Tennessee Valley Authority, Post Office Box 2000, Decatur, Alabama 35609

O. J. "Ike" Zeringue
Vice President, Browns Ferry Operations

SEP 30 1992

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555

Gentlemen:

In the Matter of	)	Docket Nos. 50-259
Tennessee Valley Authority	)	50-260
		50-296

BROWNS FERRY NUCLEAR PLANT (BFN) - RESOLUTION OF THE THERMAL GROWTH ISSUE OUTSIDE CONTAINMENT (TAC NOS. M80618, M80619, AND M80620)

References: 1) NRC letter to TVA, dated May 12, 1992, Summary of the April 30, 1992 Meeting with the Tennessee Valley Authority Regarding Thermal Growth of Steel Structures

2) NRC letter to TVA, dated July 13, 1992, Safety Evaluation and Request for Additional Information Regarding Browns Ferry Nuclear Plant Units 1, 2, and 3 Design Criteria for Lower Drywell Steel Platforms and Miscellaneous Steel

3) TVA letter to NRC, dated July 20, 1992, Resolution of the Thermal Growth Issue

This letter provides information for the resolution of the thermal growth outside containment issue at BFN. As documented in Reference 1, TVA and NRC met to discuss the methodology used to evaluate the effects of thermal growth on structural steel configurations at BFN. This issue was documented as a Safety Evaluation Report (SER) open item in Reference 2. The results of TVA's previous analysis of thermal loads on structural steel configurations and its plan for developing the additional analyses was provided in Reference 3.

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Also in Reference 3, TVA committed to prepare a summary of the calculations used to address the thermal growth issue and to perform linear analyses for those structural configurations that exhibited the highest level of thermally induced stress. The enclosure to this letter satisfies this commitment. TVA also committed to make the supporting calculations available for NRC review. These calculations are available for NRC review at TVA's Rockville office.

The enclosure discusses the specific thermal growth issues that were performed for the Reactor Building Unit 2 miscellaneous steel structures located outside the drywell and the Units 1 and 3 structures that were required to support Unit 2 operation. However, the thermal growth concerns addressed in the enclosed report are also applicable to structural steel configurations for Units 1, 2, and 3.

The criteria and methods outlined in the enclosure represent a conservative approach to determine and limit structural behavior of miscellaneous steel structures under extreme thermal loads in combination with dead, live and seismic loads. This has been confirmed by demonstrating that the acceptance criteria of BFN-50-C-7100 and Design Guide DG-C1.6.12 result in acceptably small deflections. Further validation of the criteria is provided by the linear analysis results that show the limiting case structural configurations have linear stresses less than twice the yield stress. The twice yield stress is the basis for the ASME stress intensity limit for primary plus secondary stresses. Standard Review Plan (SRP) 3.8.4 states "thermal loads can be neglected when it can be shown that they are secondary and self-limiting in nature and where the material is ductile." TVA's thermal evaluation demonstrates that implementation of BFN's design criteria is consistent with this provision of SRP Section 3.8.4.

If the Staff has any questions regarding this methodology or the supporting calculations, TVA is available for a meeting at the Staff's earliest convenience. There are no commitments contained in this letter. TVA requests a Supplemental SER be issued to document the resolution of this SER open item. If you have any questions, please contact G. D. Pierce, Interim Manager of Site Licensing, at (205) 729-7566.

Sincerely,

O. J. Zeringue

Enclosure

cc (Enclosure):

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ENCLOSURE
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INTRODUCTION

As discussed during the April 30, 1992 TVA/NRC meeting and confirmed by TVA's July 20, 1992 letter, TVA committed to provide an explanation of why the two cases it selected for analysis prior to the restart of BFN Unit 2 were the most limiting of the approximately 20 structural configurations that behaved in a non-linear fashion. TVA committed to include as part of this explanation a tabular summary of these structural configurations and their critical parameters. TVA also committed to perform ANSYS linear analyses for the structural configurations that exhibited the highest level of thermally induced stress and provide a comparison between the results of the two analyses. From this comparison, an evaluation of the acceptability of the nonlinear analysis [illegible] be prepared. In addition, the supporting calculations were [illegible] for NRC review at TVA's Rockville office.

This report and the annotated references that are available for review at TVA's Rockville Office satisfy these commitments. This report describes the methodology used to address the thermal growth issue. The evaluation included the Unit 2 miscellaneous steel structures located outside the drywell, in the Reactor Building, and the Units 1 and 3 structures required to support Unit 2 operation. While the thermal growth evaluations were performed specifically to support Unit 2 operation, the results of the evaluations included in this report and the current governing design criteria (Reference 1) are also applicable to the remaining structural steel configurations for Units 1, 2, and 3.

METHODOLOGY

The thermal growth evaluations for BFN Unit 2 miscellaneous steel structures located outside the drywell involved the evaluation of approximately 300 configurations. To facilitate the structural evaluation of this many configurations in an effective manner, the evaluation program was based on a screening approach that selected limiting structures for later rigorous evaluation (Reference 2).

The methodology for the thermal growth evaluation involved the steps listed below. Details of these steps and the methodology are described in the following sections.

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THERMAL GROWTH EVALUATION STEPS

Step 1 - Initial screening for thermally restrained structures.

Step 2 - Evaluation of thermally restrained structures and modifications to those structures that were found to be unacceptably restrained.

Step 3 - Selection of the limiting case thermally restrained structures from those that were not modified.

Step 4 - ANSYS analysis of limiting cases under combined thermal and non-thermal loads.

Step 5 - Connection evaluation for limiting configurations.

Step 6 - Summary of linear and nonlinear responses and comparisons with Design Criteria acceptance limits.

In general, the first five steps, except for the ANSYS linear analysis, were performed prior to Unit 2 restart. For the purpose of this summary report, ten additional configurations were selected for linear and nonlinear analysis (Steps 3 and 4) based on the same pre- Unit 2 restart considerations. The last step was compiled for comparison purposes and this summary report.

STEP 1 - INITIAL SCREENING

Structures most affected by thermal growth are those that are both thermally restrained and subjected to high temperatures. The purposes of the initial screening were to identify thermally restrained structures, to determine whether they were located in a harsh environment and, for those structures located in harsh environments, to define the post-accident temperature values that were to be used in the evaluations. This initial screening was performed on the basis of walkdowns and the review of structural steel and environment drawings as documented in Reference 3. To facilitate the structural evaluations, structures were classified into the following three categories:

Category I - Structures with obvious axial restraint to thermal growth. For example, the beams attached to the Torus roof steel, consisting of light structural shapes welded to embedded castellated beams were placed in this group (Figure 1).

Category II - Structures with a potentially high degree of internal thermal restraint. For example, platform flexural members spanning between beams were considered as Category II.

Category III - Structures that did not have any internal or external restraint with regard to thermal growth or were located outside harsh environment areas.

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These determinations were made by engineers experienced in structural steel design. When the category classification was in doubt, the more conservative assignment was made. The screening results, listing the structures by category, were documented in a calculation (Reference 3). The form of these results was the identification of the drawing number and associated details, and classification as Category I, II, or III. Category III structures, for which thermal effects do not apply, received no further consideration beyond this screening stage.

STEP 2 - IDENTIFICATION OF THERMALLY RESTRAINED STRUCTURES

As a result of the initial screening, only Category I and II structures remained for further screening and evaluation. These structures were analyzed for their thermal responses in accordance with the methodologies given in BFN Civil Design Guide DG-C1.6.12. To facilitate these analyses, comparisons of the design parameters (as noted below) were used to determine enveloping details or configurations. For example, several enveloping configurations for the miscellaneous steel beams attached to the Torus roof steel were defined on the basis of their having similar details of span length, environment, temperature, and beam section designation. The following is a list of the parameters used for selection of enveloping configurations (References 4 and 5):

1. Temperature
2. Span length
3. Boundary restraint
4. Beam member cross section properties
5. Column slenderness ratios
6. Width-to thickness ratios for local buckling
7. Mechanical loads
8. Similarity of geometry and loading (platforms)

The structures with high thermal restraint were selected for detailed evaluations. If the evaluations indicated that these structural responses were within acceptable limits, then it was concluded the rest of the structures in the group enveloped by the critical cases were also considered acceptable (Reference 6).

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Then the structures with nonlinear behavior (those with ductility ratios greater than 1.0) were selected for further evaluation. To facilitate these evaluations, the structures were grouped on the basis of configuration, geometry, function, and behavior, in such a way that the same basic structural design and analysis considerations applied to each group. The Groups were defined as follows:

Group 1   Miscellaneous steel beams attached to Torus roof steel (hereafter referred to as Torus roof beams).

Group 2   Platform steel and miscellaneous steel structures (beams thermally restrained).

Group 3   Short W shape posts restraining W shape beams.

Group 4   Anchorages

Group 5   Single beam support steel framing

Group 6   Torus access platform

Groups 5 and 6 were modified to eliminate large nonlinear responses that resulted from thermal loads (References 7 and 8) Therefore, further evaluations were not performed. There were 36 enveloping configurations for the Group 1, 2, 3, and 4 structures with ductility ratios greater than 1.0 (Reference 6). These enveloping configurations are provided in Table 1. Note that some of these 36 configurations envelope other configurations or contain more than one configuration for the identified case. Case 1 of Table 1, for example, has seven subcases. Also note that for the purposes of clarity and this summary report, 36 enveloping configurations are depicted as opposed to the approximately 20 most limiting structural configurations discussed in TVA's July 20, 1992 letter to NRC.

