PGandE Letter No.: DCL-85-207

ENCLOSURE

FINAL REPORT

DIABLO CANYON UNITS 1 AND 2
PIPEWAY STRUCTURES

PACIFIC GAS AND ELECTRIC COMPANY

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DIABLO CANYON UNITS 1 AND 2

PIPEWAY STRUCTURES

1.0 Introduction

The Diablo Canyon pipeway structures are steel frame structures attached to the outside of the containment shell, the auxiliary building, and the turbine building, to support main steam lines and feedwater lines. Large portions of the structures were shop-fabricated and then joined together in the field by bolted connections.

The Unit 1 pipeway seismic analysis for the Hosgri event was performed by Westinghouse, whereas the Unit 2 analysis was performed by PGandE. The Westinghouse analysis work is summarized in a report, "Structure Analysis of the Pipeway Frame Structure for Diablo Canyon Unit 1," WCAP-10269, June 1983. The PGandE Hosgri analysis for the Unit 2 pipeway structure is documented in Calculation File 52.10.2. Subsequent PGandE evaluations for load combinations including the design earthquake (DE) and double design earthquake (DDE) for Units 1 and 2 are documented in Calculation Nos. 2151C-2 and 1149C-1, respectively.

PGandE performed the Hosgri seismic evaluations for the Unit 2 pipeway structure using a three-dimensional frame model. This model incorporated a nine-mass, single stick representing the containment

shell. The adequacy of the stick model was demonstrated by a comparison of the floor response spectra generated by both the stick model and an axisymmetric finite element model of the containment exterior wall. Good agreement was found between the floor spectra from both models. The stick model of the containment was coupled with the three-dimensional assembly of beam and truss elements representing the pipeway structure plus the major piping systems. Piping and piping supports were modeled with beam elements. This coupled model was used for seismic analysis for the postulated Hosgri earthquake.

Westinghouse performed the Hosgri seismic evaluation of the Unit 1 pipeway structure and developed the pipeway in-structure seismic response spectra. The in-structure response spectra was used for pipeway area piping analyses. The seismic model accounted for the dynamic interaction between the containment shell, pipeway frame structure, pipe supports, and the main steam and feedwater piping. This coupled model was used in the seismic evaluation of the Hosgri loads on the pipeway structure and supported piping.

2.0 Background

In SSER 29, the NRC Staff documented its overall evaluation of the application, implementation, and results of the Unit 1 design verification efforts with respect to Unit 2. The Staff's evaluation of the seismic design aspects of civil structures is contained in

Sections 3 through 8 of SSER 29. The Staff's review for seismic design was expanded during the Unit 2 evaluations with respect to buried electrical conduits (selected for independent review and fully resolved in SSER 29 for Units 1 and 2), and the Units 1 and 2 pipeway structures. The pipeway structures were selected for further review because they were the subject of a recent anonymous allegation relating to analytical details used in the seismic model for the Unit 2 pipeway structure. Since allegations are resolved for both units, if applicable, the Staff's review also included the analysis work performed by Westinghouse on the Unit 1 pipeway structure.

NRC Staff civil/structural audits of the pipeway structures were performed in January 1985 at the PGandE office in San Francisco and in February 1985 at the Westinghouse office in Monroeville, Pennsylvania. As a result of the January audit on the Unit 2 structure, PGandE provided followup information to the Staff on January 31, 1985; this information is summarized in Section 3 of this report. After the Unit 1 pipeway structure audit in February 1985, PGandE provided certain additional information to the Staff in March 1985; this information is summarized in Section 4.

Included in Section 5 is a summary of the Unit 1 pipeway structure evaluation for DE and DDE load combinations. This detailed information is being provided to the Staff for the first time in this report, however, the conclusion of this work was provided to the Staff by letter

of April 19, 1985 (see Appendix 6), and in a followup audit of the Unit 1 pipeway structure conducted by the Staff on May 30 and 31, 1985.

3.0 NRC Staff Audit of January 15-17, 1985 (Unit 2)

During January 15-17, 1985, the NRC Staff and its consultants conducted an audit of the Hosgri analysis for the Unit 2 pipeway structure. As a result of the audit, the Staff requested that PGandE provide additional information related to the following items:

(1) Pipeway structure boundary conditions at the auxiliary building and the turbine building

(2) Time-step used for generation of pipeway structure response spectra

(3) Effect of containment torsion on the pipeway structure

(4) Relative motion between structures

(5) Design earthquake (DE) and double design earthquake (DDE) analysis

Information on each of the above items was forwarded to the Staff as followup to the audit on January 31, 1985; this information, with minor revisions, is included in Appendix 1. Each of these items is also summarized below.

3.1 Boundary Conditions

The Staff questioned the modeling of the slotted holes provided to allow for the relative motion between the pipeway structure and the auxiliary building. Their specific questions involved the nodes representing the connection of the pipeway structure to the auxiliary building being modeled as free nodes in both global horizontal directions. Similar modeling procedures were used for the end nodes of the radial beams of the pipeway structure which are framed into the turbine building.

PGandE confirmed that the as-built conditions at the structural connections of the pipeway structure to the auxiliary building and the turbine building are consistent with the assumption in the structural model used for the dynamic analysis (the pipeway structure is free to move relative to these buildings). (See Appendix 1, pages 1 and 2)

3.2 Integration Time-step

An integration time-step of 0.01 seconds was used to generate response spectra of the pipeway structure for the Hosgri event. The Staff requested justification of the adequacy of this time-step to properly compute response spectra above 10 Hz.

PGandE provided justification that the integration time-step for response spectra generation was sufficiently small to adequately predict

response for all frequencies of interest. Information was also provided to show that no significant numerical error was introduced in the analytical techniques used (see Appendix 1, pages 3, 4, and 5).

3.3 Containment Torsion

In the dynamic analysis of the pipeway structure, PGandE accounted for accidental torsion by increasing the structural responses by a factor of 1.06, rather than offsetting the masses at certain eccentricities from the orthogonal axes. The Staff requested justification of this procedure.

PGandE provided the results of a study performed by URS/John Blume & Associates in 1979 on the Unit 1 pipeway structure which concluded that a 6% increase in the structural responses is sufficient to account for accidental torsion effects. A comparison of critical structural parameters for Unit 2, such as mass moments of inertia and member sizes/layout, was performed. The results confirmed that the 6% increase in structural responses was also appropriate for the Unit 2 pipeway structure (see Appendix 1, pages 6, 7, and 8).

In SSER 29, the Staff concluded that the above method for accounting for accidental torsion was acceptable.

3.4 Motion Between Structures

3.4.1 Strength Considerations

The Staff requested that PGandE review the strength capability of the pipeway structure to sustain the relative motions of the containment, auxiliary building, and turbine building, and remain within allowable stresses.

PGandE provided details of the pipeway structure connections to the adjacent structures which ensure no additional stresses are developed in the pipeway members due to relative horizontal motion. Vertical motions of the containment (+0.060 inches), auxiliary building (+0.005 inches), and turbine building (+0.011 inches) can be accommodated with all resulting stresses below allowable values (see Appendix 1, pages 9 and 10).

In SSER 29, the Staff concluded this issue was resolved.

3.4.2 Input Motion Considerations

PGandE used the containment ground acceleration time-history as input to all support nodes of the pipeway structure dynamic model. The Staff requested the basis for selection of a single input time-history since the pipeway is supported by several different structures.

PGandE provided additional information in order to justify the selection of the input used in the Hosgri evaluation of the pipeway structure (see Appendix 1, pages 7 and 8). A comparison was made of vertical spectra from both the containment and the turbine building at the location where the pipeway structure is supported. It shows that the containment acceleration spectra envelope the turbine building spectra at all frequencies of interest. Due to the pinned conditions at both ends of the beams that connect the pipeway structure and the auxiliary building, and the slotted holes provided, no seismic loads can be transmitted from the auxiliary building to the pipeway structure. (See Section 4.2 for a discussion of transmission of seismic loads through the piping systems.)

3.5 DE/DDE Evaluation - Unit 2

Since the design of structural members of the pipeway structure could be controlled by the DE or DDE in combination with other loads, the Staff requested that an evaluation be performed for these load combinations.

The Unit 2 seismic evaluation for load combinations including DE and DDE is documented in Calculation No. 1149C-1, Rev. 0. A summary of results for critically loaded structural bents is included in Appendix 1, page 11. PGandE concluded that the Unit 2 pipeway structure satisfies design criteria for load combinations including the DE and DDE.

4.0 NRC Staff Audit of February 28, 1985 (Unit 1)

On February 28, 1985, the NRC Staff and its consultants conducted an audit of the Hosgri analysis performed by Westinghouse for the Unit 1 pipeway structure. At the audit exit interview, the Staff requested that PGandE provide additional information on the following items:

(1) Time-step used for generation of pipeway structure response spectra

(2) Transmission of seismic loads through the piping systems

Information on the above items was sent to the Staff on March 6, 1985 as followup to the audit; this material is included in its original form in Appendix 2. Each of the items is summarized below:

4.1 Integration Time-step

The Staff questioned whether the 2% spectra generated from the design time-history (with a time-step of 0.01 sec) envelopes the design response spectra in the high frequency region.

PGandE provided a Blume spectra for 2% damping generated from the 24-second design time-history (with a time-step of 0.01 sec) to show there was a good match in the region greater than 12 Hz. PGandE concluded that the design time-history used in the analysis was adequate (Appendix 2, Question 1).

4.2 Load Transmission Through Piping Systems

The Staff questioned the assumption of using the containment building input motion at the auxiliary building snubber locations for the main steam and feedwater lines and if this assumption could affect the response spectra generated in the pipeway structure.

PGandE provided a discussion supporting the conclusion that the relative motion between the auxiliary building and the containment transmitted through the piping systems would not affect the spectra generated in the pipeway structure (Appendix 2, Question 2).

4.3 Additional Staff Requests

After receipt of the audit followup information discussed above, the Staff requested additional information on Calculation No. 1149C-1, Rev. 0 and pipeway response spectra for 2% and 7% damping generated using two distinct integration time-steps. This information was sent to the Staff on March 18, 1985, and is reproduced in Appendices 3 and 4.

5.0 DE/DDE Evaluation (Unit 1)

Since the design of structural members of the pipeway structure could be controlled by the DE and DDE in combination with other loads, the Staff requested that an evaluation be performed for these load combinations.

The Unit 1 seismic evaluation for load combinations including the DE and DDE is documented in Calculation No. 2151C-2. A summary of results for critically loaded structural bents is included in Appendix 5. PGandE concluded that the Unit 1 pipeway structure satisfies design criteria for load combinations including the DE and DDE.

6.0 Conclusions

Based on the information contained in Appendices 1 through 4, PGandE concludes that the analytical models, boundary conditions, response spectra, input motion, and assumptions used for the Hosgri analysis of the Units 1 and 2 pipeway structures are appropriate.

The summary information contained in Appendix 1 (Attachment E) and Appendix 5 related to pipeway structure evaluations for DE and DDE load combinations supports the conclusion that the Units 1 and 2 pipeway structures satisfy design criteria for these events. This conclusion was reported to the NRC Staff on April 19, 1985, in PGandE letter DCL-85-158 (Appendix 6) and discussed with the Staff audit team on May 30 and 31, 1985.

APPENDIX 1

ADDITIONAL INFORMATION ON PIPEWAY STRUCTURE

UNIT 2

JANUARY 30, 1985

0696M

PIPEWAY STRUCTURE BOUNDARY CONDITIONS AT THE AUXILIARY BUILDING AND TURBINE BUILDING, UNIT 2

As discussed during the NRC audit, the:boundary conditions used for the analysis of the pipeway structure beams framing into the auxiliary and turbine buildings were input as restrained nodal displacement in the vertical direction and unrestrained, i.e., free to move, in both horizontal (east-west and north-south) directions. As-built conditions ensure free movement of the pipeway structure as described below.

a. The connection detail for the north end of the tangential beams framing into the auxiliary building is as shown in Attachment A (Detail 1 on SKC-PW-01). This detail allows for free movement in north-south direction through the slotted holes with finger-tightened bolts. The oversize holes provide for a limited movement in the east-west direction. This condition, however, does not restrain the pipeway structure in the east-west direction because the connection at the south end of these beams uses clip angles on either side of the beam web. The tangential beams framing into the auxiliary building do not support the main steam and feedwater lines.

b. The connection detail for the west end of the radial beams framing into the turbine building is as shown in Attachment A (Section A on SKC-PW-01).

Since the horizontal differential movement of the turbine building with respect to the pipeway structure is $\pm$ 0.17 inches in the north-south direction, and $\pm$ 0.24 inches in the east-west direction, the wide slots provide more than sufficient clearance to assure the boundary condition assumptions are representative of as-built conditions.

TIME STEP FOR PIPEWAY STRUCTURE DYNAMIC ANALYSIS

1. Unit 1 Pipeway Structure Analysis

The Δt used in both the time-history analysis and response spectra generation was 10 milliseconds. This Δt was judged to be sufficiently small for the following reasons:

a. In a linear, modal superposition, time-history analysis, the Westinghouse WECAN computer code uses an exact solution for the integration of the modal equation for each of the linear segments of the applied forcing function. In other words, each linear segment of the applied forcing function during integration is represented exactly without any approximation. Thus, for a linear structure subjected to a linear segment of the forcing function, the equations of motion are analytically integrated in one time step. Hence, a smaller integration time step is not necessary.

b. In the time-history analysis performed, all 347 modes with frequencies up to 800 Hz are included in the summation of the modes.

2. Unit 2 Pipeway Structure Analysis

The Bechtel BSAP (CE800) computer code was used in the time-history analysis of the Diablo Canyon Unit 2 pipeway structure. For response spectra generation, the computer program SPECTRA (CE802) was used.

In the time-history analysis, a time integration is required to obtain nodal point time-histories from the input ground time-history. In the BSAP computer code, two procedures are available for this purpose as shown on page 1 of Attachment B. The method used to perform the pipeway analysis used the rigorous. closed-form solution of a ramp function. The theoretical description of this closed-form method, which is based on Reference 1 on page 6 of Attachment B, is provided in pages 2 through 5 of Attachment B which are from the BSAP Users/Theoretical Manual.

The SPECTRA program was used to compute the nodal point response spectra for various damping ratios, after the time-history analysis was performed. The SPECTRA program uses the theory provided in Reference 1 on page 6 of Attachment B. This method is also a closed-form solution of a ramp function. It automatically uses a subinterval of 1/10 of the period being calculated or the input motion time-step (whichever is smaller) as indicated in Section 3.1.1.3 on page 7 of Attachment B.

Based on the above, it was concluded that no significant numerical error was introduced at either of these two analytical steps, since in both cases a closed-form solution method was actually used.

EFFECT OF CONTAINMENT TORSION ON PIPEWAY STRUCTURE ANALYSIS

The accidental torsional effects were considered in the analysis of the pipeway by using a 6 percent increase of the structural responses. The 6 percent increase was based on a study performed for Unit 1*:

a. Three different lumped mass containment exterior structure models, as shown in Attachment D, were prepared:

   (1) no eccentricity of all masses

   (2) 5% eccentricity of all masses

   (3) 7% eccentricity of all masses

b. Time-history analysis and subsequent spectra generation for these three models were performed.

c. Spectra results at the elevation of the pipeway frame were obtained.

d. The following equations (criteria was adopted from Ref. 1) were used to calculate the amplification due to torsion:

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* "DIABLO CANYON UNIT 1, Containment Structure Dynamic Seismic Analysis for the 7.5M Hosgri Earthquake," May 1979, by URS/John Blume & Associates, San Francisco, California.

