MPR ASSOCIATES, INC.

OYSTER CREEK
NUCLEAR GENERATING STATION
MARK I CONTAINMENT LONG-TERM PROGRAM

PLANT-UNIQUE ANALYSIS REPORT
TORUS ATTACHED PIPING

MPR-734

Prepared for:

General Public Utilities Nuclear
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LIST OF ACRONYMS

ASME	-	American Society of Mechanical Engineers
ACI	-	American Concrete Institute
ASTM	-	American Society for Testing and Materials
AISC	-	American Institute for Steel Construction
ANSI	-	American National Standards Institute
ADS	-	automatic depressurization system
BWR	-	boiling water reactor
CDF	-	cumulative distribution function
CO	-	condensation oscillation
DBA	-	design basis accident
DLF	-	dynamic load factor
ECCS	-	emergency core cooling system
EQ(O)	-	operating basis earthquake
EQ(S)	-	safe shutdown earthquake
FDSAR	-	Facility Design and Safety Analysis Report
FSI	-	fluid-structure interaction
FSTF	-	Full-Scale Test Facility
IBA	-	intermediate break accident
LDR	-	Load Definition Report
LOCA	-	loss-of-coolant accident
LTP	-	Long-Term Program
N	-	deadweight loading
NOC	-	normal operating conditions
NSSS	-	nuclear steam supply system
OBE	-	operating basis earthquake
PRCH	-	pre-chug
PS	-	pool swell
PTCH	-	post-chug
PSTF	-	Pressure Suppression Test Facility
PUA	-	plant-unique analysis
PUAAG	-	Plant-Unique Analysis Applications Guide
PULD	-	plant-unique load definition

LIST OF ACRONYMS (Contined)

QSTF	-	Quarter-Scale Test Facility
SBA	-	small break accident
SER	-	Safety Evaluation Report
SRV	-	safety relief valve
SSE	-	safe shutdown earthquake
STP	-	Short-Term Program

1.0 INTRODUCTION

The Oyster Creek Nuclear Generating Station uses a containment structure for the boiling water reactor (BWR) nuclear steam supply system designated as the Mark I containment system. The containment structure consists of a drywell, torus suppression chamber, and connecting vent system. It is one of 25 power plants in the United States using this early General Electric (GE) containment design.

This report documents the results of analyses performed on the piping attached to the torus suppression chamber considering the new suppression pool hydrodynamic loads which were defined in the Mark I Containment Long-Term Program. A companion report entitled "Plant-Unique Analysis Report - Suppression Chamber and Vent System" (Reference 8.5.1) covers the definition of loads and the analysis of the torus suppression chamber, vent system and related structures.

In order to keep this report brief and avoid unnecessary duplication, this report does not repeat the contents of the generic Mark I Containment Long-Term Program documents, and wherever possible, covers only briefly information which is discussed in more detail in the suppression chamber and vent system report (Reference 8.5.1). Specifically, it is assumed that the reader has the following documents available and is familiar with their content:

- NUREG-0661, Safety Evaluation Report Mark I Containment Long-Term Program Resolution of Generic Technical Activity A-7, July 1980. (Reference 8.1.2)

- NEDO-21888, Revision 2, Mark I Containment Program Load Definition Report, November 1981. (Reference 8.2.1)

- NEDO-24583-1, Revision 1, Mark I Containment Program Structural Acceptance Criteria Plant-Unique Analysis Application Guide, October 1979. (Reference 8.2.2)

- MPR-733, Oyster Creek Nuclear Generating Station Mark I Containment Long-Term Program Plant-Unique Analysis Report Suppression Chamber and Vent System, August 1982. (Reference 8.5.1)

1.1 BACKGROUND

The original design of the Mark I containment system considered postulated accident loads previously associated with containment design. These included pressure and temperature loads associated with a loss-of-coolant accident (LOCA), seismic loads, dead loads, jet impingement loads, and hydrostatic loads due to water in the suppression chamber. Torus attached piping was typically analyzed for deadweight, thermal expansion and seismic acceleration. However, since the establishment of the original design criteria, additional loading conditions which arise in the functioning of the pressure-suppression concept utilized in the Mark I containment system design have been identified. These additional loads result from dynamic effects of drywell air and steam being rapidly forced into the suppression pool (torus) during a postulated LOCA and from suppression pool response to safety relief valve (SRV) operation generally associated with plant transient conditions.

Because these additional hydrodynamic loads had not been considered in the original design of the Mark I containment, the Nuclear Regulatory Commission (NRC) required that a detailed reevaluation of the Mark I containment system be made. In February and April 1975, the NRC transmitted letters to all utilities owning BWR facilities with the Mark I containment system design, requesting that the owners quantify the hydrodynamic loads and assess the effect of these loads on the containment structure. The February 1975 letter reflected the NRC concerns about the dynamic loads from SRV discharges, while the April 1975 letter indicated the need to evaluate the containment response to the newly identified dynamic loads associated with a postulated design basis LOCA.

As a result of these letters from the NRC, and recognizing that the additional evaluation effort would be very similar for all Mark I BWR plants, the affected utilities formed an "ad hoc" Mark I Owners Group, and GE was designated as the Group's lead technical organization. The objectives of the Group were to determine the magnitude and significance of these dynamic loads as quickly as possible and to identify courses of action needed to resolve any outstanding safety concerns. The Mark I Owners Group divided this task into two programs: a Short-Term Program (STP) and a Long-Term Program (LTP).

The objectives of the Short-Term Program (STP) were to verify that each Mark I containment system and its attached piping would maintain its integrity and functional capability when subjected to the most probable loads induced by a postulated design basis LOCA, and to verify that the licensed Mark I BWR facilities could continue to operate safely without endangering the health and safety of the public while a methodical, comprehensive Long-Term Program (LTP) was being conducted.

The STP structural acceptance criteria used to evaluate the design of the torus, related structures and attached piping were based on providing adequate margins of safety; i.e., a safety-to-failure factor of two; to justify continued operation of the plant before the more detailed results of the LTP were available.

The results of the Short-Term Program evaluation of the Oyster Creek torus were submitted to the NRC by Jersey Central Power and Light letters in 1976 (References 8.3.2 and 8.3.3). The conclusion of that evaluation was that the Oyster Creek torus and attached piping met the criteria established for the Short-Term Program.

The NRC concluded that a sufficient margin of safety had been demonstrated to assure the functional performance of the containment system and, there was no undue risk to the health and safety of the public. These conclusions were documented in the "Mark I Containment Short-Term Program Safety Evaluation Report," NUREG-0408, dated December 1977 (Reference 8.1.6). The NRC granted the operating Mark I facilities an exemption relating to the structural factor of safety requirements of 10CFR50.55(a) for an interim period while the more comprehensive LTP was being conducted.

The objectives of the LTP were to establish conservative design basis loads that are appropriate for the anticipated life of each Mark I BWR facility (40 years), and to restore the originally intended design safety margins for each Mark I containment system. The plans for the LTP and the progress and results of the program were reviewed with the NRC throughout the performance of the program.

The LTP consisted of:

- The definition of loads for suppression pool hydrodynamic events.

- The definition of structural assessment techniques.

- The performance of a plant-unique analysis (PUA) for each Mark I facility.

The generic aspects of the Mark I Owners Group LTP were completed with the submittal of the "Mark I Containment Program Load Definition Report" (LDR), (Reference 8.2.1) and the "Mark I Containment Program Structural Acceptance Criteria, Plant-Unique Analysis Application Guide" (PUAAG), (Reference 8.2.2). The NRC concluded that load definitions and structural acceptance criteria documented in these two reports were acceptable for use in the plant-unique analysis of each plant. The NRC conclusions and comments were presented in "Safety Evaluation Report Mark I Containment Long-Term Program Resolution of Generic Technical Activity A-7, NUREG-0661," dated July 1980 (Reference 8.1.2).

1.2 SCOPE OF THIS REPORT

The purpose of this report is to present the Plant-Unique Analysis (PUA) of the piping systems attached to the Oyster Creek torus and vent system based on the LDR, PUAAG, NUREG-0661, and the plant-unique load definition report provided by General Electric for Oyster Creek (References 8.2.1, 8.2.2, 8.1.2 and 8.2.3). This PUA covers all torus attached piping to the extent specified in the PUAAG (Reference 8.2.2). A separate document (Reference 8.5.1) presents the results of the plant-unique analysis of the Oyster Creek torus and vent system.

Section 2.0 contains the design criteria for the original piping design, the Mark I Containment Long-Term Program and the piping modifications required to meet Mark I structural acceptance criteria. Section 3.0 of this report describes the arrangement of the attached piping systems and indicates their functions and analysis classifications. Section 4.0 defines the loads used in the analyses and Section 5.0 explains the analytical procedures used. The specific stress analyses and results are summarized in Sections 6.0 and 7.0. Section 8.0 lists the references.

A summary of the results of this report follows.

1.3 SUMMARY OF RESULTS

The analyses of the piping systems attached to the Oyster Creek torus and vent system has been completed in conformance with the requirements of the Mark I Containment Long-Term Program as prescribed in the LDR (Reference 8.2.1), the PUAAG (Reference 8.2.2), and NUREG-0661 (Reference 8.1.2).

A number of piping and piping support structural modifications were designed for installation as part of the Long-Term Program; some of these modifications are already installed in the plant. The analyses described in this report are based on the piping arrangement with all these modifications installed. The loads used in the analyses of the piping are based upon the response of the Oyster Creek containment modified as described in Reference 8.5.1.

The results of the analyses of piping systems attached to the Oyster Creek torus and vent system show that all piping, pipe hangers and supports, nozzles and related components meet the criteria of the Mark I Containment Long-Term Program with the modifications which will be completed as part of this program. Specific results of the analyses are given in Sections 6.0 and 7.0. The evaluation of the nozzle in the vent system for the safety relief valve piping penetration has not been completed. The results of this evaluation will be forwarded separately.

2.0 DESIGN CRITERIA

This section describes: (i) the original design criteria for the Oyster Creek nozzles and torus attached piping; and (ii) the acceptance criteria for the plant-unique analysis (PUA) including the specified load combinations for torus attached piping and nozzles. The requirements for piping and piping support modifications are summarized in this section as well.

For the purposes of establishing the structural design criteria to be applied, it is necessary to identify the ASME Code classification of each structural element. The following classifications, which are in accordance with the PUAAG (Reference 8.2.2), were applied for the Oyster Creek PUA.

The torus attached piping and the pumps and valves included in each system are classified as either ASME Class 2 or 3. Nozzles and penetrations in the torus and vent system are classified ASME Class MC with the welds connecting the pipe to the nozzle classified as Class 2 piping welds. Welds which connect supports to the torus pressure boundary are considered part of that component and therefore are classified ASME Class MC. There are two piping support welds which attach directly to the torus pressure boundary. These are: (i) the supports for the level indicator piping and torus drain piping which have a circular pad welded directly to the shell; and (ii) the snubber support welds for the core spray suction header. These welds were analyzed using allowable stress for Class MC.

2.1 DESIGN SPECIFICATIONS AND CODES

2.1.1 Original Design Code for Piping

The design code for the Oyster Creek piping is ASA B31.1, "Code for Pressure Piping," 1955 Edition, Sections 1, 6, Appendices, and Code cases in force. Section III of the ASME Boiler and Pressure Vessel Code of 1965 and Nuclear Code Case Interpretation 1272N5 were also invoked for piping attachments and penetrations to the containment system.

The size and arrangement of the piping systems and nozzles attached to the torus and vent system are described in Sections 3.1 through 3.8. Design conditions and load combinations for each piping system are discussed in Section 4.1.

2.1.2 Specifications for Piping, Nozzle and Hanger Modifications

A GPUN specification was prepared for each modification to the torus attached piping or piping supports which specifies functional and design requirements, stress acceptance criteria and quality assurance requirements for the modification. As a minimum, all design, material, fabrication, inspection and testing requirements of the original design specifications were met. Where appropriate, requirements from more recently NRC-approved versions of the ASME Boiler and Pressure Vessel Code, Section III, (Reference 8.4.1) were invoked. Modification work is being performed under the rules of the ASME Boiler and Pressure Vessel Code, Section XI (Reference 8.4.2).

2.2 LONG-TERM PROGRAM DESIGN REQUIREMENTS AND STRUCTURAL ACCEPTANCE CRITERIA

The ASME Section III, Class 2 and 3 piping design rules have been used as the basis for evaluation of all torus attached piping under the Mark I Containment Long-Term Program as specified in the PUAAG (Reference 8.2.2). Specifically, the ASME B&PV Code requirements of the 1977 Edition with Addenda through Summer 1977 of Section III, Division I; Article NC, "Class 2 Components for Nuclear Power Plants;" Article ND, "Class 3 Components for Nuclear Power Plants," Article NE, "MC Components;" and Article NF, "Component Supports for Nuclear Power Plants," (Reference 8.4.1) are being followed.

The specific acceptance criteria used for this evaluation are specified in the PUAAG (Reference 8.2.2) and accepted in NUREG-0661 (Reference 8.1.2). The PUAAG specifies allowable stresses to be used in the Mark I Long-Term Program by specifying service limits for each type of piping component of the containment structure and attached piping for each load combination.

The resulting matrices of load combinations and service limits for the containment nozzles and piping are summarized in Tables 5-1 and 5-2 of the PUAAG, respectively. The specific combinations considered for torus attached piping and nozzles were based on these tables and are discussed in the sections which follow. For essential piping systems, additional criteria are specified in the PUAAG to assure the operability of active components. These criteria are covered in Section 2.2.3 below.

2.2.1 Piping Load Combinations and Acceptance Criteria

The Mark I Containment Long-Term Program requires consideration of 27 different load combinations in evaluating the piping response due to various LOCA and NOC conditions as shown in Table 5-2 of the PUAAG (Reference 8.2.2). Table 2.2-1 of this report lists the limiting load combinations which were considered in evaluating the torus attached piping. These limiting load combinations were determined from the 27 load combinations shown in Table 5-2 of Reference 8.2.2 by enveloping the 27 combinations and the applicable service limits. To determine the combined effect of more than one load on the structural response of a piping system, the approach described below was employed.

The response due to each dynamic loading was calculated separately. The responses due to combined loadings were determined by summing the stress resultants and displacements for each individual load. With one exception all dynamic load responses were combined by absolute summation. This exception is the safe shutdown earthquake dynamic response which was combined by square root sum of the squares (SRSS) with the responses due to DBA pool swell dynamic loads. NUREG-0484 (Reference 8.1.1) used methods equivalent to a cumulative distribution function (CDF) analysis (PUAAG, Reference 8.2.2) to demonstrate that the SRSS method can be used for combining safe shutdown earthquake and other LOCA dynamic loads. Absolute summation was used to combine safe shutdown earthquake dynamic response with other dynamic loads for all SRV, IBA and SBA load combinations. Absolute summation was also used to combine operating basis earthquake dynamic response with all other dynamic loads for all load combinations, including DBA.

For dynamic loadings due to containment accelerations, the response spectrum analysis method was used. Using this method, responses from multiple modes are computed. The stress resultants for each significant mode are combined by applying the 10% grouping method (which applies absolute summation within groups as specified in the NRC Regulatory Guide 1.92 (Reference 8.1.3) for modes which are closely spaced in frequency.

For dynamic loads involving submerged drag harmonic pressures, the response was determined by combining the harmonic response of the piping due to each harmonic load component using LDR phasing (an absolute summation method) with one exception. For condensation oscillation drag and fluid-structure interaction, the harmonic responses were combined using a random phasing method developed on a generic basis for the Mark I Containment Long-Term Program.

For pool swell fluid loads and thrust loads on SRV piping, time history dynamic analysis was used as discussed in Section 5.1. For the SRV discharge piping, the times of the most limiting responses were determined for piping locations which were found to be controlling. The responses for each of these times were then summed with responses due to other applicable loadings to determine the total response to each load combination.

The acceptance criteria for attached piping are based upon the service limits and allowable stresses contained in the PUAAG (Reference 8.2.2). Table 2.2-1 of this report contains the applicable acceptance criteria for each of the limiting load combinations which were evaluated. With one exception, all torus attached piping is made from ASTM A-106, Grade B piping which has a basic material allowable stress of 15,000 psi as specified in the ASME Boiler and Pressure Vessel Code, Section III (Reference 8.4.1). The exception is on the SRV discharge piping which has a small amount of ASTM A-106, Grade C piping which has a basic material allowable stress of 17,500 psi. The stainless steel expansion joints (bellows) which are part of the torus to drywell vacuum relief piping and SRV discharge piping were analyzed in accordance with Paragraph NC-3649.4 of Reference 8.4.1.

The PUAAG (Reference 8.2.2) requires that an additional piping evaluation be made without drywell-to-wetwell differential pressure for plants which use drywell-to-wetwell differential pressure as a load mitigator. For this evaluation, less stringent acceptance criteria may be applied. Since Oyster Creek does not plan to use differential pressure as a load mitigator, no additional piping evaluations were required for the condition of a loss of pressure differential.

The load combinations and allowable stress limits used for analyses of supports for Class 2 and 3 piping were in accordance with NUREG-0661 and the PUAAG (References 8.1.2 and 8.2.2).

As specified by the PUAAG (Reference 8.2.2), piping supports were analyzed in accordance with Article NF as specified in Paragraphs NC-3674 and ND-3674 of the ASME Code, Section III (Reference 8.4.1) except as modified by NUREG-0661 (Reference 8.1.2). Reference 8.1.2 adds the following limitations on the allowable stresses:

a. For load combinations with Level C and D Service Limits, bolted connections shall meet Level A and B Service Limits.

b. The increase in allowable stress permitted by Paragraph NF-32311.1(a) of Reference 8.4.1 for combined mechanical and anchor motion loads is for the primary-plus-secondary stress range.

c. The increase in allowable stress permitted by Paragraph NF-3231(b) of Reference 8.4.1 for Level C Service Limit is limited when buckling is a consideration so that the allowable compressive stress does not exceed 2/3 of the critical buckling stress.

The torus attached piping supports and hangers were analyzed consistent with the above. Concrete expansion anchors were analyzed per the requirements of ACI 349-76 (Reference 8.7.8). Piping support welds connected to the torus containment pressure boundary were analyzed using Class MC (Reference 8.4.1) allowable stress.

TABLE 2.2-1

TORUS ATTACHED PIPING AND STRUCTURES
SERVICE LIMITS AND LOAD COMBINATIONS TO BE EVALUATED

LIMITING LOAD COMBINATIONS (Notes 1, 4 and 6)	ESSENTIAL (Note 2)	NONESSENTIAL (Note 2)
Ia. N + SRV(NOC)	B	B
Ib. N + SRV(NOC) + EQ(S)	B(3)	C(5)
II. N + DBA(PS) + EQ(S) + SRV(DBA)	B(4)	D(5)
III. N + DBA(CO) + EQ(O)	B(4)	D(5)
IVa. N + SBA(PRCH) + SRV(IBA)(Note 5)	B(3)	C(5)
IVb. N + SBA(PRCH) + EQ(S) + SRV(IBA)	B(4)	D(5)
Va. N + SBA(PTCH) + SRV(IBA)(Note 5)	B(3)(Note 3)	C(5)(Note 3)
Vb. N + SBA(PTCH) + EQ(S) + SRV(IBA)	B(4)(Note 3)	D(5)(Note 3)

NOTES:

1. Load combinations and service limits envelop the 27 combinations shown in Table 5-2 of the PUAAG (Reference 8.2.2).

2. Essential and nonessential piping are classified in accordance with the PUAAG (Reference 8.2.2). Numbers in parentheses () refer to specific notes to Table 5-2 of the PUAAG.

3. For IBA/SBA PTCH, a fatigue reduction factor of 0.9 applies to the allowable stress for ASME Equations 10 and 11 from Paragraph NC-3652.2 of Reference 8.4.1.

4. Because SBA and IBA have the same PRCH and PTCH spectra, only SBA need be considered for Load Combinations IVa., IVb., Va. and Vb. since the service limits are more restrictive for SBA.

5. SRV(IBA) need not be included in this combination for nonessential piping systems.

6. For definition of abbreviations used in this table, see List of Acronyms.

2.2.2 Nozzle Load Combinations and Acceptance Criteria

This section describes the load combinations and acceptance criteria that must be considered when evaluating the torus shell adjacent to piping penetrations (nozzles) and when evaluating stresses in the nozzle itself near the shell (nozzle transitions).

Per the jurisdictional requirements of the Plant-Unique Analysis Application Guide (PUAAG), Reference 8.2.2, shell regions adjacent to nozzles and nozzle transitions must meet ASME Code, Subsection NE (Class MC) requirements and must be evaluated for the loads specified in the PUAAG for the Row 1 category (External, Class MC). A review of the 27 load combinations specified in Table 5-1 of Reference 8.2.2 for this category revealed that there are six combinations out of the total that are limiting, as shown in Table 2.2-2 of this report. The corresponding Service Limits from Table 5-1 of Reference 8.2.2 are likewise shown in Table 2.2-2 of this report.

Each individual load combination involving accident loads also includes loads due to deadweight, pressure and differential temperature between the torus and attached piping. In particular, the following was added to each of the cases listed in Table 2.2-2 of this report.

$$TH_{pipe}\ (170^{o}F) + TH_{torus}\ (170^{o}F) +$$

$$PR_{torus}\ (35\ psi) + DW_{pipe} + DW_{torus}$$

Hence, conservative static thermal and pressure loads were assumed.

TABLE 2.2-2

LIMITING SERVICE LIMITS AND LOAD COMBINATIONS FOR NOZZLES AND NOZZLE TRANSITIONS

	LOAD COMBINATION	ASME SERVICE LEVEL
1.	IBA/SBA (CO/Chug) + SRV + EQ(O)	B
2.	IBA/SBA (CO/Chug) + SRV + EQ(S)	C
3.	DBA (Pool Swell) + EQ(O)	B
4.	DBA (CO/Chug) + EQ(O)	B
5.	DBA (Pool Swell) + SRV + EQ(S)	C
6.	DBA (CO/Chug) + SRV (Note 1) + EQ(S)	C

NOTE:

1. Since SRV actuation cannot occur after pool swell, SRV was not considered with DBA (CO/Chug).

2.2.3 Active Component Operability Requirements

The PUAAG (Reference 8.2.2) requires that active components in essential piping systems be evaluated to ensure operability. This section defines active components, operability and the criteria used to evaluate operability of active components.

An active component is defined in Reference 8.2.2 as a pump or valve in an essential piping system which is required to perform a mechanical motion during the course of accomplishing a system safety function. Pumps and valves in nonessential systems may be considered inactive components. Operability is defined in Reference 8.2.2 as the ability to perform required mechanical motion.

The criteria for use in evaluating the operability of an active component are specified in the PUAAG (Reference 8.2.2). Specifically, in the case of Oyster Creek, this requires that Service Limits A or B must be met in order to demonstrate operability. As shown in Section 6.0, all active components in torus attached piping systems met the Level A or B Service Limit. Therefore, the operability criteria of Reference 8.2.2 were satisfied and no further demonstration of operability was required for active components.

3.0 SYSTEM DESCRIPTIONS AND CLASSIFICATIONS

The sections which follow contain descriptions of the torus attached piping systems. The PUAAG (Reference 8.2.2) and ASME Code (Reference 8.4.1) classifications for these systems are given as well.

3.1 VACUUM RELIEF PIPING

The vacuum relief piping is part of the containment system and consists of eight separate piping assemblies. The purpose of this piping is to equalize pressure between the torus and drywell and between the reactor building and the torus. Under LOCA conditions, it is expected that the air in the drywell (normally nitrogen during operation) will be displaced by steam and forced into the torus through the vent system. The arrangement of the containment system (i.e., submerged vent discharge path) prevents this air from freely returning to the drywell. Thus, when the steam in the drywell condenses, a reduced pressure compared to that of the torus can develop. The reduced pressure would result in compressive stresses in the drywell shell beyond its design capability. To prevent this occurrence, a system of vacuum relief lines is provided. Check valves are installed in the lines to prevent flow from the drywell to the torus while permitting air flow from the torus to the drywell when the pressure differential rises sufficiently. A separate piping assembly performs a similar function for the torus by permitting air to flow from the reactor building to the torus air space.

The vacuum relief piping includes seven torus-to-drywell vacuum relief piping assemblies which are represented by the three arrangements shown in Figures 3.1-1 through 3.1-3. Each torus-to-drywell assembly consists of a 24-inch torus and a vent line nozzle connected by a system of 18-inch and 24-inch piping. Two check valves which provide parallel unidirectional flow paths from the torus to the drywell are installed in each assembly. Two expansion joints are installed per assembly to provide for differential thermal expansion between the drywell and the torus. Each assembly is supported by a set of three spring hangers. The four assemblies not represented in Figures 3.1-1 through 3.1-3 are either identical to one of these arrangements or identical but opposite hand. Connecting and branch piping are identified on the appropriate figure with the proper azimuth indicated. This piping is covered in other sections of this report.

The vacuum relief piping also includes the single vacuum relief piping assembly which connects between the torus air space and the reactor building as shown in Figure 3.1-4. The 20-inch line contains two check valves to prevent flow from the torus to the reactor building. The system also has two motor-operated gate valves which provide positive isolation for the containment. The system terminates in a 20-inch open leg which functions as an inlet for air into the system. The line is supported by two spring hangers and a series of supports mounted on slides to the floor. Additional supports being installed on the piping to provide lateral support for seismic loadings were included in the analysis as shown in Figure 3.1-4. The nitrogen purge piping connects to the reactor building-to-torus vacuum relief piping through a 6-inch branch connection.

The vacuum relief system is required to function during DBA, IBA and SBA events. Specifically, the check valves in the system are required to open and close and the butterfly and wedge gate valves may be required to close. Accordingly, this piping is classified as essential in accordance with the Mark I analysis classification as defined in the PUAAG (Reference 8.2.2). For ASME Code purposes, the vacuum relief piping has been classified as Class 2 piping.

