Attachment 1

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SONGS-1 APPROACH TO INELASTIC BEAMS

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March 18, 1986

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1.0 INTRODUCTION

During the audit of the Long Term Service (LTS) evaluation of Southern California Edison's (SCE) SONGS-1 plant, one licensing issue was raised by the NRC and their consultants. The issue is the "secant stiffness" methodology and it is a product of the SONGS-1 plant having structural steel members which support piping systems and may exhibit inelastic behavior.

The secant stiffness method was used to analyze piping systems with multiple inelastic beams. The NRC is concerned with the application of the method, the theoretical basis for the method, and the justification of the method.

SCE has addressed this issue through numerous presentations and reports to the NRC staff and their consultants [References 1, 2, 3, 4, 5, 6, 7]. Based upon the time constraints regarding the SONGS-1 plant start-up and the time remaining to resolve the NRC's concerns, SCE has decided to limit the use inelastic beam as described herein. This report describes SCE's plan to address the "secant stiffness" issue.

Section 2.0 of this report describes a program for beam reevaluations and beam modifications, in order to the resolve the secant stiffness method and Section 3.0 covers the issues of isolated inelastic beams.

2.0 INELASTIC BEAMS

Under the SONGS-1 Return to Service (RTS) and LTS seismic programs, several steel beams, which support piping systems, were shown to be inelastic when evaluated by the force/resistance equation defined in Reference [8]. This equation is based upon the general equation of $F/R = \sqrt{2\mu - 1}$ proposed in (References 9, 10).

The number of inelastic beams under this program is 28 (see Table 1), and they are distributed in five areas of the plant: the Reactor Building (RB), the North Turbine Extension (NE), the North Turbine Extension Mezzanine (NEM), the East Heater Platform (EHP) and the West Heater Platform (WHP). All beams are identified according to their location in the plant area and they have the area abbreviation in their alpha-numeric description. Figure 1 shows a plan view of these areas. A total of twelve, safety-related piping systems have either a single inelastic beam or multiple inelastic beams.

To illustrate the building location and piping system on each inelastic beam, a legend (Figure 2) and a partial plan have been developed for each area as follows:

Reactor Building:		Figures 3 and 4
Turbine Building:	• North Extension	Figure 5
	• North Mezzanine	Figure 6
	• East Heater Platform	Figure 7
	• West Heater Platform	Figure 8

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For instance, in Figure 5 there are two piping systems identified on beam NE-B5.2, pipe line SI-51 as a □ and MS-01 as a ◇.

2.1 Inelastic Beam Reevaluations

SCE will reanalyze of all 28 inelastic beams to accurately determine the maximum stress in each. This evaluation will be performed in conjunction with the approach described in Section 2.2. The beams will be reevaluated by LTS project instructions [Reference 11] and LTS criteria [Reference 12], excluding beam ductilities greater than one.

Some of the methods to be used in the beam reevaluations include; a) SRSS of the dynamic loads on each member (with appropriate justification) b) using the LTS floor response spectra, c) utilizing existing shear studs for beams under slabs, and d) use of ASME Code, Level D allowables for all structural steel members. Beams which remain elastic under the reevaluation effort will be eliminated from the modification program described in Section 2.2.

2.2 Beam Modifications

Structural modifications are currently being designed for all 28 inelastic beams. These modifications will be installed at SONGS-1 unless the analyses of sections 2.1 and 3.0 show them to be unwarranted. The beams will be modified such that they remain elastic under all loading cases currently described.

Typical examples of the types and locations of the structural steel modifications are shown in Figures 9 through 12.

2.3 "Secant Stiffness" Methodology

The secant stiffness methodology was applied to each SONGS-1 piping system only if a number of support structures were inelastic or if multiple adjacent supports were inelastic. SCE will eliminate the use of this methodology through the structural steel modifications described in Section 2.2. However, SCE may have piping systems with "isolated" inelastic support structures and description of this particular application is covered in Section 3.0.

3.0 ISOLATED INELASTIC BEAMS

In certain limited instances, SCE will utilize a beam ductility value less than three and it will only be applied to "isolated" beams on any particular piping system.

3.1 Definition and Where They Occur

Isolated inelastic beams are defined in conjuction with a piping system. An inelastic beam is considered "isolated" if a) a piping system has only one seismic support on an inelastic beam or b) if two or more elastic, seismic supports intervene before the next inelastic beam occurs on the piping system. Isolated inelastic beams occur in a limited number of piping systems and a preliminary number of them are identified in Table 2 below. The cases are identified by beam number and piping system(s):

Table 2

No.	Beam No.	Piping System(s)
1	RTS-B18	AC-108
2	WHP-B23.1	SI-05
3	EHP-B24	FW-06
4	EHP-B.3	SI-04
5	NE-B4.7	MS-01

Piping systems with "isolated" inelastic beams will be analyzed to ensure functionality. The methods used to evaluate the piping systems are described in Section 3.2 and in Reference [13].

3.2 Piping Analyses

In general, the initial analysis of the piping system is performed by assuming generic support stiffnesses (K_G). In specific cases, where a review of the supporting structure indicates that the support stiffness is lower than the generic value, the actual elastic support stiffness is used. The actual elastic support stiffness is obtained by calculating the stiffness of the pipe support (K_{ps}) and the stiffness of the supporting frame (K_F) by applying a unit load at the point of interest. The actual elastic stiffness of the supporting structure (K_s) is obtained by appropriately combining K_{ps} and K_F.

For piping systems which have isolated inelastic supporting structures, a five step process is used.

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Step 1 The first step is to compare the actual stiffness of the supporting structure (K_s) to the value assumed in the piping analysis (K_G). For this purpose, the elastic stiffness is obtained as described above. If the beam is inelastic, a modified stiffness is obtained by dividing the elastic beam stiffness by the calculated ductility value.* This stiffness is combined with the pipe support stiffness to obtain the revised stiffness (K_R) of the supporting structure. If K_R is greater than or equal to $K_G/2$, the assumed stiffness is reasonably similar to the actual stiffness and no further pipe evaluations are required.

Step 2 If the comparison shows that K_R is less than $K_G/2$, K_R is then compared to the stiffness of the local pipe span (K_p) in the direction of the restraint. If K_p is significantly lower than K_R (K_p is less than or equal to $K_R/10$), then the assumption that this supporting structure acts as a rigid restraint with respect to the piping system is still valid. As a result, the inelastic behavior of the supporting structure will not impair the pipe's functionality.