(1) $H_{t1} = / H_{tr} / + / X \times H_{t05} /$

(2) $H_{t2} = / (H_{tr})^2 + (X \times H_{t07})^2$

where:

H_{t1} and H_{t2} = the total horizontal response for 5% and 7% eccentricity, respectively

H_{tr} = translation response due to horizontal ground motion from the non-eccentricity model

H_{t05} = torsional response at the center-of-rigidity of the containment from the 5% eccentricity model

H_{t07} = torsional response at the center-of-rigidity of the containment from the 7% eccentricity model

X = radius of the containment structure = 840 in.

and, $r_1 = \frac{H_{t1}}{H_{t2}}$

$r_2 = \frac{H_{t2}}{H_{tr}}$

It was found that $r_1 = 1.06$ and $r_2 = 1.03$.

e. From the above calculation, it was concluded that the 6% increase in the structural response was sufficient to cover the accidental torsional effects for Unit 1.

For Unit 2, a comparison of the critical structural parameters such as mass moments of inertia and pipeway member size and layout for both units was performed. The results of the comparison indicated that the 6% increase in structural response was also applicable to Unit 2.

RELATIVE MOTIONS BETWEEN STRUCTURES

The relative motions of the containment, auxiliary, and turbine buildings impact the pipeway structure analysis in two aspects: (1) the strength capability of the pipeway structure, and (2) the input motion for the seismic analysis. A review of these considerations, as described below, shows that the analysis performed was appropriate and conservative.

The strength capability of the pipeway structure to sustain these relative motions and remain within allowable stresses was reviewed. The slotted hole attachments, as described above, ensure that no additional stresses are developed due to relative horizontal motion. The vertical motions of + 0.060 inches for the containment, + 0.005 inches for the auxiliary building, and + 0.011 inches for the turbine building can be accommodated with all resulting stresses maintained below allowable values.

The use of containment shell input motion for the analysis of the pipeway structure was also reviewed. For horizontal motion, it was concluded that no significant input occurs from the auxiliary or turbine buildings due to the connection details as described above.

In the vertical direction, two cases were considered: coupling with the turbine building and coupling with the auxiliary building. In the case of the turbine building, a comparison of applicable seismic response spectra (as shown in Attachment C) shows that containment spectra envelope the turbine

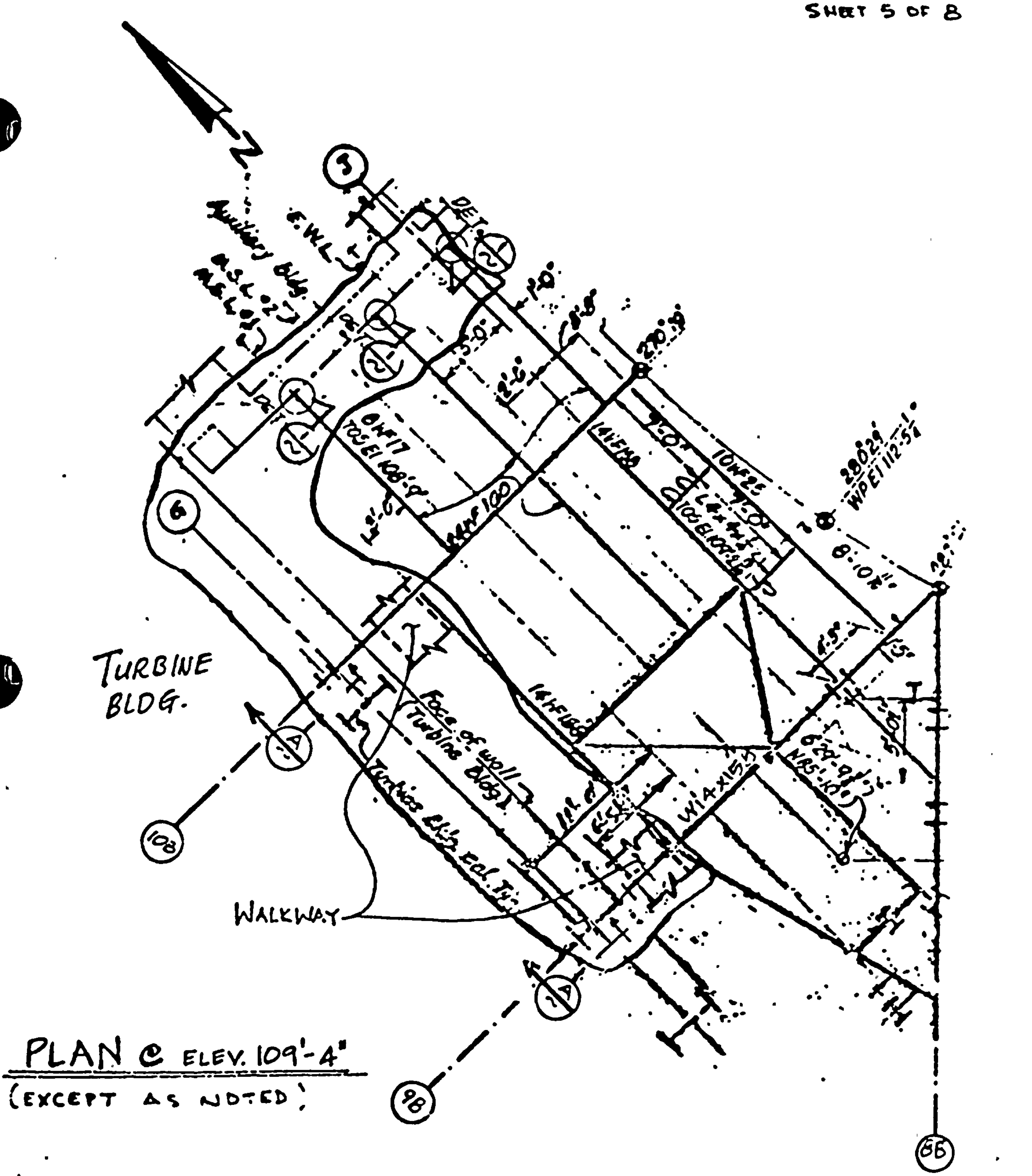
building spectra. Thus, the use of containment input motions for the turbine building support points is appropriate and conservative.

In the case of the auxiliary building, seismic input motions will not propagate from the auxiliary building support points to the pipeway structure because both ends of the beams supported on the auxiliary building are pinned and, thus, assure free movement in the east-west direction. As shown in Attachment A, slots are provided at the auxiliary building supports resulting in free movement in the north-south direction. At the south end of the connecting beams, the clip angle detail provides a pinned condition.

SEISMIC ANALYSES FOR DESIGN EARTHQUAKE AND DOUBLE DESIGN EARTHQUAKE

As part of the Diablo Canyon Internal Technical Program, the pipeway structure analyses for load combinations including DE, DDE, and pipe rupture loads were not explicitly performed. In lieu of this analysis, the original analysis work by PGandE and the followon analysis work by QUADREX were reviewed. It was judged that loads from the revised Hosgri analysis and loads from the earlier pipe rupture analysis, by QUADREX, would govern the design, making it unnecessary to perform detailed design earthquake (DE) and double design earthquake (DDE) analyses. It was noted that the effect of seismic loads on member forces was generally much smaller than the effects of pipe rupture restraint loads on member forces. It was also noted that members which were critical for seismic loads were generally not coincident with members that were critical for rupture restraint loads. In those few cases where a member was critical for both loads, it was concluded that local nonlinearities (allowed by pipe rupture restraint criteria) would result in force redustribution due to structural redundancy.

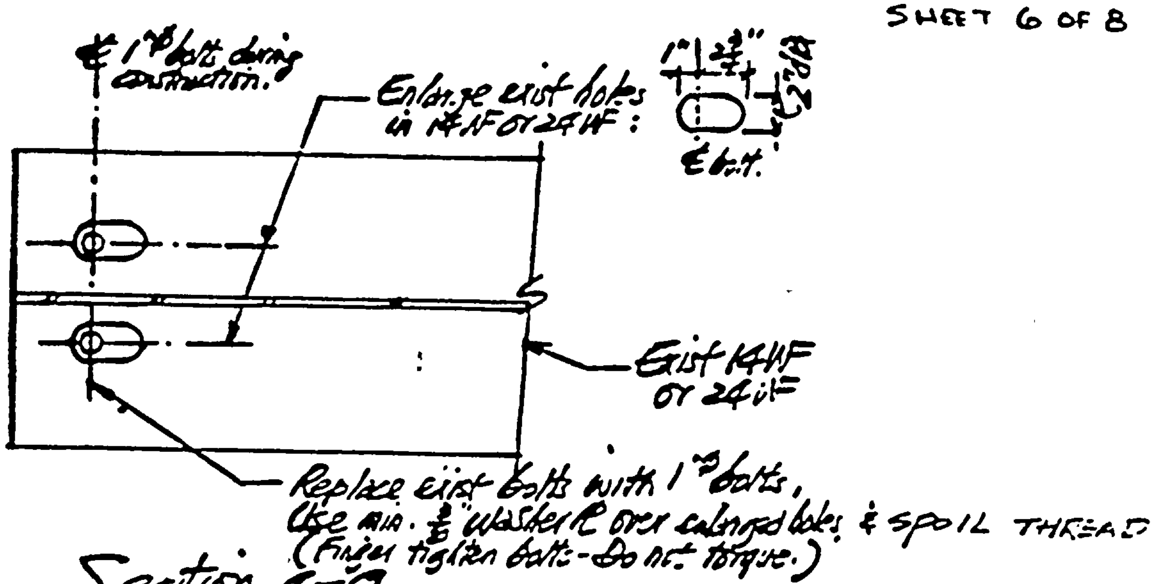
To verify this judgement, an evaluation was performed on members identified as critical for both seismic and rupture loads. The seismic critical members were determined from the Hosgri evaluation. The members critical for pipe rupture loads were determined from the verification program for rupture restraints and their supporting structures. A brief description of the critical member selection process and a summary of the results of the evaluation are given in Attachment E. The results demonstrate that the pipeway structure satisfies design criteria for DE and DDE load combinations.



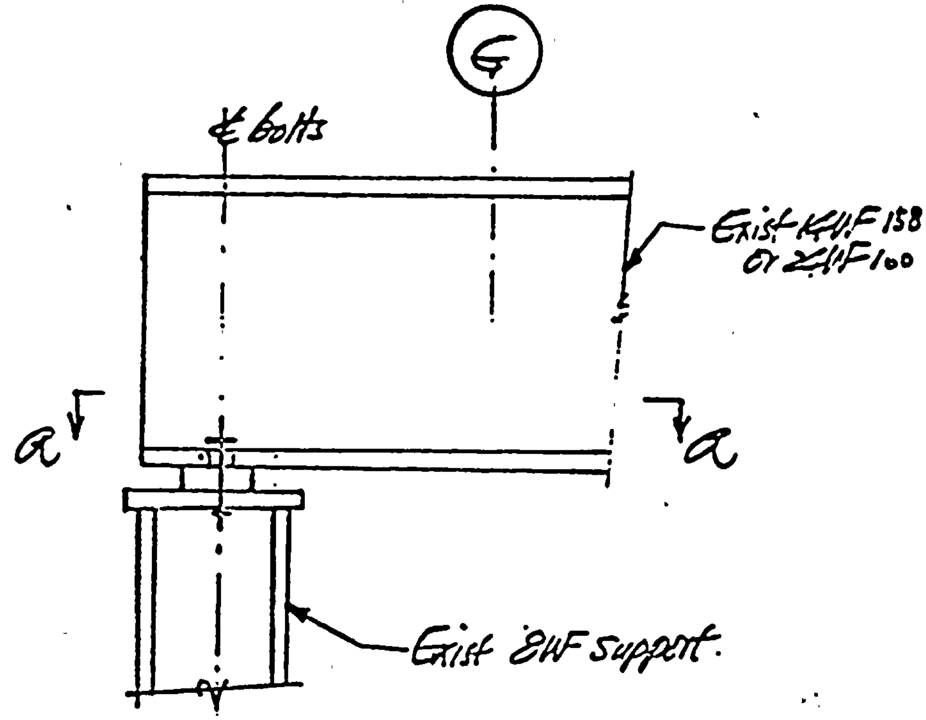
PLAN @ ELEV. 109'-4"
(EXCEPT AS NOTED)

SPECIFICATION NO. 8833XR 3 5422

N NO. DC2-Z-C-26494 REV 0	DWG. NO. 443375	SKETCH NO. SXC-PW-01			
MODIFICATIONS TO PIPEWAY FRAME SUPPORTS AT AUXILIARY & TURBINE BLDGS. DIABLO CANYON UNIT #2 P.G.&E.		SHEET NO 1 OF 4		REV. NO. 0	
		BY	CHKD	APPR.	SUPERV.
		RE	[illegible]	[illegible]	[illegible]



Section a-a
(N.T.S.)

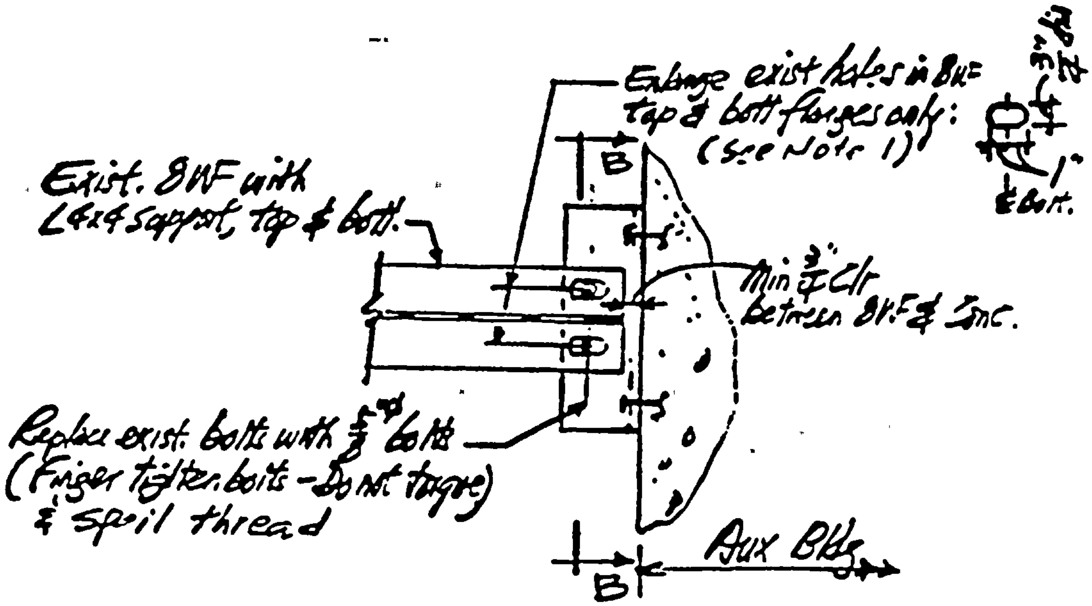


SECTION (A)
(N.T.S.)

