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ENRICO FERMI ATOMIC POWER PLANT

UNIT 2

PLANT UNIQUE ANALYSIS REPORT

VOLUME 4

INTERNAL STRUCTURES ANALYSIS

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ABSTRACT

The primary containment for the Enrico Fermi Atomic Power Plant, Unit 2, was designed, erected, pressure-tested, and ASME Code N-stamped during the early 1970's for the Detroit Edison Company by the Chicago Bridge and Iron Company. Since that time new requirements, defined in the Nuclear Regulatory Commission's Safety Evaluation Report NUREG-0661, which affect the design and operation of the primary containment system have evolved. The requirements to be addressed include an assessment of additional containment design loads postulated to occur during a loss-of-coolant accident or a safety relief valve discharge event, as well as an assessment of the effects that these postulated events have on the operational characteristics of the containment system.

This plant unique analysis report documents the efforts undertaken to address and resolve each of the applicable NUREG-0661 requirements, and demonstrates, in accordance with NUREG-0661 acceptance criteria, that the design of the primary containment system is adequate and that original design safety margins have been restored. The report is composed of five volumes which are:

- 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 PIPING ANALYSIS

This volume, Volume 4, which documents the evaluation of the internal structures, has been prepared by NUTECH Engineers, Incorporated (NUTECH), acting as an agent responsible to the Detroit Edison Company.

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LIST OF ACRONYMS

ADS	Automatic Depressurization System
ASME	American Society of Mechanical Engineers
CO	Condensation Oscillation
DBA	Design Basis Accident
DBE	Design Basis Earthquake
DLF	Dynamic Load Factor
FSAR	Final Safety Analysis Report
IBA	Intermediate Break Accident
LDR	Load Definition Report
LOCA	Loss-of-Coolant Accident
MC	Midcylinder
MJ	Mitered Joint
NOC	Normal Operating Conditions
NRC	Nuclear Regulatory Commission
NVB	Non-Vent Line Bay
OBE	Operating Basis Earthquake
PUA	Plant Unique Analysis
PUAAG	Plant Unique Analysis Application Guide
PUAR	Plant Unique Analysis Report
PULD	Plant Unique Load Definition
QSTF	Quarter-Scale Test Facility
RSEL	Resultant-Static-Equivalent Load
SBA	Small Break Accident
SRV	Safety Relief Valve
SRVDL	Safety Relief Valve Discharge Line
SSE	Safe Shutdown Earthquake
VB	Vent Line Bay

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4-1.0 INTRODUCTION

In conjunction with Volume 1 of the Plant Unique Analysis Report (PUAR), this volume documents the efforts undertaken to address the requirements defined in NUREG-0661 which affect the Fermi 2 internal structures. The internal structures PUAR is organized as follows:

- INTRODUCTION
  - Scope of Analysis
  - Summary and Conclusions
- INTERNAL STRUCTURES ANALYSIS (Catwalk, Monorail, Thermocouple and Vacuum Breaker Conduits)
  - Component Description
  - Loads and Load Combinations
  - Analysis Acceptance Criteria
  - Method of Analysis
  - Analysis Results

The INTRODUCTION section contains a general overview discussion of the internal structures evaluation. The INTERNAL STRUCTURES ANALYSIS section discusses the specific components, loads, criteria, methods, and results associated with the evaluation.

4-1.1 Scope of Analysis

The criteria presented in Volume 1 are used as the basis for all of the Fermi 2 internal structures evaluations described in this volume. The internal structures evaluated include the catwalk, monorail, and thermocouple and vacuum breaker conduits. These structures are not required for the safe operation of the primary containment system during accident conditions.

The internal structures are evaluated for the effects of LOCA and SRV discharge related loads, as defined by the NRC's Safety Evaluation Report NUREG-0661 (Reference 1) and the Mark I Containment Program Load Definition Report (LDR) (Reference 2).

The LOCA and SRV discharge loads used in this evaluation are formulated using the procedures discussed in Volume 1 of this report. The evaluation includes a structural analysis of the internal structures to ensure that these structures do not fail and result in damage to other safety related components.

