Design Summary of the Steam Generator Enclosure Roof Support Frames

The Vertical design loads on the concrete plug will be transferred into the SG compartment structure around the perimeter of the plug by the clamping forces induced by the through-bolts connecting the top and bottom steel connection frames. For example a vertical load in the upward direction, acting on the concrete plug would be transferred to the compartment structure as follows.

> The vertical load from the plug will be transferred by bearing between the concrete plug and the steel bearing plates (located between the concrete and the steel frame) to shear in the steel frame, to tension in the through bolt, back to shear in the lower frame, to bearing between the steel bearing plates and the concrete of the steam generator enclosure.

The Frames which will serve to clamp the plug and the enclosure together consist of :

- Built-up 12" wide 8" high box beams made from 1-1/4" ASTM A572 Gr 50 steel plate. Which
- Attached to the concrete plug by means of 4 - 2" A193 Gr. B7 bolts pre-tensioned to 70% of yield.
- The plug will be clamped to the SG compartment roof by means of 6 - 2 ½" and 18 - 2" diameter thru-bolts

The total weight of the steam generator enclosure roof support frames is approximately 38 kips per enclosure.

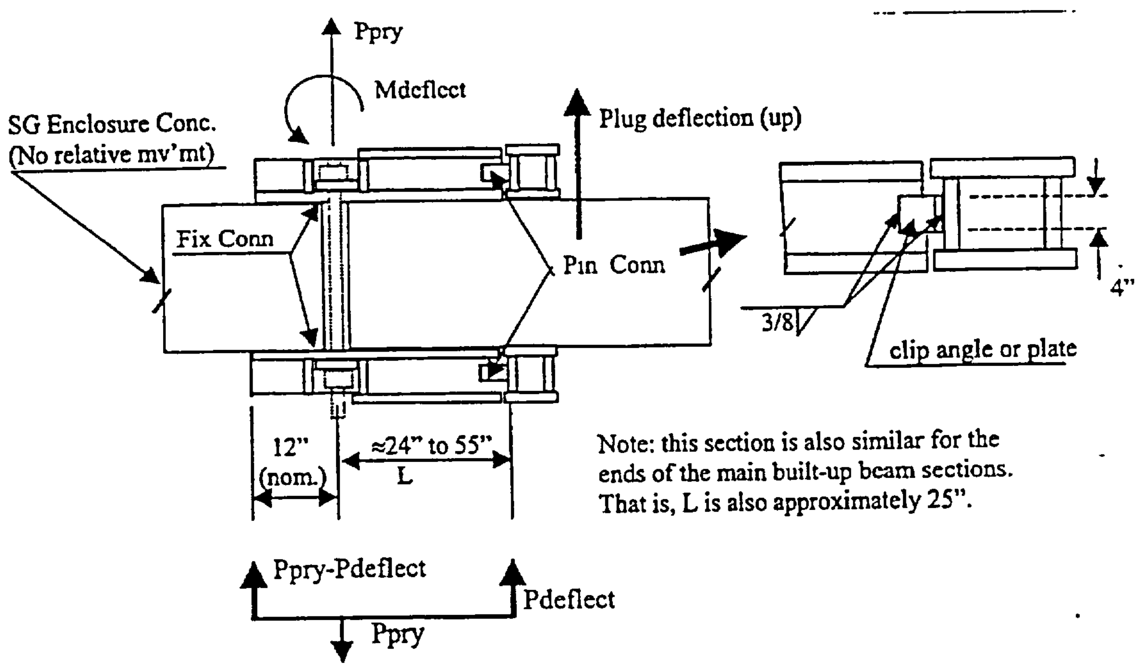
Thru-bolts:

The bolts were designed to resist three main loads:

- The enveloping loads obtained from the finite element analysis
- The vertical seismic loads due to the frame (conservatively assume resisted by only 10 bolts)
- The additional prying loads due to the plugs deflection (0.017") (dead weight of the steel frame was conservatively neglected)

The design loads remained below the bolt pre-loads for both the 2 and 2-1/2 inch bolts.

2"	-	173 kips	<	185 kips pre-load
2-1/2"	-	202 kips	<	280 kips pre-load



Design Summary of the Steam Generator Enclosure Roof Support Frames

Built-up box beams:
The box beams were designed to resist the bending stresses induced by the deflection of the plug and the shear forces from the enveloping loads obtained from the finite element analysis

Bending	42.0 ksi	<	45.0 ksi
Shear	106.5 kips	<	400 kips
Weld	4.09 kips/in	<	5.57 kips/in (3/8 fillet)
Connection Angles (shear)	4.27 ksi	<	14.4 ksi
Connection Welds	3.20 kips/in	<	5.57 kips/in (3/8" fillet)

The horizontal forces will be transferred by means of steel shims driven into the annular space between the plug and the enclosure.

The shims will be located around the perimeter of both the top and bottom of the plug Each shim will consist of a pair of wedged shaped A36 steel plates. One of the plates will be anchored to the plug while the other half of the shim being driven into the annular space and welded to the anchored half..

Concrete Bearing:
The concrete bearing stress due to the preload was checked at both the connection bolts and the plug bolts. As a conservative check the additional loads due to prying action and frame seismic accelerations was added to the pre-load used for the 2-1/2" bolts. This total load was then used to calculate the very conservative bearing stress of 4.04 ksi.

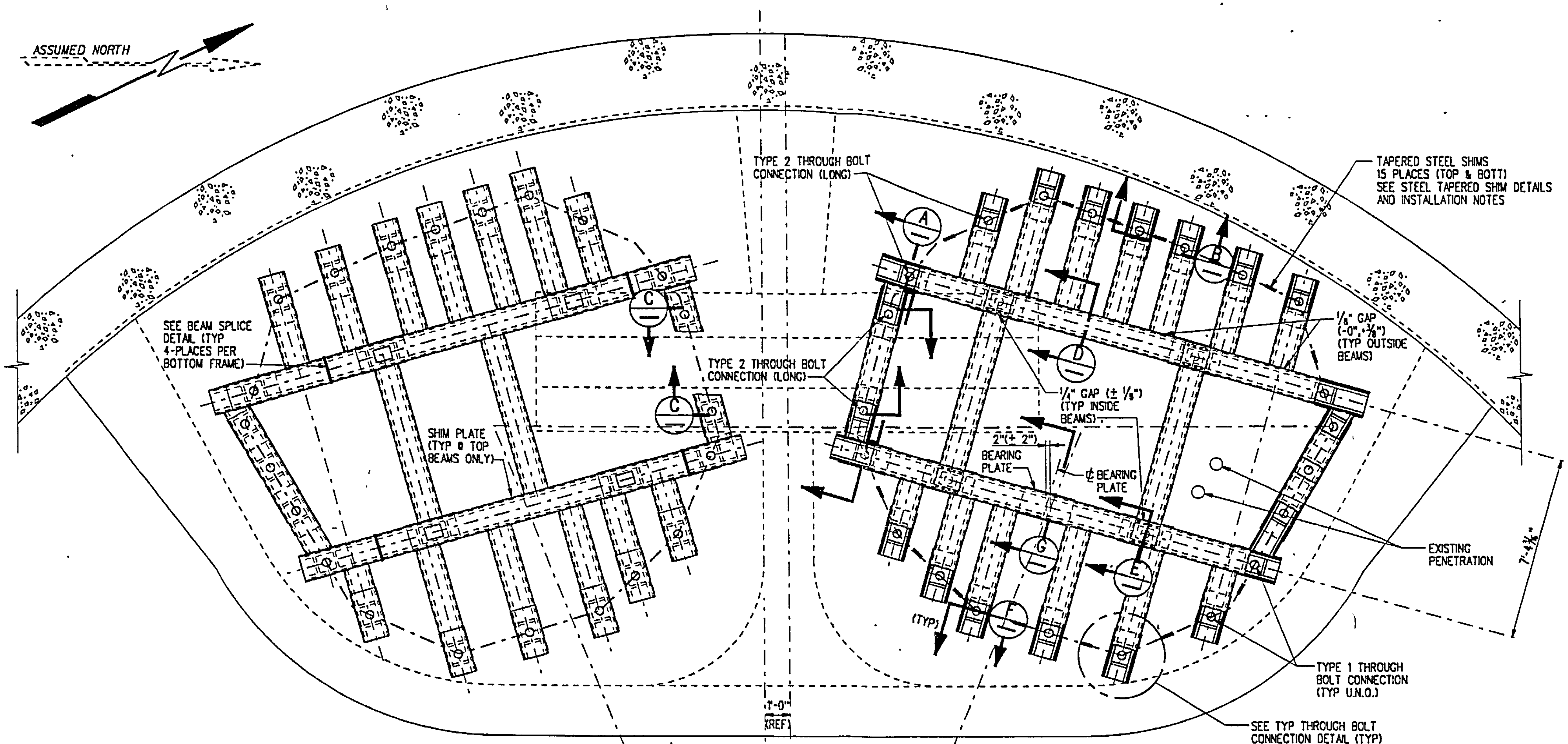
Concrete Bearing	4.04 ksi	<	6.00 ksi

Shims:
The following conservative assumptions were made in the design of the shims which are to transfer all the horizontal design loads from the plug to the enclosure.

- Only 50% of the shim faces are in contact.
- Only 2 shim sets one top and one bottom take the total horizontal load.

Bearing	462 kips	<	576 kips

Divider Barrier:
The divider barrier will be restored by placing a steel cover plate around the annular space on the bottom side of the enclosure roof. Then the annular space will be grouted for the full 3 foot thickness of the roof.



PLAN-SG ENCLOSURE ROOF SUPPORT FRAME
BOTTOM OF SLAB STEEL (LOCATION TO MATCH TOP OF SLAB STEEL)

PLAN-SG ENCLOSURE ROOF SUPPORT FRAME
TOP OF SLAB STEEL (T.O.S. E. 779.3775')

PARTIAL PLANS-TOP SLAB STEAM GENERATOR ENCLOSURES
TOP OF CONCRETE EL 778.69' (REF)
3/8"=1'-0"
DIMENSIONS AND LAYOUT OF SUPPORT FRAMES SYMMETRICAL W/RESPECT TO THE ℄ OF THE REACTOR

FIG. 1

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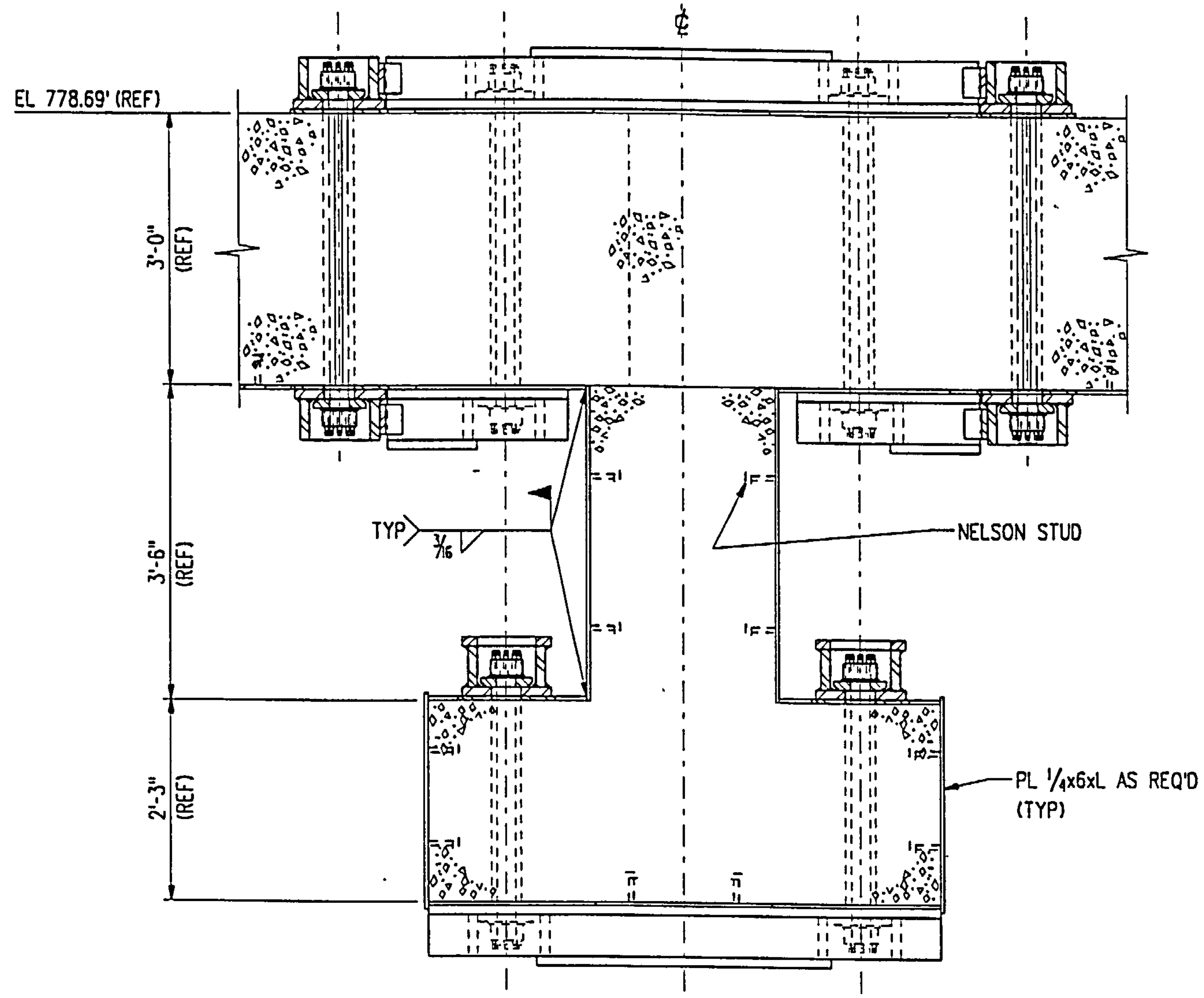
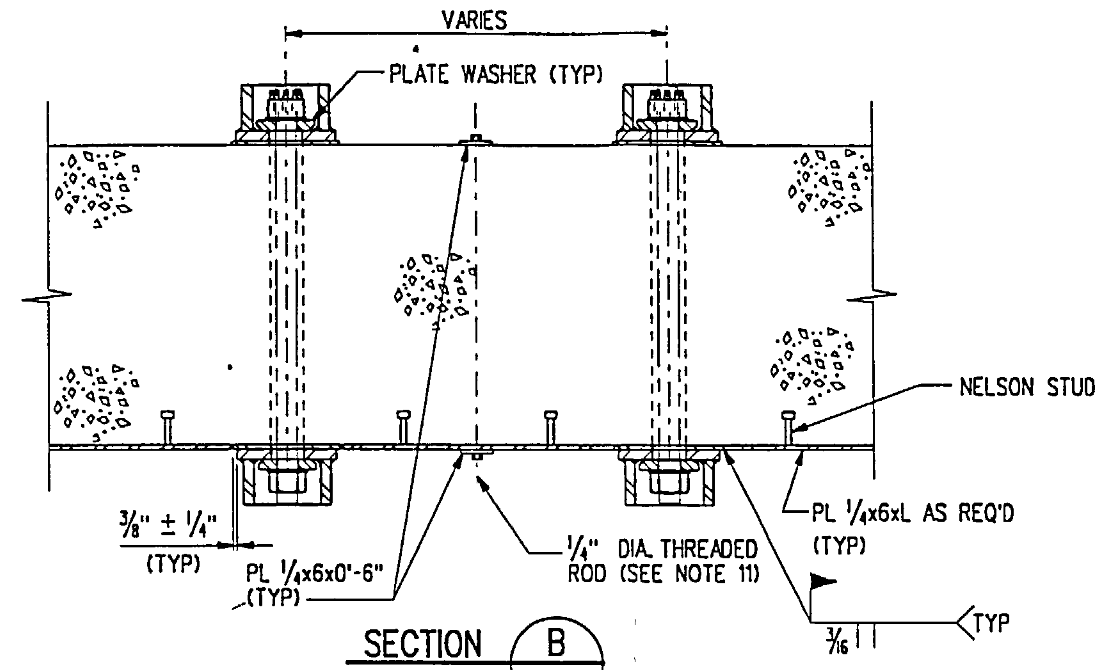


SECTION A
3/4"=1'-0"



SECTION B
3/4"=1'-0"

