional loads. Many of the load combinations listed in Table 7-2.2-3 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.

The governing load combinations for torus attached piping are presented in Table 7-2.2-4. Table 7-2.2-5 presents the basis for establishing the governing loading combinations.

Stress allowables corresponding to the following Service Levels are used for evaluation of the torus attached piping:

A - Design conditions,

B - NOC including SRV discharge,

C - NOC including SRV discharge, plus seismic loads or SBA conditions including SRV discharge, and

D - SBA, IBA, and DBA conditions including SRV discharge plus seismic loads.

Also included in the list of governing load combinations are four combinations which do not result from the 27 event combinations listed in Table 7-2.2-3. 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 as specified in the SAR (Reference 4).

The normal SAR loads included in the loading combinations are assured to occur simultaneously with the NUREG-0661 loads for the LOCA event sequence defined in the LDR (Reference 2).

The appropriate ASME Code equations for the torus attached piping are also provided in the governing load combination table.

Each of the listed governing load combinations for the torus attached piping as provided in Table 7-2.2-4 has been considered in the analysis methods described in Section 7-2.4.

Table 7-2.2-3

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
	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)	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)	B (4)	B (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)	-	-	-	-	-	-	-	-	-	-	-	-

NOTES TO TABLE 7-2.2-3

(1) REFERENCE 2 STATES "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 OF THE FIRST PRESSURE BOUNDARY ISOLATION VALVE IS DEMONSTRATED.

(2) REFERENCE 2 STATES "NORMAL LOADS (N) CONSIST OF DEAD LOADS (D)."

(3) REFERENCE 2 STATES "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) REFERENCE 2 STATES "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) REFERENCE 2 STATES "EQUATION 10 OF NC OR ND-3659 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."

(6) REFERENCE 2 STATES "IF THE NORMAL PLANT OPERATING CONDITION DOES NOT EMPLOY A DRYWELL-TO-WETWELL PRESSURE DIFFERENTIAL, THE LISTED SERVICE LEVEL ASSIGNMENTS WILL BE APPLICABLE." SINCE FERMI 2 DOES NOT UTILIZE A DRYWELL-TO-WETWELL DIFFERENTIAL PRESSURE, THE LISTED SERVICE LIMITS ARE APPLIED.

Table 7-2.2-4

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	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	TE_1 + $THAM_1$ + TD_1 or TD_2 + $CHUG_D$ + QAB_D + SSE_D	10 (3)
A-6	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-1	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	P_o + DW + PSO + PSO_I + VCLO	9
D-4 (7)	P_o + DW + PS + PS_I + VCL + QAB + QAB_I + SSE_I + OL	9
D-5 (7)	P_o + DW + CO + CO_I + OBE_I + OL	9
T-1 (8)	1.25P + DW	8

NOTES TO TABLE 7-2.2-4

(1) SEE SECTION 7-2.2.1 FOR DEFINITION OF INDIVIDUAL LOADS.

(2) EQUATIONS ARE DEFINED IN SUBSECTION NC-3650 OF THE ASME CODE (REFERENCE 7).

(3) AS AN ALTERNATE, MEET EQUATION 11 OF THE ASME CODE (REFERENCE 7).

(4) FOR THE DBA CONDITION, SRV DISCHARGE LOADS NEED NOT BE COMBINED WITH CO AND CHUGGING LOADS.

(5) SEE SECTION 7-2.2.3 FOR COMBINATION OF DYNAMIC LOADS.

(6) ONLY GOVENING LOAD COMBINATIONS FROM TABLE 7-2.2-4 ARE CONSIDERED HERE.

(7) THE LARGER OF LOCA AND SSE COMBINED BY THE SRSS METHOD OR LOCA AND OBE COMBINED BY THE ABSOLUTE SUM METHOD IS USED.

(8) HYDROSTATIC TEST CONDITION. DW FOR ALL LINES SHALL BE WITH LINES FULL OF WATER AT 70°F.

Table 7-2.2-5

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.	(3b)
2	C-1	SECONDARY STRESS BOUNDED BY EVENT COMBINATION NUMBER 3.	(3a)
3	C-1, 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.	(3b)
6,8,12	N/A	BOUNDED BY EVENT COMBINATION NUMBER 14.	(3b)
7,9,13	N/A	BOUNDED BY EVENT COMBINATION NUMBER 15.	(3b)
10	N/A	IBA BOUNDED BY EVENT COMBINATION NUMBER 15 AND SBA BOUNDED BY EVENT COMBINATION NUMBER 11.	(3b)
11	C-2, C-3 A-4, A-5	FOR SBA ONLY. IBA BOUNDED BY EVENT COMBINATION NUMBER 15.	(3b)
15	D-1, D-2 A-4, A-5	N/A	N/A
14	D-1, D-2	SECONDARY STRESS BOUNDED BY EVENT COMBINATION NUMBER 15	(3a)
16,18,22	N/A	BOUNDED BY EVENT COMBINATION NUMBER 24.	(3b)
19	N/A	BOUNDED BY EVENT COMBINATION NUMBER 25.	(3b)
17,20,23	N/A	BOUNDED BY EVENT COMBINATION NUMBER 26.	(3b)
21	N/A	BOUNDED BY EVENT COMBINATION NUMBER 27.	(3b)
24	D-4	SECONDARY STRESS BOUNDED BY EVENT COMBINATION NUMBER 25.	(3a)
25	D-4, A-6	N/A	N/A
26	D-5, A-7	FOR CO ONLY, DBA CHUGGING BOUNDED BY EVENT COMBINATION NUMBER 14. SECONDARY STRESS BOUNDED BY EVENT COMBINATION NUMBER 27.	(3b)
27	A-8, A-9	DBA CHUGGING BOUNDED BY EVENT COMBINATION NUMBER 15. EVALUATE FOR SECONDARY STRESS ONLY.	(3b)

NOTES TO TABLE 7-2.2-5

(1) EVENT COMBINATION NUMBERS REFER TO THE NUMBERS USED IN TABLE 7-2.2-3.

(2) GOVERNING LOAD COMBINATIONS ARE LISTED IN TABLE 7-2.2-4.

(3) EVENT COMBINATION GOVERNING BASIS:

   a. THE GOVERNING EVENT COMBINATION CONTAINS SSE LOADS WHICH BOUND OBE LOADS.

   b. THE GOVERNING EVENT COMBINATION CONTAINS MORE LOADS WHILE THE ALLOWABLE LIMITS ARE THE SAME.

7-2.2.3 Combination of Dynamic Loads

The methods used in the analyses for combining dynamic loads are based on NUREG-0484, "Methodology for Combining Dynamic Responses" (Reference 8). As described in NUREG-0484, when the time-phase relationship between the responses caused by two or more sources of dynamic loading is undefined or random, the peak responses from the individual loads are combined by absolute sum (except for combined SSE and LOCA loads). The peak responses which result from SSE and LOCA loads are combined using the SRSS technique.

As an alternate, when the absolute sum method of combining dynamic loads produces excessively conservative results, the dynamic loads are combined using the SRSS method, as permitted by Reference 9.

7-2.3 Acceptance Criteria

The acceptance criteria defined in NUREG-0661 on which the Dresden Unit 3 TAP 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 up to and including the 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 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. Table 7-2.3-1 lists the applicable ASME Code equations and stress limits for each of the governing piping load combinations.

Table 7-2.3-1

APPLICABLE ASME CODE EQUATIONS AND ALLOWABLE STRESSES

FOR TORUS ATTACHED PIPING

STRESS TYPE	ASME CODE EQUATION NUMBER	SERVICE LEVEL	STRESS LIMIT	ALLOWABLE VALUE (ksi) (1,2)	GOVERNING LOAD COMBINATION NUMBER (3)
PRIMARY	8	A	$1.0\ S_h$	15.0	A-1, T-1
PRIMARY	9	B	$1.2\ S_h$	18.0	B-1, B-2
PRIMARY	9	B	$1.8\ S_h$	27.0	C-1 THROUGH C-3
PRIMARY	9	B	$2.4\ S_h$	36.0	D-1 THROUGH D-5
SECONDARY	10	B	$1.0\ S_a$	22.5	A-2 THROUGH A-9
PRIMARY AND SECONDARY	11	B	S_h+S_a	37.5	(4)

(1) INCREASED ALLOWABLES AS DEFINED IN NUREG-0661 (REFERENCE 1) HAVE BEEN UTILIZED FOR PIPING SYSTEMS WHICH HAVE BEEN CLASSIFIED AS NON-ESSENTIAL.

(2) ALLOWABLE STRESS VALUES ARE FOR ASTM A106, GRADE B MATERIAL SINCE THIS MATERIAL IS USED FOR MOST OF THE TAP SYSTEMS.

(3) GOVERNING LOAD COMBINATION NUMBERS ARE LISTED IN TABLE 7-2.2-4.

(4) SEE ASME CODE, SECTION III, SUBSECTION NC, PARAGRAPH NC-3652.3 (REFERENCE 6) FOR COMBINATION OF LOADS.

7-2.4 Methods of Analysis

This section describes the methods of analysis used to evaluate the large bore piping and supporting systems attached to the torus both internally and externally, for the effects of the governing loads as described in Section 7-2.2. As described in Section 7-2.1, one small diameter torus internal piping system has also been evaluated using the analytical methods described in this section. Table 7-2.4-1 summarizes the specific analytical techniques used in analyzing the piping systems for each loading.

The methodology used to develop the analytical models of the TAP systems is presented in Section 7-2.4.1. 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 7-2.4.2, 7-2.4.3, and 7-2.4.4. The approach used to address fatigue effects is presented in Section 7-2.4.5.

A standard, commercially available piping analysis computer code, PISTAR, is used in performing the piping system analyses. The 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, response spectrum, and dynamic time-history analyses of piping systems. It also performs the ASME Code, Section III piping evaluation.

Table 7-2.4-1

SUMMARY OF ANALYSIS METHODS FOR LARGE BORE TORUS ATTACHED PIPING

LOAD	LOAD CASE NUMBER	ANALYSIS METHOD
DW	1	STATIC
OBE_I	2a	STATIC
OBE_D	2b	STATIC
SSE_I	2c	STATIC
SSE_D	2d	STATIC
P_O	3a	(1)
P	3a	(1)
TE	3b	STATIC
TE_1	3b	STATIC
THAM	3b	STATIC
$THAM_1$	3b	STATIC
OL	4	STATIC
TD	5a	STATIC
TD_1	5b	STATIC
TD_2	5c	STATIC
TD_3	5d	STATIC
QAB	6a,b	EQUIVALENT STATIC
VCL	7a,b	EQUIVALENT STATIC
PS	8a,b	EQUIVALENT STATIC
CO	9	HARMONIC(2)
PCHUG	10a	HARMONIC(2)
CHUG	10b	HARMONIC(2)
QAB_I, QAB_D	11a	COUPLED DYNAMIC(3)
PS_I, PS_D, PSO_I, PSO_D	11b	COUPLED DYNAMIC(3)
CO_I, CO_D	11c	COUPLED DYNAMIC(3)
$PCHUG_I$, $PCHUG_D$	11d	COUPLED DYNAMIC(3)
$CHUG_I$, $CHUG_D$	11e	COUPLED DYNAMIC(3)

NOTES TO TABLE 7-2.4-1

(1) THE EFFECTS OF INTERNAL PRESSURE ARE EVALUATED UTILIZING THE TECHNIQUES DESCRIBED IN SUBPARAGRAPH NC-3650 OF THE ASME CODE, SECTION III (REFERENCE 6).

(2) A DETAILED DESCRIPTION OF THE ANALYSIS METHODS USED FOR THIS LOADING IS PRESENTED IN SECTION 7-2.4.3.

(3) A DETAILED DESCRIPTION OF THE ANALYSIS METHODS USED FOR THIS LOADING IS PRESENTED IN SECTION 7-2.2.4.

7-2.4.1 Piping Analytical Modeling

The analytical models used in the analysis of the large bore TAP 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. Figure 7-2.4-1 shows a representative torus internal and external piping analytical model.

The piping systems are modeled as multi-degree of freedom (DOF), 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 also included in the model formulations.

Torus external piping supports included in the models consist of snubbers, struts, spring hangers, and their backup structures. Where required, an element is included to model the offset connection between the supporting member and the centerline of the pipe.

Snubbers are modeled as active in seismic and other dynamic load cases, while struts are active in all load cases. Spring hangers, with appropriate preloads for the dead weight case, are modeled as active in all load cases. 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 backup supporting structure.

For piping models that include torus internal piping, the entire piping system including the internal supports connected to the torus, is included in the model. The hydrodynamic mass acting on submerged portions of the piping is also included in the model, using the methods described in Volume 1.

