SONGS-1 SEISMIC PROGRAM FOR LONG TERM SERVICE

Responses to Action Items Resulting From the 02/12/85 and 02/27/85 Meetings with the NRC.

Prepared for:

NUCLEAR REGULATORY COMMISSION

Prepared by:

SOUTHERN CALIFORNIA EDISON COMPANY

March 11, 1985

The following is a list of action items resulting from the 2/12/85 and 2/27/85 meetings with the NRC.

1. Provide flow charts showing the flow paths for the LTS methodology, including use of criteria.
2. The report documenting the results of the LTS analyses should indicate where non-standard methods, such as the energy balance method, were used in the LTS analyses.
3. Prepare a matrix comparing comments in the SERs of 2/8/84 and 11/23/84, SEP guidelines, the RTS criteria, and the LTS criteria.
4. Provide justification of neglecting "snapback" effect for failed supports.
5. Provide a justification for 2 percent strain limit for stainless steel. Also, provide additional information for the use of 2.0 Sy as the allowable for elastically calculated primary stresses under Level D loadings.
6. There are several versions of the Complete Quadratic Combination (CQC) method. Which version will be used for the LTS?
7. Provide a report summarizing the small bore piping criteria. The report should address the methods used to select the worst case configurations and should identify the number of confirmatory analyses.
8. Provide the LTS criteria for buckling of support and structural steel.
9. Provide a detailed justification for the 10 percent strength increase for strain rate effects.
10. Provide information on the 18 percent overstrength factor for structural steel. The presentation should include information on the statistical variation in the test samples.
11. Provide information on the factors of safety used with anchor bolts. Provide justification for any factors of safety less than 4.0.
12. Define "Ultimate Uniform Strain". Explain and justify its application to the LTS effort.
13. Determine if the support anaylsis methods to be used for LTS will vary from the SEP guidelines. Justify any variances.
14. Provide additional information for the valve qualification.
    a. Delete the reference to valve operability in the draft criteria document.
    b. Provide the LTS criteria position on valve stem analysis.
    c. Provide the existing valve body integrity analysis.
    d. Explain why piping end loads are not listed in the design loads for valves in Section 3.6.1 of the LTS criteria and methodology report (Impell Report No. 01-0310-1368, Rev. 0, dated 2/1/85).

15. Provide an explanation of the energy balance method. Include examples of its use in other types of analysis (such as waterhammer).

16. Provide a sample calculation to show the application of the energy balance method and load redistribution from a failed pipe support.

17. Provide reasons for using the Summer 1983 Code Addenda for structural steel strength.

18. Provide a definition of the boundaries to be used for seismic analysis of the containment penetrations.

19. Make references in the criteria document to "0.67g Modified Housner Spectrum."

20. Document the criteria used for qualification of piping systems using the similarity method.

21. Define the basis and procedures for the secant stiffness method.

22. Provide a comparison of the loads generated by Impell (i.e., response spectra) with the existing spectra.

23. Provide justification for the 11 percent damping value used for soil material in the SSI.

24. Provide a copy of the RV-SUPERPIPE paper by Asfura, A., and A. Der Kiureghian, "A New Floor Response Spectrum Method For Seismic Analysis of Multiply Supported Secondary Systems," Report No. UCB/EERC-84/04, University of California, Berkeley.

25. Provide references for applications of the CLASSI, SASSI, and FLORA computer codes.

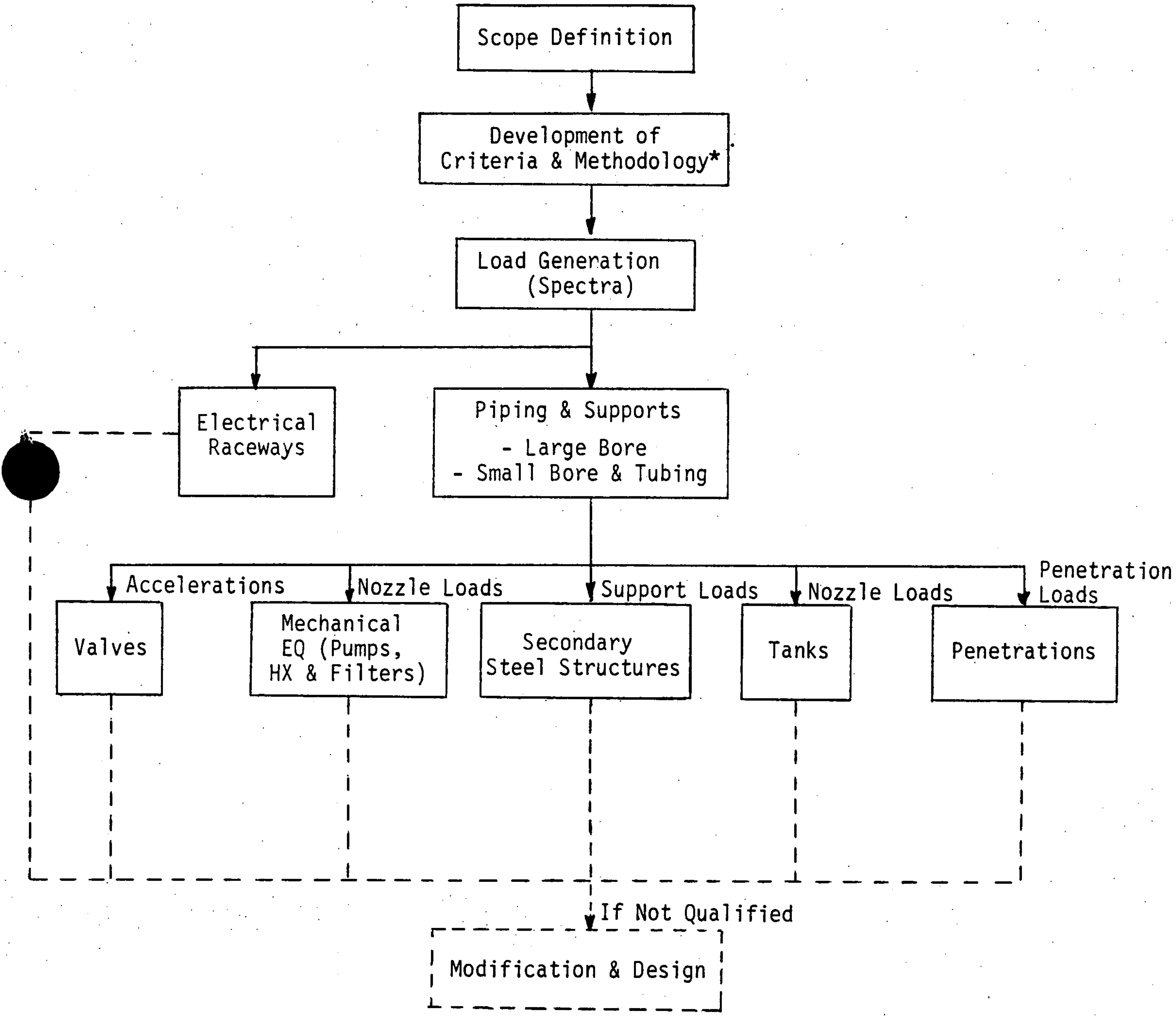
26. Define the correlation coefficient used in the Multiple Level Response Spectra (MLRS) analysis method and in RV-Superpipe. Is it identical to the definition in R.G. 1.92?