PIPEWAY FRAME &
TURBINE BUILDING CONNECTION

N NO. DC2-E-C-26494 REV 0	DWG. NO. 443375	SKETCH NO. SKC-PW-01		
MODIFICATIONS TO PIPEWAY FRAME SUPPORTS AT AUXILARY & TURBINE BUILDINGS		SHEET NO 2 OF 4		REV. NO. 0
		BY	CHKD	APPR.	SUPERV.
DIABLO CANYON UNIT #2	P.G.&E.	RK	[illegible]	[illegible]	[illegible]

SHEET 7 OF 8



Plan
(Req'd At 3 Places)

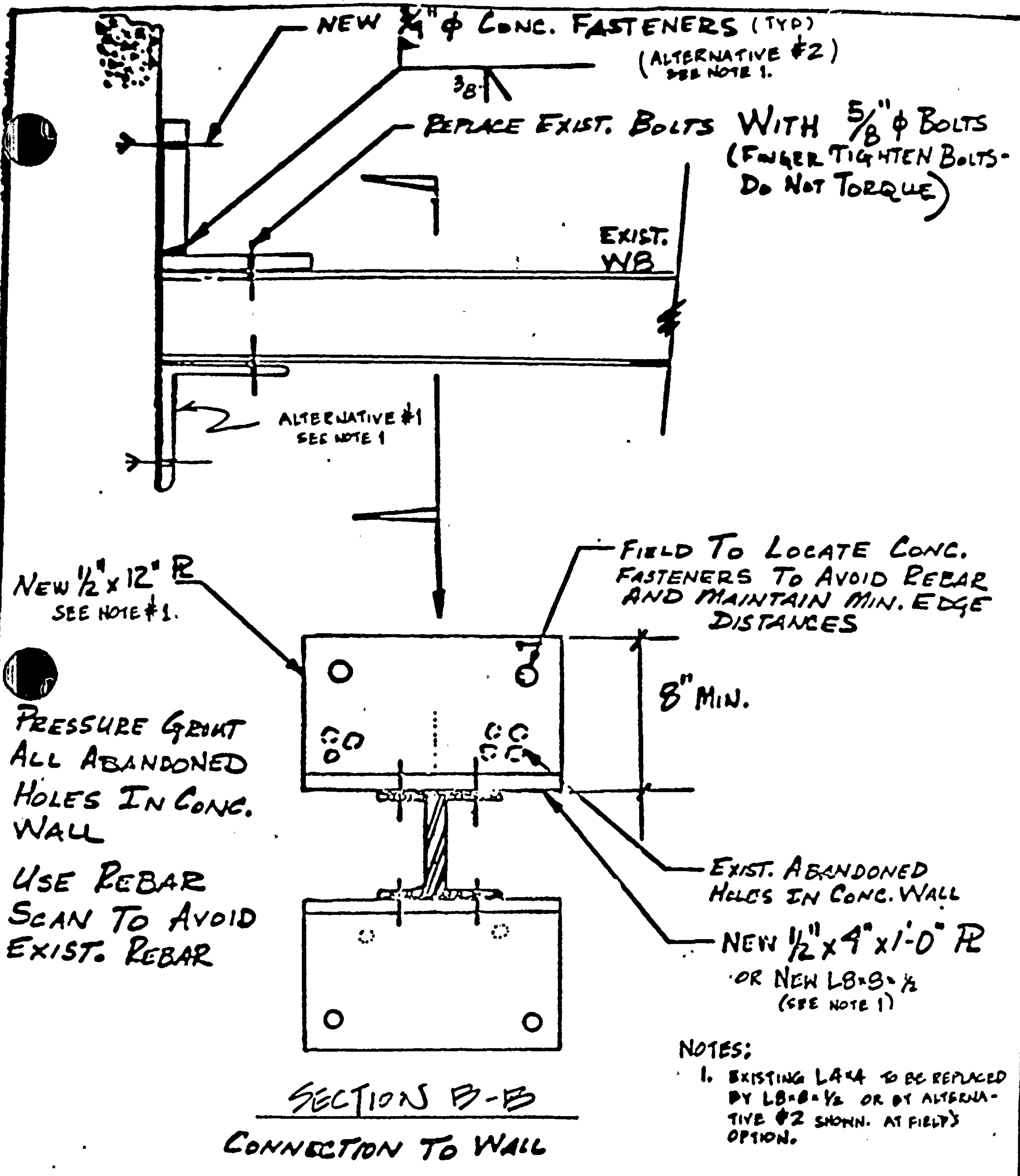
DETAIL 1

PIPEWAY FRAME & AUXILIARY BUILDING CONNECTIONS

NOTE :

1. At field's option, angles shown on sht. 4 may be slotted instead of 8WF.

NO. DC2-E-C-26491 REV 0	DWG. NO. 443375	SKETCH NO. SKC-PW-01
MODIFICATIONS TO PIPEWAY FRAME SUPPORTS AT AUXILIARY & TURBINE BUILDINGS DIABLO CANYON UNIT #2 P.G.&E.	SHEET NO 3 OF 4	REV. NO. 0
	BY: RK / CHKD: [illegible]	APPR.: [illegible] / SUPERV.: [illegible]



DCN NO. DC2-E-C-26494 REV 0	DWG. NO. 443375	SKETCH NO. . ERC- PW - 01		
MODIFICATIONS TO PIPEWAY FRAME SUPPORTS AT AUXILIARY & TURBINE BLDGS. DIABLO CANYON UNIT #2 P.G.&E.	SHEET NO 4 OF 4		REV. NO. 0	
	BY	CHKD	APPR.	SUPERV.
	[illegible]	[illegible]	[illegible]	[illegible]

3.4.2.6 Time-History Analysis

This section is required for a time-history analysis (modal technique).

3.4.2.6.1 Control Card

Column	Format	Unit	Entry	Note	
1-12	A		The words "TIME HISTORY"		
16-20	I		Total number of integration timesteps		
21-25	I		Output interval (default = 1)	(3.4.2-21)	10
26-35	F	T	Integration Timestep size ΔT	(3.4.2-22)	
36-45	F		Damping factor	(3.4.2-23)	
46-50	I		Response solution flag (default = 1) 1 = closed form solution (default) 2 = numerical integration method (not recommended)		
51-55	I		Flag for restart of analysis 0 = zero initial value 1 = continuation of computation of previous run	(3.4.2-24)	
56-60	I		Response output control flag 1 = 0, print time-history response only (default = 0) = 1, print time-history and do a response-spectrum analysis (RSA) = 2, do a response-spectrum analysis (RSA)	(3.4.2-25)	
61-65	I		Response output control flag 2 (default = 0) = 0 SRSS combination = 1 ABS combination = 2 CSM1 combination = 3 CSM2 combination = 4 CSM3 combination = 10 print the displacement vector = 100 print the velocity vector = 1000 print the acceleration vector = 10000 print stresses	(3.4.2-12) (3.4.2-26)	10
66-75	I		Time-history output scale factor (default = 1.0)	(3.4.2-27)	

Each of the six possible global directions can have a separate ground motion function applied to it.

The general solution to equation (47) expressed in terms of arbitrary initial conditions $q_{i,n}$ and $\dot{q}_{i,n}$, at $t = t_n$, and a convolution integration of the applied load, is, for $t \geq t_n$:

$$\dot{q}_i(t) = F(t-t_n)\, q_{i,n} + G(t-t_n)\, \dot{q}_{i,n} + \frac{1}{m_i} \int_{t_n}^{t} G(t-\tau)\, P_i(\tau)\, d\tau \tag{49}$$

The functions F and G are combinations of the homogeneous solutions:

$$q_i(t) = e^{\left(-\zeta \pm \sqrt{\zeta^2 - \omega_i^2}\right)(t-t_n)} \tag{50}$$

F and G satisfy, respectively, the initial conditions for unit displacement and unit velocity.

2.2.4.2.4.1 <u>Transient Analysis</u>. In BSAP it is assumed that the applied load $P_i(t)$ varies linearly between t_n and t_{n+1}. For this form of the applied load, the integral in equation (49) can be evaluated in closed form. The general form of the solutions at the next timestep, $t = t_{n+1}$, in terms of initial conditions at $t = t_n$ and the applied loads, is:

$$q_{i,n+1} = F\, q_{i,n} + G\, \dot{q}_{i,n} + A\, P_{i,n} + B\, P_{i,n+1} \tag{51}$$

$$\dot{q}_{i,n+1} = F'\, q_{i,n} + G'\, \dot{q}_{i,n} + A'\, P_{i,n} + B'\, P_{i,n+1} \tag{52}$$

The coefficients are functions of the modal parameters, m_i, ζ_i, ω_i^2, and of the time increment, h. The uncoupled modal solutions are evaluated at all timesteps by recurrent application of equations (51) and (52). The accelerations, which may be requested as output, are calculated by solving for $\ddot{q}$ from equation (47):

$$\ddot{q}_{i,n+1} = \frac{P_{i,n+1}}{m_i} - 2\zeta_i\, \dot{q}_{i,n+1} - \omega_i^2\, q_{i,n+1} \tag{53}$$

The algebraic expressions for the coefficients in equations (51) and (52) depend on whether the homogeneous solutions are under-damped ($\omega_i^2 > \zeta_i^2$), critically damped ($\omega_i^2 = \zeta_i^2$), or overdamped, ($\omega_i^2 < \zeta_i^2$). In addition, a separate set of expressions is used for undamped rigid body modes, ($\omega_i = \zeta_i = 0$). For reasons of numerical stability, the expressions for the critically damped case are used within a small interval near the critically damped condition. ($\left|\omega_i^2 - \zeta_i^2\right| < \varepsilon_1 \omega_i^2$), and the expressions for the undamped rigid body case are used within a small region near the rigid body condition, $(\omega_i^2 + \zeta_i^2)^{1/2}\, h < \varepsilon_2$. The coefficients for all four cases are listed in Table 2.2.4-4.

Table 2.2.4-4

FORMULAS FOR THE COEFFICIENTS IN EQUATIONS (51) AND (52)

Define:

$$\omega^2 = \left| \omega_i^2 - \zeta^2 \right|$$

$$k = \omega_i^2 m_i$$

Note: Subscript i has been deleted from the parameter ζ.

Integration of Uncoupled Linear Equations

1. **Underdamped Case,** $(\omega_i^2 - \zeta^2)/\omega_i^2 \geq \varepsilon_1 = 10^{-8}$

$$F = e^{-\zeta h}\left(\cos\omega h + \frac{\zeta}{\omega}\sin\omega h\right)$$

$$G = \frac{1}{\omega} e^{-\zeta h}\sin\omega h$$

$$A = \frac{1}{hk\omega}\left\{ e^{-\zeta h}\left[\left(\frac{\omega^2 - \zeta^2}{\omega_i^2} - h\zeta\right)\sin\omega h - \left(\frac{2\omega\zeta}{\omega_i^2} + h\omega\right)\cos\omega h\right] + \frac{2\zeta\omega}{\omega_i^2}\right\}$$

$$B = \frac{1}{hk\omega}\left\{ e^{-\zeta h}\left[-\left(\frac{\omega^2 - \zeta^2}{\omega_i^2}\right)\sin\omega h + \frac{2\omega\zeta}{\omega_i^2}\cos\omega h\right] + \omega h - \frac{2\zeta\omega}{\omega_i^2}\right\}$$

$$F' = -\frac{\omega_i^2}{\omega} e^{-\zeta h}\sin\omega h$$

$$G' = e^{-\zeta h}\left(\cos\omega h - \frac{\zeta}{\omega}\sin\omega h\right)$$

$$A' = \frac{1}{hk\omega} \quad e^{-\zeta h} \quad (\zeta + h\omega_i^2)\sin\omega h + \omega\cos\omega h - \omega$$

$$B' = \frac{1}{hk\omega} \quad -e^{-\zeta h}(\zeta\sin\omega h + \omega\cos\omega h) + \omega$$

2. **Critically Damped Case,** $\left|\dfrac{\omega_i^2 - \zeta^2}{\omega_i^2}\right| < \varepsilon_1 = 10^{-8}$

$$F = e^{-\zeta h}(1 + \zeta h)$$

$$G = h e^{-\zeta h}$$

$$A = \frac{1}{hk}\left[\frac{2}{\zeta} - \frac{1}{\zeta} e^{-\zeta h}(2 + 2h\zeta + h^2\zeta^2)\right]$$

Table 2.2.4-4 (Cont)

FORMULAS FOR THE COEFFICIENTS IN EQUATIONS (51) AND (52)

Transient Analysis

$$B = \frac{1}{hk\zeta}\left[-2 + \zeta h + e^{-\zeta h}(2 + \zeta h)\right]$$

$$F' = -\zeta^2 h e^{-\zeta h}$$

$$G' = e^{-\zeta h}(1 - \zeta h)$$

$$A' = \frac{1}{hk}\left[e^{-\zeta h}(1 + h\zeta + h^2\zeta^2) - 1\right]$$

$$B' = \frac{1}{hk}\left[1 - e^{-\zeta h}(\zeta h + 1)\right]$$

3. Overdamped Case, $(\omega_i^2 - \zeta^2)/\omega_i^2 \leq -\varepsilon_1 = -10^{-8}$

$$F = e^{-\zeta h}(\cosh\omega h + \frac{\zeta}{\omega}\sinh\omega h)$$

$$G = \frac{1}{\omega}e^{-\omega h}\sinh\omega h$$

$$A = \frac{1}{hk\omega}\left\{e^{-\zeta h}\left[\left(\frac{\omega^2 + \zeta^2}{\omega_i^2} - h\zeta\right)\sinh\omega h\left(\frac{2\omega\zeta}{\omega_i^2} + h\omega\right)\cosh\omega h\right] + \frac{2\zeta\omega}{\omega_i^2}\right\}$$

$$B = \frac{1}{hk\omega}\left\{e^{-\zeta h}\left[\frac{\omega^2 + \zeta^2}{\omega_i^2}\sinh\omega h + \frac{2\omega\zeta}{\omega_i^2}\cosh\omega h\right] + \omega h - \frac{2\zeta\omega}{\omega_i^2}\right\}$$

$$F' = -\frac{\omega_i^2}{\omega}e^{-\zeta h}\sinh\omega h$$

$$G' = e^{-\zeta h}(\cosh\omega h - \frac{\zeta}{\omega}\sinh\omega h)$$

$$A' = \frac{1}{hk\omega}\left[e^{-\zeta h}\left\{(\zeta + h\omega_i^2)\sinh\omega h + \omega\cosh\omega h\right\} - \omega\right]$$

$$B' = \frac{1}{hk\omega}\left[-e^{-\zeta h}(\zeta\sinh\omega h + \omega\cosh\omega h) + \omega\right]$$

Table 2.2.4-4 (Cont)

FORMULAS FOR THE COEFFICIENTS IN EQUATIONS (51) AND (52)

Integration of Uncoupled Linear Equations

4. Undamped Rigid Body Modes, $(\omega_i^2 + \zeta^2)^{1/2}\ h < \varepsilon_2 = 10^{-6}$

$$F = 1$$

$$G = h$$

$$A = \frac{h^2}{3m_i}$$

$$B = \frac{h^2}{6m_i}$$

$$F' = 0$$

$$G' = 1$$

$$A' = \frac{h}{2m_i}$$

$$B' = \frac{h}{2m_i}$$

The user can specify the output interval at which displacements and/or stresses are to be calculated. The program calculates relative displacements, stresses, and absolute accelerations. The stresses and accelerations can be saved on files for post-processing.

The structural displacements are calculated as:

$$X_i = \sum_{j=1}^{N} \phi_{ij} q_j$$

where ϕ_{ij} are the mode shapes

q_j are the solutions to equation (47) in modal coordinates

N is the total number of modes considered

2.2.4.2.4 Steady-State Analysis (Modal Superposition)

The modal superposition method can also be applied to obtain steady-state response. The basis for this is that the normal modes are solved one at a time and the results for all modes are superimposed. The equation of motion for steady-state analysis can be written as:

$$M\ddot{x} + C\dot{x} + Kx = F_k e^{i(\Omega t + \gamma_k)} \qquad (54)$$

C. Plotting the unshifted, left/right shifted or widened spectra by using a graphics plotter (CALCOMP, SC4020, etc.).

D. Plotting the unshifted spectra using the page printer.

E. Replotting the computed spectra data of a previous computer run.

F. Combining the response spectra by the square root of the sum of the squares (SRSS) method.

G. Plotting all spectra on preprinted spectra papers.

1.3 PROBLEM SIZE AND PROGRAM LIMITATIONS

There is no practical limit on problem size. The acceleration time history must be digitized at equal time intervals. It also should be noted that the SPECTRA program performs spectra computations only for the undamped and underdamped systems. In other words, the damping value, must be less than 1.0. Spectrum curves for a maximum of 16 different damping values can be computed. A maximum of 200 user-defined periods/frequencies can be input.