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 DOF linear springs. These local stiffnesses are not included when performing the coupled torus motion analyses of the piping systems since they are inherently included in this methodology.

Model boundary conditions at the torus external termination points consist of anchors at support or equipment (pump, turbine) locations. Large stiffness values are specified in the models at these locations. In some cases, piping models have been truncated at locations where stress levels due to Mark I load combinations for all service levels are less than 10% of the appropriate ASME Code allowables. For these models, truncation points have been modeled at supports by simulating the mass and stiffness of the piping system beyond the support location.

The mass and flexibility properties of in-line valves are included in the piping analytical models. The valve operator mass is lumped at the valve operator center of gravity while the mass of the valve body is uniformly distributed over the length of the valve.

Branch lines are included in the piping models unless they meet uncoupling criteria based on the relative moments of inertia of branch lines and main lines.

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 7-3.0.

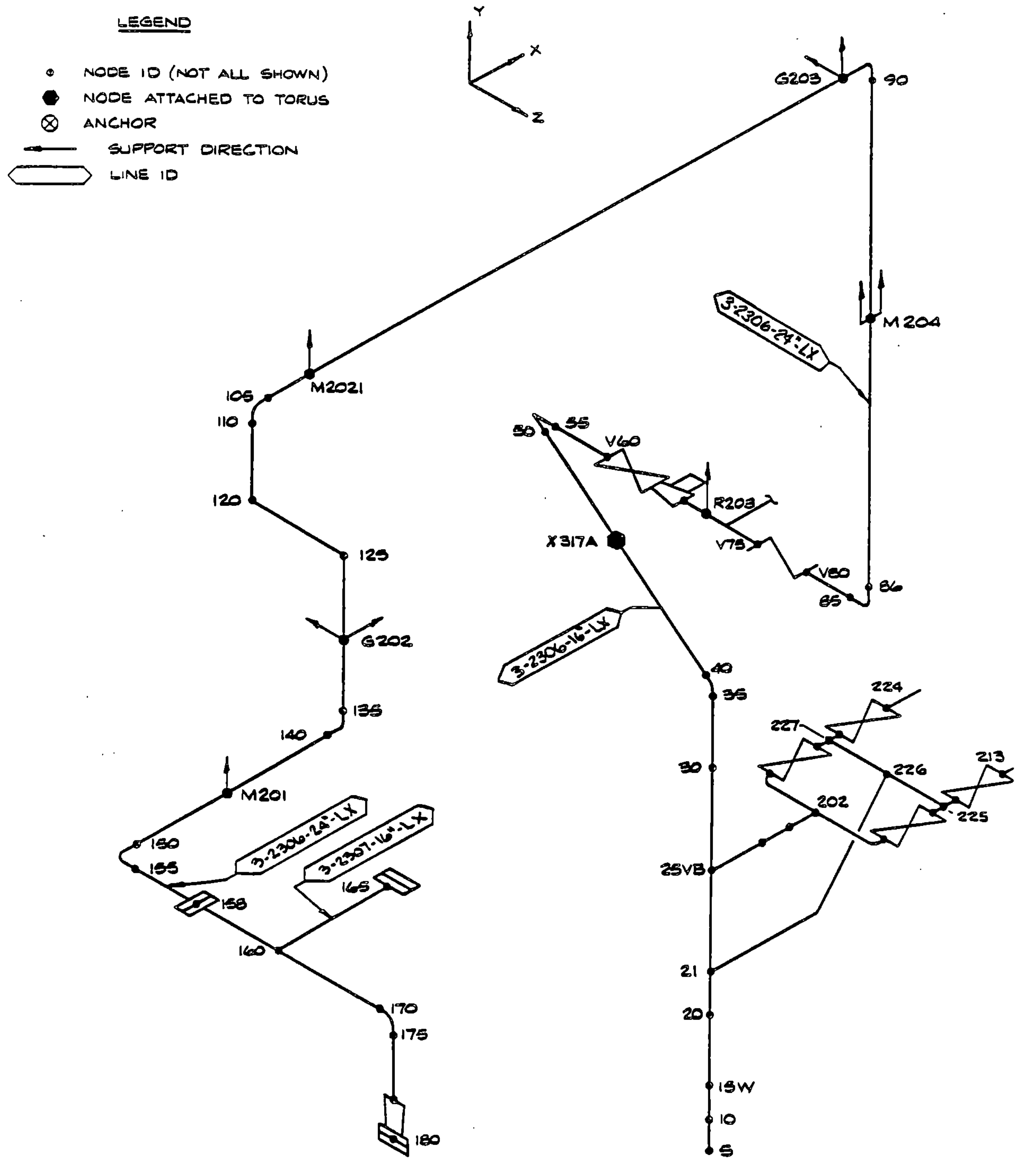


Figure 7-2.4-1

TAP SYSTEM ANALYTICAL MODEL (LINE X-317)

7-2.4.2 Methods of Analysis for SAR and Static Torus Displacement Loads

The following loads, which are described in Section 7-2.2, represent the SAR loads for which all TAP systems are analyzed. In addition, analyses are performed for static torus displacement loads due to normal and accident conditions.

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

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 static analysis is performed independently for each of the two sets (E-W plus vertical and N-S plus vertical) of acceleration values using the static acceleration coefficient uniform method.

b. OBE Displacement (OBE_D) Loads: A static analysis is performed independently for the N-S and E-W directions, since vertical displacements were negligible. The relative anchor displacements at the torus penetration and reactor auxiliary building slabs are conservatively considered to be out of phase.

c. SSE Inertia (SSE_I) Loads: Horizontal and vertical SSE_I analysis is not performed, by doubling the results of the OBE_I analysis.

d. SSE Displacement (SSE_D) Loads: The SSE_D static analysis is performed, by doubling the results of the OBE_D analysis.

3. Pressure and Temperature Loads

a. Pressure Loads: The effects of maximum operating pressure (P_O) and design pressure (P) are evaluated utilizing the techniques described in Subsection NC-3650 of the ASME Code, Section III (Reference 6). Table 7-2.2-2 lists the values of P_O and P used in the analysis.

b. Temperature Loads: A static thermal expansion analysis is performed for the piping temperature cases TE and TE_1, as described in Table 7-2.2-2. A static analysis is performed for anchor movement, as described in Section 7-2.2, at the torus supports and penetrations.

4. Operating (OL) Loads

Line operating loads are applied statically, using piping end segment thrust loads to the TAP systems, as described in Section 7-2.2.1.

5. Static Torus Displacement Loads

The static displacements of the torus at the appropriate TAP penetration location due to torus movement induced by normal (TD) and accident (TD_1, TD_2, TD_3) condition torus pressures, weight, and the weight of water in the torus are applied to each piping system as an applied displacement load case.

7-2.4.3 Methods of Analysis for Hydrodynamic Loads

Portions of TAP systems internal to the torus are subjected to hydrodynamic impact and drag loads as a result of SRV discharge and LOCA events, as discussed in Section 7-2.2.1. 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 pressures by the appropriate submerged piping projected areas to convert them into nodal piping forces. An equivalent static analysis is then performed by multiplying the forces by a value of 2.0, which is the maximum DLF for the rectangular pulse jet pressure loading. The final analysis results are multiplied by a scale factor of 1.5. This value is used to account for the effects of both multifrequency excitation and multimode response.

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 represent the peak dynamic loads from the loading transient multiplied by the peak DLF of the structure within the load frequency range (1 to 50 hertz). The final analysis results are multiplied by a scale factor of 1.5, as described in Load Case 6a. This value is used to account for the effects of both multifrequency excitation and multimode response.

7. Vent Clearing Loads

a. Vent Clearing (VCL) Loads with ΔP = 1.0 psi

1. 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 of 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 dynamic load factor. The final analysis results are multiplied by a scale factor of 1.5, as described in Load Case 6a.

2. 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. For a given loading time-history, the peak DLF of the structure within the load frequency range (1 to 50 hertz) is determined. A scale factor of 1.5 is applied to the analysis results, as described in Load Case 6a.

b. Vent Clearing (VCLO) Loads with $\Delta P = 0.0$ psi

1. LOCA Water Jet Impingement Loads: These loads are the same as Load Case 7.a.1, except the ΔP is equal to 0.0 psi.

2. LOCA Air Bubble Drag Loads: These loads are the same as Load Case 7.a.2, except the ΔP is equal to 0.0 psi.

8. Pool Swell Loads

The method of equivalent static loads is used in analyzing the piping system for the effects of pool swell loads. Since pool swell loads are time-limited pulses with regular shapes, their DLF's are constants and are well defined. The applied equivalent static piping section forces are equal to the peak section forces multiplied by their corresponding dynamic load factors. These section forces are converted into nodal forces for application to the piping models.

a. Pool Swell (PS) Loads with ΔP = 1.0 psi

1. 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.

2. 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 Volume 1.

3. 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.

b. Pool Swell (PSO) Loads with ΔP = 0.0 psi

1. Impact and Drag Loads: These loads are the same as Load Case 8.a.1, except the ΔP is equal to 0.0 psi.

2. Pool Fallback Loads: These loads are the same as Load Case 8.a.3, except the ΔP is equal to 0.0 psi.

The final pool swell loading analysis results for each of the above loads are multiplied by a scale factor of 1.5, as described in Load Case 6a.

9. Condensation Oscillation Loads

As discussed in Section 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 Volume 1.

Once the amplitudes of the drag forces for a given piping system have been determined, they are converted to the PISTAR coordinate system and applied as PISTAR nodal forces.

Given the harmonic nodal force time-histories for acceleration and standard drag as well as the results of a PISTAR mode-frequency analysis for each piping system, a steady-state response calculation is carried out using the modal superposition method. The FSI effect is also considered in the analysis. The FSI effect is superimposed on results from the PISTAR mode frequency analysis.

10. Chugging Loads

a. Pre-Chug (PCHUG) Loads: As described in Section 7-2.2.1, 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. The specific frequency chosen for performing the piping analysis is the frequency that is most critical for the particular piping system being evaluated. Details of the loading definition are described in Volume 1. The pre-chug loading is applied to the piping models as a nodal force, and a dynamic response analysis is carried out to obtain maximum system response. Torus FSI effects are also included in the analysis.

b. Post-Chug (CHUG) Loads: The post-chug loading definition is similar to that for CO in that it is defined as a 50 harmonic forcing function. The piping analysis procedures for post-chug loads are therefore the same as for the CO loads described above.

7-2.4.4 Methods of Analysis for Torus Motions

11. Torus Motion Loads

Torus motion loads, as discussed in Section 7-2.2.1, are considered for the analysis of all 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)

b. Pool Swell Torus Motion (PS_I, PS_D, PSO_I, PSO_D)

c. Condensation Oscillation Torus Motion (CO_I, CO_D)

d. Pre-Chug Torus Motion ($PCHUG_I$, $PCHUG_D$)

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

The coupling analysis method is utilized to obtain piping response for the five torus motion load cases. The methods of analysis for each torus motion event are described in the following paragraphs.

Coupling Analysis

The conventional method for performing dynamic analyses of a torus and attached piping systems is to perform independent uncoupled dynamic analyses of the torus and of the attached piping. A detailed model of the torus is first developed. A dynamic analysis of the uncoupled torus is performed, and the response time-history at the attachment point of the piping is obtained. This response time-history or the corresponding response spectra is then used to calculate the piping response of an uncoupled dynamic model of the piping system. This conventional method of analysis is termed an uncoupled analysis because the dynamic models of the torus and the piping are never directly coupled or combined.

Conventional uncoupled analyses tend to overestimate the response of the attached piping. The response at the piping attachment point obtained from the uncoupled torus analysis will include the contribution of all uncoupled torus modes excited by the input time-history. The spectra from this time-history will show amplified spectral peaks at each of the significant uncoupled torus modes. If the uncoupled piping model has natural modes near these spectral peaks, then the uncoupled torus response will engender an amplified response of the piping system. However, when the uncoupled torus and piping natural modes are nearly the same, the piping system will actually inhibit the response of the torus at that frequency, and the torus response will be less than that obtained from an uncoupled torus analysis. This effect is particularly significant for the SRV and pre-chug torus motion analyses, since the LDR requires "tuning" the loading frequencies to the critical piping response frequencies.

This overestimation of piping response may be corrected by performing a coupled analysis, in which a single dynamic model including both the torus and piping is used. In this way, the coupling effects between the torus and piping are automatically included. 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 has been developed which is used to incorporate the coupling effects into the results of the uncoupled torus and piping analyses. This program has been formulated in the time domain. For loads such as pool swell, where the torus load definition is defined in the time domain, the coupling program may be applied directly. For LOCA-related loads such as CO and chugging, which are defined in the frequency domain, the coupling program is not directly applicable, since it is formulated in the time domain. The coupling program is also impractical for performing analyses for SRV loads due to the wide range of forcing frequencies involved and to the number of separate load cases that must be considered in addressing the LDR "tuning" requirement.