The results of the structural evaluation for each load are used to evaluate load combinations for the internal structures, in accordance with the Mark I Containment Program Plant Unique Analysis Application Guide (PUAGG) (Reference 3). The evaluation results are conservatively compared with the acceptance limits specified by the applicable sections of the ASME Code (Reference 4) to ensure that failure will not occur.

4-1.2 Summary and Conclusions

The evaluation documented in this volume is performed for the Fermi 2 internal structures identified in Section 1-1.1 and described in Section 1-2.1. These structures include the catwalk, monorail, and thermocouple and vacuum breaker conduits.

The LOCA and SRV discharge related events defined in NUREG-0661 result in hydrodynamic loadings on the internal structures. The major loadings which affect the catwalk, monorail, and the portions of the thermocouple and vacuum breaker conduits above the suppression pool include pool swell impact loads, froth impingement loads, and pool fallback loads. The major loadings which affect submerged portions of the thermocouple conduits include submerged structure loadings. Conservative values for these loadings are developed using the methodology discussed in Section 1-4.0. Other loads, such as dead weight loads, seismic loads, and support displacement loads, have a lesser effect on the internal structures and are also considered in the evaluation.

The analysis results for these loadings are used to formulate the controlling event combinations which affect the internal structures, as discussed in Section 1-3.2. The results are compared to acceptance limits which ensure that the internal structures do not fail and result in damage to safety-related components. The evaluation results show that the stresses for all of the internal structure components are within acceptable limits. The intent of the NUREG-0661 requirements as they affect the internal structures is therefore considered to be met.

4-2.0 INTERNAL STRUCTURES ANALYSIS

An evaluation of each of the NUREG-0661 requirements which affect the design adequacy of the Fermi 2 internal structures is presented in the sections which follow. The criteria used in the evaluation are contained in Volume 1 of this report.

The component parts of the internal structures which are examined are described in Section 4-2.1. The loads and load combinations which are evaluated are described and presented in Section 4-2.2. The analysis methodology used to evaluate the effects of these loads and load combinations is discussed in Section 4-2.4. The acceptance limits to which the analysis results are compared are discussed and presented in Section 4-2.3. The analysis results and the corresponding design margins are presented in Section 4-2.5.

4-2.1 Component Description

The internal structures which are evaluated include the catwalk, the monorail, and the thermocouple and vacuum breaker conduits, which are described in Sections 4-2.1.1 through 4-2.1.3, respectively.

4-2.1.1 Catwalk

The catwalk is a platform-type structure approximately 3 feet wide, which extends around the full circumference of the suppression chamber. The catwalk is located in the upper outside quadrant of each suppression chamber mitered cylinder.

The catwalk frame consists of two W10 x 17 stringers which extend from mitered joint to mitered joint with intermittently spaced MC8 x 8.5 cross beams. The catwalk frame is supported at two intermediate locations between mitered joints. The mitered joint supports consist of one vertical and one horizontal support member. The intermediate supports consist of two vertical support members.

A vacuum breaker platform approximately 4' wide by 6' long is located adjacent to the catwalk at midcylinder of each vent line bay. The vacuum breaker platform is supported by the catwalk frame on one side and by two additional support members connecting to the suppression chamber shell on the other side. The catwalk and vacuum breaker platform configurations are shown in Figure 4-2.1-1.

The catwalk and vacuum breaker platform are covered by grating which is bolted to the catwalk frame. The catwalk frame is braced against lateral loads by diagonal members located between the stringers and by the horizontal support members at the mitered joints.

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4-2.1.2 Monorail

The monorail consists of S8 x 18.4 beam sections curved to a 61'-7" radius and connected end-to-end to form a continuous monorail beam around the circumference of the suppression chamber. The monorail is located in the upper outside quadrant of each suppression chamber mitered cylinder. An expansion joint is provided at one location in the monorail beam.

The monorail beam is supported at three locations in each vent line bay and at one location in each non-vent line bay. The supports in the vent line bay are located near the center and the ends of the bay. The non-vent line bay support is located near the center of the bay.

The monorail supports consist of a vertical support member and a horizontal support member. The monorail support members are constructed from 2-1/2" x 2-1/2" x 5/16" thick double angles. A typical monorail support is shown in Figure 4-2.1-2.