Step 3 If K_p and K_R are of the same order of magnitude, a review of the localized piping and pipe support stress margins is performed. If significant margins are present in both the piping and supporting structures, no further evaluations are required.

Step 4 When necessary, a localized evaluation of the piping and adjacent supports is performed to determine if functionality is maintained. The evaluation is usually performed by removing the support and analyzing the stresses in the pipe.

In addition, load redistribution to adjacent supporting structures is performed and the adequacy of these supporting structures is checked. If as a result of these evaluations, both the piping and support structures meet the LTS criteria in Reference [12], pipe-structure interaction has been adequately represented. Otherwise, an upgrade to the supporting structure is implemented to eliminate the inelastic behavior.

Step 5 Should local evaluation of the piping system prove to be cumbersome, a response spectrum analysis of the complete piping system will be performed. The support will be represented by the revised stiffness K_R and the piping system will be checked for functionality.

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*Beam ductility is calculated by a force/resistance relationship [Ref. 10].

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3.3 Justification for "Isolated" Inelastic Beams

The justification for the "isolated" inelastic beam criterion is supported by a piping parametric study. The details of the study are described in Reference [14].

4.0 CONCLUSIONS

This comprehensive program will resolve all 28 inelastic beams at SONGS-1 through the method of reanalyzing beams to demonstrate that they are elastic or by structurally modifying the beams to be elastic. Of the 28 beam population, only a limited number of beams (which support safety-related piping) will be allowed to remain inelastic, provided the piping system functionality is maintained.

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6.0 REFERENCES

1. Presentation to the NRC and Dr. W. F. Hall at Impell Corporation, Chicago, Ill., May 15, 1984.

2. Letter from D. Crutchfield, NRC, to K. Baskin, SCE, dated August 7, 1984, Docket No. 50-206, "Seismic Evaluations of Structural Elements," with Dr. W. J. Hall May 21, 1984 letter Report, Describing Various Issues and Request for Further Evaluations.

3. Letter Report, M. Medford (SCE) to J. Zwolinski, U.S. Nuclear Regulatory Commission, dated Oct. 25, 1984, Docket No. 50-206, SEP Topic III-6, San Onofre Nuclear Generating Station, Unit 1, and attached Report, "Evaluation of Piping and Structures."

4. Letter Report, M. Medford (SCE) to Z. Zwolinski, NRC, dated June 26, 1985, Docket No. 50-206, SEP Topic III-6, San Onofre Nuclear Generating Station, Unit 1, and attached report, "Summary Report on the Evaluation of Piping and Structures."

5. Letter, Dr. W. J. Hall to L. C. Shieh, LLNL, dated October 30, 1985.

6. Presentation to Dr. W. J. Hall/NRC by SCE/Impell Corporation, December 19, 1985, University of Illinois, Champaign, IL.

7. Presentation to NRC and Consultants by SCE/Impell Corporation, February 18-21, 1986, Impell Corporation, Walnut Creek, CA.

8. Bechtel Power Corp. Project Design Criteria, "Impact of Pipe Support Loads on Structures", Job No. 14000-430/470, Revision 1, dated November 10, 1984.

9. Blume, J. A., "A Reserve Energy Technique for the Earthquake Design and Rating of Structures in the Inelastic Range", Proceedings, Second World Conference on Earthquake Engineering, Tokyo, 1960, Vol. II.

10. Blume, J. A. Newmark, N. M. and Corning, L. "Design of Multi-Story Reinforced Concrete Buildings for Earthquake Motions", Portland Cement Association, Chicago, 1961.

11. "Structural Steel Member Evaluation," Impell Project Instruction No. 01, Job No. 0310-070-1355, Revision 1, Southern California Edison.

12. "Seismic Program for Long Term Service," San Onofre Nuclear Generating Station, Unit 1, Southern California Edison, Report No. 01-0310-1368, March 8, 1985.

13. "Pipe-Structure Interaction Analysis," Impell Project Instruction No. 01, Job No. 0310-071-1355, Revision 1, Southern California Edison.

14. Impell Calculations, PSYS-01, Rev. 0, Job No. 0310-054-1355.

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TABLE 1

DUCTILE BEAMS

Location	Beam No.	Ductility
Reactor Building		
1	RTS-B11	2.19
2	RTS-B18	1.50
T.B. North Extension		
3	NE-B4.3	1.80
4	NE-B4.4	2.72
5	NE-B4.7	2.21
6	NE-B4.8	2.15
7	NE-B5.2	1.30
T.B. North Extension Mezzanine		
8	NEM-B2.9	1.03
9	NEM-B4	1.36
10	NEM-B2.10	1.64
11	NEM-B2.11	1.83
12	NEM-B2.2	~3
13	NEM-B2.4	2.82
14	NEM-B2.5	2.47
15	NEM-B2.8	~3
16	NEM-B5	2.60
17	NEM-B6	1.29
T.B. East Heater Platform		
18	EHP-B5	1.32
19	EHP-B6.2	1.31
20	EHP-B7	1.33
22	EHP-B24	1.34
23	EHP-B2	1.91
24	EHP-B4	1.70
25	EHP-B22	1.61
26	EHP-B3	2.32
T.B. West Heater Platform		
26	WHP-B4.1	1.08
27	WHP-B23.1	1.09
28	WHP-B6	2.06