Transfer Function Approach

In order to facilitate application of the coupling methods for the CO, chugging, and SRV loads, a transfer function approach, based on a white noise time-history analysis, is utilized in conjunction with the coupling program. This method provides for determination of the critical coupled response frequencies of the piping systems, which are in turn used in selecting the appropriate frequencies of the applied loadings.

The transfer functions relate piping system response to torus shell forcing functions, and are calculated in the time domain by applying to the analytical model of the torus a white noise time-history with a spatial distribution equivalent to that specified for the particular hydrodynamic load under consideration. The resulting uncoupled torus shell motions are then used in conjunction with piping and torus modal characteristics to obtain the coupled piping responses in the time domain. These time domain piping responses, together with the white noise time-history that is employed for the torus forcing function, are then transformed into the frequency domain using standard fast-fourier transform methods. The transfer function of the piping system is then obtained by dividing the coupled white noise response by the white noise input in the frequency domain. The critical piping response frequencies are then obtained by examining the relative magnitudes of the transfer function peaks.

Knowing the critical piping response frequencies, appropriate frequencies from the range of CO, chugging, and SRV load frequencies can be selected to determine the forcing functions to be applied to the torus. The forcing function time-histories are then transformed into the frequency domain and multiplied by the transfer function to obtain piping system responses in the frequency domain which, in turn, are transformed back into the time domain to conclude the process. For CO and post-chug loads, it is also necessary to sum the responses from each of the 50 harmonics that must be considered.

The flow chart provided in Figure 7-2.4-2 shows the basic steps involved in performing the coupled/transfer function TAP analysis.

The specific coupling analysis procedure used for each category of torus motions loads is described as follows:

a. SRV Torus Motion

1. Using the mathematical model of the torus attached piping systems described in Section 7-2.4.1, the uncoupled piping dynamic characteristics (mode shapes and frequencies) are determined using the PISTAR piping analysis program. All

modes up to 60 hertz have been considered in the analysis.

2. Similarly, using the finite element model of a 1/32 segment of the suppression chamber as described in Volume 2, the torus dynamic characteristics (mode shapes and frequencies) are determined. The STARDYNE computer program is used for this analysis.

3. The time-history response of the suppression chamber at the torus-pipe intersection due to a band limited white noise time-history is determined. The STARDYNE computer program is used for this analysis.

4. Using information derived in Steps 1 through 3 above, the coupled response of the piping system for each mode due to the white noise input is determined using the coupling computer program.

5. Using the modal superposition technique, the modal responses of the piping system

obtained from Step 4 are used in calculating the response of the piping system due to the white noise input. The static response of the piping at high frequencies is accounted for by use of a pseudomode computer program.

6. Transformation of the white noise response time-history from Step 5 and the input white noise time-history to the frequency domain is then performed using the fast-fourier transform method.

7. The transfer function for each component of the piping system is calculated by dividing the white noise response by the white noise input in the frequency domain.

8. Critical piping frequencies within the prescribed SRV load frequency range are selected at the transfer function peaks.

9. The torus safety relief valve bubble loading is generated by "tuning" the SRV

bubble pressure frequency to the piping critical frequencies obtained in Step 8 above.

10. The "tuned" torus shell load time-histories are transformed into the frequency domain using the fast-fourier transform method.

11. Piping response in the frequency domain for each piping component is computed by multiplying the transfer function (determined in Step 7) times the torus shell load in the frequency domain obtained in Step 10. In this step the response is scaled down based on results from the SRV alternate analysis method, which calibrates the results of the coupled fluid-torus analysis to in-plant SRV test data.

12. Final piping time-history responses are derived from piping response in the frequency domain (Step 11) by using the inverse fast-fourier transform method.

13. The peak of the time-history response is selected for the piping stress evaluation.

b. Pool Swell Torus Motion

1. Uncoupled torus and TAP system mode shapes and frequencies, as described above, are again utilized.

2. The actual time-history response of the suppression chamber is determined at the torus-pipe intersection due to the pool swell pressure time-history load.

3. The coupled response of the piping system for each mode due to the pool swell load input is determined using the coupling computer program.

4. The modal response of the piping system is obtained and is used in calculating the final response time-history using the modal superposition technique.

5. The peak of the time-history response is selected for the piping stress evaluation.

c. Condensation Oscillation and Chugging Torus Motions

1. Transfer functions relating piping responses to CO, pre-chug, and post-chug torus internal pressures are obtained in a manner similar to Steps 1 through 7, described above for SRV torus motion.

2. Calculations are then performed to obtain piping responses in the frequency domain utilizing the fast-fourier technique and applying amplitudes of pressure versus frequency for the CO and post-chug load cases. The pressure amplitudes and frequencies utilized for CO and post-chug loads are defined in Volume 1. The pre-chug load is defined as a single harmonic with an amplitude of ±2 psi in the frequency range of 6.9 to 9.5 hertz. The selection of the critical piping frequency in this range is

based on the transfer function peak which occurs most frequently.

3. For CO and post-chug, the frequency domain harmonic response is conservatively determined for each of the 50 defined harmonic forcing frequencies as the product of the pressure amplitude and the peak of the transfer function in each frequency band.

4. The final time domain response for the CO load case is taken as 1.15 times the direct sum of 50 harmonic responses which are randomly phased by introduction of a set of 50 random phase angles. Cumulative distribution functions of analytical and test data form the basis for this random phasing. A 50% non-exceedance probability (NEP) with 90% confidence is achieved as a result of this method.

5. For the post-chug case, the final time domain response is obtained as the absolute sum of the 50 harmonic responses. The phase angles are set to zero in this case.

6. The peak magnitude of the time domain response for CO, pre-chug, and post-chug load cases is selected for the piping stress evaluation.

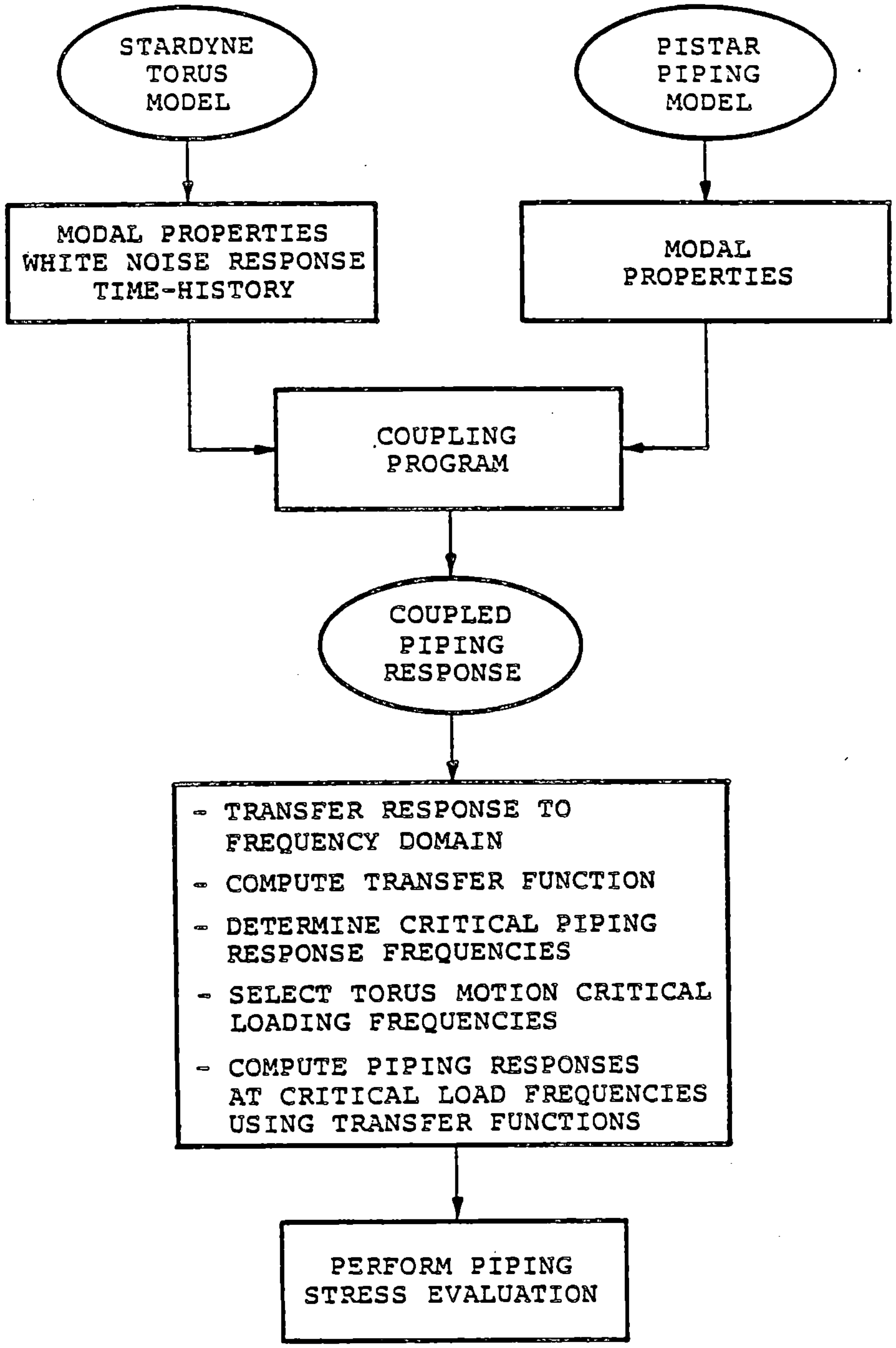


Figure 7-2.4-2

TAP SYSTEM COUPLED/TRANSFER FUNCTION ANALYSIS PROCEDURE

7-2.4.5 Fatigue Evaluation

Section 4.3.3.2 of NUREG-0661 requires that a fatigue evaluation of SRV piping and TAP 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 in late 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. Therefore, the Dresden Unit 3 TAP is qualified based on this generic evaluation.

7-2.5 Analysis Results

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

The maximum piping stresses resulting from governing load combinations for highly stressed locations on each large bore TAP line and for small diameter torus internal lines, are presented in Table 7-2.5-1. The maximum stresses for each service level are listed along with the associated Code equations and allowable stress values.

Fatigue evaluations for the TAP lines have been performed generically as described in Section 7-2.4.5. The Dresden Unit 3 TAP is qualified for fatigue effects based on this generic evaluation.

In summary, the results show that the design of the large bore TAP systems are adequate for the loads, load combinations, and acceptance criteria limits specified in NUREG-0661 (Reference 1) and the PUAAG (Reference 5).

Table 7-2.5-1

ANALYSIS RESULTS FOR TORUS ATTACHED PIPING STRESS

SERVICE LEVEL	A	B	C	D	SECONDARY
ASME CODE EQUATION	8	9	9	9	10
ALLOWABLE STRESS (ksi)	15.00 17.50 (1)	18.00 21.00 (1)	27.00 31.50 (1)	36.00 42.00 (1)	22.50/37.50 (2) 26.25 (1)/43.75 (1) (2)
SYSTEM DESCRIPTION	MAXIMUM STRESS (ksi)				
ECCS SUCTION HEADER	10.62	18.93	22.99	29.01	31.73 (3)
VACUUM RELIEF	5.35	10.20	18.70	21.40	30.81 (2)
LPCI TEST LINE AND SPRAY HEADER DISCHARGE FROM PUMPS 3A/3B	4.90	12.91	19.33	25.32	33.09 (2)
LPCI TEST LINE AND SPRAY HEADER DISCHARGE FROM PUMP 3C/3D	5.72	17.37	23.83	30.36	33.53 (2)
HPCI POT DRAIN CONDENSATE	0.44	6.44	19.79	21.46	0.0
HPCI TURBINE EXHAUST	7.86	10.72	14.40	27.85	30.18 (2)
PRESSURE SUPPRESSION	2.40	5.72	9.60	10.70	10.10
CORE SPRAY 3A DISCHARGE	5.62	12.67	22.95	35.73	31.01 (2)
CORE SPRAY 3B DISCHARGE	4.06	11.36	17.05	34.82	13.24
LPCI PUMP 3A/3B SUCTION	2.86	7.53	10.15	10.22	26.38 (2)
LPCI PUMP 3C/3D SUCTION	2.22	10.53	15.12	15.15	32.04 (2)
CORE SPRAY 3A SUCTION	9.65	17.96	22.10	23.37	14.18
CORE SPRAY 3B SUCTION	6.80	14.31	18.07	18.38	12.12
HPCI PUMP SUCTION	5.00	11.48	14.71	14.77	19.25

(1) FOR ECCS SUCTION HEADER.