A subsequent detailed evaluation of Group 3 structures showed that they were elastic and Group 4 was not considered critical because of the anchorage's ability to accommodate thermal growth in the lateral direction. Therefore, further evaluations of these groups were not performed.

STEP 3 - SELECTION OF LIMITING CONFIGURATIONS

Prior to Unit 2 restart, one enveloping case from Group 1 and one from Group 2 were selected for nonlinear analyses by ANSYS. This selection was based on the degree of thermal restraint and the magnitude of calculated ductility ratios and superimposed dead and live loads. The pre- Unit 2 enveloping cases are included as Case 1 in Table 2 and Case 1 in Table 3. For the purposes of this report, ten additional cases were selected for linear and nonlinear analysis using the previous selection criteria.

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Of the twelve total cases, eight were Torus roof beams (seven subcases of Case 1 plus Case 34 in Table 1) and four were platform steel and miscellaneous steel structural configurations (Cases 14, 15, 21, and 28 of Table 1). These 12 cases envelope the Groups 1 and 2 configurations. The results of these analyses are provided in Tables 2 and 3, respectively.

STEP 4 - ANSYS ANALYSIS OF LIMITING CONFIGURATIONS

The ANSYS computer program was used to perform linear as well as iterative nonlinear analysis for the eight Group 1 (Torus roof beams) and four Group 2 (Platform and miscellaneous steel) enveloping configurations. In the ANSYS nonlinear analyses, both large displacement effects and nonlinear stress-strain behavior were considered. The modeling and analysis considerations for the enveloping case ANSYS nonlinear analyses were as follows:

For the Group 1 structures (Figure 1), the finite element model of the W6 beam attached to the bottom flanges of the embedded castellated beams is shown in Figure 2. The beam is divided into 12 STIF24 type beam finite elements. STIF24 is a uniaxial, three-dimensional, thin-walled beam element with tension-compression and bending capabilities. The element material property was specified as elastic, perfectly plastic. ANSYS analyses were performed for the thermal plus superimposed loads for each of these seven configurations based on this finite element model. For the single case of a 6 x 6 square tube attached to the castellated beams (Case 34), the analysis and modeling approach was similar.

For the Group 2 structures, analysis and modeling was similar to that for the Group 1 described above. The analysis for the W24x68 access platform beam, shown as AB in Figure 4, typifies the general approach. A three-dimensional elastic-plastic beam analysis was performed for the member of interest with the restraints provided by surrounding and adjacent members represented by three-dimensional elastic beam finite elements. Figure 5 shows the detailed modeling of the W24. The cross sections were modeled in the same manner as the Torus roof beams of Group 1 (Figure 2).

Included in the ANSYS nonlinear analyses of two cases were the use of ANSYS buckling option for the consideration of local and global buckling effects. These analyses were performed for the enveloping configurations, comprising the highest slenderness ratio and temperature for Groups 1 and 2, respectively. Using the ANSYS buckling option, buckling was identified if increments of applied load result in excessive or unbounded deflections. The calculated displacement responses for the analyzed cases were small. This indicated that, for the enveloping configurations, buckling does not occur. These results are summarized in Reference 9.

In addition to ANSYS nonlinear analyses, corresponding ANSYS linear analyses were also performed for Groups 1 and 2 in order to provide linear solutions for comparison with the corresponding nonlinear solutions.

STEP 5 - CONNECTION EVALUATION FOR LIMITING STRUCTURES

The various connections of the structural configurations were also evaluated. These connections were from Groups 1, 2, 3, and 4 and were categorized as follows:

1. Anchored - member ends (W shapes, tube steel, etc.) welded to embedded or anchor bolted plates.

2. Welded - member to member welded connections.

3. Flexible - member to member clip angle connections.

For anchored connections, the anchor bolts and studs were evaluated and found to satisfy the Design Criteria.

For welded connections, the welds were evaluated per the Design Criteria. The interaction ratios were found to be less than one except for Evaluation Numbers 4, 5 and 7 of Table 2. These resulted in an interaction ratio of 1.07. This is within the accuracy range of engineering calculations. Furthermore, the ambient temperature used in the calculation for this area was 62°F. The actual normal operating ambient temperature for this area should be at least ten degrees higher. This higher temperature would reduce the thermal effects.

For flexible connections, the behavior of connections was found to be secondary (deformation of connections would not cause structural instability) and self-limiting (deformation of connections would relieve the thermal stresses in the members) in nature and therefore acceptable. The rotations and bending ductility of flexible connection members, such as base plates and plate elements of connections, are acceptable unless that bending is critical to overall structural stability (e.g., a plate supporting a cantilever). Behavior is analogous to a clip angle which, although it may bend inelastically, is still acceptable per Section 1.2 of the AISC Specification (Reference 11). For the BFN Unit 2 miscellaneous steel thermally restrained enveloping configurations, the plates and angles are of the flexible type and their deformations are not critical to overall structural stability.

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STEP 6 - SUMMARY OF LINEAR AND NON-LINEAR RESPONSES

The summary of the linear and non-linear response for Group 1 structures, in terms of both stresses and deflections, is provided in Table 2. The results of the most critical Group 1 analyses, as shown in Table 2, indicated that the nonlinear vertical deflection is less than the corresponding linear deflection. This is shown in Figure 3.

Figure 3 shows the linear and the nonlinear behavior of the Torus roof beams under thermal loading. The dominant response characterization was the longitudinal expansion of the beam with vertical deflections being of secondary importance. This expansion caused a rotation of the rigid member accompanied by corresponding vertical beam deflections for the linear solutions. The linearly calculated deformed shape at 1.45 S_y (1.45 S_y defines a load which is 1.45 times the load which causes first yield S_y) corresponds to the limiting case for the W6 beams attached to the Torus roof steel (see Table 2, Evaluation No. 7). It is similar and linearly proportional to the shape at 1.0 S_y. In the nonlinear solution, the behavior was the same as for the linear solution up to first yielding. After yielding occurs, by initiation of a plastic hinge at joint B, the system acted as a propped cantilever. Additional thermal load increments resulted in unrestrained longitudinal thermal expansion of the member BC. The rigid link, AB, was pinned at both ends and free to rotate under additional increments of thermal load. Thus, the thermal load increment following hinge initiation did not result in a vertical deflection increment. This explains why under combined thermal and mechanical loading, the vertical deflections for the linear solution may exceed those for the nonlinear solution.

Table 3 summarizes the linear and nonlinear results for four Group 2 limiting cases. For all Group 1 and 2 configurations, the maximum stresses based on linear behavior were less than twice the yield stress. Twice the yield stress is the basis for the ASME stress intensity limit for primary plus secondary stresses (Reference 10). As discussed in Reference 10, twice the yield stress limit ensures acceptable behavior during thermal loading.

Review of Tables 2 and 3 indicated that the elastically calculated stresses due to non-thermal loading conditions produced a typical ratio of non-thermal load stress to combined load stress of about 1/5. This meant that the non-thermal loads were so small that the combined loading condition, for a typical enveloping configuration, behaved as a secondary load.

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SUMMARY AND CONCLUSIONS

This report gives: (1) a detailed history of the evaluations of thermal growth at BFN; (2) a summary of limiting case configurations (Table 1) for screening purposes; (3) a summary of more rigorous linear and nonlinear calculational results using the ANSYS computer code with refined boundary conditions (Tables 2 and 3); and (4) a summary of the evaluation results that demonstrate the BFN steel structures are acceptable for thermal conditions (Reference 9).

It is noted that the two time yield stress limit concept is used in the ASME Code (Section III) for normal operating and upset conditions only. Thermal evaluation is exempted in the ASME code for emergency and faulted conditions because of the low number of stress cycles. Since the analyzed load is a faulted condition and has only one stress cycle, it is conservative to use the two times yield stress limit concept for structural thermal evaluation.

The calculated results presented in Tables 2 and 3 demonstrate that the displacements for enveloping configurations under combined thermal, dead and seismic loads are small. The comparisons of displacements in the linear and nonlinear analyses demonstrates that the nonlinear results are reasonable.

The criteria and methods outlined in this report represent a conservative approach to determine and limit structural behavior of miscellaneous steel structures under thermal loads in combination with dead, live, and seismic loads. This has been confirmed by demonstrating that the acceptance criteria of BFN-50-C-7100 and Design Guide DG-C1.6.12 result in acceptably small deflections. Further validation of the criteria is provided by the linear analysis results that show that the limiting case structural configurations have linear stresses less than twice the yield stress. The twice yield stress is the basis for the ASME stress intensity limit for primary plus secondary stresses. Standard Review Plan (SRP) 3.8.4 states "thermal loads can be neglected when it can be shown that they are secondary and self-limiting in nature and where the material is ductile." TVA's thermal evaluation demonstrates that implementation of BFN's design criteria is consistent with SRP Section 3.8.4.