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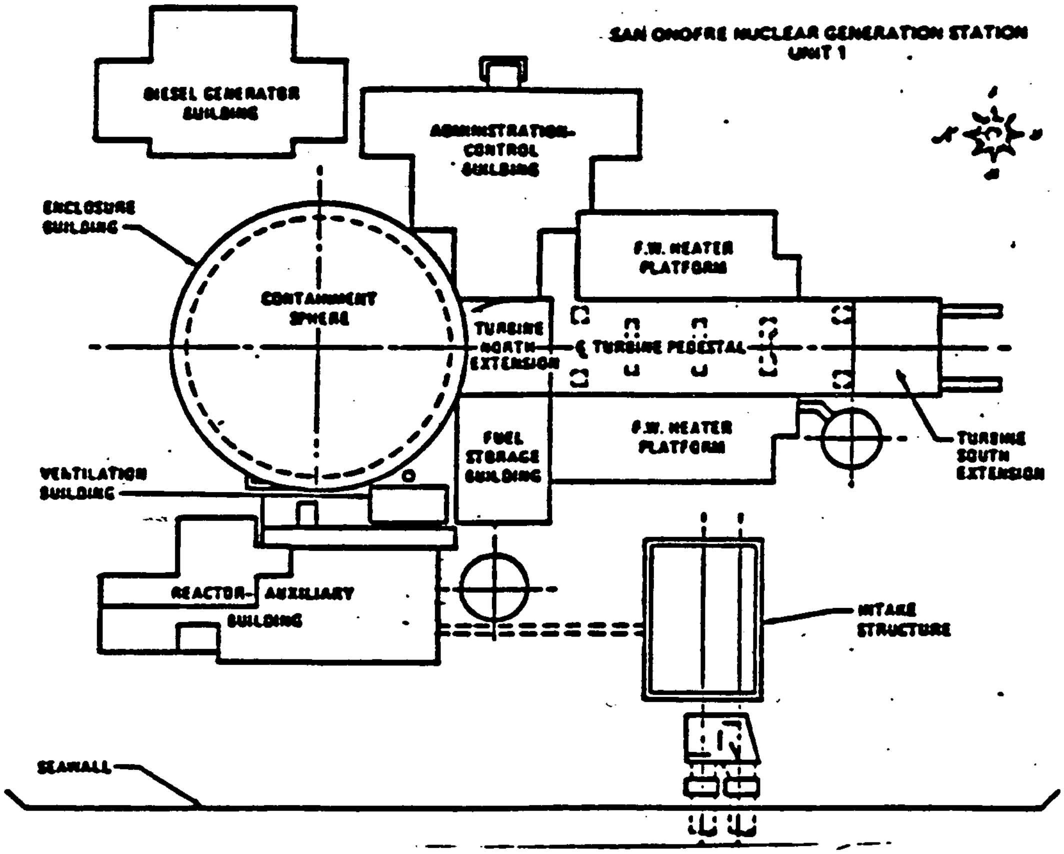

GENERAL SITE PLAN

Figure 1

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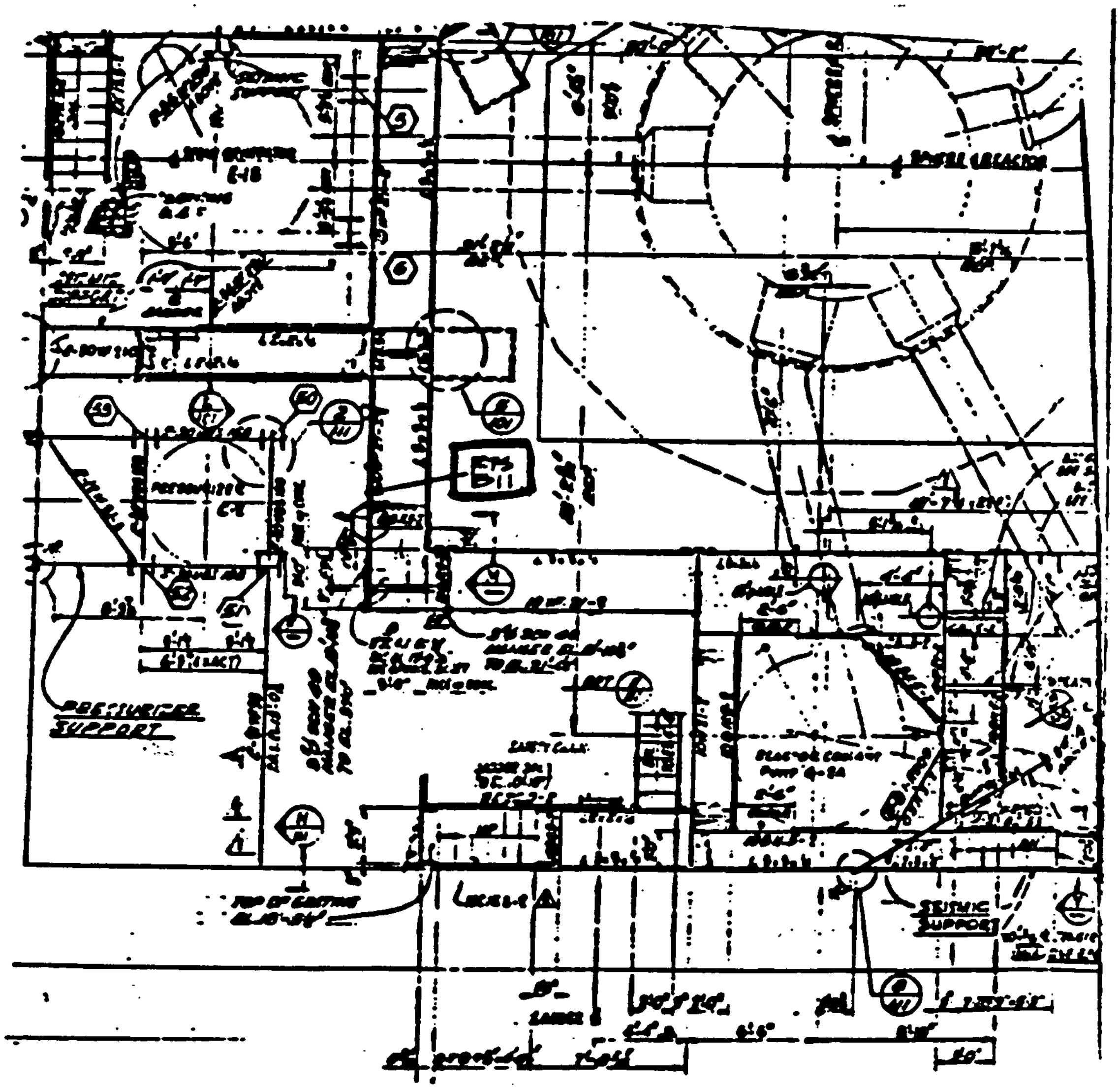
No.	Symbol	Piping System
1	□	SI-51
2	◁	FW-04
3	○	SI-04
4	◇	MS-01
5		FW-06
6	■	MS-03
7	◀	SI-05
8	●	MS-02
9	◆	FW-05
10	▷	RC-103
11	⬡	RC-102
12	⬢	AC-108

LARGE BORE PIPING LEGEND

Figure 2



REACTOR BLDG. PARTIAL PLAN

Elev. 14'-0"