(2) EQUATION 11 IS USED IN PLACE OF EQUATION 10.

7-3.0 SMALL BORE PIPING

An evaluation of each of the NUREG-0661 (Reference 1) requirements which affect the design adequacy of the Dresden Unit 3 small bore piping (SBP) is presented in the following sections. The general criteria used in this evaluation are contained in Volume 1 of this PUAR.

The components of the SBP which are examined are described in Section 7-3.1. The loads and load combinations for which the SBP are evaluated are described and presented in Section 7-3.2. The acceptance limits to which the analysis results are compared are discussed and presented in Section 7-3.3. The analysis methodologies used to evaluate the effects of the loads and load combinations on the SBP are discussed in Section 7-3.4. The analysis results and the corresponding design margins are presented in Section 7-3.5.

7-3.1 Component Description

The SBP lines for the Dresden Unit 3 plant unique analysis (PUA) fall into the following five categories.

1. Small bore piping lines which meet the 10% exclusion criteria
2. Cantilevered lines
3. Small bore piping with flex loops
4. Other torus extended small bore systems
5. Torus internal small bore lines

Of the 123 small bore lines, 84 initiate from large bore piping lines that meet the 10% exclusion criteria; therefore, they are not evaluated. There are 13 lines cantilevered from the torus or large bore TAP that are evaluated. Table 7-3.1-1 provides typical SBP systems design data. Figure 7-3.1-1 shows two typical cantilever lines.

Several small bore lines are attached directly to the torus or large bore torus attached piping (TAP). Evaluation of these systems included a flex loop installed to reduce the effects of torus motion on the piping systems. Downstream of the flex loop is an anchor separating the remaining SBP from the effects of anchor separating the remaining SBP from the effects of Mark I loads. Figure 7-3.1-2 shows a typical flex loop installation.

Several small bore lines range in size from 1" to 2" Schedule 80, to 2-1/2" to 4" Schedule 40 pipe supported by rigid struts, rods, guides, and spring supports. These lines are either attached to the torus or other large bore lines connected to the torus, and serve a multitude of functions such as nitrogen purges, RHR pump bypasses, and HPCI minimum flow returns. Figure 7-3.1-3 provides an example of these lines.

Only one small bore line internal to the torus is analyzed by methods used in the large bore piping analyses described in Section 7-2.4.

TABLE 7-3.1-1

SMALL BORE PIPING - SYSTEM DESIGN DATA

SYSTEM TYPE	DESIGN PRESSURE (psi)	DESIGN TEMPERATURE (°F)	NORMAL PRESSURE (psi)	NORMAL TEMPERATURE (°F)
CANTILEVERS	350	360	290	245
PIPING	170	285	155	90
FLEX LOOPS	350	350	290	165

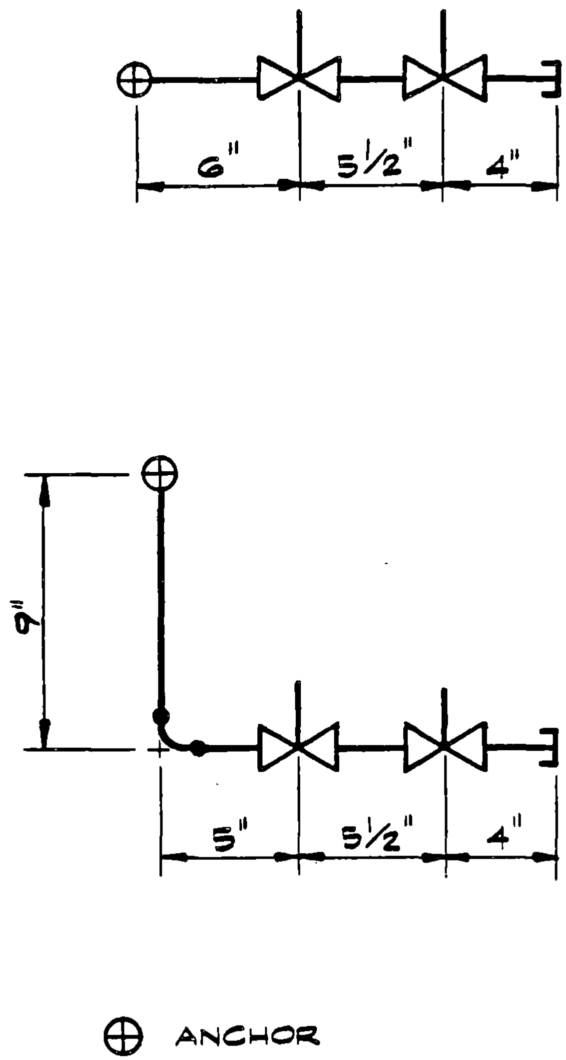


Figure 7-3.1-1

TYPICAL CANTILEVERED VENT OR DRAIN

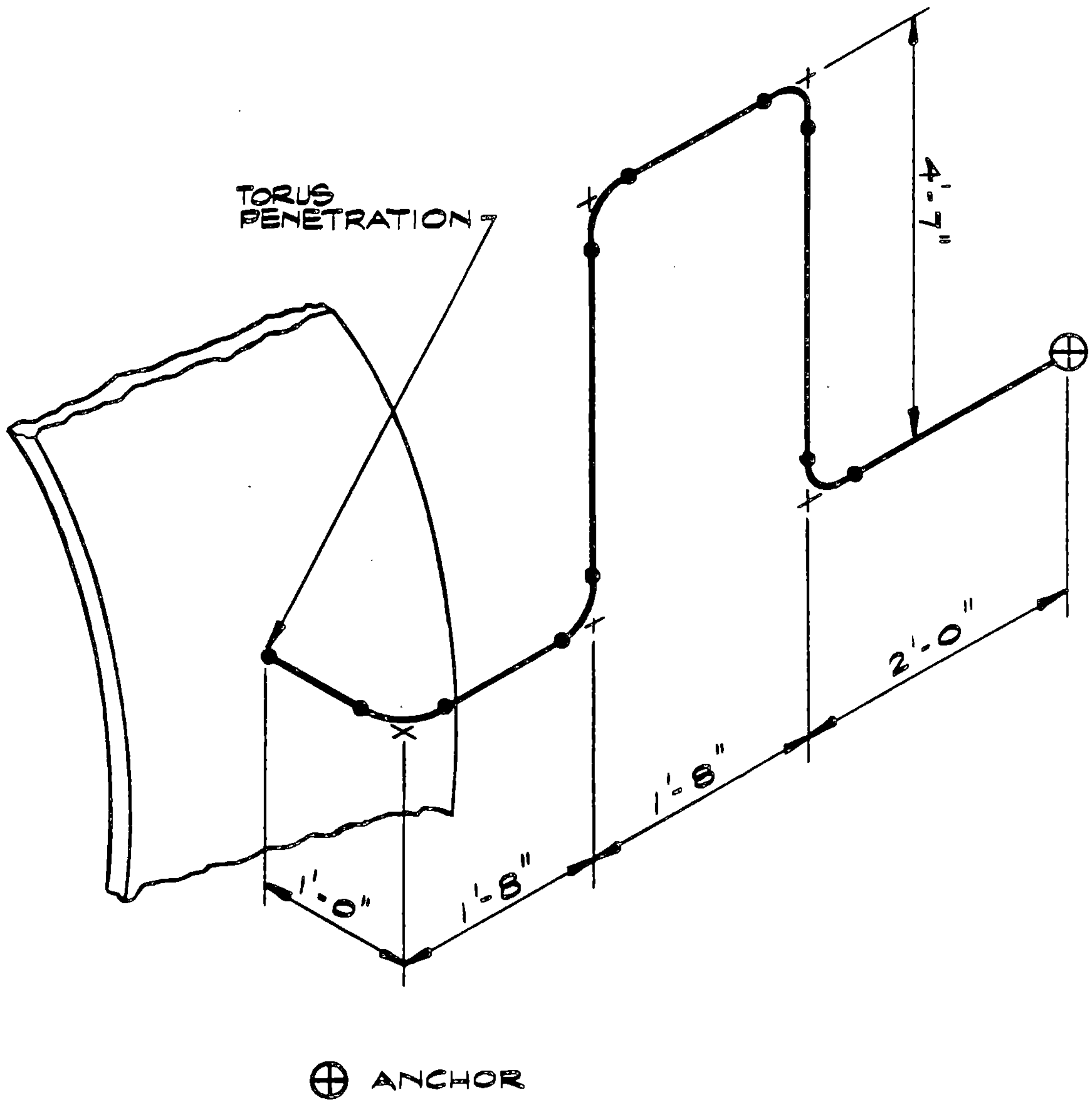


Figure 7-3.1-2

TYPICAL FLEX LOOP INSTALLATION

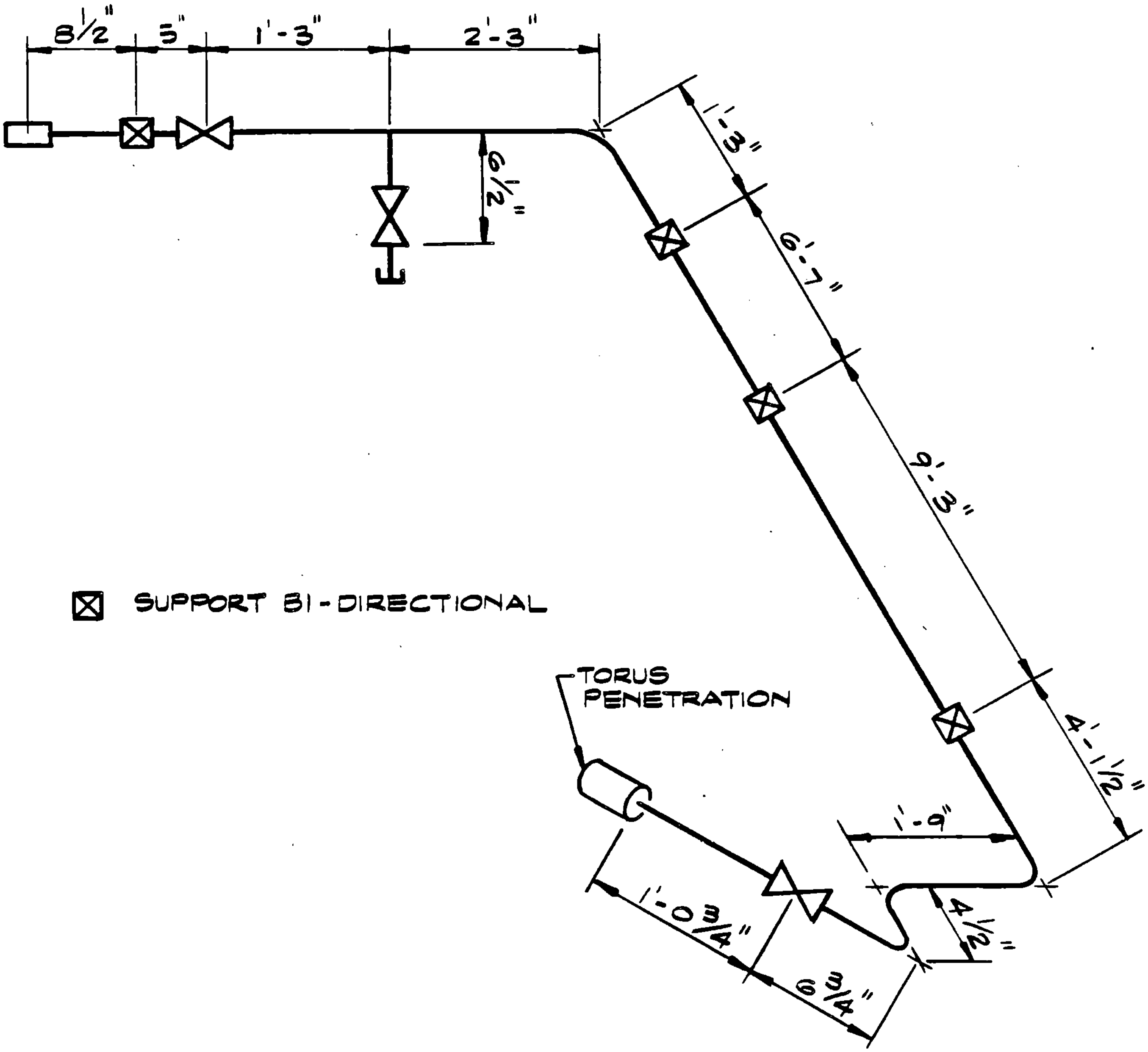


Figure 7-3.1-3

TYPICAL SMALL BORE PIPING LINE

7-3.2 Loads and Load Combinations

The loads for which the Dresden Unit 3 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 Volume 1. 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 7-3.2.1.