27. What combination method is used for piping loads on gang supports. Provide justification for the method used.

28. Provide justification to use same allowable 2 S_y for Class 1 and Class 2/3 piping.

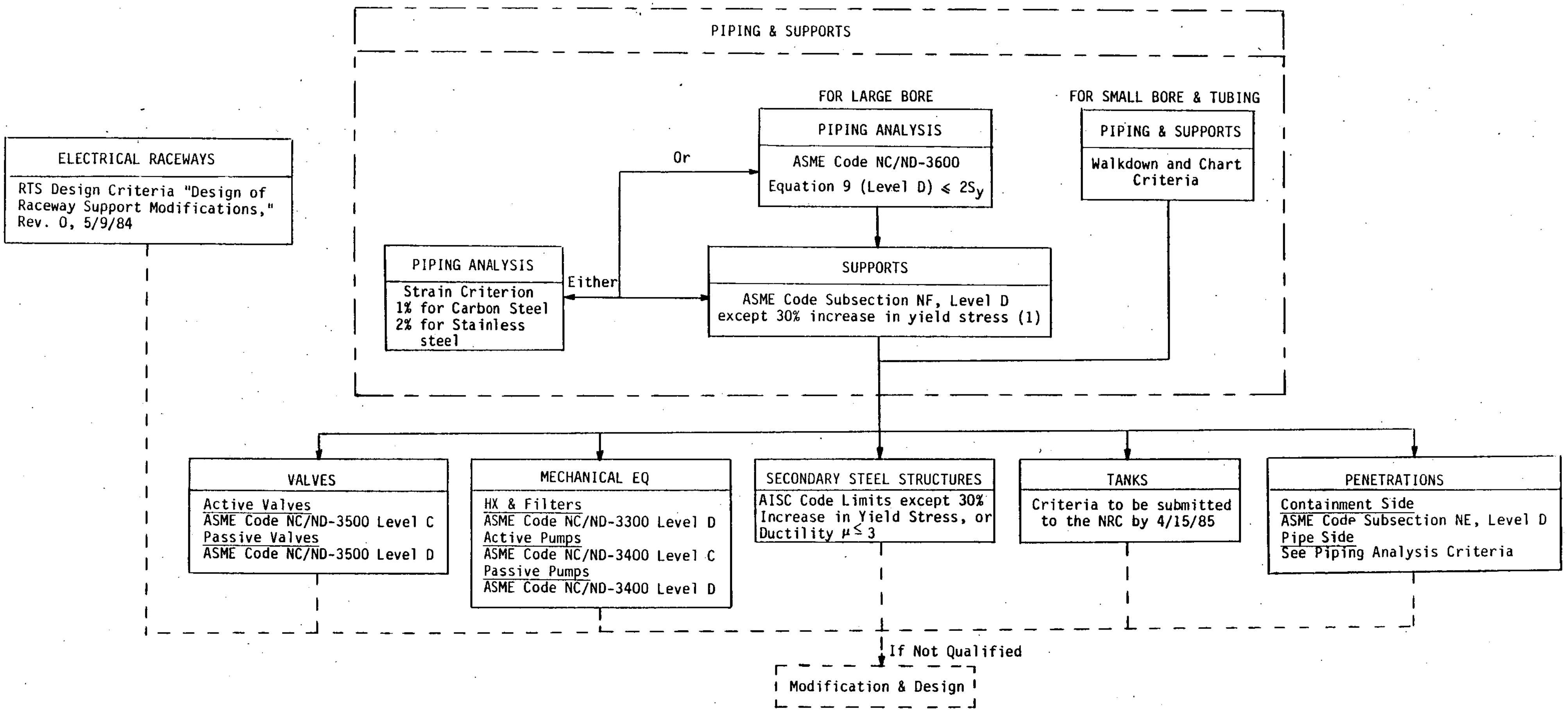
ACTION ITEM 1: Provide flow charts showing the flow paths for the LTS methodology, including use of criteria.