4-2.1.3 Thermocouple and Vacuum Breaker Conduits

The sixteen thermocouples located inside the suppression chamber are part of the containment monitoring system. The extension wires for the thermocouples are routed inside 3/4" diameter rigid steel conduit and cold-formed channel sections from junction boxes at three suppression chamber penetration locations. A typical routing for a suppression chamber thermocouple system is shown in Figure 4-2.1-3.

The thermocouple conduits and channels are supported by the suppression chamber shell and the catwalk at regular intervals along their length. The supports for the conduits and channels are constructed from 3/4" thick plate and standard brackets. Pad plates are used where attachments to the suppression chamber shell are made.

The vacuum breaker conduits provide power and circuitry for solenoids and instrumentation located inside the drywell/wetwell vacuum breakers. The instrumentation is used to monitor the valve open and closed positions. The wiring for the vacuum breaker electrical system is routed inside 1-1/4" and 3/4" diameter rigid steel

conduit from three suppression chamber penetration locations to the vacuum breakers, as shown in Figure 4-2.1-4.

The vacuum breaker electrical conduits are supported by the suppression chamber shell and the catwalk at regular intervals along their length. The supports for the conduits are constructed from 1" thick plate with pad plates used where attachments to the suppression chamber shell are made.

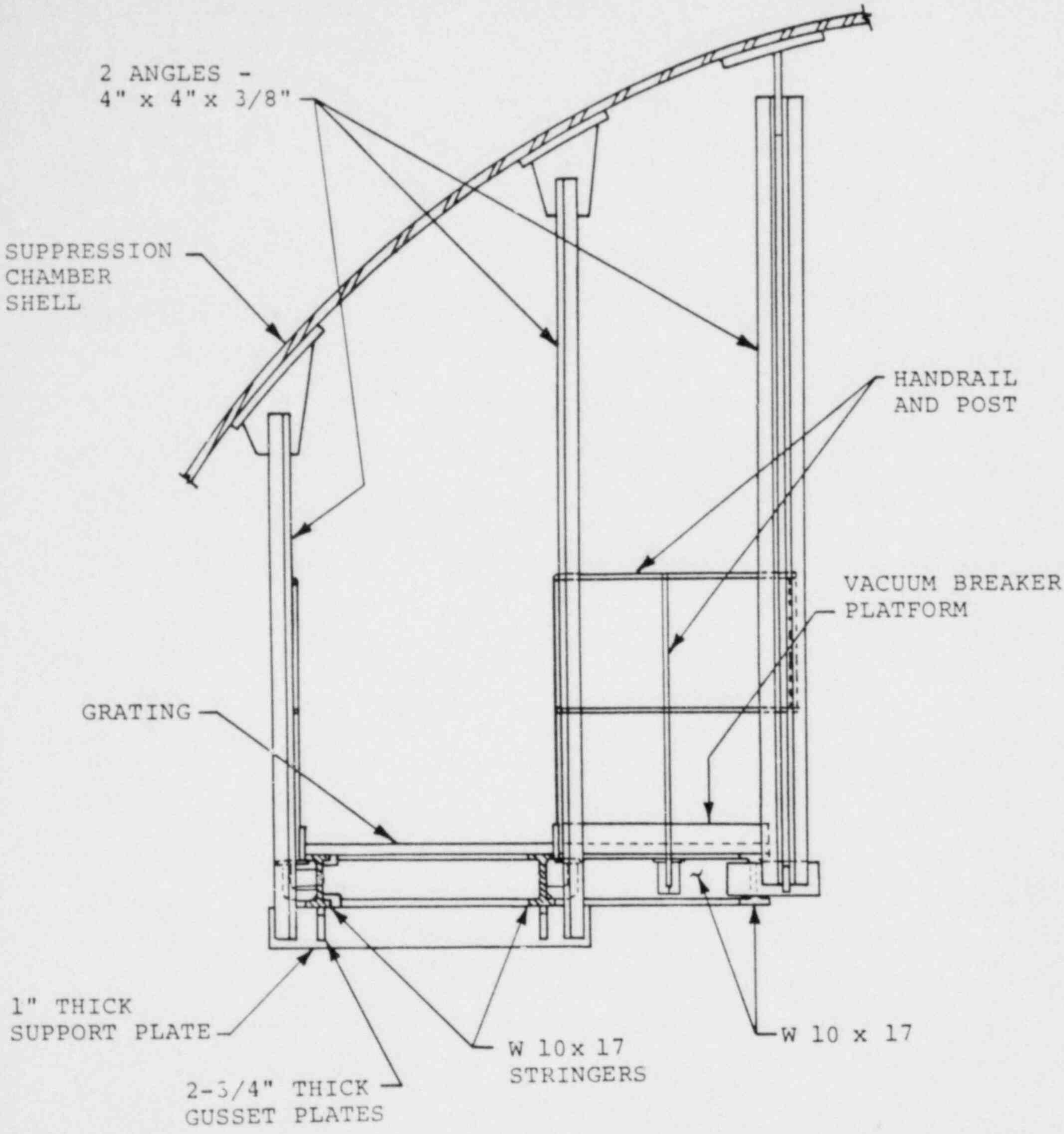

Figure 4-2.1-1

CATWALK SUPPORT AT VACUUM BREAKER PLATFORM

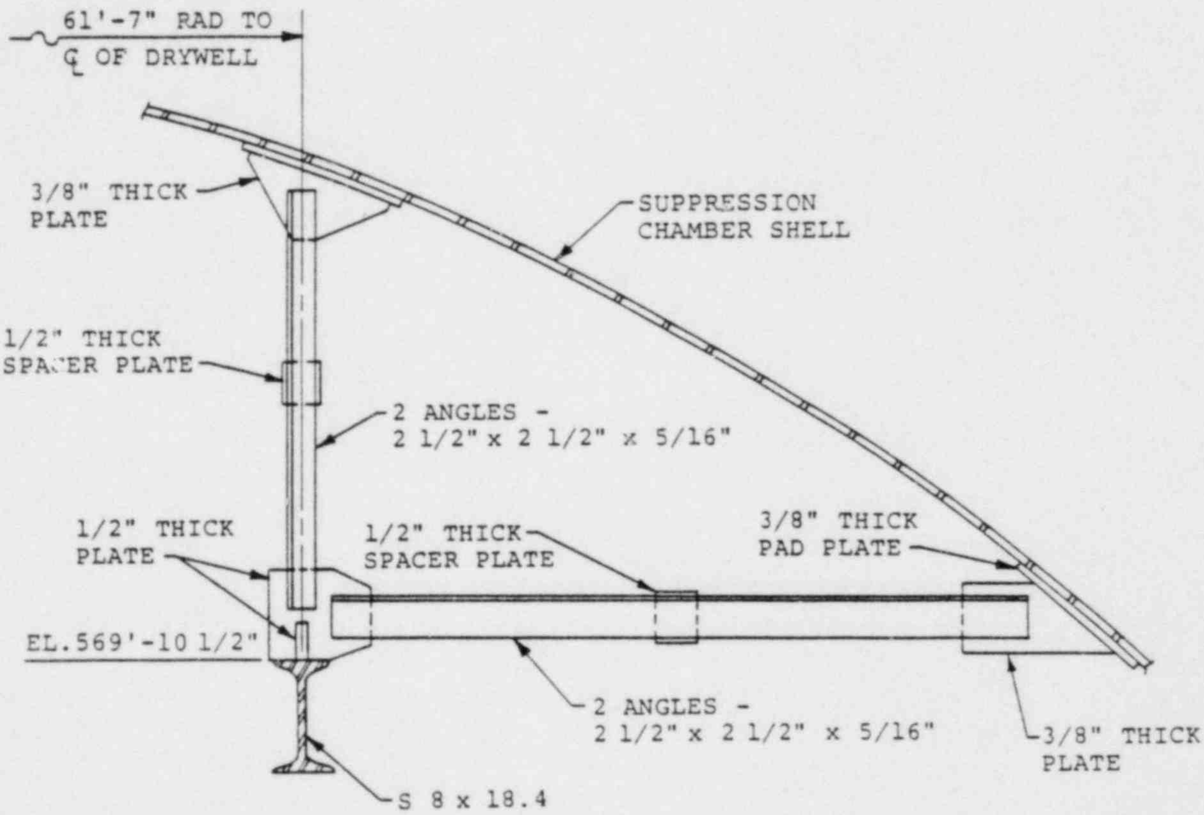

Figure 4-2.1-2

TYPICAL MONORAIL SUPPORT

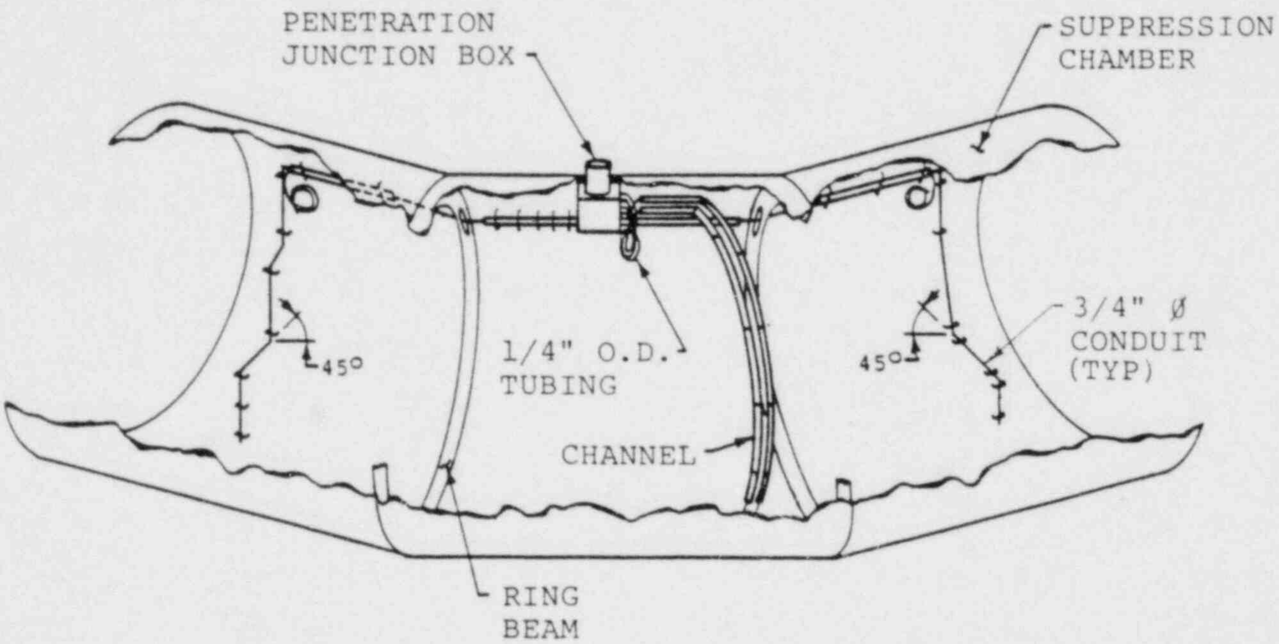

Figure 4-2.1-3

TYPICAL THERMOCOUPLE CONDUIT ROUTING

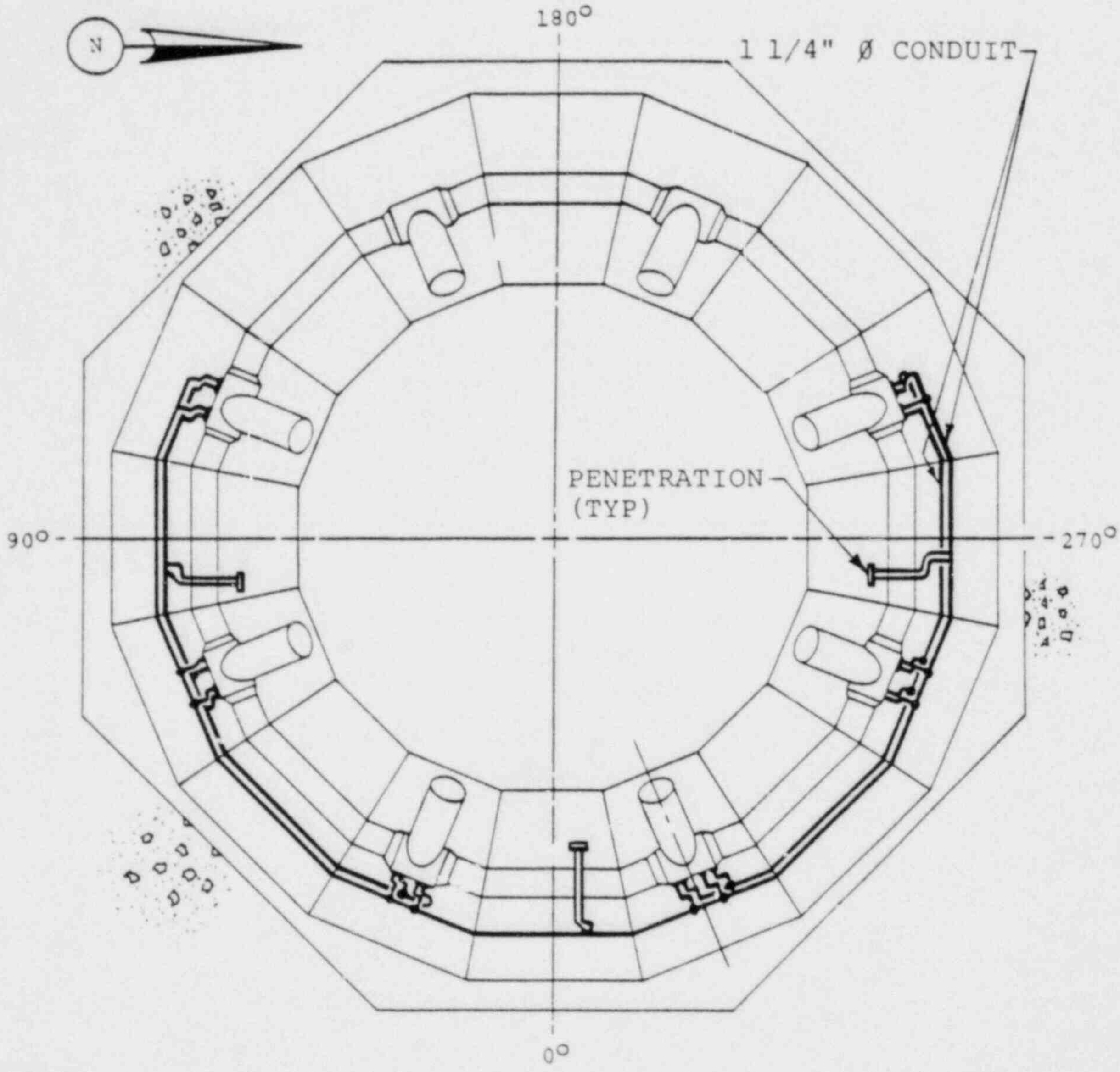

Figure 4-2.1-4

VACUUM BREAKER CONDUIT ROUTING - PLAN VIEW

4-2.2 Loads and Load Combinations

The loads for which the Fermi 2 internal structures are evaluated are defined in NUREG-0661 on a generic basis for all Mark I plants. The methodology used to develop plant unique loads, for each applicable load defined in NUREG-0661, is discussed in Section 1-4.0. The results of applying the methodology to develop specific values for each of the controlling loads are discussed and presented in Section 4-2.2.1.

The controlling load combinations which affect the internal structures are formulated by using the event combinations and event sequencing defined in NUREG-0661 and discussed in Sections 1-3.2 and 1-4.3. The controlling load combinations are discussed and presented in Section 4-2.2.2.