FIG. 2

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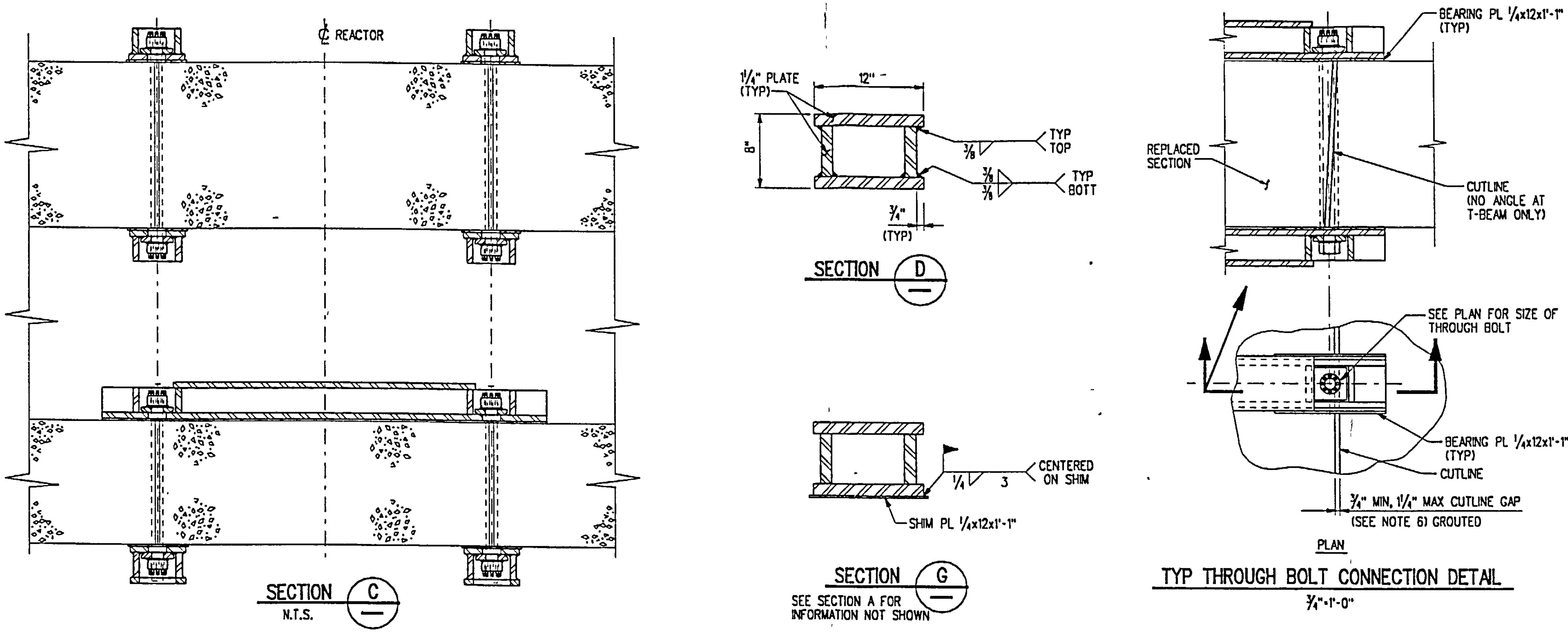
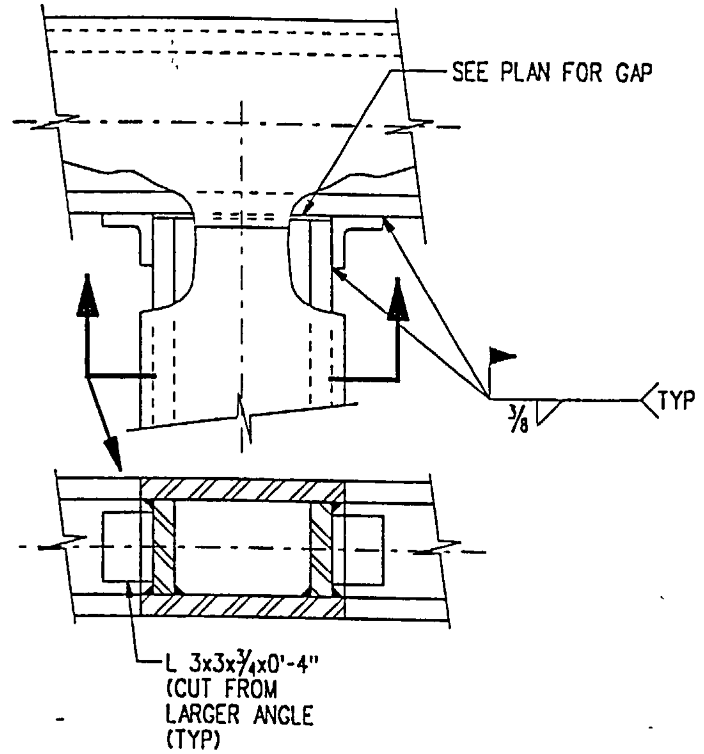
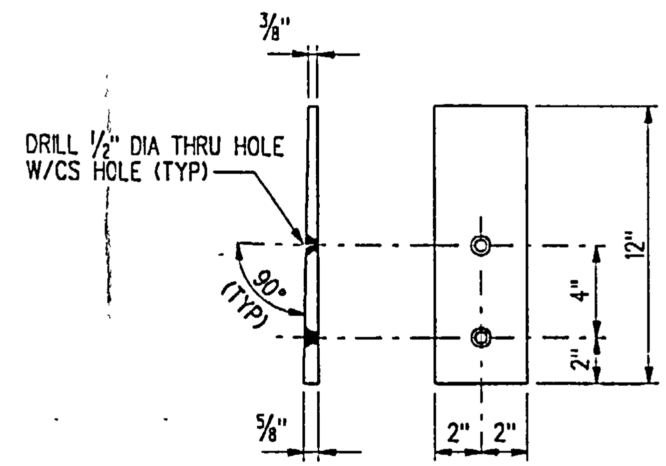


℄ REACTOR
SECTION C
N.T.S.
1/4" PLATE (TYP)
12"
8"
TYP TOP
TYP BOTT
3/4" (TYP)
SECTION D
CENTERED ON SHIM
SHIM PL 1/4x12x1'-1"
SECTION G
SEE SECTION A FOR INFORMATION NOT SHOWN
BEARING PL 1/4x12x1'-1" (TYP)
REPLACED SECTION
CUTLINE (NO ANGLE AT T-BEAM ONLY)
SEE PLAN FOR SIZE OF THROUGH BOLT
BEARING PL 1/4x12x1'-1" (TYP)
CUTLINE
3/4" MIN, 1 1/4" MAX CUTLINE GAP (SEE NOTE 6) GROUTED
PLAN
TYP THROUGH BOLT CONNECTION DETAIL
3/4"=1'-0"

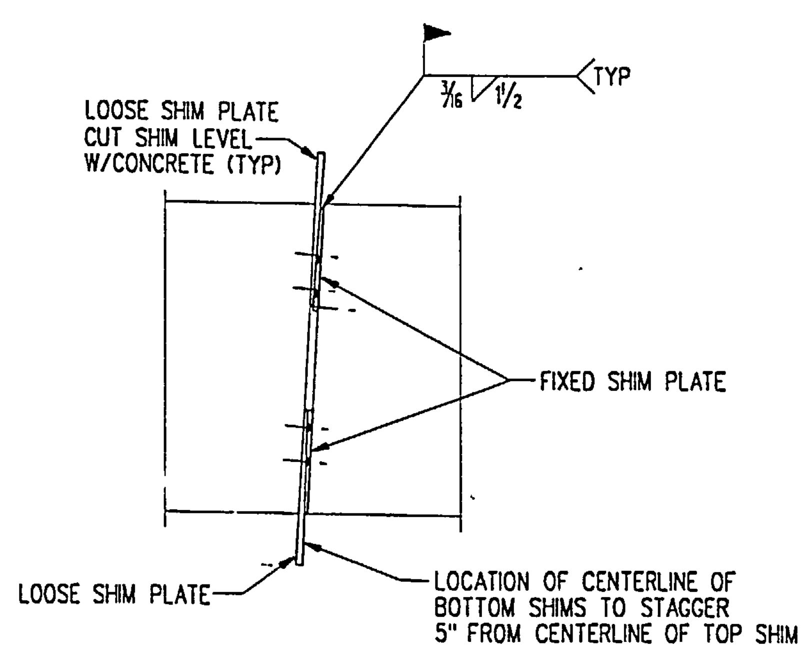
FIG. 3



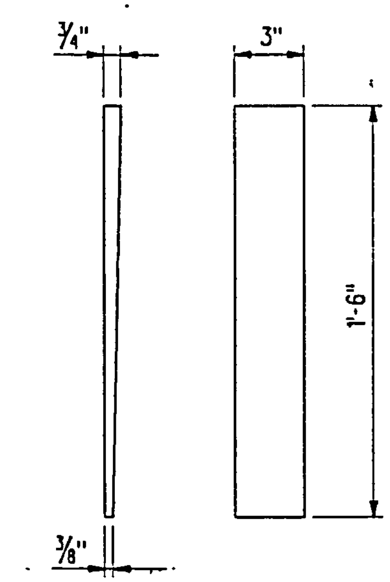
TYP BEAM TO BEAM CONNECTION



FIXED TAPERED STEEL SHIM PLATE



TAPERED STEEL SHIM DETAIL



LOOSE TAPERED STEEL SHIM PLATE

FIG. 4

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SEQUOYAH UNIT 1 STEAM GENERATOR REPLACEMENT

STEAM GENERATOR COMPARTMENT ROOF MODIFICATION

TOPICAL REPORT

1	2-7-03	Revised to Address NRC RAIs	SWK	MRA	JWS
0	02/19/02	Issued for TVA use	SWK	JC	JWS
REV.	DATE	REASON FOR REVISION	BY	EGS	PE
BECHTEL			JOB NO.: 24370		
			DOCUMENT NO.: 24370-TR-C-003		

Attachment 3

SEQUOYAH UNIT 1

STEAM GENERATOR REPLACEMENT

STEAM GENERATOR COMPARTMENT ROOF MODIFICATION

TOPICAL REPORT

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Tables

Figures

1.0 Abstract

The four steam generators of the Sequoyah Nuclear Plant Unit 1 will be replaced during the spring of 2003. To support the replacement of the old steam generators (OSGs) with the replacement steam generators (RSGs), access openings will be created in the roof of the steam generator (SG) compartments inside containment. An appropriately sized access opening will be made in each SG compartment roof by cutting out a section of concrete from the roof of the compartments using wire saws. Upon completion of installation of the RSGs, the original cut concrete section (plug) of the SG compartment roof will be reattached to the respective compartment roof by means of through-bolted connections, comprised of steel connection frames and threaded rods. The plug will be attached to the top and bottom connection frames using four 2-inch diameter threaded rods that are installed in core bore holes through the plug. The top and bottom connection frames will clamp the concrete plug to the complimentary portion of the SG compartment using six 2-1/2 inch and eighteen 2-inch diameter threaded rods. The threaded rods are installed in the core bore holes located around the perimeter of the concrete plug A series of steel shims will be driven into the annular space (created at the cut line) and mechanically locked into place. Next the annular space will be grouted and the threaded rods will be pre-tensioned.

The original design of the SG compartment was based in part on the load combinations defined in Table 3.8.3-2 of the UFSAR. This UFSAR table is based on Table CC-3200-1 of the Proposed ASME Section III, Division 2, 1973, Proposed Standard Code for Concrete Reactor Vessels and Containments, Section CC-3000 which was issued in 1973 (the time of original design) by the ACI-ASME Committee on Concrete Pressure Components for Nuclear Service, for trial use and comment. The purpose of this topical report is to provide the technical basis for use of the slightly modified load combinations and allowable stresses in the adopted 1975 edition of ASME Section III, Division 2, instead of those described in the UFSAR. Analyses performed using the adopted ASME load combinations have shown that the modified SG compartment roof design will not exceed allowable stresses in the concrete, rebar and structural steel when subjected to the design basis differential pressure of 24 psi combined with the other design basis loads such as seismic, pipe thrust, dead load and live load. This design differential pressure is approximately 23% higher than the maximum compartment accident pressure differential of 19.52 psi.

2.0 Introduction

The steam generator compartments are designed and constructed as cast in-place reinforced concrete structures. As indicated in UFSAR Section 3.8.3.6.1, the minimum compressive strength of the containment interior concrete structures is 5000 psi. UFSAR Section 3.8.3.1.7 describes the steam generator compartments. Two double-compartment structures house the four steam generators in pairs on opposite sides of the containment. For each pair of steam generators, divider barrier walls exist around the two steam generators and are capped with a three-foot thick concrete roof spanning over the steam generators from the crane wall. A wall between each pair of steam generators extends from the divider walls to the crane wall, completing the double compartment. The center wall does not extend up to the concrete roof. This area above the wall, except for the portions occupied by the main steam pipe restraint beam, reduces the compartment pressure buildup in a single compartment by venting the steam to the other compartment. These features are depicted on UFSAR Figures 1.2.3-11, 1.2.3-12, and 1.2.3-13 (provided as Figures 2-1, 2-2, and 2-3, respectively).

The steam generator compartments form part of the interior concrete structure that is referred to as the divider barrier. UFSAR Section 3.8.3.1.1 defines the divider barrier as that part of the interior structure that separates the upper containment from the lower containment. This barrier forces steam that is released from a LOCA/ DBA to pass through the ice condenser. The failure of any part of the divider barrier is considered critical since it would allow LOCA/DBA steam to bypass the ice condenser, thereby increasing the pressure within the primary containment. The original design loads for the compartment concrete were based on preliminary accident pressurization calculations. Conservative design basis loads were used in the original design to bound potential changes between the preliminary and the final pressurization analysis results. UFSAR Section 3.8.3.2 details the codes and standards to which the internal concrete structures were designed. The load combinations and allowable stresses for the internal concrete structures including the divider barrier are detailed in UFSAR Tables 3.8.3-1 and 3.8.3-2 (provided as Tables 6-1 and 6-2, respectively).

There are no Technical Specifications (TSs) associated specifically with the steam generator compartments. However, there are TSs associated with other portions of the divider barrier. TSs 3/4.6.5.3, 3/4.6.5.5, and 3/4.6.5.9 address the ice condenser doors, divider barrier personnel access doors and equipment hatches, and divider barrier seal, respectively. The planned changes to the steam generator compartment roof will restore the leaktightness of the roof and will not affect the ice condenser doors, divider barrier personnel access doors and equipment hatches, or divider barrier seal. Therefore, the TSs will not be affected by the planned changes to the steam generator compartment roof portion of the divider barrier.

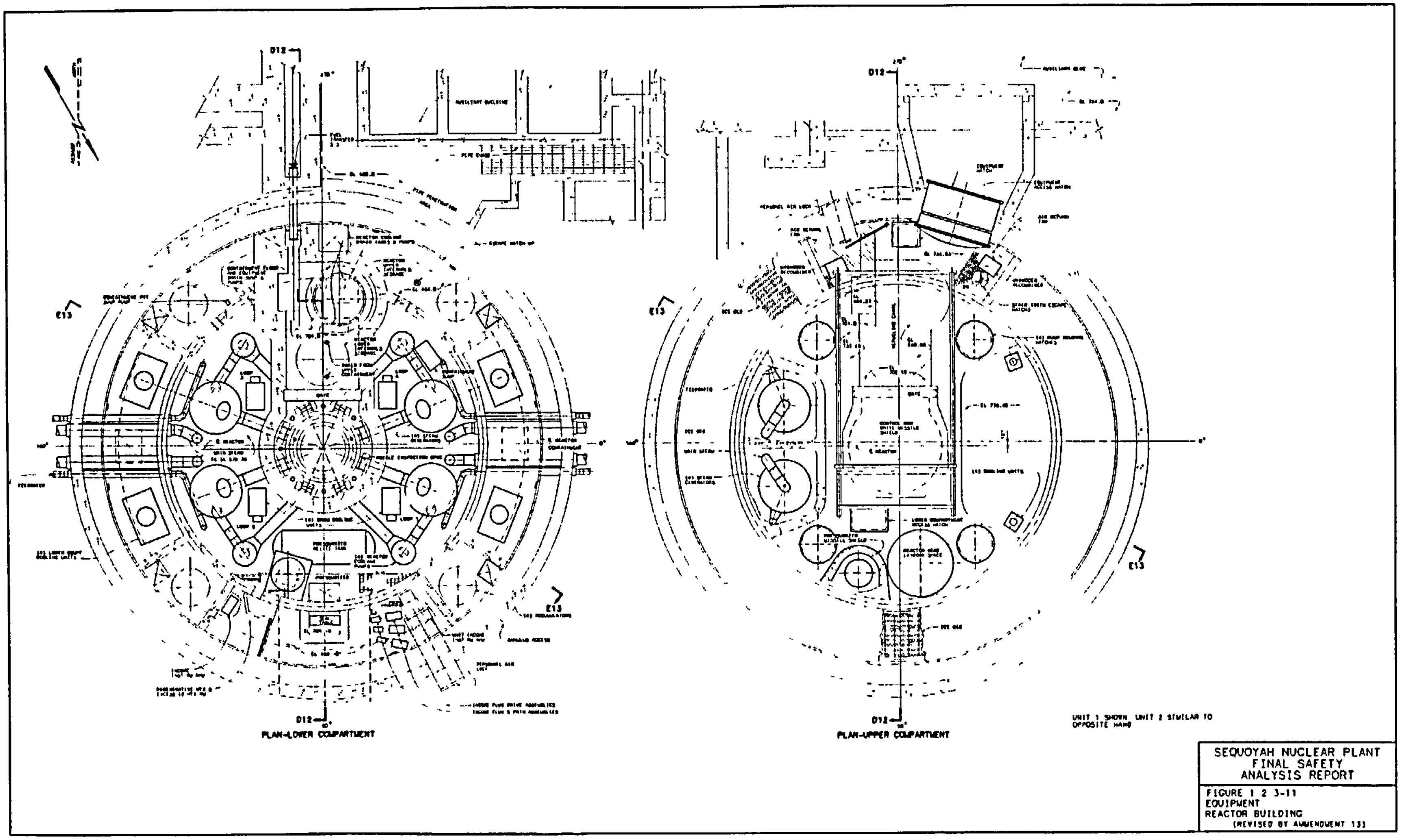

Figure 2-1 – Equipment – Reactor Building (UFSAR Figure 1.2.3-11)