Using the event combinations and event sequencing defined in NUREG-0661 and discussed in Volume 1, the governing load combinations which affect the SBP are formulated. The load combinations are discussed and presented in Section 7-3.2.2.

7-3.2.1 Loads

The loads acting on the SBP are categorized as follows:

1. Dead Weight Loads
2. Seismic Loads
3. Pressure and Temperature Loads
4. Safety Relief Valve Discharge Loads
5. Pool Swell Loads
6. Condensation Oscillation Loads
7. Chugging Loads

Loads in Categories 1 and 3 are defined in Section 7-2.2.1. Table 7-3.1-1 provides further definition of Category 3 loads for typical SBP systems. Category 2 loads are defined in Section 7-3.4.1. Loads in Categories 4 are defined in Category 11 in Section 7-2.2.1.

Small bore piping attached to the torus experiences LOCA-induced and SRV discharge-induced loadings directly from the torus response to these loads. Small bore piping attached to large bore TAP lines experiences these loads indirectly, from the response of the large bore piping to the input response of the torus.

Not all of the loads defined in NUREG-0661 need 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.

7-3.2.2 Load Combinations

The loads for which the SBP are evaluated are presented in Section 7-3.2.1. The NUREG-0661 criteria for grouping these loads into load combinations are discussed in Volume 1.

Load combinations specified for the SBP are the same as those specified for the large bore TAP in Table 7-2.2-4. Several of the load combinations presented in this table do not result in controlling stresses in the SBP, and are not evaluated. Load combinations which contain hydrotest loadings are not evaluated since these loadings have a negligible effect on the small bore piping.

The governing load combinations for the SBP as described above have been considered in the analytical methods described in Section 7-3.4.

7-3.3 Acceptance Criteria

The acceptance criteria defined in NUREG-0661 on which the Dresden Unit 3 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 and the ASME Code (Reference 5 and 6, respectively).

The SBP systems are evaluated in accordance with the requirements for piping systems contained in Subsection NC of the ASME Code.

7-3.4 Methods of Analysis

The governing load combinations for which the Dresden Unit 3 SBP are presented in Section 7-3.2.2. The methodology used to evaluate the SBP for the effects of these loads is discussed in Section 7-3.4.1.

7-3.4.1 Analysis for Major Loads

The SBP systems are evaluated for the effects of the loads discussed in Section 7-3.2.1 using several different methods, depending on the type of system configuration. A description of methods used for each type of configuration follows.

a. Cantilevered Drains and Vents: Section 7-3.1 provides a description of these systems, which are shown in Figure 7-3.1-1. A beam model of the system is used to calculate the natural frequency using standard beam formulations of the system. 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 loads and load combinations defined in Sections 7-3.2.1 and 7-3.2.2.

b. SBP Lines with Flex Loops: Flex loops, shown in Figure 7-3.1-2, are designed for locations of large input displacements. The loops have resonant frequencies outside the critical frequency range of the input motion. An anchor isolates the remainder of the piping system from the Mark I loads. Since the flex loop orientation is critical in determining stresses within the loop, a method for analyzing stress in the loop for a given location is necessary. To do this, the coefficient method was developed. Stresses are determined in the loop when a reference load is applied to each direction of the six DOF's at the penetration, or loaded point. For the static case, the reference load is defined as a unit displacement or unit rotation, depending on the nature of the loading. For the dynamic loading, the reference load is defined by the motion whose response spectrum envelops other response spectra obtained at other locations on the suppression chamber in terms of frequency content.

c. Instrument Lines and Other Piping Systems: Section 7-3.1 provides a description of the systems shown in Figures 7-3.1-2 and 7-3.1-3. A beam model is generated and a frequency analysis is performed in which all modes of vibration in the range of 0 to 60 hertz are extracted. Selected lines underwent in situ testing to determine the dynamic characteristics of the SBP systems. The hammer impact method is used for excitation during the dynamic test. Modal parameters, i.e., resonant frequencies and modal damping, are extracted using the multi-degree of freedom curve fit algorithm. A dynamic load factor is calculated based on the resulting first natural frequency. An equivalent static analysis is performed using a finite element model.

The specific treatment of each load in each load category identified in Section 7-3.2.1 is discussed in the following paragraphs.

1. Dead Weight (DW) Loads

   A static analysis is performed for a unit vertical acceleration applied to the weight of steel and the weight of water contained inside the small bore piping.

2. Seismic Loads

   a. OBE Inertia (OBE_I) Loads: A static analysis is performed for a 1.0g maximum horizontal and 0.185g maximum vertical acceleration applied to the combined weight of steel and water in the analytical model.

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

c. SSE Inertia (SSE_I) Loads: A static analysis is performed for a 2.0g maximum horizontal and 0.370g maximum vertical acceleration applied to the combined weight of steel and water in the analytical model.

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

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.

b. Temperature (TE, TE1) Loads: A static analysis is performed for the TE and TE1 temperature cases, with the load applied uniformly to the small bore piping. The temperatures applied to the SBP are equal to the maximum pipe temperature.

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) Loads

A multiple response spectra analysis is performed for the loads defined in Section 7-2.2.1.

5. Pool Swell (PSO) Loads

A multiple response spectra analysis is performed for the pool swell loads defined in Section 7-2.2.1.

6. Condensation Oscillation Loads

A multiple response spectra analysis is performed for the loads defined in Section 7-2.2.1.

7. Chugging Loads

a. Pre-Chug (PCHUG) Loads: Post-chug loads bound pre-chug loads. Accordingly, the analysis results for post-chug are used in load combinations which include pre-chug loads.

b. Post-Chug (CHUG) Loads: An equivalent static analysis is performed for the loads defined in Section 7-2.2.1.

The methodology described in the preceding paragraphs results in conservative values for the SBP stresses for the controlling loads defined in NUREG-0661. Therefore, use of the analysis results obtained by applying this methodology leads to conservative estimates of design margins for the small bore piping.

7-3.5 Analysis Results

The component descriptions, loads, and load combinations, acceptance criteria, and analysis methods used in the evaluation of the Dresden Unit 3 SBP are presented and discussed in the preceding sections. The results from the evaluation of the SBP are presented in the following paragraphs.

Table 7-3.5-1 shows maximum stresses for a typical SBP evaluation resulting from ASME Code piping equations for the controlling load combinations.

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

Table 7-3.5-1

GOVERNING SMALL BORE PIPING STRESSES FOR CONTROLLING LOAD COMBINATIONS (1)

SYSTEM TYPE	LEVEL A	LEVEL B	LEVEL C	LEVEL D
	ALLOWABLE STRESS (psi)			
	MAXIMUM STRESS (psi)			
CANTILEVERS				
PIPING				
FLEX LOOPS				

(1) DATA TO BE SUPPLIED LATER.

7-4.0 PIPING SUPPORTS

An evaluation of the NUREG-0661 (Reference 1) requirements related to the design adequacy of the Dresden Unit 3 piping supports is presented in the following sections. The general criteria used in this evaluation are contained in Volume 1 of this PUAR.

The piping supports are described in Section 7-4.1. The loads and load combinations for which the piping supports are evaluated are described in Section 7-4.2. The acceptance limits to which the analysis results and the analysis methodologies to evaluate the effects of the loads and load combinations on the piping supports are discussed in Section 7-4.3. The analysis results are presented in Section 7-4.4.

7-4.1 Component Description

External TAP lines are supported by U-bolts, rod and spring hangers, rigid struts, guides, anchors, and snubbers attached to building walls or slabs using structural steel frames and baseplates or directly to the main structural steel in the building. Figures 7-2.1-2 and 7-2.1-3 show typical TAP supports outside the suppression chamber. Torus internal piping is generally supported by rigid structural steel supports attached directly to the torus shell or ring girders, as shown in Figures 7-2.1-5 and 7-2.1-6.

An example of a TAP support outside the suppression chamber consists of a pipe clamp attached to a rigid strut, which is welded to a steel base plate anchored to the building structure with anchor bolts. These components are designed and qualified by the manufacturers for specific load magnitudes. For the addition of piping supports and the modification to existing piping supports, the standard component pipe support hardware from the following manufacturers include: rigid struts, clamps, and springs - Elcen Metal Products Co. and NPS Industries, Inc.; mechanical snubbers and clamps - Bergen-Paterson Pipe Support Corp.; and anchor bolts - ITT Phillips Drill Division, Hilti, Inc. and Drillco Services Limited. Typically, pipe clamps are fabricated from ASTM A36 steel plate which are connected with ASTM A307 carbon steel bolts. Rigid struts are usually constructed of ASTM A106, Grade B pipe of various diameters and schedules. Base plates are cut from ASTM A36 carbon steel of various thicknesses. Anchor bolts are wedge-type or undercut type and of various diameters and lengths. Integral attachments (lugs, trunnions, and pads) welded to the pipe pressure boundary are used where necessary to provide shear resistance between the pipe clamp and piping or to anchor the piping system.

Torus attached piping supports connected to the torus shell or ring girders inside the suppression chamber are generally made from ASTM A516, Grade 70 carbon steel plate and ASTM A516 pipe.

7-4.2 Loads and Load Combinations

The loads for which the Dresden Unit 3 torus attached piping (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 transmitted via the response of the piping to loads defined in Sections 7-2.2.1 and 7-3.2.1. Piping supports inside the suppression chamber experience these same loads, with the addition of hydrodynamic impact and drag loads as defined in Section 7-2.2.1 for large bore torus attached piping.

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 7-4.2-1 presents the governing load combinations. For external piping supports, loads resulting from dynamic events have been combined using the SRSS method in accordance with Reference 9.

Table 7-4.2-1

LOAD COMBINATIONS - TORUS ATTACHED PIPING SUPPORTS

LOAD COMBINATION NUMBER	LOAD CONDITIONS[1,3,6]
S-1	DW + OL + OBE_I
S-2	DW + OL + QAB + QAB_I
S-3	DW[5]
S-4	DW + OL + QAB + QAB_I + SSE_I
S-5	DW + OL + QAB + QAB_I + PCHUG + $PCHUG_I$
S-6	DW + OL + QAB + QAB_I + CHUG + $CHUG_I$
S-7[2]	DW + OL + QAB + QAB_I + SSE_I + PCHUG + $PCHUG_I$
S-8[2]	DW + OL + QAB + QAB_I + SSE_I + CHUG + $CHUG_I$
S-9	DW + OL + OBE_I + CO + CO_I
S-10[2]	DW + OL + QAB + QAB_I + SSE_I + PS + PS_I + VCL
S-11	DW + OL + PSO + PSO_I + VCLO
S-12	DW + OL + OBE_I + TE + THAM + TD + OBE_D
S-13	DW + OL + QAB + QAB_I + TE + THAM + TD + QAB_D
S-14[2]	DW + OL + QAB + QAB_I + PCHUG + $PCHUG_I$ + TE_1 + $THAM_1$ + TD_3[4] + QAB_D + $PCHUG_D$
S-15[2]	DW + OL + QAB + QAB_I + CHUG + $CHUG_I$ + TE_1 + $THAM_1$ + TD_3[4] + QAB_D + $CHUG_D$
S-16[2]	DW + OL + QAB + QAB_I + SSE_I + PCHUG + $PCHUG_I$ + TE_1 + $THAM_1$ + TD_3[4] + QAB_D + SSE_D + $PCHUG_D$
S-17[2]	DW + OL + QAB + QAB_I + SSE_I + CHUG + $CHUG_I$ + TE_1 + $THAM_1$ + TD_3[4] + QAB_D + SSE_D + $CHUG_D$
S-18	DW + OL + OBE_I + CO + CO_I + TE_1 + $THAM_1$ + TD_3[4] + OBE_D + CO_D
S-19[2]	DW + OL + QAB + QAB_I + SSE_I + PS + PS_I + VCL + TE_1 + $THAM_1$ + TD_3[4] + QAB_D + SSE_D + PS_D
S-20	DW + OL + PSO + PSO_I + VCLO TE_1 + $THAM_1$ + TD_3[4] + PSO_D
S-21	DW + OL + QAB + QAB_I + SSE_I + TE + THAM + TD + QAB_D + SSE_D

(1) SEE SECTION 7-2.2.1 FOR DEFINITION OF INDIVIDUAL LOADS.