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(CONTINUED)

REFERENCES

1. BFN-50-C-7100, Revision 2, Attachments F, BFN Design Criteria.
2. TVA Civil Design Guide D.G.-C1.6.12 Revision 0, Evaluation of Steel Structures with Thermal Restraint and Design Guide Change Notices DGCN-CEB-89-01 and DGCN-CEB-89-02. (*)
3. TVA Calculation No. CD-Q0303-883587, Establish Criteria for the Thermal Evaluation of Miscellaneous and Structural Steel and Identify the Drawings Which Require Evaluation, Revision 2, August 7, 1989. (*)
4. TVA Calculation No. CD-Q2303-890359, Thermal Evaluation of Miscellaneous Steel, Revision 3, November 3, 1989. (*)
5. TVA Calculation No. CD-Q2303-890364, Thermal Growth Analysis of Structural and Miscellaneous Steel, Revision 5, June 1, 1990. (*)
6. TVA Calculation No. CD-Q2303-890683, Miscellaneous Steel - Thermally Restrained Structures with Superimposed Loadings, Revision 4, September 23, 1990. (*)
7. DCN No. W7157A, Modifications for Torus Access Platform. (*)
8. DCN No. W5921A, Modification for Miscellaneous Structures below Elevation 565. (*)
9. TVA Calculation No. CD-Q2303-923155, Summary Calculation of Thermal Issue for Miscellaneous Steel, September 30, 1992. (*)
10. Criteria of the ASME BPV Code for Design by Analysis in Sections III and VIII, Division 2, 1969, ASME.
11. AISC, Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings, American Institute of Steel Construction, 8th Edition.

(*) - The annotated references are available for review at TVA's Rockville Office.

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(CONTINUED)

TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

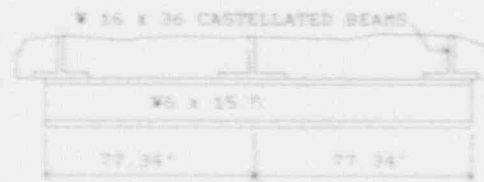
CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
1	48W1002-2	PART PLAN A2,E2	1	 W SECTIONS WELDED TO TORUS AREA ROOF BEAMS ELEVATION
	48W1002-3	PART PLAN A3,F3,L3, R3		
	48W1002-4	PART PLAN E4		

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TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

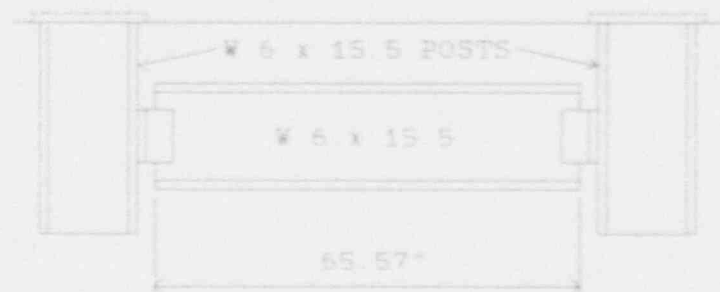
CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
2	48W1002-4	H4-H4	3 & 4	 HPCI - TORUS ROOM ELEVATION

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TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

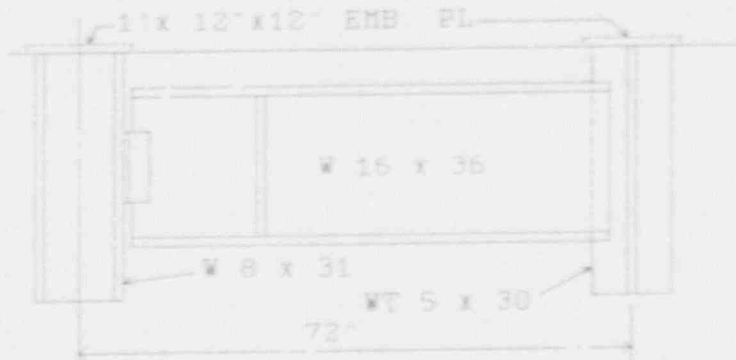
CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
3	48W1004-2	PART PLAN ℄2	3 & 4	 ELEVATION

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TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

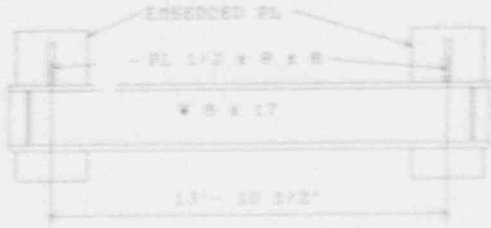
CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
4	48W1002-4	DET. A4	3 & 4	 ELEVATION

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TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

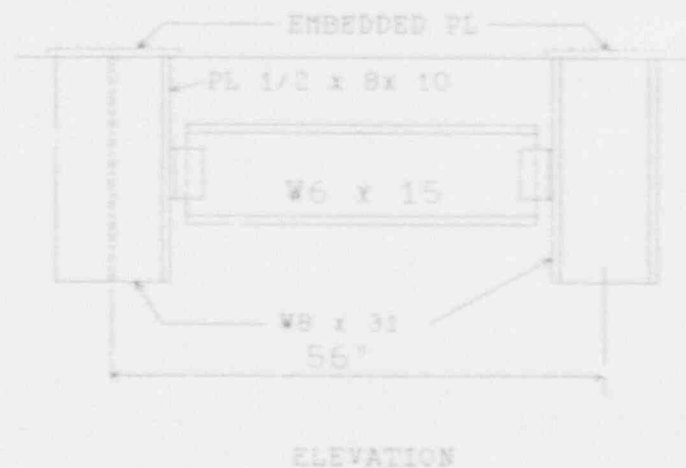
CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
5	48W1004-4	PART PLAN K4	3 & 4	
6	48W1004-3	PART PLAN A3 N.E.PUMP ROOM	3 & 4	SIMILAR TO CASE NO. 5
7	48W1022-1 (48N1005)	MAIN STEAM TUNNEL	3 & 4	SIMILAR TO CASE NO. 5
8	48W1022-2 48W1022-6	PART PLAN A3 PART PLAN F6	3 & 4	SIMILAR TO CASE NO. 5

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TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
9	48N990	MONORAIL R13-R14/ S-T EL. 620-3	1 & 4	 ELEVATION
10	48N990	R13-R14/ S-T EL. 620-3	3 & 4	SIMILAR TO CASE NO. 5

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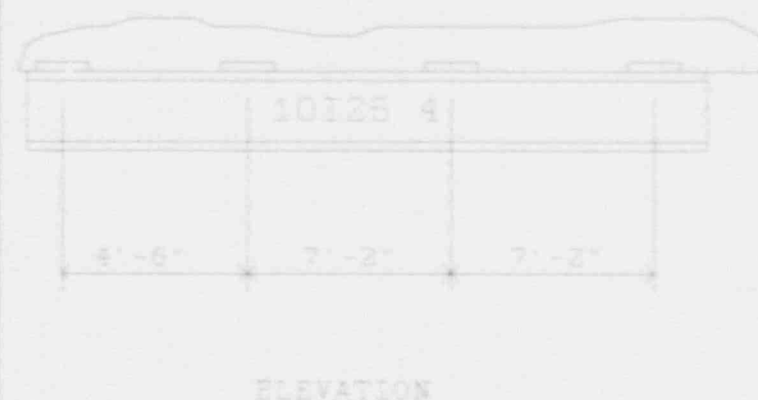
TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
11	48N990	R8-R9/ N-P NW PUMP ROOM EL. 531	1 & 4	

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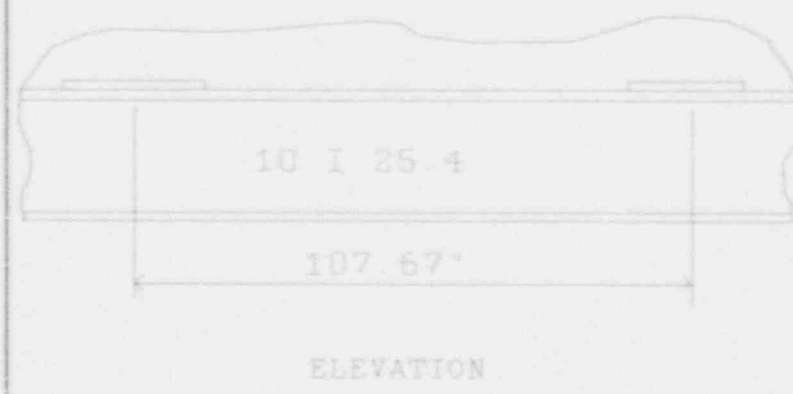
(CONTINUED)

TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
12	48W1002-2	HPCI ROOM U-R14 EL. 548	1 & 4	