Figure 3

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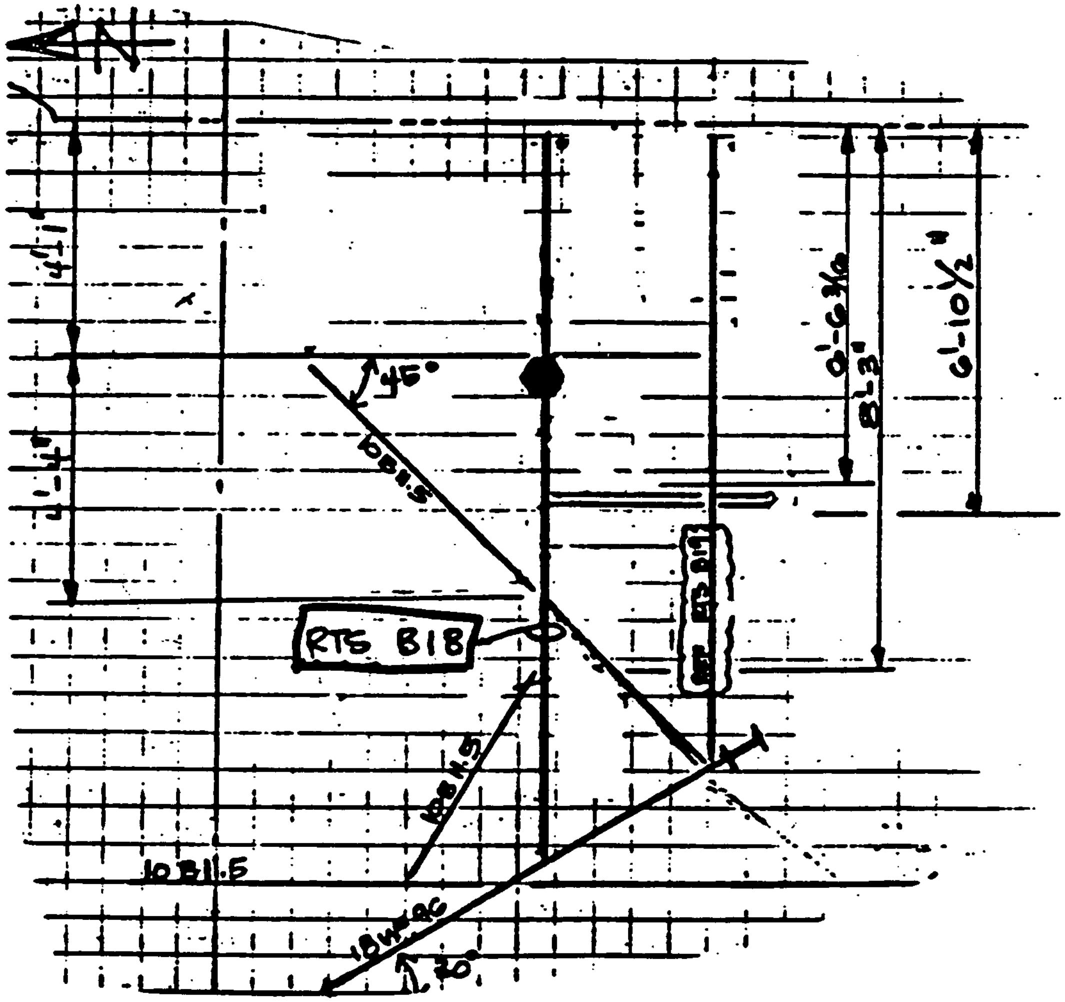

REACTOR BLDG. PARTIAL PLAN

Elev. 14'-0"

Figure 4

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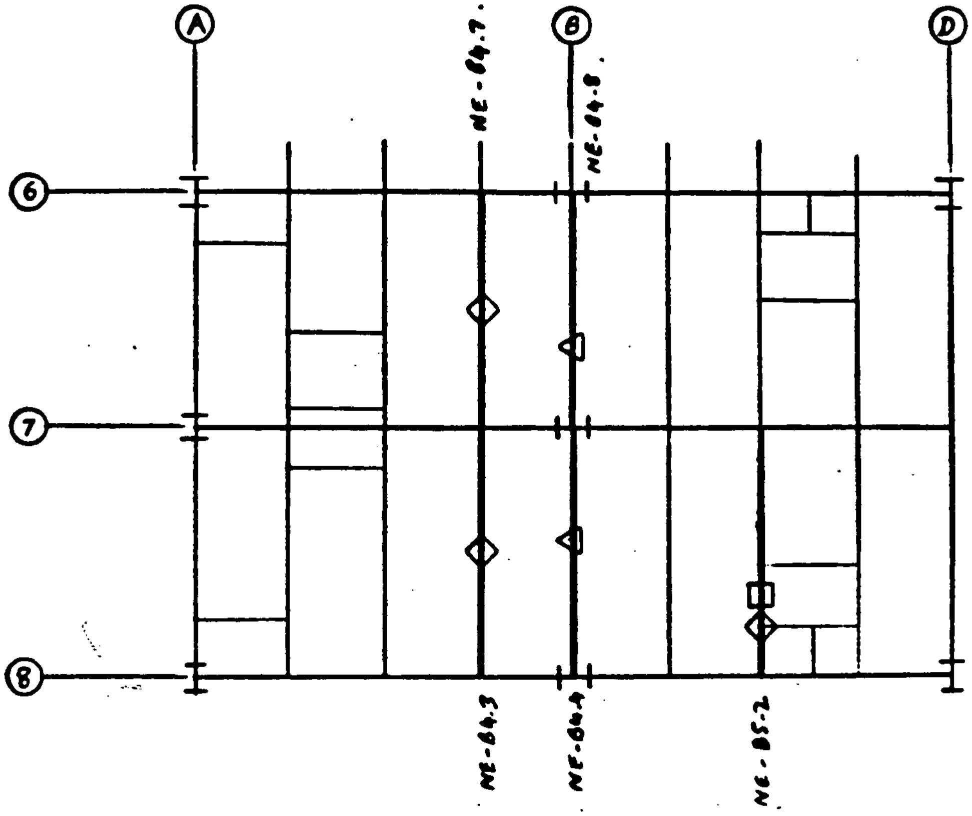

NORTH EXTENSION PLAN

Elev. 42'-0"