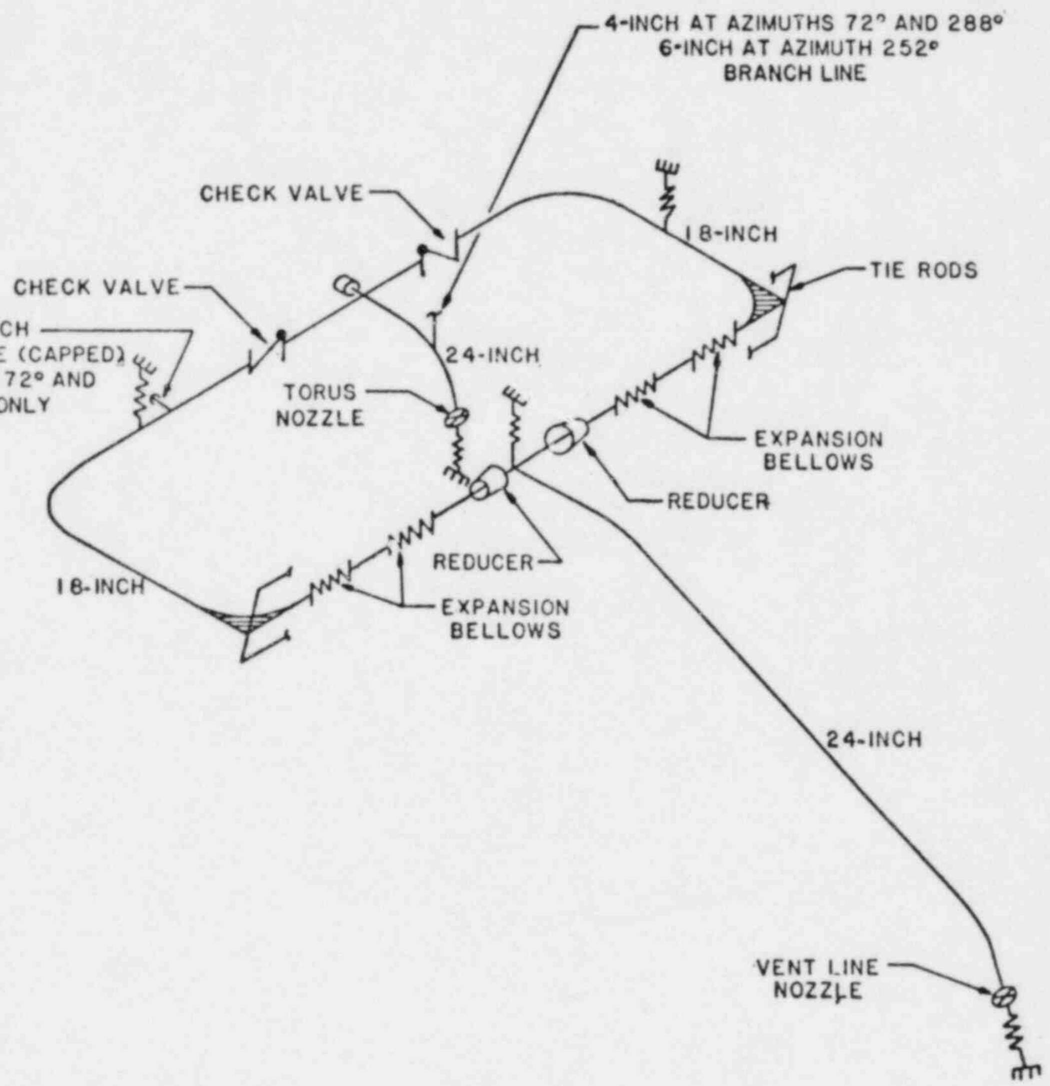

FIGURE 3.1-1

ARRANGEMENT OF VACUUM RELIEF PIPING AT AZIMUTHS 72°, 108°, 252°, AND 288°

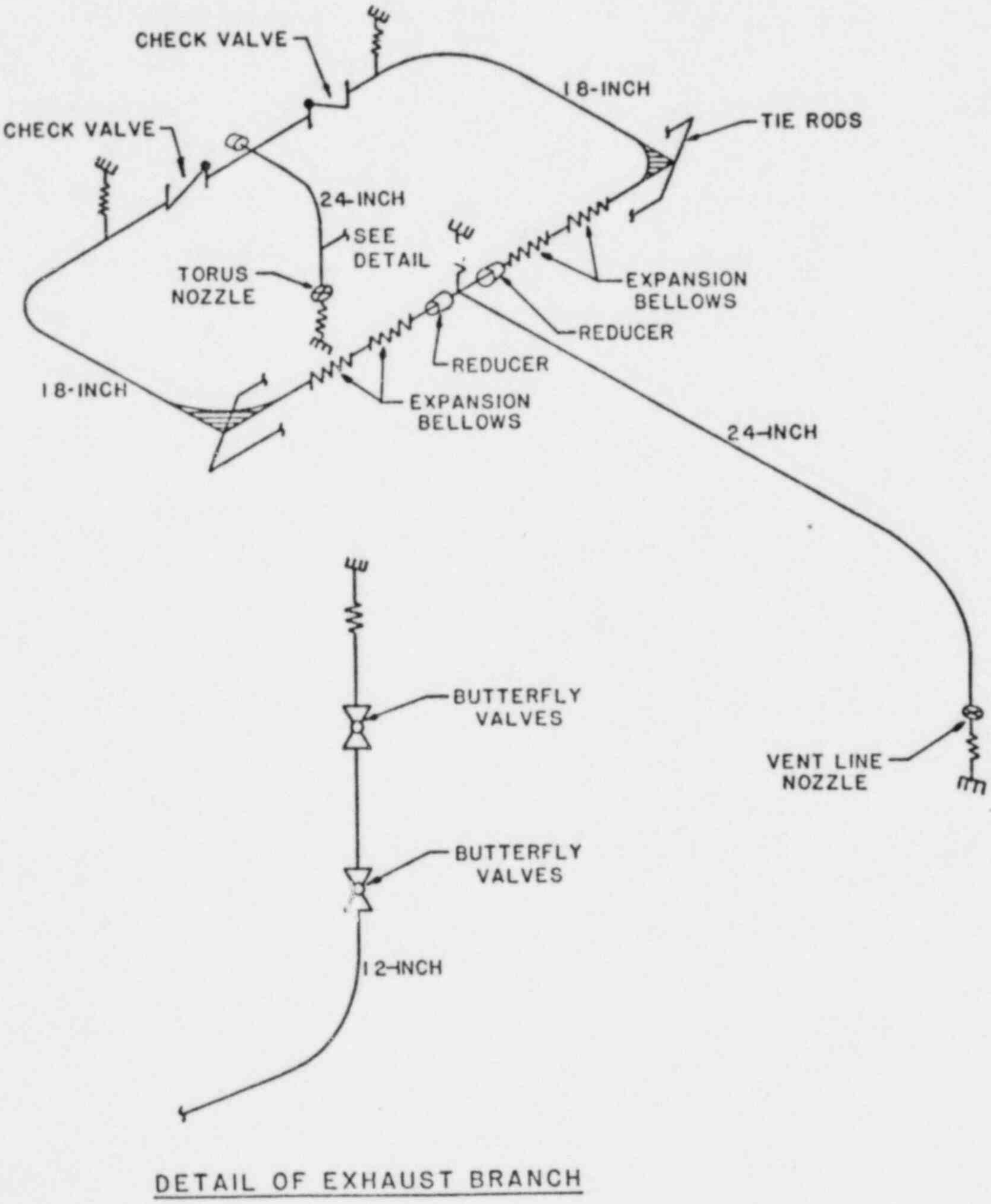

FIGURE 3.1-2

ARRANGEMENT OF VACUUM RELIEF PIPING
AT AZIMUTH 0°

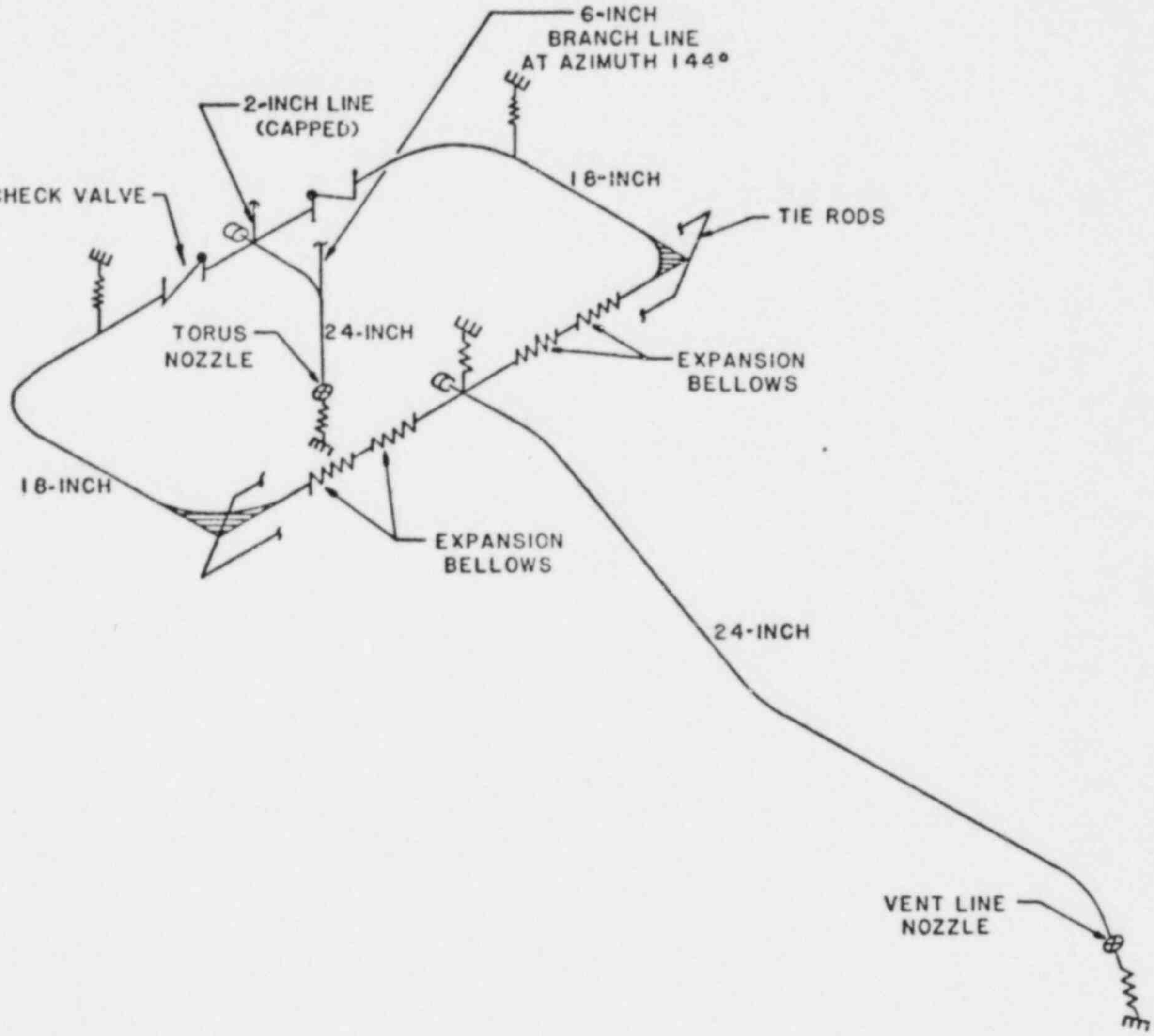

FIGURE 3.1-3

ARRANGEMENT OF VACUUM RELIEF PIPING
AT AZIMUTHS 144° AND 216°

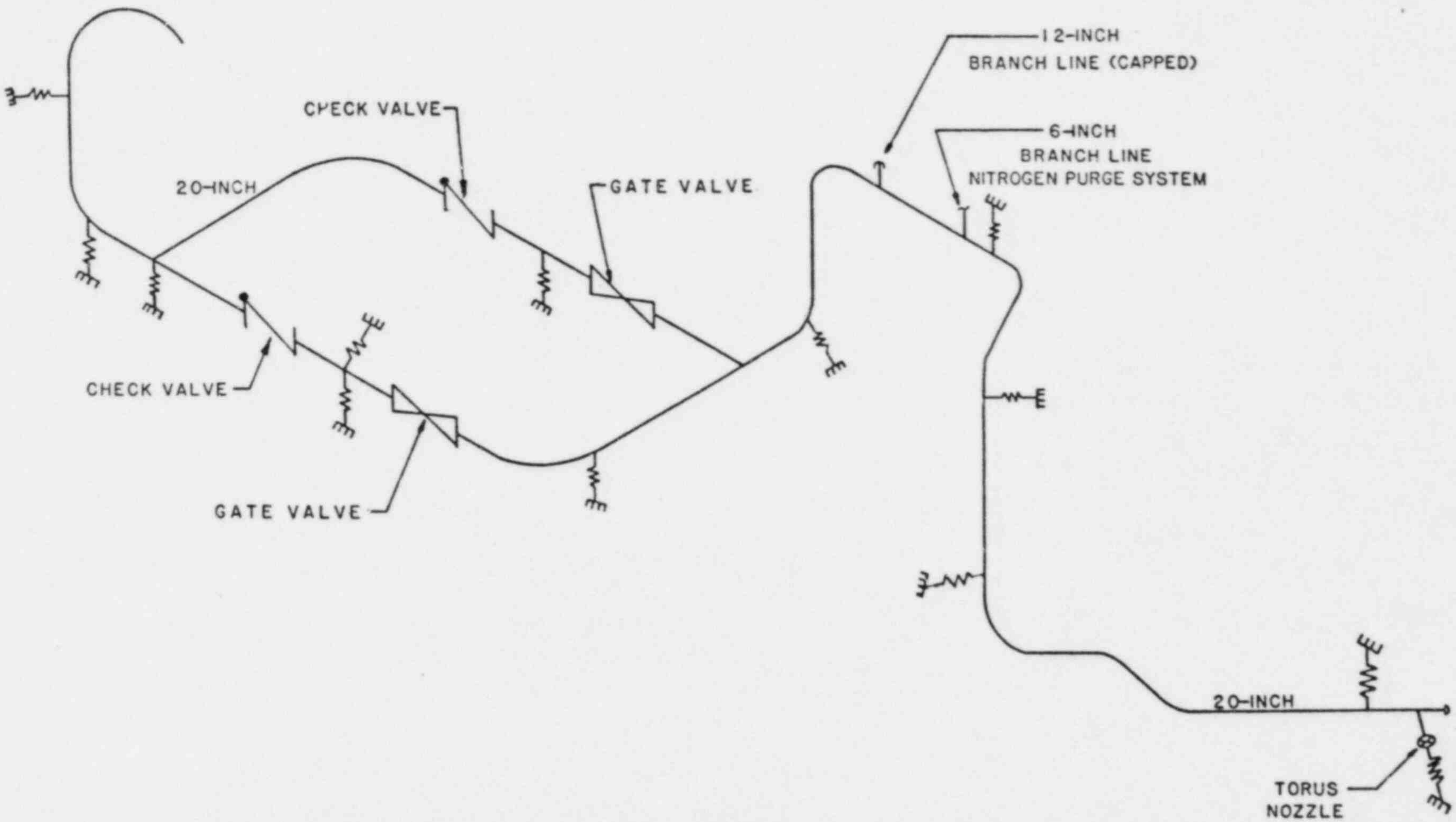

FIGURE 3.1-4

ARRANGEMENT OF REACTOR BUILDING-TO--TORUS
VACUUM RELiEF PIPING

3.2 DEMINERALIZER RELIEF VALVE DISCHARGE PIPING

The demineralizer relief valve discharge piping is part of the cleanup demineralizer system. The purpose of this system is the filtration and demineralization of the water in the reactor vessel and recirculation lines to maintain its purity. The cleanup demineralizer system also provides for draining water from the primary system to maintain or lower reactor water level during startup, shutdown, and refueling operations. The demineralizer relief valve provides protection for the cleanup system under conditions when the pressure exceeds the acceptable operating range. The discharge piping provides a path for venting the cleanup demineralizer system to the torus pressure-suppression pool under these conditions.

The overall arrangement of the demineralizer relief valve discharge piping is shown in Figure 3.2-1. This piping connects to the cleanup demineralizer system at the pressure relief valve located immediately downstream of the cleanup system pressure control valve. The pressure relief valve is set to lift at 150 psig to protect the low pressure portions of the cleanup demineralizer system. The design flow rate for the discharge piping is 125 pounds per second.

The demineralizer relief valve discharge piping carries the exhaust from the pressure relief valve into the torus pressure-suppression pool. The discharge piping, initially 10-inch pipe, increases to 20-inch pipe a few feet downstream from the valve. The portion of the discharge line external to the torus is supported by five spring hangers which are adjusted to minimize the deadweight bending loads applied to the torus nozzle. This portion of the line is supported laterally by a rigid support located near the vertical midpoint between the torus and the pressure relief valve connection. Directly adjacent to the torus penetration on the outside of the torus is a check valve which provides containment isolation. This check valve also limits the height to which water from the torus pressure-suppression pool may rise in the discharge line after relief actuation.

As the result of analysis to satisfy Mark I loadings, the in-torus section required modification. The modification consisted of rerouting the piping to be adjacent to a ring girder to provide the line with lateral support through two connections to the ring girder (Figure 3.2-2). The previous open pipe vertical discharge was replaced with a horizontal discharge tee which exhausts at the same depth in the torus pressure-suppression pool and eliminates vertical discharge loads on the torus. This modification was completed in July 1980.

The demineralizer relief valve discharge piping has no required function in a DBA, IBA or SBA event. Accordingly, this piping is classified as nonessential in accordance with the Mark I analysis classification given in the PUAAG (Reference 8.2.2). For ASME Code purposes, the portion of the piping external to the torus has been classified as Class 2 piping and the in-torus section of piping has been classified as Class 3 piping. For purposes of analysis, the entire line is treated as Class 2 piping.

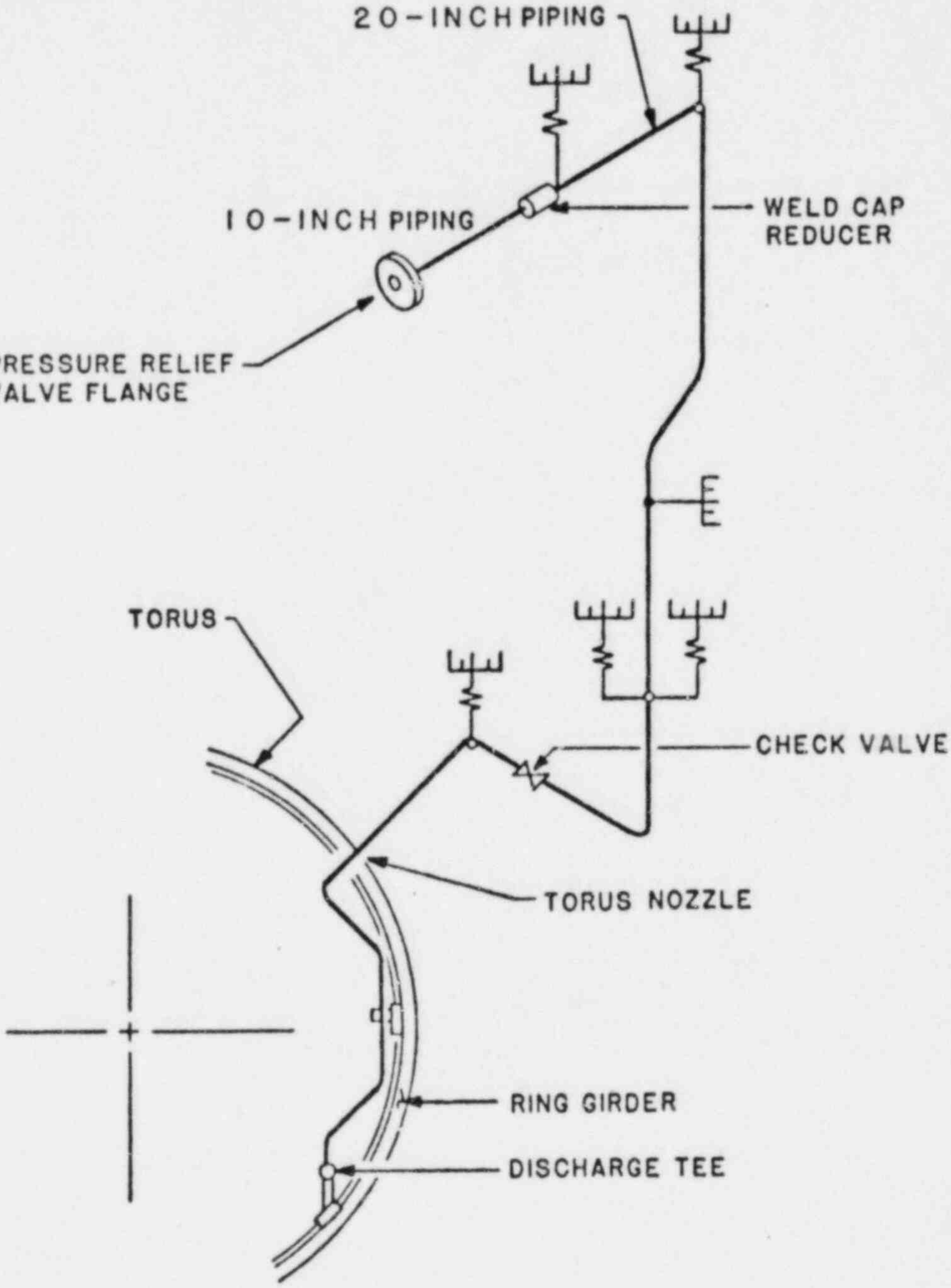

FIGURE 3.2-1

ARRANGEMENT OF DEMINERALIZER
RELIEF VALVE DISCHARGE PIPING

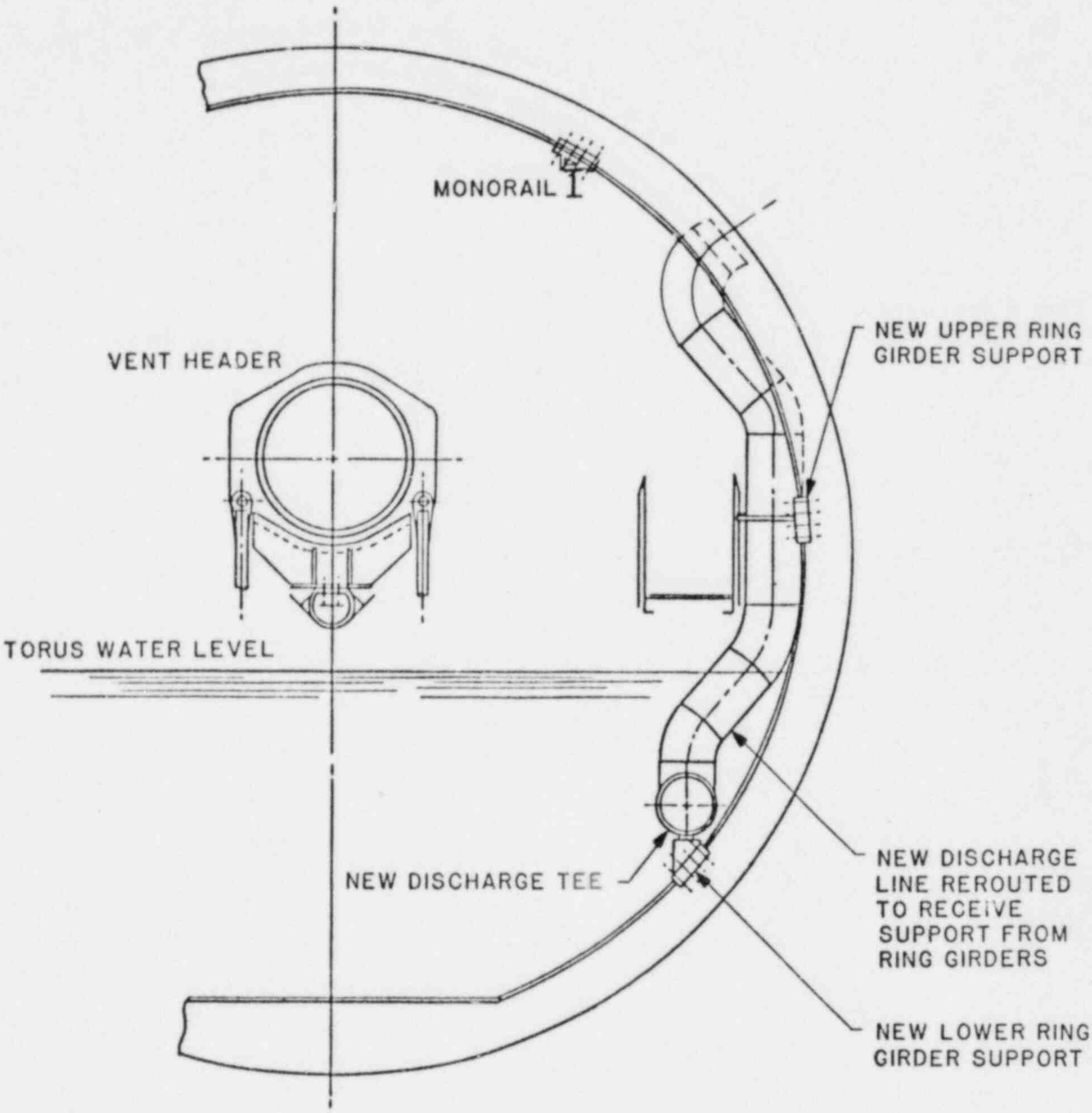

FIGURE 3.2-2

REROUTE OF IN-TORUS SECTION OF
DEMINERALIZER RELIEF VALVE DISCHARGE LINE

3.3 CONTAINMENT SPRAY AND TEST RETURN PIPING

The containment spray system is a standby cooling system for removing heat from the containment system after a postulated loss-of-coolant accident (LOCA). The system consists of two independent loops of piping, each of which is designed to operate over an extended period to remove heat from the containment system. Each containment spray system loop consists of suction and distribution piping. Only the distribution piping will be discussed in this section. The suction piping is discussed in Section 3.5.

The overall arrangement of the two containment spray loops is shown in Figures 3.3-1 and 3.3-2. The piping for each loop is shown beginning at the branch tee. The piping to the drywell containment spray headers and the supply piping from the containment spray system heat exchangers has been omitted from the analytical model, since the response in this piping due to torus motion is small. This is in accordance with the PUAAG (Reference 8.2.2) requirements for the extent of torus attached piping to be modeled. The design flow rate for the containment spray system is 6,000 gallons per minute. Only a small fraction of this flow is discharged by the torus containment spray supply line, a 4-inch line which connects to the torus containment spray header. The test return piping, the 6-inch line to the torus, is designed for the entire flow. The test return piping provides an alternate discharge path to the torus to allow test operation of the containment spray system pumps.

The containment spray and test return piping, initially 14-inch pipe from the containment spray pumps, separates at the branch tee into a 14-inch drywell supply line and a 6-inch torus supply line. The torus supply line separates at the reducing tee into the 6-inch test return piping and the 4-inch torus spray supply piping. A gate valve in each of these lines, immediately downstream from the reducing tee, controls the flow distribution in the system. Downstream from the 6-inch gate valve, a 1-inc' containment spray minimum flow line is attached to the test return piping of each loop. A 2-inch air test line is attached to the torus spray supply piping, on the loop which connects at vacuum relief piping assembly B, downstream from the 4-inch gate valve. Vertical support outside the torus is provided by five rigid hangers and one spring hanger for the loop at vacuum relief piping assembly G and four rigid hangers, two spring hangers and a snubber for the loop at vacuum relief piping assembly B. Both loops have three rigid lateral supports.

The torus spray header supply piping from each loop enters the torus through penetrations in each of two torus-to-drywell vacuum relief assemblies. The torus containment spray header is supplied by both of these loops on opposite sides of the torus. The spray header is suspended at the apex of the torus air space by a support welded to each ring girder. The header bends 18^0 at each ring girder to follow the axis of the torus.

The test return piping configuration shown in Figures 3.3-1 and 3.3-2 is a modification of the original design to eliminate (i) vibration transmitted from the vacuum relief piping, and (ii) test return discharge loadings on the vacuum relief piping. The modification consists of rerouting the piping to a new torus penetration and providing a discharge tee immediately inside the torus. The modification is shown in Figures 3.3-3 and 3.3-4.

The containment spray piping is required to function in connection with DBA events to remove heat from the containment system. Accordingly, this piping is classified as essential in accordance with the Mark I analysis classification given in the PUAAG (Reference 8.2.2). For ASME Code purposes, the containment spray and test return piping have been classified as Class 2 piping.

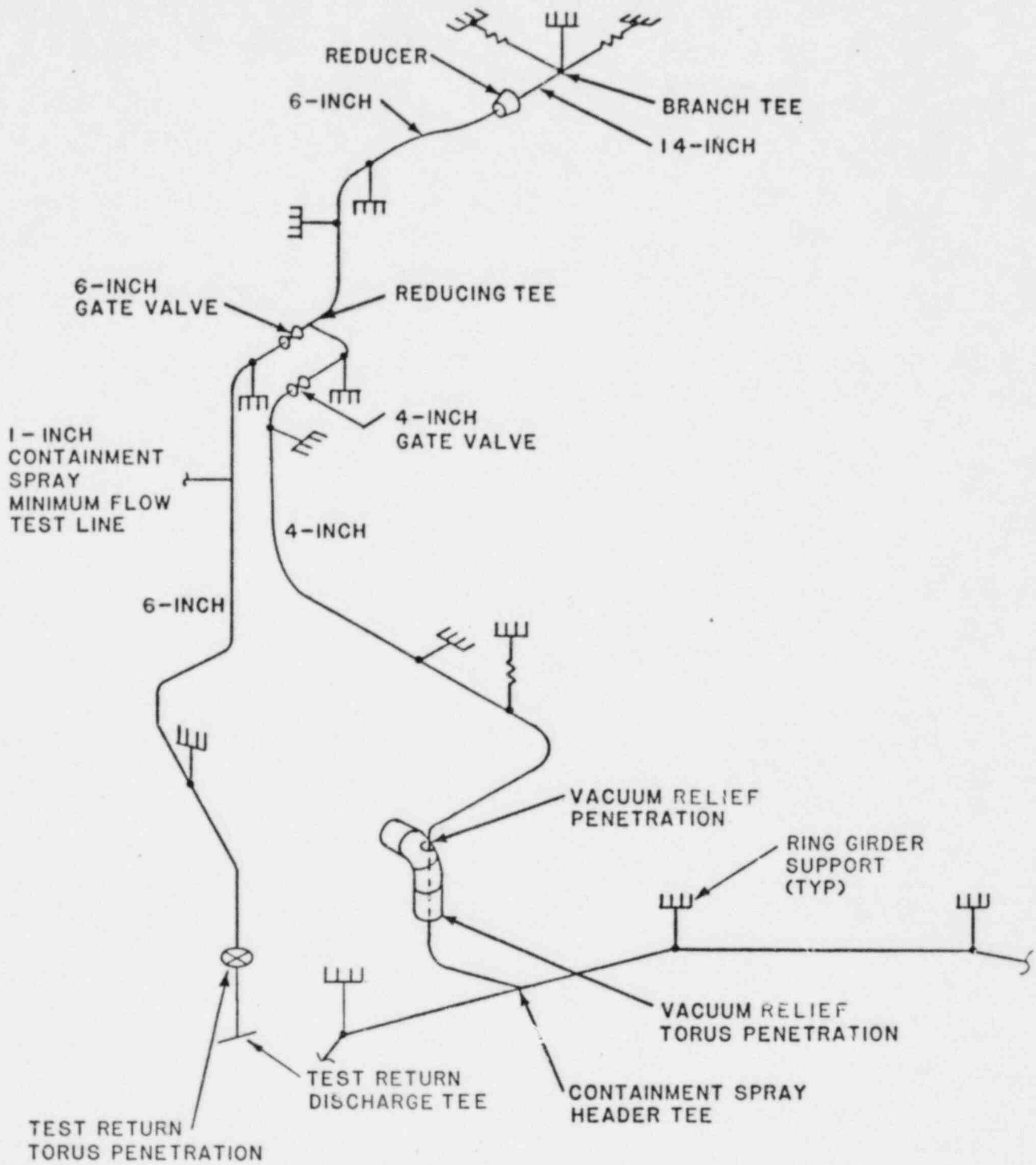

FIGURE 3.3-1

ARRANGEMENT OF CONTAINMENT SPRAY AND TEST RETURN PIPING AT VACUUM BREAKER G

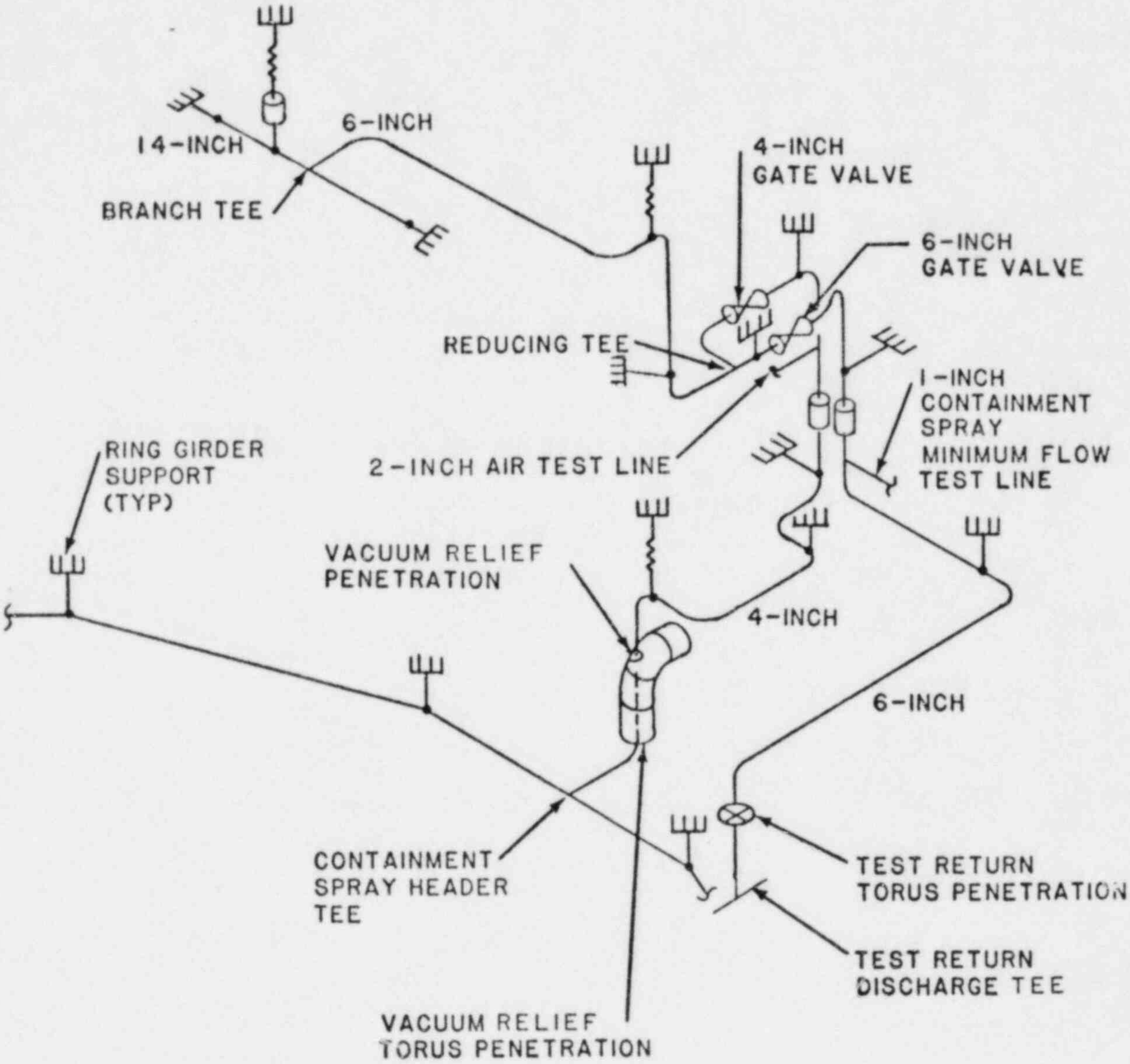

FIGURE 3.3-2

ARRANGEMENT OF CONTAINMENT SPRAY AND TEST RETURN PIPING AT VACUUM BREAKER B

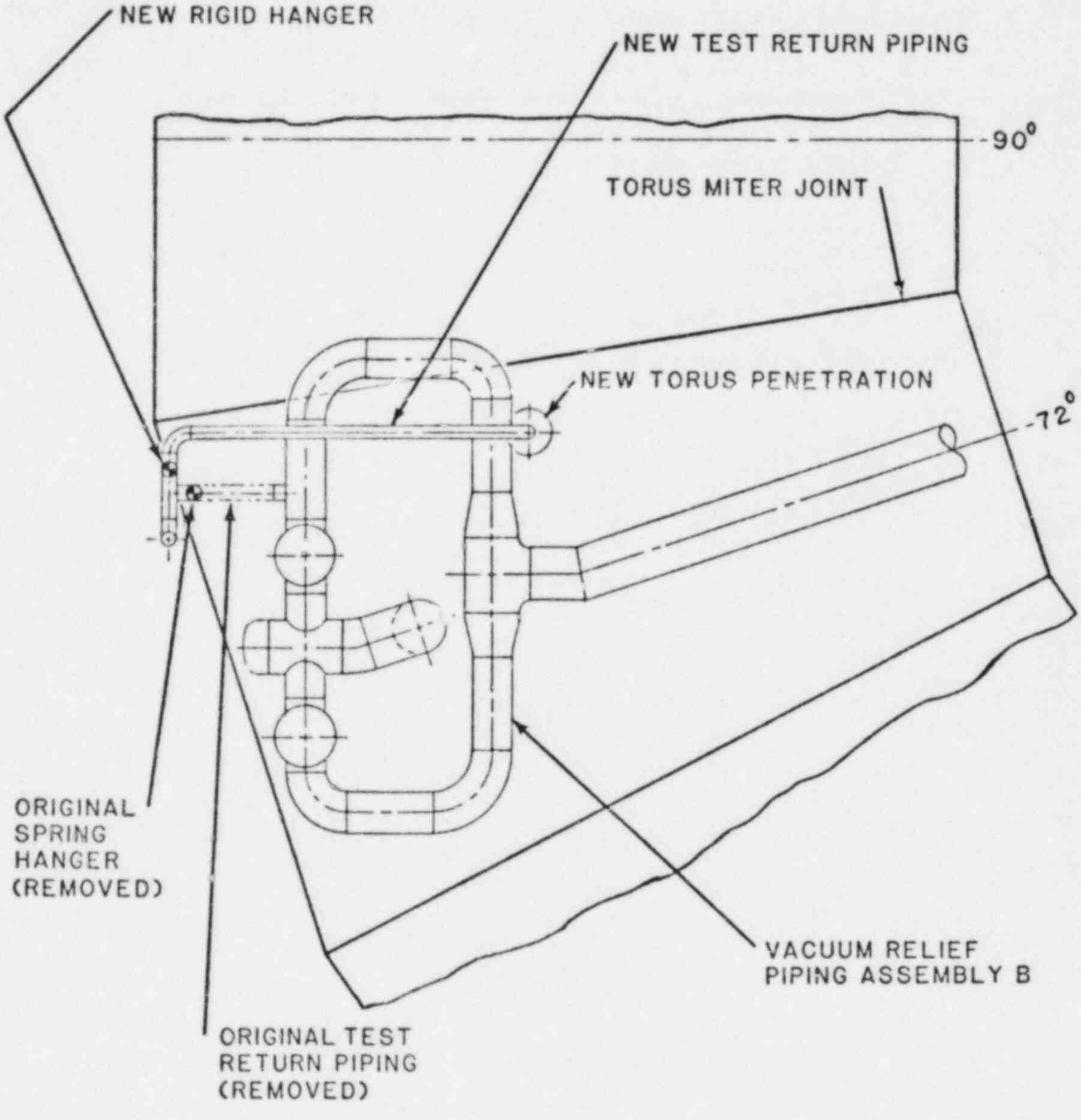

FIGURE 3.3-3

CONTAINMENT SPRAY TEST RETURN PIPING MODIFICATION

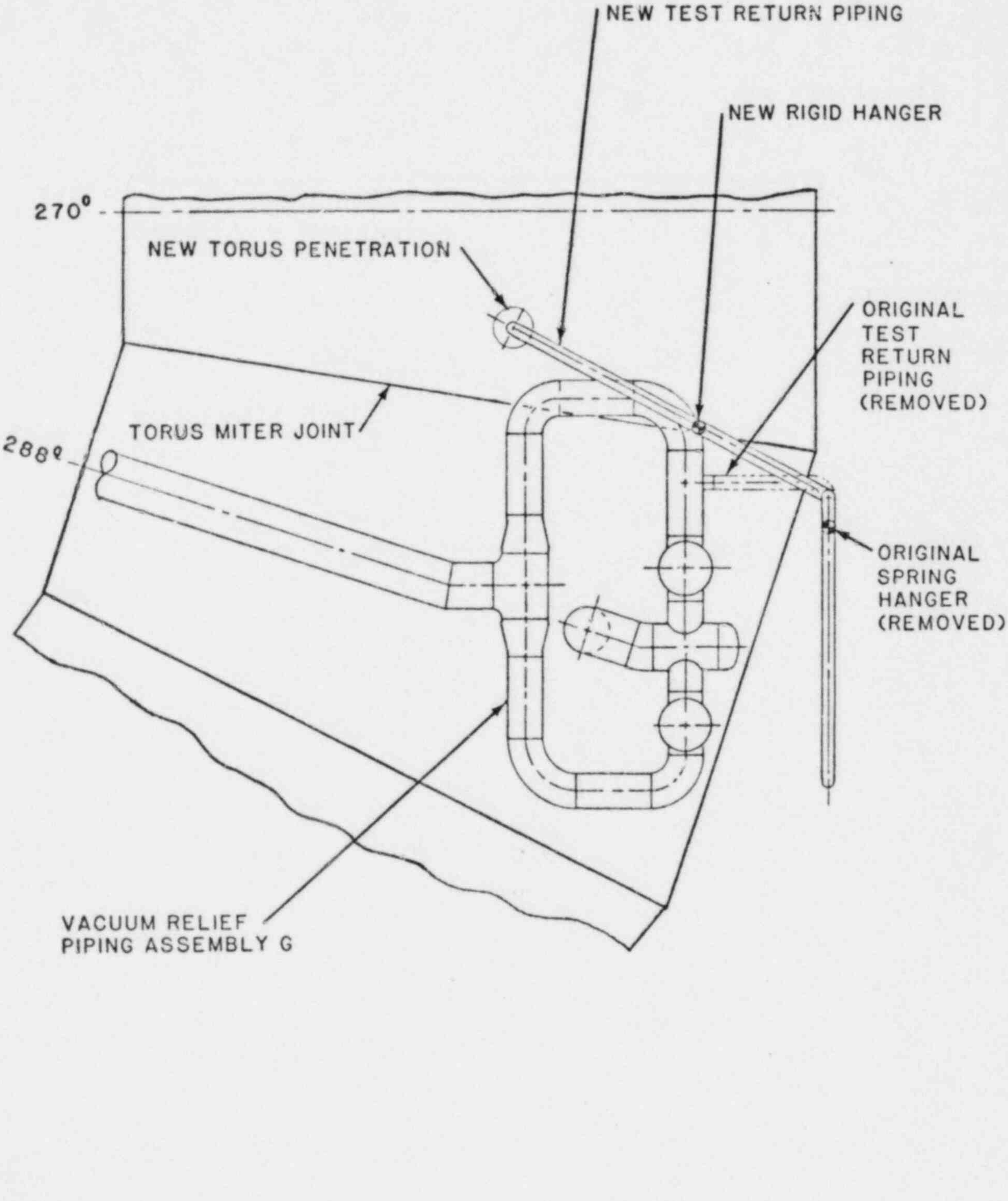

FIGURE 3.3-4

CONTAINMENT SPRAY TEST RETURN PIPING MODIFICATION

3.4 CORE SPRAY TEST RETURN PIPING

The core spray test return piping is an intermittently operated part of the core spray system for testing the operation of the core spray system under full flow conditions. This piping also provides a minimum flow path for the booster pumps under normal operating conditions through a restricting orifice. Separate runs of test return piping connect to each of the two core spray loops. Tests are run periodically on each core spray loop including the core spray pumps, booster pumps and associated valves. For these tests, the valves in the loop being tested are lined up to direct the flow through the corresponding core spray test return piping run into the air space above the torus suppression pool, rather than into the reactor core spray sparger. The maximum flow rate of each booster pump is 4,700 gpm. Swing check valves are installed in the return piping to isolate the core spray system from the torus containment. The suction piping for the core spray system is discussed in Section 3.5.