Flow Chart of Seismic Program for LTS



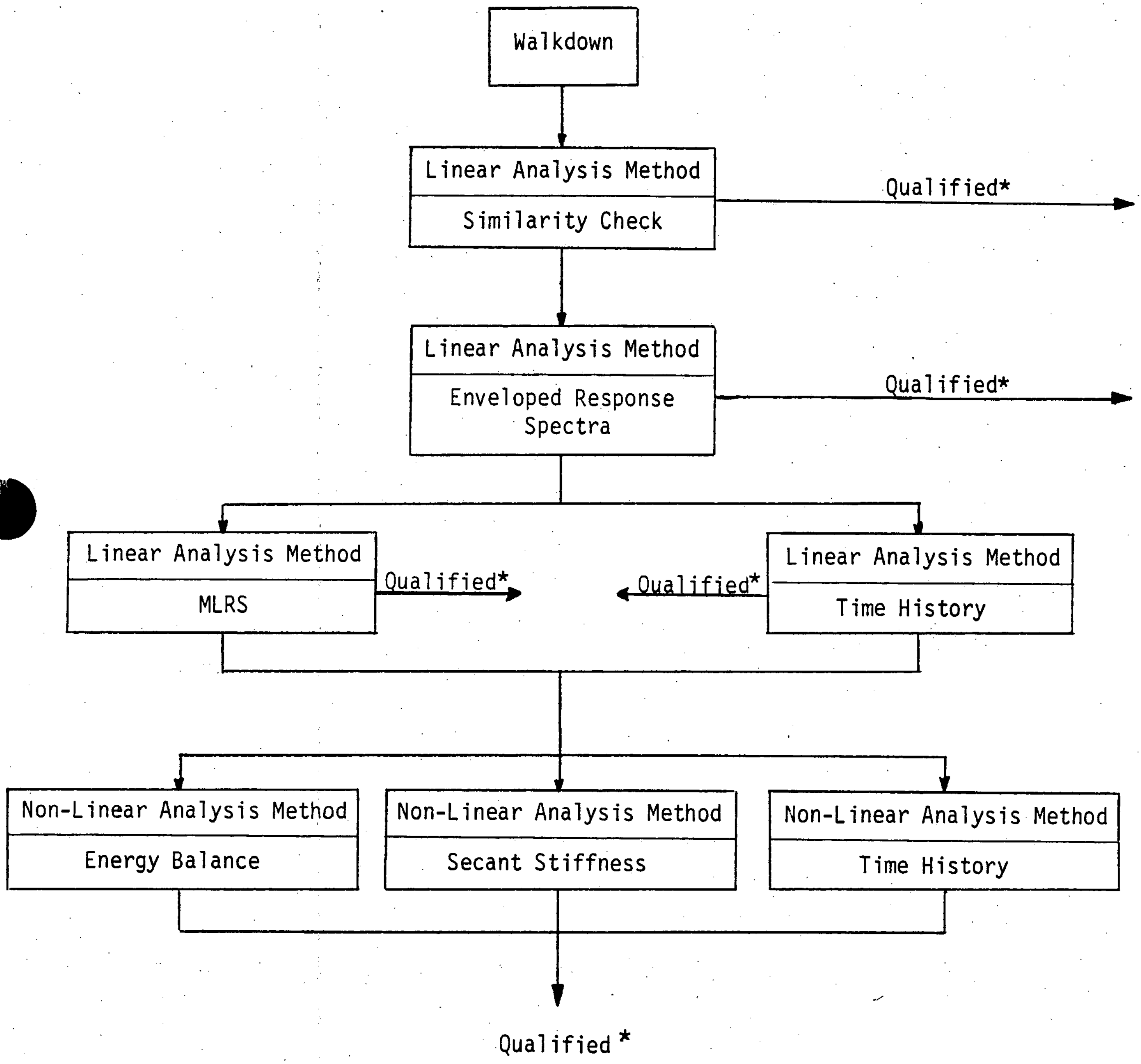
*See separate criteria and methodology flow charts on the following pages.

Criteria Flow Chart



NOTE: (1) For concrete anchor bolts, if factor of safety of less than 4.0 or 5.0 is used on a case-by-case basis, the calculations will be documented and identified to NRC.

Methodology Flow Chart for Piping & Supports Qualification (Large Bore)



*"Qualified" means with or without modifications.

ACTION ITEM 2: The report documenting the results of the LTS analyses should indicate where non-standard methods, such as the energy balance method, were used in the LTS analyses.

RESPONSE:

This will be done.

ACTION ITEM 3: Prepare a matrix comparing comments in the SERs of 2/8/84 and 11/23/84, SEP guidelines, the RTS criteria, and the LTS criteria.

RESPONSE:

Attached are three pages containing a comparison of Criteria.

Comparison of Criteria for SONGS-1 Reevaluation of 0.67g Modified Housner Ground Motion

Item	SEP	RTS	RTS - SER Comment	Proposed LTS	Remark
Piping Analysis					
- Large Bore					
• Primary Stress check: code Eqn. 9 Level D (P + G + DBE inertia)	2.4S_h for Class 2/3 1.8 S_h for Class 1 (or 3Sm using Class 1 rules)	2.0S_y	- Lower stress limit (2/8/84 SER) - The staff will develop the specific criteria for the long-term evaluation in conjunction with the review of the licensee's implementation of the restart program (2/8/84 SER).	2.0S_y	- See responses of Action Item 5 - Also see Appendix A of Impell Report 01-0310-1368, Rev. 0 "SONGS-1 Seismic Program for LTS."
• Strain Limit	---	1% for carbon steel 2% for stainless steel	- The SEP guidelines should be used (2/8/84 SER)	1% for carbon steel 2% for stainless steel	- See responses of Action Item 5
- Small Bore	Same as large bore	Walkdown & chart method	- Some sampling anlayses should be conducted to confirm the applicability of the historical and experimental evidence and to investigate the capability of any unusual or unique design features (2/8/84 SER). - The staff will work with the licensee to develop appropriate criteria for sampling analyses prior to the conduct of a plant walkdown (2/8/84 SER).	- Walkdown & Chart method. This method will be validated by rigorous sample analysis. - Or, use large-bore criteria.	- Submit report to the NRC by 4/15/85. (Action Item 7)

Note:
SEP - Systematic Evaluation Program
RTS - Return to Service
RTS-SER Comment - NRC's Safety Evaluation Report related to RTS, dated 2/18/84 and 11/23/84.
LTS - Long Term Service

Comparison of Criteria for SONGS-1 Reevaluation of 0.67g Modified Housner Ground Motion

Item	SEP	RTS	RTS - SER Comment	Proposed LTS	Remark
Pipe Supports					
- Structural Steel	ASME Level D	ASME Level D plus 1.2 factor on F_y (for material overstrength).	- Staff Recommends SEP guidelines for LTS (2/8/84 SER).	ASME Level D plus 1.3 factor on F_y (for material overstrength plus strain rate effect).	- See responses of Action Items 9 and 10. - Also see Appendix A of Impell Report 01-0310-1368, Rev. 0 "SONGS-1 Seismic Program for LTS."
- Concrete Expansion Anchor Bolts	Wedge Type: FS = 4 Shell Type: FS = 5	In general, FS = 4 On a case-by-case basis, $2 < FS \leqslant 4$	---	Wedge Type FS = 4 Shell Type FS = 5 On a case-by-case basis, FS less than 4 will be used with the following restrictions. 1. Adjacent supports elastic, with FS = 4. 2. Minimum of 4 bolts per base plate and no more than half subject to tension simultaneously.	- See responses of Action Item 11. - Also see Appendix A of Impell Report 01-0310-1368, Rev. 0, "SONGS-1 Seismic Program for LTS."