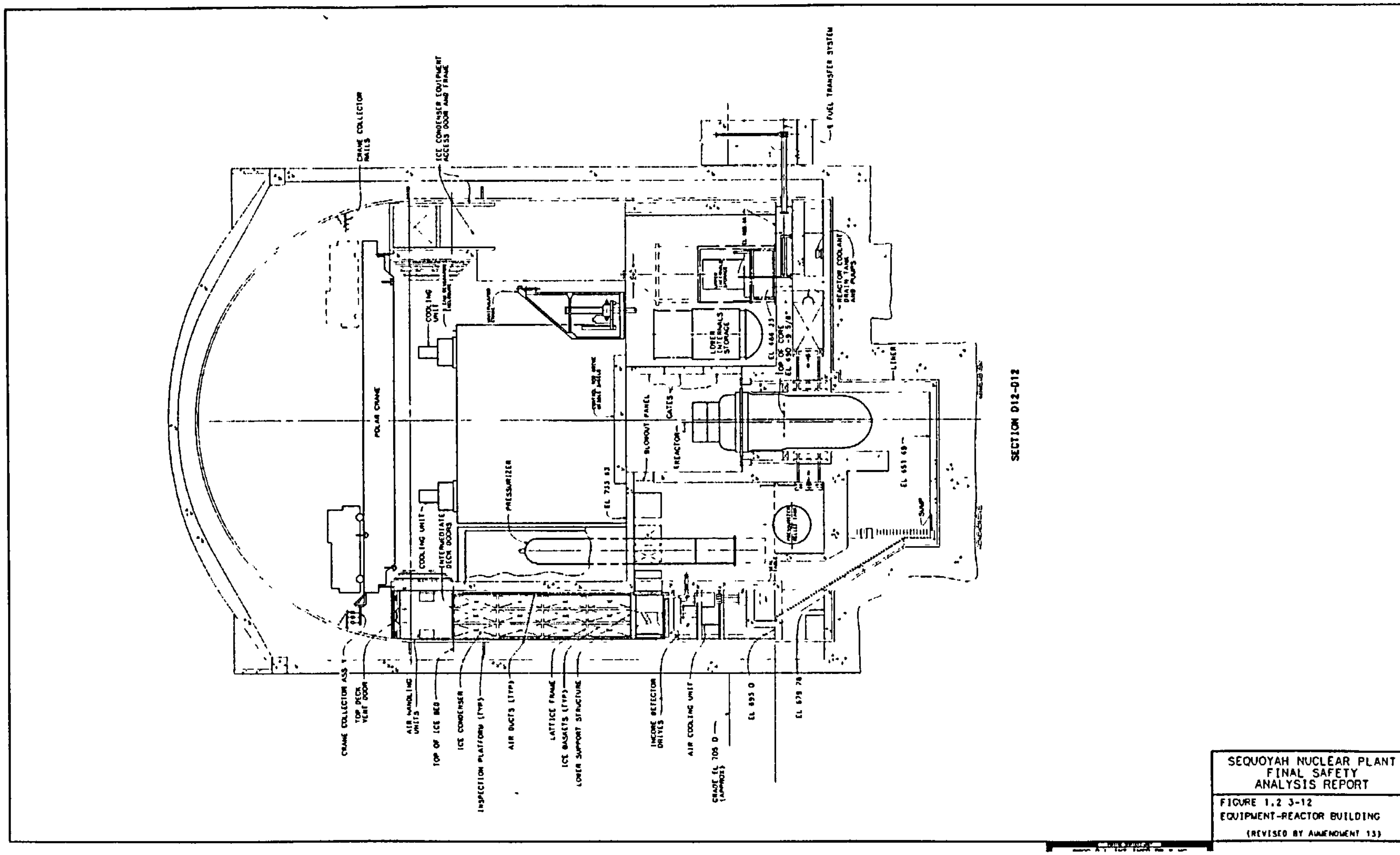

Figure 2-2 – Equipment – Reactor Building (UFSAR Figure 1.2.3-12)

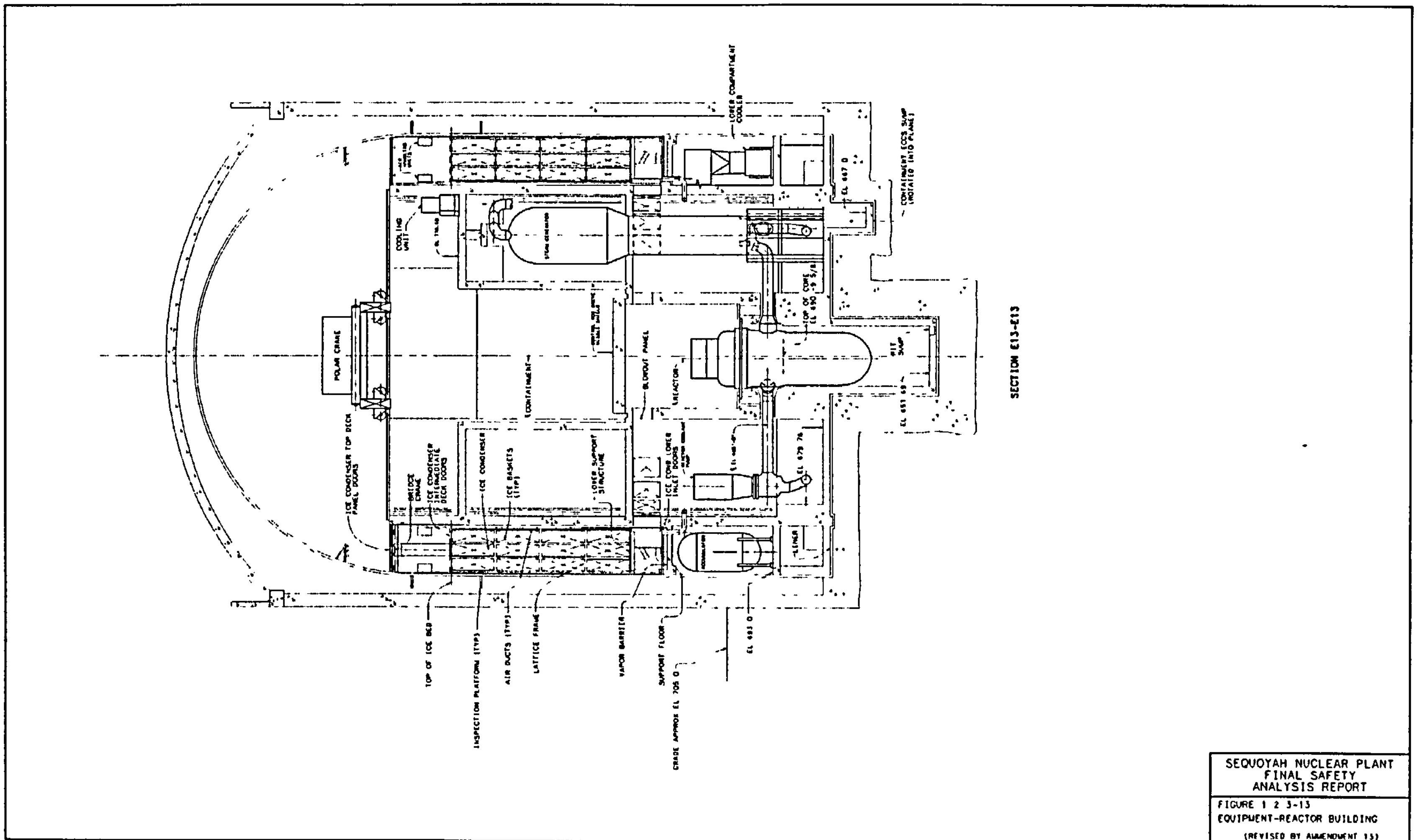

Figure 2-3 – Equipment – Reactor Building (UFSAR Figure 1.2.3-13)

3.0 Objectives

- To describe the current steam generator compartment roof design and proposed modification.
- To present data that supports and justifies the reinstallation of the cut steam generator compartment roof concrete sections using frames installed on the top and bottom of the section and then through-bolted together.
- To support a license amendment for using load combinations and allowables for reinforced concrete provided in "adopted" ASME Section III, Division 2, 1975 instead of the load combinations provided in "Proposed" ASME Section III, Division 2, 1973.

4.0 Regulatory Requirements/Criteria for Ice Condenser Divider Barriers

Detailed below are regulatory requirements/criteria that are relevant to the design of the divider barrier portion of internal structures in an ice condenser containment. Since the SG compartment roof is part of the divider barrier, the planned modification to the roof must conform to the requirements/criteria below. Following each requirement/criteria is an *italicized* discussion of how the requirement/criteria is met and/or where the requirement/criteria is addressed within this topical report.

4.1 SRP Section 3.8.3 – Concrete and Steel Internal Structures of Steel or Concrete Containments

Standard Review Plan (SRP) 3.8.3 details the information required for NRC review of containment internal structures and the criteria for NRC acceptance of these structures. This review is performed to assure conformance with the requirements of 10CFR50.55a and 10CFR50, Appendix A, General Design Criteria (GDC) 1, 2, 4, 5, and 50. The parts of these regulations that are relevant to the divider barrier design are:

1) 10CFR50.55a and GDC 1 as they relate to the divider barrier being designed, fabricated, executed, and tested to quality standards commensurate with the importance of the safety function to be performed.

   The quality standards used in the design, fabrication, execution, and testing of the modified divider barrier are the same or equivalent to those used for the original divider barrier.

2) GDC 2 as it relates to the design of the divider barrier being capable to withstand the most severe earthquake and appropriate combination of all loads.

   The modified SG compartment roof has been designed for the same loads and load combinations as the original design (described in Section 6.0), except as noted in Section 7.0. The results described in Section 8.0 show that it is capable of withstanding the most severe earthquake loads and the appropriate combination of other loads.

3) GDC 4 as it relates to the divider barrier being capable of withstanding the dynamic effects of equipment failures including missiles, pipe whips and blowdown loads associated with the loss of coolant accidents.

As described in Sections 7.0 and 8.0, the modified SG compartment design has been evaluated for the dynamic effects of pipe whip and jet impingement loads following a pipe break inside the SG compartment.

4) GDC 5 as it relates to the sharing of structures important to safety.

   The divider barrier is not a shared structure. Therefore, conformance to GDC 5 is not applicable for the modified SG compartment.

5) GDC 50 as it relates to the divider barrier being designed with sufficient margin of safety to accommodate appropriate design loads.

   As described in Sections 7.0 and 8.0, the modified SG compartment design is capable of withstanding the same design pressure as the original SG compartment design without exceeding allowable stresses in the concrete, rebar and structural steel. This design pressure is 23% greater than the maximum calculated post-LOCA differential pressure. Since the design pressure and the maximum calculated accident pressure have not changed, there is no reduction in the margin of safety for the modified SG compartment design.

The descriptive information provided is considered acceptable if it meets the minimum requirements set forth in Section 3.8.3.1 of NRC Regulatory Guide (RG) 1.70. This RG indicates that the descriptive information relevant to the divider barrier that should be provided includes plan and section views to define the primary structural aspects and elements relied upon to perform the safety-related function of the divider barrier. General arrangement diagrams and the principal features of the divider barrier should be described.

A description of the revised SG compartment roof design is provided in Section 7.0. Figure 7-2 provides details for the frames to be installed on the top and the bottom of the compartment concrete section and the layout of the connection through-bolts. Other aspects of the divider barrier design will remain as described in the Sequoyah UFSAR. An update to the UFSAR will be prepared to reflect the revised Unit 1 SG compartment roof design.

The design, materials, fabrication, erection, inspection, testing, and in-service surveillance of the divider barrier are covered by the following codes, standards, and regulatory guides:

1) ACI-349

   As indicated in Section 1.1 of Part 1 of ACI-349, structures covered by ASME Section III, Division 2 are specifically excluded from the requirements of this standard. As discussed in Section 7.0, the modified SG compartment roof design conforms to ASME Section III, Division 2. Therefore, this standard is not applicable to the modified SG compartment roof design.

2) ASME Section III, Division 2

   Conformance of the original design of the SG compartment roofs to the ASME Code is discussed in Section 6.0. As detailed in Section 7.0, the reinforced concrete part of the modified SG compartment roof design is consistent with the adopted edition of *the ASME Code. The basis and justification for use of the later edition of the Code is also provided in Section 7.0.*

3) ANSI N45.2.5, "Supplementary Quality Assurance Requirements for Installation, Inspection and Testing of Structural Concrete and Structural Steel During the Construction Phase of Nuclear Power Plants".

   Addressed under the response to RG 1.94 below.

4) Regulatory Guide 1.94, "Quality Assurance Requirements for Installation, Inspection and Testing of Structural Concrete and Structural Steel During the Construction Phase of Nuclear Power Plants"

   RG 1.94 endorses ANSI N45.2.5-74, but specifies additional requirements related to use of other codes and standards, RG 1.55, concrete consolidation, and rebar splice welding. The TVA Nuclear Quality Assurance Plan (NQAP) (Reference 15) follows this regulatory guide, but also provides alternatives to the regulatory guide guidance. The installation, inspection, and testing activities associated with the through-bolted connection frame modification to the SG compartment roofs will conform to the RG 1.94 guidance or the alternatives allowed by the TVA NQAP.

5) Regulatory Guide 1.142, "Safety-Related Concrete Structures for Nuclear Power Plants"

   RG 1.142 endorses ACI 349-76. As discussed in Section 7.0, the modified SG compartment roof design conforms to ASME Section III, Division 2 (1975). As such, the modified SG compartment roof design is not required to be evaluated against the requirements of RG 1.142 or ACI 349-76.

The divider barrier design is reviewed to determine if the loads and load combinations used meet the acceptance criteria. For concrete pressure-resisting portions of the divider barrier, the loads and load combinations of Article CC-3000 of ASME Section III, Division 2 Code apply.

As described in Section 7.0, the load combinations of Table CC-3230-1 of Article CC-3000 of ASME Section III, Division 2, 1975 were used in the evaluation of the modified SG compartment roof design.

The design and analysis procedures utilized for the divider barrier are acceptable if they are in accordance with ACI 318.

As described in Section 6.0, the original SG compartment structural design is in compliance with a combination of ACI 318 and the Proposed ASME Section III, Division 2, 1973. Section 7.0 describes how the modified SG compartment design complies with ASME Section III, Division 2, 1975 (ACI 359-74).

The structural acceptance criteria for the divider barrier are acceptable if the specified stress and strain limits are in accordance with Subsection CC-3430 of ASME Section III, Division 2. The 33-1/3% increase in allowable stresses is only permitted for temperature loads and not for OBE seismic or wind loads.

As described in Section 8.0, the stresses in the reinforced concrete of the modified SG compartment roof stresses under the load combinations defined in Table CC-3230-1 of ASME Section III, Division 2, 1975 are less than or equal to the stress allowables defined in Section CC-3400 of ASME Section III, Division 2, 1975. The 33-1/3% increase in allowable stresses was only used for temperature loads. The structural steel through-bolted connection frames are designed in accordance with Reference 3.

The specified materials of construction and quality control programs for the divider barrier are reviewed. Information on the materials used and the extent of compliance with ANSI N45.2.5 should be provided to support this review. Information on special, new, or unique construction techniques should also be provided in order to assess their effects on the structural integrity of the completed divider barrier.

The materials used in the modified SG compartment design are detailed in Section 7.0. Installation, inspection and testing of the modified SG compartment roof will conform to the quality assurance requirements of ANSI N45.2.5. Other than tensioning or preloading the threaded rods, there are no special, new, or unique construction techniques that will be used during installation of the modified SG compartment roof.

4.2 SRP Section 6.2.1.2 – Subcompartment Analysis

SRP 6.2.1.2 details the information required for NRC review of the design differential pressure analyses for containment subcompartments. This review is performed to assure conformance with the requirements of 10CFR50, Appendix A, GDC 4 and 50. The parts of these regulations that are relevant to the divider barrier design are:

1) GDC 4 as it relates to the ability of the divider barrier to accommodate the dynamic effects of missiles, pipe whipping, and discharging fluids that may occur during normal operations or during an accident.

   As described in Sections 7.0 and 8.0, the modified SG compartment design has been evaluated for the dynamic effects of pipe whip and jet impingement loads following a pipe break inside the SG compartment.

2) GDC 50 as it relates to the divider barrier being designed with sufficient margin to prevent fracture of the barrier due to pressure differential across the barrier.

   As described in Sections 7.0 and 8.0, the modified SG compartment design is capable of withstanding the same design pressure as the original SG compartment design without exceeding the allowable stresses in the concrete, rebar or structural steel. This design pressure is 23% greater than the maximum calculated post-LOCA differential pressure.

5.0 Description of Concrete Work to be Performed

The modification of the steam generator compartment roof will first entail cutting out a section of the concrete roof over each steam generator. Cutting of the concrete will be accomplished by first core-boring holes around the perimeter of the cut, then using wire saws to cut the straight lines between the cores. The cores also serve as the bolt holes for the through-bolts used to connect the concrete section back to the structure. After removal, the edges of the concrete section will be bush-hammered to provide an annular gap of about 1" upon reinstallation of the concrete section. Each concrete section will be sized to allow the removal and replacement of the steam generator in the compartment. The concrete section will be re-installed once the RSG and associated piping are placed inside the compartment. Restoration of the SG compartments will involve re-attaching the cut out concrete sections to the existing structure using a top and bottom frame sandwiching the cut out concrete sections and connecting the frames with through-bolted threaded rods around the perimeter of the cut. Tapered steel shims will be placed in the annular gap between the concrete sections and the bolt holes and annular space will be grouted using non-shrink grout The bolts will be tensioned once the grout has set. Additional details of the through-bolted connection frame design and the capability of the non-shrink grout to limit bypass leakage through the divider barrier is provided in Section 7.0.