The overall arrangement of the two core spray test return runs is shown in Figures 3.4-1 and 3.4-2. The core spray test return piping consists of two 6-inch piping runs: one terminating at vacuum relief piping assembly D and the other terminating at vacuum relief assembly F. Vertical and lateral support for each run is provided by a series of spring hangers, rigid struts and guide frames. A check valve is installed just upstream of the discharge termination in each vacuum relief assembly. The piping for each run is shown beginning at a 6-inch penetration in the 24-inch torus-to-drywell vacuum relief piping. The analytical model for the piping has been terminated at a point between the torus and the core spray booster pumps where the response due to torus motion has been shown to be small. This termination was selected in accordance with guidelines specified in the PUAAG (Reference 8.2.2) for the extent of piping to be modeled.

The core spray test return piping is not required to function in connection with DBA events. Accordingly, this piping is classified as nonessential in accordance with the Mark I analysis classification given in the PUAAG (Reference 8.2.2). For ASME Code purposes, the core spray test return piping has been classified as Class 2 piping.

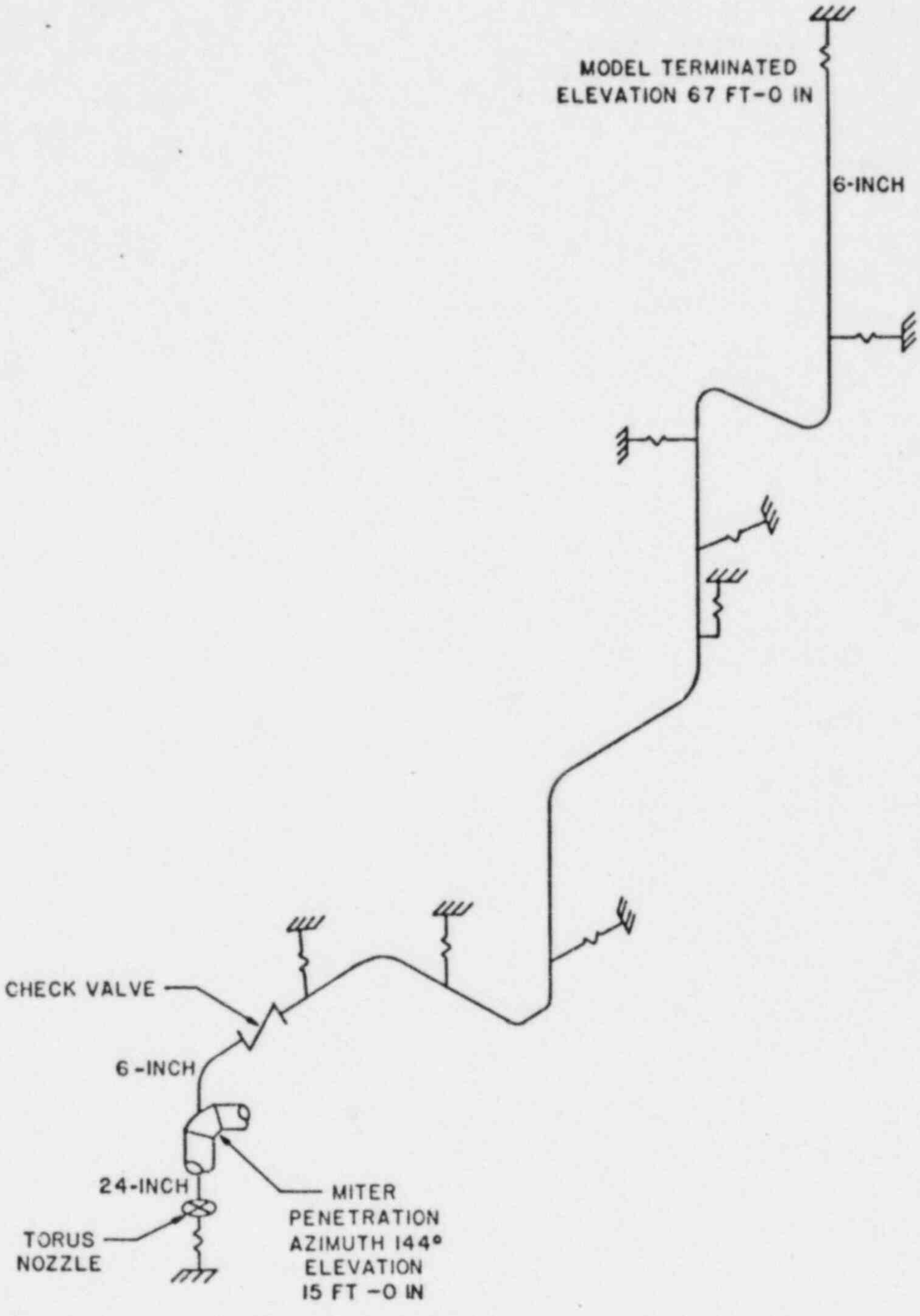

FIGURE 3.4-1

ARRANGEMENT OF CORE SPRAY RETURN PIPING
AT VACUUM BREAKER F

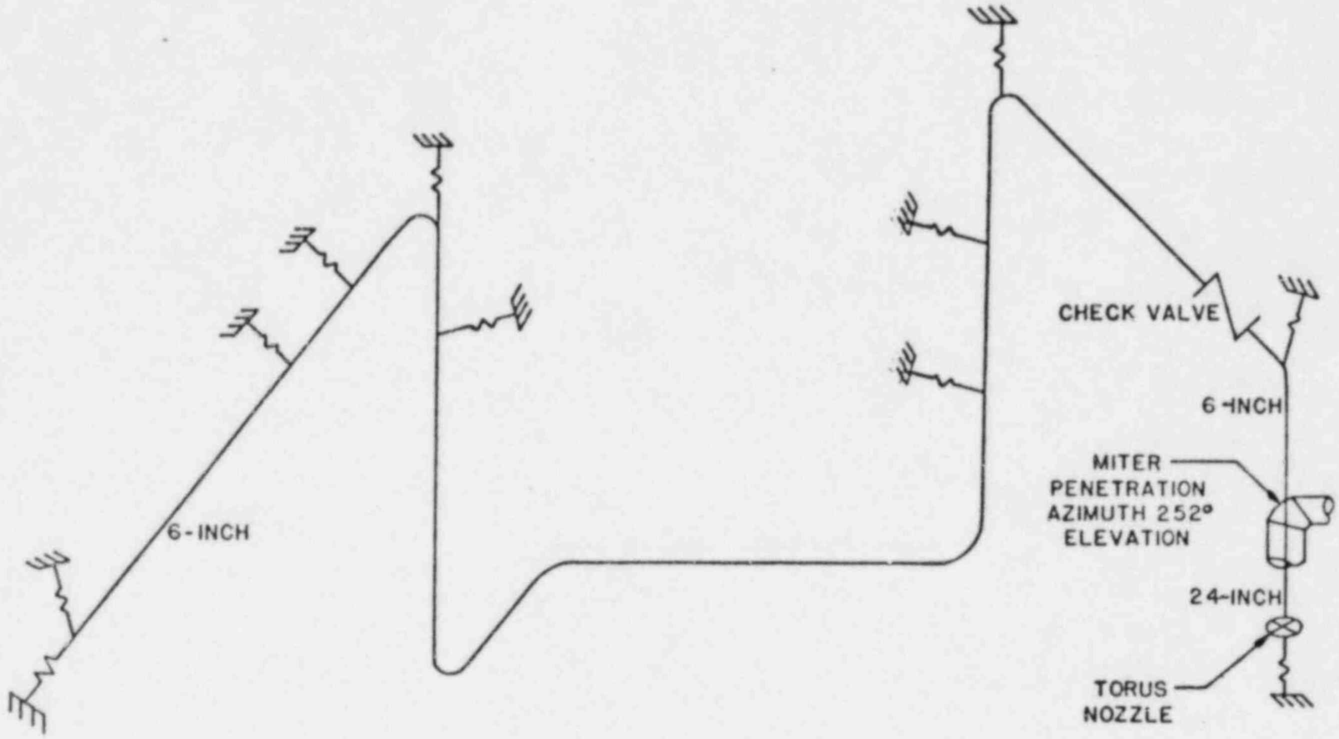

FIGURE 3.4-2

ARRANGEMENT OF CORE SPRAY RETURN PIPING
AT VACUUM BREAKER D

3.5 CORE SPRAY SUCTION HEADER AND BRANCH PIPING

The core spray suction header and branch piping is part of two piping systems: the core spray system and the containment spray system. The purpose of the core spray system is to provide an alternate supply of reactor cooling water after a postulated loss-of-coolant accident (LOCA). The purpose of the containment spray system is to provide a standby method for removing heat from the primary containment after a postulated LOCA. The core spray suction header and branch piping accomplishes these purposes by providing a path for water to flow from the torus pressure-suppression pool to the core spray and containment spray pumps.

The overall arrangement of the core spray suction header is shown in Figure 3.5-1. The arrangements of the four containment spray branch lines (designated as Branches 1, 2, 7 and 8) are shown in Figures 3.5-2, 3.5-3, 3.5-8, and 3.5-9, respectively. The arrangements of the four core spray branch lines (designated as Branches 3, 4, 5 and 6) are shown in Figures 3.5-4, 3.5-5, 3.5-6 and 3.5-7, respectively.

Three 16-inch nozzles connect the 20-inch core spray suction header to the torus. The suction header is supported horizontally by six pairs of hydraulic snubbers that attach to the torus ring girders. Vertically, the suction header is supported by 17 vertical supports. The water in the core spray suction header flows to the four core spray and four containment spray pumps through 12-inch branch lines. Each of the four containment spray branch lines has a gate valve upstream of its pump, and is supported by two vertical supports. Each of the four core spray branch lines has a 12-inch branch line which provides an alternate suction from the condensate storage tank. In addition, Branches 3 and 5 have 4-inch drain line connections. Each of the four core spray branches has a gate valve located upstream of its pump, and each branch is supported by three vertical supports.

As a result of analyses for Mark I loadings, it was found that the eight 12-inch branch connections on the core spray suction header require local reinforcement. To provide this reinforcement, a 5/8-inch thick saddle is being installed at each branch connection.

The core spray suction header and branch piping is required to operate during DBA, IBA and SBA events. Accordingly, this piping is classified as essential in accordance with the Mark I analysis classification as defined in the PUAAG (Reference 8.2.2). For ASME Code purposes, the core spray suction header and branch piping has been classified as Class 2.