Note: SEP - Systematic Evaluation Program
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Comparison of Criteria for SONGS-1 Reevaluation of 0.67g Modified Housner Ground Motion

Item	SEP	RTS	RTS - SER Comment	Proposed LTS	Remark
Secondary Steel Members	---	- Acceptable if $\mu \leq 3$ - For $3 < \mu \leq 10$, review on a case-by-case basis to assure pipe functionality.	- Staff accepts ductility concept for LTS. However, recommends that ductility ratio calculation be based on yield displacement instead of plastic moment capacity (2/8/84 SER).	- Acceptable if $\mu \leq 3$ - Limit strain to one-half ultimate uniform strain. - 1.3 factor on F_y (For material overstrength plus strain rate effects. This applies to linear analyses only).	- See responses of Action Items 9, 10 and 12.
Penetrations					
- Penetration Structure - See criteria for pipe supports.					
- Containment	---	Level D Subsection NE	---	Level D Subsection NE	See responses of Action Item 18
- Piping - See criteria for Piping.					
Valves					
- Passive Valves					
• Pressure Retaining Parts	Level D	Level D	---	Level D	See responses of Action Item 14
• Non-Pressure Retaining Parts	Not Addressed	Level D	---	Level D	
- Active Valves					
• Pressure Retaining Parts	Level C	Level C	---	Level C	
• Non-Pressure Retaining Parts	Not Addressed	Level C	---	Level C	

Note: SEP - Systematic Evaluation Program
RTS - Return to Service
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Comparison of Criteria for SONGS-1 Reevaluation of 0.67g Modified Housner Ground Motion

Item	SEP	RTS	RTS - SER Comment	Proposed LTS	Remark
Equipment					
- Supports - See criteria for pipe supports.					
- Pressure Retaining Parts					
• Vessels & Heat Exchangers	Level D	Level D	---	Level D	
• Active Pumps	Level C	Level C	---	Level C	
• Inactive Pumps	Level D	Level D	---	Level D	

Note: SEP - Systematic Evaluation Program
RTS - Return to Service
RTS-SER Comment - NRC's Safety Evaluation Report related to RTS, dated 2/18/84 and 11/23/84.
LTS - Long Term Service

ACTION ITEM 4: Provide justification for neglecting "snapback" effect of failed pipe supports.

RESPONSE:

In the evaluation of support capacity, supports which are found to be overstressed (brittle failure) are conservatively assumed to be completely inactive in the reevaluation of the piping. In reality, the support components have a greater capacity than the design capacity. As a result, the support may never exhibit catastrophic failure, but just gross deformation during the seismic event.

In some cases, a component of a support structure may fail brittlely during the seismic event (e.g., a single anchor bolt failure). However, gross support failures will occur over a period of time and the "snapback" effect on the piping will only be realized after the peak seismic stresses have been experienced by the pipe. Since the seismic loadings will be lower at the time of actual support failure (seismic input motions usually contain only one predominant peak), the energy associated with the snapback effect will be small compared to the kinetic energy input of the earthquake. Consequently, the snapback effect is insignificant and the evaluation of the piping for snapback type loading is not required.

5. Provide a justification for 2 percent strain limit for stainless steel. Also, provide additional information for the use of 2.0Sy as the allowable for elastically calculated primary stresses under Level D loadings.

Response:

In the "Seismic Program for Long Term Service" Report No. 01-310-1368, March 8, 1985, the piping stress criterion provides for a stress allowable of 2.0 Sy for the ASME Code Equation 9 primary stresses. In lieu of this stress criterion, a piping strain criterion may be use. The allowable strains in piping components are one percent and two percent strain for carbon and stainless steel, respectively. The basis for the allowable strain of 2 percent for stainless steel and the use of 2.0 Sy is justified by the following points:

- Nonlinear Analysis

  Nonlinear analysis of a representative stainless steel piping system was performed for SONGS-1. This analysis demonstrated that the maximum strain corresponding to an elastically calculated stress of 2.0 Sy was less than 2 percent. With 2 percent strain, the flow area reduction is acceptable for delivering rated flow. The details of this analysis are discussed in more detail in Section 5.a.

- Testing Programs

  Numerous testing programs have been conducted, or are in progress, to study the behavior of piping systems under severe seismic or other dynamic loading. The conclusions from these programs support the use of 2 percent strain limit of stainless steel and the details of the results of one program can be found in Section 5.b.

- Dynamic versus Static Loadings

  Current ASME Code elastic analysis stress response acceptance criteria do not differentiate between dynamic (such as seismic) and static loading events. Inelastic response of piping systems to seismic and other dynamic loadings is significantly different than inelastic response to static loadings of the same magnitude. Studies have demonstrated that the margin against failure of piping systems is significantly greater for dynamic loads than for static loads when the elastically computed responses are held to the same allowable stresses. Reference, Campbell, R. D., Kennedy, R. P., and Thrasher, R. D., "Development of Dynamic Stress Criteria for Design of Nuclear Piping Systems", Structural Mechanics Associates, Inc., Report SMA 17401.01, November, 1982.

- Strain Limit for High Temperature Piping

  In Code Case N-47 titled "Class 1 Component in Elevated Temperature Service" of ASME Boiler and Pressure Vessel Code, the deformation and strain limits for structural integrity are two percent strain at the surface due to bending. A detailed description of the code case is presented in Section 5.C.

- Operating Plant Experience

  The El Centro Steam Plant has been subjected to strong (over 0.5 g) earthquake motion without disruption to operation. Similarly, Lawrence Livermore Laboratory and the Hamaoka Units in Japan have been subjected to moderate earthquake motion without disruption of operation. Numerous other electrical and process plants have been subject to earthquakes with no failure of piping systems, as supported by the ongoing findings of the SQUG program. SRV discharge piping systems in both PWR and BWR plants have also been subjected to dynamic loads without damage, where conventional alysis indicates dynamic stresses well above current Code allowables. See Section 5.d for a more detailed description of the El Centro Steam Plant.

- Categorization of Seismic Loading

  In current ASME Code rules, seismic inertia stress is categorized as the primary stress and evaluated in the Code Equation 9. Studies have been performed, or are in progress, to investigate the licensing support for the elimination of the primary stress requirement for seismic loading on piping, Reference "Proposed Code Change to Place Seismic Loading in the Fatigue Category," PVRC Technical Committee on Piping Systems, dated July 11, 1984. If seismic inerita stress is categorized as the secondary stress, the 2 Sy allowable represents a conservative limit for "shakedown" to elastic action when the yield stress is surpassed in an ideally plastic material.

  In addition, the following information was requested in support of the use of 2 percent strain and 2.0 Sy.

  - Comparison of LTS and SEP methods for piping analysis. See Section 5.e.

  - List of piping materials with allowable stresses at maximum operating temperatures. See Section 5.f.

Section 5.a: Impell's nonlinear analysis confirming 2 percent strain and the 2 Sy limit.

The purpose of the nonlinear analyses performed for SONGS-1 [1] was to show that typical piping systems remain functional at an elastically calculated stress limit of $2S_y$. The load combination considered in the analysis was pressure, gravity and seismic inertia.