The steam generator compartments have been re-evaluated, with specific focus on the modified roof, for the effects on structural response and found to be acceptable. The through-bolted connection frames and the tapered steel shims have been designed to be adequate for the applicable design loadings. Details of these evaluations are provided in Section 7.0. The design of the repaired steam generator compartments is in compliance with the requirements of Reference 2.

6.0 Description of Existing Design Basis and Original Analyses

The original design bases of the concrete internal structures, which includes the SG compartments, is discussed in detail in Section 3.8.3 of the UFSAR and Section 2.9 of Reference 2. UFSAR Section 3.8.3.2 states that the structural design of the interior concrete structures is in compliance with the American Concrete Institute (ACI) 318-63 Building Code Working Stress Design Requirements for load combinations shown in UFSAR Table 3.8.3-1 (provided as Table 6-1), including LOCA calculated pressures with moisture entrainment received from the NSSS contractor; or the ACI-ASME (ACI 359) Article CC3000 document, "Proposed Standard Code for Concrete Reactor Vessels and Containments" (Proposed ASME Section III, Division 2, 1973), and ACI 318-71 for the load combinations shown in Table 3.8.3-2 (provided as Table 6-2), including LOCA calculated pressure. Section 3.8.3.2 of the UFSAR also states that the design and construction of the interior concrete structures is based on the appropriate sections of NRC Standard Review Plan 6.2.1.2, "Subcompartment Analysis".

The original design loads for the SG compartment concrete were based on preliminary accident pressurization calculations. Because of the uncertainties associated with these preliminary accident analyses, conservative design basis loads were used in the original design to bound potential changes between the preliminary and the final pressurization analysis results. The preliminary accident pressurization loads were higher than the final accident loads, which resulted in a conservative SG compartment design.

The maximum differential pressure used in the original design was 21.3 psi which is a 25% increase over the design basis accident (DBA) differential pressure of ~17 psi (Reference 5) for the SG compartment provided by Westinghouse (i.e., 1.25 x 17 psi). The original design was based on loads, load combinations and allowable stresses documented in Table 3.8.3-1 of the UFSAR (provided as Table 6-1).

As detailed in UFSAR Section 3.8.3.4.1, each component of the interior concrete structure was evaluated individually. Its boundary conditions and degrees of fixity were established by comparative stiffness; loads were applied, and moments, shears, and direct loads determined by either moment distribution or finite element methods of analysis. UFSAR Section 3.8.3.4.1 also states that reinforcing steel was proportioned for the component sections in accordance with UFSAR Tables 3.8.3-1 or 3.8.3-2 and the ultimate strength provisions of ACI 318-71 Building Code were used to check the combined effects of torsion, shear, and direct tensile loads.

At the construction permit stage, a factor of 1.4 was applied to the DBA pressure provided by Westinghouse. The structural adequacy of the steam generator compartments was checked based on the 40 percent margin and the recommendations of the ACI/ASME Joint Committee contained in "Proposed Standard Code for Concrete Reactor Vessels and Containments". Accordingly, the SG compartment design was evaluated for a maximum design internal differential pressure of 24 psi (i.e., 1.4 x 17 psi) using loads, load combinations, and allowable stresses documented in UFSAR Table 3.8.3-2 (provided as Table 6-2). This is reflected in Section 3.8.3.4.1 of the UFSAR, which indicates that a factor of 1.4 was applied to the design pressures resulting from a LOCA during the construction stage. The results are tabulated in UFSAR Table 3.8.3-6 (provided as Table 6-3).

NRC Standard Review Plan 6.2.1.2, Subcompartment Analysis, Section II.B.5, addresses the application of peak differential pressure to be used in the design of the subcompartment. At the construction permit stage, a factor of 1.4 is applied to the calculated peak differential pressure to establish the differential pressure used for design of the subcompartment. At the operating permit stage, the calculated peak differential pressure should not exceed the design pressure. As noted in UFSAR Section 3.8.3.3 and consistent with SRP 6.2.1.2, Section II.B.5, the maximum calculated differential compartment pressures were increased by 40% to account for uncertainties. At the Operating License stage, the design pressures equaled or exceeded the peak calculated differential pressure. Therefore, the design conformed to the requirements of SRP 6.2.1.2.

UFSAR Section 6.2.1.3.10 indicates that the SG compartments were originally designed for two separate pressure loadings. These loadings are (1) a 24 psi maximum internal differential pressure from a break in the main steam line and (2) a uniform internal pressure of 43 psi. The SG compartments were also designed to resist the jet thrust force (910 kips on the roof per Reference 5) that would result following a main steam line break.

The largest blow-down flow results from the severance of the main steam pipe. As indicated in UFSAR Section 3.6.7.6.3, postulated main steam line break locations are shown on UFSAR Figures 3.6.7-1 and 3.6.7-2 (provided as Figures 6-6 and 6-7, respectively). Operating thermal conditions and accident thermal effects accompanying a pipe break (See UFSAR Figure 3.8.3-2, provided as Figure 6-5) were also accounted for.

The blow-down flow analysis of the main steam breaks described in Section 6.2.1.3.10 of the UFSAR resulted in a maximum pressure differential of 19.15 psi compared to the design differential pressure of 24 psi. The UFSAR analysis assumed the main steam flow restrictor is located downstream of the pipe break. Reanalysis of the main steam line break, based on the RSG design with the flow restrictor upstream of the pipe break, resulted in the maximum pressure differential increasing to 19.52 psi. Thus, the design pressure exceeds the maximum calculated differential pressure by 23%, and is therefore conservative.

As stated in UFSAR Section 3.8.3.4.8, the SG compartment was also originally designed to resist a 43-psi hypothetical pressure from a reactor coolant pipe break. This loading was used to provide a high degree of conservatism in the preliminary design of the SG compartment.

The center wall and the beam below the concrete roof are used as bumper points for main steam pipe whip restraints. These members restrain pipe whip in case of a pipe break and transmit forces to the roof and/or to the wall. It is noted that these whip restraints are bumpers that provide restraint against the pipe-whip in one direction only. Additionally, they also provide lateral restraint by means of saddle/bracket devices.

The original design of the steam generator compartments, in particular, is documented in Reference 5 and summarized in UFSAR Section 3.8.3.4.8. The roof of the SG compartments was analyzed using a combined member-grid and flat plate finite element STRUDL model. Manual calculations were performed at various locations to confirm computer results. The inverted T-beam, which stiffens the roof, was analyzed for the dynamic effects of a main steam pipe breaking and loading the flange of the beam. The roof was also independently analyzed as a plate using the finite element plate-bending program, GENDEK 3. The roof was analyzed both as a beam-stiffened slab and a uniform slab, neglecting the effects of the beam. The edges of the roof were considered fixed.

From Reference 16 and Figure 6-1, the design compressive strength of the SG compartment concrete at 28 days is 5000 psi. Note that the estimated in-place design compressive strength of the SG compartment roof concrete at 90 days is 5700 psi (Reference 5, Sheets 2e and 2f). The reinforcing used for the interior structures conforms to ASTM A615 Grade 60 (Reference UFSAR Section 3.8.3.2). Figures 6-2 and 6-3 provide additional details of the pre-modification design of the SG compartment roofs. This paragraph provides the historical data as to the required design strength and actual strength of the in-situ steam generator compartment concrete.

Table 6-1 (UFSAR Table 3.8.3-1)
Loading Combinations and Allowable Stresses for the Interior Concrete Structure

LOADINGS	COMBINATIONS											
	1	1A	2	2A	3	3A	4		5		5A	
DEAD LOAD	X		X		X		X		X		X	
LIVE LOAD	X		X		X				X		X	
NORMAL TEMP.	X		X		X							
LOCA PRESSURE	X		X		X						X	
LOCA TEMP.		X		X		X						
HYPOTHETICAL PRESSURE							X					
½ SSE			X									
SSE					X				X		X	
PIPE FORCES INITIAL JET									X			
PIPE FORCES SATURATED (REDUCED) JET OR ANCHOR											X	
W S D. ALLOWABLE STRESSES	DIVIDER BARRIER	OTHER	DIVIDER BARRIER	OTHER	DIVIDER BARRIER	OTHER	DIVIDER BARRIER	OTHER	DIVIDER BARRIER	OTHER	DIVIDER BARRIER	OTHER
fc	0 45 f'c	0 45 f'c	0 45 f'c	0.45 f'c	0 60 f'c	0 75 f'c			0 60 f'c	0 75 f'c	0 60 f'c	0 75 f'c
fs	0 40 fy	0 40 fy	0 50 fy	0.50 fy	0 72 fy	0 90 fy			0 72 fy	0 90 fy	0 72 fy	0 90 fy
U.S D. LOAD FACTORS					1 25	1 0	1 0		1.25	1 0	1 25	1 0

f'c = Ultimate strength of concrete　　fy = Yield strength of reinforcement

Table 6-2 (UFSAR Table 3.8.3-2)
Loading Combinations and Load Factors

Category	T_a	D	$L_{(1)}$	P_a	T_o	F_{ego}	F_{eqs}	R_o	R_a	Y_r	Allowable Stresses
Service:											
Const	—	1 0	1.0	—	1.0	—	—	—	—	—	(Flexure)
Normal	—	1.0	1.0	—	1.0	1.0	or	1.0	—	—	$f_c = 0.45 f'c$
Factored											$f_s = 0.50 f_y$
											(Shear)
Extreme Environ-mental	—	1.0	1 0	—	1.0	—	1.0	1 0	—	—	50% of Factored
Abnormal	1 0	1.0	1 0	1.5	—	—	—	—	1 0 and/or 1 0		(Flexure) $f_c = 0\ 75 f'_c$
Abnormal/ Severe Environ-mental	1.0	1.0	1.0	1.25	—	1.25	—	—	1.0 and/or 1.0		$f_s = 0\ 90 f_y$ (Shear)
Abnormal/ Extreme Environ-mental	1.0	1 0	1.0	1.0	—	—	1.0	—	1.0 and/or 1.0		(2) $V_c = 2\sqrt{f}$ $f_s = 0\ 85$

1. Includes all temporary construction loading during and after construction of containment

2. V_c is lower for tension members and is essentially the same as given by (ACI 318-71).

LOADS NOMENCLATURE:

D	Dead loads, or their related internal moments and forces
F_{eqo}	Operating basis earthquake
F_{eqs}	Design basis earthquake
L	Live load, or their related internal moments and forces
P_a	Accident/incident maximum pressure
R_o	Piping loads during operating conditions
R_a	Piping loads due to increased temperature resulting from the design accident
T_a	Thermal loads under the thermal conditions generated by the postulated break and including T_o
T_o	Operational temperature
Y_r	Reaction load on broken pipe due to fluid discharge

* The term "design basis earthquake" has the same meaning as the term "safe shutdown earthquake."

Table 6-3 (UFSAR Table 3.8.3-6)
Original Design Stress Margin Table 3.8.3-1 Criteria Versus Table 3.8.3-2 Criteria (4)

	TABLE 3 8 3-1 CRITERIA LOCA PRESSURE + 20%			TABLE 3 8 3-2 CRITERIA LOCA PRESSURE + 40%		
DESIGN FEATURE	(2) CONTROLLING LOAD COMBINATION	STRESS MARGIN (%) SHEAR	MOMENT	(3) CONTROLLING LOAD COMBINATION	STRESS MARGIN (%) SHEAR	MOMENT
REACTOR VESSEL ANNULUS WALL @ R C. PUMP SUPPORT	5A	-(1)	18 5	ABNORMAL	-(1)	80
*REACTOR CAVITY COLUMNS	4-FLEXURE 2-SHEAR	17	18 5	ABNORMAL/SEVERE ENVIRONMENTAL	64	22
*CONTROL ROD DRIVE MISSILE SHIELD	4	9	7	ABNORMAL	70	61
CRANE WALL @ EL. 679.78	5	0	0	ABNORMAL/EXTREME ENVIRONMENTAL	0	0
*CRANE WALL COLS @ 194°-08'-24" & 204°-31'-57"	5A	7	19	ABNORMAL/SEVERE ENVIRONMENTAL	20	10
*STEAM GEN COMPTS, SIDE WALL @ CRANE WALL	1	58	17 5	ABNORMAL	87	34
*PRESSURIZER COMPT @ CRANE WALL	4	16	11	ABNORMAL	>100	>100
*FLOOR EL 733 63 @ INTERSECTION W/CRANE WALL	1	9	8 5	ABNORMAL	19	39
*FLOOR EL. 721 0 @ CRANE WALL	1	62	73	ABNORMAL/SEVERE ENVIRONMENTAL	68	>100
MISC COMPTS, RADIAL WALL @ CRANE WALL	1	25	61	ABNORMAL	36	>100
FILL SLAB EL. 679 78 @ CRANE WALL	5	>20	0	ABNORMAL/EXTREME ENVIRONMENTAL	>20	0
*CANAL WALL (SPAN C - VERT POS MOM)	1	-(1)	3 5	ABNORMAL	-(1)	51
*CRANE WALL (SPAN C - NEG MOM @ OPERATING FLOOR)	1	40	3 5	ABNORMAL/SEVERE ENVIRONMENTAL	28	11
CRANE WALL, EL 714 0, HORIZ, NF	1	-(1)	5 5	ABNORMAL	-(1)	36

* DENOTES DIVIDER BARRIER
(1) NEGLIGIBLE SHEAR STRESSES IN THESE AREAS
(2) SEE TABLE 3 8 3-1 FOR LOADS
(3) SEE TABLE 3 8 3-2 FOR LOADS

(4) This table does not reflect the evaluations documented in Exhibit F of report CEB 86-19-C. Tabulated stress margins are from the original calculations and do not reflect later evaluations Changes have been documented in calculation packages.