(2) USE THE LARGER OF LOCA AND SSE COMBINED BY THE SRSS METHOD OR LOCA AND OBE COMBINED ABSOLUTELY.

(3) THE MOST SEVERE COMBINATION OF STATIC LOADS MUST BE CONSIDERED.

(4) USE THE TD_1, TD_2, OR TD_3 CASE; WHICHEVER IS MOST SEVERE.

(5) APPLICABLE TO NON-WATER LINES ONLY (HYDROTEST LOAD).

(6) DYNAMIC LOAD COMBINED BY SRSS (REFERENCE 9) FOR SELECTED SUPPORTS.

7-4.3 Methods of Analysis and Acceptance Criteria

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

Standard component allowables for Levels B, C, and D service limits are supplied by the manufacturer. Allowables for structural members, base plates, and welds are defined in Subsection NE or NF of the ASME Code, Section III, Division I, up to and including the 1977 Summer Addenda and in NUREG-0661. The application of these allowables is as described in Table 7-4.3-1.

Anchor bolt allowables are based on manufacturer's test data in accordance with IEB-79-02 requirements and the American Concrete Institute (ACI) Standard ACI-349-80 (References 10 and 11, respectively). Base plate flexibility and shear-tension interaction are considered in the anchor bolt evaluation.

Integral attachments are evaluated by adding the local stresses in the pipe from each load combination to the corresponding pipe stress load combination listed in

Table 7-2.2-4. Allowable stresses are given in Table 7-2.3-1. Local stresses are generally calculated using methods described in Welding Research Council Bulletin WRC-107 and in ASME Code Case N-318 (References 12 and 13, respectively).

Table 7-4.3-1

PIPE SUPPORT ALLOWABLES

LOAD[3] COMBINATION	SERVICE LIMITS STRUCTURAL COMPONENTS	SERVICE LIMITS STANDARD COMPONENTS
S-1 S-2 S-3	B	B
S-4 S-5 S-6	C	C
S-7 S-8 S-9 S-10 S-11	D	D
S-12 S-13 S-14 S-15 S-16 S-17 S-18 S-19 S-20 S-21	3 x B[1,2]	D

(1) LIMITS APPLY TO THE RANGE OF STRESS. COMPRESSIVE STRESS NOT TO EXCEED 2/3 OF THE CRITICAL BUCKLING STRESS.

(2) PEAK VALUE OF THE RANGE OF STRESS APPLIES TO ANCHOR BOLTS.

(3) SEE TABLE 7-4.2-1 FOR DEFINITION OF THESE LOAD COMBINATIONS.

7-4.4 Analysis Results

New pipe supports and modifications to existing pipe supports were designed and analyzed to satisfy the acceptance criteria of Section 7-4.3. As a result, the design of the TAP supports for Dresden Unit 3 is adequate for the loads, load combinations, and acceptance criteria limits specified in NUREG-0661 (Reference 1) and the PUAAG (Reference 5).

7-5.0 EQUIPMENT AND VALVES

An evaluation of each of the NUREG-0661 (Reference 1) requirements which affect the design adequacy of the Dresden Unit 3 equipment and valves is presented in the following sections. The general criteria used in this evaluation are contained in Volume 1 of this PUAR.

The components of the equipment and valves which are examined are described in Section 7-5.1. The loads and load combinations for which the equipment and valves are evaluated are described and presented in Section 7-5.2. The analysis methodologies used to evaluate the effects of the loads and load combinations on the equipment and valves and the acceptance limits to which the analysis results are compared are discussed in Section 7-5.3. The analysis results are presented in Section 7-5.4.

7-5.1 Component Description

The torus attached piping (TAP) systems include equipment and valves. Three torus external TAP systems required analysis up to connections to pumps and a turbine. All valves included in the piping analytical models as described in Section 7-2.4.1 are considered in this evaluation. Strainers attached to torus internal piping systems are also included in the equipment evaluation. The principal valve manufacturers are Crane (gate, globe, and check valves) and Pratt (butterfly valves). Valve operator types include Bettis air operators and Limitorque motor operators.

7-5.2 Loads and Load Combinations

The loads acting on the valves, valve operators, and equipment nozzles are caused by the response of the torus attached piping system to the loads defined in Sections 7-2.2.1 and 7-3.2.1. These components of the TAP systems are evaluated for those loading conditions resulting from hydrodynamic responses of the torus due to LOCA and SRV discharge events, as generically defined in NUREG-0661.

Equipment nozzle connections are modeled as anchors, as described in Section 7-2.4.1. Stresses on equipment nozzles and the weakest section of the yoke are computed using the governing load combinations listed in Table 7-2.2-4.

7-5.3 Methods of Analysis and Acceptance Criteria

7-5.3.1 Equipment

Since all equipment nozzle piping stresses for these load combinations meet the 10% rule of Section 6.2.b of the PUAAG (Reference 5), no further evaluation of equipment nozzles is performed.

7-5.3.2 Valves

Check valves and manual valves are modeled in the piping analysis as piping elements, with increased stiffnesses and masses to represent the properties of the valve body. Lumped mass models are included in the piping analysis to represent valves with actuators, with the valve operator mass lumped at the center of gravity. For these valves, the stiffness and mass of the valve body and stem are considered, along with the eccentricity of the valve operator. Stresses are computed at the weakest sections of the yoke for each dynamic load combination given in Table 7-2.2-4.

7-5.3.3 Acceptance Criteria for Valves

a. Operability requirement:

The stresses in the valve body and the actuator components will not exceed the yield stress at temperature.

b. Functionality requirement:

In accordance with Section 4.3.4 of NUREG-0661, no additional functionality requirements must be satisfied if the operability criteria of Service Level A and B limits are met.

The results of the analysis of valves in TAP systems are presented in Section 7-5.4.1.

7-5.4 Analysis Results

7-5.4.1 Valves

All active valves in TAP systems are evaluated for yoke stresses according to the loads and load combinations listed in Table 7-2.2-4. For Dresden Unit 3, all the active valves' yoke stresses are below Service Level A and B limits; thus, all the active valves meet the operability and functionality requirements.

7-6.0 SUPPRESSION CHAMBER PENETRATIONS

An evaluation of the NUREG-0661 requirements which affect the design adequacy of the Dresden Unit 3 torus attached piping TAP penetrations is presented in the following sections. The general criteria used in this evaluation are contained in Volume 1 of this report.

The components which are analyzed are described in Section 7-6.1. The loads and load combinations for which the penetrations are evaluated are described and presented in Section 7-6.2. The acceptance limits to which the analysis results are compared are discussed and presented in Section 7-6.3. 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 7-6.4. The analysis results are presented in Section 7-6.5.

7-6.1 Component Description

The large bore piping suppression chamber penetrations evaluated in this section are numbered and located as shown in Figure 7-1.1-1. The principal components of the penetrations are the nozzles and the insert plates, as shown in Figure 7-6.1-1. 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 reinforcing is provided for many penetrations, as shown in Table 7-6.1-1 and Figures 7-6.1-2 through 7-6.1-4.

Radial penetrations are aligned radially with the suppression chamber segment and are symmetrical about their centerline, as shown in Figure 7-6.1-3. Slightly non-radial penetrations are aligned parallel to the horizontal or vertical centerline of the suppression chamber segment and are slightly offset. Non-radial penetrations are aligned parallel to the suppression chamber vertical centerline, producing an oblique orientation with respect to the torus shell, as shown in Figure 7-6.1-4.

Typical penetration reinforcement modifications are shown in Figures 7-6.1-2 through 7-6.1-4. The modifications include pipe section which are installed as sleeves to reinforce the penetration nozzles. Support arms extend radially from the pipe sleeves to pad plates attached to the suppression chamber shell.

Each penetration modification is designed to allow the penetrations to sustain TAP reaction loads produced by suppression chamber motions due to normal loads and hydrodynamic loads while keeping component stress intensities below the allowable values specified in Reference 6.

Table 7-6.1-1

PENETRATION GEOMETRY AND REINFORCEMENT SCHEDULE

PENETRATION NUMBER	PENETRATION DIAMETER (INCHES)	EXTERNAL REINFORCEMENT SUPPORT ARMS	REFERENCE FIGURE
X-301A-F	30	NO	7-6.1-1
X-302A-F	24	NO	7-6.1-1
X-303A, B, C, D	20	YES	7-6.1-3
X-304	20	NO	7-6.1-1
X-310A, B	14	YES	7-6.1-4
X-311A, B	6.625	YES	7-6.1-4
X-312	2.375	NO	7-6.1-1
X-317	16	YES	7-6.1-3
X-318	18	NO	7-6.1-1