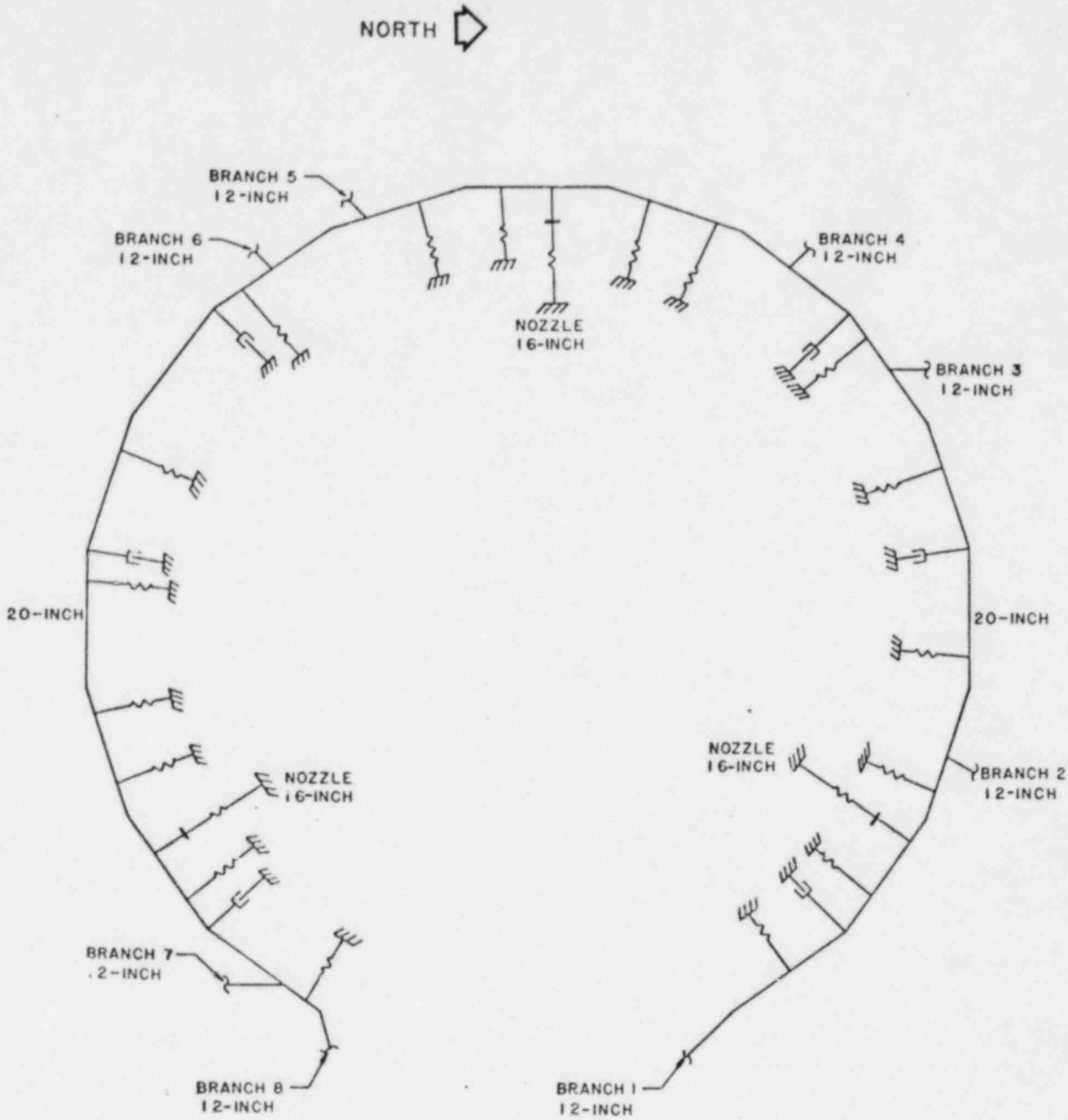

FIGURE 3.5-1

ARRANGEMENT OF
CORE SPRAY SUCTION HEADER

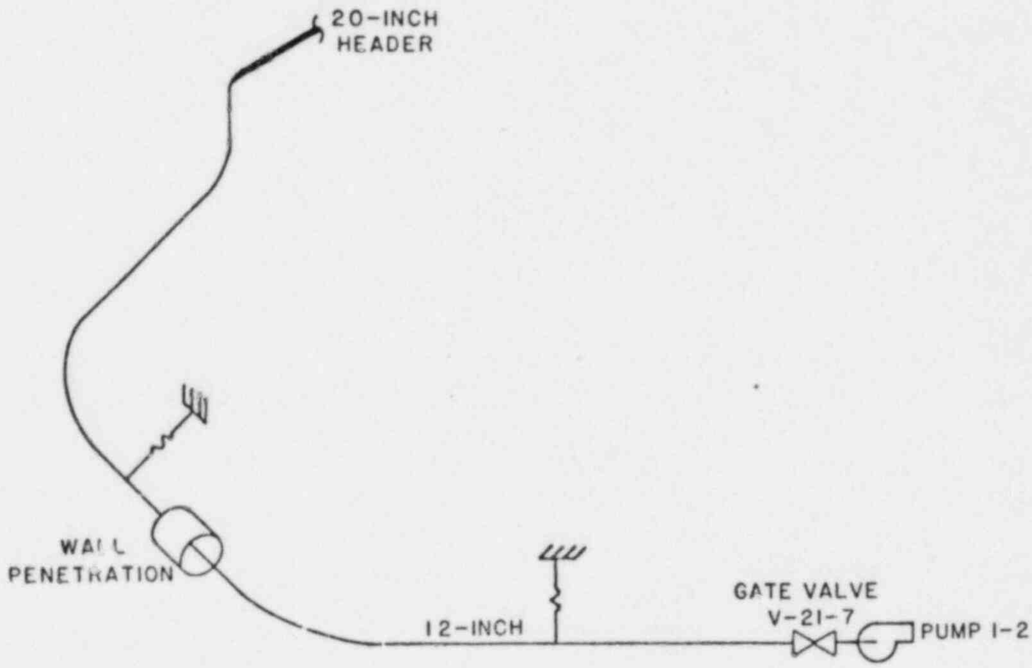

FIGURE 3.5-2

ARRANGEMENT OF BRANCH I
TO CORE SPRAY SUCTION HEADER

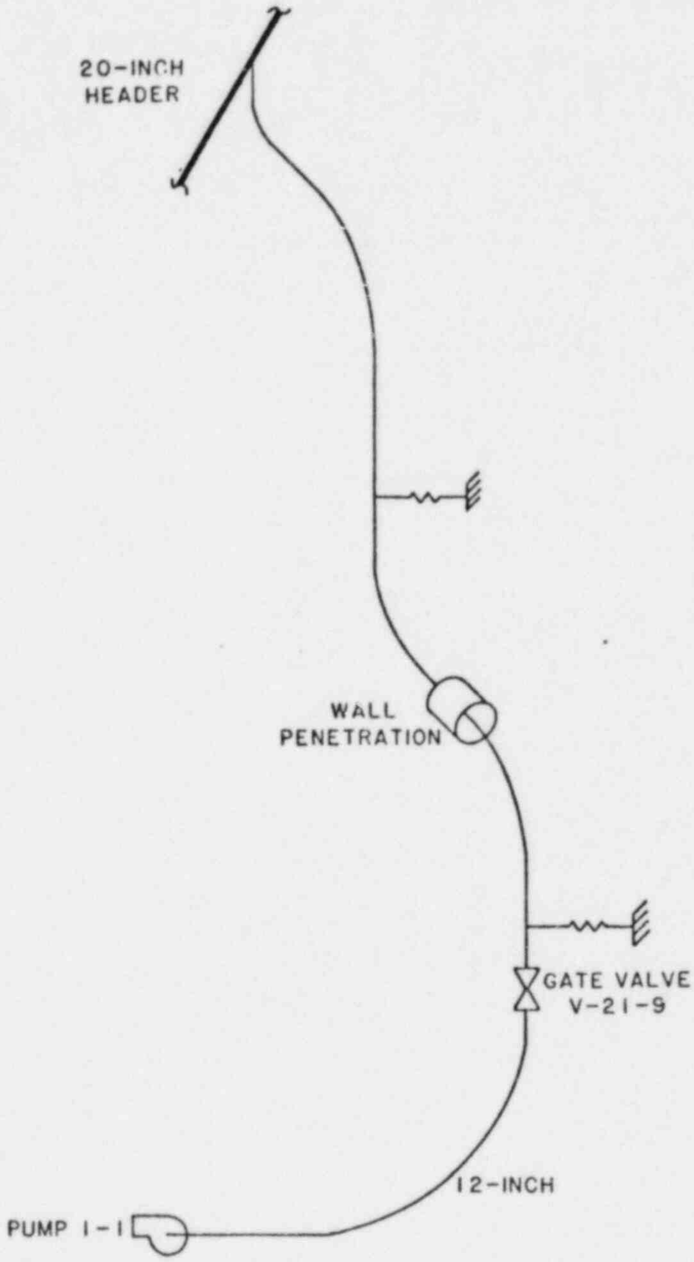

FIGURE 3.5-3

ARRANGEMENT OF BRANCH 2
TO CORE SPRAY SUCTION HEADER

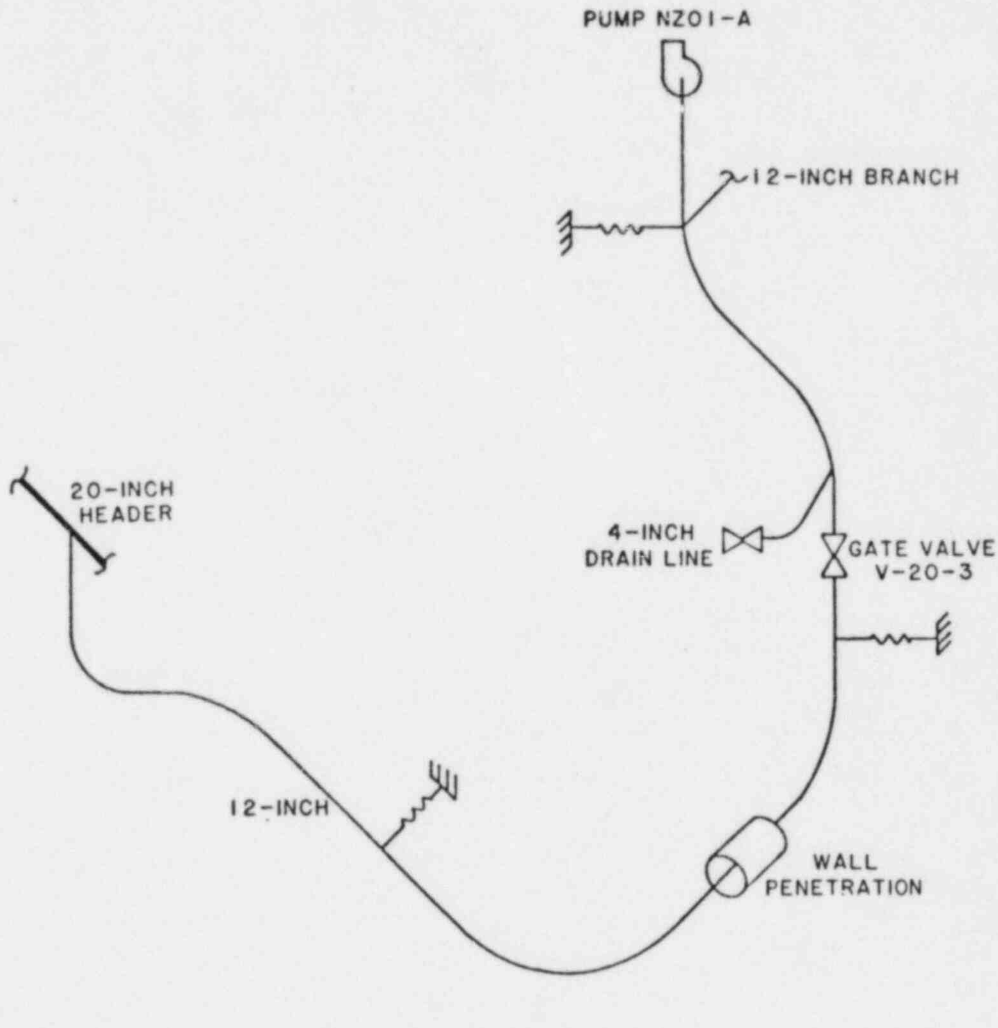

FIGURE 3.5-4

ARRANGEMENT OF BRANCH 3
TO CORE SPRAY SUCTION HEADER

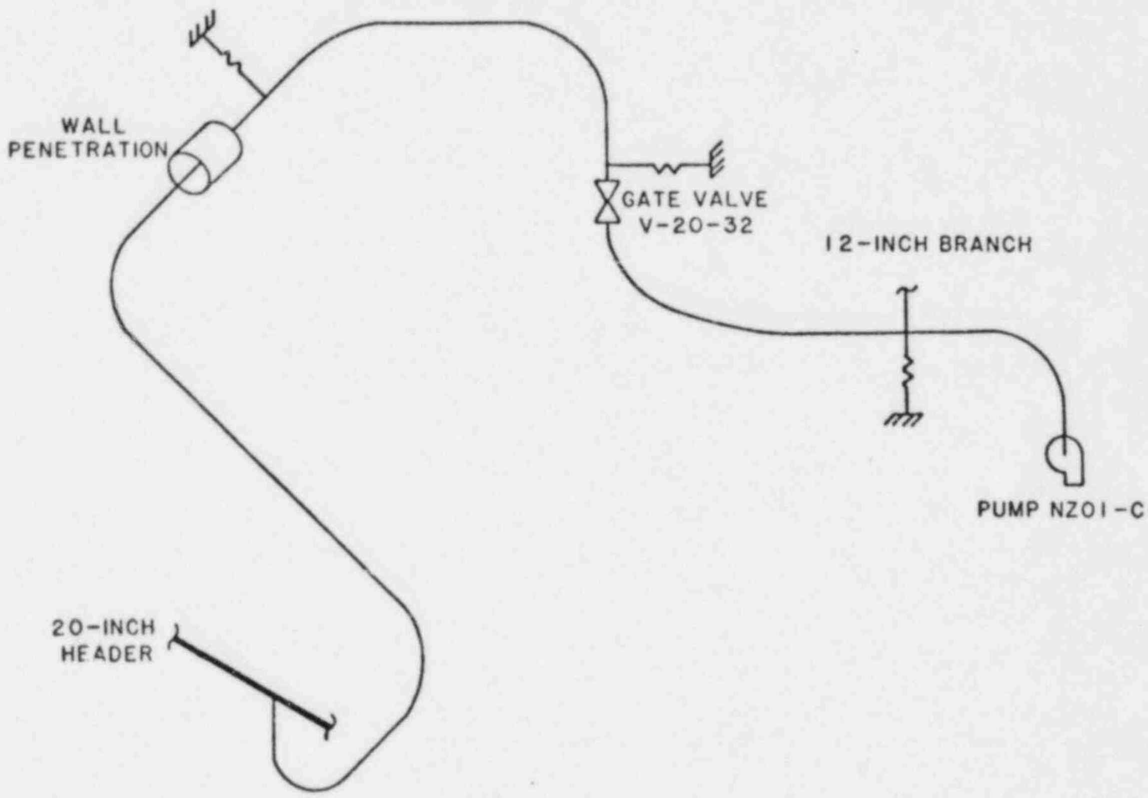

FIGURE 3.5-5

ARRANGEMENT OF BRANCH 4
TO CORE SPRAY SUCTION HEADER

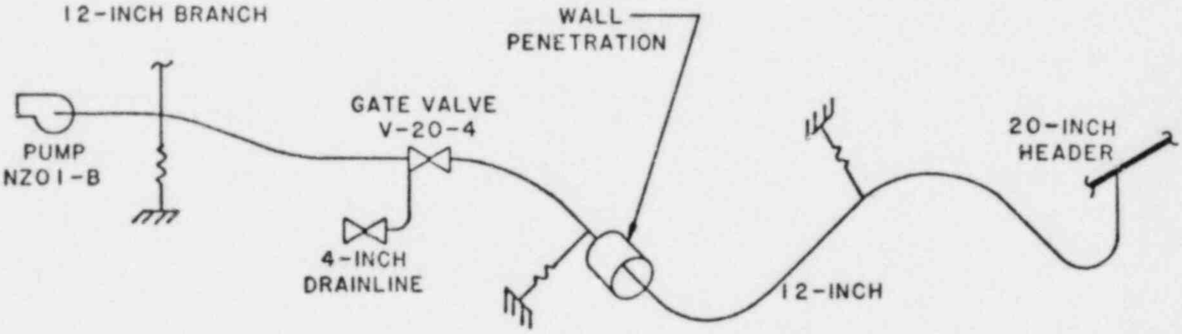

FIGURE 3.5-6

ARRANGEMENT OF BRANCH 5
TO CORE SPRAY SUCTION HEADER

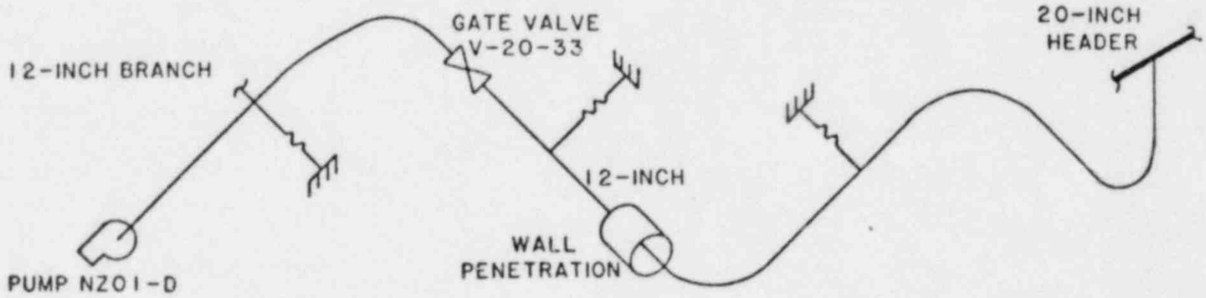

FIGURE 3.5-7

ARRANGEMENT OF BRANCH 6
TO CORE SPRAY SUCTION HEADER

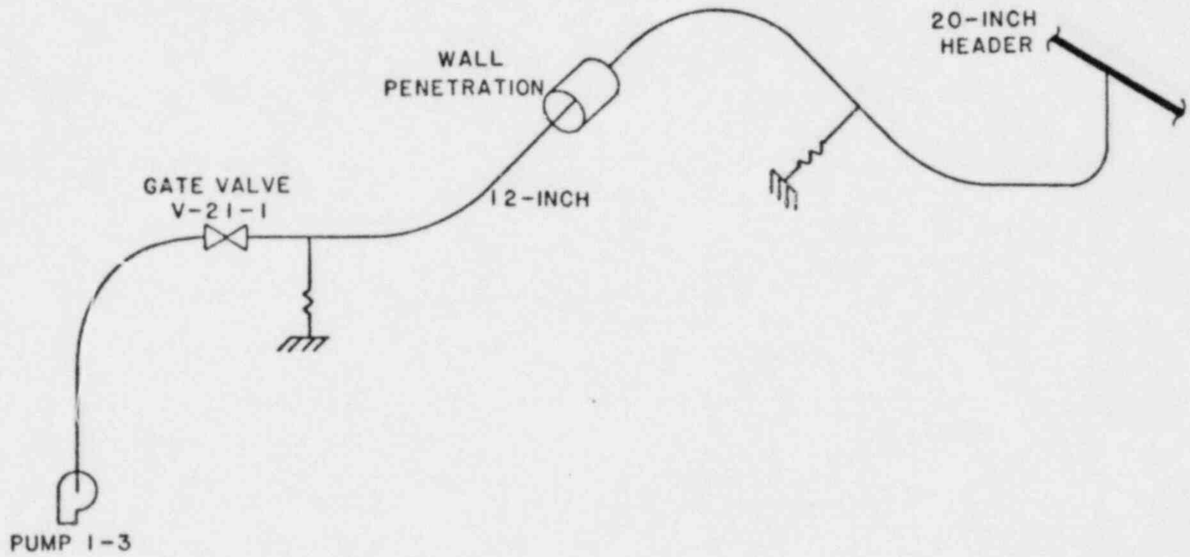

FIGURE 3.5-8

ARRANGEMENT OF BRANCH 7
TO CORE SPRAY SUCTION HEADER

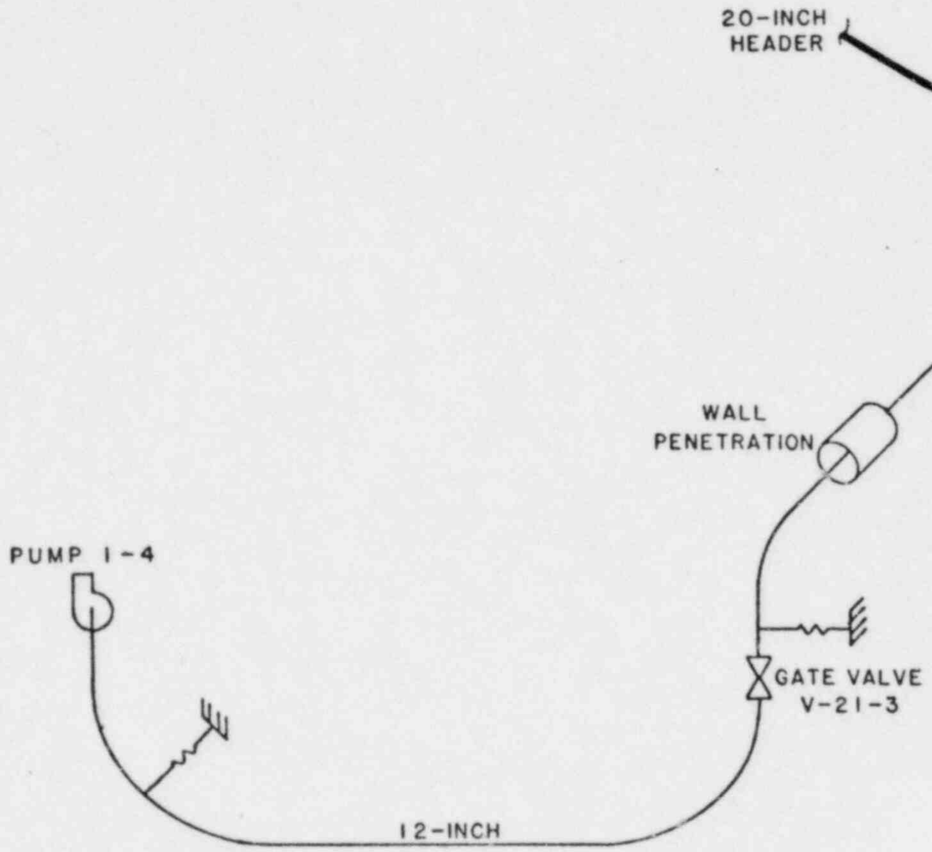

FIGURE 3.5-9

ARRANGEMENT OF BRANCH 8
TO CORE SPRAY SUCTION HEADER

3.6 SRV DISCHARGE PIPING

The Oyster Creek reactor and main steam system is equipped with five safety relief valves (SRVs). These valves are mounted to flanges which connect through short lengths of pipe to the main steam piping and are provided to remove energy during reactor pressure transients sufficient to prevent safety valves from lifting. These valves also provide for automatic reactor vessel depressurization for enhanced effectiveness of the emergency core cooling system (ECCS) during a small break accident (SBA). Discharge piping is attached to groups of these valves which direct the steam flow to the torus where it is quenched. There are 16 additional safety valves required for overpressure protection per the ASME Code which discharge directly into the drywell and thus have no discharge piping.

Each of the two main steam headers (north and south) in the drywell at Oyster Creek has a separate piping system to discharge steam from the associated SRVs to the torus. There are three SRVs on the south steam header and two SRVs on the north steam header. The north header SRV discharge piping arrangement is shown in Figure 3.6-1 and the south header SRV discharge piping arrangement is shown in Figure 3.6-2. The SRV discharge piping system contains piping runs both inside and outside the torus.

The out-of-torus runs of each discharge line consist of 8-inch diameter piping attached to each SRV which connects to a 14-inch header. The headers reduce to a 12-inch diameter before they enter the torus. The piping runs which connect the SRVs and the steam header branch connection are 6, 8 and 10 inches in diameter. With three SRVs, the out-of-torus runs of the south header discharge piping are more extensive than those of the north header piping, which has only two valves.

The in-torus runs of the SRV discharge piping consist of 12-inch diameter discharge lines which enter the torus through the ellipsoidal head on the vent line to vent header intersections at azimuths 216° and 144°. The discharge lines each terminate with a Y-quencher submerged in the torus water. The Y-quenchers are centered about the torus ring girders at azimuths 225° and 135° as shown in Figure 3.6-3. Each quencher consists of two piping arms capped at their outer ends and connected to the existing vertical discharge pipe through a fabricated ramshead tee. The Y-quenchers were installed in May 1977 to reduce SRV discharge loads on the torus. The modified quenchers have numerous small holes drilled on the sides of each arm. The size and pattern of the holes are designed to control the release of water, air and steam so as to reduce resulting loads and dynamic pressures in the suppression pool (torus) when an SRV opens.

Each SRV discharge line is also equipped with two swing check valves which act as vacuum breakers for the lines. These vacuum breakers were modified to increase their relief capability in May 1977. The purpose of these vacuum breakers is to admit air from the drywell into the discharge pipe after an SRV recloses and steam remaining in the discharge pipe condenses. Readmitting air prevents pressure in the pipe from dropping significantly below torus air pressure. Without the vacuum breakers, line pressure would drop below that of the torus and a long water slug could be drawn up the discharge line. A subsequent SRV discharge under these conditions would result in higher than normal SRV discharge torus and piping loads.

As a result of analyses for Mark I loadings, it was found that the vertical 14-inch run of the south discharge piping requires local reinforcement at the branch tee where the 8-inch run from one valve (valve E) joins the 14-inch discharge riser from the other two valves (valves A & B). To provide this reinforcement, a 5/8-inch-thick saddle is being installed on the pipe at this intersection.

The SRV discharge piping is classified as essential in accordance with the Mark I analysis classification as defined in the PUAAG (Reference 8.2.2). For ASME Code purposes, the SRV discharge piping has been classified as Class 2 piping for all but the piping which connects the SRVs to the main steam piping. The six-inch and ten-inch branch connections which connect the SRVs to the main steam piping have been classified as Class 1 piping.

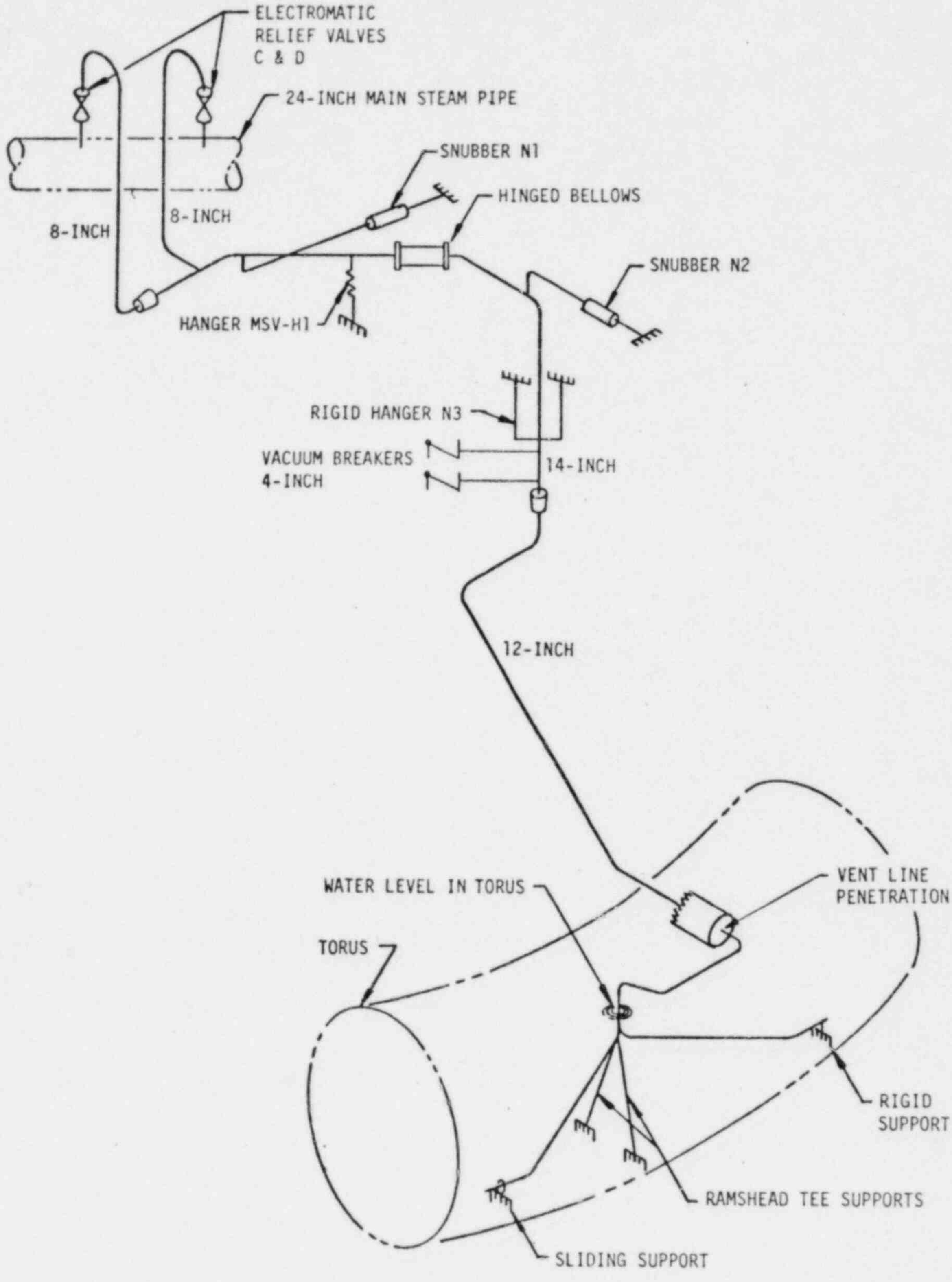

FIGURE 3.6-1

ARRANGEMENT OF NORTH HEADER
SAFETY RELIEF VALVE DISCHARGE PIPING

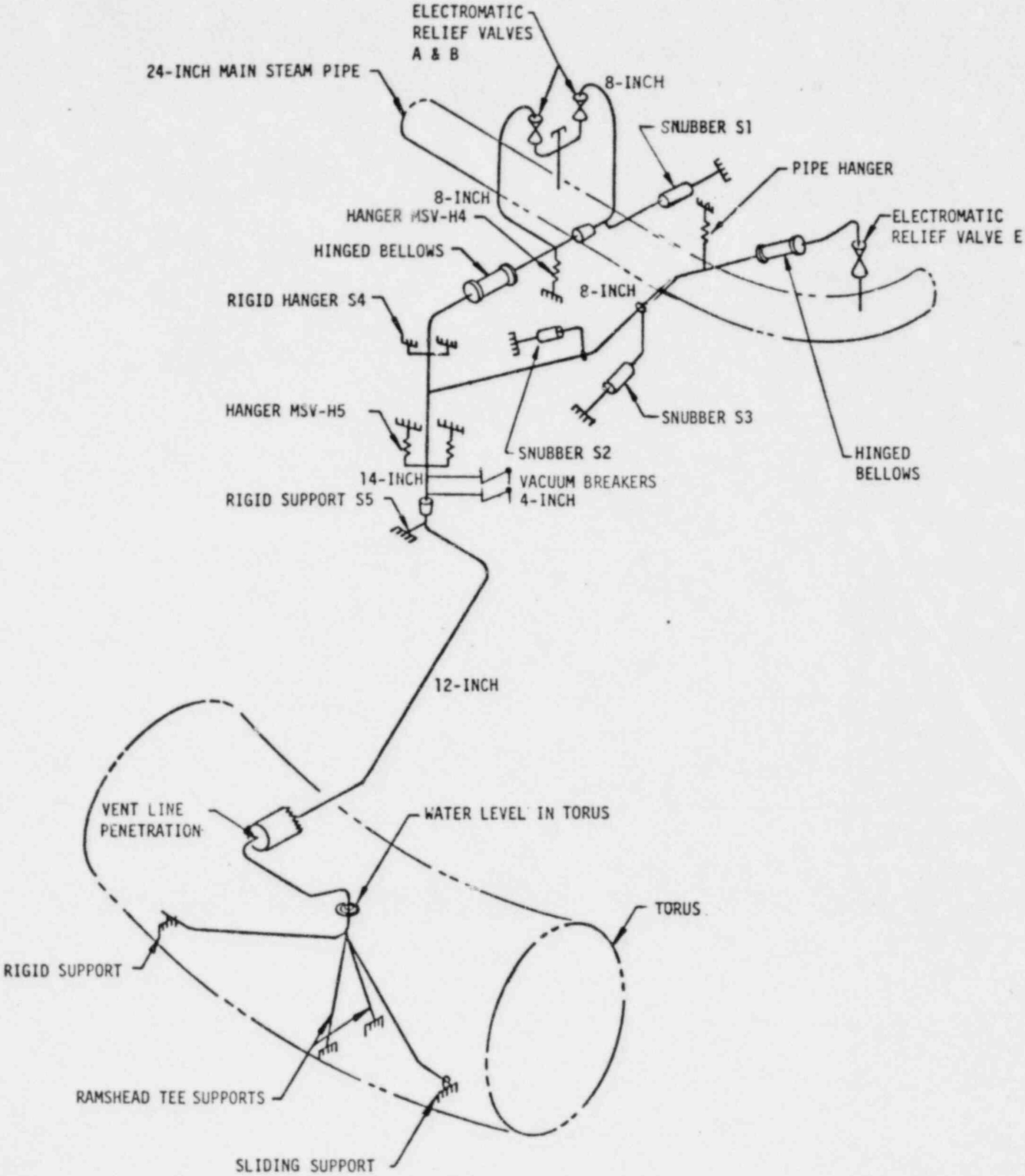

FIGURE 3.6-2

ARRANGEMENT OF SOUTH HEADER
SAFETY RELIEF VALVE DISCHARGE PIPING

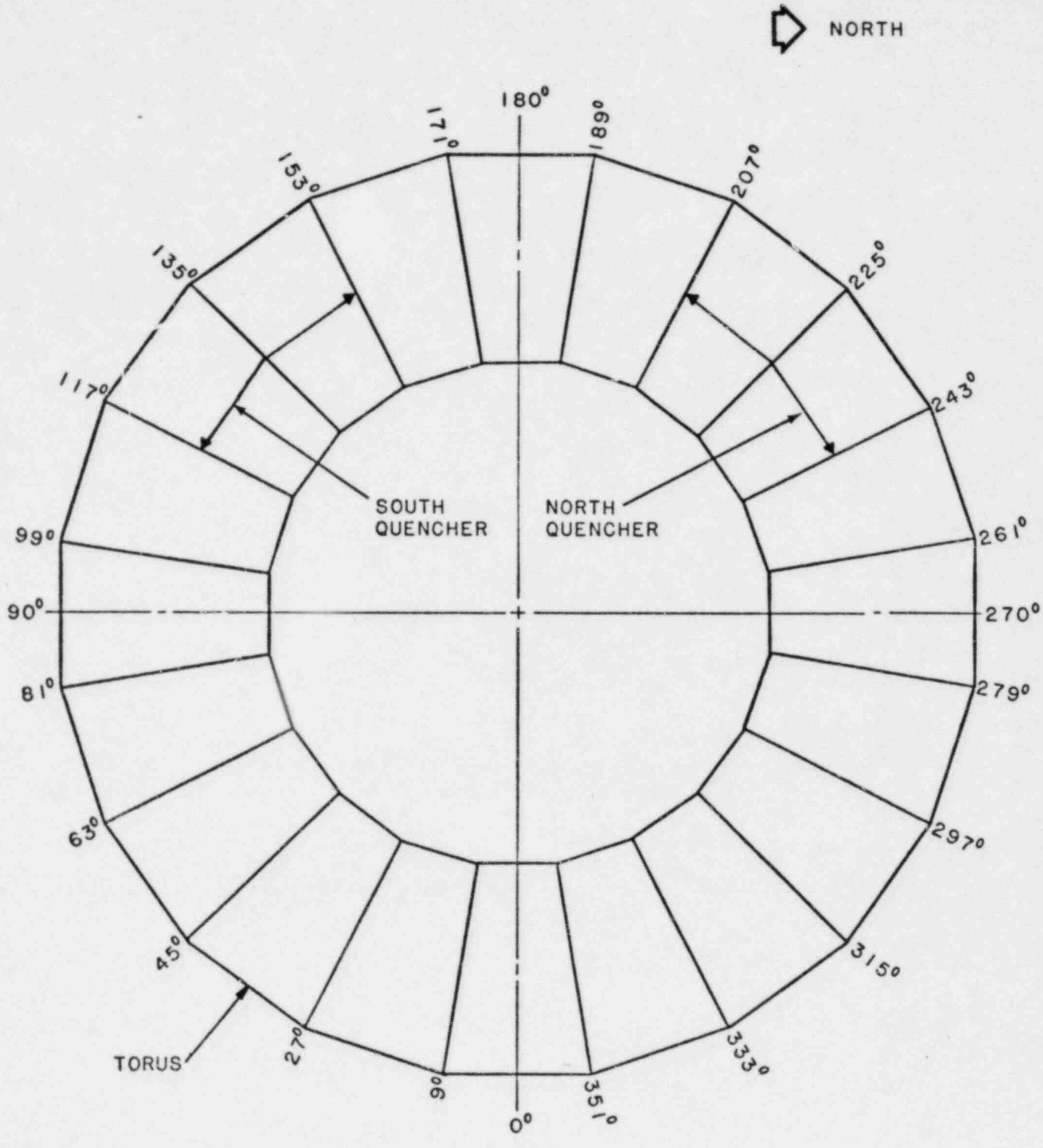

FIGURE 3.6-3

LOCATION OF SRV DISCHARGE QUENCHERS

3.7 SMALL BORE PIPING AND CORE SPRAY SUCTION STRAINERS

Table 3.7-1 provides a list of the small bore piping lines attached to the torus which were analyzed and an identification of the appropriate ASME Code and Mark I Containment Long-Term Program analysis classifications. Lines 1 through 4 are small diameter instrumentation lines (typically one-inch), which connect to a larger diameter torus penetration and terminate after an extended run at the instrumentation transducer (or sample connection). Line 5 is a valved torus drain which is 1-1/2 inches in diameter and is capped during normal plant operation. Line 6 is the core spray suction strainer which is mounted to a 16-inch diameter pipe and extends 24 inches into the interior of the torus. Attached at the end of the pipe is a wire mesh basket which is 24 inches in diameter and 36 inches in length.

Also covered in this section are several branch piping lines which connect to larger diameter piping lines which, in turn, connect to the torus. Table 3.7-2 lists these lines, identifies the systems to which the lines are connected, and lists the appropriate ASME Code and Mark I analysis classifications.

With two exceptions, the small diameter piping and suction strainers covered in this section are classified as nonessential in accordance with the Mark I analysis classification given in the PUAAG (Reference 8.2.2). The exceptions are the torus level instrumentation piping and the core spray suction strainers which are classified as essential.

TABLE 3.7-1

CLASSIFICATION OF SMALL BORE PIPING ATTACHED TO TORUS AND CORE SPRAY SUCTION STRAINERS

	PIPING LINE	ASME CODE CLASSIFICATION	MARK I ANALYSIS CLASSIFICATION
1.	Torus Level Instrumentation Line	3(Note 1)	Essential
2.	Torus Pressure Transducer Line	3(Note 1)	Nonessential
3.	Oxygen Analyzer Line	3(Note 1)	Nonessential
4.	Temperature Transducer Line	Non-class	Nonessential
5.	Torus Drain Line	3(Note 1)	Nonessential
6.	Core Spray Suction Strainer	2	Essential

NOTE:

1. The piping which connects between the containment and the isolation valve is Class 2 piping.

TABLE 3.7-2

CLASSIFICATION OF BRANCH PIPING CONNECTED TO TORUS ATTACHED PIPING

BRANCH PIPING	SYSTEM WHERE CONNECTED	ASME CODE CLASSIFICATION	MARK I ANALYSIS CLASSIFICATION
1. Torus Level Instrumentation Reference Leg	Vacuum Relief Piping Assembly E (Azimuth 252^{o})	3(Note 1)	Essential
2. Air Test Piping	Containment Spray and Test Return Piping at Vacuum Relief Piping Assembly B (Azimuth 72^{o})	3(Note 1)	Nonessential
3. Containment Spray Pump Minimum Flow Piping (two connections)	Containment Spray Test Return Piping at Vacuum Relief Piping Assemblies B and G (Azimuths 72^{o} and 288^{o})	2	Nonessential
4. Core Spray Suction Branch Piping	Branches 3, 4, 5 and 6 of Core Spray Suction Header	2	Nonessential
5. Emergency Exhaust Line Isolation Valve Bypass Piping	Emergency Exhaust Branch of Vacuum Relief Piping Assembly A (Azimuth 0^{o})	3(Note 1)	Nonessential
6. Drywell Pressure Transducer	Vacuum Relief Piping Assembly G (Azimuth 288^{o})	3	Nonessential

NOTE:

1. For branch piping that connects to systems at locations where no isolation valves isolate the branch piping from the containment, the branch piping which connects between the system and the branch isolation valve is Class 2 piping.

3.8 NOZZLES AND PENETRATIONS

Nozzles and penetrations will be described in terms of the piping system of which they are part. The special case of nozzle transitions is discussed in Section 3.8.7, below.

3.8.1 Vacuum Relief Piping Systems

Typical arrangements of the piping, including nozzle locations, are shown in Figures 3.1-1 through 3.1-4. Nozzles are identical among the seven torus-to-drywell vacuum relief systems represented by Figures 3.1-1 through 3.1-3, and have the geometry described in Table 3.8-1. Note that each system has two nozzles, one in the torus and one in the vent line. Figures 3.8-1 and 3.8-2 show the torus and vent line nozzles, respectively. The torus nozzle for the reactor building-to-torus vacuum relief system, Figure 3.1-4, is also described in Table 3.8-1 and shown in Figure 3.8-3. Stress and fatigue analyses for all these nozzles have been performed at the intersection between the nozzle reinforcing plate and torus shell, and also at the intersection between the nozzle and reinforcing plate. These locations are classified as ASME Code, Class MC structural parts.

3.8.2 Demineralizer Relief Valve Discharge Piping System

The arrangement of the piping, including the penetration, is shown in Figures 3.2-1 and 3.2-2. Dimensions of the penetration and its reinforcement are given in Figure 3.8.4 and also in Table 3.8-1. Stress and fatigue analyses are performed at the edge of the reinforcement in the torus shell and at the pipe-to-reinforcement intersection in the reinforcement. These locations are classified as ASME Code, Class MC structural parts.

3.8.3 Core Spray and Containment Spray Test Return Piping

These systems, discussed in Sections 3.3 and 3.4 can be considered for nozzle analysis as follows:

(a) Containment Spray Test Return Piping (Figures 3.3-1, 3.3-2, and 3.3-3) -- The two test return lines have identical piping penetrations in the torus itself. The dimensions of these penetrations are given in Table 3.8-1, and the penetration details are shown in Figure 3.8-5.

(b) Core Spray Test Return and Torus Containment Spray and Test Return Piping (Figures 3.3-1, 3.3-2 and 3.4-1) -- These lines penetrate the vacuum breaker piping near the vacuum relief piping assembly torus-side nozzles. Static and dynamic loads generated by these small lines are added to the main vacuum breaker loads for the torus-side vacuum breaker nozzle and nozzle transition analyses.

Like the other nozzles discussed above, the core spray and containment spray test return penetrations have been analyzed at the intersection between the reinforcement plate and torus and at the intersection between the pipe and reinforcement plate. Both locations are classified as ASME Code, Class MC structural components.

3.8.4 Core Spray Suction Header Piping

The arrangement of the main suction header is described in Section 3.5 and shown in Figure 3.5-1. The three penetrations are identical except for wall thickness. Dimensions are given in Table 3.8-1 and the penetration geometry is shown in Figure 3.8-6. This figure shows a modified penetration reinforcement that ties the penetration to nearby torus straps or to the saddle upper flange. This reinforcement is being added as part of the Mark I Long-Term Program. Stresses were calculated for the reinforcement plate adjacent to the nozzle. This location is an ASME Code, Class MC structural part.

3.8.5 SRV Discharge Piping

The two SRV discharge piping systems are described in Section 3.6 and the lines, called north and south headers, are shown in Figures 3.6-1 and 3.6-2. In both lines, the penetration of interest is at the vent line head, inside the torus. Details of the penetrations are given in Table 3.8-1 and shown in Figure 3.8-7. Like the other penetrations and nozzles, stress analyses were performed at the reinforcement-to-head intersection and at the intersection between the pipe and reinforcement plate. Both locations are Class MC structural parts.

3.8.6 Small Bore Piping

Among the small bore piping lines described in Section 3.7, only one, the 1-1/2-inch torus level line, penetrates the torus directly and has significant loads. Penetration for other small lines, such as the torus drain and the instrumentation wells are loaded less than this line and were not analyzed. The torus level nozzle is described in Table 3.8-1. Analyses were performed at the edge of the pipe only, since there is no reinforcement plate. This penetration is classified as an ASME Code, Class MC structural part.

3.8.7 Nozzle Transitions

Paragraph NE-3227.5 of the ASME Code, Section III (Reference 8.4.1), assigns special classifications to stresses in piping or nozzles near the torus shell. These areas are called "nozzle transitions" and must meet more restrictive stress allowables than for the attached piping. The PUAAG, Reference 8.2.2, limits the extent of these regions to be within the "limits of reinforcement" defined in the ASME Code, Paragraph NE-3334. Typically, this involves several inches of the pipe or nozzle adjacent to the shell. Therefore, separate stress calculations were performed in the nozzle or penetration wall itself, adjacent to the torus reinforcing pad. The nozzle transitions are classified as ASME Code, Class MC components.

TABLE 3.8-1

NOZZLE AND PENETRATION DIMENSIONS

System	Pipe/Nozzle Outer Diameter (Inches)	Wall Thickness (Inches)	Reinforcing Pad Outer Diameter (Inches)	Reinforcing Pad Thickness (Inches)	Location
1. Vacuum Relief					
a. Torus End	24.00	.9375	42.125	1.000	Upper Torus
b. Vent Line End	24.00	.500	36.00	0.722	Vent Line
c. Torus-to-Reactor Building	20.00	.750	37.50	1.000	Upper Torus
2. Demineralizer Relief	20.00	.625	36.00	1.000	Upper Torus
3. Test Return Piping	6.625	.562	30.00	1.000	Upper Torus
4. Core Spray Suction Header	16.00	.938 (Note 1)	N/A	1.375	Lower Torus
5. SRV Discharge	12.75	.687	20.00	1.000	Vent Line Head
6. Torus Level	1.90	.200	N/A	N/A	Lower Torus

Notes:

1. One nozzle out of three has a wall thickness of .875 inches.

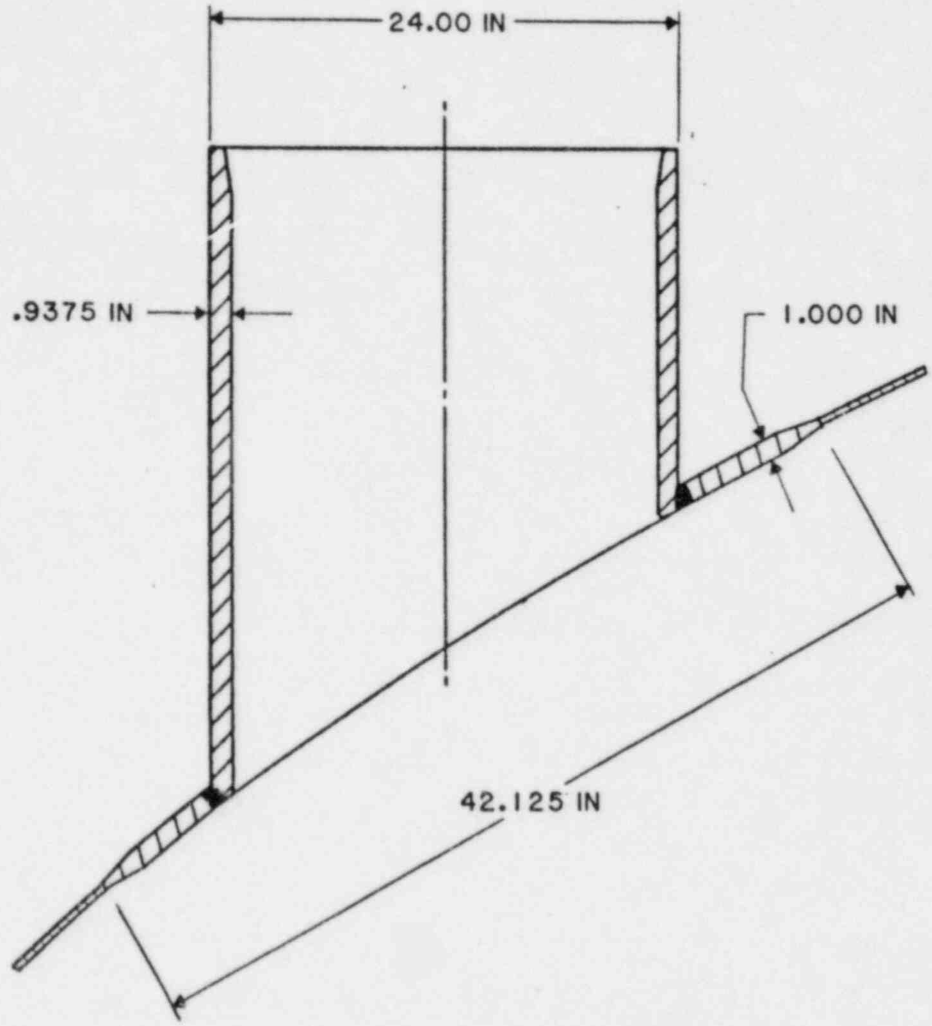

FIGURE 3.8-1

VACUUM RELIEF PIPING NOZZLE-TORUS END

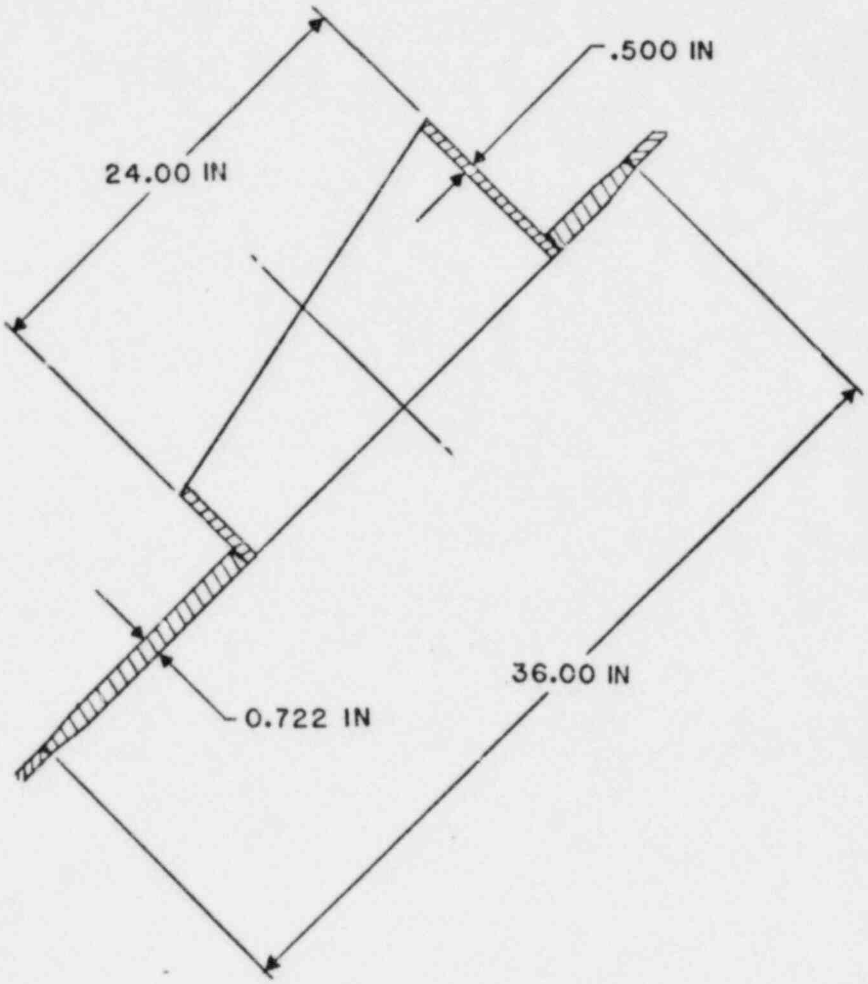

FIGURE 3.8-2

VACUUM RELIEF PIPING NOZZLE - VENT LINE END

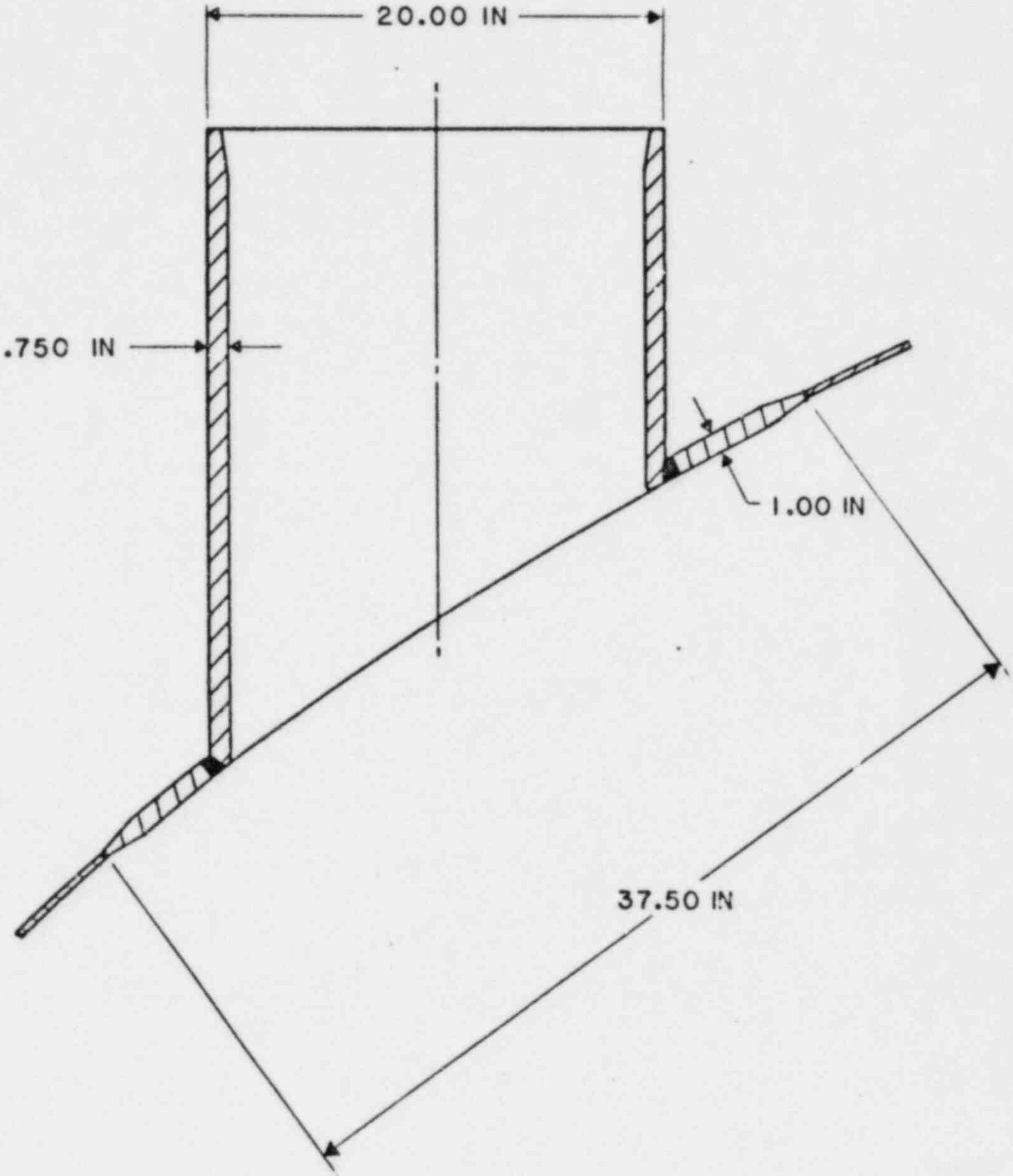

FIGURE 3.8-3

REACTOR BUILDING-TO-TORUS PIPING NOZZLE

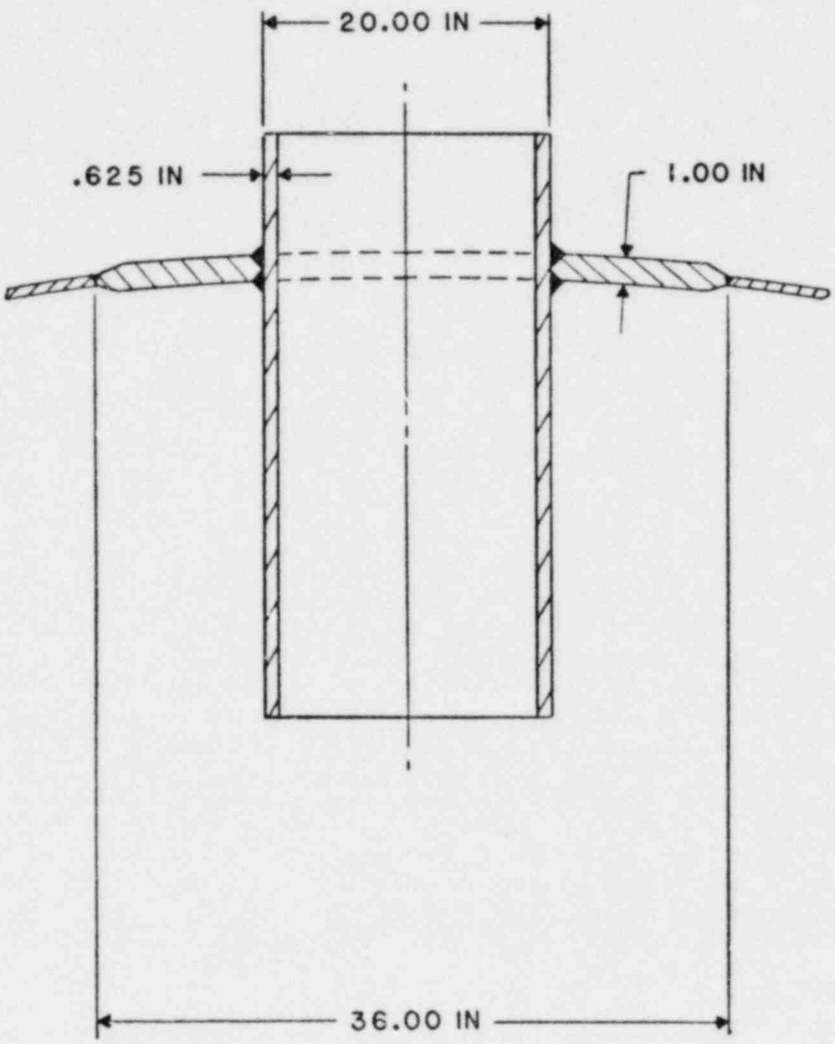

FIGURE 3.8-4

DEMINERALIZER RELIEF VALVE DISCHARGE PIPING PENETRATION

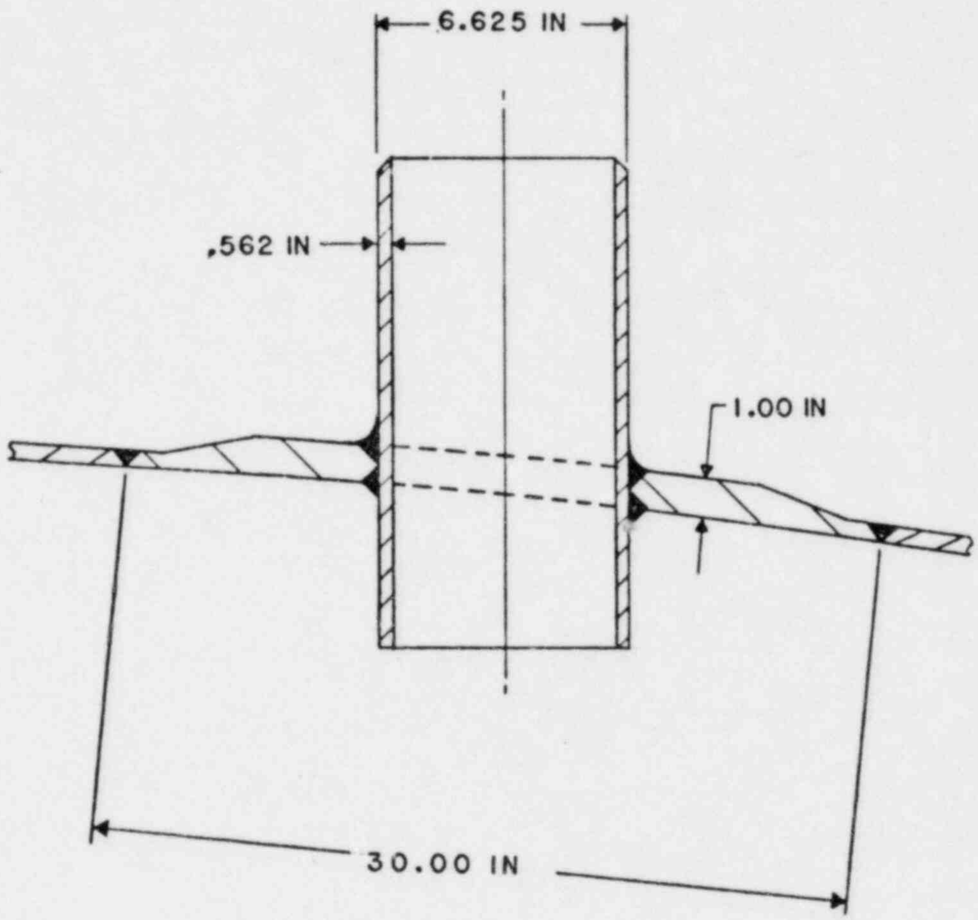

FIGURE 3.8-5

CONTAINMENT SPRAY TEST RETURN PIPING PENETRATION

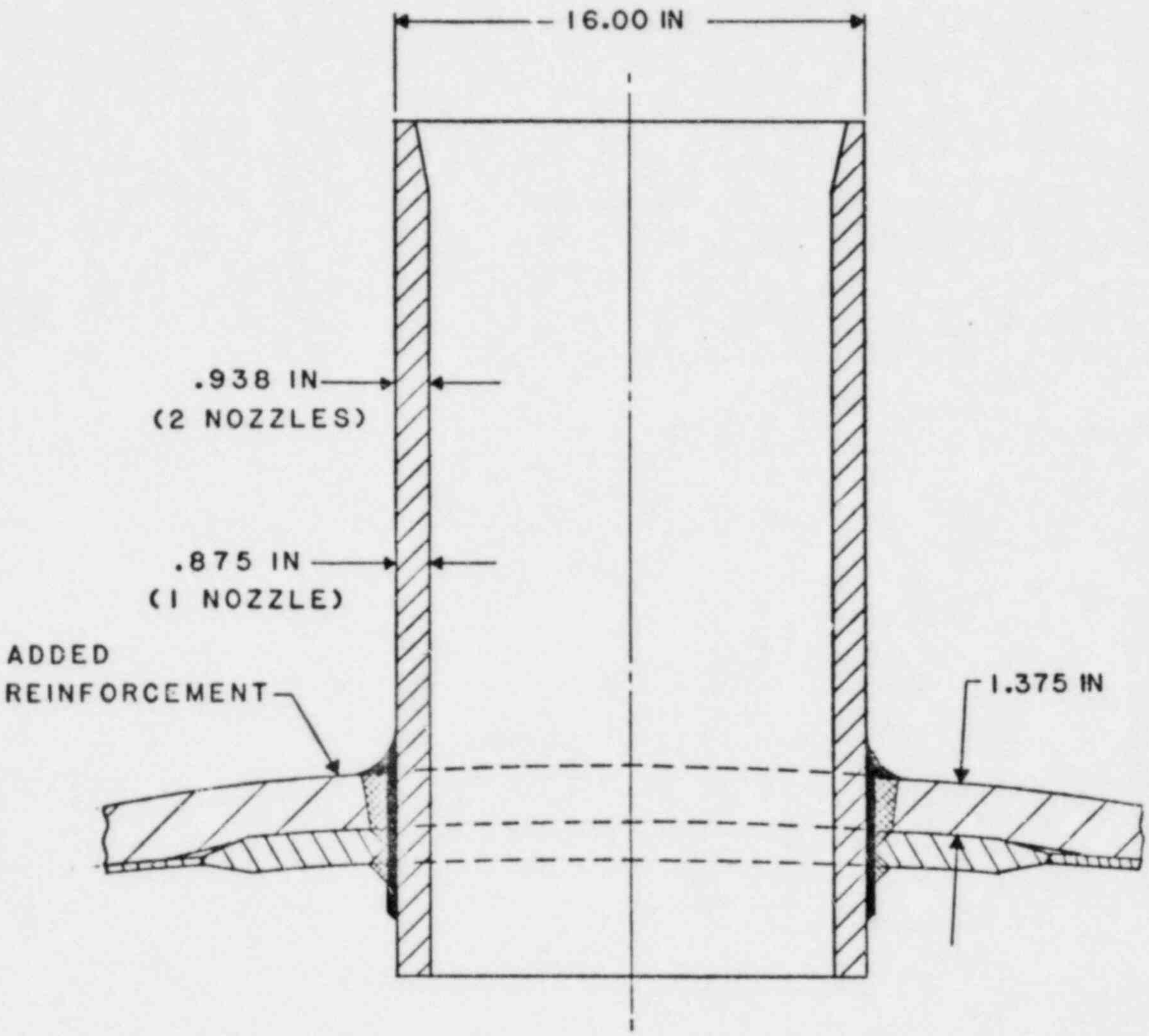

FIGURE 3.8-6

CORE SPRAY SUCTION HEADER PIPING PENETRATION

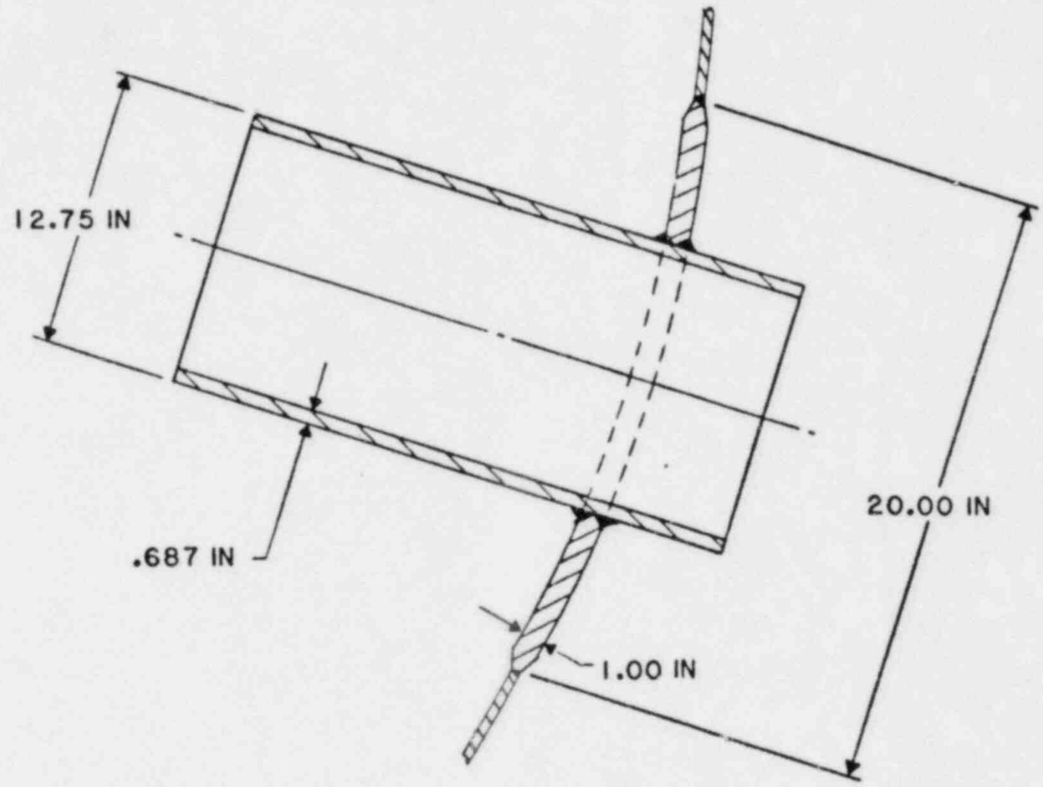

FIGURE 3.8-7

SRV DISCHARGE PIPING VENT PENETRATION

4.0 LOAD DEFINITIONS

Many diverse loads on the Oyster Creek containment and attached piping are considered in this Mark I Long-Term Program evaluation. The specific loads used are defined in this section. The response of the piping systems and related structures to each load has been analyzed; the results of these analyses are discussed in Sections 6.0 and 7.0.

The loads used in this evaluation are derived from the requirements of the LDR (Reference 8.2.1), the PULD (Reference 8.2.3), and NUREG-0661 (Reference 8.1.2). The sources of the load definitions vary. For example, in some cases, the loads are defined generically by GE in the LDR for all Mark I containments (e.g., chugging loads). Some loads are defined specifically for Oyster Creek in the PULD (e.g., pool swell loads). Some SRV discharge loads are based on data obtained during in-plant tests at Oyster Creek. In each case, the loads used comply with the requirements of NUREG-0661. For loads involving dynamic excitation of the torus shell, ring girder and vent header, acceleration response spectra were generated for each penetration and piping support attachment point. Section 5.0 of Reference 8.5.1 contains a discussion of the methods used to calculate these response spectra.

For purposes of this discussion, the loads have been divided into several groups which are covered below. Specifically,

- Original design loads.
- Loads on piping due to LOCA containment pressure and temperature.
- Loads on piping due to LOCA loads on the torus shell and vent system.
- LOCA loads on piping structures inside the torus.

- Safety relief valve induced loads on the SRV piping and piping structures inside the torus.

- Other normal operating condition loads.

The source of the load definition and any plant-unique considerations are identified below for each load. The requirements for combining these individual loads for purposes of structural assessment are described in Section 2.2 of this report.

In the description of the loads, the structures to which they have been directly applied are identified. The structural analyses of piping systems account for the effects of each load on any additional structures to which the loaded structure is attached. For example, piping systems attached to the torus and the vent system are analyzed considering the dynamic response of both the torus and the vent system to each applied load.

4.1 ORIGINAL DESIGN LOADS

The original design requirements for the Oyster Creek torus and vent system are contained in Burns and Roe Specification S-2299-4 (Reference 8.6.1) and the Oyster Creek FDSAR (Reference 8.3.1). The original design requirements for the piping systems attached to the torus and vent system are contained in the Oyster Creek FDSAR (Reference 8.3.1). These documents specified a number of design loads, however they did not address all the hydrodynamic loads which have been developed as part of the Mark I Containment Long-Term Program.

The specific loads specified in the Burns and Roe piping design specification which are applicable to the Mark I Containment Long-Term Program are the following:

- Dead load of structure.
- Dead load of water.
- Earthquake load.

The dead load and earthquake loads on the torus are as specified in the plant-unique analysis of the Oyster Creek torus and vent system (Reference 8.5.1). The dead load and seismic load on the containment result in movements of the torus and vent system piping penetrations and support attachment points. These movements are included in the analysis of each attached piping system.

For the torus attached piping, the seismic loads used for analysis were as specified in the original piping design specification as described in Reference 8.3.5.

4.2 LOADS ON PIPING DUE TO LOCA CONTAINMENT PRESSURE AND TEMPERATURE

The containment pressure and temperature response during a LOCA is described in Section 4.1 of the LDR (Reference 8.2.1). The pressures and temperatures used in this analysis for the accident conditions were obtained from the Oyster Creek PULD provided by GE (Reference 8.2.3). Since the Oyster Creek plant will operate with no differential pressure between the drywell and wetwell, the values used are those for the zero delta P conditions (0 psi between drywell and wetwell) as discussed below.

The curves of containment system pressure and temperature used were for the plant conditions resulting in the most severe loads. Specific values and references for these curves are contained in Section 4.2 of Reference 8.5.1. For load combinations, the pressure at the appropriate point in time in each LOCA was used. For example, pressures early in a DBA combine with pool swell loads while pressures late in a DBA combine with chugging loads. The timing of the various loads was based on the requirements in the LDR (Reference 8.2.1).

The LOCA pressure and temperature of the containment result in movements of the torus and vent system piping penetrations and support attachment points. These movements are included in the analysis of each attached piping system for the appropriate LOCA condition (DBA, IBA or SBA). For analysis of pressure and thermal expansion stresses in piping other than SRV discharge piping, the limiting values of containment LOCA pressure and temperature were applied in the stress analysis. For the SRV discharge piping, the maximum temperature and pressure corresponding to limiting relief valve discharge conditions were applied in the analysis. For some piping systems, for calculational convenience, a bounding value of pressure or temperature was used for all LOCA conditions.

4.3 LOADS ON PIPING INDUCED BY LOCA LOADS ON THE CONTAINMENT

During the course of a LOCA several types of loads are imposed on the containment which in turn induce dynamic excitations in the attached piping. These have been defined as pool swell, condensation oscillation, and chugging. Each of these phenomena is described in the LDR (Reference 8.2.1). The load definitions used in this analysis for each of these loads are described in the following sections.

4.3.1 Pool Swell

The pool swell loads occur as the result of a DBA. As explained in the LDR, the pool swell shell loads are defined for the Oyster Creek plant based on plant-unique tests. The resulting load definitions were provided by GE in the Oyster Creek PULD (Reference 8.2.3). The specific PULD data and the criteria used in defining the pool swell load used in this analysis are contained and referenced in Section 4.3.1 of the plant-unique analysis of the Oyster Creek torus and vent system (Reference 8.5.1).

A time history analysis technique was used to evaluate the response of the torus and vent header for the pool swell dynamic pressure histories. Based on the time history displacement results from these analyses, acceleration response spectra were computed for all piping penetrations and attachment points (shell, vent header and ring girder). The response spectra were peak broadened in accordance with the NRC Regulatory Guide 1.92 (Reference 8.1.3). Since pool swell impact loads on the vent header were found to have a significant effect on the torus response, analyses were performed to determine the effect o, these loads on the piping attached to the torus. Based on the results of these analyses, the pool swell loads were modified to include the effect of pool swell loads on the vent header.

4.3.2 Condensation Oscillation

Condensation oscillation (CO) loads on the torus shell occur during a DBA or IBA. The IBA(CO) loads are defined in the LDR (Reference 8.2.1) to be the same as pre-chug loads, which are discussed in Subsection 4.3.3. The DBA(CO) shell load definition and the development of the torus response to the DBA(CO) load are described in Section 4.3.2 of the plant-unique analysis of the Oyster Creek torus and vent system (Reference 8.5.1).

Response spectra were generated for all piping penetrations and attachment points (shell, ring girder and vent header) based on these torus responses. The response spectra were peak broadened in accordance with NRC Regulatory Guide 1.92 (Reference 8.1.3).

4.3.3 Chugging

Chugging loads on the torus shell occur during a DBA, IBA, or SBA when the steam flow rate through the downcomers falls below a certain critical rate. The chugging shell load definition and the development of the torus response used in this analysis is described in Section 4.3.3 of the plant-unique analysis of the Oyster Creek torus and vent system (Reference 8.5.1).

As described in the LDR, the chugging load definition is divided into a pre-chug load and a post-chug load. The pre-chug load is a single harmonic load which is required to be applied at the frequency in the range of 6.9 to 9.5 Hz which produces the maximum response. For Oyster Creek this frequency is 9.5 Hz.

The post-chug load definition and the development of the torus response to this load are described in Section 4.3.3 of Reference 8.5.1.

Based on the summed harmonic displacement results, acceleration response spectra for pre-chug and post-chug loads were computed for all piping penetrations and attachment points (shell, vent header and ring girder). The response spectra were peak broadened in accordance with NRC Regulatory Guide 1.92 (Reference 8.1.3).

The asymmetric pre-chugging shell load distribution specified in the LDR was used to obtain the net lateral load on the torus as discussed in Section 4.3.3 of Reference 8.5.1. The resulting displacement of the piping penetrations and attachment points due to this load were included in the piping analysis.

4.4 LOCA LOADS ON PIPING STRUCTURES INSIDE THE TORUS

During the course of a LOCA, several types of loads are imposed on the piping structures inside the torus. These are separated into pool swell loads and condensation oscillation and chugging loads. All of these loads are described in the LDR (Reference 8.2.1). The load definitions used in the analyses of Oyster Creek torus internal structures follow the LDR and NUREG-0661 (Reference 8.1.2). They are described in the following sections.

4.4.1 Pool Swell

Pool swell loads occur as the result of a DBA. The LDR (Reference 8.2.1) subdivides pool swell loads on internal structures into pool swell impact and drag, froth impingement (Regions I and II), fallback, LOCA jet and LOCA bubble drag loads. The methodology for defining these pool swell loads is defined generically for the Mark I Containment Long-Term Program in the LDR (Reference 8.2.1). This methodology uses as input plant-unique data from the Oyster Creek PULD (Reference 8.2.3). The PULD data used in this methodology were for two plant conditions: (i) maximum downcomer submergence (4.06 feet); and (ii) minimum downcomer submergence (3.0 feet). Both conditions were evaluated assuming no differential pressure between wetwell and drywell.

The maximum submergence case results in the highest loads for Region II froth impingement, fallback, LOCA jet and LOCA bubble drag. The minimum submergence case results in maximum pool swell impact and drag and Region I froth impingement loads. Peak pool swell loads on piping structures inside the torus are summarized in Table 4.5.1-1 of the Oyster Creek plant-unique analysis of the torus and vent system (Reference 8.5.1).

4.4.2 Condensation Oscillation and Chugging

During condensation oscillation and chugging, the oscillation and collapse of steam bubbles at the exits of the downcomers induce velocity and acceleration fields in the torus pool. These result in fluid drag loads on internal structures submerged in the pool. The LDR (Reference 8.2.1) establishes generic methodology for defining condensation oscillation and chugging drag loads on submerged internal structures. The LDR subdivides this load definition into a condensation oscillation load and two chugging loads based on the two distinct chugging phenomena observed during full-scale testing. The chugging loads are designated as the pre-chug and the post-chug loads.

Drag loads are defined as discussed in Section 4.5.2 of Reference 8.5.1 for the following internal piping and structures in the Oyster Creek torus in accordance with the procedures in the LDR and NUREG-0661:

- SRV line and spargers
- Demineralizer discharge line
- Core spray suction header nozzles and strainers
- Containment spray test return piping

A separate drag load is defined for each of the following cases:

- Condensation oscillation
- Pre-chug
- Post-chug

For each case, the drag load-time history is expressed as two distinct Fourier series. One Fourier series represents load caused by velocity and acceleration fields resulting directly from steam bubble oscillation. The other Fourier series represents loadings caused by the velocity and acceleration fields resulting from torus fluid-structure interaction (FSI).

Each Fourier series load is defined as a set of vector loads on sections of the submerged internal structures for a unit bubble source strength oscillation independent of frequency along with a table of bubble source strengths as a function of frequency. The response of the piping to each load was calculated and summed to obtain the total response. The individual frequency responses were summed using LDR phasing, an absolute summation method, except for DBA condensation oscillation. For DBA condensation oscillation this summation was performed using a random phasing methodology which was developed generically for the Mark I owners. This summation was verified by demonstrating that it bounded the test data from the Full-Scale Test Facility (FSTF). Specifically, the summation procedure involves adding the individual harmonic responses assuming random phase angles and multiplying the results by 1.15.

4.5 SAFETY RELIEF VALVE INDUCED LOADS

Oyster Creek is equipped with five safety relief valves (SRVs) to provide overpressure protection and automatic depressurization for the primary system. The SRVs are mounted on the main steam lines inside the drywell, with discharge pipes routed into the suppression pool in the torus. Two discharge pipes are installed; three valves discharge into the south discharge pipe, and two discharge into the north discharge pipe. Each discharge pipe terminates in a quencher device under the water in the torus. These quenchers are in a "Y" configuration and were installed and successfully tested in 1977 (Reference 8.3.4).

When an SRV is actuated, steam from the primary system is discharged through the discharge line and quencher into the torus water where it is condensed. The water initially in the quencher is discharged first, followed by the air from the discharge line, and then the steam. The definition of the loads which result from this SRV discharge transient at Oyster Creek is discussed in Section 4.6 of Reference 8.5.1. These loads are used in the structural evaluation of the torus, its supports and internal structures, and attached piping systems.

The discharge thrust and Y-quencher loads on the SRV discharge piping are applied directly to the piping system. The response of the shell ring girder and vent header to the SRV loads is used to define the excitation loads which are transmitted to the piping through the various piping penetrations, nozzles and attachment points.

The definitions of the loads caused by the various SRV discharge transients are discussed in the sections below.

4.5.1 SRV Discharge Loads on the SRV Discharge Piping

SRV discharge loads on the SRV discharge piping are caused by transient and steady-state steam and water thrust loads. These loads are calculated for Oyster Creek using the procedures in the LDR (Reference 8.2.1) in accordance with NUREG-0661 (Reference 8.1.2).

Section 4.6.1.1 of Reference 8.5.1 covers the method used to analyze the thrust loads on the Oyster Creek SRV discharge piping caused by both transient and steady-state steam flow during an SRV actuation. Actuation of an SRV causes the discharge piping to pressurize rapidly. As the pressure increases, the water slug in the bottom of the discharge line is accelerated until the slug is completely expelled from the pipe. The acceleration and redirection of the water slug as it is cleared causes transient thrust loads on the bottom of the discharge line and the discharge device. Section 4.6.1.2 of Reference 8.5.1 discusses the method of analysis used to define the water thrust loads on the Oyster Creek SRV discharge device caused by transient water slug clearing. It also summarizes the results of the analysis.

4.5.2 SRV Discharge Loads on the Torus Shell

The definition of shell loads due to SRV discharge was performed in accordance with the LDR (Reference 8.2.1) and NUREG-0661 (Reference 8.1.2). Since Oyster Creek uses a Y-quencher SRV discharge device instead of a standard T-quencher, in-plant tests were used to define shell loads. This is in accordance with the requirements of NUREG-0661 for non-standard quenchers. The Y-quencher design and in-plant test results are described in the report forwarded to the NRC by Reference 8.3.4.

The approach which was used in the analysis of the shell loads and the results of the analysis are described in Section 4.6.2 of Reference 8.5.1.

The response spectra and deflections resulting from the SRV design case transients were calculated as described in Section 5.0 of Reference 8.5.1. These responses account for the torus response to the pressure time history on the shell and the net lateral load on the overall torus structure. The torus response (response spectrum and deflection) was calculated for each piping penetration and support attachment point on the torus and vent header for use in the piping analyses.

4.5.3 SRV Discharge Loads on Piping Structures Inside the Torus

Loads on torus internal structures resulting from SRV discharge are caused by water jet impingement and SRV bubble drag. Plant-unique loads for Oyster Creek internal structures were calculated in accordance with the procedures assumptions and conditions specified in the LDR (Reference 8.2.1) and NUREG-0661 (Reference 8.1.2) as described in Section 4.6.3 of Reference 8.5.1.

4.6 DEMINERALIZER RELIEF VALVE DISCHARGE LOAD

The demineralizer relief valve discharge piping experiences an internal load transient due to discharge flow in the line when the pressure relief valve in the cleanup demineralizer system lifts. Under normal operating conditions, the valve discharges subcooled liquid with only a trace of vapor with a maximum discharge velocity of 3.7 feet per second. The quantity of discharge is limited because the pressure relief valve closes rapidly after reducing the cleanup demineralizer system pressure. The low energy and volume connected with a discharge transient under normal operating conditions results in negligible loads on the piping.