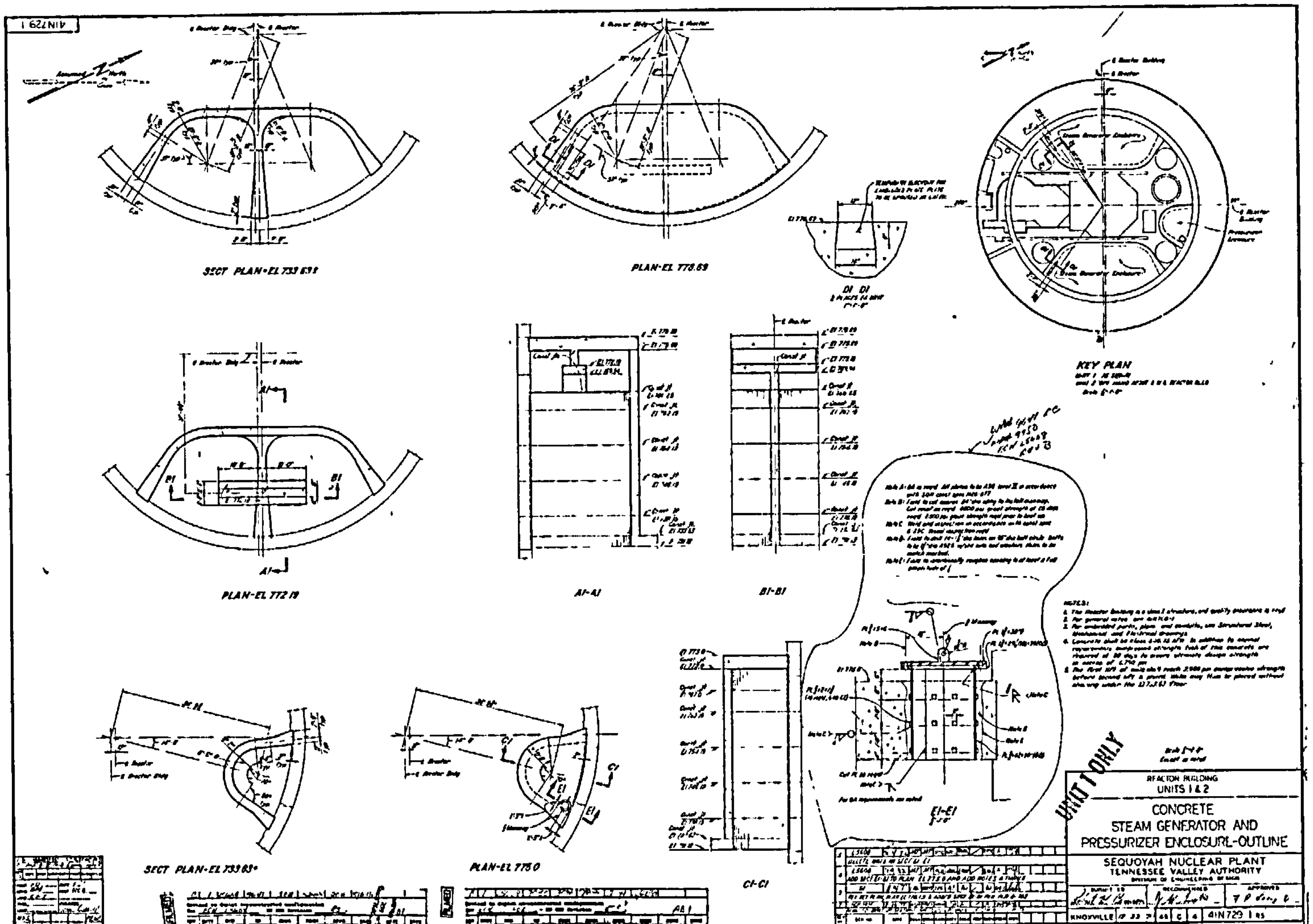

Figure 6-1 – Concrete Steam Generator and Pressurizer Compartment - Outline

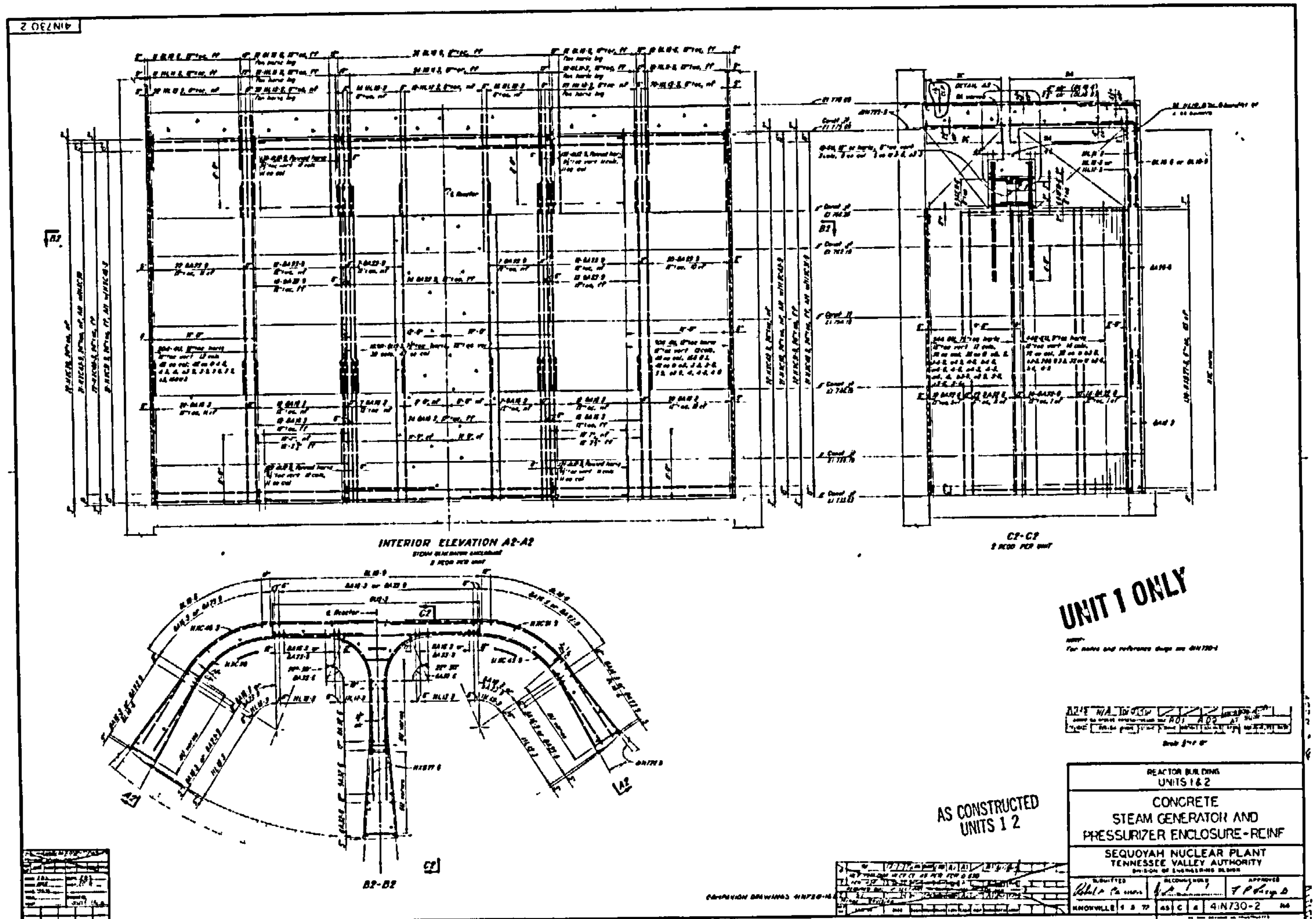

Figure 6-2 – Concrete Steam Generator and Pressurizer Compartment - Reinforcement

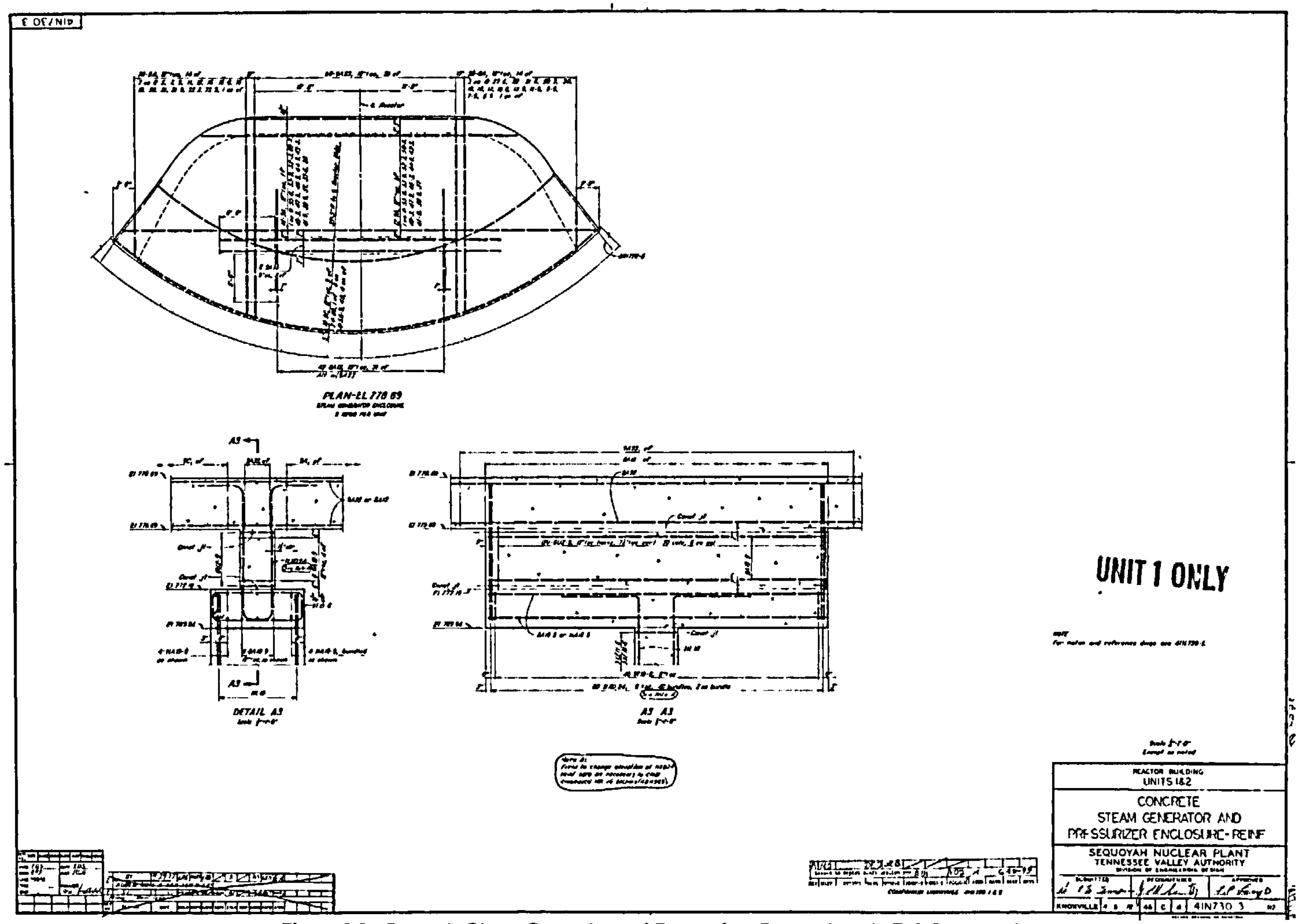

Figure 6-3 - Concrete Steam Generator and Pressurizer Compartment - Reinforcement

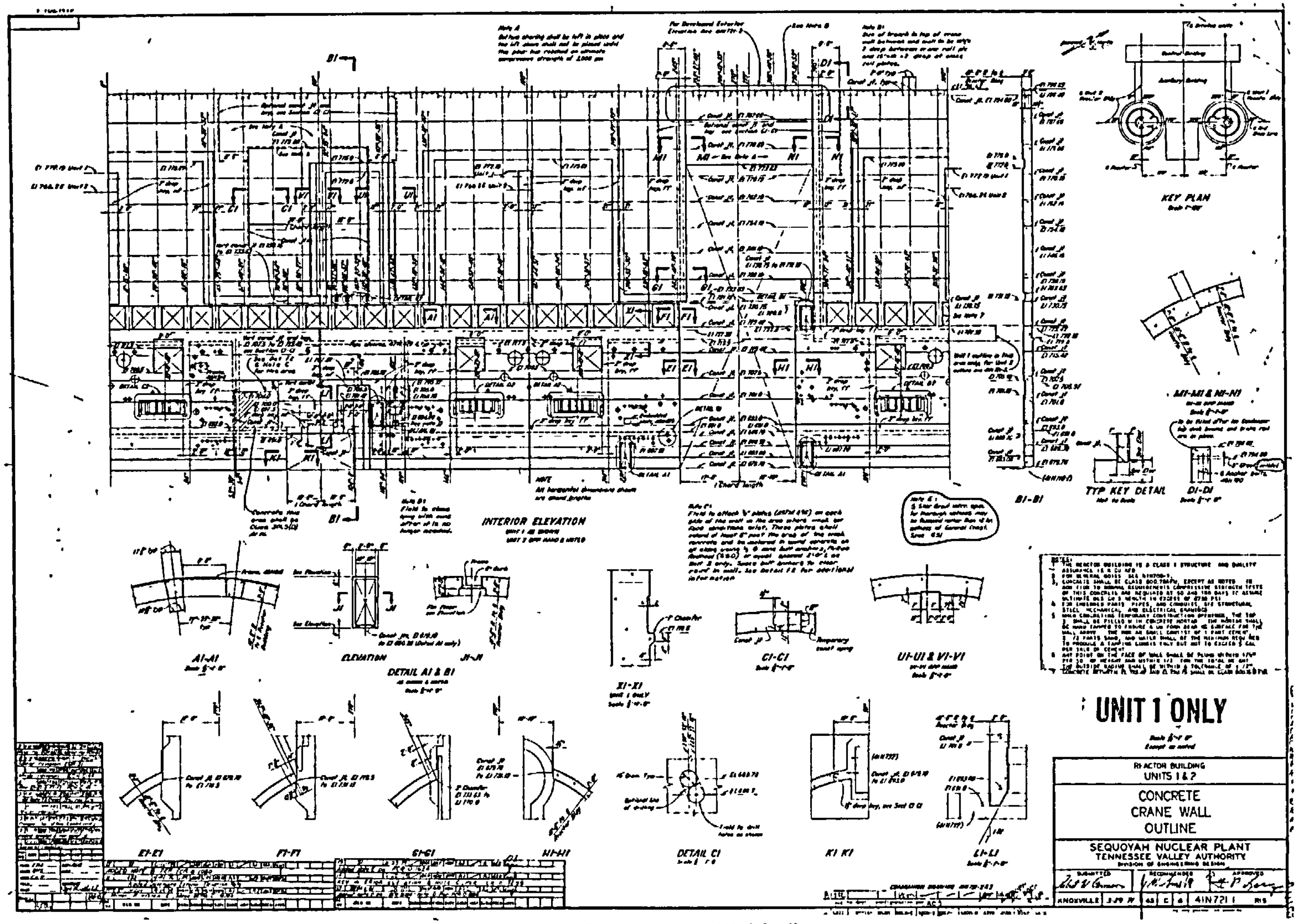

Figure 6-4 – Concrete Crane Wall Outline

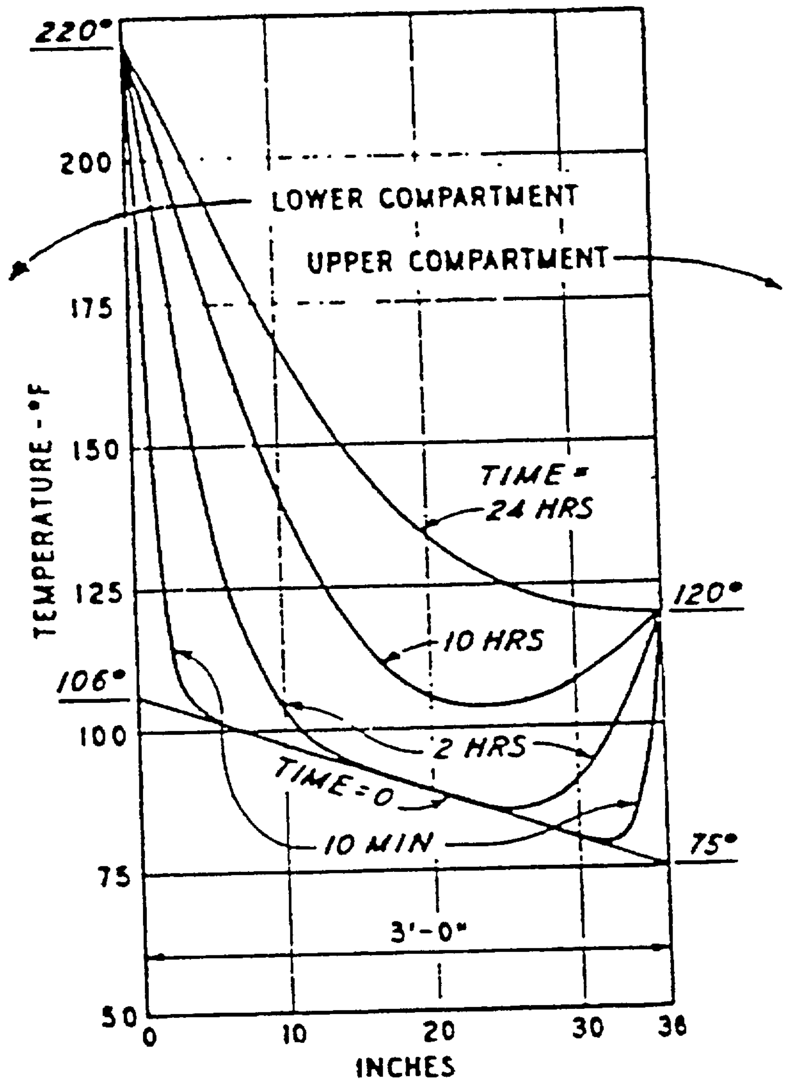

Figure 6-5 – Temperature Gradient (UFSAR Figure 3.8.3-2)

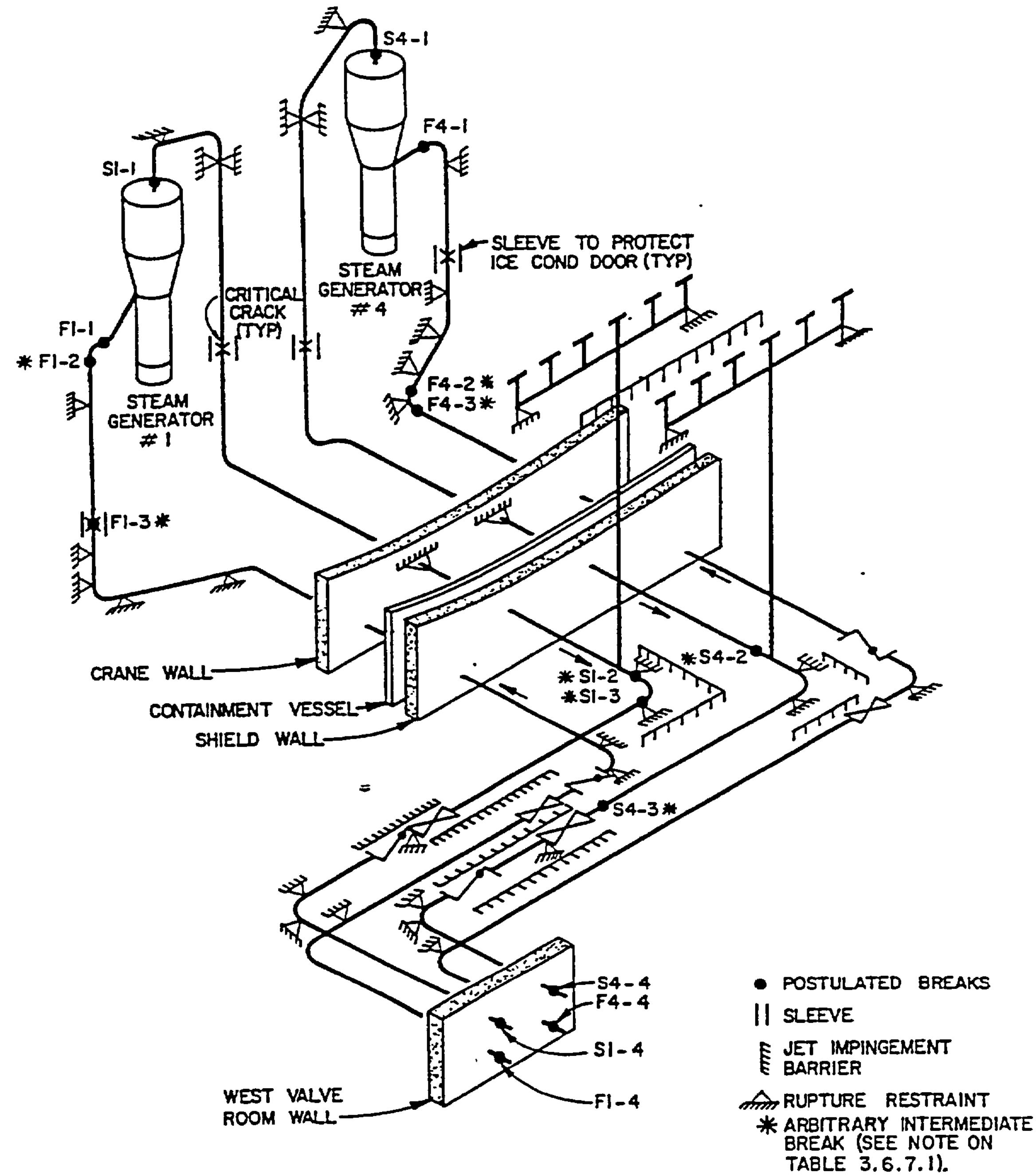

Figure 6-6 – Steam Generators 1 and 4 Postulated Break Locations and Fixes (UFSAR Figure 3.6.7-1)