Figure 5

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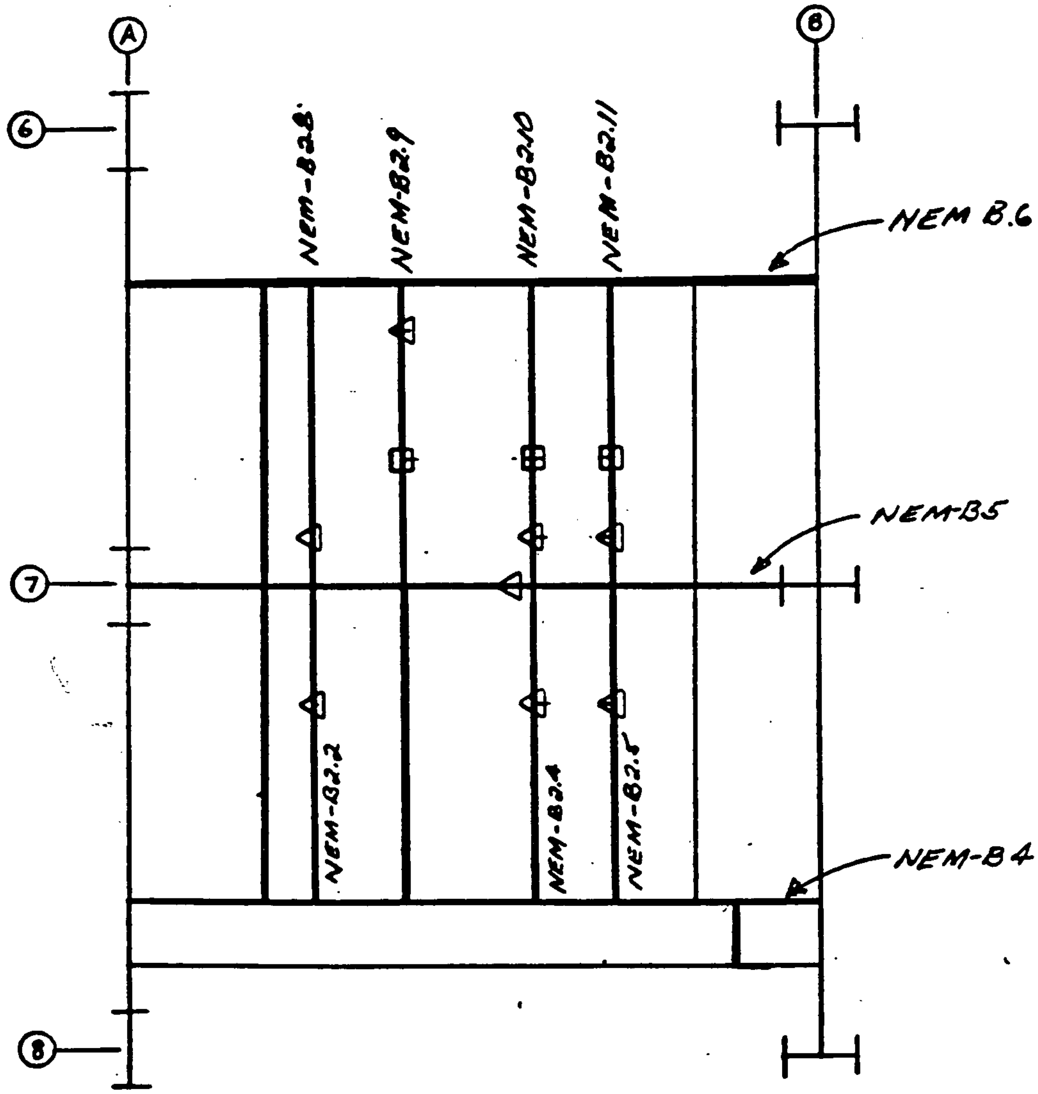

NORTH EXTENSION MEZZANINE PLAN

Elev. 30'-0"

Figure 6

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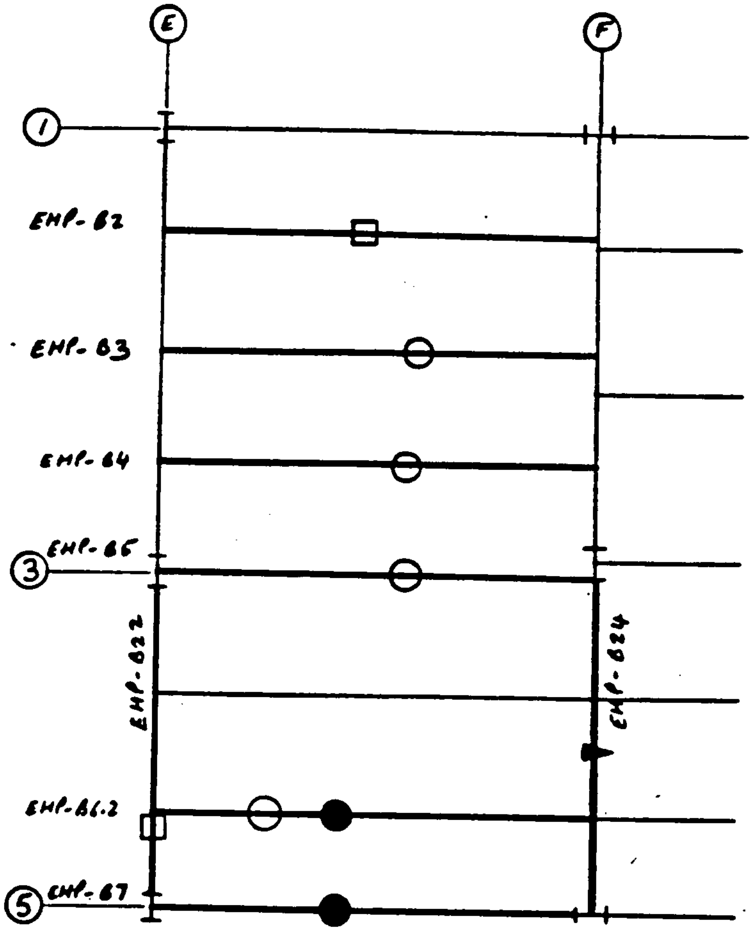

EAST HEATER PLATFORM PLAN

Elev. 35'-6"