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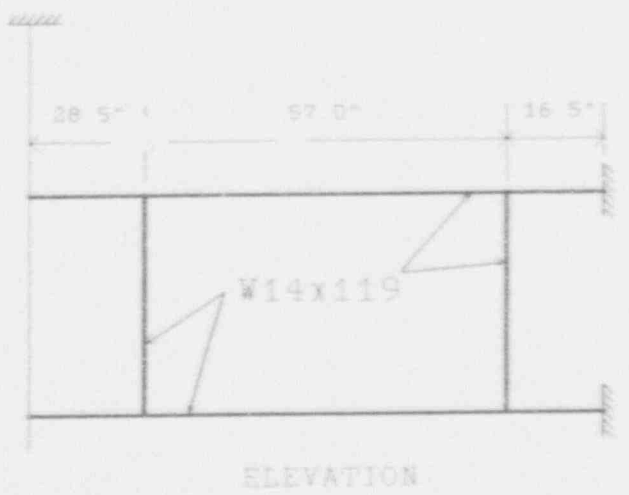
(CONTINUED)

TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
13	48N1030	SECTION A-A	2 & 4	

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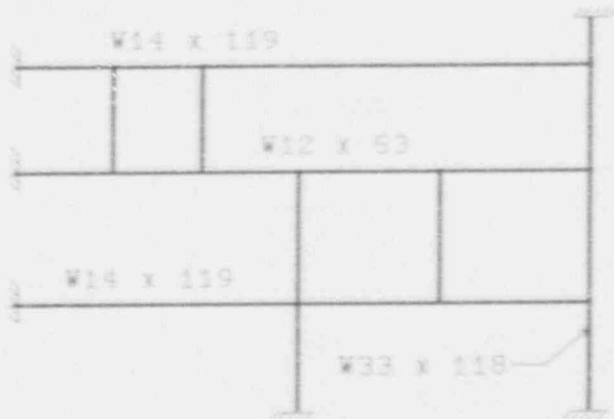
(CONTINUED)

TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
14	48N1030	SECTION B-B	2 & 4	 ELEVATION

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(CONTINUED)

TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
15	48N996 48N997	MAIN STEAM TUNNEL	2 & 4	

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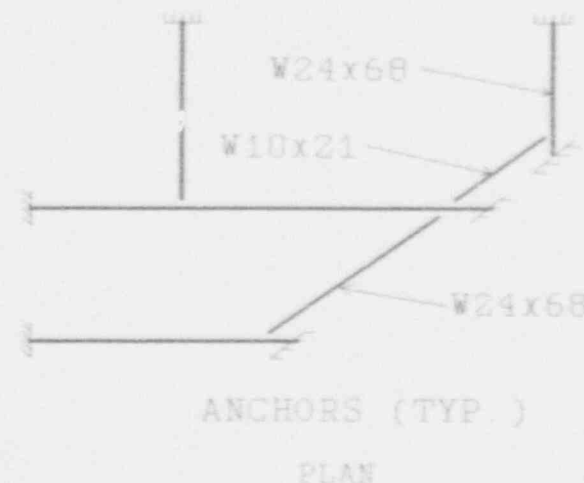
TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
16	48N435 41N708	NW CORNER ROOM EL. 541-6	2 & 4	

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(CONTINUED)

TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

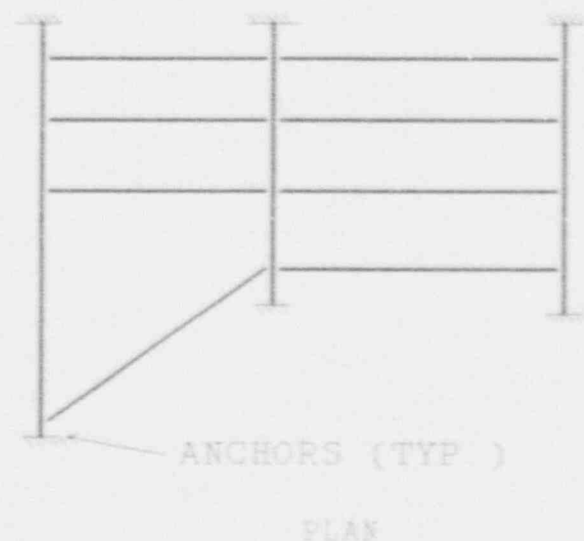
CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
17	48N928	CORE SPRAY VALVE ACCESS PLATFORM SEC. C-C	2 & 4	

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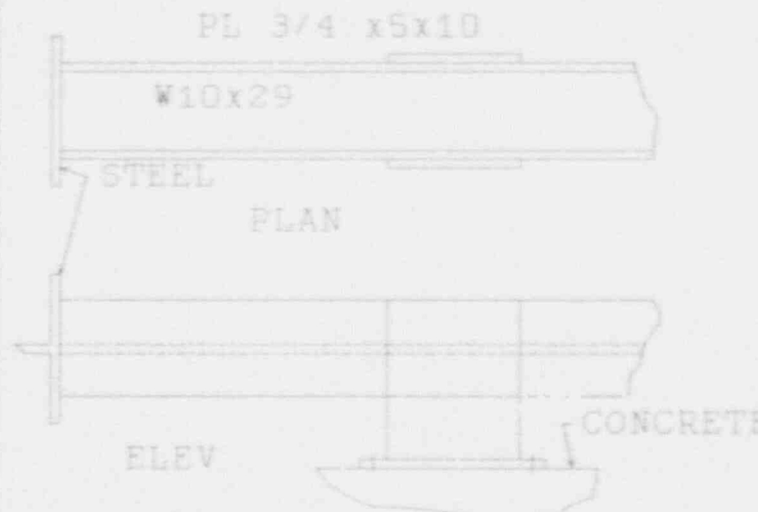
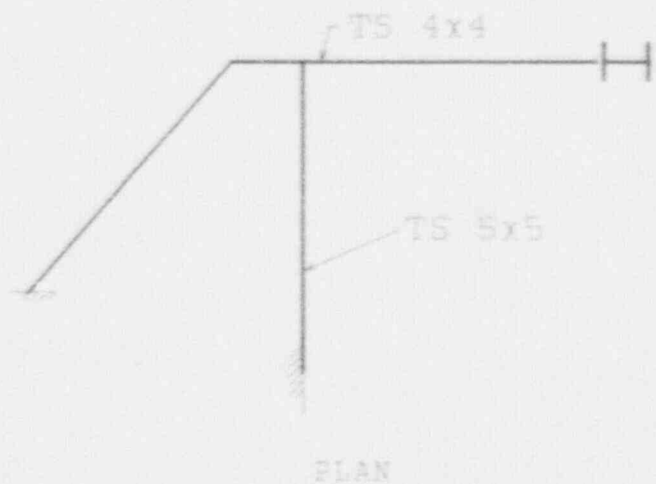
TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
18	48N944-3	CRD RELIEF VALVE PLATFORM S3-S3	2 & 4	

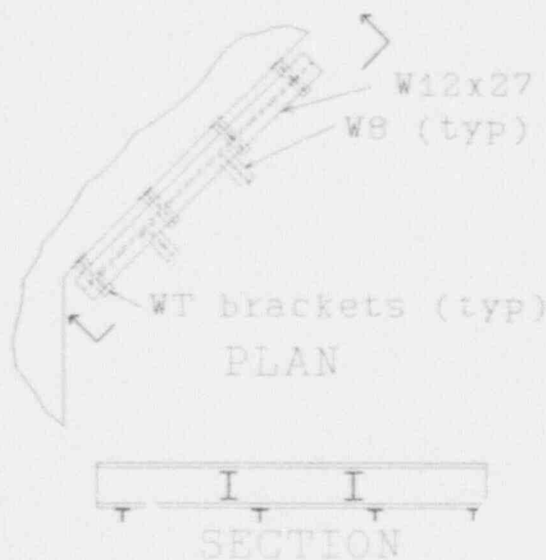
ENCLOSURE
BROWNS FERRY NUCLEAR PLANT
RESOLUTION OF THE THERMAL GROWTH ISSUE
(CONTINUED)

TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
19	48N944-6	DET. K6	2 & 4	

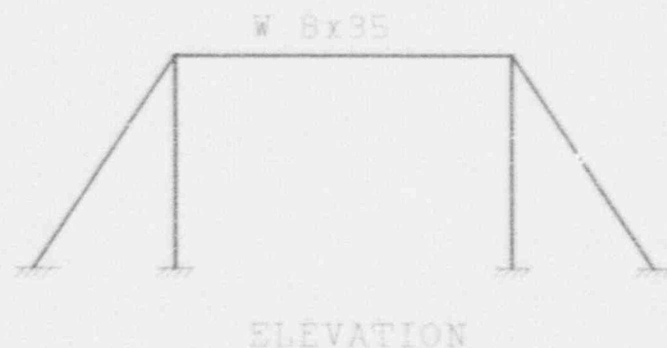
ENCLOSURE
BROWNS FERRY NUCLEAR PLANT
RESOLUTION OF THE THERMAL GROWTH ISSUE
(CONTINUED)

TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
20	48N992	CORNER ROOM AZ. 315 EL. 557-2	2 & 4	
21	48N992	CORNER ROOM AZ. 45 EL. 557-2	2 & 4	SIMILAR TO CASE NO. 20
22	48N992	CORNER ROOM AZ. 135 EL. 557-2	2 & 4	SIMILAR TO CASE NO. 20