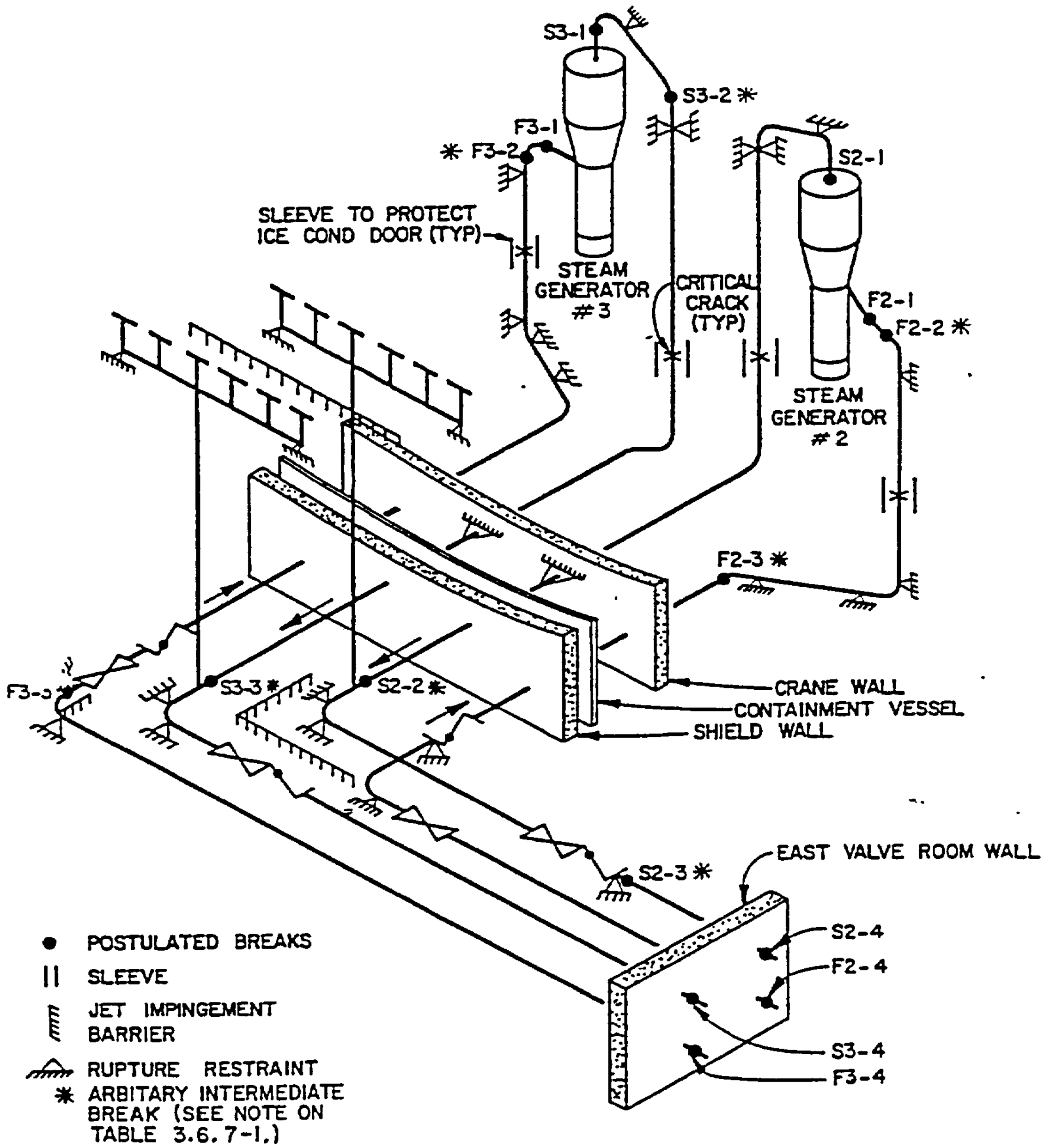

Figure 6-7 – Steam Generators 2 and 3 Postulated Break Locations and Fixes (UFSAR Figure 3.6.7-2)

7.0 Description of Modification to the Structure and New Analyses

After installation of the replacement steam generators, the removed concrete section (plug) of the steam generator compartment roof will be reattached to the complimentary portion of the existing SG compartment by means of top and bottom steel connection frames The plug will be attached to the top and bottom connection frames using four 2-inch diameter threaded rods that are installed in core bore holes through the plug. The top and bottom connection frames will clamp the concrete plug to the complimentary portion of the SG compartment using six 2-1/2 inch and eighteen 2-inch diameter threaded rods. The threaded rods are installed in the core bore holes located around the cut line as shown on Figure 7-2. The frames consist of box beams made from 1-1/4 inch ASTM A572 Grade 50 material with a yield stress of 50 ksi. The threaded rods conform to ASTM A193 Grade B7 material with a yield stress (F_y) of 105 ksi. The threaded rods will be preloaded to a stress level of 0 7 (F_y) after the annular space between the concrete plug and the complimentary portion of the existing SG compartment is grouted. This configuration will transfer all the vertical forces from the concrete plug to the complimentary portion of the existing SG compartment structure The lateral forces will be transferred to the existing SG compartment structure by a series of steel shims (ASTM A36 material) that will be driven into the annular space around the perimeter of the plug and mechanically locked into place prior to grouting.

The width of the opening between the concrete plug and the complimentary portion of the SG compartment will vary as the wire rope used to make the cuts wears. The surface of the cutout section of concrete will be prepared to provide a gap that ranges from ¾-inches to 1-¼ inches The non-shrink grout to be used to fill the annular gap and the core bore holes is Masterflow 928 or Masterflow 713 Plus as manufactured by ChemRex This grout is produced under a Quality Assurance program and is certified to comply with the requirements of ASTM C1107. This ASTM standard requires that the grout be tested for height change and compressive strength. The non-shrink grout, like the surrounding concrete, could "theoretically" experience the formation of micro-cracks when subjected to the design pressure load. Conservative estimates (Reference 8) of the flow path through these micro-cracks yield values that are 1.6 percent of the total design bypass leakage flow area of 5 square feet discussed in UFSAR Section 6.2.1.3.5. The design leakage area is composed of a known leakage area of approximately 2 square feet and an undefined leakage area. Any leakage through cracks in the grout would be part of this undefined leakage area. UFSAR Figure 6.2.1-22 (provided as Figure 7-1) shows that this percentage increase in bypass area would result in a very small increase in the upper containment pressure. Therefore, micro-cracks resulting from the design pressure load will have a negligible effect on the function of the divider barrier and the analyses that depend on the divider barrier. The SG compartment roof modification described above is detailed on Figure 7-2.

The above mode of restoration results in a modified configuration to the roof of the SG compartment. The use of steel through-bolted connection frames essentially results in a more flexible boundary condition along the cut-line. In other words, this boundary condition behaves more like a hinge. This means that the reinstalled concrete section of the roof is more flexible than the original configuration, and therefore, subjected to higher deflections and bending moments towards its center. The frame structure is designed to accommodate this increased deflection Also, the inverted concrete T-beam section under the concrete roof acts like a spacer transmitting the whip-restraint forces from the main steam pipe to the 3 feet thick roof. In the original configuration, the T-beam provided considerable strength in resisting the pipe whip loads. It is noted that since the reinstalled concrete section in the modified configuration is more flexible than the original design, the forces are redistributed within the reinstalled concrete section. The effects on the walls surrounding the SG compartment (3 feet thick crane wall, 2 feet thick compartment wall and the center wall) were also evaluated. Therefore, as described below, the evaluation of the modified configuration included the T-beam, roof, crane wall, SG compartment walls, and center wall.

The modified SG compartment roof was evaluated to load combinations, load factors, and allowable stresses tabulated in Table 7-2. Table 7-2 is based on Sections CC-3200 and CC-3400 of ASME Section III, Division 2, 1975, which are generally consistent with UFSAR Table 3.8.3-2. Exceptions to UFSAR Table 3.8.3-2 are the load factors associated with the Yr load and the allowable stresses when thermal effects are included with other loads. The Yr load factors used to evaluate the modified SG compartment roof are consistent with ASME Section III, Division 2, 1975. The allowable stresses due to thermal effects are consistent with both the Proposed ASME Section III, Division 2, 1973 and ASME Section III, Division 2, 1975. The structural steel through-bolted connection frames are designed in accordance with Reference 3.

As noted in Section 6.0, the load combinations in Table 3.8.3-2 of the UFSAR are based on Table CC-3200-1 of the Proposed ASME Section III, Division 2, 1973, Proposed Standard Code for Concrete Reactor Vessels and Containments, Section CC-3000 which was issued in 1973 (the time of original design) by ACI-ASME Committee on Concrete Pressure Components for Nuclear Service for trial use and comment. The purpose of this topical report is to support taking an exception for the load factors associated with the Yr load (reaction load due to fluid discharge on broken pipe, which in the present case is the pipe thrust load) for the Abnormal and Abnormal/Severe Environmental Load Categories as described below. Use of this exception is consistent with the adopted 1975 and later editions of ASME Section III, Division 2 (Reference 12).

In the original design analyses the Yr load was combined with load factors of 1.5 and 1.25 that are associated with the DBA design pressures for the Abnormal and Abnormal/Severe Environmental Load Categories, respectively. The jet impingement / pipe-whip / pipe break loading (Yr) will rapidly increase, peaking shortly after pipe break and then rapidly decrease in amplitude. The associated DBA pressure loadings will take considerable time following pipe break to reach their design basis peak amplitude values. It is, therefore, overly conservative to combine the DBA pressures with design basis pipe-whip load. The adopted 1975 and later editions of ASME Section III Division 2 (Reference 12) do not include this load combination. The load combinations and allowables used in this analysis for the Abnormal and Abnormal/Severe Environmental Load Categories were based on Table CC-3230-1 (included in this report as Table 7-1) of the adopted 1975 Edition of ASME Section III Division 2 (Reference 12), which superseded the Proposed Code (Reference 11). Note that the load denoted as Rr in Reference 12 corresponds to the Yr load in Reference 11. Also, as allowed by Section CC-3400 of both the proposed 1973 and adopted 1975 versions of ASME Section III, Division 2, credit is taken for the allowable stresses in concrete and rebar to be increased by 33-1/3% for service loads, and the tensile strain in rebar to exceed yield for factored loads when thermal gradient effects are included in the load combinations.

It is also noted that it is acceptable to use a later edition of the ASME Section III code for repairs and replacement per ASME Section XI (Reference 13). Further, it is noted that the design DBA differential pressure of 24 psi being used in the SG compartment roof evaluation is conservative since it is higher than the maximum calculated differential pressure of 19.52 psi by 23%. These conservatisms further justify the use of load factors for the Abnormal and Abnormal/Severe Environmental Load Categories based on the adopted 1975 Edition of ASME Section III, Division 2 (Reference 12) without compromising the integrity of the modified SG compartment roof.

The modified configuration of the SG compartment was analyzed for design loads using a 3D finite element ANSYS (Version 5.6) model (Reference 6). Although the roof remains the focus of the evaluation, the model (provided as Figure 7-3) included five components – the 3 feet thick roof, entire SG compartment wall, center wall, 180° sector of the crane wall, and the whip restraint beam; to obtain an accurate representation of the system. The finite elements used were SHELL43 elements for the roof and walls, BEAM44 elements for the whip restraint beam, and BEAM4 elements for the portions of the crane wall where it has openings to the ice condenser. The top of the SG compartment roof is at elevation 778.69'. The compartment wall was modeled as fixed at elevation 733.63 at the top of the containment operating floor; and the crane wall (Figure 6-4) is modeled as fixed at elevation 721' where the ice condenser floor is located. The nodes at the cut-line along which the connection frames and tapered steel shims are located were realistically modeled to transmit vertical forces and in-plane compression only. The material properties used in the model for the concrete were consistent with those used in the original analysis in Reference 5.

The loads, load combinations and allowable stresses to which the modified SG compartment was evaluated are documented in Reference 7 and summarized in Table 7-2. The modified configuration of the SG compartment roof was analyzed for the following design loads: dead load, live load, design pressure differential of 24 psi from a DBA (main steam pipe break), operating and accident temperature effects, seismic effects (OBE and SSE), and pipe thrust load on the whip-restraint beam from a broken main steam pipe. Design pressure, seismic, and pipe thrust effects were modeled as equivalent static loads. The pipe thrust load applied was 926.25 kips, which is based on the blowdown load documented in Reference 14 and conservatively includes a factor of 1.5 to account for the gap between the MS piping and the restraint (as used in the original analysis).

As noted in Section 6.0, the SG compartments were originally designed for a hypothetical pressure of 43 psi resulting from the rupture of a reactor coolant pipe. This pressure was used to provide a high degree of conservatism in the original design, which allowed the structure to accommodate a range of possible equipment configurations and final analysis results. The concrete strength used in the roof evaluation is the in-place compressive strength of the SG compartment roof concrete at 90 days, which is 5700 psi (Reference 5, Sheets 2e and 2f).

The steel through-bolted connection frames and tapered steel shims were designed and evaluated for the load combinations as described in the previous discussion based on criteria in Section 5.1 of Appendix A to Reference 3.

The vertical design loads on the concrete plug will be transferred into the SG compartment structure around the perimeter of the plug by the clamping forces induced by the through-bolts connecting the top and bottom steel connection frames. For example, a vertical load in the upward direction, acting on the concrete plug, would be transferred to the compartment structure as follows:

The vertical load from the plug will be transferred by bearing between the concrete plug and the steel bearing plates (located between the concrete and the steel frame), to shear in the steel frame, to tension in the through-bolt, back to shear in the lower frame, to bearing between the steel bearing plates and the concrete of the SG compartment

The horizontal design loads on the concrete section will be transferred into the SG compartment structure via tapered steel shim sets. Each tapered shim set will be comprised of a tapered shim attached to the face of the concrete section and a loose tapered shim that will be driven into the gap between the fixed tapered shim and the existing compartment concrete. When installed snugly, the loose tapered shim will be welded to the tapered fixed shim to prevent movement. Approximately 30 tapered shim sets (~15 top and ~15 bottom) will be installed around the perimeter of the compartment concrete section Conservatively, only four (4) tapered shim sets will be considered to transfer all the horizontal design loads between the concrete section (with frame attached) and the compartment structure. The grout between the concrete section and compartment structure will not be considered to transfer any design basis loads

The Divider Barrier will be restored by covering the annular space around the perimeter of the plug on the bottom side of the 3-foot thick SG compartment roof and filling the space with non-shrink grout

Table 7-1 (Table CC-3230-1 from ASME Section III, Division 2, 1975) Load Combinations and Load Factors

Category	D	L[1]	F	P_t	P_a	T_t	T_o	T_a	E_o	E_{ss}	W	W_t	R_o	R_a	R_r	P_v	H_q
Service:																	
Test	1.0	1.0	1.0	1 0	...	1 0	...	...	...	.	.	...	...	...	...	...	...
Construction	1.0	1.0	1.0		...	...	1.0	...	..	...	. .	...	...	...	...	...	. .
Normal	1.0	1.0	1.0	.	. .	...	1.0	. .	...	. .	..	.	1.0	...	...	1.0	...
Severe environmental	1.0	1.0	1 0		..	...	1.0	...	1 0	..	..	...	1 0	...	...	1.0	. .
	1 0	1.0	1.0	.		...	1 0	...	...	...	1 0		1 0	...	...	1.0	...
Factored:																	
Severe environmental	1 0	1.3	1.0	...	..	..	1 0	..	1.5	...	...	...	1 0	..	...	1 0	...
	1.0	1.3	1.0	..		...	1 0	...	...	...	1.5	...	1 0	. .	...	1.0	...
Extreme environmental	1.0	1.0	1.0	..		..	1 0	...	...	1.0	...	. .	. .	..	...	1.0	...
	1 0	1.0	1.0	..	. .	.	1 0	...	...	...	...	1 0	...	...	..	1 0	...
Abnormal	1 0	1.0	1.0	..	1 5	.	. .	1 0	...	...	...	...	...	1 0	...	..	...
	1.0	1.0	1 0	..	1 0	.	..	1.0	...	...	..	...	.	1 25	...	...	...
Abnormal/Severe environmental	1 0	1.0	1.0	..	1.25	...	...	1.0	1.25	...	...	..	. .	1 0	...	. .	...
	1.0	1 0	1.0	.	1 25	.	...	1.0	...	...	1 25	...	. .	1 0	...	...	...
	1.0	1 0	1 0	..	...	...	1.0	...	1.0	...	1 0		...	...	...	...	...
Abnormal/Extreme environmental	1.0	1 0	1.0	..	1.0	...	...	1.0	...	1.0	...	.	...	1 0	1.0	...	...

NOTE:
(1) Includes all temporary construction loading during and after construction of containment.