1.4 REFERENCES

1. Nigam, Navin C., and Jennings, Paul C., "Digital Calculation of Response Spectra from Strong-Motion Earthquake Records," Bulletin of the Seismological Society of America, Vol 59, No. 2, April 1969, pp. 909-922.

2. "Seismic Analyses of Structures and Equipment for Nuclear Power Plants," Bechtel Design Guide C-2.44, Revision 0, August 1980.

Column	Format	Entry
11-20	I	Unit of acceleration time history =1 time history in in/sec^2 (default) =2 time history in ft/sec^2 =3 time history in "g" unit
21-30	F	Multiplier used to scale acceleration time history (default = 1.0)
31-40	I	Number of time points in acceleration time histories (not required if CC 1-4 contains the word "BSAP") (default = 2399)
41-50	F	Time step size for acceleration time histories (not required if CC 1-4 contains the word "BSAP") (default = 0.10)

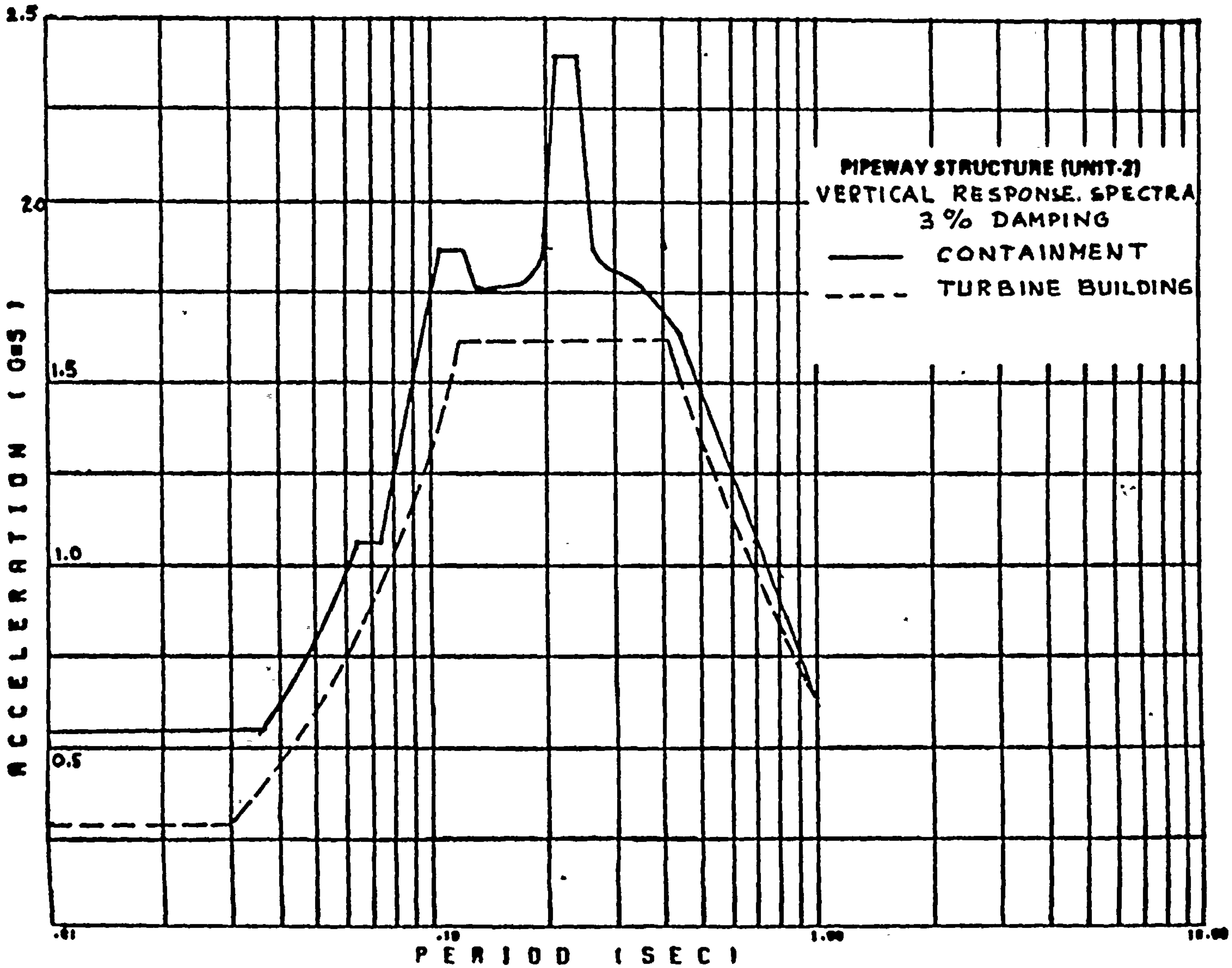
3.1.1.3 Integration Parameter (Optional)

This card is used to specify the number of integration time steps, N, for a given period, P. The value of N set by this card remains in effect until changed by a new parameter card. A default value of 10 will be used until a PARAMETER card is read. The number of time steps N is applied to all specified periods used to compute a spectrum curve. The integration time step size of a specific period P will be the input acceleration time step size or P/N; whichever is smallest will be used as the integration time interval. For detailed information regarding the integration step length, the user is referred to Reference (1).

Column	Format	Entry
1-9	A	The word "PARAMETER"
11-20	I	N, the number of time steps in a given period P (default = 5)

DAMPING VALUES

NEWMARK HOSGRI



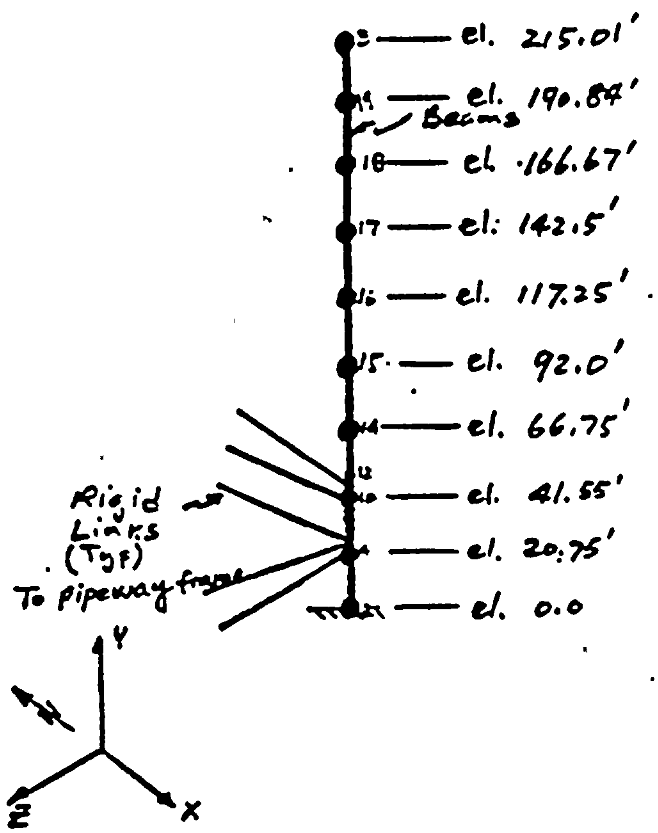


FIGURE 4-1.j

CONTAINMENT EXTERIOR STRUCTURE MODEL (BEAM)

Evaluation of combining DE/DDE Seismic loads with pipe rupture loads in the Unit 2 pipeway structure.

Summary of Load Combinations and Stress Allowables

The members are verified for the following load combinations in accordance with FSAR requirements:

1 - D + DE

2 - D + DDE

3 - D + DDE + Y_r

4 - D + 1.25 DE + Y_r

D = Dead Load

DE = Design Earthquake

DDE = Double Design Earthquake

Y_r = Pipe Rupture Restraint load

The material used in the Unit 2 pipeway is ASTM A441. The allowable stresses used in the evaluation are as follows:

LOAD COMBINATION	SHEAR (ksi)	BENDING (ksi)
1	18	27
2	24.8	45*
3	34.56	53.8
4	34.56	53.8

* The minimum code yield stress of this material varies with thickness groupings from 40 ksi to 50 ksi.

Selection of Critical bent

Stresses were reviewed in all beams due to

a) D + Hosgri
b) Y_r

Review of a) is included in Calculations 1141C-1 to 1147C-1.

Review of b) is included in Calculations 52.23.164 and 52.23.165.

From this review the following conclusions can be drawn:

1. All elements of the pipeway are qualified for these load combinations.

2. The critical elements are found in radial members. Tangential and vertical members are not as highly loaded as the radial ones.

2. In general, members that are highly loaded by Hosgri, are not highly loaded by Y_r.

There are two radial bents which are highly loaded by Y_r and by Hosgri, bents 2B and 3B. The calculations performed for the purpose of evaluating the effect of combining DE/DDE and pipe rupture loads are for these bents.

Calculation (Calculation 1149C)

a) Amplification factors

Amplification factors are computed based on the response spectra and the appropriate damping for DE and DDE for the following commodities:

Dead Weight of Structure
Small bore dead weight
Large bore Class 2 dead weight
Pipe component dead weight
Mechanical equipment dead weight
Conduit dead weight
Platform dead weight
Grating dead weight

b) For large bore Class 1 hanger loads, tables are prepared for hangers affecting the critical bent. Factors are computed which are to be applied to the Hosgri loading to obtain DE and DDE effect of the large bore Class 1 piping loads.

c) Computation of DE and DDE loading on members.

From the computer analysis for Hosgri, there are 15 basic load cases, computed without amplification. To these 15 basic load cases, amplification factors computed as outlined in section a) and b) above are applied. From the 15 basic load cases with the appropriate amplification factor, 16 load permutations are applied.

Seismic loads under DE and DDE are computed in 3 directions, the North-South (Y), the East-West (Z) and Vertical (V). The 16 load permutatuions reflect the following combinations:

$$\pm \left\{ \begin{bmatrix} |V| & + & |Y| \\ |V| & + & |Z| \end{bmatrix} \right.$$

<u>Evaluation of Bent 2B and 3B</u> (Calculation 1149C)

<u>Bent 2B</u> (Shown in Figure E-1)

For load combinations 1 and 2 with seismic loads, the stresses are within allowables.

For load combinations 3 and 4, which combine seismic and pipe rupture loads, element 297 is loaded to it's shear capacity. As a result, redistribution of the load to element 321, 322 etc. would occur and the vertical member A consisting of element 321, 322 etc. transfers additional load to beams B and C. Therefore elements 310, 311 and 329 are loaded to full capacity in bending. The attached table shows the utilization factors of these elements.

<u>Bent 3B</u> (Shown in Figure E-1)

For load combinations 1 and 2, the stresses are within allowables.

For load combinations 3 and 4, element 405 is qualified. The Utilization factor is ≈ 0.8. No redistribution of load is required.

BENT 2B

Utilization Factors *

Element No.	LOAD COMBINATION 1		2		3&4		Yr	
	Shear	Bending	Shear	Bending	Shear	Bending	Shear	Bending
297	1.0	0.62	0.91	0.52	1.00	0.80	0.94	0.69
310	small		0.03	0.05	0.35	1.0	0.13	0.50
311	small		0.13	0.03	0.72	1.0	0.40	0.52
328	small		0.16	0.20	0.55	0.91	0.36	0.43
329	small		0.11	0.27	0.50	0.98	0.36	0.43
330	small		0.11	0.19	0.50	0.90	0.36	0.43
331	small		0.16	0.23	0.70	1.00	0.51	0.49

* Note: Utilization factor (applied load divided by section capacity).

BENT 3B

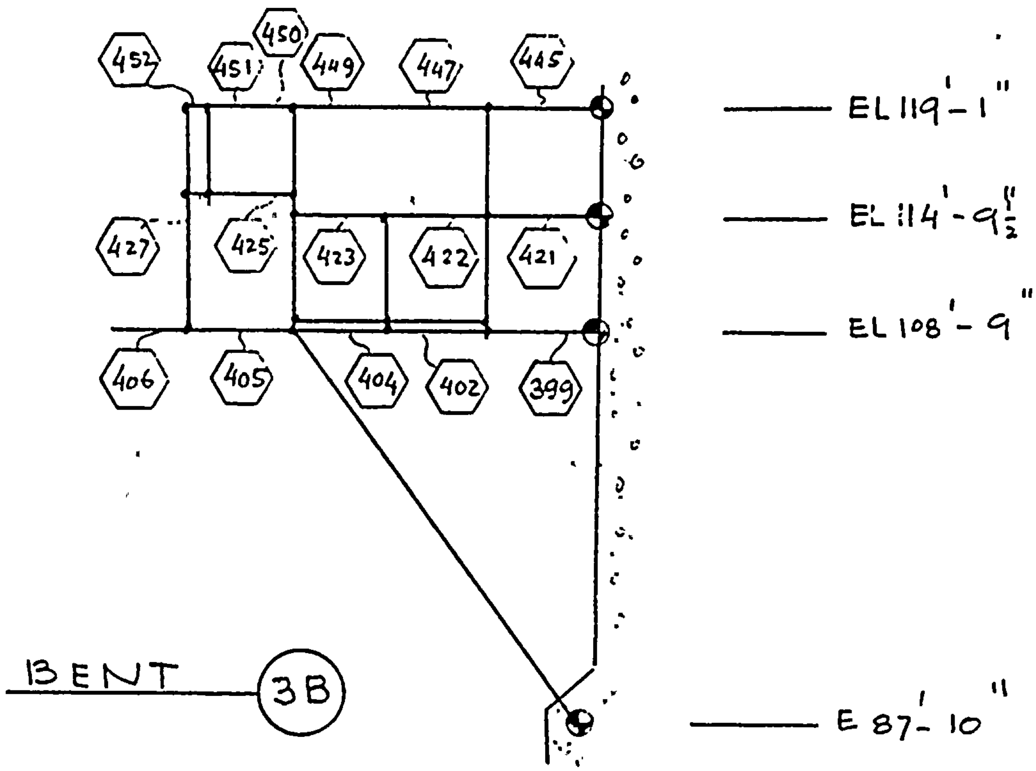
Utilization Factors *

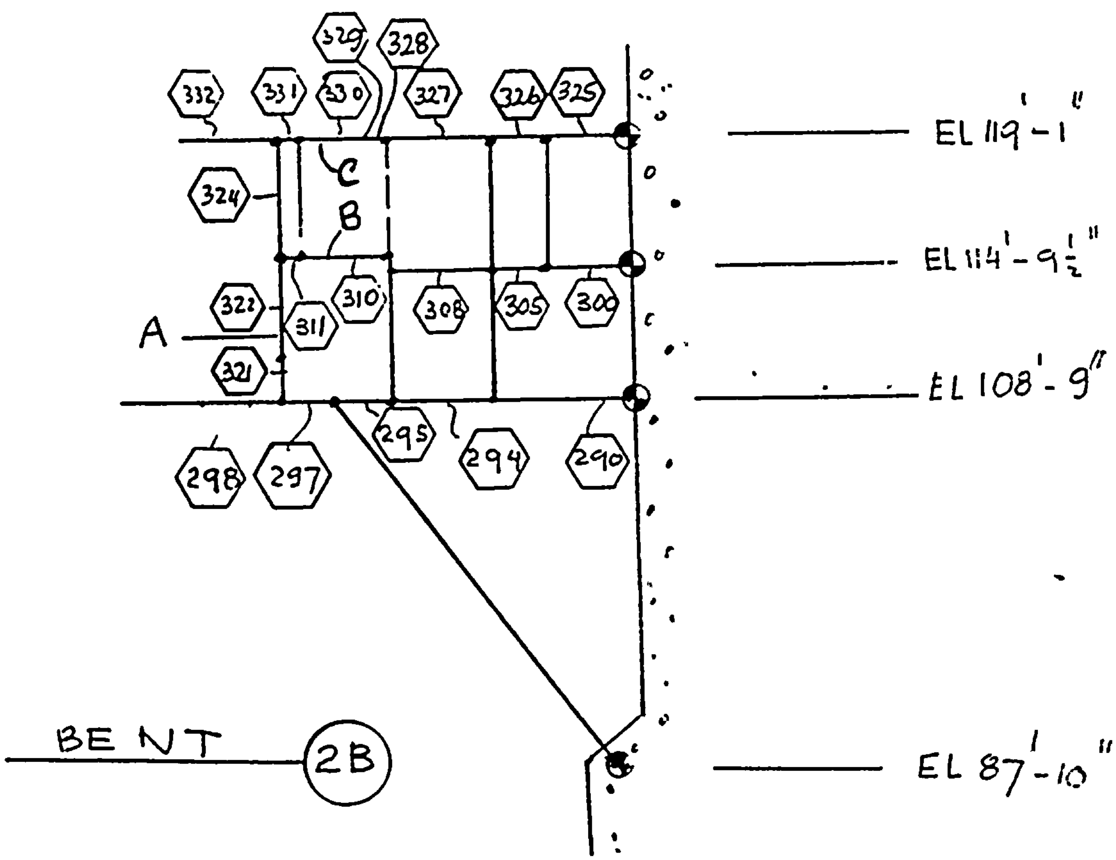
Element No.	LOAD COMBINATION 1		2		3&4		Yr	
	Shear	Bending	Shear	Bending	Shear	Bending	Shear	Bending
405	0.29	0.63	0.26	0.52	0.55	0.8**	0.35	0.71

* See Note in Bent 2B

** This utilization factor is based on the plastic design principle in which the full plastic hinge is the ultimate condition.