Numerous hot safe-shutdown piping systems were reviewed and two representative piping systems (AC-19 and MW-01) were selected for the study. The two systems provided a good representation of the various piping components, materials, and system types represented in the plant. Both carbon and stainless steel materials were considered, as well as piping components of different sizes and flexibilities. Both systems have typical run configurations with a mix of various component types. Although the seismic stress levels in the systems were not at the functionality stress limit of $2S_y$, the input motions were increased to obtain the desired maximum elastic stress.

Elastic analyses were performed for gravity, eigenvalue and seismic inertia to provide the correlation of results with the nonlinear analyses. This ensures proper development and accuracy of the nonlinear analysis model.

To maintain functionality, the elbow, tee and straight pipe elements must not distort excessively (ovalization) in order to deliver the rated flow. The ANSYS computer program was used for the nonlinear analyses. Models were developed with elbow and tee components which closely matched experimentally verified behavior (see attached nonlinear analysis models, Figs. 5.1 and 5.2). The time history loading used to develop the elastically calculated stress of $2\ S_y$ (the study used $2\ S_y$ limit for carbon steel and $2.2\ S_y$ limit for stainless steel) at critical components (elbow for both systems) was input for the nonlinear analysis. The strains calculated from the nonlinear analysis were compared with the stresses calculated from the elastic analyses with the same input. As shown in the attached Tables, 5.6 and 5.10, the maximum strains were less than 1 percent for carbon steel and equal to 2 percent for stainless steel. At these strain levels, maximum ovalization and flow rate reductions were considered to be acceptable (less than 5 percent flow area reduction). See note below.

A major conservatism in the nonlinear analyses is the material law assumed for the ANSYS model. The moment-deflection curves used on the ANSYS model match closely with experimental data; thus, the proper global response is assured. Additionally, by matching the moment-deflection curves, a conservative moment-strain relationship is produced. This can be seen by reviewing the attached Figures, 5.7 and 5.8. For example, a moment of 200 in-kips produces deflections of approximately .35 inches in both the ANSYS and experimental studies (Figure 5.7). However, this same

NOTE: These strain levels were used to compute maximum ovalization.

moment produced experimental strains of .16 percent while the ANSYS model predicted .45 percent. Thus, the ANSYS-calculated strains are greater than those reported in experimental studies, but are still within experimentally verified limits.

Other conservatisms in the nonlinear analysis are as follows:

- Code-specified minimum material strengths were used in the analyses. Actual material strengths are greater than Code-specified minimums.

- Nominal component thicknesses were used on the analysis. Component thicknesses are normally greater than nominal values. This increases the strength and moment-carrying capacity of the components.

- Strain rate effects which enhance yield strength are conservatively neglected.

- Pressure effects increase collapse moments of components. These effects were conservatively neglected in the analysis.

In summary, this study conclusively demonstrates that an elastic piping stress limit of $2S_y$ for carbon and stainless steel piping systems provides assurance that the piping systems are capable of withstanding a DBE magnitude motion without loss of function. This criterion allows local yielding in components such that load redistribution reduces maximum moments and stresses, yet provides limits on the extent of yielding such that functionality of the system is maintained.

Similar nonlinear analyses have also been performed at Commonwealth Edison's Dresden and Quad Cities Plants to successfully license the $2.0S_y$ stress limit as part of their IE Bulletin 79-14 program [2].

REFERENCES:

[1] Impell Report No. 04-0310-0063, "SONGS-1 Functionality Criteria for Piping Systems in Response to the DBE Event," Revision 1, December 1983.

[2] Impell Report No. 01-0590-1355, "Quad Cities Unit 1 Functionality Study of Piping Systems in Response to the SSE Event," Revision 0, December 1980.

TABLE 5.6 AC-19 Nonlinear Analysis Results - Strains

Location (See Figure 5.1)	Linear Analysis Stress, ksi	Nonlinear Analysis Maximum Strain, Percent
Elbow 1 @ Node 2	49.7	0.49
Elbow 2 @ Node 7	39.6	Remained Elastic
Elbow 3 @ Node 8	69.4 (2.0 S_y (1))	0.74
Pipe @ Node 14	53.8	0.21
Pipe @ Node 16	77.5 (2.2 S_y (1))	0.41
Tee 1	86.6 (2.5 S_y (1))	Remained Elastic(2)

Notes: (1) S_y = 34.7 ksi
(2) See text for discussion

TABLE 5.10 MW-01 Nonlinear Analysis Results - Strains

Location (See Figure 5.2)	Linear Analysis Stress, ksi	Nonlinear Analysis Maximum Strain, Percent
Elbow 3 @ Node 8	23.1	0.10
Elbow 4 @ Node 14	55.0 (2.2 S_y (1))	2.0
Elbow 4 @ Node 16	31.8	0.42
Pipe @ Node 19	38.9	0.07
Tee 1	90.8 (3.6 S_y (1))	Remained Elastic