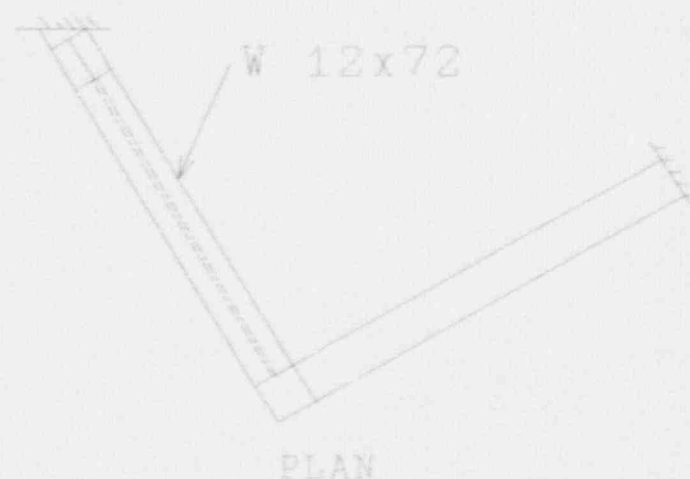
ENCLOSURE
BROWNS FERRY NUCLEAR PLANT
RESOLUTION OF THE THERMAL GROWTH ISSUE
(CONTINUED)

TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
23	48N992	CORNER ROOM AZ. 225 EL. 557-2	2 & 4	SIMILAR TO CASE NO. 20
24	48N1214-1	SEC. B1-B1	2 & 4	

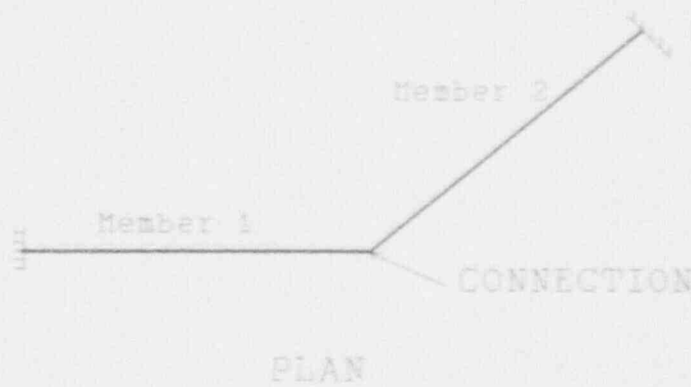
ENCLOSURE
BROWNS FERRY NUCLEAR PLANT
RESOLUTION OF THE THERMAL GROWTH ISSUE
(CONTINUED)

TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
25	48N1032	SEC. F-F EL. 554-7	2 & 4	

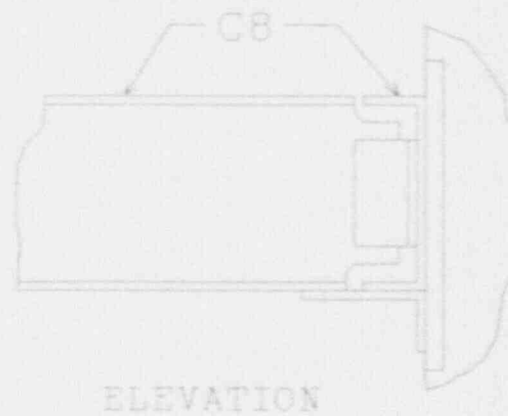
ENCLOSURE
BROWNS FERRY NUCLEAR PLANT
RESOLUTION OF THE THERMAL GROWTH ISSUE
(CONTINUED)

TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
26	48N1218-1 48N1218-2 48N1218-9	SEC. A-A	2 & 4	

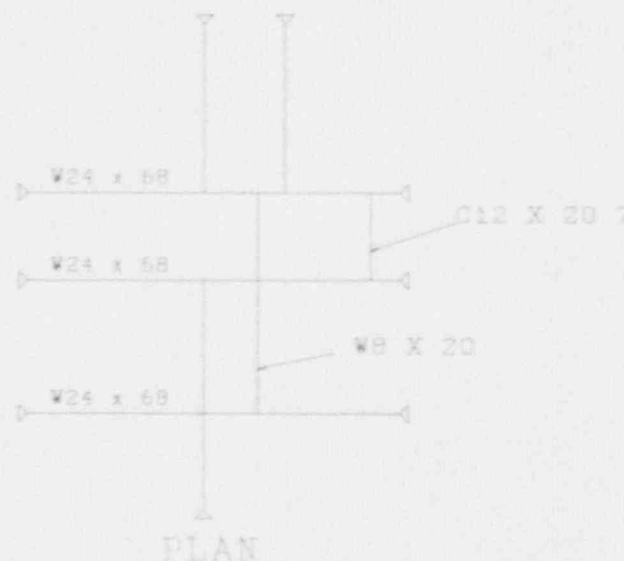
ENCLOSURE
BROWNS FERRY NUCLEAR PLANT
RESOLUTION OF THE THERMAL GROWTH ISSUE
(CONTINUED)

TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
27	48N908	SECTIONS C-C & D-D	2 & 4	

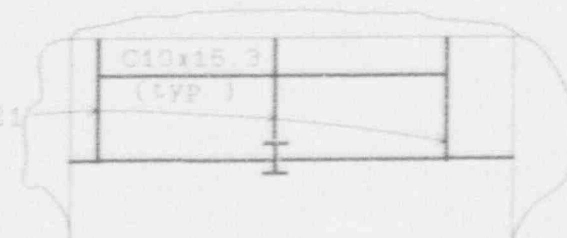
ENCLOSURE
BROWNS FERRY NUCLEAR PLANT
RESOLUTION OF THE THERMAL GROWTH ISSUE
(CONTINUED)

TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
28	48N1021 48N926	HEAT EXCHANGER PLATFORM EL. 587	2 & 4	

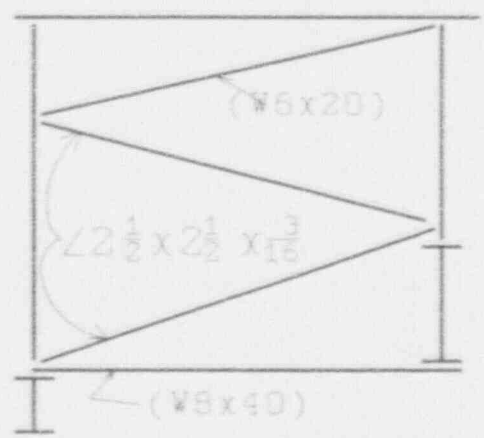
ENCLOSURE
BROWNS FERRY NUCLEAR PLANT
RESOLUTION OF THE THERMAL GROWTH ISSUE
(CONTINUED)

TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
29	48N927	MAIN STEAM VAULT ACCESS PLATFORM MK. 4 @ EL. 571-9	2 & 4	 PLAN

ENCLOSURE
BROWNS FERRY NUCLEAR PLANT
RESOLUTION OF THE THERMAL GROWTH ISSUE
(CONTINUED)

TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
30	48N1018	SEC. A-A MAIN STEAM AND FEEDWATER PIPE SUPPORT	2	 ELEVATION

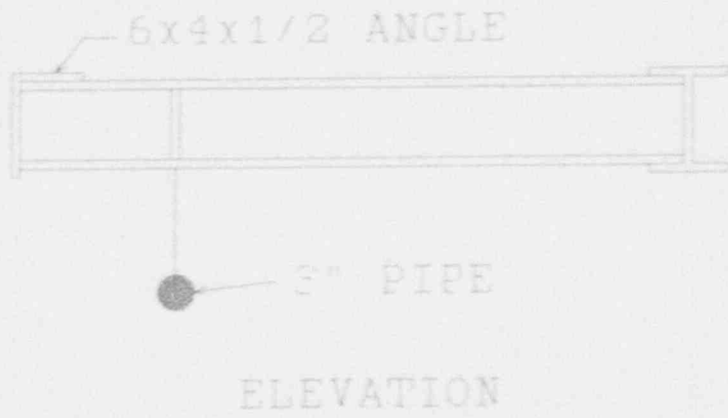
ENCLOSURE
BROWNS FERRY NUCLEAR PLANT
RESOLUTION OF THE THERMAL GROWTH ISSUE
(CONTINUED)

TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
31	47A455-409	A409-A409 HPCI SUPT AT TORUS ROOF	1	

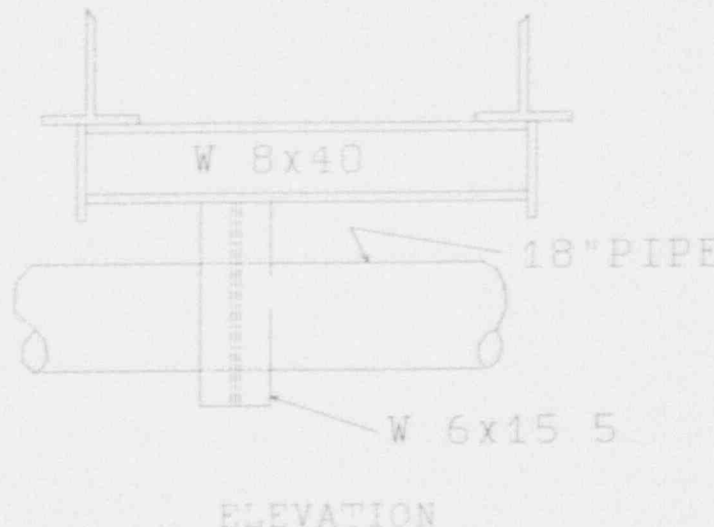
ENCLOSURE
BROWNS FERRY NUCLEAR PLANT
RESOLUTION OF THE THERMAL GROWTH ISSUE
(CONTINUED)

TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
32	47B456-70	A70-A70 RCIC PIPE SUPPORT	1	

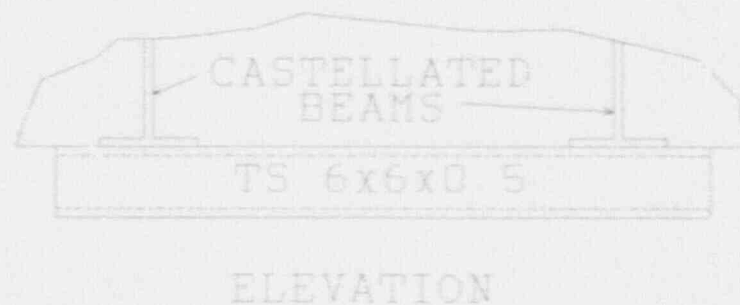
ENCLOSURE
BROWNS FERRY NUCLEAR PLANT
RESOLUTION OF THE THERMAL GROWTH ISSUE
(CONTINUED)

TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
33	47B920-63	A63-A63 TORUS PURGE PIPE SUPPORT	1	

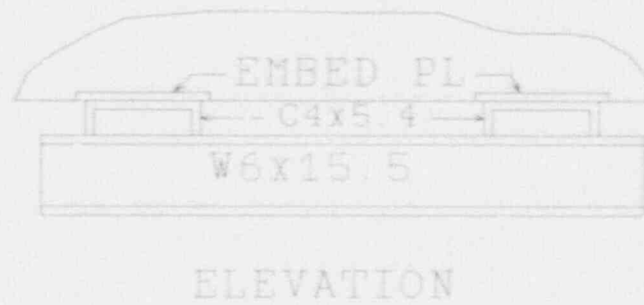
ENCLOSURE
BROWNS FERRY NUCLEAR PLANT
RESOLUTION OF THE THERMAL GROWTH ISSUE
(CONTINUED)

TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
34	47B920-64	A64-A64 TORUS PURGE PIPE SUPPORT	1	

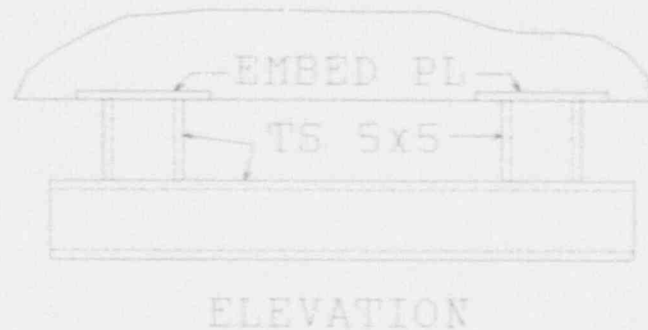
ENCLOSURE
BROWNS FERRY NUCLEAR PLANT
RESOLUTION OF THE THERMAL GROWTH ISSUE
(CONTINUED)

TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
35	47B2349-9	A9-A9 CONTROL ROD DRIVE PIPE SUPPORT	1 & 4	

ENCLOSURE
BROWNS FERRY NUCLEAR PLANT
RESOLUTION OF THE THERMAL GROWTH ISSUE
(CONTINUED)

TABLE 1
SUMMARY TABLE FOR CONFIGURATIONS

CASE NO.	DRAWING NO.	LOCATION	GROUP NO.	CONFIGURATION
36	47B2349-12	A12-A12	3 & 4	

ENCLOSURE
BROWNS FERRY NUCLEAR PLANT
RESOLUTION OF THE THERMAL GROWTH ISSUE
(CONTINUED)

TABLE 2
SUMMARY FOR TORUS ATTACHED STEEL
THERMAL EVALUATION BY ANSYS

No.	Designation	Span (l)	kl/r	$b/2t_f$	d/t_w	Non Thermal Stress (ksi)	Linear			Non-linear			Reference Drawing	Weld Interaction Ratio	Reference (Table 1)
							Stress (ksi)	Maximum Displacement (Inches)	DAFS	Stress (ksi)	Maximum Displacement (Inches)	DAFS			
1	W6X15.5	6'-7⅝"	43	11.10	25.5	$f_b = 17.68$	51.858	0.0239 - axial 0.0999 - vertical	1/3326 1/795	36.0	0.0316 - axial 0.0918 - vertical	1/2514 1/864	48W1002-1 48W1002-3	0.76	PART PLAN R3 CASE I
2	W6X25	5'-9¼"	30	6	20.4	$f_b = 6.64$	50.573	0.0190 - axial 0.0683 - vertical	1/3647 1/1014	36.0	0.0256 - axial 0.0645 - vertical	1/2701 1/1073	48W1002-1 48W1002-4	0.815	PART PLAN E4 CASE I
3	W6X15.5	5'-10"	38	11.10	25.5	$f_b = 6.32$	51.459	0.0215 - axial 0.0808 - vertical	1/3221 1/867	36.0	0.0277 - axial 0.0754 - vertical	1/2528 1/929	48W1002-1 48W1002-2	0.98	PART PLAN E2 CASE I
4	W6X15.5	6'-6"	43	11.10	25.5	$f_b = 4.9$	51.521	0.0239 - axial 0.0988 - vertical	1/3270 1/789	36.0	0.0306 - axial 0.0932 - vertical	1/2544 1/837	48W1002-1 48W1002-2	1.07	PART PLAN A2 CASE I
5	W6X15.5	6'-1"	40	11.10	25.5	$f_b = 9.05$	52.128	0.0216 - axial 0.0820 - vertical	1/3373 1/892	36.0	0.0291 - axial 0.0744 - vertical	1/2513 1/981	48W1002-1 48W1002-3	1.07	PART PLAN F3 CASE I
6	W6X15.5	5'-0"	33	11.10	25.5	$f_b = 6.92$	51.58	0.0183 - axial 0.0573 - vertical	1/3279 1/1049	36.0	0.0232 - axial 0.0549 - vertical	1/2584 1/1094	48W1002-1 48W1002-3	0.91	PART PLAN L3 CASE I
7	W6X15.5	5'-3"	35	11.10	25.5	$f_b = 11.85$	52.208	0.0186 - axial 0.0601 - vertical	1/3387 1/1048	36.0	0.0249 - axial 0.0552 - vertical	1/2534 1/1141	48W1002-1 48W1002-3	1.07	PART PLAN A3 CASE I

ENCLOSURE
BROWNS FERRY NUCLEAR PLANT
RESOLUTION OF THE THERMAL GROWTH ISSUE
(CONTINUED)

TABLE 2
SUMMARY FOR TORUS ATTACHED STEEL
THERMAL EVALUATION BY ANSYS

No.	Desig-nation	Span (l)	kl/r	$b/2t_f$	d/t_w	Non Thermal Stress (ksi)	Linear			Non-linear			Reference Drawing	Weld Interaction Ratio	Reference (Table 1)
							Stress (ksi)	Maximum Displacement (Inches)	DAFS	Stress (ksi)	Maximum Displacement (Inches)	DAFS			
8	TS6X6X0.5	5'-10¾"	20.81	6.0	12	f_b = 9.953	44.764	0.0349 - axial 0.2172 - vertical	1/2028 1/326	36.0	0.035 - axial 0.224 - vertical	1/2023 1/316	47B920-64	0.72	SUPPORT R23 CASE 34

DAFS - Displacement As a Fraction of Span

ENCLOSURE
BROWNS FERRY NUCLEAR PLANT
RESOLUTION OF THE THERMAL GROWTH ISSUE
(CONTINUED)

TABLE 3
SUMMARY FOR PLATFORM STEEL
THERMAL EVALUATION BY ANSYS

No.	Designation	Span (l)	kl/r	$b/2t_f$	d/t_w	Non Thermal Stress (ksi)	Linear			Non-linear			Reference Drawing	Weld Interaction Ratio	Reference (Table 1)
							Stress (ksi)	Maximum Displacement (Inches)	DAFS	Stress (ksi)	Maximum Displacement (Inches)	DAFS			
1	W24X68	13'-7⅝"	27.0	7.7	57.0	f_{bx} = 6.79	69.36	0.0008 - axial 0.0431 - vertical 0.1250 - transverse	negligible 1/3798 1/1312	36.0	0.0021 - axial 0.0507 - vertical 0.1290 - transverse	negligible 1/3229 1/1264	48N926	Less than 1.0	Heat Exchanger platform Case 28
2	2WF18X85	14'-2½"	28	9.7	17.41	f_{bx} = 5.1	52.070	0.0414 - axial 0.0992 - vertical	1/4118 1/1718	36.0	0.0600 - axial 0.0831 - vertical	1/2842 1/2051	48N996 48N997	Less than 1.0	Main Steam tunnel Case 15
3	W33X118	12'-0"	49.6	7.78	59.3	f_{bx} = 1.0 f_{by} = 12.3	38.895	0.0006 - axial 0.0017 - vertical 0.0274 - transverse	negligible negligible 1/5247	36.0	0.0006 - axial 0.0017 - vertical 0.0280 - transverse	negligible negligible 1/5203	48N1030 SEC. B-B	Less than 1.0	Penetration X-12 Case 14
4	W12X27	9'-11"	82.64	15.0	49.83	f_{bx} = 1.52 f_{by} = 1.34	66.725	0.0522 - axial 0.1014 - vertical 0.0664 - transverse	1/2280 1/1173 1/1792	36.0	0.1092 - axial 0.0396 - vertical 0.2129 - transverse	1/1089 1/3000 1/559	48N992 48N1005	Less than 1.0	Corner room S.E. platform Case 20