Figure 7

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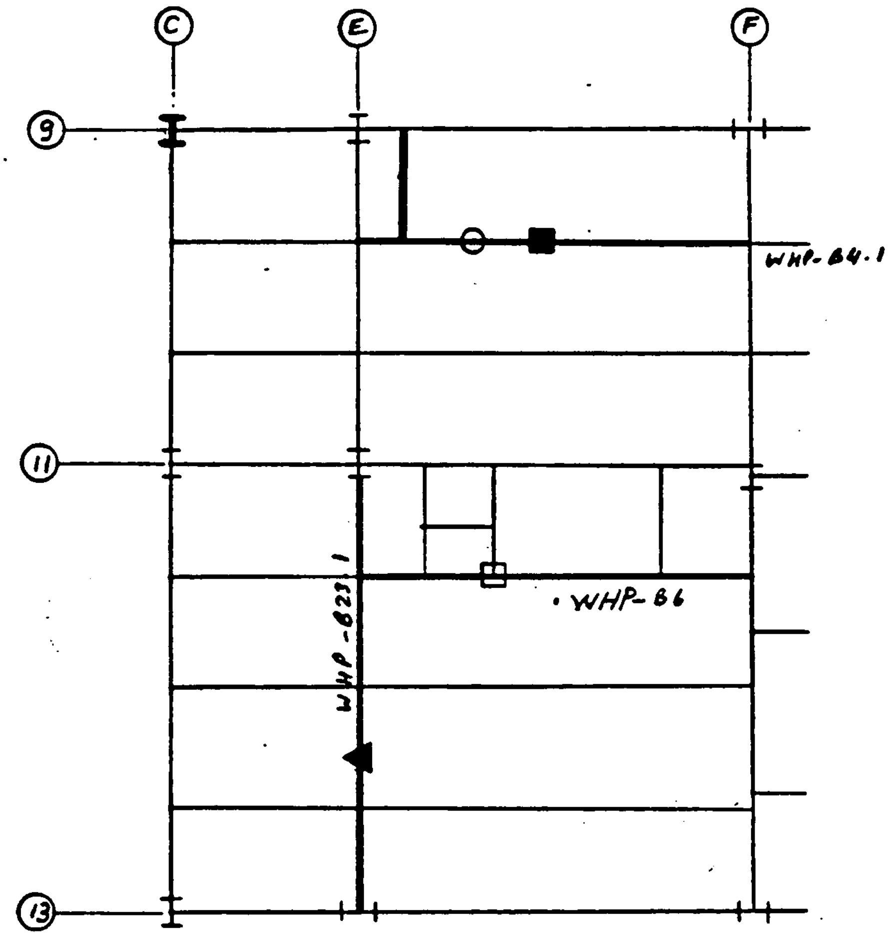

WEST HEATER PLATFORM PLAN

Elev. 35'-6"

Figure 8

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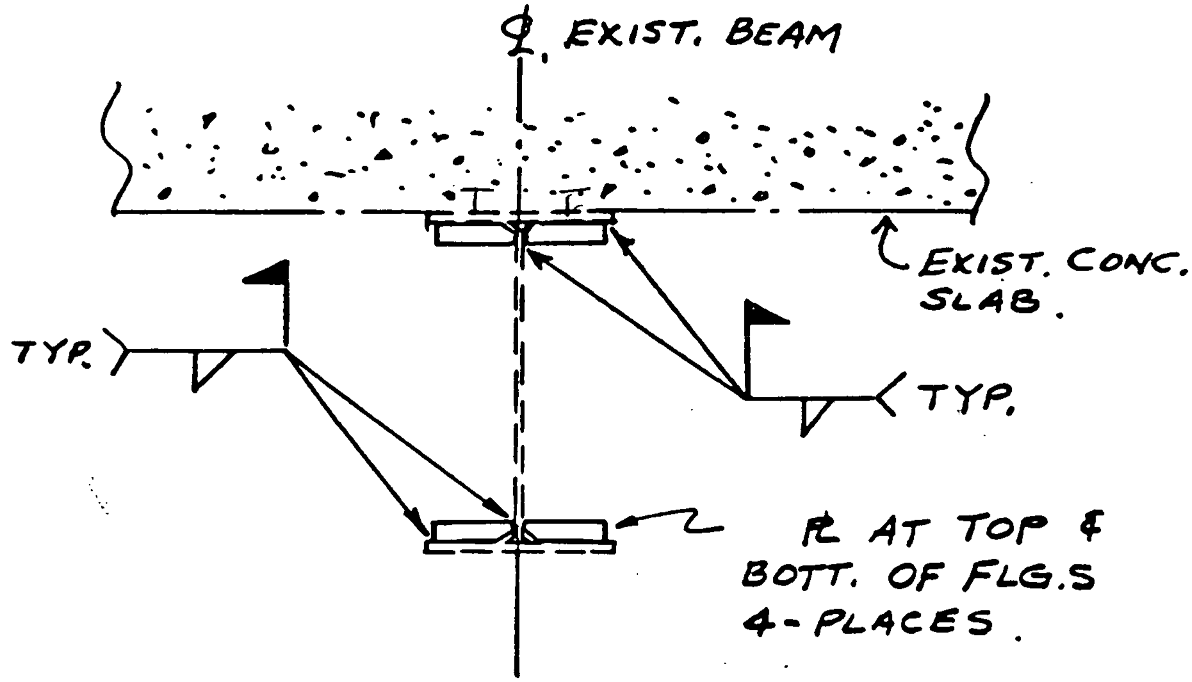
TYPICAL MODIFICATIONS