Figure E-1


452
451
450
449
447
445
EL 119'-1"
EL 114'-9½"
427
425
423
422
421
EL 108'-9"
406
405
404
402
399
BENT
3B
E 87'-10"


329
328
332
331
330
327
326
325
EL 119'-1"
324
C
B
EL 114'-9½"
322
310
308
305
300
A
311
321
EL 108'-9"
295
294
290
298
297
BENT
2B
EL 87'-10"

APPENDIX 2

ADDITIONAL INFORMATION REQUESTED
BY THE NRC AS FOLLOWUP TO THE UNIT 1 PIPEWAY STRUCTURE
AUDIT ON FEBRUARY 28, 1985

0696M

ADDITIONAL INFORMATION REQUESTED BY THE NRC AS FOLLOWUP TO THE UNIT 1 PIPEWAY STRUCTURE AUDIT AT WESTINGHOUSE ON FEBRUARY 28, 1985

1. QUESTION: Does the 2% spectra generated from the design time-history (with ΔT = 0.01 sec) envelop the design response spectra in the high frequency region?

PGandE RESPONSE:

Attached is a Blume spectra for 2% damping (Figure 1) generated from the 24-second design time-history provided by PGandE with ΔT = 0.01 seconds. From the figure, it is seen that there is a good match in the high frequency region (f > 12 Hz). Therefore, the design time-history used in the analysis is considered adequate.

2. QUESTION: In the response spectra of the pipeway structure, the auxiliary building motion at snubber locations of main steam and feedwater lines are assumed to be the same as the containment building input motion. How does this assumption affect the response spectra generated in the pipeway structure?

PGandE RESPONSE:

The assumption is based upon the fact that the pipe and pipe supports are flexible in the region between the auxiliary building and pipeway structure. Therefore, the relative motion between the auxiliary building and containment transmitted through the pipe will not affect the spectra generated in the pipeway structure. The following discussion supports this conclusion:

a. Considering a main steam line in the region, the shortest span between two snubbers is 48.4 feet in Unit 1 [one is on the pipeway structure (1032-12SL) and the other is on the auxiliary building (1032-14SL)] and 42.0 feet in Unit 2 [one is on the pipeway structure (2032-11BL) and the other is on the auxiliary building (413-370R)]. For this 28-inch diameter pipe in Unit 1, the bending stiffness of a fixed-free condition is 3,250 #/in. which is very flexible in comparison to the stiffnesses of nearby pipeway structures and the

auxiliary building having a value of 415,000 #/in. Unit 2 has similar conditions.

b. The frequency calculation from a cantilever beam analogy of this pipe with a 48.4-foot span yields a fundamental mode of 2.94 Hz. A review of applicable auxiliary building and containment shell spectra (Figure 2) indicates that the containment spectra envelopes the auxiliary building at a frequency of 2.94 Hz. Furthermore, the frequency of 2.94 Hz is not close to the amplified frequencies in the auxiliary building, f $>$ 11 Hz.

3. QUESTION: Can the potential high frequency spectra issue raised in Question 1 affect the piping analyses which may have used the spectra at nodes 637 and 822?

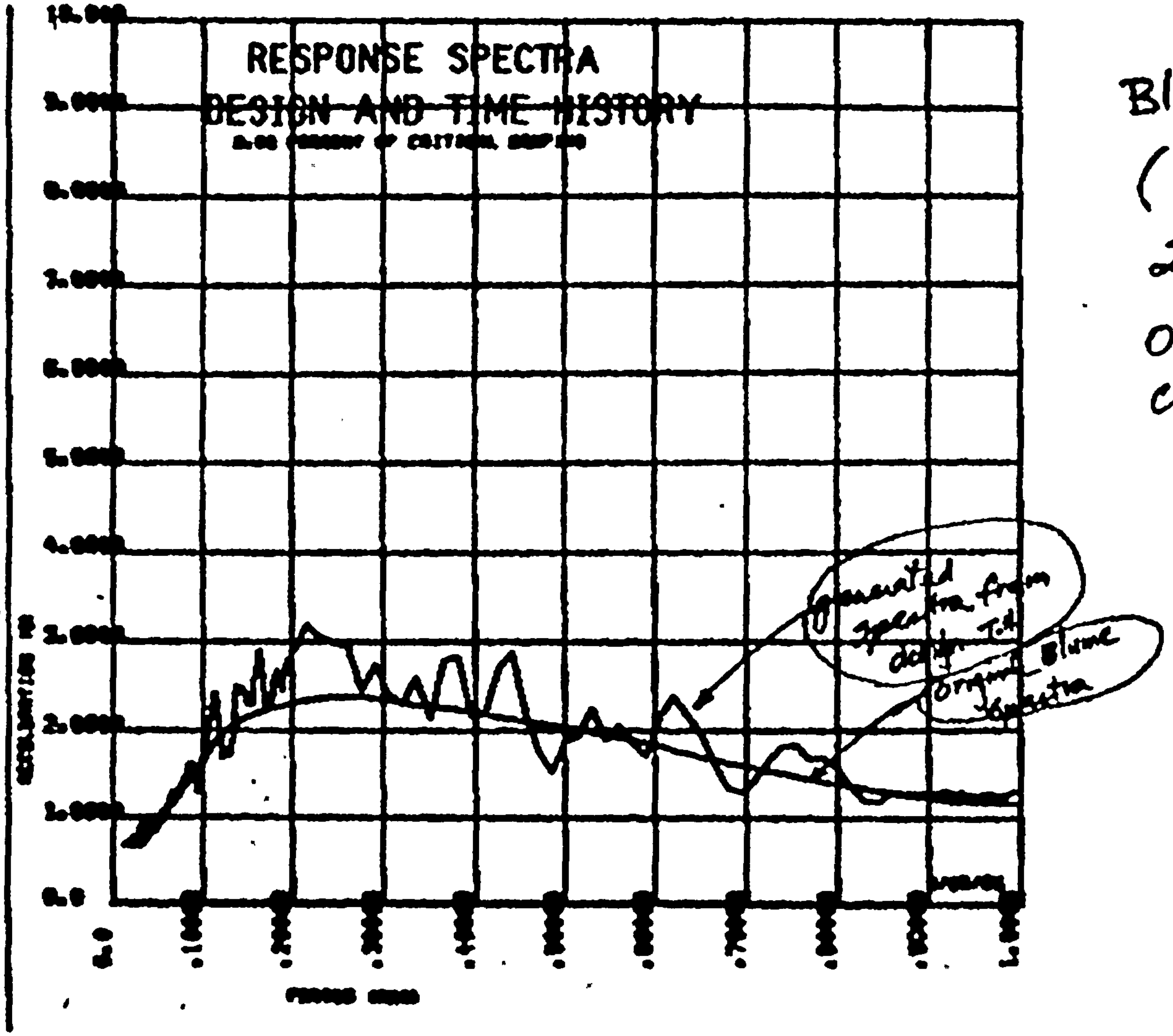
PGandE RESPONSE:

The response provided to Question 1 has addressed the high frequency input issue from the point of view that spectra generated from the design time history adequately respresents the original design spectra. Therefore, the high frequency spikes in the response spectra at nodes 637 and 822 are appropriately calculated.

4. QUESTION: Provide calculations supporting Appendix E to the information provided on January 31 relative to the January 17, 1985 audit.

PGandE RESPONSE:

Calculation No. 1149C-1 is attached. Informal explanatory notes are included within the calculation.



Blume Spectra for Containment

($T = 0.04$)

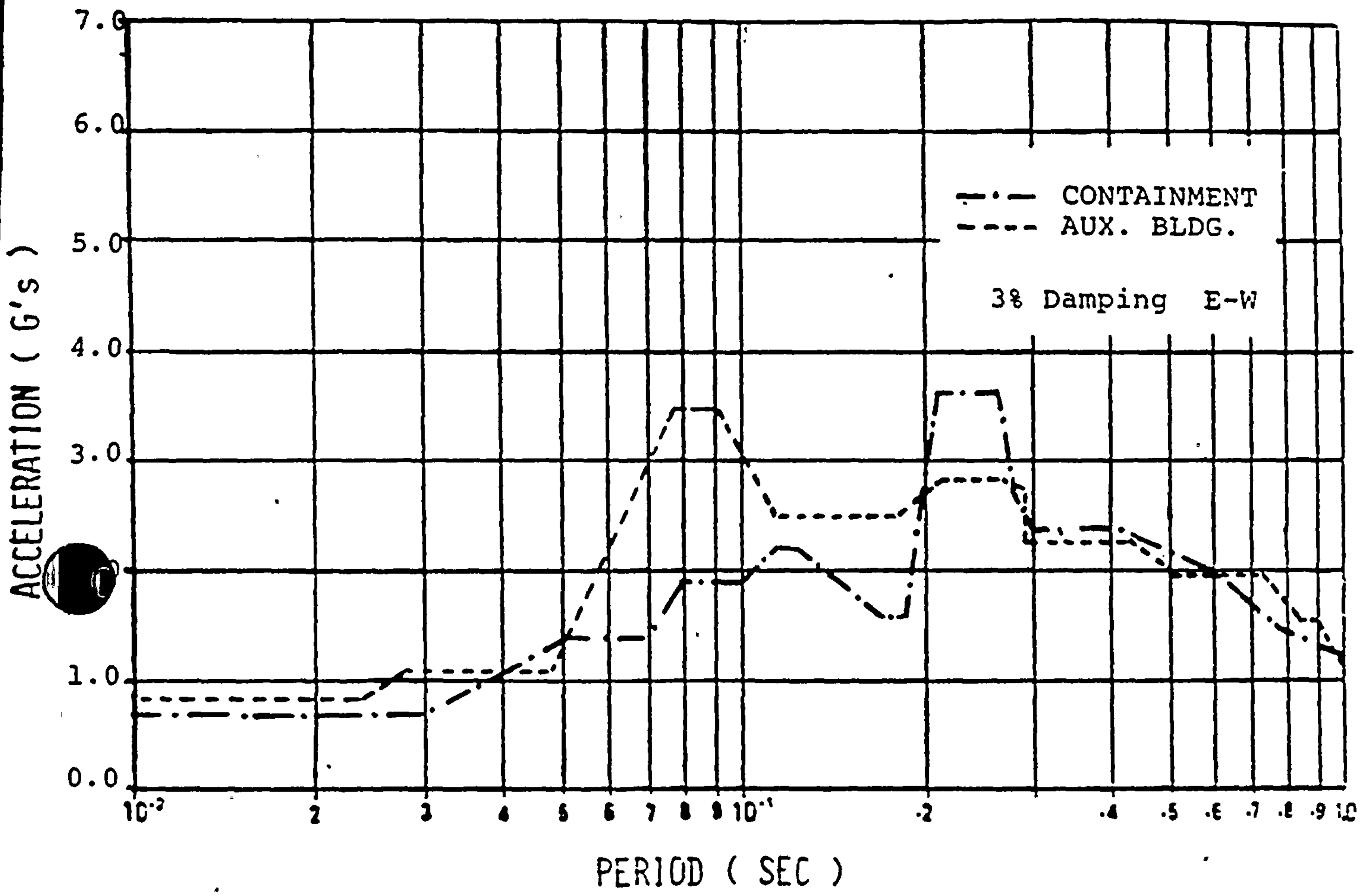
2% damping

Originator: T. H. Lin 3/5/85

Checker: L. Tuñón S. 3/6/85

Figure 1

Figure 2


7.0
6.0
5.0
4.0
3.0
1.0
0.0
ACCELERATION (G's)
CONTAINMENT
AUX. BLDG.
3% Damping E-W
10⁻²
2
3
4
5
6
7
8
9
10⁻¹
.2
.4
.5
.6
.7
.8
.9
1.0
PERIOD (SEC)

APPENDIX 3

EXPLANATION OF THE
[A] MATRIX IN CALC. NO. 1149C-1

EXPLANATION ABOUT THE [A] MATRIX

The matrix relation presented on page 5 of calculation 1149C-1 can be written as follows:

$$C_1 = a_{11} P_1$$

$$C_2 = a_{21} P_3 + a_{22} P_6 + a_{23} P_8 + a_{24} P_{14}$$

$$C_3 = a_{31} P_2 + a_{32} P_5 + a_{33} P_9 + a_{34} P_{13}$$

$$C_4 = a_{41} P_4 + a_{42} P_7 + a_{43} P_{10} + a_{44} P_{15}$$

$$C_5 = a_{51} P_{11}$$

$$C_6 = a_{61} P_{12}$$

The presentation on page 5 of calculation 1149C-1 is to enhance execution in the computer.

C_1 is the dead load associated with class 1 large bore piping.

C_2 is the total seismic forces in the North-South direction.

C_3 is the total seismic forces in the vertical direction including the dead load of the commodities which will be explained later.

C_4 is the total seismic forces in the East-West direction.

C_5 is the total seismic indicued moments about the 2 horizontal axis which are applied to the structural members.

C_6 the same as C_5 for moments induced by seismic about veritical axis.

P_1 is the dead load of class 1 large bore piping.

P_2 is the 1 g load applied to weight of all small bore and Class 2 large bore piping in downward direction.

P_3 is the 1 g load applied to weight of all small bore and class 2 large bore piping in North-South direction.

P_4 the same as P_3 in East-West direction.

P_5 is the 1 g load applied to weight of the structural members and members of pipe supports and pipe rstraints in vertical direction.

P_6 . is the same as 5 applied in North-South direction.

P_7 is the same as 5 applied in the East-West direction.

P_8 is the sum of all the North-South components of HOSGRI induced loads from the Class 1 large bore piping.

P_9 is the sum of all vertical components of HOSGRI induced loads from the class 1 large bore piping.

P_{10} is the same as P_8 in the East-West direction.

P_{11} is the sum of all moments about the 2 horizontal directions applied to the structural members due to Hosgri.

P_{12} is the same as P_{11} for moments about the vertical direction.

P_{13} is the 1 g load applied to weights of mechanical equipment, conduit, grating and platform in veritical direction.

P_{14} is the same as P_{13} applied in the North-South direction.

P_{15} is the same as P_{13} applied in the East-West direction.

From the linear equation shown on page 1, we will note the following:

a_{11} is the amplification factor associated with P_1.

a_{21} is the amplification factor associated with P_3.

a_{22} is the amplification factor associated with P_6.