4-2.2-1 Loads

The loads acting on the internal structures are categorized as follows:

1. Dead Weight Loads
   - 1a. Dead Weight of Steel
2. Seismic Loads
   - 2a. OBE Loads
   - 2b. SSE Loads
3. Pool Swell Loads
   - 3a. Pool Swell Impact and Drag Loads
   - 3b. Froth Impingement and Fallback Loads
   - 3c. Pool Fallback Loads
   - 3d. LOCA Air Clearing Submerged Structure Loads
4. Condensation Oscillation (CO) Loads
   - 4a. DBA CO Submerged Structure Loads
   - 4b. IBA CO Submerged Structure Loads
5. Chugging Loads
   - 5a. Pre-Chug Submerged Structure Loads
   - 5b. Post-Chug Submerged Structure Loads
6. Safety Relief Valve Discharge Loads
   - 6a. SRV Discharge Air Clearing Submerged Structure Loads

7. Containment Interaction Loads

7a. Containment Structure Motions

Table 4-2.2-1 shows the specific internal structures which are affected by each of the above loads. The methodology used to develop values for each of these loadings is discussed in Section 1-4.0. The resulting magnitudes and characteristics of each loading are similar to those described in Volumes 2 and 3 of this report.

Table 4-2.2-1

INTERNAL STRUCTURES

COMPONENT LOADING IDENTIFICATION

Volume 4 Load Designation		PUAR Volume Section Reference	Catwalk	Monorail	Elevated Thermocouple Conduit	Submerged Thermocouple Conduit	Vacuum Breaker Conduits
Category	Case Number						
Dead Weight	1a	1-3.1	X	X	X	X	X
Seismic	2a	1-3.1	X	X	X	X	X
	2b	1-3.1	X	X	X	X	X
Pool Swell Loads	3a	1-4.1.4.2	X		X		X
	3b	1-4.1.4.3	X	X	X		X
	3c	1-4.1.4.4	X		X		X
	3d	1-4.1.6				X	
Condensation Oscillation	4a	1-4.1.7.3				X	
	4b	1-4.1.7.3				X	
Chugging	5a	1-4.1.8.3				X	
	5b	1-4.1.8.3				X	
SRV Discharge	6a	1-4.2.4				X	
Containment Interaction	7a	Vols. 2-4	X	X	X	X	X

4-2.2.2 Load Combinations

The loadings which affect each of the internal structures are presented in Section 4-2.2.1. The general NUREG-0661 criteria for grouping these loads into event combinations are discussed in Section 1-3.2. Since the majority of the internal structures are located above the suppression pool, the event combinations which produce controlling stresses are those which contain pool swell loads. These include the DBA 18 and DBA 25 combinations as shown in Table 4-2.2-2. The catwalk, monorail, vacuum breaker conduits, and thermocouple conduits located above the suppression pool are therefore evaluated for the DBA 18 and DBA 25 event combinations.

The submerged portion of the thermocouple conduits are subjected to LOCA air clearing, condensation oscillation, chugging, and SRV discharge submerged structure loads identified in Section 4-2.2.1. These submerged structure loadings are specified to occur during various event combinations. The DBA 18 and DBA 25 combinations contain only LOCA air clearing and/or SRV discharge submerged structure loadings. A bounding combination of

the submerged structure loads is used to envelop the possible event combinations affecting the submerged portion of the thermocouple conduits.

Table 4-2.2-2

INTERNAL CONTROLLING STRUCTURES

LOAD COMBINATIONS

Section 4-2.2.1 Load Designation	Event	DBA	
	NUREG-0661 Combination Number	18	25
1) Dead Weight		1a	1a
2) Seismic	OBE	2a	
	SSE		2b
3) Pool Swell Loads		3a-3d (1)	3a-3d (1)
6) SRV Discharge (1)		6a	6a
7) Containment Interaction		7a	7a
8) Service Level	Torus Shell	B	C
	Internal Structures	E	E

Note:

1. Submerged structure loadings only affect the submerged portion of the thermocouple conduits.

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4-2.3 Analysis Acceptance Criteria

The service level assignments for the internal structures and the suppression chamber shell at attachment points to internal structures are shown in Table 4-2.2-2. The table shows that all internal structures are designated as Service Level E components, and as such, are not required to meet ASME Code acceptance limits. In order to employ a consistent set of design criteria which ensures that failure will not occur, the internal structures are conservatively evaluated for the Service Level D acceptance limits contained in the ASME Code. The suppression chamber shell near attachment points to internal structures is evaluated in accordance with the requirements for Class MC components contained in the ASME Code. The corresponding allowable stresses for the internal structures are presented in Section 4-2.5 for the DBA 18 and DBA 25 combinations.