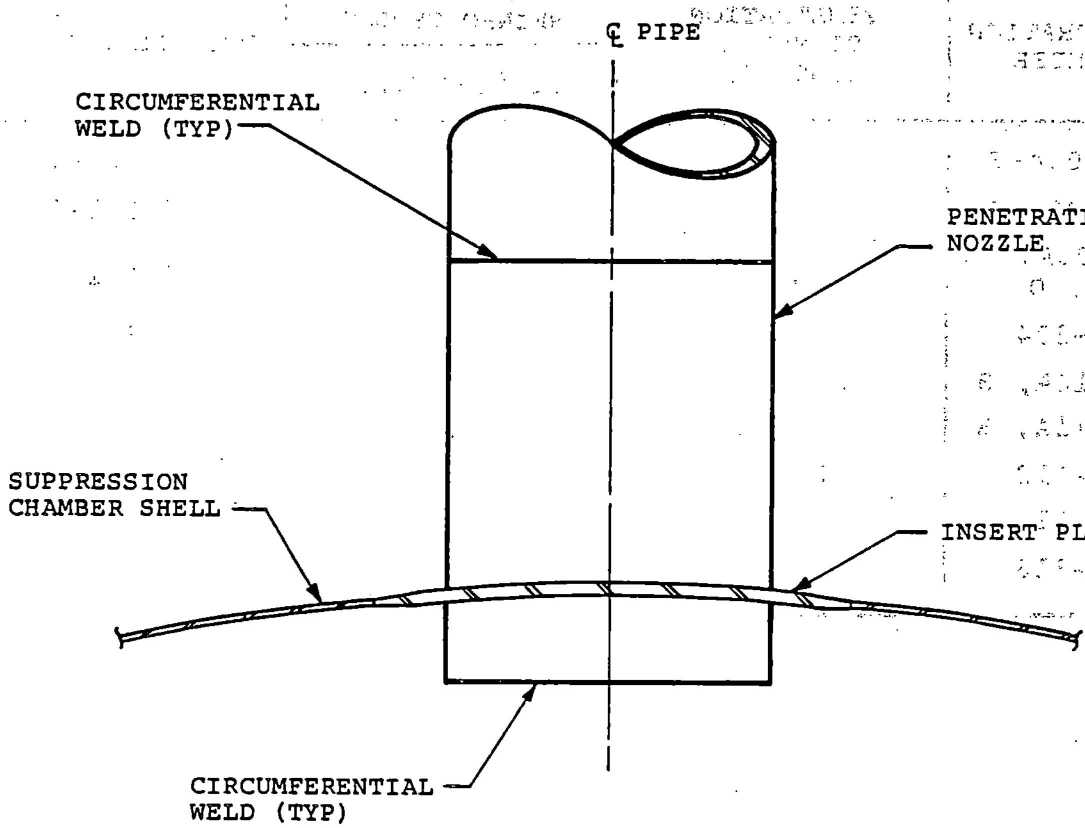


Figure 7-6.1-1

TYPICAL UNREINFORCED PENETRATION

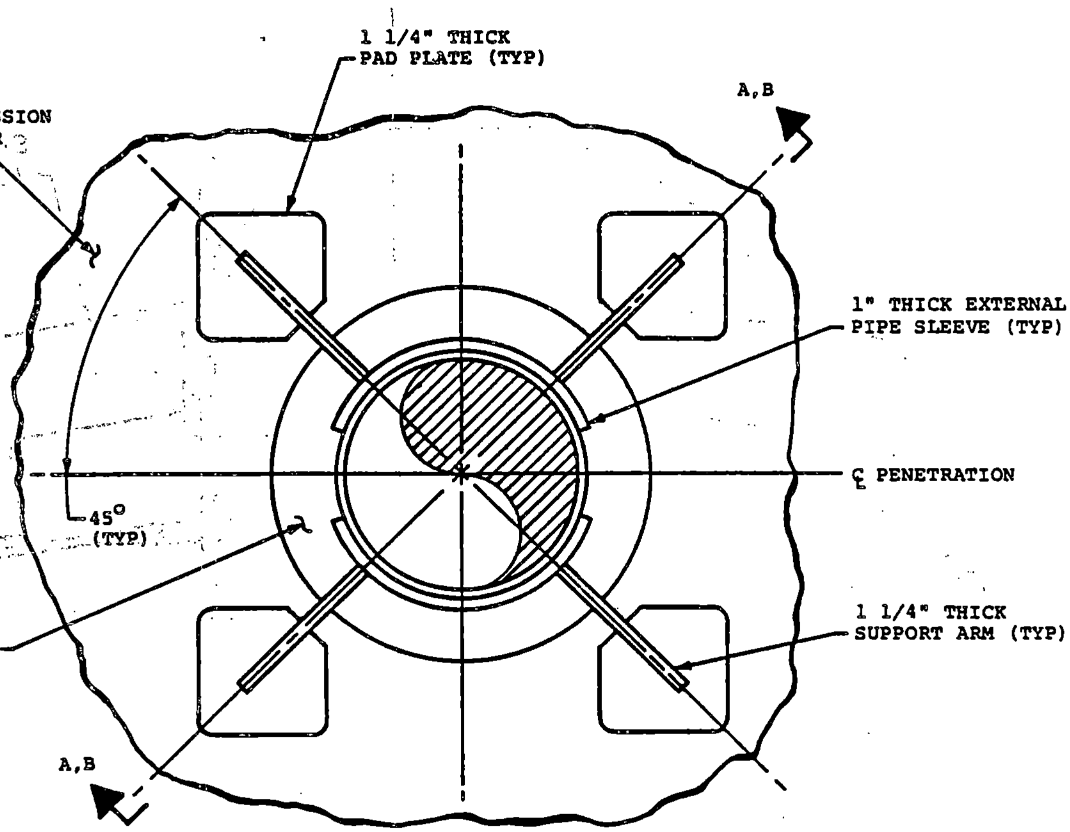
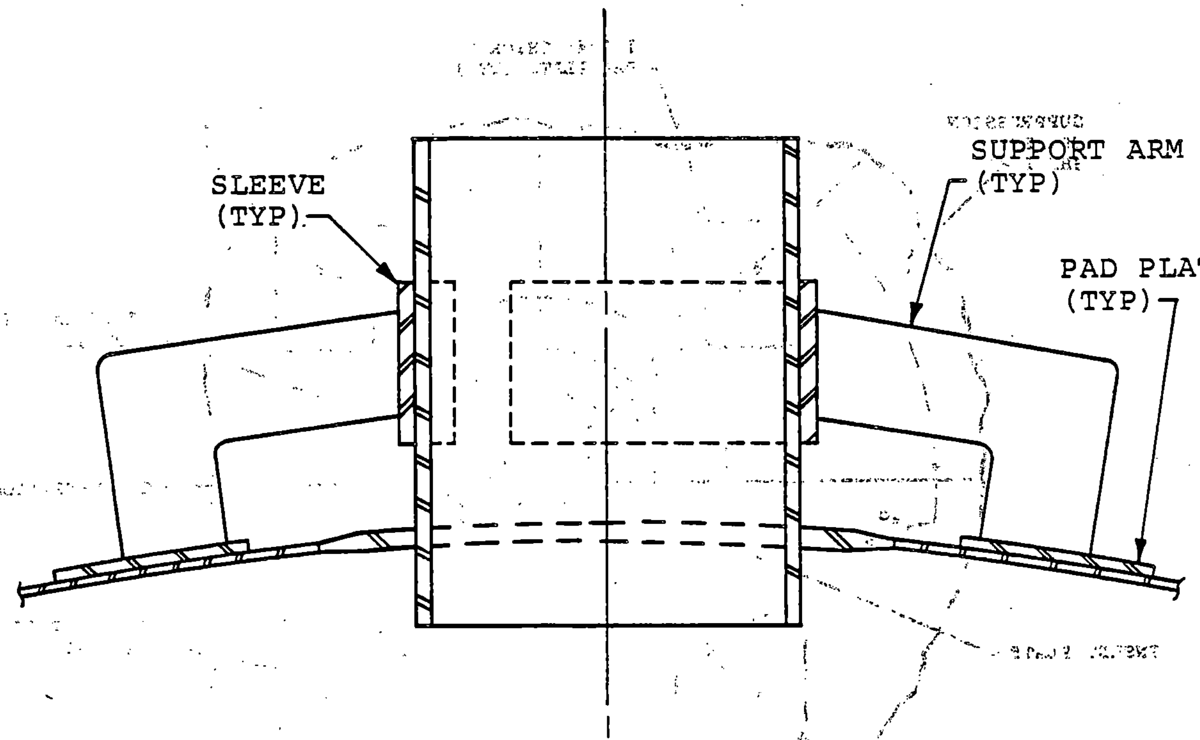


Figure 7-6.1-2

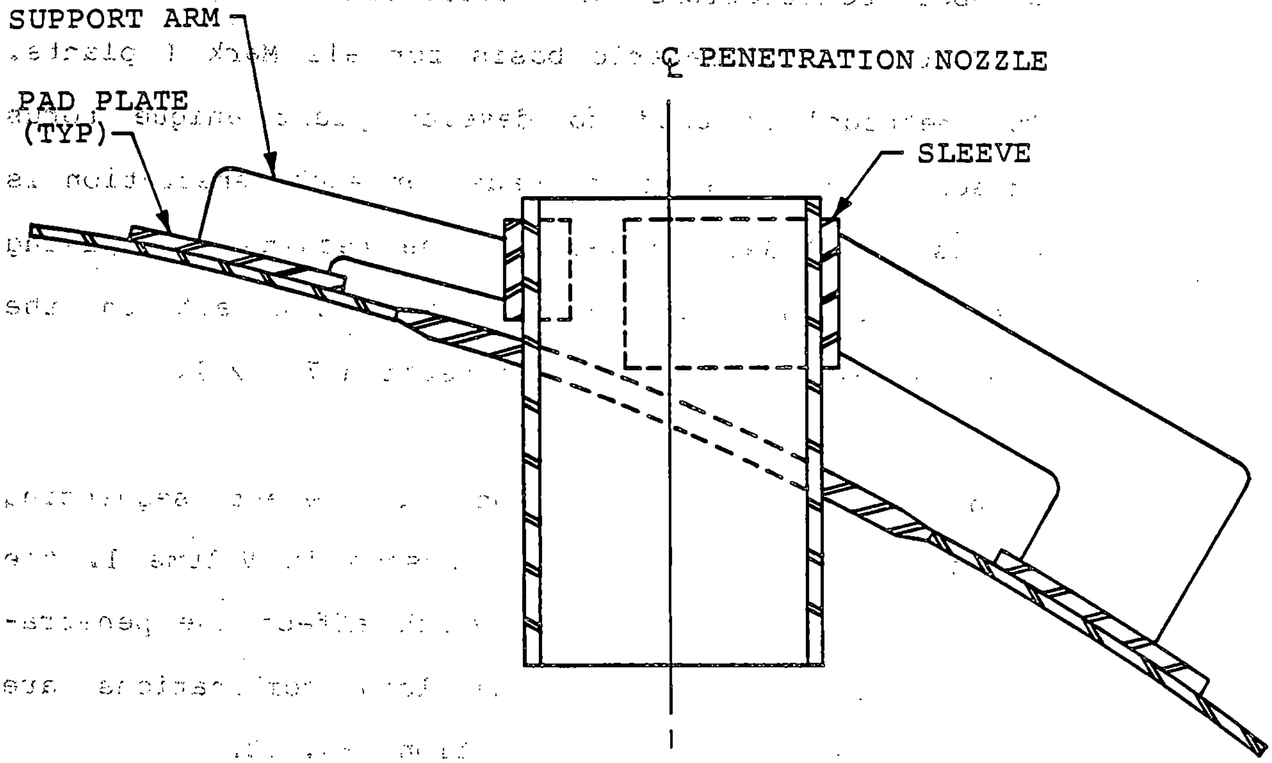
EXTERNAL VIEW OF TYPICAL PENETRATION REINFORCEMENT



SECTION A-A

Figure 7-6.1-3

REINFORCEMENT DETAILS FOR TYPICAL RADIAL PENETRATIONS



SECTION B-B

Figure 7-6.1-4

REINFORCEMENT DETAILS FOR

TYPICAL NON-RADIAL PENETRATIONS

7-6.2 Loads and Load Combinations

The loads for which the Dresden Unit 3 suppression chamber penetrations are evaluated are defined in NUREG-0661 on a generic basis for all Mark I plants. The methodology used to develop plant unique torus attached piping reaction loads for each penetration is discussed in Section 7-2.0. The results of applying the controlling reaction loads which act on the penetrations are discussed in Section 7-6.2.1.

Using the event combinations and event sequencing defined in NUREG-0661 and discussed in Volume 1, the governing load combinations which affect the penetrations are formulated. The load combinations are discussed and presented in Section 7-6.2.2.

7-6.2.1 Loads

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

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

Loads in the above categories include those acting on torus attached piping discussed in Section 7-2.2.1 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 and produce reaction loads on the penetrations. In addition, loads acting directly on the torus shell produce initial stresses in the shell and insert plate, which are included in the evaluation as discussed in Section 7-6.4.

The reaction loads used in the suppression chamber penetration evaluation for each load category are taken from the TAP system evaluation presented in Sections 7-2.4 and 7-2.5. The components of these reaction loads at the penetrations consist of the maximum forces and moments acting on the penetration nozzle both inside and outside the suppression chamber. The reaction loads include the coupling effects of the TAP system and the suppression chamber as discussed in Section 7-2.4.

Maximum torus operating temperature and pressure values are used in the analysis of the penetrations. These values are taken from Reference 3 and envelop the maximum operating pressures and temperatures.

7-6.2.2 Load Combinations

The loads for which the suppression chamber penetrations are evaluated are presented in Section 7-6.2.1. The general NUREG-0661 criteria for grouping the loads into load combinations are discussed in Volume 1. Not all load combinations for each event need to be examined, since many are enveloped by others which contain the same or additional loads. Table 7-6.2-1 shows the governing load combinations used in evaluating the suppression chamber penetrations.

Table 7-6.2-1

GOVERNING PENETRATION LOAD COMBINATIONS AND SERVICE LEVELS

LOAD COMBINATION NUMBER	LOAD COMBINATIONS (1)	SERVICE LEVEL
CHUG-14E	$\|DW + TE_1 + THAM_1 + TD^{(3)} + OL\| + (\|QAB\| + \|CHUG\| + \|QAB_I\| + \|OBE\|^{(4)} + \|CHUG_I\|)$ or $2(\|QAB\| + \|CHUG\| + \|QAB_I\| + \|OBE\|^{(4)} + \|CHUG_I\|)$, WHICHEVER IS HIGHER	B
CHUG-14M	$\|DW + TE_1 + THAM_1 + TD^{(3)} + OL\| + \|QAB\| + \|QAB_I\| + \|OBE\|^{(4)} + \|CHUG\| + \|CHUG_I\|$	B
CHUG-27M	$\|DW + TE_1 + THAM_1 + TD^{(3)} + OL\| + \|QAB\| + \|SSE\|^{(5)} + \|QAB_I\| + \|CHUG\| + \|CHUG_I\|$	C
PS-15M	$\|DW + TE_1 + THAM_1 + TD^{(3)} + OL\| + \|QAB\| + \|SSE\|^{(5)} + \|QAB_I\| + \|PS\| + \|PS_I\|$	C
PS-18M (2)	$\|DW + TE_1 + THAM_1 + TD^{(3)} + OL\| + \|OBE\|^{(4)} + \|PS\| + \|PS_I\|$	B
CO-27M	$\|DW + TE_1 + THAM_1 + TD^{(3)} + OL\| + \|SSE\|^{(5)} + \|CO\| + \|CO_I\|$	C

(1) SEE SECTION 6-2.2.1 FOR DEFINITION OF SYMBOLS USED IN LOAD COMBINATION.

(2) PRIMARY PLUS SECONDARY STRESS INTENSITY RANGE AND FATIGUE EVALUATION ARE NOT REQUIRED, SINCE CHUG-14E GOVERNS.

(3) TD IS THE MAXIMUM OF TD_1, TD_2, AND TD_3.

(4) OBE IS DEFINED AS $OBE_I + OBE_D$.

(5) SSE IS DEFINED AS $SSE_I + SSE_D$.

7-6.3 <u>Analysis Acceptance Criteria</u>

The acceptance criteria defined in NUREG-0661 are the basis for the Dresden Unit 3 suppression chamber penetrations analysis. These criteria are discussed in Volume 1. In general, the acceptance criteria follow the rules contained in the ASME Code, 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 reinforcing modifications are evaluated in accordance with the requirements for Class MC components contained in the ASME Code. The jurisdictional boundaries for the penetration MC components are defined at the inner and outer piping/nozzle circumferential welds nearest to the suppression chamber.