A faulted condition was postulated for the cleanup demineralizer system to maximize the discharge loading on the piping. The postulated condition requires concurrent failure of the cleanup system isolation valves and either trip of the cleanup pumps or failure of the flow control valve. To achieve maximum loading on the pipe, it is assumed that a water slug, rising past the check valve in the line to a height corresponding to full vacuum, must be expelled from the line by the discharging fluid.

This postulated faulted condition results in a maximum fluid discharge velocity of 19.7 feet per second. The water slug is discharged from the line 6.6 seconds after pressure relief valve lift at the maximum discharge pressure of 14.7 psia. The volume of liquid discharged is small and exits the discharge tee parallel to the torus within the torus pressure-suppression pool. This produces negligible discharge loads on adjacent structures.

4.7 CONTAINMENT SPRAY DISCHARGE LOAD

The containment spray and test return piping experiences internal loadings due to the operation of either of the containment headers or the test return piping. These loadings, due to thrust from changes in flow direction, are in addition to the internal pressure loading on the piping. All loads resulting from transient discharge flow conditions, which occur while starting system operation, are less limiting than the steady-state discharge flow loads.

The containment spray system is designed to operate subsequent to a design basis LOCA. Under steady-state discharge conditions, the torus spray header and supply piping portions of the containment spray system discharge 300 gallons per minute. This flow produces negligible piping stresses, less than 5 psi. Therefore, the torus spray header discharge loads were not included in the DBA load combinations, Load Combinations II and III in Table 2.2-1 of this report.

Test return piping discharge occurs whenever the containment spray system pumps are tested. Operation of both pumps simultaneously will produce a discharge flow of 4,400 gallons per minute. This produces significant thrust forces at the elbows in the test return piping. The maximum thrust force, which is directed along the axis of the piping, is 1,300 pounds. The test return piping discharge loading can occur during any load event when the torus spray header is not operating. Therefore, the test return piping discharge loads were included in the non-DBA load combinations, Load Combinations I, IV and V.

5.0 GENERAL ANALYTICAL PROCEDURES

This section describes the general analytical procedures used in the analysis of the Oyster Creek torus attached piping and nozzles. The procedures are described for attached piping in Section 5.1, for nozzles in Sections 5.2 and 5.3, and for nozzle transitions in Section 5.4. These procedures were developed consistent with the analysis guidelines of the PUAAG (Reference 8.2.2) and conform to the requirements of NUREG-0661 (Reference 8.1.2).

5.1 PIPING ANALYSIS METHODS

The analysis methods used in the analysis of the torus attached piping were developed so that all significant responses of the piping due to SRV and LOCA-induced loads would be considered. The specific analysis approach for each piping system and each load was selected based on consideration of the loading, the system complexity, the diameter, and the degree to which the piping could induce loads in other containment structures such as the vent header, ring girder and the torus nozzles.

The ANSYS engineering analysis system computer code (Reference 8.7.3) was used for all torus attached piping computer analyses. This code is a large-scale, general purpose computer code employing the finite element technique for the solution of several classes of engineering analysis problems. The code capabilities include both static and dynamic structural analyses. The program has other capabilities which are not required for the torus attached piping analyses. The matr displacement method of analysis is employed throughout the ANSYS code. The piping system to be analyzed is mathematically modeled as a system of nodal points, interconnected by various finite elements. Element masses and rotational inertias are represented with a consistent mass matrix which is a more refined representation than the traditional lumped mass approach. For piping with segments submerged in the suppression pool, additional water mass was included in the element mass to account for the hydrodynamic mass of the displaced water wherever the effect was significant. The degrees of freedom were selected to properly represent the dynamic response of the piping. The interconnected elements were assigned stiffnesses equivalent to that of the actual structure.

Several types of analyses were used in the analysis of the torus attached piping. These include the following:

- <u>Static</u> -- used to solve for the displacements, stress resultants and forces in piping for statically (or quasi-statically) applied loads; or dynamic loads that could be treated statically as discussed below.

- <u>Response Spectrum Analysis</u> -- used to solve for the displacements, stress resultants and forces in piping for loads which were defined as a response spectrum. The frequencies, mode shapes and mode participation factors characterizing the piping were determined as part of the solution.

- <u>Harmonic Analysis</u> -- used to determine the steady-state solution of a linear elastic system under a set of harmonic loads of known amplitude and frequency. Complex displacements were output Stresses were calculated at specified frequencies and phase angles. The maximum stresses over an interval were calculated using a post processing routine.

- <u>Reduced Linear Dynamic Analysis</u> -- used to determine the time history solution of the displacement and stress resultant responses of the piping to a time-dependent forcing function.

Static analyses were used to evaluate piping responses to deadweight, thermal, expansion and other static loads.

Response spectrum analysis was used to evaluate piping responses due to torus motions induced by LOCA and SRV discharge. Time history and harmonic analysis methods were used to evaluate piping responses due to SRV thrust loads and pool swell fluid loads (impact, drag, underwater bubble drag) on the SRV discharge line.

When calculating the response in piping systems due to dynamic loadings, account was taken of the effect of the damping characteristics of the piping systems. The guidelines provided in NUREG-0661 (Reference 8.1.2) were used to select the appropriate level of damping for each piping system. The guidelines which are contained in Reference 8.1.2 specify the use of Regulatory Guide 1.61 (Reference 8.1.4) for selecting the damping ratios. Reference 8.1.4 relates the damping ratio to be used in dynamic analyses to the stress level in the piping and the diameter of the piping. The specific damping values applied for the torus dynamic loading due to the various events were related to the nomenclature of Reference 8.1.4 as follows:

Loading Specified (Reference 8.1.4)	Corresponding Mark I Loading
OBE	NOC, IBA, SBA
SSE	DBA

A uniform level of damping was used over the length of each piping system.

Interaction between the piping and the torus was modeled by analyzing the torus on a "clean shell" basis (i.e., without restraint from the piping) and then applying the resulting displacement and acceleration loadings to the piping through analytical models of the nozzles. These models were stiffness matrices calculated from the individual geometry properties of each torus nozzle. Section 5.2 covers the methods used to determine the nozzle stiffness matrices.

When the piping evaluation indicated that a piping or piping support modification was required, the effect on the piping analysis was evaluated. When the modification had a significant effect on the piping dynamic response, such as a nozzle reinforcement, the modification was incorporated and the model was reanalyzed. For modifications which did not have a significant effect on the piping dynamic response, such as branch reinforcements, only the affected ASME Code analysis equations were reevaluated. The results reported in Section 6.0 reflect the final modified configuration of the piping and piping supports.

The torus attached piping analysis was done in accordance with ASME Code, Section III, Paragraph NC-3650 (Reference 8.4.1) for three load categories: M_A-sustained loads, M_B-occasional loads and M_C-thermal and anchor motion loads. For the torus attached piping, the only sustained load (M_A) is pipe deadweight. All other piping loads were classified as either M_B or M_C as appropriate.

Small diameter piping (4-inch diameter and less), branch piping (piping connected to other torus attached piping) and the core spray suction strainers were analyzed using hand methods. For hand analyses, classical mechanics methods were used to determine the stress resultants and displacements for each piping system. For piping analyzed with hand analyses, dynamic effects were accounted for through the use of applicable response spectra which were generated for each shell acceleration loading or by dynamic load factors which were determined based on the frequencies of each loading and the natural periods of the piping system or structure. For loads which have very short duration, dynamic load factors were determined based on the duration of the load, the time-dependent shape of the loading function and the natural period of the structure.

5.2 NOZZLE STIFFNESSES AND STRESS FACTORS

Nozzle stresses were calculated using the classical methods of Bijlaard, described in References 8.7.4 through 8.7.6. Because the Oyster Creek torus radius-to-wall-thickness ratio is large, Bijlaard stress factors were calculated using Bijlaard's original equations rather than using the pre-calculated factors in WRC Bulletin 107 (Reference 8.7.7).

The nozzle stiffness and stress factors were calculated for radial loads and overturning moments per the methods of Reference 8.7.4. Shell and nozzle geometries, including shell wall thickness and internal pressure as accounted for in this analysis. These stiffnesses were used in the torus attached piping analyses.

5.3 NOZZLE ANALYSIS METHODS

Stresses in the torus shell and reinforcing pads adjacent to nozzles and penetrations were calculated using the Bijlaard analysis method described in Reference 8.7.7. Bijlaard stress coefficients were obtained from separate calculations described in Section 5.2, above. The analysis work proceeded as follows:

a. Piping reactions for the load combinations discussed in Section 2.2.2 of this report were rotated into the local nozzle coordinate system specified in Reference 8.7.7.

b. Stresses were calculated at four representative locations around the nozzle using the stress coefficients. These stresses included the effects of internal pressure.

c. Principle stresses and stress intensities were calculated at the four locations. Both membrane and membrane plus bending stress categories were computed.

d. The maximum membrane stress intensity and membrane plus bending stress intensity range were calculated and reported. Maximum values were determined by considering all possible combinations of static plus or minus dynamic loads for each component of force or moment; as a consequence, sixty-four Bijlaard analyses (six force and moment components each with two possible signs of the dynamic load) were performed for each load combination in order to determine the maximum stress intensity value.

Stress intensities that exist in the torus shell without consideration of the attached piping were determined in the vicinity of each nozzle for each load combination. These "clean shell" stress intensities were determined from the finite element analysis of the torus shell, as described in Section 5.0 of Reference 8.5.1. The total stress intensity adjacent to each nozzle was determined by summing the Bijlaard stress intensity with the clean shell stress intensity. This total was compared to ASME Code allowables. A summary of the stress results for each nozzle is given in Section 6.8.

5.4 NOZZLE TRANSITION ANALYSIS METHODS

Stresses in the nozzle or piping wall adjacent to the torus or vent line were determined using equations of classical mechanics for a pressurized cylinder with one end clamped. For nozzles, the loads and load combinations were the same as for the Bijlaard analysis of the torus shell near the nozzle described in Section 5.3 above. For penetrations where piping passes through the torus wall and continues, reaction loads for the transition region were determined from the stress resultants in the pipe element adjacent to the torus intersection. Load combinations, however, were the same as for nozzles where piping does not pass through the wall. Membrane, bending and shear stresses were computed and added in the most conservative possible fashion. Stress intensities computed in this manner included secondary and local effects, but both were classified as primary membrane stress intensities per the requirements of the ASME Code, Section III, Paragraph NE-3227.5 (Reference 8.4.1). A summary of the stress results for each nozzle and penetration is given in Section 6.8.

6.0 ANALYSIS RESULTS

The sections which follow contain summaries of the evaluations performed on all torus attached piping systems and the core spray suction strainers. Both the calculated maximum and the allowable piping stresses are tabulated for each system for each of the limiting Mark I Containment Long-Term Program load cases as listed in Table 2.2-1 of this report. The maximum calculated hanger stresses and the results of the active component evaluation are given as well. All piping systems were found to satisfy the Mark I Containment Long-Term Program design criteria. Several systems require modifications as discussed below. The analysis results reported in the sections which follow correspond to the piping system arrangements with required modifications installed. These modifications will be installed as part of the Mark I Containment Long-Term Program. The evaluation of the nozzle in the vent system for the safety relief valve piping penetration has not been completed. The results of this evaluation will be forwarded separately.

6.1 VACUUM RELIEF PIPING

The vacuum relief piping was analyzed for the five limiting load cases shown in Table 2.2-1 of this report. The stresses resulting from these cases are required to meet essential piping allowable stresses as listed in Table 2.2-1. These stress levels apply to the occasional load (ASME Equation 9) allowable stresses. The thermal and sustained load (ASME Equation 10) allowable stresses are determined in accordance with Section NC-3611.2 of Reference 8.4.1. For Load Case V, a stress range reduction factor of 0.9 is applied since the number of response cycles for the post-chug load included in this combination could be up to 14,000 cycles.

The limiting piping stresses resulting from analysis of all five load cases have been determined for the vacuum relief piping. The results in Tables 6.1-1 and 6.1-2 contain stresses for all four vacuum relief piping assembly models and are representative of results for all eight vacuum relief piping systems. All stresses are within the required allowable limits. The maximum calculated occasional load piping stress required to meet the 18,000 psi Level B allowable stress is 7,100 psi, 39% of the allowable stress. The maximum calculated occasional load piping stress for the 27,000 psi Level B(3) allowable stress is 26,600 psi, 99% of the allowable stress. The maximum calculated occasional load piping stress for the 36,000 psi Level B(4) allowable stress is 36,000 which is at the allowable stress. The maximum calculated thermal and sustained load piping stress of 18,400 psi is 82% of the allowable stress. The SBA post-chug thermal and sustained load case (Load Case V), is required to meet a reduced allowable due to the number of effective cycles (up to 14,000). The maximum calculated piping stress for this thermal and sustained load case is 26,400 psi, 75% of the allowable stress. A more complete summary of the limiting stress values for this piping is contained in Tables 6.1-1 and 6.1-2.

The support and hanger stresses for the vacuum relief piping are all required to meet the allowable stresses specified in ASME B&PV Code, Subsection NF (Reference 8.4.1). All support and hanger stresses are within these requirements except for one hanger on the reactor building-to-torus vacuum relief piping which is being modified to meet these requirements. The maximum calculated support stress is 17,400 psi, 81% of the allowable stress. The maximum calculated hanger load is 3,300 pounds, 92% of the allowable load specified by the hanger manufacturer. Supports which are secured with concrete expansion anchors were analyzed and found to be acceptable based on the criteria of ACI 349-76 (Reference 8.7.8).

The stresses resulting from each of the applicable torus nozzle reaction combinations have been tabulated and compared with the allowable stress corresponding to each applicable service limit as described in Section 6.8.

The vacuum relief piping contains four types of active components: 20-inch gate valves, 12-inch butterfly gate valves, 18-inch swing check valves, and 20-inch swing check valves. To satisfy the operability requirements for active components as specified by the PUAAG (Reference 8.2.2), the stresses at the valves must meet Level A/B allowables, 18,000 psi. The maximum calculated stress at the most limiting gate valve is 7,300 psi, 41% of the allowable stress The maximum calculated stress at the most limiting check valve is 7,500 psi, 42% of the allowable stress. Therefore, the active components satisfy all operability requirements.

TABLE 6.1-1

SUMMARY OF MAXIMUM AND ALLOWABLE STRESSES
VACUUM RELIEF PIPING
AT AZIMUTHS 0°, 72°, 108°, 252° AND 288°

OCCASIONAL LOADING STRESSES - ASME EQUATION (9)					
	Vacuum Relief Piping at Azimuths 72°, 108°, 252° and 288°		Vacuum Relief Piping at Azimuth 0°		
LOAD CASE (Note 1)	Maximum Stress (ksi)	Location(Note 2)	Maximum Stress (ksi)	Location(Note 3)	Allowable Stress (ksi)
Ia	5.5	Cross A	7.1	Tee C	18.0
Ib	14.5	Cross A	12.5	Cross B	27.0
II	27.6	Cross A	28.9	Cross B	36.0
III	36.0	Cross A	35.6	Cross B	36.0
IVa	14.3	Cross A	9.5	Tee C	27.0
IVb	22.7	Cross A	15.2	Cross B	36.0
Va	26.6	Cross A	21.8	Cross B	27.0
Vb	35.7	Cross A	29.4	Cross B	36.0

THERMAL AND SUSTAINED LOADING STRESSES - ASME EQUATION (10)					
	Vacuum Relief Piping at Azimuths 72°, 108°, 252° and 288°		Vacuum Relief Piping at Azimuth 0°		
LOAD CASE (Note 1)	Maximum Stress (ksi)	Location(Note 2)	Maximum Stress (ksi)	Location(Note 3)	Allowable Stress (ksi)
I	7.2	Cross A	7.6	Cross B	22.50
II & III	10.6	Cross A	11.0	Cross B	22.50
IV & V	9.2	Cross A	9.6	Cross B	20.25

NOTES:

1. Load cases defined in Table 2.2-1.
2. Maximum stress locations defined in Figure 6.1-1.
3. Maximum stress locations defined in Figure 6.1-2.

TABLE 6.1-2

SUMMARY OF MAXIMUM AND ALLOWABLE STRESSES
VACUUM RELIEF PIPING AT AZIMUTHS 144°, 216° AND 180°

OCCASIONAL LOADING STRESSES - ASME EQUATION (9)					
	Vacuum Relief Piping at Azimuths 144° and 216°		Vacuum Relief Piping Reactor Building-to-Torus, Azimuth 180°		
LOAD CASE (Note 1)	Maximum Stress (ksi)	Location(Note 2)	Maximum Stress (ksi)	Location(Note 3)	Allowable Stress (ksi)
Ia	7.0	Cross D	2.4	Elbow G	18.0
Ib	13.7	Cross D	3.6	Elbow F	27.0
II	22.5	Cross D	5.8	Elbow F	36.0
III	25.6	Cross D	8.5	Elbow G	36.0
IVa	16.3	Cross D	3.2	Elbow F	27.0
IVb	22.7	Cross D	4.4	Elbow F	36.0
Va	24.1	Cross D	5.1	Elbow F	27.0
Vb	30.8	Cross D	6.1	Elbow F	36.0

THERMAL AND SUSTAINED LOADING STRESSES - ASME EQUATION (10)					
	Vacuum Relief Piping at Azimuths 144° and 216°		Vacuum Relief Piping Reactor Building-to-Torus, Azimuth 180°		
LOAD CASE (Note 1)	Maximum Stress (ksi)	Location(Note 2)	Maximum Stress (ksi)	Location(Note 3)	Allowable Stress (ksi)
I	6.5	Cross D	16.6	Tee E	22.5
II & III	9.5	Cross D	18.4	Tee E	22.5
IV & V	8.3	Cross D	--	--	20.3
	--	--	26.4 (Note 4)	Tee E	35.3

NOTES:

1. Load cases defined in Table 2.2-1.

2. Maximum stress locations defined in Figure 6.1-3.

3. Maximum stress locations defined in Figure 6.1-4.

4. Case IV and V evaluated in accordance with ASME Equation (11) for reactor building-to-torus vacuum relief piping.

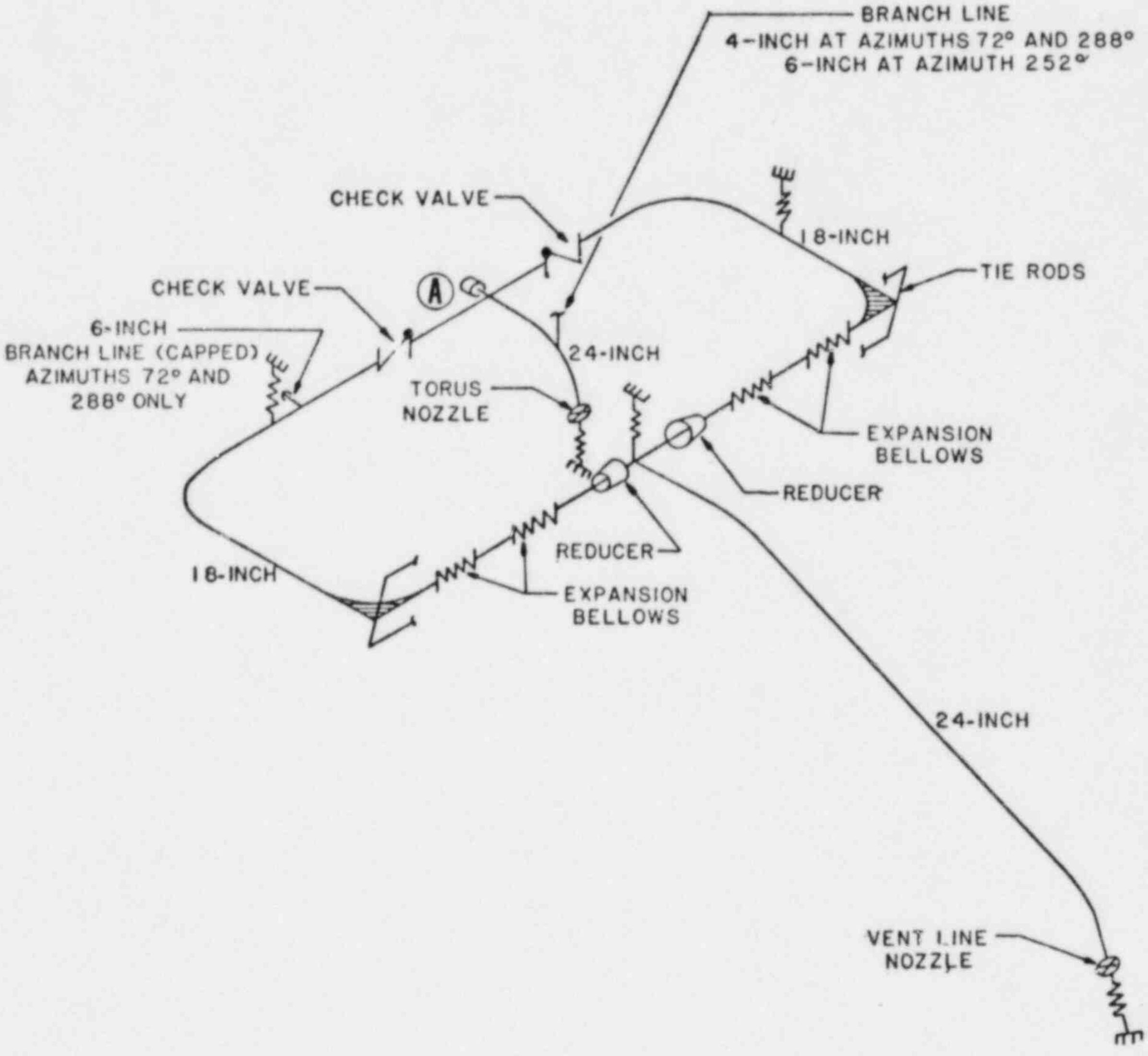

FIGURE 6.1-1
LIMITING STRESS LOCATIONS
VACUUM RELIEF PIPING
AT AZIMUTHS 72°, 108°, 252°, AND 288°

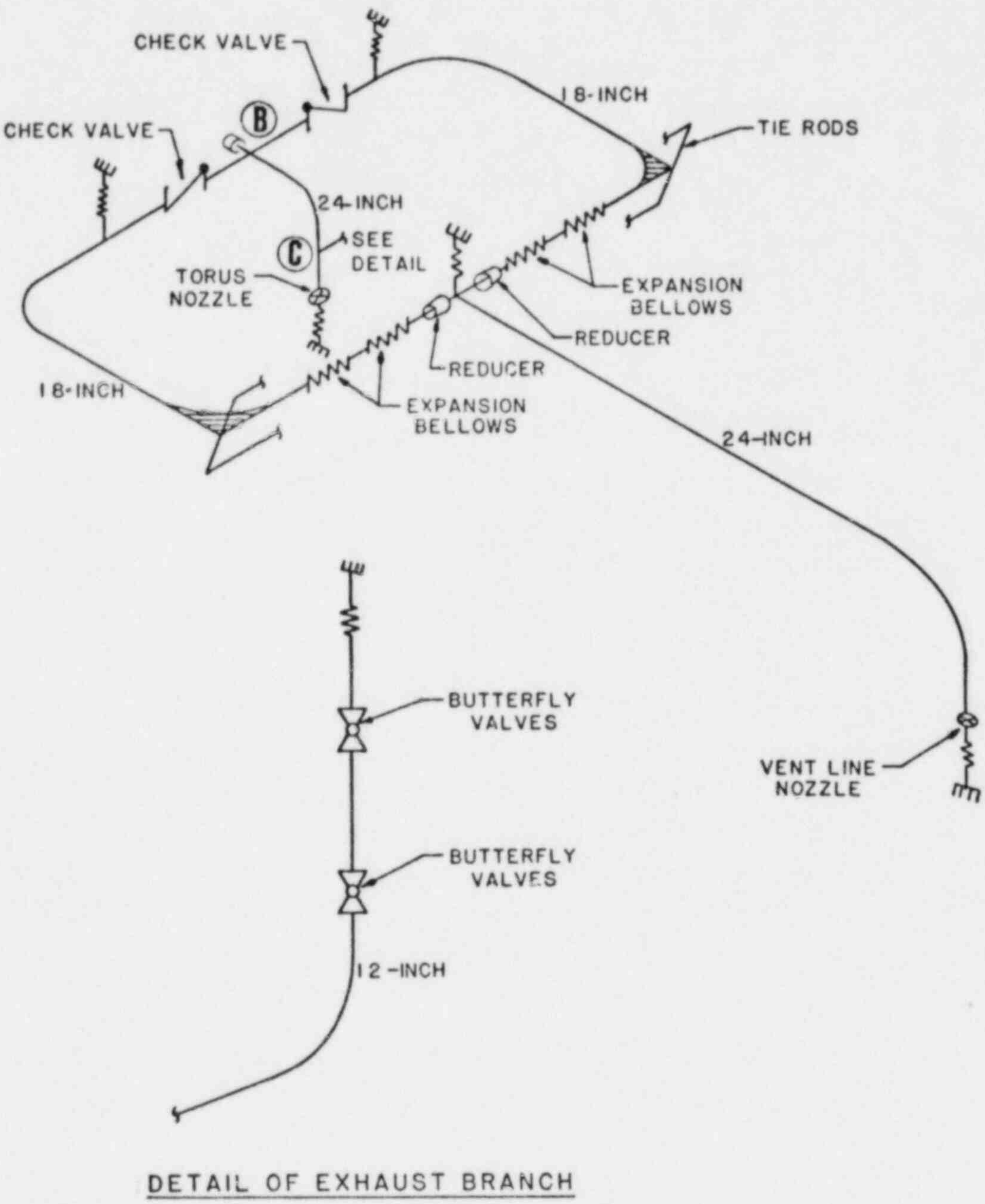

FIGURE 6.1-2
LIMITING STRESS LOCATIONS
VACUUM RELIEF PIPING
AT AZIMUTH 0°

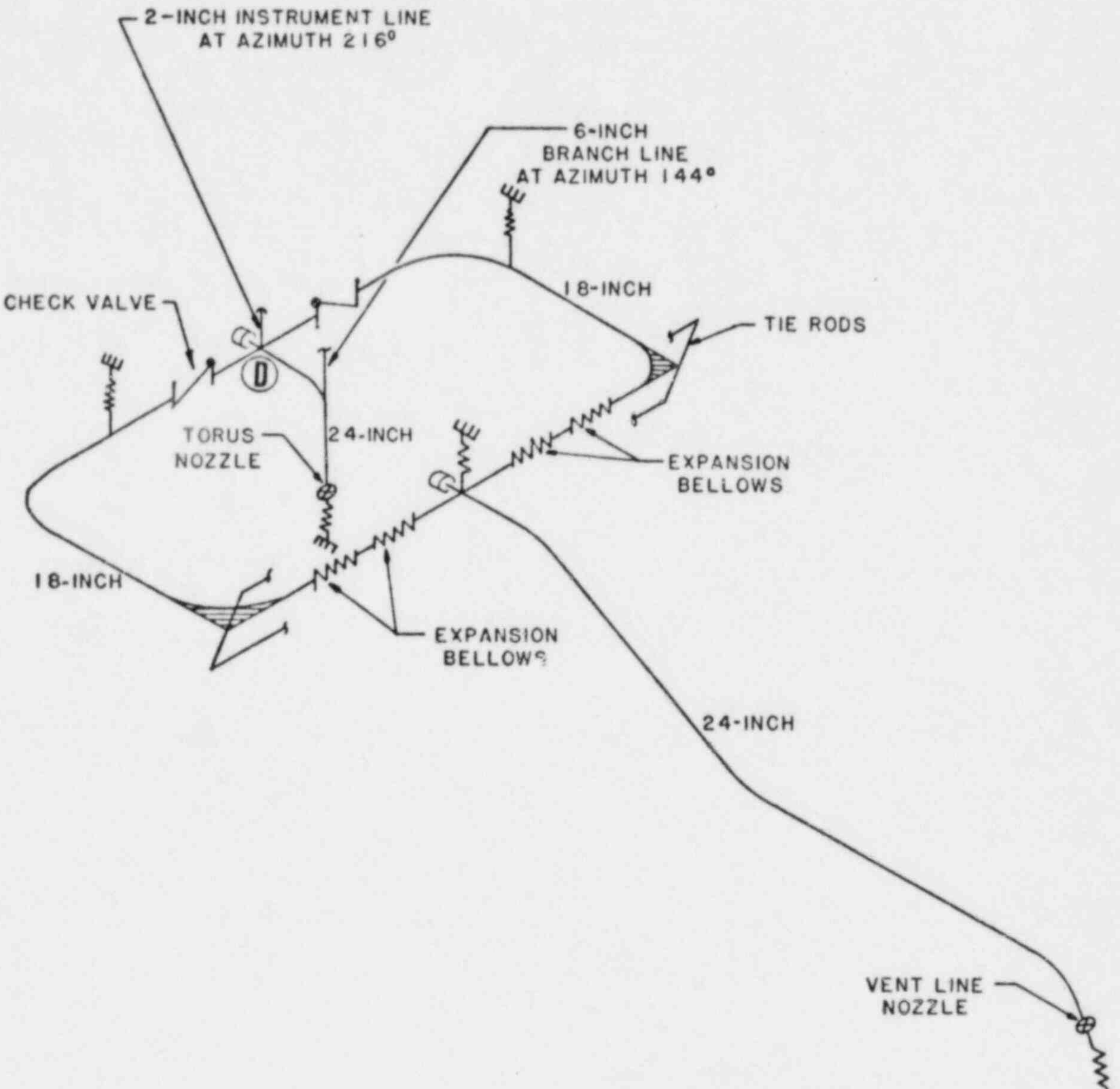

FIGURE 6.1-3
LIMITING STRESS LOCATIONS
VACUUM RELIEF PIPING
AT AZIMUTHS 144° AND 216°

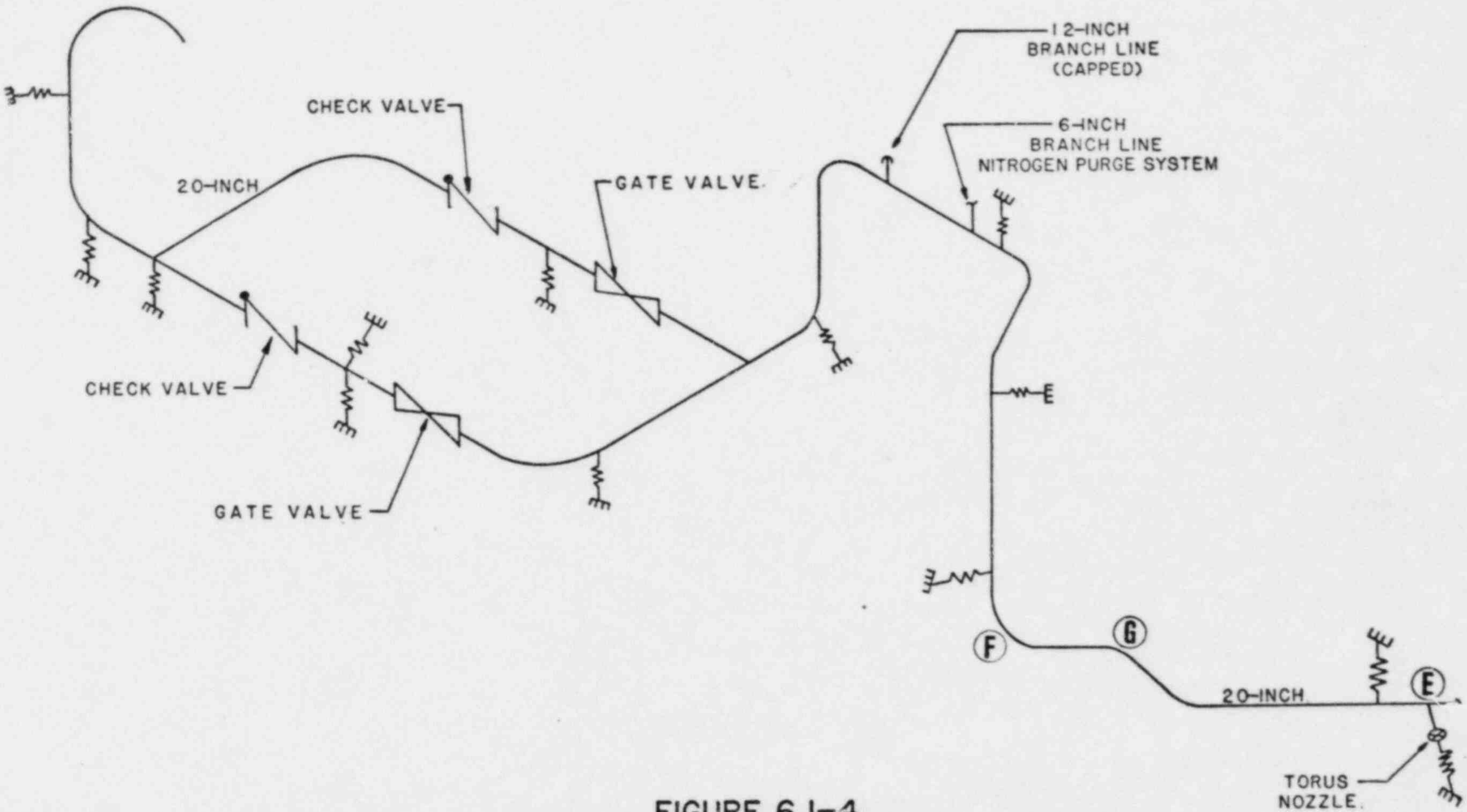

FIGURE 6.1-4

LIMITING STRESS LOCATIONS
REACTOR BUILDING-TO-TORUS
VACUUM RELIEF PIPING

6.2 DEMINERALIZER RELIEF VALVE DISCHARGE PIPING

The demineralizer relief valve discharge piping was analyzed for all five limiting load cases shown in Table 2.2-1 of this report. The resulting stresses are required to meet the nonessential piping allowable stresses as listed in Table 2.2-1. The line was also analyzed for a sixth load case involving the relief valve discharge load under faulted conditions described in Section 4.6. This load case, using the nomenclature of Table 2.2-1 is defined as:

$$N + \text{Discharge} + EQ(S)$$

For this load case, the occasional load (ASME Equation 9) piping stresses are required to meet Level B allowable stresses. The thermal and anchor motion load (ASME Equation 10) allowable stresses are determined without a stress range reduction, due to the low number of these events.