. . .
. . .
. . .

a_{61} is the amplification factor associated with P_{12}.

a_{ij} are taken from:

page 22 of calc. 1149C-1 for bent 2B

page 23 of calc. 1149C-1 for bent 3B

page 24 of calc. 1149C-1 for bent 4B

page 25 of calc. 1149C-1 for bent 5B

page 26 of calc. 1149C-1 for bent 6B

page 27 of calc. 1149C-1 for bent 7B

page 28 of calc. 2249C-1 for bent 8B

The DE values of a_{ij} tabulated on page 22 of calc. 1149C-1 related to P_1 to P_7 and $P_{13} \longrightarrow P_{15}$ are calculated on page 9 of calc. 1149C-1. The a_{ij} values associated with P_2, P_5 and P_{13} are the values shown on page 9 plus 1 to account for the dead load itself.

The DE values of a_{ij} tabulated on page 22 of calc. 1149C-1 related to P_8 to P_{12} are calculated on pages 11 $\longrightarrow$ 13 of calc. 1149C-1. The total Class 1 large bore piping load due to DE and Hosgri tributary to bent 2B were calculated on page 13. Since $P_8 \longrightarrow P_{12}$ are the HOSGRI loads, inorder to get the class 1 large bore DE effect, the ratios of the total DE and total HOSGRI loads are applied to $P_8 \longrightarrow P_{12}$.

Determination of the g values on pages 9 and 10.

DCM-C-27 and DCM-C-82 specify the following:

For small bore and class 2 large bore piping, peak accelerations of ½% damping should be used.

For deadload of structure, the ZPA should be used.

For mechanical equipment, conduits, platforms and grating, peak accelerations of 2% damping should be used.

Since the pipeway structure is attached to the containment wall at elevations 109', 114', 119', 122', and 131' - 138' the enveloped accelerations of the wall at these elevations are taken. These acceleration values are taken from DCM-C25 for DE and DCM-C-30 for DDE.

Example

We will show how the [A] matrix used for the verification of the computer program is constructed (see page 73 of calc. 1149C-1). This is for DE applicable to bent 2B.

a_{11}

Per the matrix relation shown on page 5 of calc. 1149C-1, a_{11} is related to P_1. Per page 22 of calc. 1149C-1, under DE column. $a_{11} = 1$.

a_{21}

According to page 5 of calculation 1149C-1; a_{21} is related to P_3. Per page 22 of calc. 2249C-1 the value under DE is 8.2.

a_{22}

a_{22} is related to P_6. Per page 22 of calc. 2249C-1 the value for a_{22} =.70.

a_{23}

$a_{23} \longleftrightarrow P_8$.

a_{23} = .53 (page 22)

$a_{33} \longleftrightarrow P_9$.

a_{33} = .55 (page 22)

$a_{34} \longleftrightarrow P_{13}$

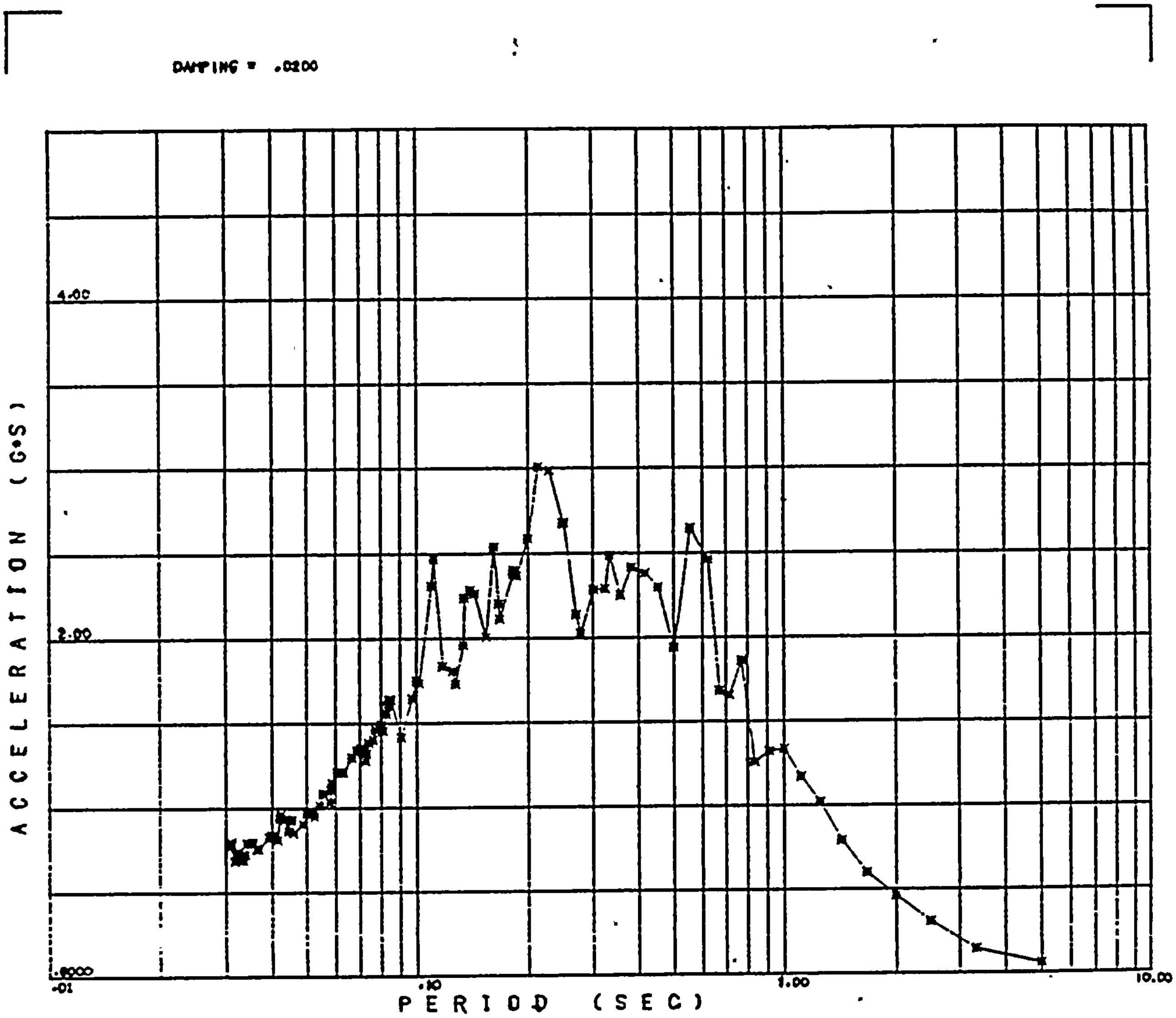
a_{34} = 1.73 (page 22)

By inspection, these values are found in [A] shown on page 73, and also shown on the computer input on page 6 of Attachment "A". (The matrix shown on page 6 of Attachment "A" is the $[A]^T$)

APPENDIX 4

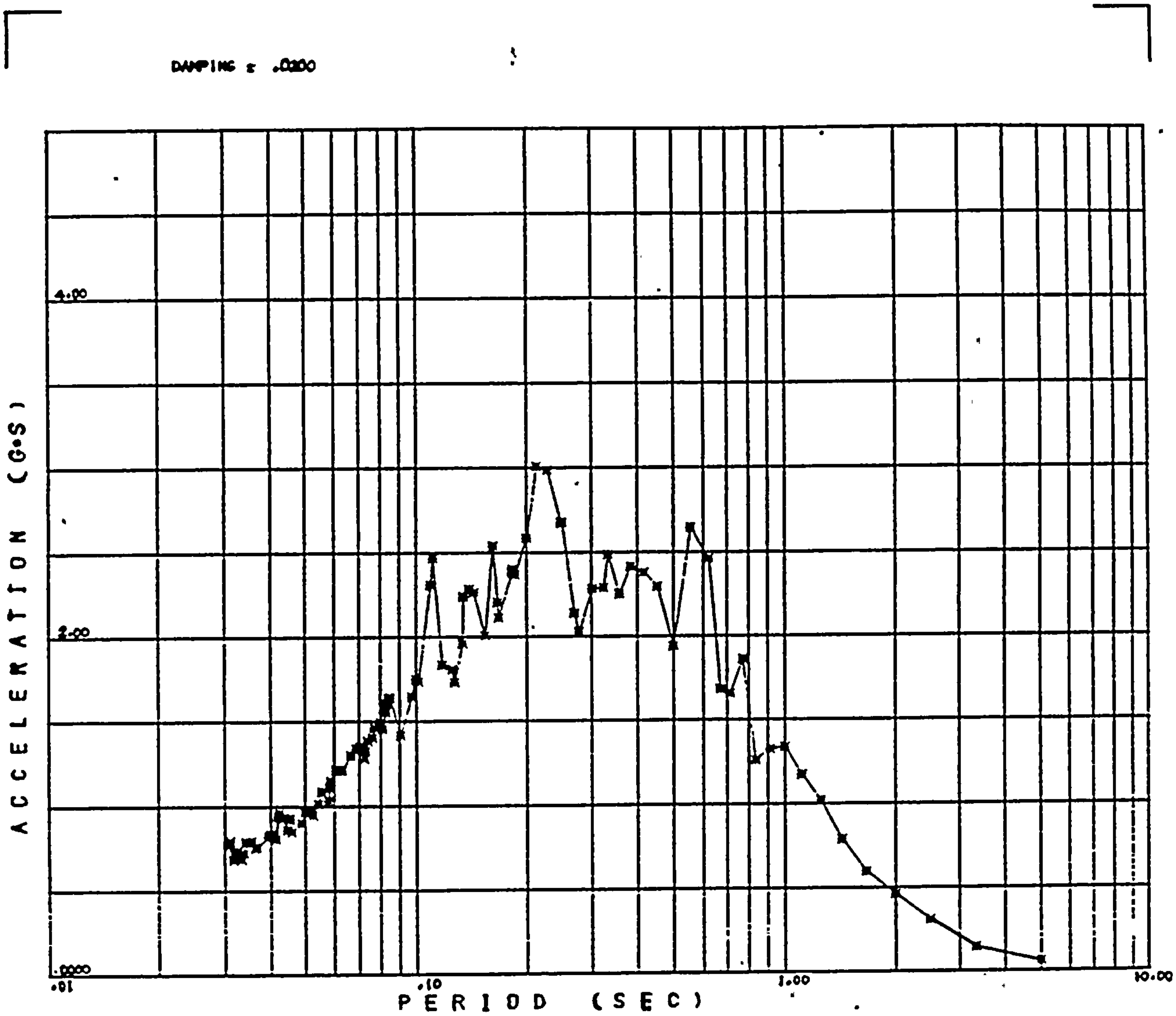
BLUME/NEWMARK SPECTRA

(2% AND 7% DAMPING)



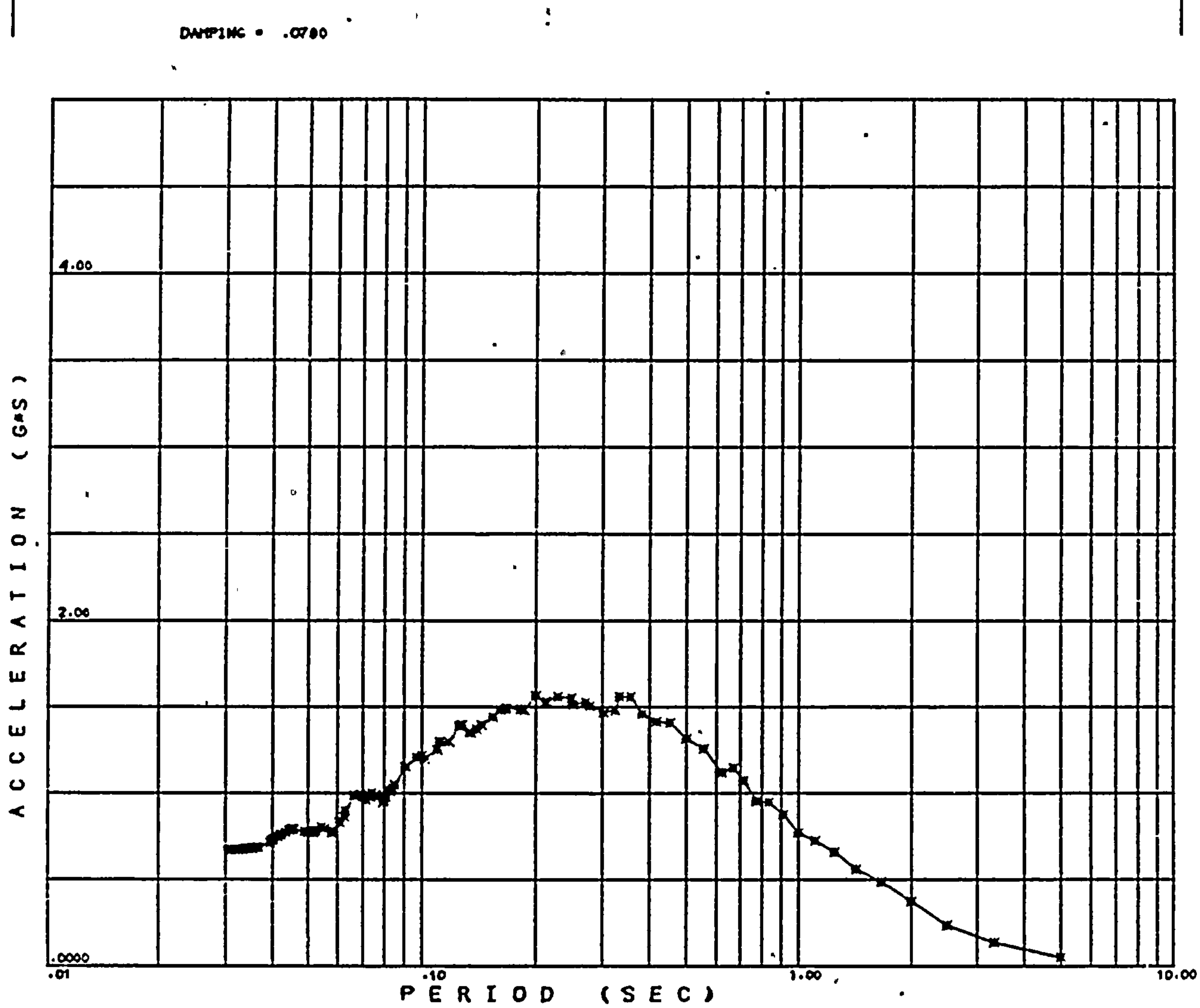
NEWMARK GROUND SPECTRA DT=.01

CI.502/02-6 X4032 03/14/65 FRAME :