7-6.4 Methods of Analysis

The methodology used to evaluate the penetrations for the loading condition described in Section 6-6.2.1 is discussed in the following paragraphs.

All of the large bore suppression chamber penetrations listed in Table 7-6.1-1 have been evaluated using finite element model except for Penetrations 301 and 302, which were evaluated using the methods described in Reference 12.

Based on similarities in geometric configurations of selected penetrations discussed in Section 7-6.1, four analytical models are used to represent a total of eleven penetrations. The mechanical and thermal loads for each group of penetrations are enveloped and applied to the associated analytical model. The allowable stresses for the representative penetrations are determined at the maximum temperature, as discussed in Section 7-6.2.

The finite element models of the penetrations consist of the external and internal nozzles, the insert plate, a portion of the suppression chamber shell, and for the reinforced penetrations, the support arms, the pad plates, and the nozzle sleeves. Thin plate finite elements are used to model each component explicitly. Figure 7-6.4-1 shows a typical penetration analytical model.

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 models is chosen to minimize the impact of boundary effects on the region of stress evaluation. Translational restraints are imposed at the boundary nodes on the suppression chamber shell section of the models. Where pad plates are attached to the suppression chamber, shell element thicknesses are taken as the effective thickness of the suppression chamber shell and the pad plate.

The maximum absolute value of each force and moment component for each reaction load case is conservatively applied to the analytical models in a manner which maximizes penetration stresses. Local thermal effects at each penetration are also evaluated.

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. These stresses are taken from the suppression chamber analysis results discussed in Volume 2. The stress intensities of the dynamic loads are combined using direct summation in accordance with Reference 9. The maximum stress intensities for each penetration component are calculated and compared to stress allowables.

The small bore piping penetrations are evaluated in a manner similar to the above described procedure. For these penetrations, however, a computer code 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 nozzles. The maximum stress intensities for each penetration component are then calculated and compared to the allowable stresses.

Fatigue effects for the penetration with the highest stress levels and maximum loading cycles are evaluated.

The number of stress cycles and load cycles for each loading case is established using the suppression chamber analysis results presented in Reference 10. The alternating stress intensity for each loading is then calculated. Fatigue strength reduction factors of 2.0 for major component stresses and 4.0 for component weld stresses are conservatively used. The governing cumulative fatigue usage factor is determined by calculating fatigue usage for the controlling event combination.

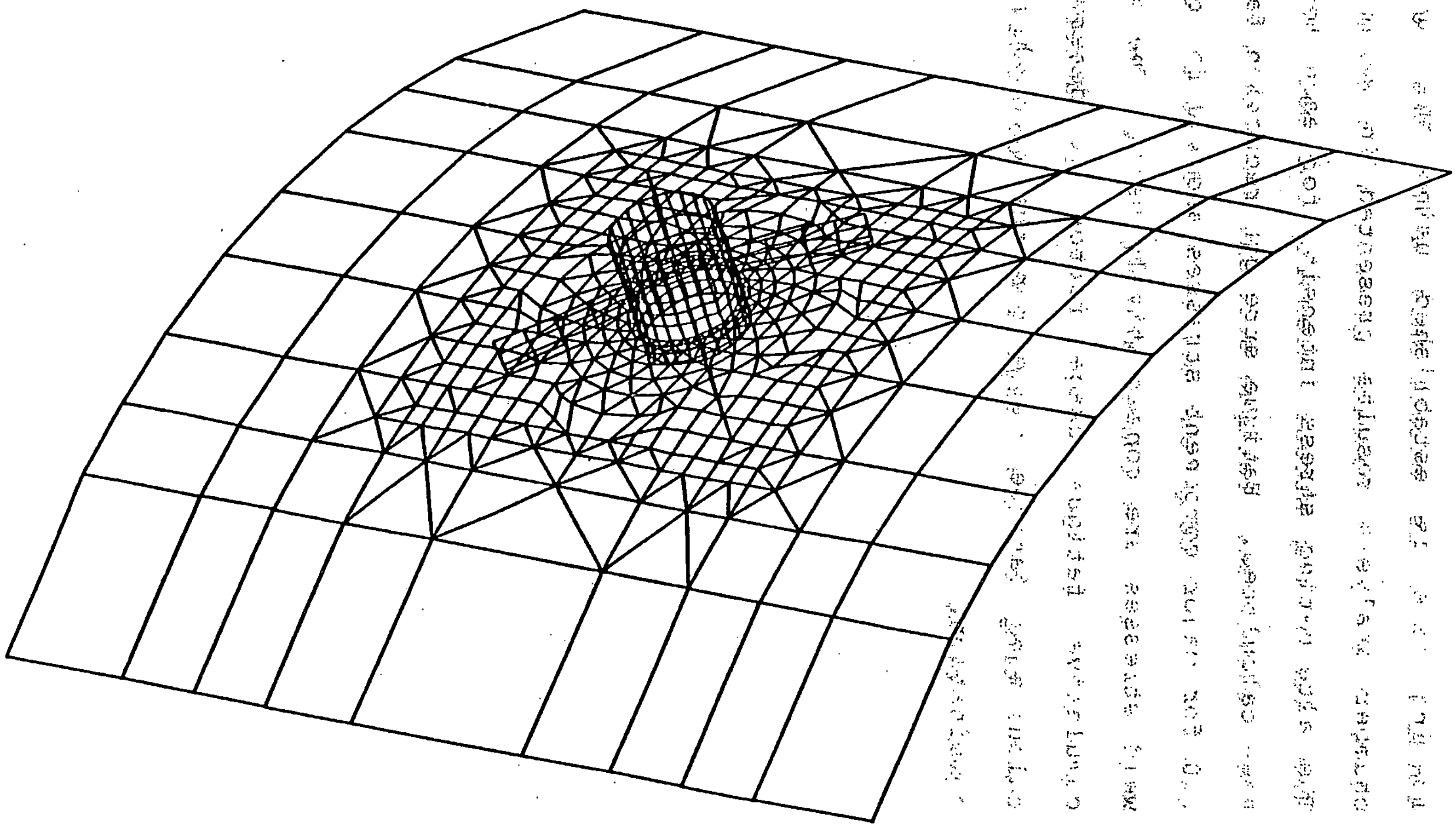


Figure 7-6.4-1

SUPPRESSION CHAMBER REINFORCED PENETRATION-

TYPICAL FINITE ELEMENT MODEL

7-6.5 Analysis Results

The geometry, loads and load combinations, acceptance criteria, and analysis methods used in the evaluation of the Dresden Unit 3 suppression chamber penetrations are presented and discussed in the previous sections. The results from the evaluation of the penetrations are presented in Tables 7-6.5-1 through 7-6.5-5.

These tables show the maximum calculated stresses and the associated design margins for the major penetration components for the governing load combinations.

The reinforced SBP penetrations were also evaluated and found to be within the specified allowable limits.

The cumulative fatigue usage factors for the controlling components and welds are within the acceptable fatigue usage factor of 1.0.

Table 7-6.5-1

PENETRATION EVALUATION STRESS SUMMARY

FOR PENETRATION X-303

CONTAINMENT COMPONENT	LOAD CASE(1)			
	CHUG-14E		CHUG-14M	
	STRESS INTENSITY			
	MAXIMUM (ksi)	LIMIT (ksi)	MAXIMUM (ksi)	LIMIT (ksi)
TORUS	63.50	69.50	17.50	28.95
INSERT PLATE	52.70	69.50	18.80	28.95
PAD	60.70	69.50	15.70	28.95
STIFFENER	38.40	69.50	18.80	28.95
NOZZLE	65.70	69.50	10.40	28.95

(1) THESE TWO LOAD CASES BOUND ALL OTHERS EVALUATED FOR THESE PENETRATIONS (SEE TABLE 7-6.2-1).

Table 7-6.5-2

PENETRATION EVALUATION STRESS SUMMARY

FOR PENETRATION X-304

CONTAINMENT/ COMPONENT	LOAD CASE					
	CHUG-14E		CHUG-14M		PS-15M	
	STRESS INTENSITY					
	MAXIMUM (ksi)	LIMIT (ksi)	MAXIMUM (ksi)	LIMIT (ksi)	MAXIMUM (ksi)	LIMIT (ksi)
TORUS	33.67	69.50	16.36	28.95	27.90	53.80
INSERT PLATE	27.21	69.50	15.61	28.95	27.93	53.80
PAD	N/A	N/A	N/A	N/A	N/A	N/A
STIFFENER	N/A	N/A	N/A	N/A	N/A	N/A
NOZZLE	17.79	54.90	4.81	22.65	6.69	42.45

Table 7-6.5-3

PENETRATION EVALUATION STRESS SUMMARY FOR PENETRATIONS X-310, X-311

CONTAINMENT/ COMPONENT	LOAD CASE (1)			
	CHUG-14E		CHUG-14M	
	STRESS INTENSITY			
	MAXIMUM (ksi)	LIMIT (ksi)	MAXIMUM (ksi)	LIMIT (ksi)
TORUS	31.19	69.50	21.67	28.95
INSERT PLATE	17.35	69.50	15.44	28.95
PAD	30.25	69.50	14.38	28.95
STIFFENER	13.75	69.50	8.24	28.95
X-310 NOZZLE	28.51	69.50	8.54	28.95
X-311 NOZZLE	20.00	54.90	9.72	22.65
WAGON WHEEL AND GUSSET PLATE	5.09	69.50	2.62	28.95

(1) THESE TWO LOAD CASES BOUND ALL OTHERS EVALUATED FOR THESE PENETRATIONS (SEE TABLE 7-6.2-1).

Table 7-6.5-4

PENETRATION EVALUATION STRESS SUMMARY

FOR PENETRATION X-317

CONTAINMENT/ COMPONENT	LOAD CASE					
	CHUG-14E		CO-27M		PS-18M	
	STRESS INTENSITY					
	MAXIMUM (ksi)	LIMIT (ksi)	MAXIMUM (ksi)	LIMIT (ksi)	MAXIMUM (ksi)	LIMIT (ksi)
TORUS	27.51	69.50	18.80	53.80	14.80	28.95
INSERT PLATE	19.78	69.50	18.70	53.80	14.81	28.95
PAD	28.40	69.50	14.89	53.80	13.24	28.95
STIFFENER	6.88	69.50	9.35	53.80	6.42	28.95
NOZZLE	13.35	54.90	12.22	42.45	6.83	22.65

Table 7-6.5-5

PENETRATION EVALUATION STRESS SUMMARY

FOR PENETRATION X-318

CONTAINMENT/ COMPONENT	LOAD CASE					
	CHUG-14E		CHUG-14M		CHUG-27M	
	STRESS INTENSITY					
	MAXIMUM (ksi)	LIMIT (ksi)	MAXIMUM (ksi)	LIMIT (ksi)	MAXIMUM (ksi)	LIMIT (ksi)
TORUS	67.70	69.50	17.96	28.95	15.20	53.80
INSERT PLATE	27.70	69.50	16.25	28.95	14.42	53.80
PAD	N/A	N/A	N/A	N/A	N/A	N/A
STIFFENER	N/A	N/A	N/A	N/A	N/A	N/A
NOZZLE	26.70	54.90	4.92	22.65	4.56	42.45

7-7.0 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; Addenda, Sheet 1, April 1982.

3. "Mark I Containment Program Plant Unique Load Definition," Dresden Station, Units 2 and 3, General Electric Company, NEDO-24566, Revision 1, November 1981.

4. "Safety Analysis Report (SAR)," Dresden Station, Units 2 and 3, Commonwealth Edison Company, July 1969, Amendments 1 through 14.

5. "Mark I Containment Program Structural Acceptance Criteria Plant Unique Analysis Applications Guide," Task Number 3.1.3, Mark I Owners Group, 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. "Methodology for Combining Dynamic Responses," USNRC, NUREG-0484, Revision 1, May 1980.

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

10. "Pipe Support Base Plate Designs Using Concrete Expansion Anchor Bolts," NRC Office of Inspection and Enforcement, IEB-79-02, Revision 2, November 8, 1979.

11. "Code Requirements for Nuclear Safety-Related Concrete Structures," American Concrete Institute, ACI 349-80, 1980.

12. Wichman, K. R., Hopper, A. G., and Mershon, J. L., "Local Stresses in Spherical and Cylindrical Shells due to External Loadings," Welding Research Council Bulletin 107, March 1979.

13. "Procedures for Evaluation of the Design of Rectangular Cross Section Attachments on Class 2 or 3 Piping," ASME Code Case N-318, Section III, Division 1, July 13, 1981.