As described in Section 3.2, the in-torus section of this piping required modification to withstand Mark I loadings. This modification, which was completed in July 1980, consisted of rerouting the piping to run adjacent to a torus ring girder and adding two supports. Also, the preload settings in the spring hangers are being adjusted to more evenly distribute the deadweight stresses on the piping.

The limiting piping stresses resulting from analysis of all six load cases have been determined for the demineralizer relief valve discharge piping as modified. All stresses are within the required allowables. The maximum calculated occasional load piping stress required to meet the 18,000 psi Level B allowable stress is 6300 psi, 35% of the allowable stress. The maximum calculated occasional load piping stress for the 27,000 psi Level C(5) allowable stress is 27,100, which is less than 1% over the allowable stress. However, if the load cases which are bounded by Load Case IV are considered individually, all allowable stress limits are satisfied. The maximum calculated occasional load piping stress for the 36,000 psi Level D(5) allowable stress is 24,200 psi, 67% of the allowable stress. The maximum calculated thermal and sustained load piping stress for ASME Equation (10) of 13,800 psi is 61% of the allowable stress. The maximum calculated thermal and sustained load piping stress for ASME Equation (11) of 24,700 psi is 66% of the allowable stress. The SBA post-chug thermal and sustained load case (Load Case V) is required to meet a stress range reduced allowable stress, due to the large number of effective cycles (up to 14,000). The maximum piping stress calculated using ASME Equation (10) of 10,000 psi is 49% of this allowable. A more complete summary of the limiting stress values for this line is contained in Table 6.2-1.

The support and hanger stresses for the demineralizer relief valve discharge piping are all required to meet the allowable stresses specified in the ASME Code Section NF (Reference 8.4.1). All support and hanger stresses are within these requirements except for one support which is being modified to meet these requirements. For the remaining supports, the maximum calculated support stress is 22,800 psi, 56% of the allowable stress. The maximum calculated hanger load is 3500 pounds, 66% of the allowable load specified by the hanger manufacturer. Supports which are secured with concrete expansion anchors were analyzed and found to be acceptable based on the criteria of ACI 349-76 (Reference 8.7.8).

The stresses resulting from each of the applicable torus nozzle reaction combinations have been tabulated and compared with the allowable stress corresponding to each applicable service limit as described in Section 6.8.

The demineralizer relief valve discharge piping contains no active components. The piping line has one check valve, which is not required to perform a mechanical function to maintain containment integrity. Accordingly, there are no operability requirements for this valve. The valve is normally closed and no discharge which might open it can occur during any accident. The check valve is analyzed as piping and meets all the piping allowable stress requirements.

TABLE 6.2-1

SUMMARY OF MAXIMUM AND ALLOWABLE STRESSES

DEMINERALIZER RELIEF VALVE DISCHARGE PIPING

OCCASIONAL LOADING STRESSES - ASME EQUATION (9)					
	In-Torus		Out-of-Torus		
LOAD CASE (Note 3)	Maximum Stress (ksi)	Location(Note 4)	Maximum Stress (ksi)	Location(Note 4)	Allowable Stress (ksi)
I	4.5	Elbow A	6.3	Elbow C	18.0
II	21.4	Elbow A	22.2	Elbow C	36.0
III	24.2	Elbow A	18.4	Elbow C	36.0
IV	27.1(Note 1)	Elbow B	14.9	Elbow C	27.0
V	17.9	Elbow A	15.5	Elbow C	27.0
Discharge	2.3	Elbow A	4.0	Elbow E	18.0

THERMAL AND SUSTAINED LOADING STRESSES - ASME EQUATION (10) (Note 2)					
	In-Torus		Out-of-Torus		
LOAD CASE (Note 3)	Maximum Stress (ksi)	Location(Note 4)	Maximum Stress (ksi)	Location(Note 4)	Allowable Stress (ksi)
I	6.3	Elbow B	8.2	Elbow D	22.50
II	24.7(Note 5)	Elbow B	13.8	Elbow D	22.50
III	10.3	Elbow B	10.2	Elbow D	22.50
IV	10.0	Elbow B	10.8	Elbow D	22.50
V	8.0	Elbow B	10.0	Elbow D	20.25
Discharge	1.9	Elbow B	3.1	Elbow D	22.50

NOTES:

1. Stress exceeds allowable slightly, however, this load case bounds several required combinations. If load combinations bounded by Load Case IV are considered individually, all allowable stress limits are satisfied.

2. All stresses computed using ASME Equation (10) except where noted.

3. Load cases defined in Table 2.2-1.

4. Maximum stress locations identified in Figure 6.2-1.

5. Stress calculated using ASME Equation (11). The allowable stress is 37.50 ksi.

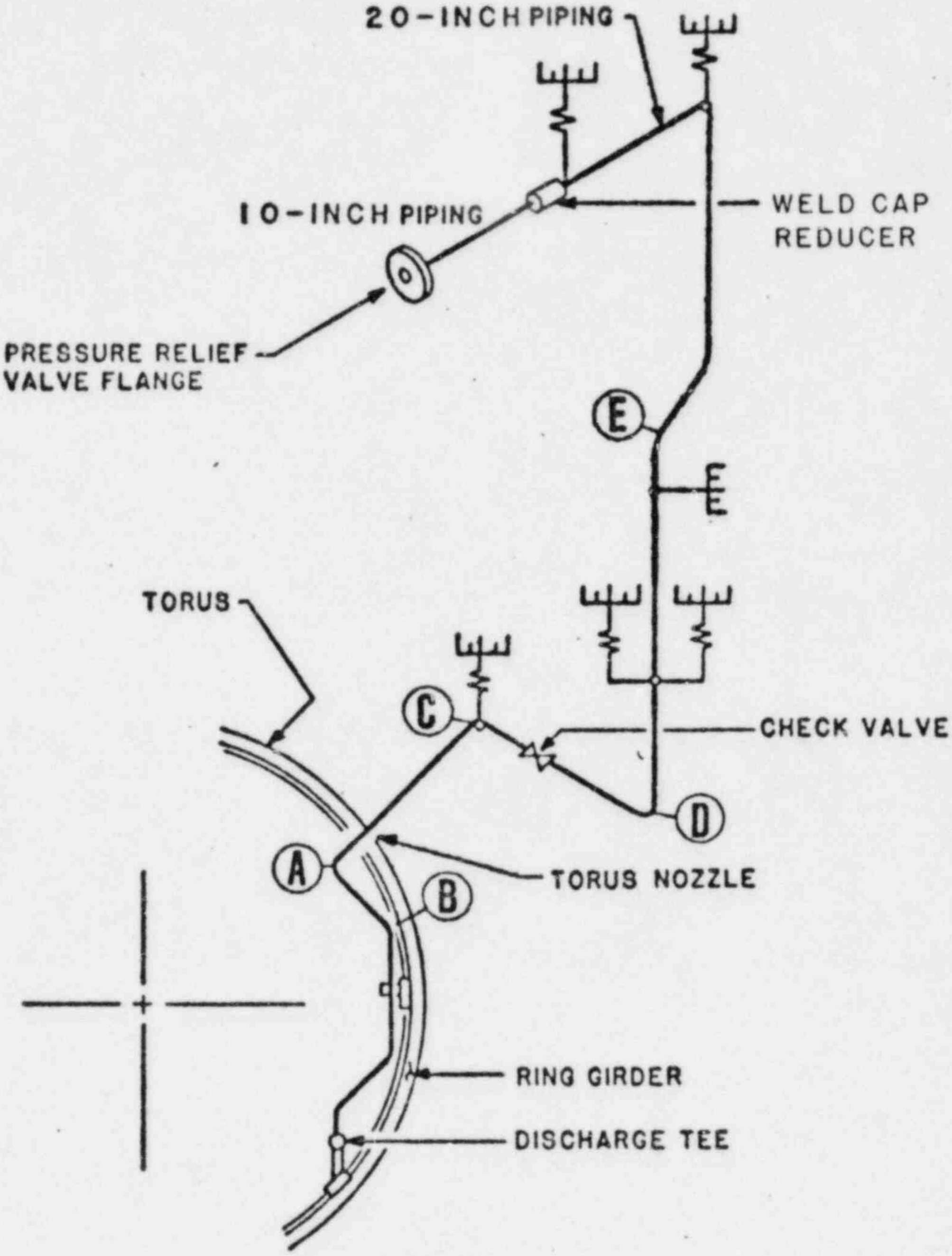

FIGURE 6.2-1

LIMITING STRESS LOCATIONS
DEMINERALIZER RELIEF DISCHARGE PIPING

6.3 CONTAINMENT SPRAY AND TEST RETURN PIPING

The containment spray and test return piping was analyzed for all five limiting load cases shown in Table 2.2-1. An additional load was included in Load Cases I, IV and V to include the discharge loading from test return piping discharge. The torus containment spray header discharge loading, however, was not included in any load case because it was insignificant. The discharge loadings are described in Section 4.7.

The stresses resulting from these combinations are required to meet essential piping allowable stresses as listed in Table 2.2-1. These levels apply to the occasional load (ASME Equation 9) allowable stresses. The thermal and sustained load (ASME Equation 10) allowable stresses are determined in accordance with Section NC-3611.2 of Reference 8.4.1. For Load Case V, a stress range reduction factor of 0.9 is applied since the number of response cycles for the post-chug load included in this load case could be up to 14,000 cycles.

The limiting piping stresses resulting from analysis of all five load cases have been determined for the containment spray and test return piping as modified. As described in Section 3.3, the test return piping is being modified so that it discharges directly to new torus penetrations rather than to the vacuum relief piping. Since the loop at vacuum relief piping assembly B is similar to the loop at vacuum relief piping assembly G, only a limited number of load cases were run with the assembly B line. The results in Table 6.3-1 contain stresses for the piping in the containment spray system loop at vacuum relief piping assembly G and are representative of both loops. All stresses are within the required allowable limits except the stress at the mid-bay of the torus containment spray header (location B in Figure 6.3-1). This stress exceeds the 36,000 psi Level B(4) allowable by less than one percent. The stress is acceptable considering the conservatisms inherent in the analysis approach, such as use of the response spectrum analysis method for calculating dynamic responses and use of absolute summation to combine independent dynamic responses due to SRV and LOCA loadings. The maximum calculated occasional load piping stress required to meet the 18,000 psi Level B allowable stress is 6900 psi, 38% of the allowable stress. The maximum calculated occasional load piping stress for the 27,000 psi Level B(3) allowable stress is 26,900 psi, 99% of the allowable stress. The maximum calculated thermal and sustained load piping stress of 18,000 psi is 80% of the allowable stress. The SBA post-chug thermal and sustained load case (Load Case V) is required to meet a reduced allowable due to the number of effective cycles (up to 14,000 cycles). For this thermal and sustained load case, the maximum calculated piping stress is 17,500 psi, 86% of the allowable stress. A more complete summary of the limiting stress values for this line is contained in Table 6.3-1.

The support and hanger stresses for the containment spray and test return piping are all required to meet the allowable stresses specified in ASME Subsection NF (Reference 8.4.1). All support and hanger stresses are within these requirements except for (i) the torus containment spray header supports which are being replaced, and (ii) one support on the loop at assembly G which is being modified or replaced. For the remaining supports, the maximum calculated support stress is 16,100 psi, 75% of the allowable stress. The maximum calculated hanger load is 290 pounds, 94% of the allowable load specified by the hanger manufacturer. Supports which are secured with concrete expansion anchors were analyzed and found to be acceptable based on the criteria of ACI 349-76 (Reference 8.7.8).

The nozzle reactions resulting from the containment spray and test return piping were combined with the corresponding vacuum relief piping torus nozzle reactions. The stresses from these reactions are tabulated and compared with the allowable stress corresponding to each applicable service limit as described in Section 6.8.

Each loop of the containment spray and test return piping contains two active components, a 4-inch gate valve and a 6-inch gate valve. To satisfy the operability requirements for active components as specified by the PUAAG (Reference 8.2.2), the valve stresses must meet Level A/B allowables, 18,000 psi. The maximum calculated stress in the 6-inch valve is 7,600 psi, 42% of the allowable stress, and in the 4-inch valve is 16,300 psi, 91% of the allowable stress. Therefore, the active components satisfy all operability requirements.

TABLE 6.3-1

SUMMARY OF MAXIMUM AND ALLOWABLE STRESSES
CONTAINMENT SPRAY AND TEST RETURN PIPING

OCCASIONAL LOADING STRESSES - ASME EQUATION (9)					
	In-Torus		Out-of-Torus		
LOAD CASE (Note 1)	Maximum Stress (ksi)	Location(Note 2)	Maximum Stress (ksi)	Location(Note 2)	Allowable Stress (ksi)
I	3.5	Bend A	6.9	Elbow D	18.0
II	36.3 (Note 3)	Pipe B	13.7	Valve E	36.0
III	21.2	Pipe B	26.3	Valve E	36.0
IV	22.3	Pipe B	8.8	Elbow D	27.0
V	26.9	Bend A	23.6	Valve E	27.0

THERMAL AND SUSTAINED LOADING STRESSES - ASME EQUATION (10)					
	In-Torus		Out-of-Torus		
LOAD CASE (Note 1)	Maximum Stress (ksi)	Location(Note 2)	Maximum Stress (ksi)	Location(Note 2)	Allowable Stress (ksi)
I	3.4	Bend A	14.2	Elbow F	22.50
II	7.4	Tee C	18.0	Elbow F	22.50
III	4.9	Bend A	16.4	Elbow F	22.50
IV	4.6	Bend A	18.0	Elbow F	22.50
V	4.8	Bend A	17.5	Elbow F	20.25

NOTES:

1. Load cases defined in Table 2.2-1
2. Maximum stress locations defined in Figure 6.3-1.
3. Stress exceeds allowable by less than 1%, therefore, piping stress is acceptable (see Section 6.3).

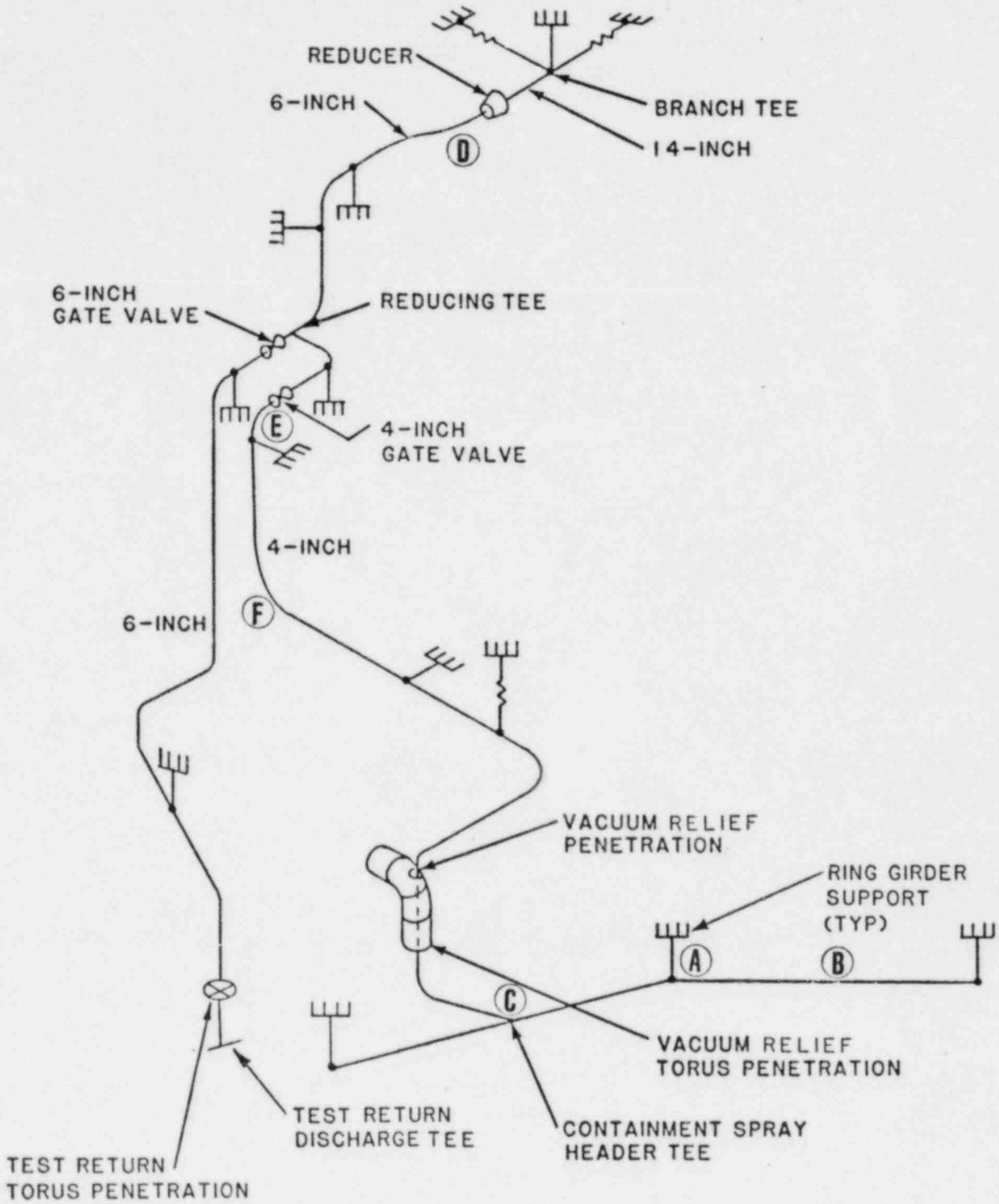

FIGURE 6.3-1

LIMITING STRESS LOCATIONS
CONTAINMENT SPRAY AND TEST RETURN PIPING
AT VACUUM BREAKER G

6.4 CORE SPRAY TEST RETURN PIPING

The core spray test return piping was analyzed for all five limiting load cases shown in Table 2.2-1 of this report. The resulting stresses are required to meet the nonessential piping allowable stresses as shown in Table 2.2-1. The thermal and anchor motion load (ASME Equation 10) allowable stresses are determined in accordance with Paragraph NC-3611.2 of Reference 8.4.1.

The limiting piping stresses resulting from analysis of all five load cases have been determined. All stresses are within the required allowables. The maximum calculated occasional load piping stress required to meet the 18,000 psi Level B allowable stress is 8,100 psi, 45% of the allowable stress. The maximum calculated occasional load piping stress for the 36,000 psi Level D(5) allowable stress is 18,600 psi, 52% of the allowable stress. The maximum calculated thermal and sustained load piping stress of 11,700 psi is 52% of the allowable stress. The SBA post-chug thermal and sustained load case (Load Case V) is required to meet a reduced allowable stress, due to the number of effective cycles (up to 14,000). The maximum calculated piping stress of 11,300 psi is 56% of this allowable. A more complete summary of the limiting stress values for this piping is contained in Table 6.4-1.

The support and hanger stresses for the core spray test return piping are all required to meet the allowable stresses specified in the ASME Code Section NF (Reference 8.4.1). All support and hanger stresses were within these requirements except for two supports on the core spray test return piping at assembly D, which are being replaced or modified so as to satisfy these requirements. For the remaining supports, the maximum calculated support stress is 12,300 psi, 57% of the allowable stress. The maximum calculated hanger load is 962 pounds, 79% of the allowable load specified by the hanger manufacturer. Supports which are secured with concrete expansion anchors were analyzed and found to be acceptable based on the criteria of ACI 349-76 (Reference 8.7.8).

The nozzle reactions resulting from the core spray test return piping were combined with the corresponding vacuum relief piping torus nozzle reactions. The stresses from these reactions are tabulated and compared with the allowable stress corresponding to each applicable service limit in Section 6.8.

The core spray test return piping contains no active components. Each piping run has one check valve which is not required to perform a mechanical function to maintain containment integrity. Accordingly, there are no operability requirements for this valve. The valve is normally closed and no discharge which might open it can occur during any accident. The check valves are analyzed as piping and meet all the piping allowable stress requirements.

TABLE 6.4-1

SUMMARY OF MAXIMUM AND ALLOWABLE STRESSES
CORE SPRAY TEST RETURN PIPING

OCCASIONAL LOADING STRESSES - ASME EQUATION (9)					
	Core Spray Test Return at Vacuum Breaker D		Core Spray Test Return at Vacuum Breaker F		
LOAD CASE (Note 1)	Maximum Stress (ksi)	Location(Note 2)	Maximum Stress (ksi)	Location(Note 3)	Allowable Stress (ksi)
Ia	8.1	Branch D	7.7	Elbow B	18.0
Ib	18.6	Elbow E	15.5	Elbow B	36.0
II	13.9	Branch D	12.7	Pipe C	36.0
III	17.0	Branch D	18.6	Pipe C	36.0
IVa	7.7	Elbow E	7.0	Elbow B	27.0
IVb	12.0	Elbow E	10.1	Elbow B	36.0
Va	8.7	Branch D	8.4	Elbow B	27.0
Vb	13.0	Elbow E	11.5	Pipe C	36.0

THERMAL AND SUSTAINED LOADING STRESSES - ASME EQUATION (10)					
	Core Spray Test Return at Vacuum Breaker D		Core Spray Test Return at Vacuum Breaker F		
LOAD CASE (Note 1)	Maximum Stress (ksi)	Location(Note 2)	Maximum Stress (ksi)	Location(Note 3)	Allowable Stress (ksi)
I	9.9	Elbow E	7.8	Elbow A	22.50
II & III	11.7	Elbow E	9.4	Elbow B	22.50
IV & V	11.3	Elbow E	8.7	Elbow A	20.25

NOTES:

1. Load cases defined in Table 2.2-1.
2. Maximum stress locations defined in Figure 6.4-2.
3. Maximum stress locations defined in Figure 6.4-1.

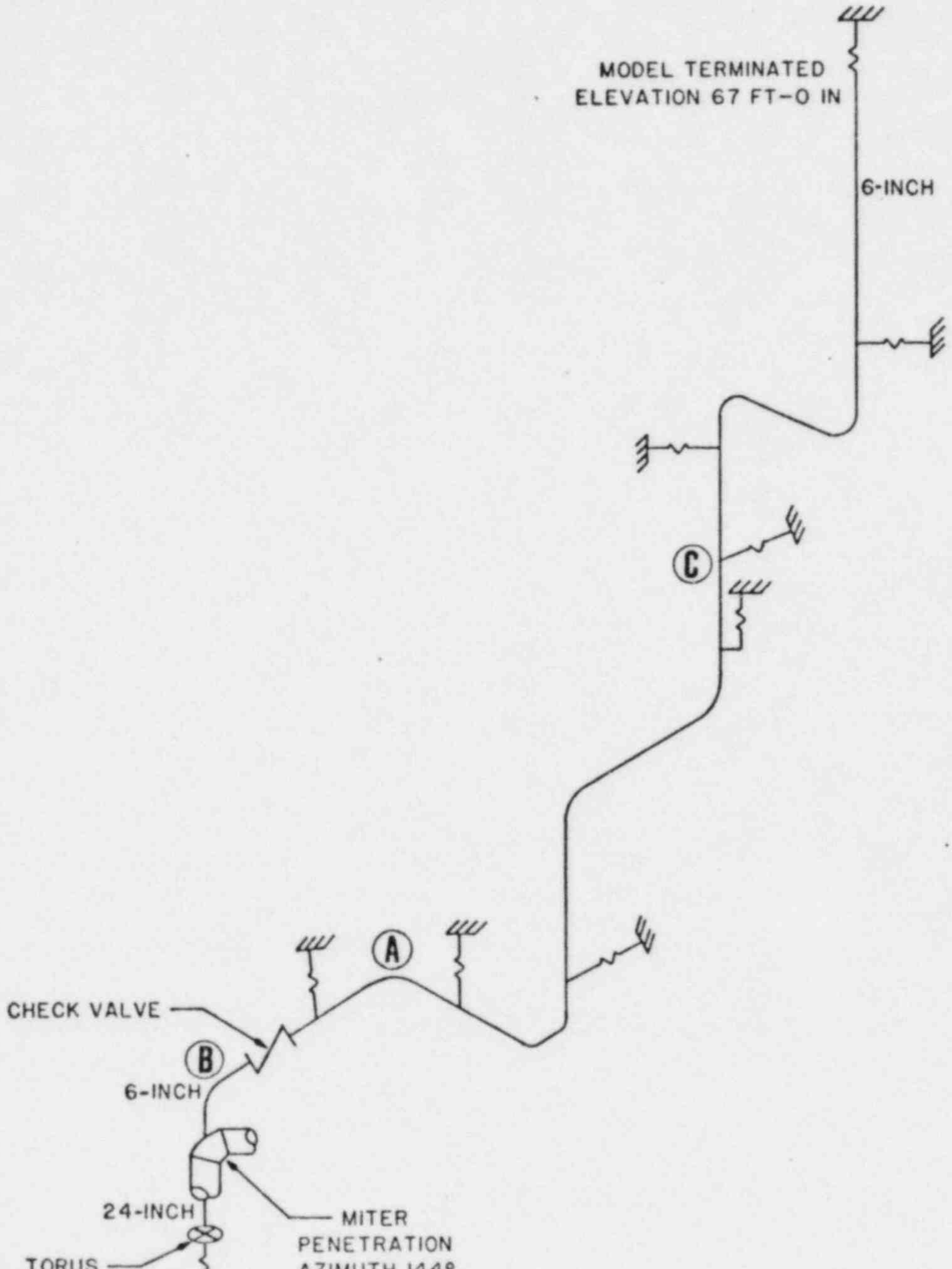

FIGURE 6.4-1

LIMITING STRESS LOCATIONS
CORE SPRAY RETURN PIPING
AT VACUUM BREAKER F

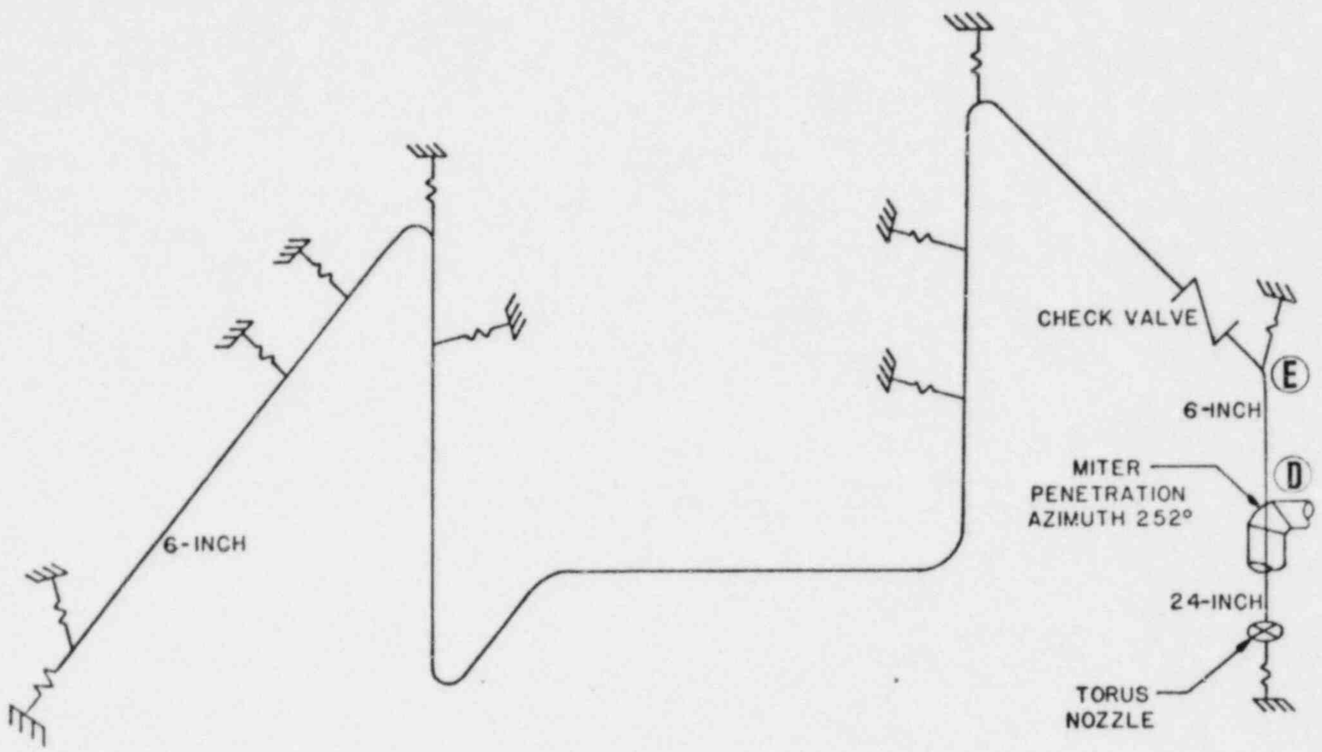

FIGURE 6.4-2

LIMITING STRESS LOCATIONS
CORE SPRAY RETURN PIPING
AT VACUUM BREAKER D

6.5 CORE SPRAY SUCTION HEADER AND BRANCH PIPING

The core spray suction header and branch piping were analyzed for all five limiting load cases shown in Table 2.2-1. The stresses resulting from these cases are required to meet essential piping allowable stresses as listed in Table 2.2-1. These stress levels apply to the occasional load (ASME Equation 9) allowable stresses. The thermal and sustained load (ASME Equation 11) and the nonrepeated load (ASME Equation 10A) allowable stresses are determined in accordance with Section NC-3611.2 of Reference 8.4.1. For Load Case V, a stress range reduction factor of 0.9 is applied since the number of response cycles for the load included in this combination could be up to 14,000 cycles.

The limiting piping stresses resulting from analysis of all five load cases have been determined for the core spray suction header and branch piping as modified. As described in Section 3.5, a modification to reinforce the 12-inch branch connections to the core spray suction header is being installed on each branch connection. Table 6.5-1 contains the maximum stresses for the suction header and the branch piping. The locations given in the table are defined in Figure 6.5-1. All stresses are within the required allowable limits except the occasional loading stresses for Load Case II at location D, one of the nozzle tees, and at location E, one of the branch connection tees. At these two locations, the tabulated stresses exceed the allowable limits by less than 8%. These stresses are considered acceptable since there is sufficient conservatism in the response spectrum analysis method and in the absolute summation method that, if more realistically accounted for, would cause the stresses at these locations to be less than the required allowable values. The maximum calculated occasional load piping stress required to meet the 18,000 psi Level B allowable stress is 6,700 psi, 37% of the allowable stress. The maximum calculated occasional loading stress for the 27,000 psi Level B(3) allowable stress is 21,300 psi, 79% of the allowable stress. The maximum calculated thermal and sustained load piping stress is 30,900 psi, 82% of the allowable stress. The SBA post-chug thermal and sustained load case (Load Case V), which is required to meet the reduced allowable due to the large number of effective cycles (up to 14,000), has a maximum calculated piping stress of 31,200 psi, 89% of the allowable stress. A more complete summary of the limiting stress values for this piping is contained in Table 6.5-1.

The vertical support and snubber support stresses for the core spray suction header and branch piping are required to meet the allowable stresses specified in ASME Subsection NF (Reference 8.4.1). All calculated vertical and snubber support stresses are within these requirements. The maximum calculated vertical support stress is 7,600 psi, 48% of the allowable stress. The maximum calculated snubber support load is 8,350 pounds, 84% of the allowable load specified by the snubber manufacturer. The maximum calculated stress in the snubber end connection is 18,700 psi, 87% of the allowable stress.

The stresses resulting from each of the applicable torus nozzle reaction combinations have been tabulated and compared with the allowable stress corresponding to each applicable service limit as described in Section 6.8.

The core spray suction header contains two types of components that were evaluated as active components: (i) 12-inch gate valves, and (ii) core and containment spray pumps. To satisfy operability requirements for active components as specified by the PUAAG (Reference 8.2.2), the stresses at the valves and pumps must meet the Level A/B allowable stress of 18,000 psi. The maximum calculated stress at the most limiting valve is 17,100 psi, 95% of the allowable stress. The maximum calculated stress at the most limiting pump is 17,500 psi, 97% of the allowable stress. Therefore, the active components satisfy all operability requirements.