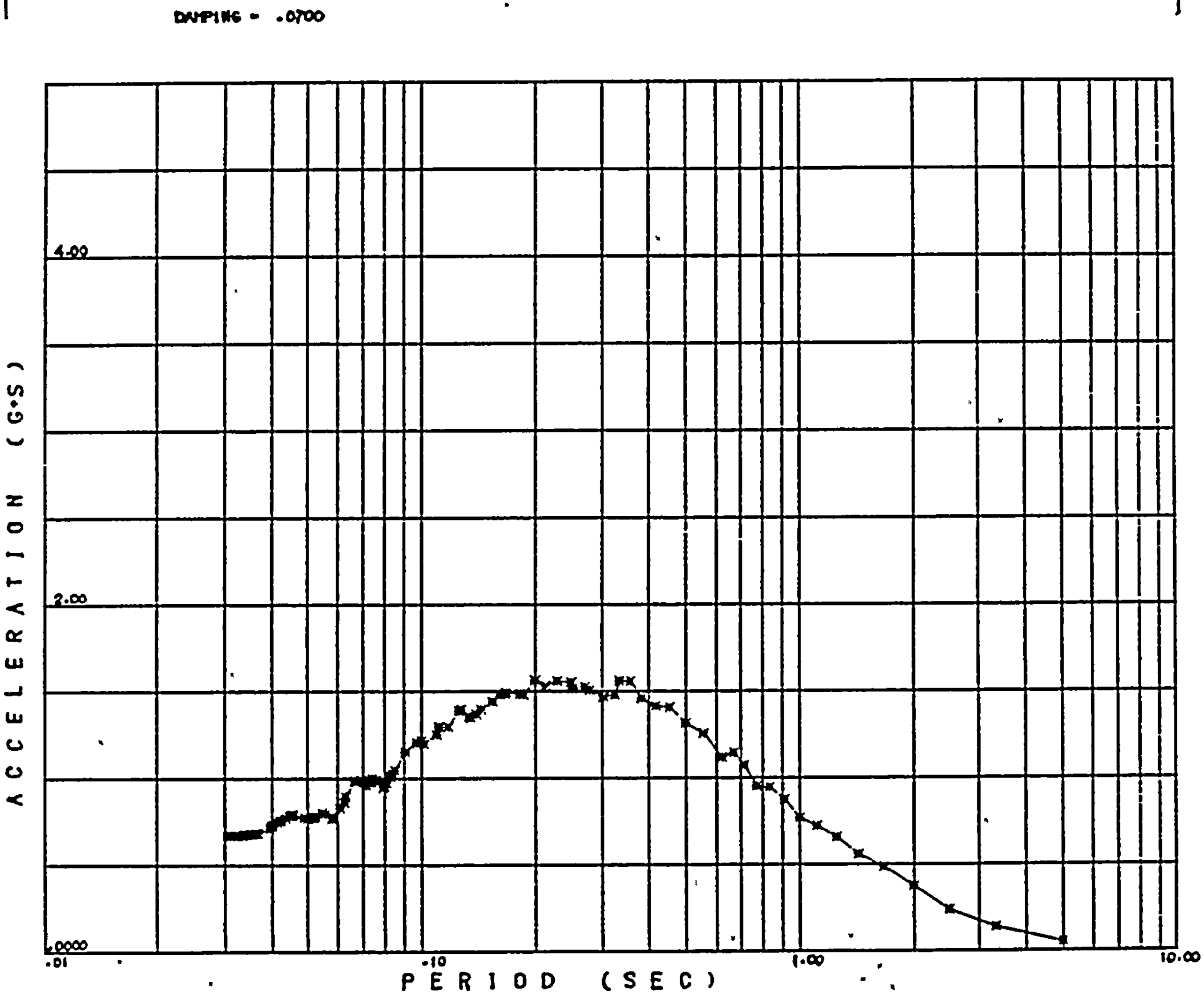
NEWMARK GROUND SPECTRA DT=.003

CI6C2/62-6 X4033 03/14/8? FRAME 1



BLUME GROUND SPECTRA DT=.01.

CE802/62-8 X4068 03/14/85 FRAME 2



BLUME GROUND SPECTRA .DT=.003

CE602/62-B X4053 03/14/85 FRAME 2

APPENDIX 5

SUMMARY OF RESULTS OF

DE/DDE EVALUATION FOR UNIT 1 PIPEWAY STRUCTURE

1. Introduction

This appendix summarizes Calculation No. 2151C-2 (Ref. 1), which evaluates the Unit 1 pipeway structure for load combinations including the design earthquake (DE), double design earthquake (DDE), and pipe rupture loads (Y_r). This calculation utilizes Unit 1 specific information and provides a greater level of detail than previous analyses.

2. Load Combinations, Materials, and Stress Allowables

The pipeway structure members were verified for the following load combinations in accordance with the FSAR requirements:

1 - D + DE
2 - D + DDE
3 - D + DDE + Y_r
4 - D + 1.25 DE + Y_r

where:

D	=	Dead Load
DE	=	Design Earthquake
DDE	=	Double Design Earthquake
Y_r	=	Pipe Rupture Restraint load

The material used in the Unit 1 pipeway is ASTM A441. The allowable stresses used in the evaluation are as follows:

LOAD COMBINATION	SHEAR (ksi)	BENDING (ksi)
1	18	27
2	24.8	45*
3	34.56	53.8
4	34.56	53.8

* The minimum code yield stress of this material varies with thickness groupings from 40 ksi to 50 ksi.

3. Evaluation Procedure

The evaluation of the Unit 1 pipeway structure involves: (1) identifying the critically loaded members based on the results of the Unit 1 pipeway Hosgri evaluation (Reference 4) and the Unit 1 pipeway pipe rupture load evaluation (Reference 2); (2) obtaining the Hosgri seismic member forces and moments from the Hosgri evaluation for the critical members identified; (3) converting the Hosgri member forces and moments to the corresponding DE/DDE member forces and moments based on the spectral acceleration ratios between DE/DDE and Hosgri, taking into account the difference in criteria for the damping values and the directional combination rules*, i.e., SRSS for Hosgri vs. absolute sum for DE/DDE; (4) combining the DE/DDE member forces and moments as derived with the member forces and moments due to the dead load and the pipe rupture restraint load according to the load combinations of Section 2 and qualifying the structural adequacy of the members based on the allowable stress criteria of Section 2.

* Soil structure interaction is not significant because the shear wave velocity of the soil is high.

The detailed description of the step-by-step evaluation procedure is provided below.

3.1 A total of 14 members (16 elements) were identified for further evaluation as follows:

For pipe rupture effects, the most critical member from each of the bents 1B to 4B (including 3B+ and 3B2) was selected and, in addition, a second critical member was selected from bent 3B. This resulted in the selection of seven members.

For seismic effects, all pipeway members were reviewed for Hosgri stress ratios as reported in Westinghouse's report (Ref. 4). All members with stress ratios of 0.9 or greater were identified for further evaluation. This resulted in the selection of seven members.

3.2 Member forces and moments for all of the above members were obtained from Westinghouse's dynamic analysis for the Unit 1 pipeway structure (Ref. 5). Member force data were divided (based on the load category) into dead load (D), North-South Hosgri load ($Hosgri_{N-S}$), East-West Hosgri load ($Hosgri_{E-W}$), and Vertical Hosgri load ($Hosgri_{Vert}$).

3.3 The following response ratios were calculated:

$$a_1 = \frac{DDE}{Hosgri} \; ; \qquad a_2 = \frac{DE}{Hosgri}$$

These ratios were determined based on structural amplification effects and dynamic inertia load sources (inertia loads from structural members, large bore Class 1 piping, equipment, and small bore and Class 2 piping).

These ratios were computed separately for the North-South, East-West, and Vertical directions. The structural members, large bore Class 1 piping, equipment, and small bore piping inertia forces contribute approximately 50%, 40% 6% and 4% of the total load, respectively.

The response ratios for member inertia loads were determined from the ratios of maximum accelerations. The response ratios for large bore Class 1 piping were obtained directly from the ratios of DE or DDE pipe support forces to the corresponding Hosgri forces. The response ratios for small bore and Class 2 pipeway and equipment were obtained from the average of the ratios of the Unit 1 pipeway structure response spectra of DE/DDE to those of Hosgri for at least 15 structural frequencies.

The spectral accelerations used in determining the spectral ratios were based on the following damping values:

	DE	DDE	Hosgri
Small Bore & Class 2 Piping	1/2%	1/2%	2%
Equipment	2%	2%	7%

Since the Hosgri member forces and moments obtained in Step 3.2 are not separated according to inertia load sources, a weighted average of the response ratios from the four load sources was used for each of the structural bents 1B to 4B. The weighting factors used in this Calculation No. 2151C-2 are the tributory weights for each bent from each load source.

As an example, for bent 2B, small bore and Class 2 piping contribute 1%, equipment contributes 6%, structural members contribute 50%, and the large bore piping contributes 43% of the total weight. These percentages were used as the weighting factors to calclate the weighted average responses ratios of bent 2B. This resulted in the following six response ratios for each bent:

$$a_{1,E\text{-}W};\quad a_{1,N\text{-}S};\quad a_{1,Vert}$$
$$a_{2,E\text{-}W};\quad a_{2,N\text{-}S};\quad a_{2,Vert}$$

These ratios for bents 1B, 2B, 3B, and 4B are summerized in Section 4.

3.4 The response ratios obtained in Step 3.3 were multiplied by the Hosgri member forces and moments obtained in Step. 3.2 to determine the DE and DDE member forces and moments for each direction (E-W, N-S and Vertical). These forces and moments were combined following the DCP absolute sum combination rule:

$$DDE = |DDE_{E-W}| + |DDE_{Vert}|$$

or

$$DDE = |DDE_{N-S}| + |DDE_{Vert}|$$

whichever is greater. The same procedure is used for the DE load.

3.5 Member forces were calculated based on the applicable load combinations in Section 2. The value for D were taken from Step 3.2, DDE and DE were taken from Step 3.4, and Y_r were taken from References 2 and 3.

3.6 Member qualifications were based on the equations and analyses as described in Reference 4.

4. Summary of a_1 and a_2 values computed in step 3.3 of Section 3

Member #	Bent No	$a_1 = \frac{DDE}{Hosgri}$ E-W	N-S	Vert	$a_2 = \frac{DE}{Hosgri}$ E-W	N-S	Vert
1103	1B	0.97	1.24	0.39	0.67	0.74	0.19
1086	2B	0.73	0.95	0.44	0.51	0.65	0.17
1070	3B	0.99	0.87	0.38	0.61	0.57	0.19
920	3B+	0.99	0.87	0.38	0.61	0.57	0.19
890	3B2	0.95	0.85	0.42	0.63	0.54	0.21
828	4B	0.97	1.24	0.38	0.67	0.74	0.20
*	3B+	0.99	0.87	0.38	0.61	0.57	0.19
496	66B	0.98	1.24	0.39	0.68	0.74	0.20
1310	3B	0.99	0.87	0.38	0.61	0.57	0.19
974	1B,2B	0.95	0.85	0.42	0.63	0.54	0.21
961	1B	0.95	0.85	0.42	0.63	0.54	0.21
962	1B	0.95	0.85	0.42	0.63	0.54	0.21
971	1B,2B	0.95	0.85	0.42	0.63	0.54	0.21
972	1B,2B	0.95	0.85	0.42	0.63	0.54	0.21

*element identified between nodal points 469 and 472

5. Summary of Stress Ratios

Element #	Bent #	Stress Ratios Comb 1	Comb 2	Comb 3	Comb 4	Remarks
1103	1B	0.09	0.07	0.79	0.77	Controlled by rupture restraint load Y_r
1086	2B	0.09	0.05	0.76	0.75	
1070	3B	0.07	0.05	0.51	0.50	
920	3B+	0.09	0.09	0.52	0.51	
*	3B+	0.01	0.01	0.89	0.89	
890	3B2	0.14	0.06	0.33	0.25	
828	4B	0.07	0.09	0.33	0.27	
496	6.6B	0.96	0.97	0.97	0.72	Controlled by seismic load
1310	Platform	0.91	0.92	0.77	0.62	
974	1B - 2B	0.97	0.85	0.82	0.69	
961	1B	0.15	0.17	0.15	0.13	
962	1B	0.18	0.17	0.15	0.13	
971	1B - 2B	0.94	0.85	0.82	0.69	
972	1B - 2B	0.93	0.83	0.69	0.57	

*element identified between nodal points 469 and 472

6. Conclusion

PGandE has reviewed all of the Unit 1 pipeway structure members for load combinations involving DE, DDE, and pipe rupture loads. As discussed above, detailed evaluations were performed for critically loaded members. It was determined that these members satisfy the FSAR design criteria. PGandE, therefore, concludes that the entire Unit 1 pipeway structure satisfies the design criteria for load combinations including DE, DDE, and pipe rutpure loads.

7. References

1. DCP Unit 1 Calculation No. 2151C-2, Rev. 1.

2. DCP Unit 1 Calculation No. S-330, Rev. 1.

3. DCP Unit 1 File 52.23, Calculation S1.

4. "Structural Analysis of the Pipeway Frame Structure for Diablo Canyon Unit 1," by Westinghouse Electric Corporation, Pittsburgh, Pennsylvania, WCAP-10269, June 1983.

5. Letter from Westinghouse to J.V. Rocca, No. PGE-6585, dated June 5, 1985.

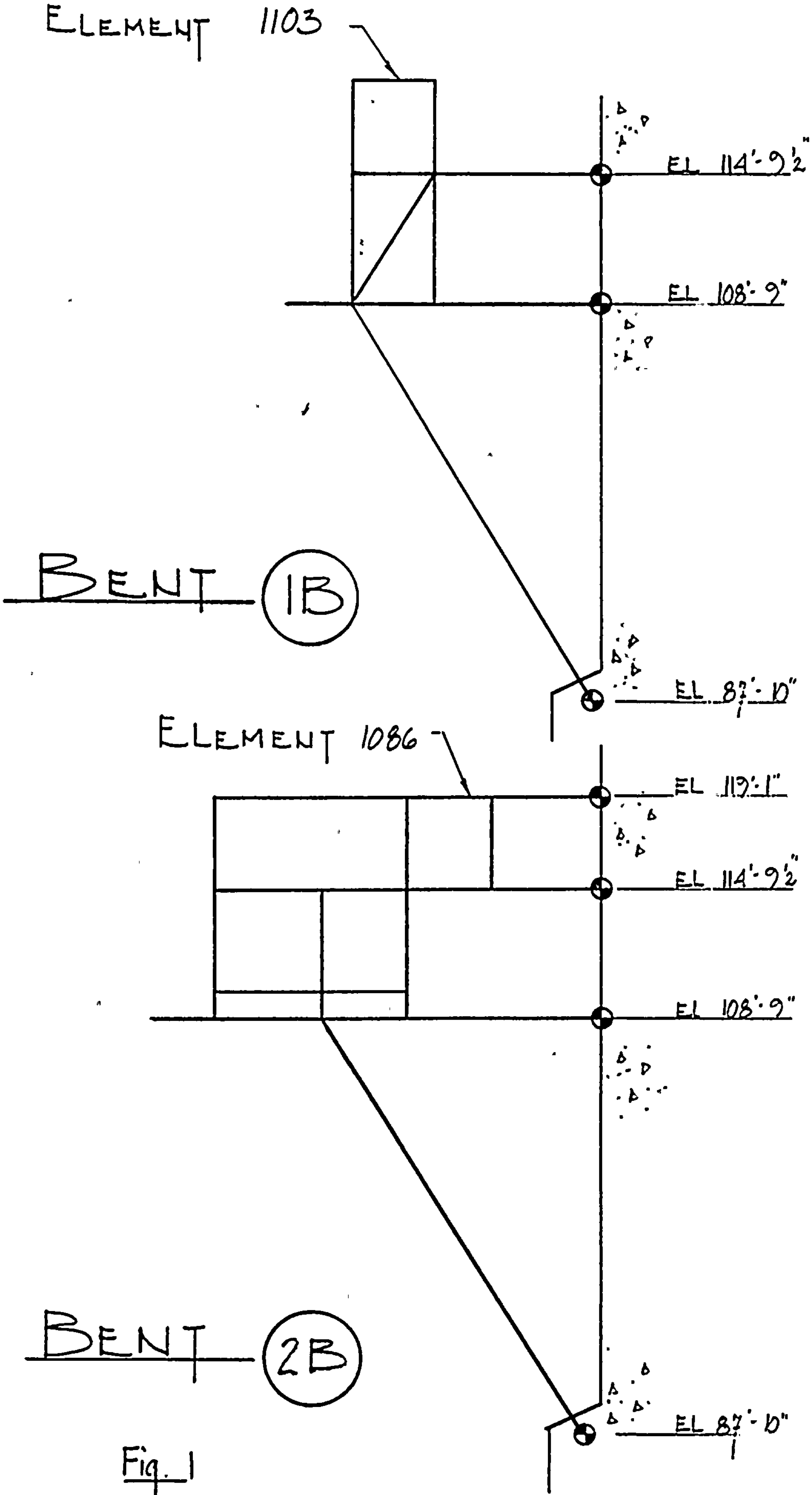
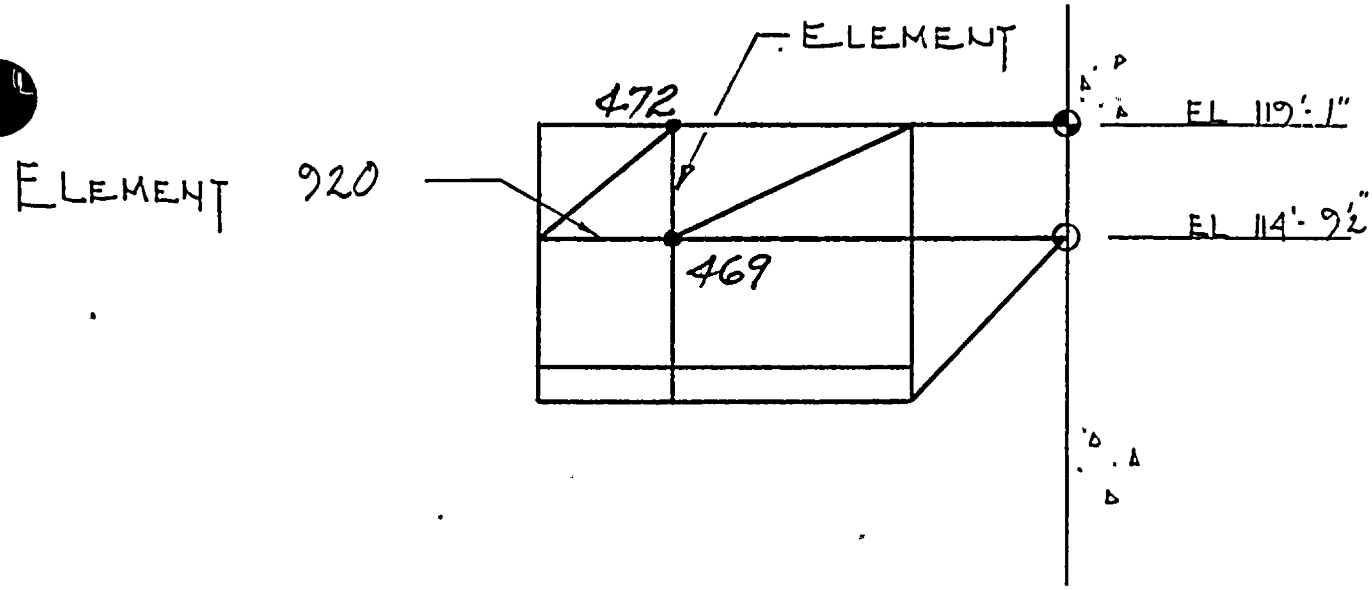
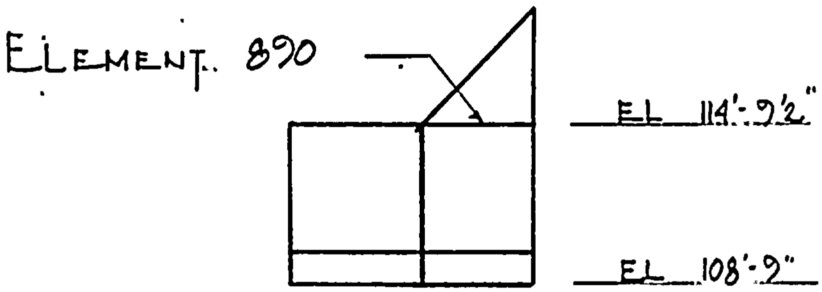