Notes: (1) $S_y = 25.0$ ksi

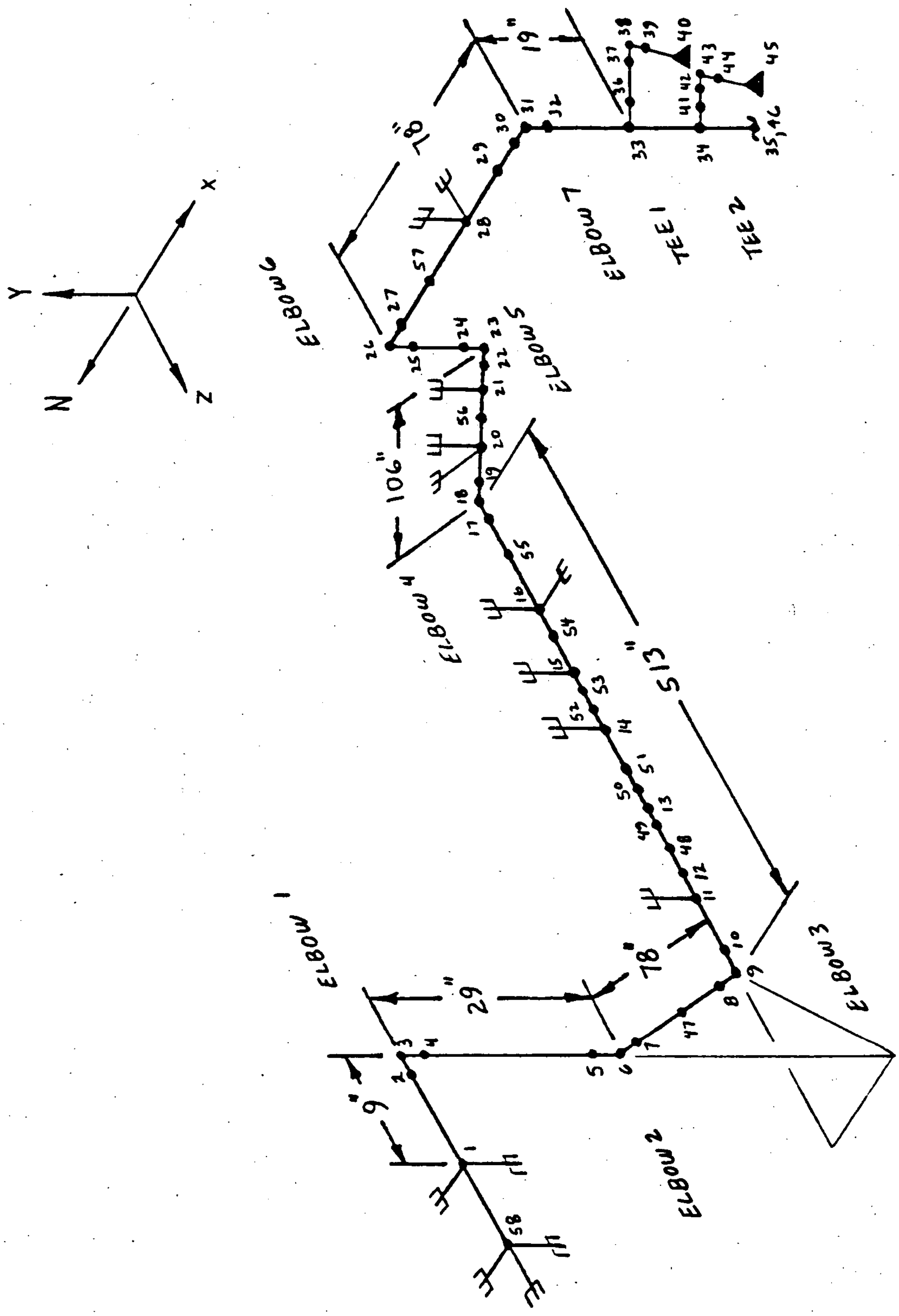


FIGURE 5.1 AC-19 Mathematical Model - Nonlinear Analysis

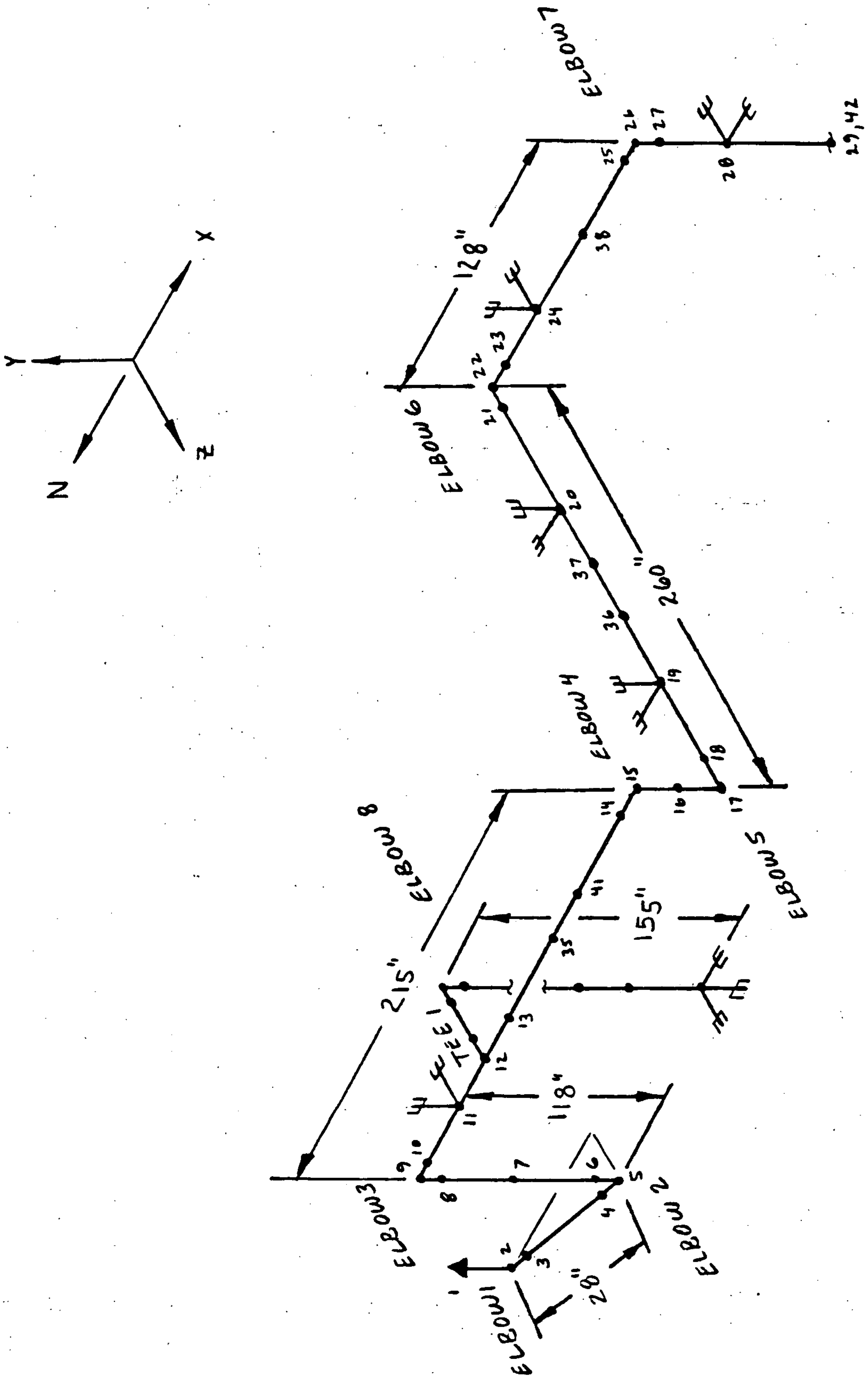


FIGURE 5.2 MW-01 Mathematical Model - Nonlinear Analysis