4-2.4 Method of Analysis

The loadings for which the internal structures are evaluated are identified in Section 4-2.2.1.

The analysis of the catwalk is performed using a beam finite element model which includes the stringers, hangers, and associated catwalk components. A transient analysis is performed for pool swell impact loads, froth impingement loads, and containment interaction loads. An equivalent static analysis is performed for the remaining catwalk loadings. The reaction loads in the catwalk hangers are used to evaluate local stresses in the suppression chamber shell.

The analysis of the monorail is performed using a beam finite element model which includes the monorail beam and the monorail supports. An equivalent static analysis is performed for all monorail loadings. The reaction loads in the monorail supports are used to evaluate local stresses in the suppression chamber shell.

The thermocouple and vacuum breaker conduits and their supports are evaluated using hand calculation techniques and first principles. The reaction loads at the attachments and penetrations to the suppression chamber are used to evaluate local stresses in the suppression chamber shell.

4-2.5 Analysis Results

The geometry, loads, load combinations, acceptance criteria, and analysis methods used in the evaluation of the internal structures are presented in the preceding sections. The resulting maximum stresses for the catwalk, monorail, and thermocouple and vacuum breaker conduits for the controlling load combination are shown in Table 4-2.5-1. As is evident from this table, the calculated stresses for these components are less than the corresponding allowable stresses.

Table 4-2.5-1

INTERNAL STRUCTURES STRESSES FOR CONTROLLING LOAD COMBINATIONS

Item	Material	Material Properties (ksi)	Beam Stress Type	Load Combination Stresses (ksi)		
				DBA 25		
				Calc. Stress	Allowable Stress (Service Level E)	Calc.[1] / Allow
Catwalk Stringer	SA-36	S_y = 33.66 S_u = 58.0	Compressive	3.49	19.04	0.78
			Weak Axis Bending	17.90	50.49	
			Strong Axis Bending	9.61	39.86	
Catwalk Vertical Hanger Support	SA-36	S_y = 33.66 S_u = 58.0	Compressive	7.67	18.03	0.93
			Bending	18.60	40.39	
Monorail Beam	SA-36	S_y = 33.66 S_u = 58.0	Tensile	2.49	40.39	0.45
			Weak Axis Bending	15.75	50.49	
			Strong Axis Bending	2.25	30.12	
Monorail Vertical Support	SA-36	S_y = 33.66 S_u = 58.0	Compressive	0.62	21.48	0.23
			Bending	8.29	40.39	
Monorail Horizontal Support	SA-36	S_y = 33.66 S_u = 58.0	Compressive	0.67	2[illegible].48	0.12
			Bending	3.73	40.39	
Thermocouple Conduit	SA-36	S_y = 33.66 S_u = 58.0	Bending	9.97	40.39	0.25
Vacuum Breaker Conduit	SA-36	S_y = 33.66 S_u = 58.0	Bending	21.18	40.39	0.52

Note:

1. Values shown obtained from beam interaction equation.

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4-2.5.1 Closure

The values of the loads used to evaluate the internal structures are conservative estimates of the loads postulated to occur during an actual LOCA or SRV discharge event. The event combinations for which the internal structures are evaluated envelop the actual events expected to occur during a LOCA or SRV discharge event.

The acceptance limits to which the evaluation results are compared are more restrictive than those required by NUREG-0661. Use of these acceptance limits ensures that the internal structure components will not fail and cause damage to safety-related components.

As is evident from the analysis results presented, stresses in the internal structure components are within these conservative acceptance limits. The intent of the NUREG-0661 criteria as it relates to the design adequacy of the Fermi 2 internal structures is therefore considered to be met.

4-3.0 LIST OF REFERENCES

1. "Mark I Containment Long-Term Program," Safety Evaluation Report, Nuclear Regulatory Commission, NUREG-0661, July 1980.

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

3. "Mark I Containment Program Structural Acceptance Criteria Plant Unique Analysis Application Guide," Task Number 3.1.3, General Electric Company, NEDO-24583, Revision 1, July 1979.

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