DAFS - Displacement As a Fraction of Span

ENCLOSURE
BROWNS FERRY NUCLEAR PLANT
RESOLUTION OF THE THERMAL GROWTH ISSUE
(CONTINUED)

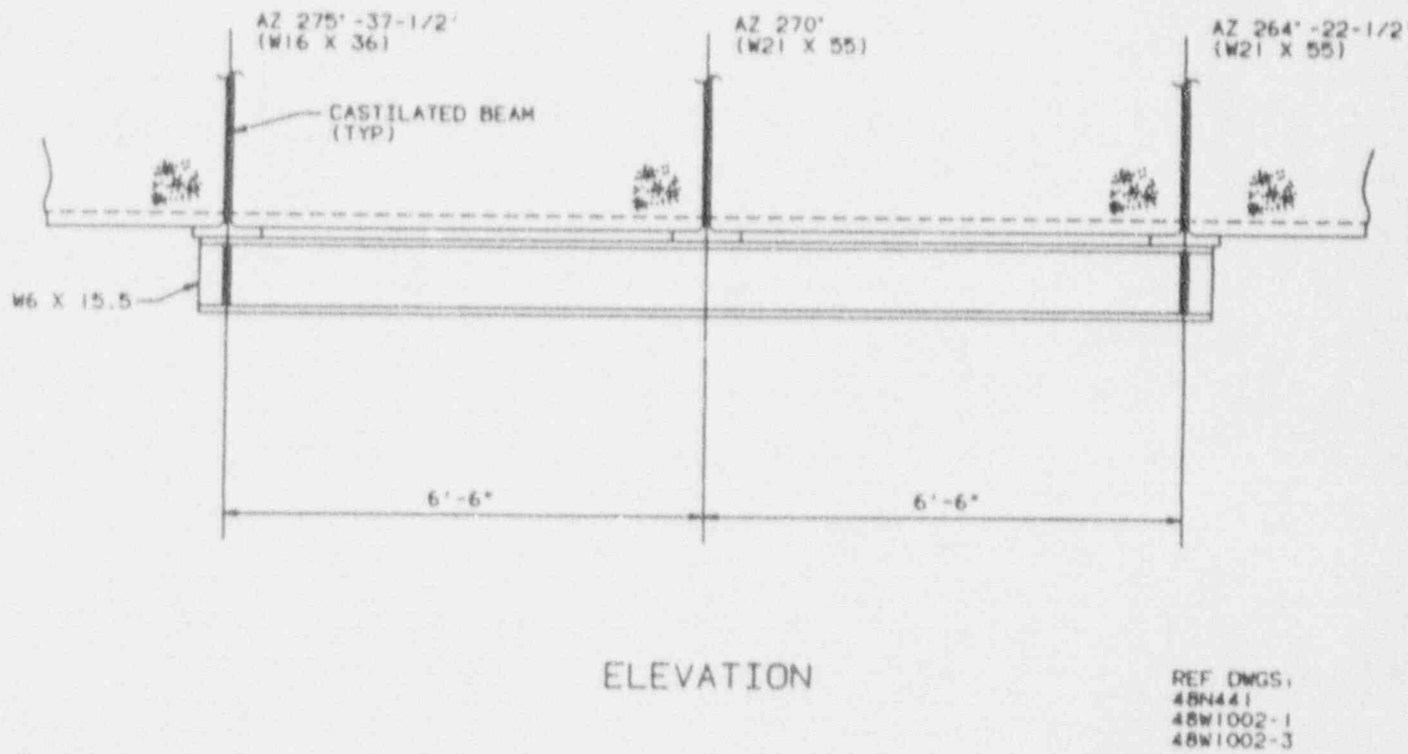
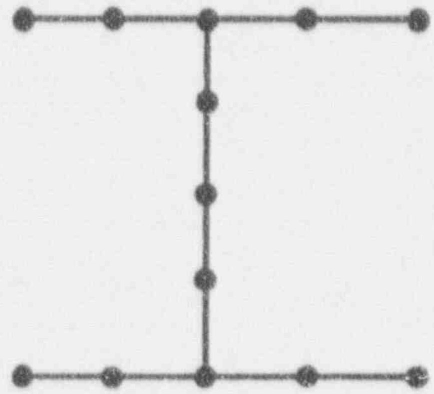


Figure 1. Typical Torus Roof Beam Detail (Case 1)



CROSS SECTIONAL PROFILE
OF NONLINEAR BEAM MODEL WITH
STIFF24 ELEMENTS

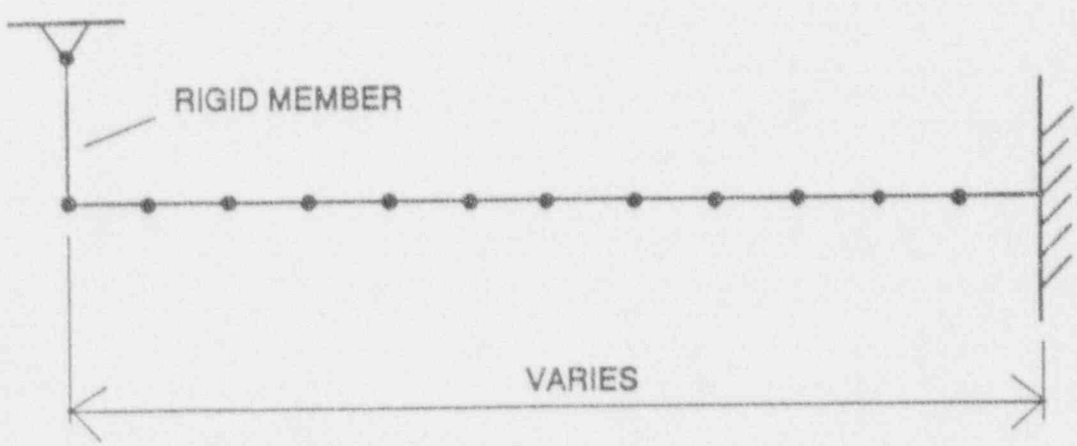


Figure 2. Torus Roof Beam Finite Element Model (Case 1)

ENCLOSURE
BROWNS FERRY NUCLEAR PLANT
RESOLUTION OF THE THERMAL GROWTH ISSUE
(CONTINUED)