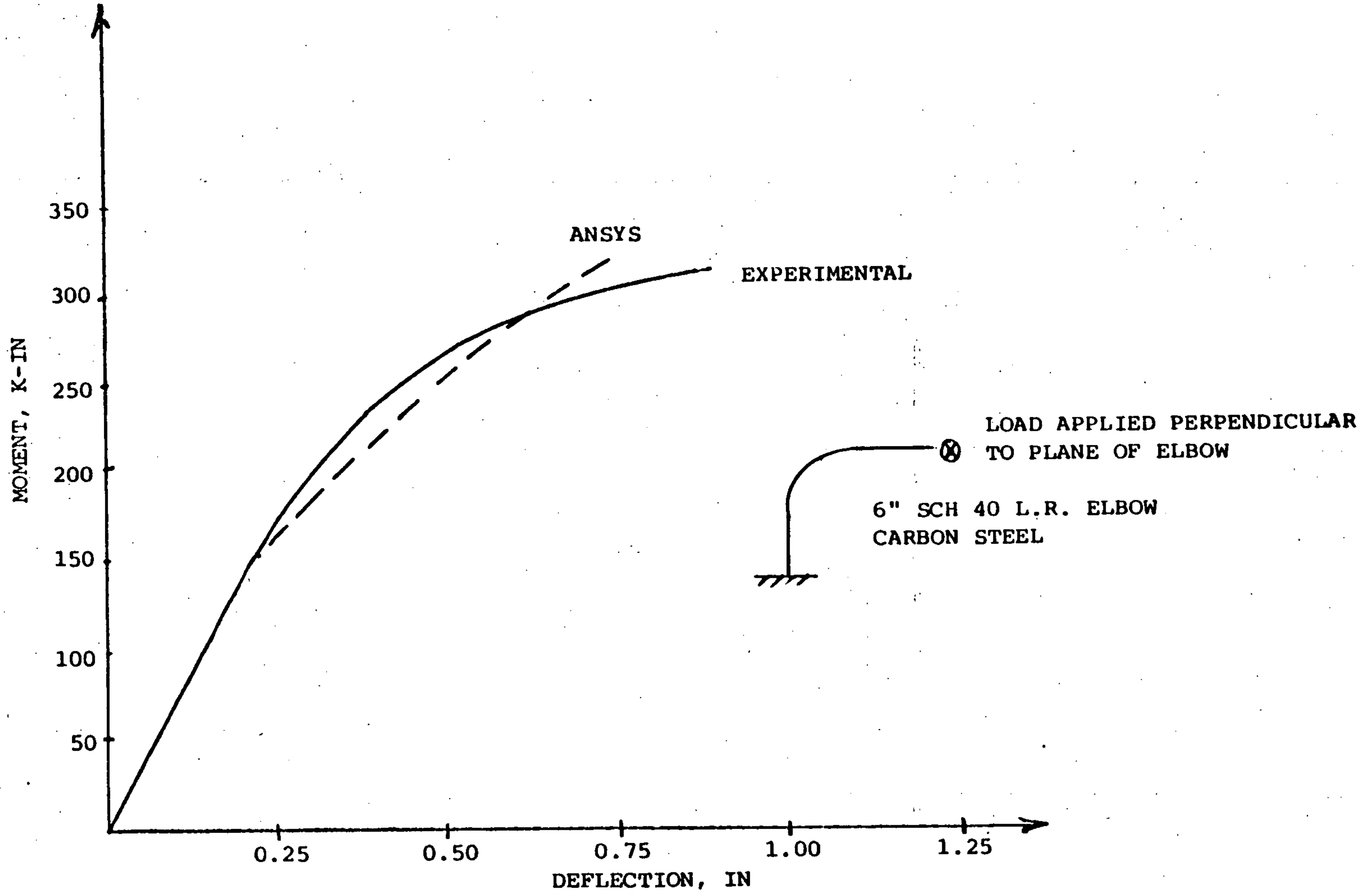
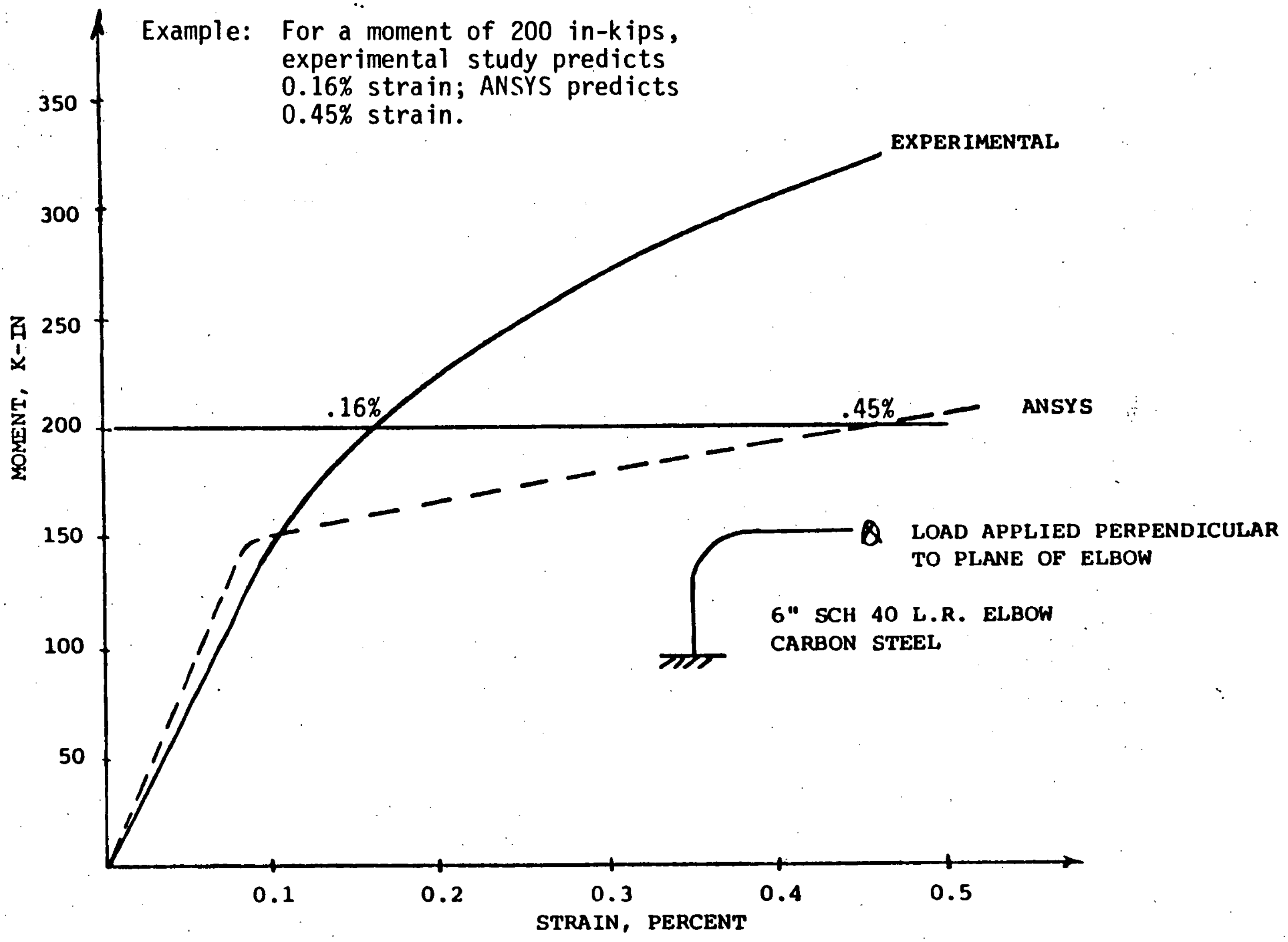


FIGURE 5.7 6-Inch Schedule 40 Carbon Steel Elbow Moment-Strain Curve



Example: For a moment of 200 in-kips, experimental study predicts 0.16% strain; ANSYS predicts 0.45% strain.