TYP. MODIFICATION

OPTION NO. 1

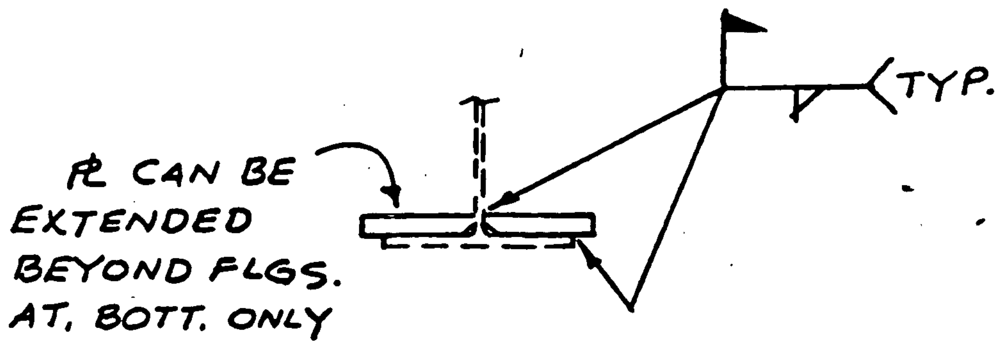


Figure 9

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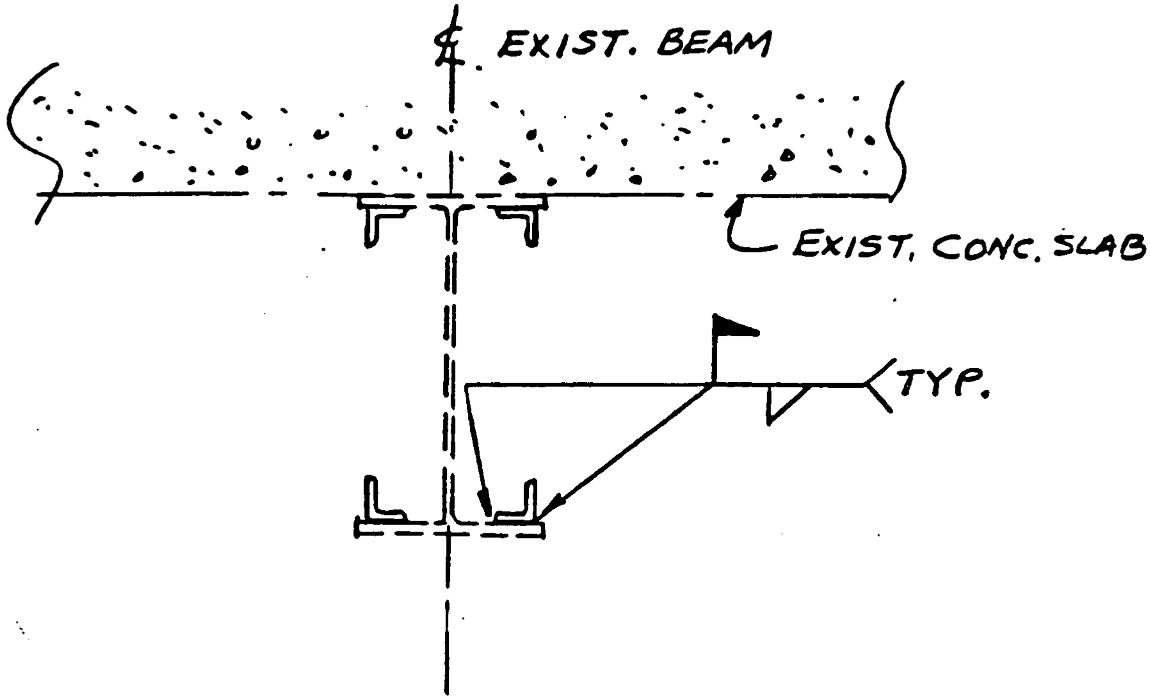

TYP. MODIFICATION

OPTION NO. 2

Figure 10

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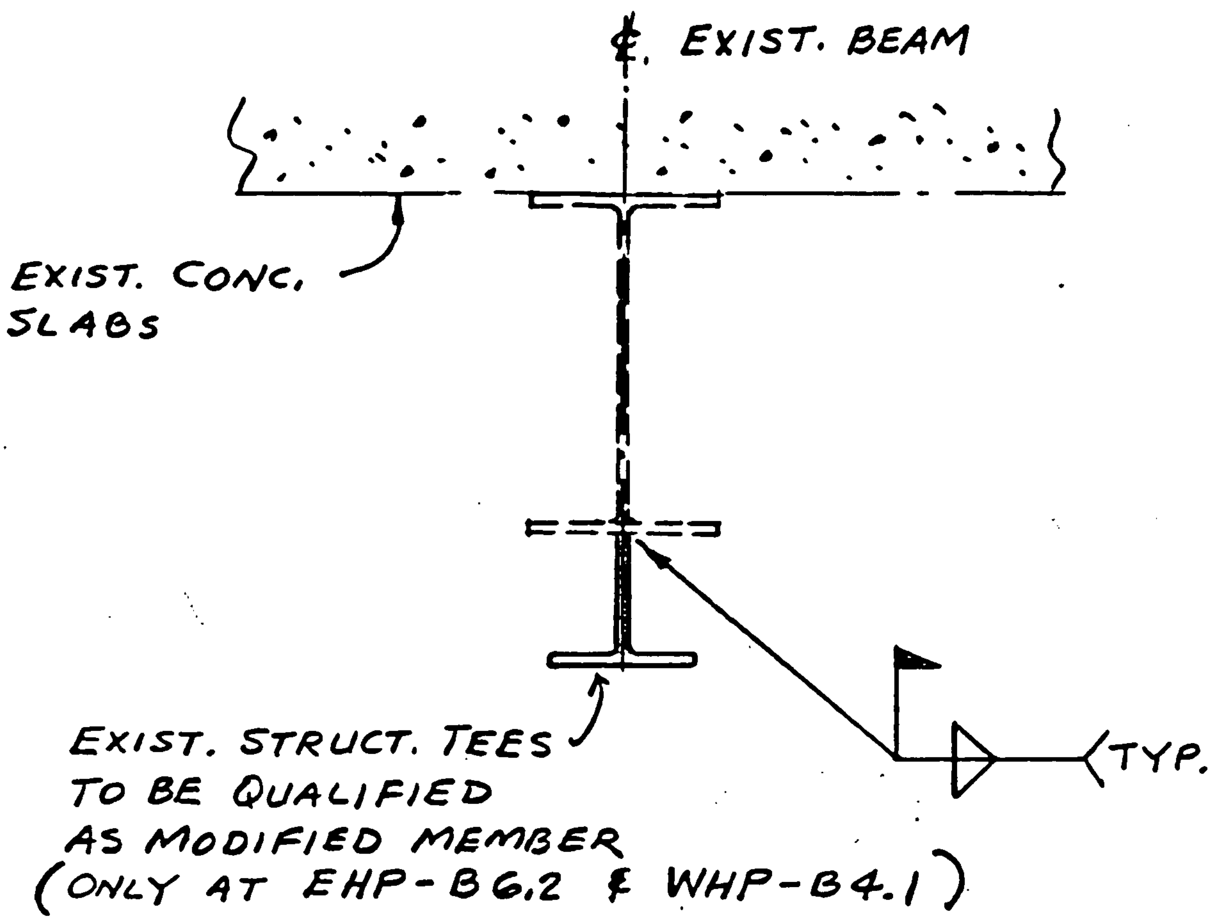
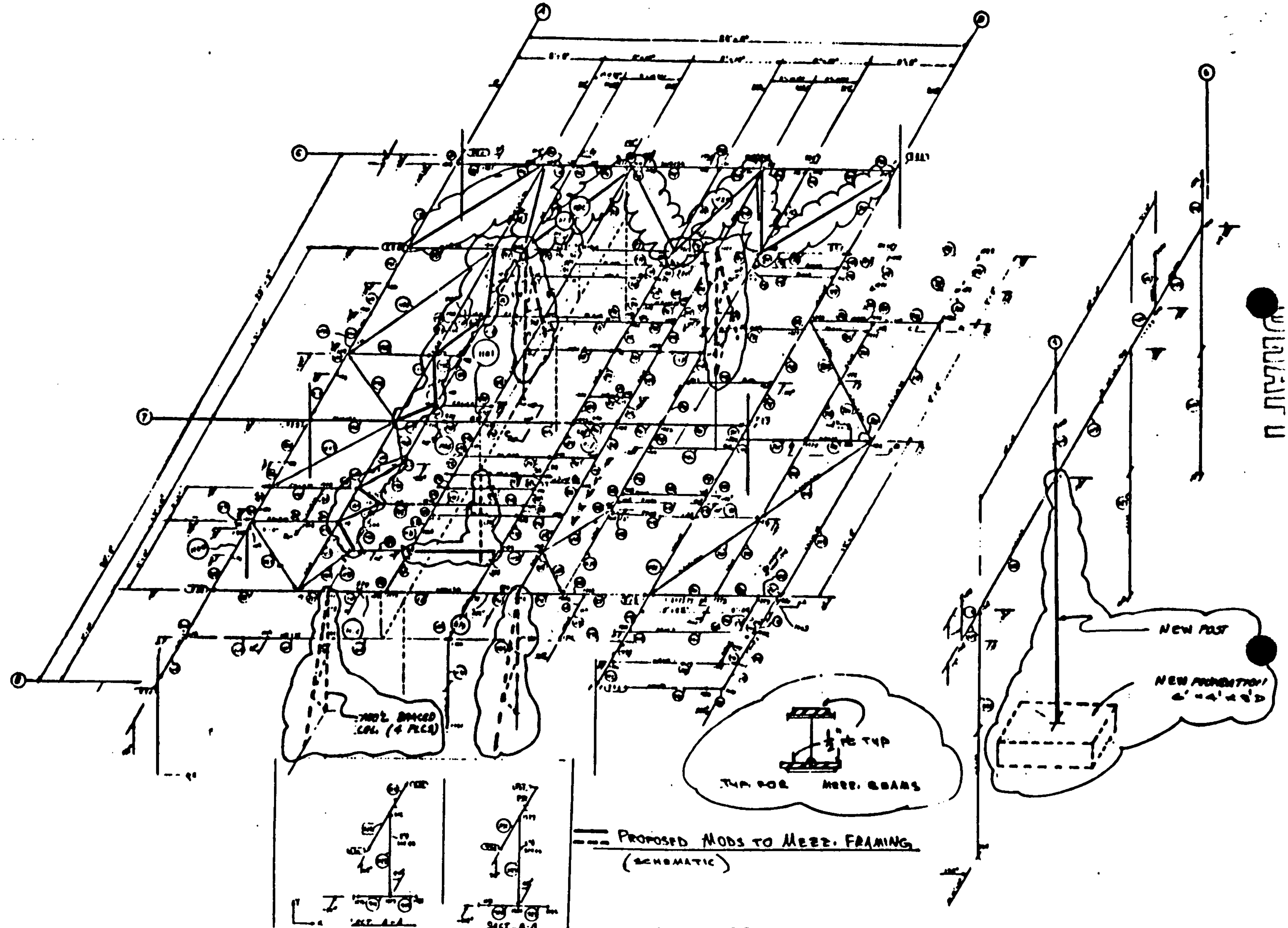