TABLE 6.5-1

SUMMARY OF MAXIMUM AND ALLOWABLE STRESSES
CORE SPRAY SUCTION HEADER AND BRANCH PIPING

OCCASIONAL LOADING STRESSES - ASME EQUATION (9)					
	20-INCH SUCTION HEADER		12-INCH BRANCHES		
LOAD CASE (Note 1)	Maximum Stress (ksi)	Location(Note 2)	Maximum Stress (ksi)	Location(Note 2)	Allowable Stress (ksi)
Ia	6.7	Tee D	6.5	Tee E	18.0
Ib	10.6	Tee D	8.2	Tee E	27.0
II	38.2 (Note 4)	Tee D	38.8 (Note 4)	Tee E	36.0
III	25.1	Tee F	23.3	Tee E	36.0
IVa	15.4	Tee D	12.9	Tee E	27.0
IVb	19.2	Tee D	14.5	Tee E	36.0
Va	20.6	Tee D	21.3	Tee E	27.0
Vb	24.4	Tee D	23.0	Tee E	36.0

THERMAL AND SUSTAINED LOADING STRESSES - ASME EQUATION (11)					
	20-INCH SUCTION HEADER		12-INCH BRANCHES		
LOAD CASE (Note 1)	Maximum Stress (ksi)	Location(Note 2)	Maximum Stress (ksi)	Location(Note 2)	Allowable Stress (ksi)
I	26.8	Tee A	28.3	Tee C	37.50
II	13.3 36.3 (Note 3)	Tee G Tee B	30.9 14.3 (Note 3)	Tee C Tee H	37.50 45.00
III	29.7	Tee A	25.3	Tee C	37.50
IV & V	31.2	Tee A	29.8	Tee C	35.25

NOTES:

1. Load cases defined in Table 2.2-1.
2. Locations defined in Figure 6.5-1.
3. The DBA(PS) load of Combination II has been evaluated as an M_D load using ASME Equation (10A) from Paragraph NC-3652.3 of the ASME Code, Section III (Reference 8.4.1). Equation (10A) has an allowable stress = 45,000 psi for A106 GrB material.
4. Stress exceeds allowable by less than 8%; therefore, piping stress is acceptable (see Section 6.5).

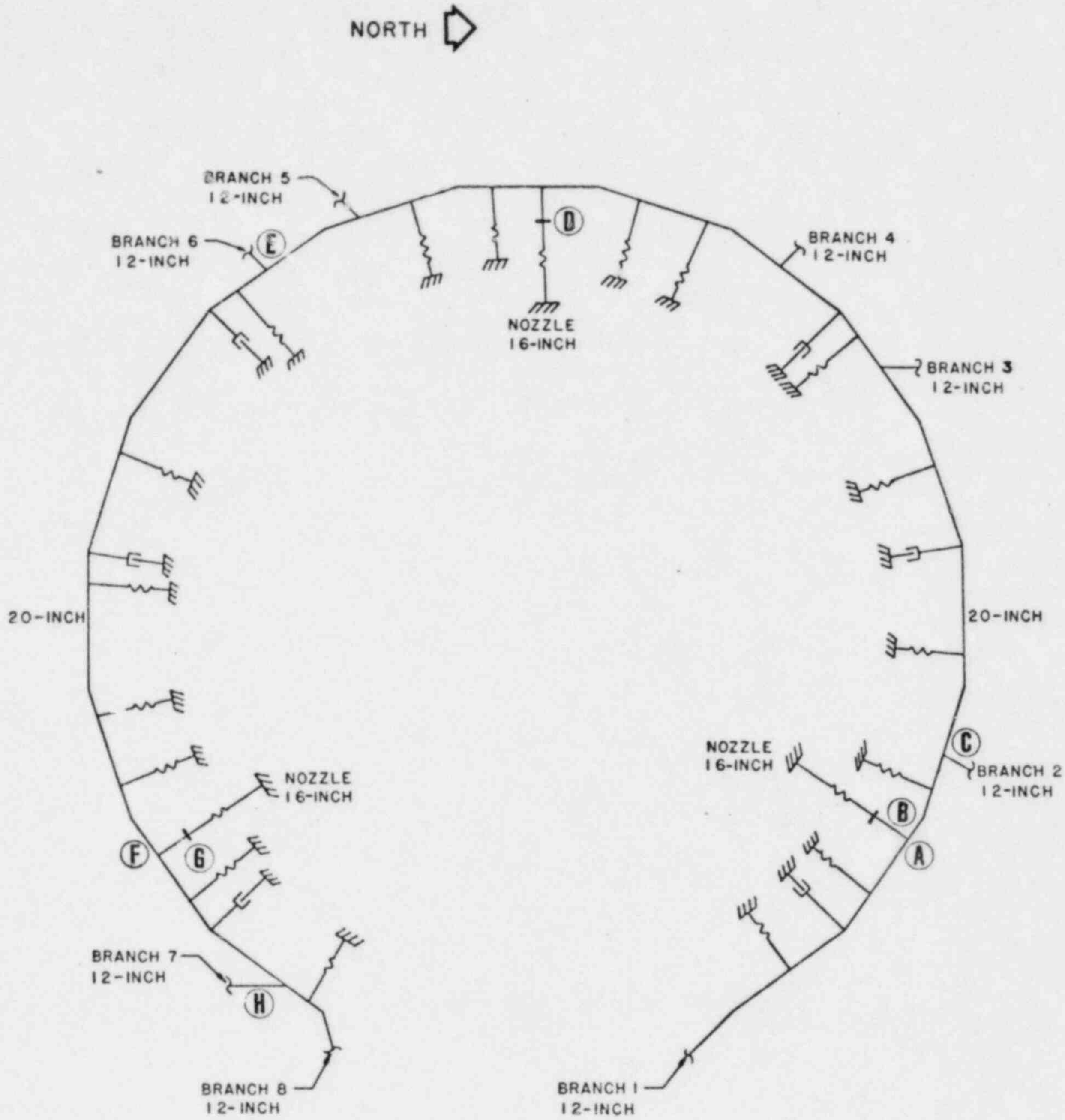

FIGURE 6.5-1

LIMITING STRESS LOCATIONS
CORE SPRAY SUCTION HEADER AND BRANCH PIPING

6.6 SRV DISCHARGE PIPING

The SRV south header discharge piping was analyzed for all five limiting load cases shown in Table 2.2-1. The stresses resulting from these combinations are required to meet essential piping allowable stresses as listed in Table 2.2-1. These levels apply to the occasional load (ASME Equation 9) allowable stresses. The thermal and sustained load (ASME Equation 10) allowable stresses are determined in accordance with the ASME Code, Section III, Paragraph NC-3611.2 of Reference 8.4.1. For Load Case V, a stress range reduction factor of 0.9 is applied since the number of response cycles for the post-chug load included in this combination could be up to 14,000 cycles.

The limiting piping stresses resulting from analysis of all five load cases have been determined for the south header SRV discharge line as modified. As described in Section 3.6, a modification to reinforce the 8-inch branch connection in the SRV south discharge line riser is being installed. Due to the similarity between the north header and south header, the north header was analyzed only to a limited extent. The south header piping has one more SRV than the north header, more extensive out-of-torus runs, and higher SRV discharge loads in comparison to the north header piping. The results in Table 6.6-1 contain stresses for the south header discharge piping. All stresses are within the required allowable limits except for three locations where stresses are slightly in excess of allowable. All stresses are considered acceptable based on the conservative response spectrum analysis method used for many loads and the conservative load case methodology used; i.e., use of absolute summation to combine independent dynamic responses due to SRV and LOCA loadings.

The maximum calculated occasional load piping stress for the Level B allowable stress is 20,800 psi, which is essentially at the allowable limit. The maximum calculated occasional load piping stress for the Level B(3) allowable stress is 33,800 psi, 7% above the allowable stress. The maximum calculated occasional load piping stress required to meet the Level B(4) allowable is 38,700 psi, 7% above the allowable stress. The maximum calculated thermal and sustained load piping stresses of 22,400 psi is essentially at the allowable stress. The SBA post-chug thermal and sustained load case (Load Case V) which is required to meet the reduced allowable due to the number of effective cycles (up to 14,000) has a maximum calculated piping stress of 17,200 psi, 85% of the allowable stress. A more complete summary of the limiting stress values is contained in Table 6.6-1.

The support and hanger stresses for the SRV discharge piping are all required to meet the allowable stresses specified in ASME Subsection NF (Reference 8.4.1). The results of analyses show substantially larger loads on several SRV discharge piping supports in the drywell than originally considered in their design. Based on review of available documentation, modifications are expected to be required for these piping supports. The affected supports are designated S1, S2, S3 and S5 on the south header. There are similar supports on the north header. The as-built configuration of the affected supports will be reviewed and any required modifications made to ensure that the supports and structural attachments are adequate.

Each SRV discharge line has several active components. There are three SRVs attached to the main steam header. In addition, there are two vacuum breakers attached to the vertical 14-inch discharge piping in the drywell. To satisfy the operability requirements for active components as specified by the PUAAG (Reference 8.2.2), the stresses at the valves must meet Level A/B allowables, 18,000 psi. The maximum calculated stress in the SRV is 11,100 psi, which is 61.6% of the allowable stress. The maximum calculated vacuum breaker stress is 16,500 psi, which is 91.7% of allowable. The evaluation of the nozzle in the vent system for the safety relief valve piping penetration has not been completed. The results of this evaluation will be forwarded separately.

TABLE 6.6-1

SUMMARY OF MAXIMUM AND ALLOWABLE STRESSES
RELIEF VALVE DISCHARGE PIPING

OCCASIONAL LOADING STRESSES - ASME EQUATION (9)					
	In-Torus		Out-of-Torus		
LOAD CASE (Note 1)	Maximum Stress (ksi)	Location(Note 2)	Maximum Stress (ksi)	Location(Note 2)	Allowable Stress(Note 5) (ksi)
Ia	9.2 --	Quencher A --	-- 20.8	-- Nozzle D	18.0 21.0(Note 3)
Ib	9.2 --	Quencher A --	-- 21.8	-- Nozzle D	27.0 31.5(Note 3)
II	27.8	Quencher A	38.2 (Note 4)	Elbow B	36.0
III	38.7(Note 4)	Quencher A	32.0	Nozzle D	36.0
IV	11.9	Quencher A	12.7	Elbow C	27.0
V	29.5(Note 4) --	Quencher A --	-- 33.8 (Note 4)	-- Nozzle D	27.0 31.5(Note 3)

THERMAL AND SUSTAINED LOADING STRESSES - ASME EQUATION (10)					
	In-Torus		Out-of-Torus		
LOAD CASE (Note 1)	Maximum Stress (ksi)	Location(Note 2)	Maximum Stress (ksi)	Location(Note 2)	Allowable Stress (ksi)
I & II	22.4	Elbow E	10.8	Elbow B	22.5
III	16.0	Elbow E	9.0	Elbow B	22.5
IV & V	17.2	Elbow E	9.5	Elbow B	20.25

NOTES:

1. Load cases defined in Table 2.2-1.
2. Maximum stress locations defined in Figure 6.6-1.
3. Allowable stresses based on A106 Grade C material.
4. Stress exceeds allowable by less than 9.5%; therefore, piping stress is acceptable (see Section 6.6).
5. Except as noted, all allowable stresses are based on A106 GrB material.

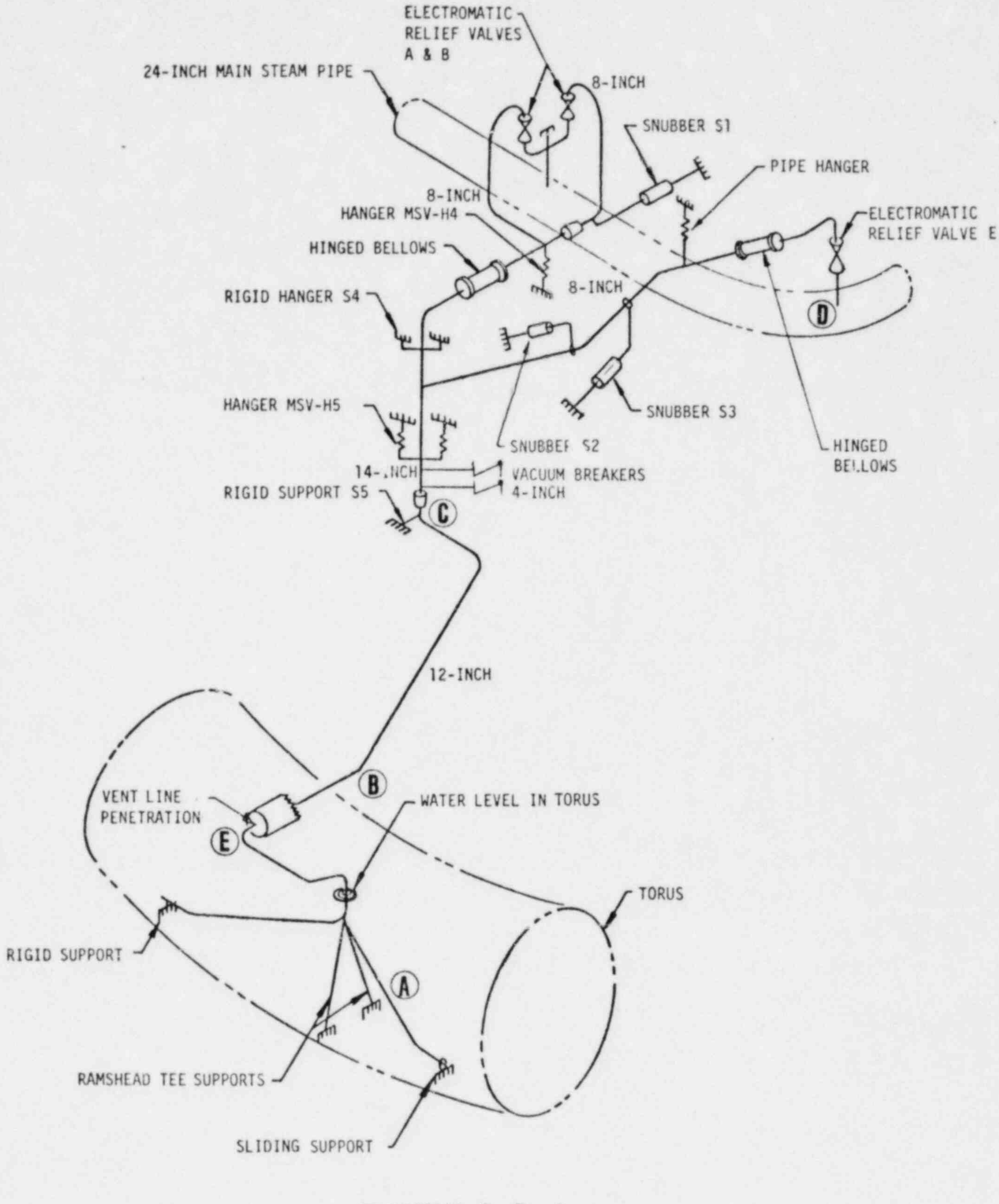

FIGURE 6.6-1

LIMITING STRESS LOCATIONS
SOUTH HEADER
SAFETY RELIEF VALVE DISCHARGE PIPING

6.7 SMALL BORE PIPING AND CORE SPRAY SUCTION STRAINERS

Structural evaluations of the various piping lines were performed based on the loads, load cases and acceptance criteria described in Section 2.0 of this report.

Table 6.7-1 provides a summary of the maximum and allowable stresses for the various piping lines attached to the torus for Load Cases I through V as defined in Table 2.2-1 of this report. Table 6.7-2 provides a summary of the maximum and allowable stresses for the branch piping lines from the torus attached piping. Maximum stresses are listed for Load Cases II to V. Stresses for Load Case I and thermal expansion and anchor motion are all within the appropriate allowables.

As shown in the tables, all piping stresses meet the allowable values. Certain piping support modifications were identified in order to meet these allowables as indicated in Tables 6.7-1 and 6.7-2. These modifications will be installed as part of the Mark I Containment Long-Term Program. For the core spray suction strainer, certain assumptions were made regarding the configuration of the strainer based on available design information. Confirmation of the assumed configuration will be obtained by inspection of the strainer during the next plant refueling outage.

Only one small bore piping system has a torus penetration which results in significant reaction forces on a torus nozzle: the torus level instrumentation line. The stresses resulting from each of the applicable load cases on the torus level instrumentation line have been tabulated and compared with allowable stresses corresponding to each applicable service limit as described in Section 6.8. Penetrations for other small lines such as the torus drain and the instrumentation wells are loaded less than this line and therefore are not included in Section 6.8.

TABLE 6.7-1

SUMMARY OF MAXIMUM AND ALLOWABLE STRESSES
SMALL BORE TORUS ATTACHED PIPING AND CORE SPRAY SUCTION STRAINERS

	STRESSES (psi)					
	LOAD COMBINATION I OCCASIONAL - EQUATION (9)		LOAD COMBINATION II to V OCCASIONAL - EQUATION (9)		LOAD COMBINATION I TO V EXPANSION - EQUATION (10)	
PIPING LINE	MAXIMUM	ALLOWABLE	MAXIMUM	ALLOWABLE	MAXIMUM	ALLOWABLE
Torus Level Instrumentation (Note 1)	< 1,900	18,000	< 1,900 1,900	27,000 36,000	14,600	22,500
Pressure Transducer	< 18,000	18,000	15,800 38,900(Note 3)	27,000 36,000	<1,000	22,500
Oxygen Analyzer	< 18,000	18,000	15,800 38,900(Note 3)	27,000 36,000	<1,000	22,500
Temperature Transducer	2,300	18,000	6,300 6,300	27,000 36,000	<1,000	22,500
Torus Drain	300	18,000	600 600	27,000 36,000	<1,000	22,500
Core Spray Strainer (Note 2)	1,300	18,000	7,300 9,000	27,000 36,000	<1,000	22,500

NOTES:

1. The stresses shown are based on support modifications which are being performed as part of the Mark I Containment Long-Term Containment Program.

2. The stresses shown are based in part on approximate dimensions which will be confirmed at the next opportunity.

3. The stresses shown exceed the allowable values for Combination III by about 8% which is judged to be acceptable due to the conservatism inherent in the stress evaluation method. Stresses for Combinations II, IV and V are within the allowable values.

TABLE 6.7-2

SUMMARY OF MAXIMUM AND ALLOWABLE STRESSES BRANCH PIPING

	STRESSES (psi)	
	LOAD COMBINATION II to V (Note 4)	
PIPING LINE	MAXIMUM	ALLOWABLE
Torus Level Reference Leg(Note 1)	< 8,100	27,000
	8,100	36,000
Air Test Piping(Note 1)	< 15,700	27,000
	15,700	36,000
Containment Spray Minimum Flow		
- At Vacuum Breaker B(Note 1)	< 18,500	27,000
	18,500	36,000
- At Vacuum Breaker G(Note 1)	< 18,500	27,000
	18,500	36,000
Core Spray Suction Branch Piping	< 27,000	27,000
(Note 3)	< 36,000	36,000
Emergency Exhaust Isolation		
Valve Bypass	< 10,000	27,000
	10,000	36,000
Drywell Pressure Transducer	17,600	27,000
	41,300(Note 2)	36,000

NOTES:

1. Piping support modifications may be required for these lines depending on verification of as-built support configuration.

2. The stress shown exceeds the allowable value for Combination III by about 15% which is judged to be acceptable due to the conservatisms inherent in the stress evaluation method. Stresses for Combinations II, IV and V are within allowable values.

3. Support modifications are being made to this line.

4. Load Case I was evaluated for all piping lines listed and the 18,000 psi allowable was met. Thermal expansion stresses were evaluated for Load Cases I to V and the 22,500 psi allowable was met.

6.8 NOZZLES AND PENETRATIONS

The nozzles and penetrations were analyzed for all six limiting load combinations shown in Table 2.2-2. These load combinations can be further broken down into the expanded load combinations shown in Table 6.8-1 after noting that: (1) SBA/IBA/DBA chugging loads are identical (except for internal pressure); and (2) the IBA(CO) load is enveloped by the IBA(PRCH) load, as specified in the LDR (Reference 8.2-1). All load combinations listed in Table 6.8-1 were considered for nozzle and nozzle transition analysis.

The limiting torus shell stresses adjacent to nozzles and penetrations were determined using the methods described in Section 5.3 of this report. Stress intensity results for limiting load combinations for each nozzle are shown in Table 6.8-2. As can be seen, all stresses are less than the relevant ASME Code allowable, and therefore the nozzles and penetrations meet the requirements of the Mark I Containment Long-Term Program. The evaluation of the nozzle in the vent system for the safety relief valve piping penetration has not been completed. The results of this evaluation will be forwarded separately.

Nozzle transition stress intensities were determined using the methods described in Section 5.4 of this report. Resultant stress intensities for limiting load combinations are shown in Table 6.8-3. As can be seen from the table, stress intensities are less than ASME Code allowables, and therefore, nozzle transitions meet the requirements for acceptability for the Mark I Containment Long-Term Program. The SRV nozzle transitions of the nozzle in the vent system for the safety relief valve piping penetration has not been completed. The results of this evaluation will be forwarded separately.

TABLE 6.8-1

EXPANDED NOZZLE AND NOZZLE TRANSITION LOAD COMBINATIONS

	LOAD COMBINATION	ASME SERVICE LEVEL
1.	IBA(PRCH) + SRV(IBA) + EQ(O)	B
2.	IBA(PTCH) + SRV(IBA) + EQ(O)	B
3.	IBA(PRCH) + SRV(IBA) + EQ(S)	C
4.	IBA(PTCH) + SRV(IBA) + EQ(S)	C
5.	DBA(PS) + EQ(O)	B (Note 1)
6.	DBA(CO) + EQ(C[illegible]	B
7.	DBA(PS) + SRV(DBA) + EQ(S)	C
8.	DBA(CO) + EQ(S)	C

NOTE:

1. This combination must be evaluated for membrane stresses only per the PUAAG, Reference 8.2.2.

TABLE 6.8-2

SUMMARY OF LIMITING STRESSES IN TORUS NOZZLES AND PENETRATIONS

NOZZLE/ PENETRATION	STRESS CLASSIFICATION	ASME SERVICE LEVEL	CALCULATED STRESS (ksi)	ALLOWABLE STRESS (ksi)(200°F)	LOAD COMBINATION
Vacuum Relief Piping: Torus End	Primary Local Membrane Stress Intensity(P_L)	A/B	25.3	28.9	STAT[1] + IBA(PTCH) + SRV + EQ(OBE)
		C	26.8	51.9	STAT + IBA(PTCH) + SRV + EQ(SSE)
	Primary Local Membrane + Bending Stress Intensity (P_L + Q)	A/B	55.4	69.3	STAT + IBA(PTCH) + SRV + EQ(OBE)
Vacuum Relief Piping: Vent Line End	P_L	A/B	27.6	28.9[2]	STAT + DBA(CO) + EQ(OBE)
		C	30.5	49.9[2]	STAT + DBA(CO) + EQ(SSE)
	P_L + Q	A/B	61.8	66.5[2]	STAT + DBA(CO) + EQ(OBE)
Reactor Building-to-Torus Piping	P_L	A/B	19.4	28.9	STAT + DBA(CO) + EQ(OBE)
		C	19.7	51.9	STAT + DBA(CO) + EQ(SSE)
	P_L + Q	A/B	29.3	69.3	STAT + IBA(PRCH) + SRV + EQ(OBE)
Demineralizer Relief Valve Discharge Piping	P_L	A/B	28.6	28.9	STAT + DBA(CO) + EQ(OBE)
		C	30.4	51.9	STAT + DBA(CO) + EQ(SSE)
	P_L + Q	A/B	64.0	69.3	STAT + DBA(CO) + EQ(OBE)
Containment Spray Test Return Piping	P_L	A/B	23.3	28.9	STAT + DBA(CO) + EQ(OBE)
		C	23.4	51.9	STAT + DBA(CO) + EQ(SSE)
	P_L + Q	A/B	51.4	69.3	STAT + DBA(CO) + EQ(OBE)
Core Spray Suction Header Piping	P_L	A/B	14.3	28.9	STAT + DBA(PS) + EQ(OBE)
		C	15.3	51.9	STAT + DBA(PS) + SRV + EQ(SSE)
	P_L + Q	A/B	65.0	69.3	STAT + DBA(CO) + EQ(OBE)
SRV Discharge Piping[4]	P_L	A/B		28.9[2]	
		C		49.9[2]	
	P_L + Q	A/B		66.5[2]	
Torus Level Piping	P_L	A/B	19.4	28.9	STAT + DBA(PS) + SRV + EQ(SSE)[3]
		C	19.4	51.9	STAT + DBA(PS) + SRV + EQ(SSE)[3]
	P_L + Q	A/B	35.8	69.3	STAT + DBA(PS) + SRV + EQ(SSE)[3]

NOTES

1. STAT includes deadweight of pipe and torus plus thermal and pressure loads.
2. Allowables at 340°F (vent line only).
3. The single most limiting load combination was evaluated for all service levels.
4. This nozzle is still being analyzed.

TABLE 6.8-3

SUMMARY OF LIMITING STRESSES IN TORUS NOZZLE AND PENETRATION TRANSITIONS

NOZZLE/ TRANSITION	STRESS CLASSIFICATION	ASME SERVICE LEVEL	CALCULATED STRESS (ksi)	ALLOWABLE STRESS (ksi)(340°F)[1]	LOAD COMBINATION[2]
Vacuum Relief Piping: Torus End	General Primary Membrane Stress Intensity (P_m)	A/B/C	3.3	16.5	STAT + DBA(CO) + SRV + EQ(SSE)
Vacuum Relief Piping: Vent Line End	General Primary Membrane Stress Intensity (P_m)	A/B/C	6.2	16.5	STAT + DBA(CO) + SRV + EQ(SSE)
Reactor Building-to-Torus Piping	General Primary Membrane Stress Intensity (P_m)	A/B/C	4.9	16.5	STAT + DBA(CO) + SRV + EQ(SSE)
Demineralizer Relief Valve Discharge Piping	General Primary Membrane Stress Intensity (P_m)	A/B/C	5.9	16.5	STAT + DBA(CO) + SRV + EQ(SSE)
Containment Spray Test Return Piping	General Primary Membrane Stress Intensity (P_m)	A/B/C	13.5	16.5	STAT + DBA(CO) + SRV + EQ(SSE)
Core Spray Suction Header Piping	General Primary Membrane Stress Intensity (P_m)	A/B/C	11.7	16.5	STAT + DBA(PS) + SRV + EQ(SSE)
SRV Discharge Piping[3]	General Primary Membrane Stress Intensity (P_m)	A/B/C		16.5	
Torus Level Piping	General Primary Membrane Stress Intensity (P_m)	A/B/C	3.3	16.5	STAT + DBA(PS) + SRV + EQ(SSE)

NOTES:

1. The limiting (weakest) nozzle transition material used in any system is A201 GrB for which the allowable was determined, based on Level A/B Service Limits.

2. Absolute worst case combinations were evaluated.

3. This nozzle is still being analyzed.

7.0 FATIGUE EVALUATION

The requirements for fatigue evaluation of nozzles and torus attached piping are specified in the PUAAG (Reference 8.2.2) and are limited to loads and load combinations which do not include pool swell loadings. The method of analysis, acceptance criteria and results are discussed separately for torus attached piping and nozzles in Sections 7.1 and 7.2, below.

7.1 PIPING FATIGUE

7.1.1 Method of Analysis

The method used for evaluating fatigue of the torus attached piping satisfies the requirements of Article NC-3611.2 of the ASME Code, Section III (Reference 8.4.1). This article requires that a stress range reduction factor, f, be applied when evaluating piping stresses in accordance with Equations (10) and (11) of Paragraph NC-3652.3 of Reference 8.4.1. The value of the reduction factor depends on the number of full range cycles and varies from 1.0 for 7,000 cycles or less to 0.5 for 100,000 cycles and over. Table NC-3611.2(e)-1 of Reference 8.4.1 lists the values of the factor applicable to each range of cycles.

High cycle fatigue analysis for piping supports in accordance with Paragraph NF-3132.3(a) and Appendix XVII-3000 of Reference 8.4.1 is not required unless the total number of fatigue cycles exceeds 20,000. An evaluation of the response of the Oyster Creek torus attached piping to Mark I containment loadings was made and it was found that the fatigue cycles for all Mark I containment loadings combined does not exceed 20,000. Accordingly, high cycle fatigue analysis was not performed for torus attached piping supports.

7.1.2 Acceptance Criteria

The criteria for evaluating fatigue for torus attached piping are that Equations (10) or (11) of Article NC-3653.2 (Reference 8.4.1) must be satisfied for the range of resultant moments which are included in the M_C loading category with the allowable stress range reduced by a factor determined in accordance with Table NC-3611.2(e)-1 for the number of cycles corresponding to the loading.

7.1.3 Results

An evaluation was made of the principle Mark I containment loadings on piping considering the number of cycles and the corresponding value of the stress range reduction factor.

Based on the above, a stress range reduction factor less than unity was required for load combinations of Table 5-2 (Reference 8.2.2) involving the post-chug (PTCH) loading. These combinations are enveloped by Load Combination Va and Vb in Table 2.2-1 of this report. As shown in Section 6.0, the piping stress evaluations were performed with this reduced allowable stress and all piping systems were found to be acceptable. Accordingly, the acceptance criteria for evaluating fatigue on torus attached piping are satisfied.

7.2 NOZZLES AND NOZZLE TRANSITION FATIGUE

The purpose of this section is to present the methodology and results for the fatigue evaluation of the torus nozzles and nozzle transitions. This section is comprised of three parts: (i) method of analysis; (ii) acceptance criteria; and (iii) results.

7.2.1 Method of Analysis

The fatigue analysis of each torus nozzle was performed in three parts: (a) determination of the number of cycles experienced by the nozzle during the life of the plant, under the assumption that the attached piping system determines the magnitude and frequency of loading; (b) determination of the allowable number of cycles the nozzle can experience during the life of the plant; and (c) determination of fatigue usage of the nozzle based on (a) and (b).

7.2.1.1 Number of Cycles

As required by Reference 8.4.1, each nozzle was evaluated for normal operating condition (NOC) cycles (fill and drain, normal SRV discharges, etc.) and the cycles that occur during either a SBA, IBA or DBA postulated loss-of-coolant accident (LOCA). The NOC combined with one of the three LOCAs constitute a "LOCA scenario". For each nozzle, the maximum frequency of the piping system's dominant spectral response was determined. The duration of each load that occurs during a LOCA scenario, as specified in the LDR (Reference 8.2.1), was multiplied by this frequency to produce the total number of cycles occurring during the load. A reduction factor was applied to this number for all loads except IBA(CO), to convert the total number of cycles to equivalent number of cycles of maximum amplitude (i.e., the specified load cycles are of varying peak amplitude). This factor was not required for IBA(CO) since all cycles were of equal amplitude.

7.2.1.2 Allowable Number of Cycles

For each nozzle, the alternating stresses for each load were generated using the Bijlaard methods described in Section 5.3 of this report. In accordance with the ASME Code (Reference 8.4.1), peak stresses were estimated by the application of two factors: (i) stress concentration factors to account for discontinuities in the nozzle; and (ii) fatigue strength reduction factors to account for weld toe discontinuities. The design fatigue curve given in Figure I-9.1 of Appendix I to ASME Code, Section III (Reference 8.4.1) was used in conjunction with the alternating stress to determine the allowable number of cycles for each load, for each nozzle.

7.2.1.3 Fatigue Usage

For each nozzle, the ratio of the number of cycles occurring during a LOCA scenario to the allowable number of cycles was determined for each load within each LOCA scenario. The ratios for all of the loads within each LOCA scenario, expressed as percentages, were summed to produce percent fatigue usages for each nozzle.

7.2.2 Acceptance Critera

In accordance with the ASME Code, Section III (Reference 8.4.1), for each nozzle, the percent fatigue usages for each LOCA scenario must be less than 100%.

7.2.3 Results

As shown in Table 7.2-1, the percent fatigue usage for each of the three LOCA scenarios is less than 100% for each of the nozzles evaluated; therefore, these nozzles are acceptable for fatigue. The fatigue evaluation of the nozzle in the vent system for the safety relief valve piping penetration has not been completed. The results of this evaluation will be provided separately.

TABLE 7.2-1

SUMMARY OF NOZZLE AND PENETRATION FATIGUE USAGE

NOZZLE	PERCENT USAGE FOR LOCA SCENARIO SBA	IBA	DBA
Vent Line Nozzle - Vacuum Relief Piping	54.8	46.4	17.4
Torus Nozzle - Vacuum Relief Piping	89.5	90.0	13.9
Torus Nozzle - Demineralizer Relief Piping	35.0	45.5	15.6
Torus Nozzle - Core Spray Suction Header	48.2	86.2	14.0
Torus Nozzle - Test Return Line	51.2	66.8	12.5
Torus Nozzle - Reactor Building to Torus Vacuum Relief Piping (Note 1)	--	--	--
SRV Discharge Nozzle (Note 3)	---	---	---
Torus Level (Note 2)	--	--	--

NOTE:

1. This nozzle was not evaluated for fatigue usage because it had stresses 40% lower than the stresses of the other vacuum relief nozzles and therefore was not limiting.

2. By inspection of Table 6.8-2, peak stresses in this nozzle are expected to be smaller than the others evaluated for fatigue and, therefore, this nozzle was not evaluated.

3. This nozzle is still being analyzed.

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8.7 OTHER

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