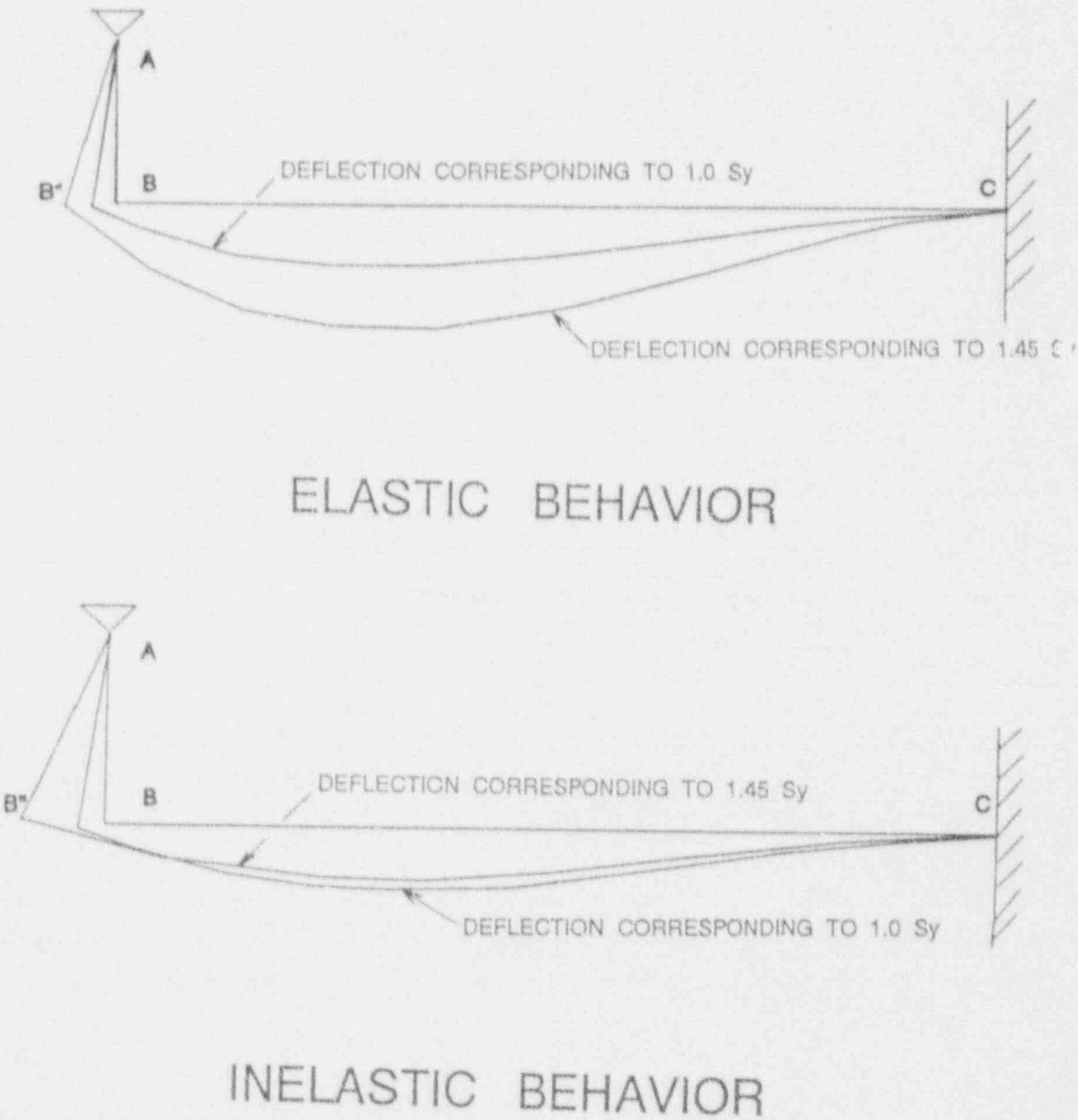


Figure 3. Torus Roof Beam Elastic and Inelastic Behavior

ENCLOSURE
BROWNS FERRY NUCLEAR PLANT
RESOLUTION OF THE THERMAL GROWTH ISSUE
(CONTINUED)

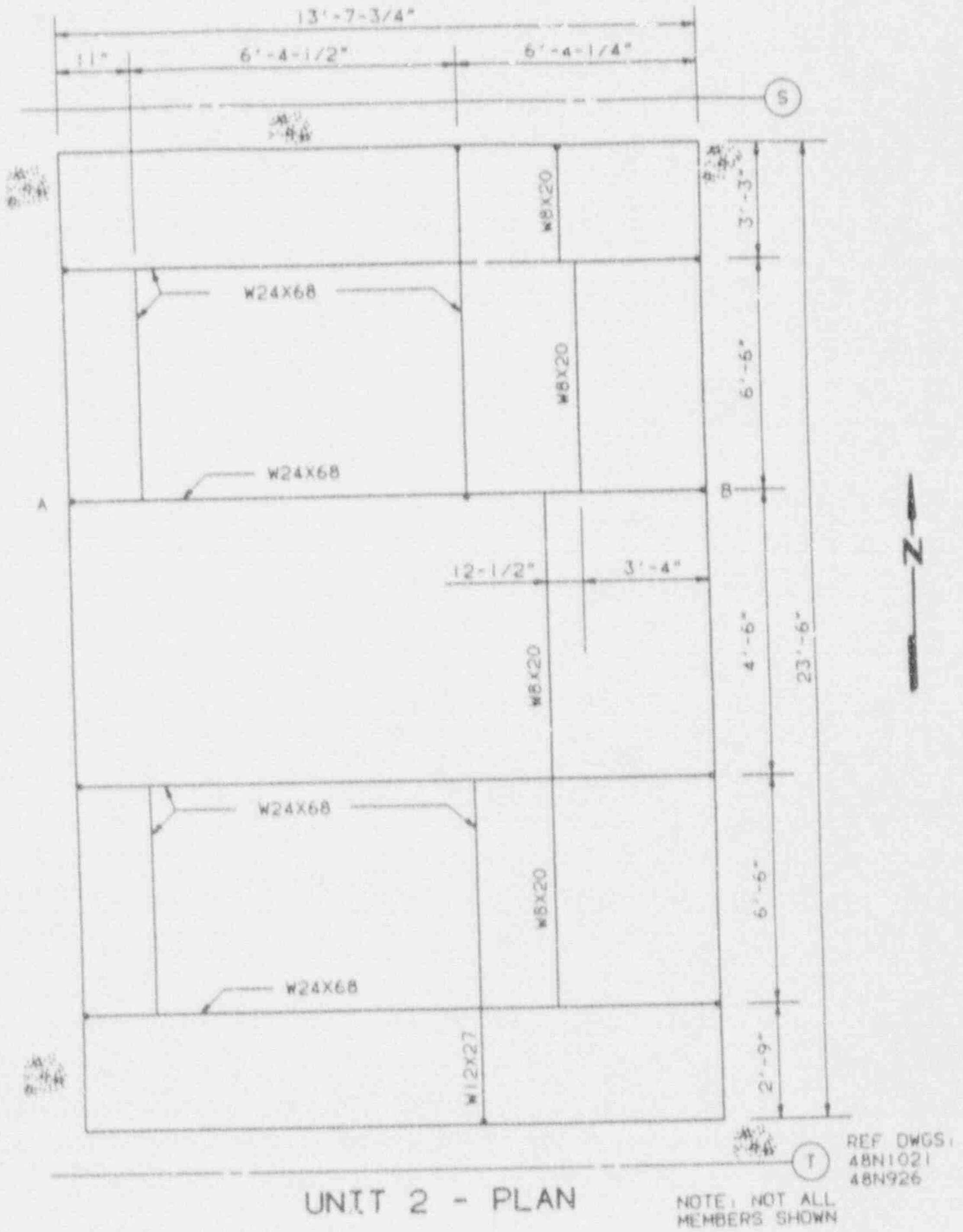


Figure 4. Access Platform Plan (Case 28)

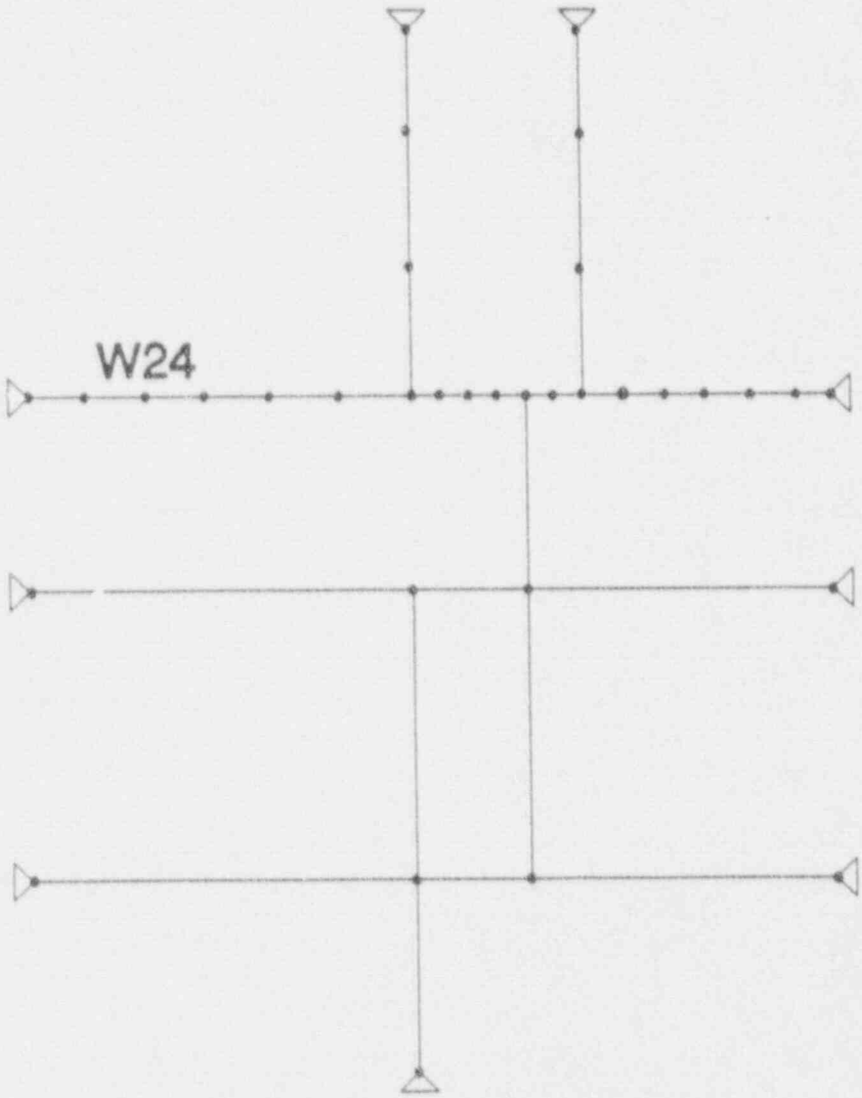


Figure 5. Access Platform Finite Element Model (Case 28)