TYP. MODIFICATION

OPTION No 3

Figure 11



NEW POST
NEW FOUNDATION
PROPOSED MODS TO MEZZ. FRAMING
(SCHEMATIC)
TYP FOR MEZZ. BEAMS

Figure 12

Attachment 2

QUESTIONS ON SONGS 1 APPROACH TO INELASTIC BEAMS

The following questions are keyed to paragraphs in the draft submittal (attachment 1)

1) (2.1) - Reference 11 (the LTS Beam Evaluation Project Instruction) has not been reviewed in terms of this proposal. Will a copy of it be made available for review?

2) (2.1) - Provide an example of an appropriate justification for using SRSS combination of beam loads.

3) (2.1) - Will the SRSS combination of beam loads be performed at the beam stress level? If not, describe how the combinations will be done.

4) (2.1) - How will shear studs be utilized in evaluating beams?

5) (2.1) - Clarify the usage of LTS spectra. Haven't they been used all along in LTS analysis?

6) (2.1) - Justify using ASME Level D allowable stresses in determining that beam response will remain elastic.

7) (2.2) - What criteria will be used to evaluate the modified beams?

8) (3.1) - Will an inelastic beam with two attached pipe supports, each from a different piping system, be considered isolated (example - NEM-B2.9 in Figure 6)?

9) (3.1) - Will an inelastic beam which supports multiple inelastic beams with attached pipe support be considered isolated (example NEM-B5 in Figure 6)?

10) (3.1) - Table 2 has been designated as "Preliminary". Will the size of table 2 increase as the evaluation progresses?

11) (3.2, step 2) - How will the stiffness of the local pipe span be determined?

12) (3.2, step 3) - Clarify the term "same order of magnitude", does this term mean that step 3 will be performed if the test in step 2 is failed?

13) (3.2, step 3) - Clarify the term "significant margin".

14) (3.2, step 4) - What are the details of the proposed piping evaluation in step 4?

15) (3.2, step 4) - In evaluating adjacent support structures for redistributed laods, will the isolation criteria of section 3.1 be applied? If not, what criteria are to be applied?

16) (3.2, step 4) - What criteria will be used to ensure functionality of piping and supports in step 4?

17) (3.2, step 5) - Will supports be evaluated for the new loads predicted by the response spectrum analysis in step 5?

18) (3.3) - Provide the justification for the inelastic beam criterion (Reference 14)

19) (Table 1, p 7) - Can Table 1 be amended to include a column identifying the disposition of each beam? Entries like "elastic by SRSS", "modified" and "inelastic" are suggested.

20) (General) - Confirmatory analysis and audit activities can be expected for the inelastic beam analyses. To support the audits, a copy of the Project Instruction governing this work (Reference 13) should be provided prior to the audit activity.

21) (General) - A coupled pipe/structure interaction analysis, consisting of the FW-04, SI-51, and mezzanine models, has been undertaken. What is the status of this analysis? Will the results be provided?