ELEMENT 1103
EL 114'-9½"
EL 108'-9"
BENT 1B
EL 87'-10"
ELEMENT 1086
EL 119'-1"
EL 114'-9½"
EL 108'-9"
BENT 2B
EL 87'-10"

Fig. 1



BENT 3B1



BENT 3B2

Fig. 2

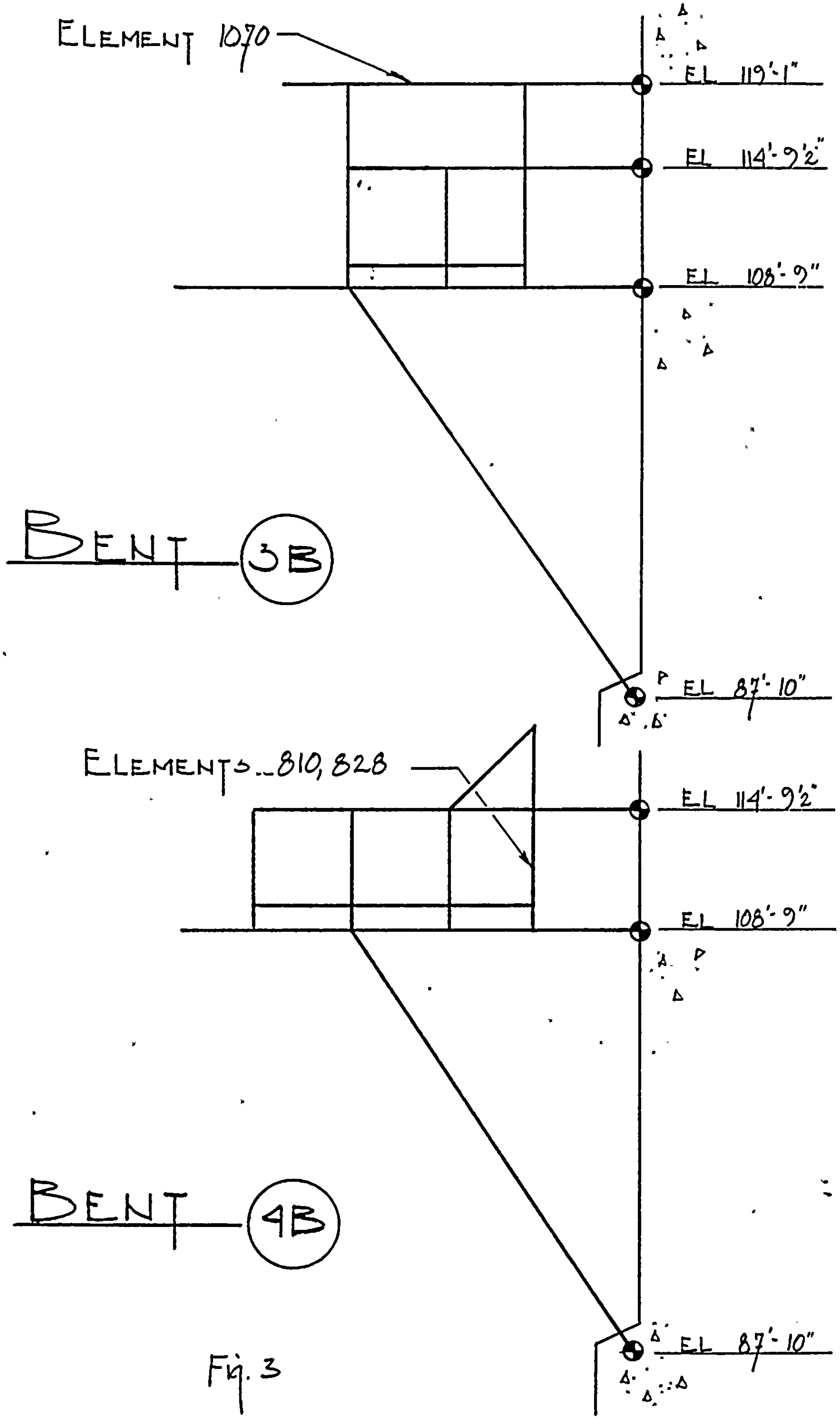
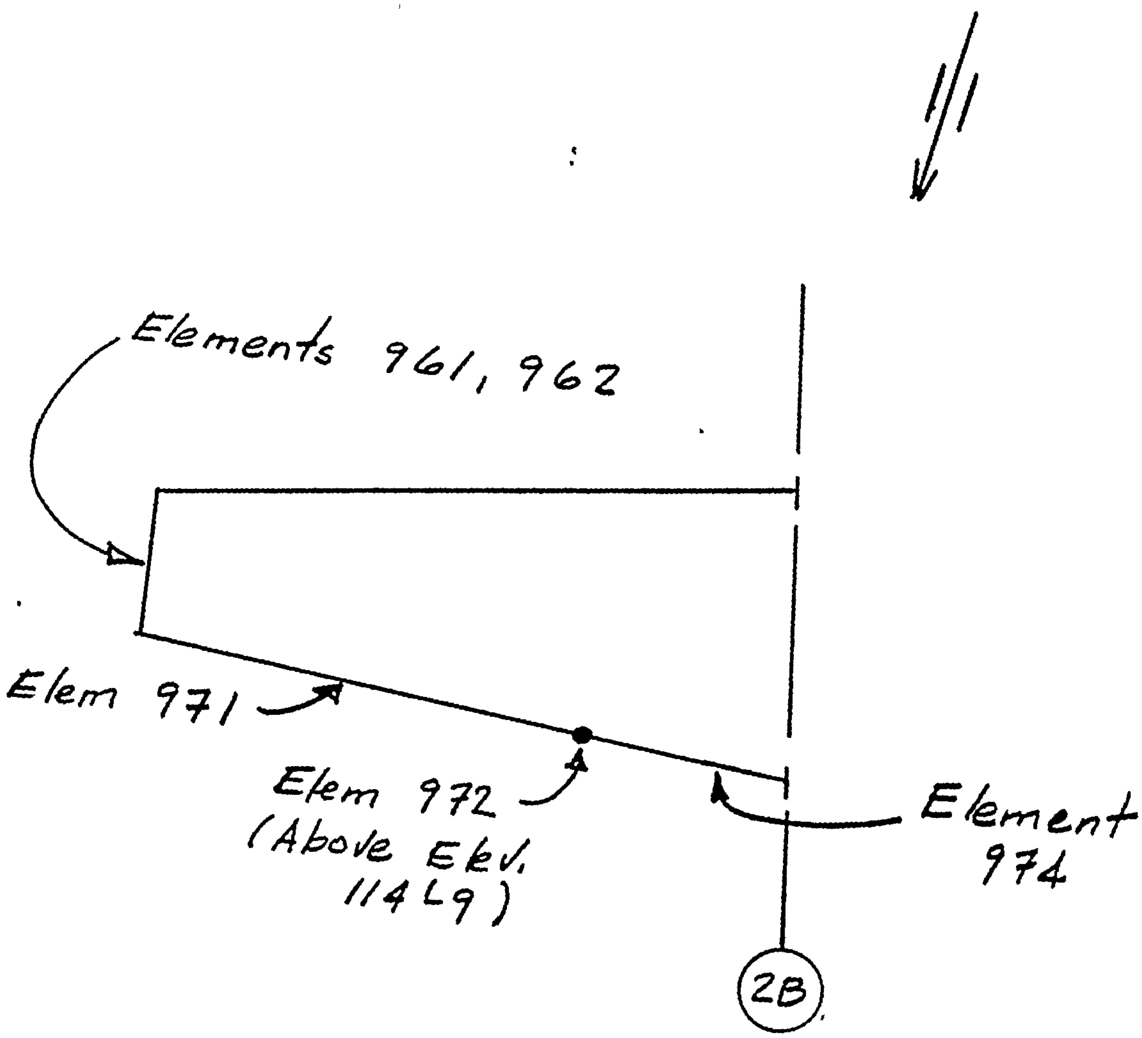
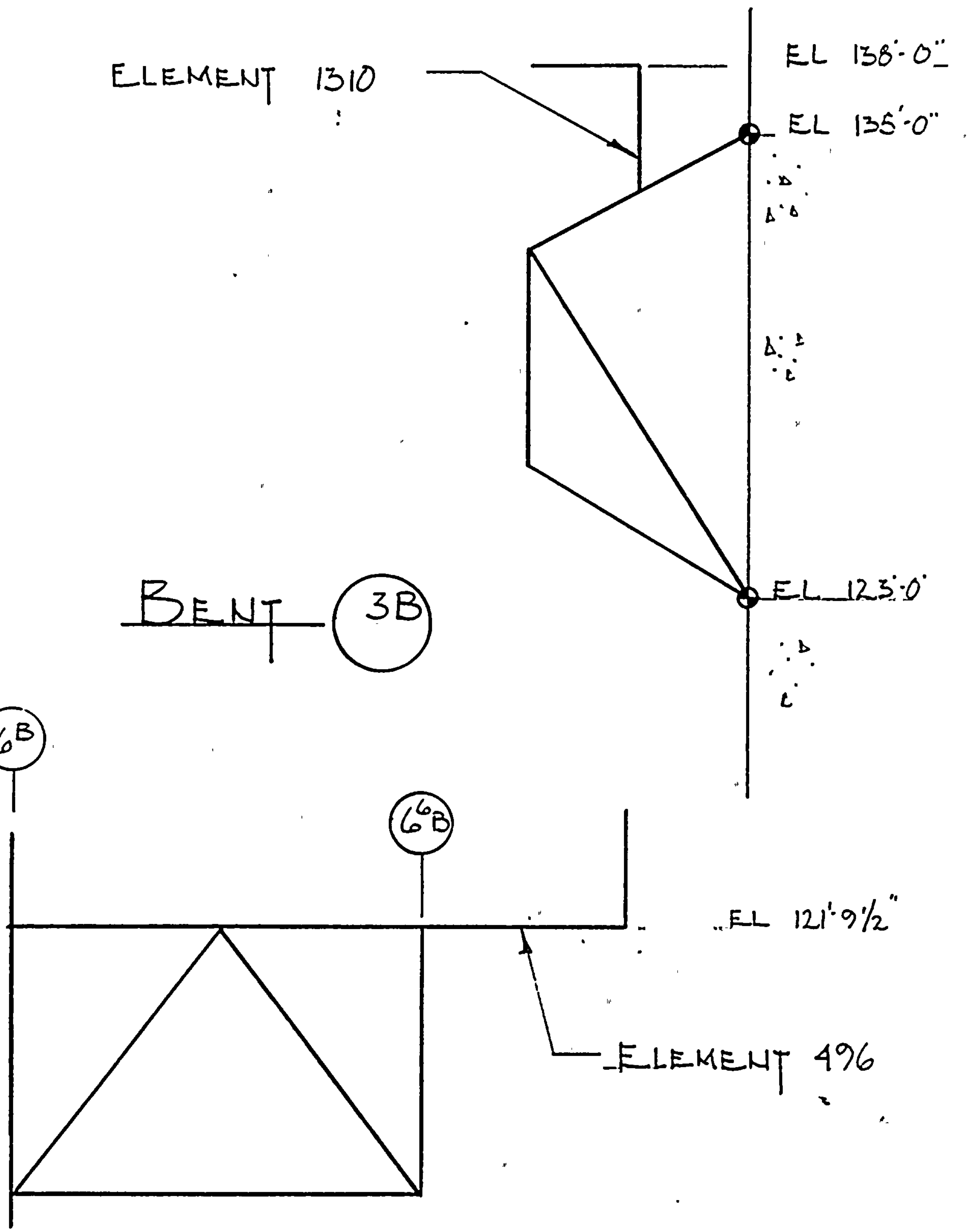

ELEMENT 1070
EL 119'-1"
EL 114'-9½"
EL 108'-9"
BENT 3B
EL 87'-10"
ELEMENTS 810, 828
EL 114'-9½"
EL 108'-9"
BENT 4B
EL 87'-10"

Fig. 3



Plan @ Elevation 114'-9½


ELEMENT 1310
EL 138'-0"
EL 135'-0"
EL 123'-0"
BENT 3B
6B
6B
EL 121'-9½"
ELEMENT 496

APPENDIX 6

PGandE LETTER NO. DCL-85-158

DATED APRIL 19, 1985

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