Table 7-2
Loading Combinations, Load Factors and Allowable Stresses for SG Compartment Roof Modification (5)(6)

Category	T_a	D	$L_{(1)}$	P_a	T_o	F_{eqo}	F_{eqs}	R_o	R_a	Y_r	Allowable Stresses
Service:											(Flexure) $f_c = 0.45 f'c$
Const	—	1.0	1.0	—	1.0	—	—	—	—	—	$f_s = 0.50 f_y$ (3)
Normal	—	1.0	1.0	—	1.0	1.0	—	1.0	—	—	(Shear) 50% of Factored (3)
Factored. Extreme Environmental	—	1.0	1.0	—	1.0	—	1.0	1.0	—	—	(Flexure) $f_c = 0.75 f'_c$ $f_s = 0.90 f_y$ (4)
Abnormal	1.0	1.0	1.0	1.5	—	—	—	—	1.0	—	(Shear) (2) $v_c = 2\sqrt{f'_c}$
Abnormal/ Severe Environmental	1.0	1.0	1.0	1.25	—	1.25	—	—	1.0	—	$\phi = 0.85$
Abnormal/ Extreme Environmental	1.0	1.0	1.0	1.0	—	—	1.0	—	1.0	1.0	

NOTES:

1. Includes all temporary construction loading during and after construction of containment
2. v_c is lower for tension members and is given by $v_c = 2\sqrt{f'_c}$ (1 + 0 002N_u/A_g), with Nu negative for tension
3. The allowable stress is increased by 33-1/3% when temperature effects are combined with other loads.
4. The tensile strain may exceed yield when the effects of thermal gradients are included in the load combination, i e , f_s can be <= f_y, and ε_s can be > ε_y when thermal effects are included
5. The load combinations, load factors and allowable stresses in this table are based on the ASME Section III Division 2, 1975, which are, in general, consistent with the proposed ACI 359 - ASME Section III Division 2, 1973 with the exception of load factors associated with the Y_r load
6. Structural steel components of the through-bolted connection frames and tapered steel shims were designed in accordance with TVA Design Criteria SQN-DC-V-1 3 2, Miscellaneous Steel Components for Class I Structures

LOADS NOMENCLATURE:

D	Dead loads, or their related internal moments and forces
F_{eqo}	Operating basis earthquake
F_{eqs}	Design basis earthquake
L	Live load, or their related internal moments and forces
P_a	Accident/incident maximum pressure
R_o	Piping loads during operating conditions
R_a	Piping loads due to increased temperature resulting from the design accident
T_a	Thermal loads under the thermal conditions generated by the postulated break and including T_o
T_o	Operational temperature
Y_r	Reaction load on broken pipe due to fluid discharge (corresponds to R_r in ASME Section III, Division 2, 1975)

* The term "design basis earthquake" has the same meaning as the term "safe shutdown earthquake "

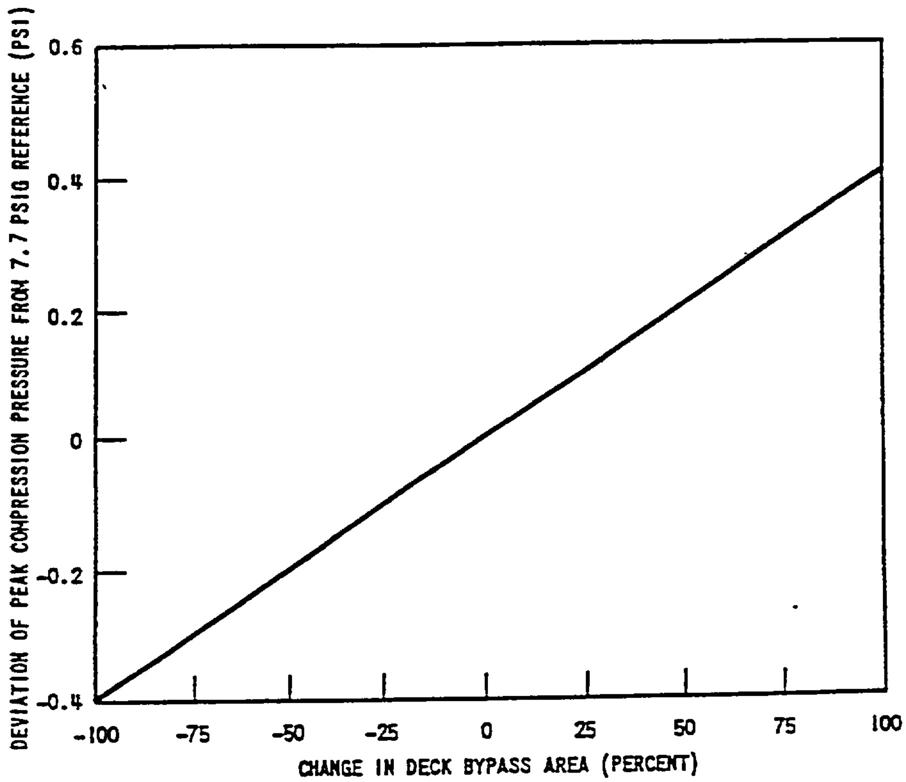

Figure 7-1 – Sensitivity of Peak Compression Pressure to Deck Bypass (UFSAR Figure 6.2.1-22)

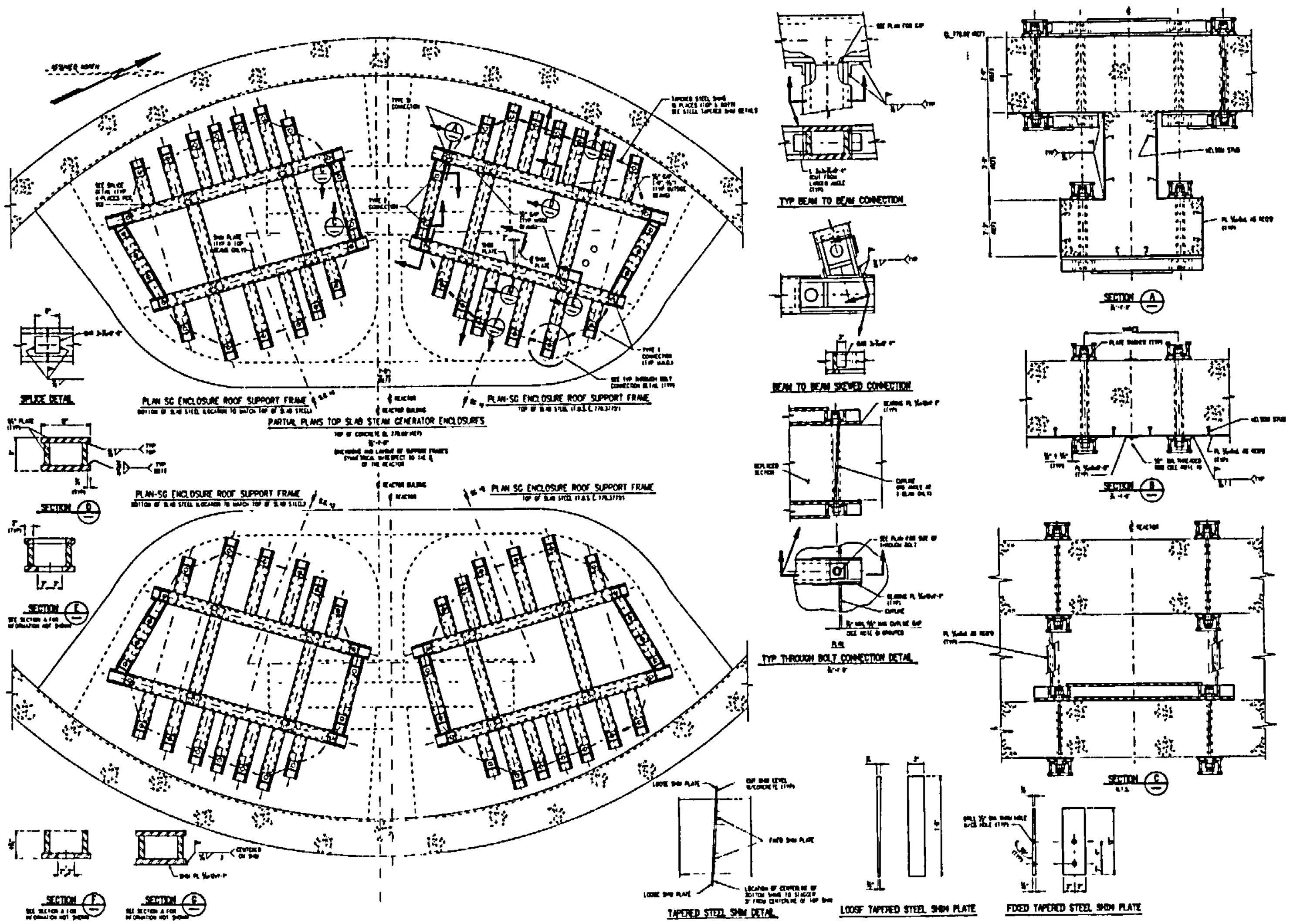

Figure 7-2 – Steam Generator Compartment Roof Connection Frame Layout and Connection Details

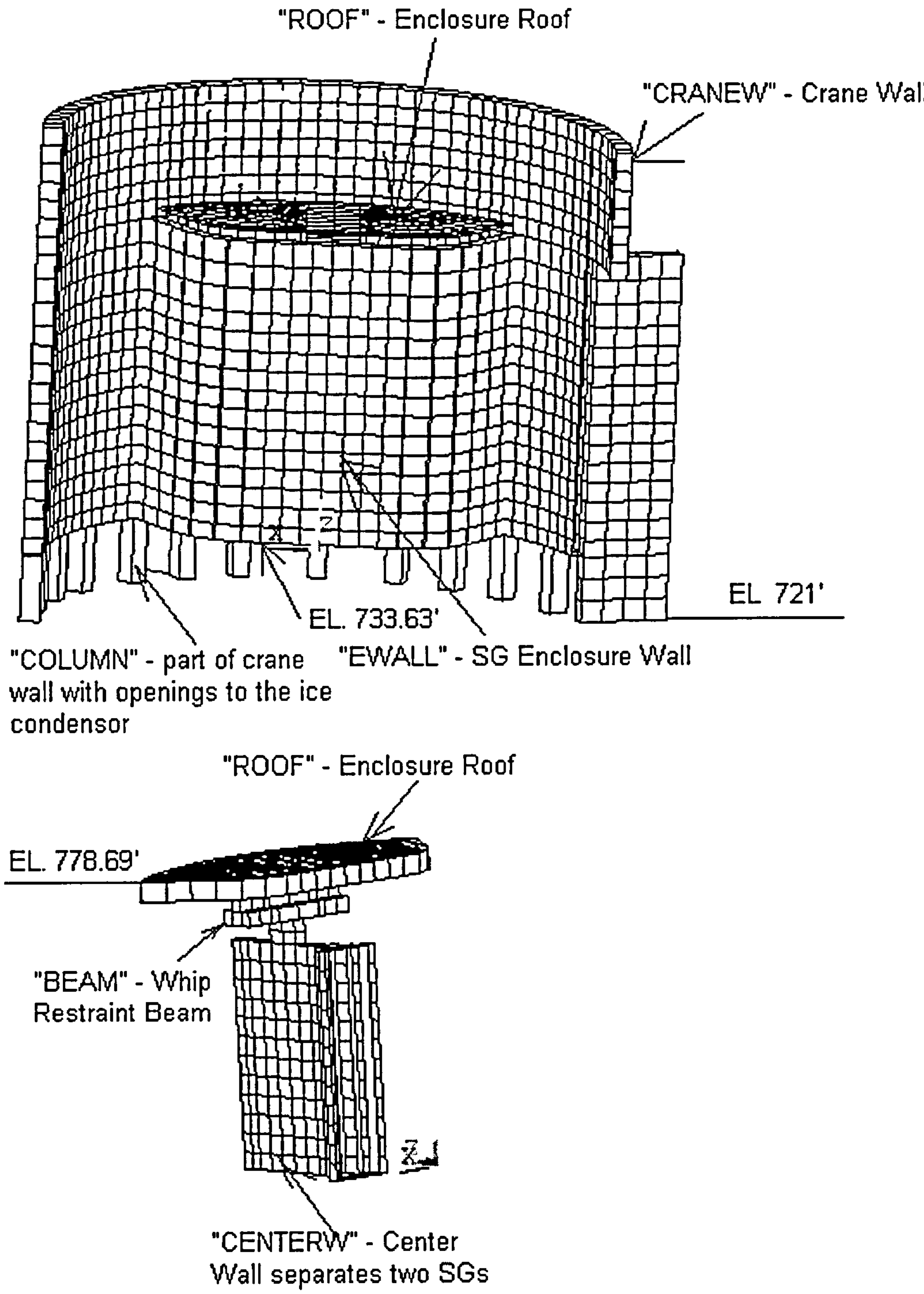

Figure 7-3 – Finite Element Model "SGE1" and "SGE2" and Element Groups and Global Coordinate Systems (Reference 6)

8.0 Results of New Analyses

The modified configuration of the steam generator compartment roofs has been evaluated for the design loads and load combinations documented in Reference 7 as described in Section 7.0. Except as noted in Section 7.0, these design loads and load combinations are consistent with those used in the original analyses for the SG compartments. The structural adequacy of the modified SG compartment roof configuration under these design loads and load combinations was evaluated in Reference 8. The design of the steel through-bolted connection frames and tapered steel shims is documented in Reference 9. The results are briefly summarized below.

Normal service load combinations used to evaluate the modified SG compartment roof configuration were the same as those used for the original configuration. Under normal service load conditions, the maximum concrete and rebar stresses in the modified roof are within the allowable normal service concrete and rebar stress limits as specified in Section CC-3430 of ASME Section III, Division 2, 1975 (summarized in Table 7-2). The critical areas where these stresses occur are near the middle surface of the cut section at the junction of the roof and the end of the whip restraint beam (Reference Area 1 on Figure 8-1). The stress levels in other areas are generally much lower. Therefore, the modified SG compartment roof configuration is acceptable under normal service conditions.

The load combinations evaluated for the modified roof were based on Table CC-3230-1 (included in this report as Table 7-1) of the adopted 1975 Edition of ASME Section III Division 2 (Reference 12), which replaced the Proposed Code (Reference 11) as discussed in Sections 6.0 and 7.0. These load combinations are similar to those used for the original SG compartment roof design except for the Abnormal and Abnormal / Severe Environmental load categories for which the Yr load is now not considered in the load combination. For factored load combinations on the modified roof configuration, the most critical load combinations are the Abnormal and Abnormal / Extreme Environmental load categories. The critical areas of high stresses for the Abnormal load combination are the approximately triangular corner areas of the existing roof bounded by the cut-line near each end of the center wall (Reference Areas 2 and 3 on Figure 8-1). For the Abnormal / Extreme Environmental load combination the critical area included the area near the middle of the cut section at the junction of the roof and the end of the whip restraint beam (Reference Area 1 on Figure 8-1) in addition to the corner areas identified for the Abnormal load combination. It is noted that the maximum stresses/forces occurred only in the localized areas mentioned above. The stresses in other areas are lower. The maximum stresses, in these critical areas, for the factored load combinations were found to be within the allowable concrete and rebar stresses based on limits specified in Section CC-3400 of ASME Section III, Division 2, 1975. The maximum vertical deflection occurred for the Abnormal / Extreme Environmental load combination at the middle of the roof near the end of the whip restraint beam.

It is noted that the design DBA differential pressure of 24 psi was used in the modified SG compartment roof stress evaluation. Even though the calculated stresses under accident conditions equaled the allowable stresses in some locations, this analysis is conservative since it used a differential pressure that is 23% higher than the maximum calculated differential pressure of 19.52 psi.

The influence of the modified roof configuration on stresses in the SG compartment wall sections adjacent to the roof has been determined to be insignificant and the wall and roof stresses remain within design allowables.

The design of the steel through-bolted connection frames and tapered steel shims documented in Reference 9 is described in Section 7.0 and shown on Figure 7-2. The through-bolts will be installed with a pre-tension load based on 0 $7F_y$. Using conservative design checks, the maximum calculated bending stress in the connection frame beams and the maximum calculated bearing stress on concrete and the tapered steel shims were determined to be below allowables. The connection frame beams will be used in conjunction with the through-bolts to provide the clamping action that will transfer the vertical design basis loads from the concrete section to the compartment The connection frame beams span over all of the connection through-bolts. Since all the connection frame beams are connected together, rigid body rotations of the beams about the bolt axes are prevented at all concrete section/compartment connections.

The connection frame beams have been designed to transfer all vertical design loads, at the concrete section/compartment interface, via bending and shear stresses. The beams have been designed such that the maximum stresses in the beam plates and connecting welds are less than the allowable stresses

The connection frame beams are sized such that the concrete bearing stresses under the beams are below allowables due to both the connection through-bolt pre-tension loads and due to all design basis loads

The connection frame beams are connected by web angles or connection plates. The welded angles/plates are designed to be flexible in order to transfer all vertical design loads between beam members of the frame, as pinned connections. Vertical loads are due to the vertical seismic inertia from the concrete and the maximum DBA pressure (seismic inertia loading from the steel frame is negligible). As the concrete section deflects, it lifts the individual frame members, hence, inducing vertical loads at the beam-to-beam connections and vertical prying loads at the through-bolt connections The beam connection angles/plates are also designed to transfer all horizontal seismic loads due to the maximum accelerations of the frame.

Based on the evaluations in the calculations noted above, the modified SG compartment roofs have been found to be structurally adequate for the loads associated with the design loading conditions/combinations which are in general consistent with the original design except as noted above and in Section 7.0.

The modifications to the steam generator compartment roofs do not affect the structural capability of the steam generator compartments to contain the internal pressure associated with the design bases main steam line breaks. The modifications do not affect temperature differentials through the compartment roof or the radiation shielding capacity of the structures.

As discussed in Section 6.5.6.3 of the UFSAR, there is a maximum calculated leakage of 250 cfm between the upper and lower containment through the divider barrier, of which the steam generator compartments are part. The amount of leakage between the two sections of the containment will not be affected by the restoration of the steam generator compartment roofs. The use of non-shrink grout to seal the joint created between the concrete sections and the remaining structure will maintain the boundaries between upper and lower containment. It is noted that any leakage due to possible cracks in the grout, particularly under design DBA loading, will be extremely small and therefore insignificant (Reference 8).

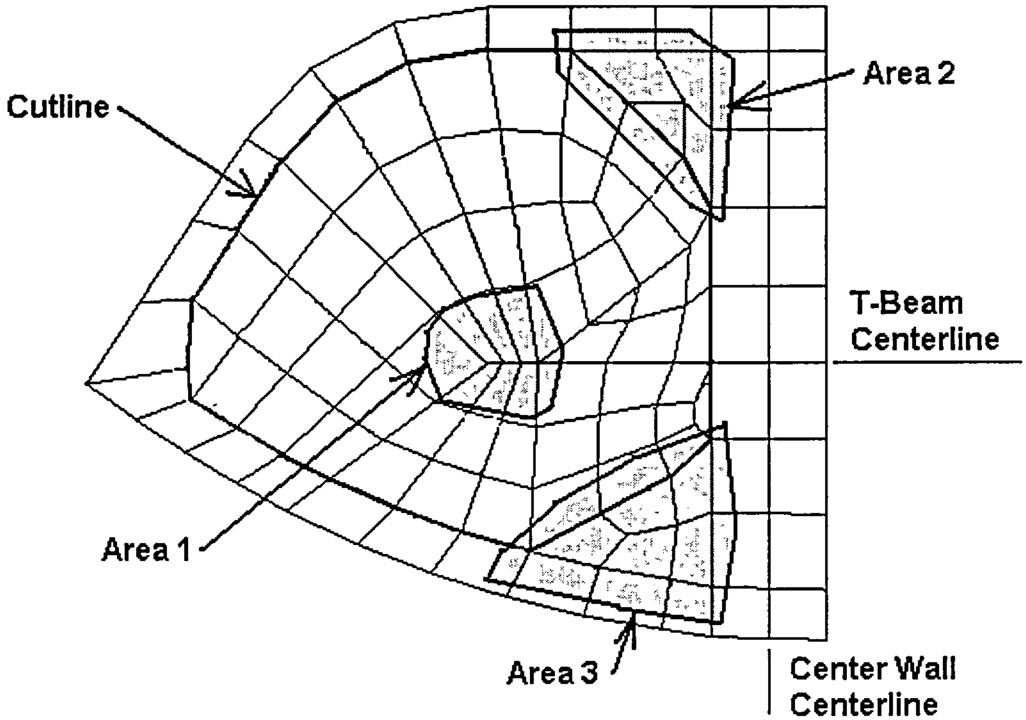

Figure 8-1
Areas of Critical Stresses

9.0 Summary and Conclusions

Restoration of the SG compartment will be accomplished by reattaching the removed section of concrete using through-bolted structural steel connection frames and tapered steel shims in the annular gap. The SG compartments have been reanalyzed to determine that the modified configuration is acceptable. This analysis follows the same basic approach as documented in the existing SG compartment design calculations, the Sequoyah design criteria, and/or the Sequoyah UFSAR. Areas where the two analyses differ are summarized in Table 9-1.

Table 9-1
Differences Between Original and
New Steam Generator Compartment Analyses

Original Analyses	New Analyses
• Analyzed compartment structure as several individual components (roof, enclosure wall, center wall, and crane wall) using two-dimensional model.	• Analyzed compartment structure using a three dimensional ANSYS finite element model comprised of system components.
• Evaluated compartment structure for a 43-psi hypothetical pressure.	• Did not evaluate compartment structure for a 43-psi hypothetical

Original Analyses	New Analyses
	pressure.
• Analyzed compartment structure initially for a maximum differential pressure of 21.3 psi which is a 25% increase over the DBA pressure differential of ~17 psi for the SG compartment provided by Westinghouse (i.e., 1.25 x 17 psi). Per NRC request, a 40% increase in DBA differential pressure (i.e., 1.4 x 17 psi) was investigated later.	• Analyzed compartment structure for a maximum design internal differential pressure of 24 psi as specified in the UFSAR using loads, load combinations and allowable stresses documented in Table 7-2.
• Evaluated compartment roof globally for an equivalent static jet thrust force (~910 kips on the roof) that would result following a main steam pipe break inside a single compartment.	• Evaluated the modified roof globally for an equivalent static pipe thrust load of 926.25 kips which is based on the shock spectrum from the MS Blow Down Analysis.
• Analyzed the compartment structure using the load combinations, load factors, and allowable stresses shown in UFSAR Tables 3.8.3-1 or 3.8.3-2.	• Analyzed the modified compartment structure using load combinations and allowable stresses in Table 7-2. Load factors for the load combinations and allowable stresses were based on Table CC-3230-1 and Section CC-3400, respectively, of the 1975 Edition of ASME Section III, Division 2.

Use of the methodologies, loads and load combinations discussed in this topical report are either consistent with the original design basis or based on accepted industry design standards. The proposed modifications to the SG compartment design are therefore justified.

10.0 References

1. Sequoyah Nuclear Plant Updated Final Safety Analysis Report, Amendment 16.
2. TVA Design Criteria SQN-DC-V-1.1, Design of Reinforced Concrete Structures. Revision 16.
3. TVA Design Criteria SQN-DC-V-1.3.2, Miscellaneous Steel Components for Class I Structures, Revision 10.
4. TVA Design Criteria SQN-DC-V-1.3.3.1, Additions After November 14, 1979 – Reinforced Concrete, Structural, and Miscellaneous Steel, Revision 6.
5. TVA Calculation SCG-1-40, Steam Generator Compartment, Final Design, Revision 4.
6. TVA Calculation SCG-1S-607, Evaluation of Steam Generator Compartment Modification – 3D Finite Element Model, Revision 0.
7. TVA Calculation SCG-1S-608, Evaluation of Unit 1 Steam Generator Compartment Modification – Load Conditions and Allowable Stresses, Revision 0.
8. TVA Calculation SCG-1S-609, Evaluation of Steam Generator Compartment Modification – Finite Element Analysis Results, Revision 0.
9. TVA Calculation SCG-1S-610, Evaluation of Unit 1 Steam Generator Compartment Modification – Design of Roof Support Frames, Revision 1.
10. Bechtel Calculation 24370-C-013, Rev. 0, ANSYS 5.6 Verification.

11. Proposed ASME Section III Division 2, 1973, Proposed Standard Code for Concrete Reactor Vessels and Containments, Section CC-3000 (This draft code was issued in 1973 by ACI-ASME Committee on Concrete Pressure Components for Nuclear Service for Trial Use and Comment).
12. ASME Section III Division 2, 1975 Edition, Concrete Reactor Vessels and Containments, Section CC-3000.
13. ASME Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components.
14. TVA Calculation 0600117- S002, R0, Blow Down Analysis – Main Steam System.
15. TVA-NQA-PLN89-A, Nuclear Quality Assurance Plan, Revision 10.
16. General Engineering Specification G-2, Plain and Reinforced Concrete, Revision 7.

Appendix A
No Significant Hazards Consideration Determination

I. DESCRIPTION OF THE PROPOSED CHANGE

The four steam generators of the Sequoyah Nuclear Plant Unit 1 will be replaced during the spring of 2003. To support the replacement of the old steam generators (OSGs) with the replacement steam generators (RSGs), access openings will be created in the roof of the steam generator (SG) compartments inside containment. An appropriately sized access opening will be made in each SG compartment roof by cutting out a section of concrete from the roof of the compartments.

Upon completion of installation of the RSGs, the original cut section (plug) of the SG compartment roof will be reinstalled using a modified configuration from the original. The concrete plug removed from each of the SG compartment roofs will be reattached to the complimentary portion of the SG compartment roof by means of top and bottom steel connection frames. The plug will be attached to the top and bottom connection frames using four 2-inch diameter threaded rods that are installed in core bore holes through the plug. The top and bottom connection frames will clamp the concrete plug to the complimentary portion of the SG compartment using six 2-1/2 inch and eighteen 2-inch diameter threaded rods. These threaded rods are installed in the core bore holes located around the plug cutline The frames consist of box beams mad from 1-1/4 inch steel A series of steel shims will be driven into the annular space around the perimeter of the plug and mechanically locked into place prior to grouting.

The threaded rods will be preloaded after the annular space between the concrete plug and the complimentary portion of the existing SG compartment is grouted. The core bores and the annular space between the concrete plug and the complimentary portion SG compartment roof will be grouted using non-shrink grout that conforms to ASTM C 1107, thereby sealing the roof.

II. REASON FOR THE PROPOSED CHANGE

The process for restoration of the steam generator compartment roof using the through-bolted connection frames results in less construction debris in containment since the concrete cuts will not require chipping for rebar splicing. The process is also simpler and faster than splicing new rebar and pouring new concrete.

III. SAFETY ANALYSIS

Normal service load combinations used to evaluate the modified SG compartment roof configuration were the same as those used for the original configuration. Under normal service load conditions, the maximum concrete and rebar stresses in the modified roof are within the allowable normal service concrete and rebar stress limits as specified in Section CC-3430 of ASME Section III, Division 2, 1975. The critical areas where these stresses occur are near the middle surface of the cut section at the junction of the roof and the end of the whip restraint beam. The stress levels in other areas are generally much lower. Therefore, the modified SG compartment roof configuration is acceptable under normal service conditions.

The load combinations evaluated for the modified roof were based on Table CC-3230-1 of the adopted 1975 Edition of ASME Section III Division 2, which replaced the proposed 1973 ASME Section III, Division 2. These load combinations are similar to those used for the original SG compartment roof design except for the Abnormal and Abnormal/Severe Environmental load categories for which the Yr load is now not considered in the load combination. For factored load combinations on the modified roof configuration, the most critical load combinations are the Abnormal and Abnormal/Extreme Environmental load categories. The critical areas of high stresses for the Abnormal load combination are the approximately triangular corner areas of the existing roof bounded by the cut-line near each end of the center wall. For the Abnormal/Extreme Environmental load combination the critical area included the area near the middle of the cut section at the junction of the roof and the end of the whip restraint beam in addition to the corner areas identified for the Abnormal load combination. It is noted that the maximum stresses/forces occurred only in the localized areas mentioned above. The stresses in other areas are lower. The maximum stresses for the factored load combinations were found to be within the allowable concrete and rebar stresses based on limits specified in Section CC-3400 of ASME Section III, Division 2, 1975. The maximum vertical deflection occurred for the Abnormal/Extreme Environmental load combination at the middle of the roof near the end of the whip restraint beam.

It is noted that the design DBA differential pressure of 24 psi was used in the modified SG compartment roof stress evaluation. Even though the calculated stresses under accident conditions equaled the allowable stresses in some locations, this analysis is conservative since it used a differential pressure that is 23% higher than the maximum calculated differential pressure of 19.52 psi.

The influence of the modified roof configuration on stresses in the SG compartment wall sections adjacent to the roof have been determined to be insignificant and the wall and roof stresses remain within design allowables.

The bolts used in the steel through-bolted connection will be preloaded to a stress level of 0.7 F_y. By conservative analysis, the maximum calculated bending stress in the connection frame beams and the maximum calculated bearing stress on concrete and the tapered steel shims were determined to be below allowables. The connection frame beams will be used in conjunction with the through-bolts to provide the clamping action that will transfer the vertical design basis loads from the concrete section to the compartment. The connection frame beams span over all of the connection through-bolts. Since all the connection frame beams are connected together, beam rigid body rotation about the bolt axes are prevented at all concrete section/compartment connections

The connection frame beams have been designed to transfer all vertical design loads, at the concrete section/compartment interface, via bending and shear stresses The beams have been designed such that the maximum stresses in the beam plates and connecting welds are less than the allowable stresses.

The connection frame beams are sized such that the concrete bearing stresses under the beams are below allowables due to both the connection through-bolt pre-tension loads and due to all design basis loads.

The connection frame beams are connected by web angles or connection plates The welded angles/plates are designed to transfer all vertical design loads between beam members of the frame, as pinned connections Vertical loads are due to the vertical seismic inertia from the concrete and the maximum DBA pressure (seismic inertia loading from the steel frame is negligible). As the concrete section deflects, it lifts the individual frame members, hence, inducing vertical loads at the beam-to-beam connections and vertical prying loads at the through-bolt connections. The beam connection angles/plates are also designed to transfer all horizontal seismic loads due to the maximum accelerations of the frame.

The modified SG compartment roofs have been found to be structurally adequate for the loads associated with the design loading conditions/combinations which are in general consistent with the original design except as noted above.

The modifications to the steam generator compartment roofs do not affect the structural capability of the steam generator compartments to contain the internal pressure associated with the design bases main steam line breaks. The modifications do not affect temperature differentials through the compartment roof or the radiation shielding capacity of the structures.

As discussed in Section 6.5.6.3 of the UFSAR, there is a maximum calculated leakage of 250 cfm between the upper and lower containment through the divider barrier, of which the steam generator compartments are part. The amount of leakage between the two sections of the containment will not be significantly affected by the restoration of the steam generator compartment roofs. The use of non-shrink grout to seal the joint created between the concrete sections and the remaining structure will maintain the boundaries between upper and lower containment. It is noted that any leakage due to possible cracks in the grout, particularly under design DBA loading, will be extremely small and therefore insignificant.

IV. NO SIGNIFICANT HAZARDS CONSIDERATION DETERMINATION

TVA has concluded that operation of SQN Unit 1, in accordance with the proposed modification to the steam generator compartment roof, does not involve a significant hazards consideration. TVA's conclusion is based on its evaluation, in accordance with 10 CFR 50.91(a)(1), of the three standards set forth in 10 CFR 50.92(c).

A. <u>The proposed amendment does not involve a significant increase in the probability or consequences of an accident previously evaluated.</u>

The probability of occurrence or the consequences of an accident are not increased as presently analyzed in the safety analyses since the objective of the event mitigation is not changed. No changes in event classification as discussed in UFSAR Chapter 15 will occur due to the modification of the Unit 1 steam generator compartment roof design.

The grout used to fill the gap between the replaced concrete and the surrounding concrete, like the surrounding concrete, could "theoretically" experience the formation of micro-cracks when subjected to the design pressure load. Conservative estimates of the flow path through these micro-cracks yield values that are numerically insignificant when compared to the allowable divider barrier bypass leakage. Micro-cracks resulting from the design pressure load will have a negligible effect on the function of the divider barrier and the analyses that depend on the divider barrier. Therefore, the containment design pressure is not challenged, thereby ensuring that the potential for increasing offsite dose limits above those presently analyzed at the containment design pressure of 12.0 pounds per square inch is not a concern.

Therefore, the proposed modification to the Unit 1 steam generator compartment roof design will not significantly increase the probability or consequences of an accident previously evaluated.

B. The proposed amendment does not create the possibility of a new or different kind of accident from any accident previously evaluated.

The possibility of a new or different accident situation occurring as a result of this condition is not created. The steam generator compartment roof forms part of the divider barrier. This barrier is not an initiator of any accident and only serves to force steam that is released from a LOCA/ DBA to pass through the ice condenser. The failure of any part of the divider barrier is considered critical since it would allow LOCA/DBA steam to bypass the ice condenser, thereby increasing the pressure within the primary containment.

As discussed in Section 6.5.6.3 of the UFSAR, there is a maximum calculated leakage of 250 cfm between the upper and lower containment through the divider barrier. The amount of leakage between the two sections of the containment will not be significantly affected by the restoration of the steam generator compartment roofs. The use of non-shrink grout to seal the joint created between the concrete sections and the remaining structure will maintain the boundaries between upper and lower containment. It is noted that any leakage due to possible cracks in the grout, particularly under design DBA loading, will be extremely small and therefore insignificant.

Therefore, the potential for creating a new or unanalyzed condition is not created.

C. The proposed amendment does not involve a significant reduction in a margin of safety.

A design DBA differential pressure of 24 psi was assumed in the original design of the steam generator compartment roof. This differential pressure is 23% higher than the maximum calculated differential pressure of 19.52 psi. Since the same design differential pressure was also used in the modified SG compartment roof stress evaluation, the margin of safety was not reduced.

As discussed previously, the amount of leakage that bypasses the divider barrier will not be affected by the restoration of the steam generator compartment roofs. The use of non-shrink grout to seal the joint created between the concrete sections and the remaining structure will maintain the boundaries between upper and lower containment. Hence, the worse-case accident conditions for the containment will not be affected by the proposed modifications.

Therefore, a significant reduction in the margin to safety is not created by this modification.

V. ENVIRONMENTAL IMPACT CONSIDERATION

The proposed change does not involve a significant hazards consideration, a significant change in the types of or significant increase in the amounts of any effluents that may be released offsite, or a significant increase in individual or cumulative occupational radiation exposure. Therefore, the proposed change meets the eligibility criteria for categorical exclusion set forth in 10 CFR 51.22(c)(9). Therefore, pursuant to 10 CFR 51.22(b), an environmental assessment of the proposed change is not required.