FIGURE 5.8 6-Inch Schedule 40 Carbon Steel Elbow Moment-Strain Curve

Section 5.b: Pipe Testing Programs

The U.S. Nuclear Regulatory Commission and the Electric Power Research Institute have jointly sponsored a piping research program involving the design, analysis, fabrication, erection, and dynamic testing of prototypical piping systems [1]. One objective of this program was to stimulate recognition of safety margins implicit in ASME B&PV Code rules for Classes 2 and 3 piping by demonstrating the existence of large design margins in piping and support systems when subject to seismic loads much greater than those acceptable according to the ASME Code.

Results from this effort and other similar experimental programs [2, 3, 4] have confirmed that piping systems are able to sustain extreme dynamic loads without plastic collapse, leakage, or loss of pressure-retention capability. Results of these programs demonstrate that piping systems have large inherent reserve margins under seismic loading. These programs have generated proposed changes to the ASME Code requirements to remove seismic loading from a primary stress check requirement [5].

Below, we briefly discuss two of the recent testing programs for piping systems, performed by ANCO. The first system consists of a 70 ft. long, six-inch Schedule 40 pipe run. The piping was subjected to accelerations as high as 15g and response accelerations over 50g were measured. The second system consists of a 20 ft. long, four-inch, Schedule 40 pipe run. Accelerations as high as 14g were input and response accelerations greater than 21g were measured.

a) 70 ft. long, six-inch Schedule 40 Piping System

The first piping system tested was a single run of A106B carbon steel about 70 ft. long. It is shown in Figure 1. Six-inch, Schedule 40 and eight-inch, Schedule 40 piping was employed, with the larger diameter pipe located at the ends of the pipe run. The 6-in. and 8-in. pipe were joined together using standard 6 x 8 reducers. The pipe elbows were 90° long radius elbows. The piping was designed following ASME Code rules.

Comparison of analytical and test frequencies of this piping system is shown in Table 1. The first natural frequency is 4.18 and 4.62 H_Z from analysis and test, respectively.

Multiple tests were conducted with various magnitudes of dynamic input and support configations. The piping was pressurized to 1150 psig and driven with a 20 second input earthquake time history. Selected test results are shown in the Table below:

TEST CASE	INPUT ZPA(G)	MAX. EXP. STRESS (KSI)	RATIO TO * ASME LEVEL D	RATIO TO ** S_Y	MAX. STRAIN %
1 (XEQ3C1)	2.24	32.4	0.9	.93	.0677
2 (XEQ1)	4.32	42.12	1.17	1.2	.0953
3 (XEQ2)	4.86	47.16	1.31	1.35	0.1040
4 (XEQ3)	5.38	47 52	1.32	1.36	0.1070
5 (YEQ1)	4.33	65 88	1.83	1.88	0.1153
6 (YEQ2)	5 55	74.52	2.07	2.13	0.1312
7 (YEQ3)	1.75	65.16	1.81	1.B6	0.1100
8 (YEQ4)	8.38	83.52	2.32	2 39	0.1400

* Maximum Experimental Stress/2.4S_h

** Maximum Experimental Stress/S_y

From this table, it is observed that at just below Level D Stress (Test Case 1), the maximum measured strain in the piping was 0.06 percent. The maximum input acceleration for this case was 2.24g. Test Case 6 shows that at a stress level corresponding to 2 times Level D (or 2.13 S_y for the pipe material) the maximum measured strain was 0.13 percent. The maximum input acceleration was 5.5g for this test case. Test Case 8 shows that for a stress level corresponding to 2.39 S_y, the maximum measured strain in the piping was only 0.14 percent.

These experimental results show that low strains are obtained at stress levels greater than 2 S_y. Thus, a stress limit criteria of 2S_y is conservative.

To show the severity of the input for a particular test case, the input response spectrum for Test Case 6 is compared in Figure 2 to the input required to just achieve the Level D stress condition in the piping system of Test Case 1. This test was about a factor of four greater than the input necessary to match the Level D stress limits in the frequency region of interest for the first piping system. That is, the piping system successfully withstood an earthquake input about four times greater than the Code design rules would indicate to be acceptable. The piping system, in fact, withstood several more severe dynamic tests with no gross distortion or loss of pressure retaining capacity.

b) Testing of 4-inch Diameter, Schedule 40 Piping System

The second piping system consisted of a prototypical nuclear power plant piping segment which was tested by ANCO Engineers Inc., under EPRI sponsorship, to determine its ultimate dynamic load capacity. The selected piping was a 20-foot run of 4-inch, Schedule 40 ferretic material with two elbows and three supports. An earthquake-like dynamic input was specified at each one of these supports. The piping tested is shown in Figure 3.

The piping run was designed in accordance with ASME Code Class 2 rules and was dynamically excited to varying response levels while under the Code maximum allowable internal pressure.

Figure 4 shows the horizontal dynamic spectra imposed on the piping. Also shown in Figure 4, for comparison purposes, is an SSE response spectra for a typical nuclear power plant. As may be seen, the test spectra input to the piping is seven to eleven times the SSE spectra in the frequency range of importance to the tested piping system (approximately 6 to 13 Hz.). That is, the imposed horizontal seismic-like input to the piping was roughly an order of magnitude greater than that typically used on the design of nuclear power piping.

The first and second test frequencies of this piping system are 6 and 13 H_Z, respectively.

Figure 5 is a comparison of the actual input test spectra with a spectra which produced stresses in the piping system equal to Code allowable (2.4 S_h). It is observed that the dynamic input to the test, resulted in elastically calculated stresses equivalent to 4.0 Sy (which corresponds to 3.3 times the Code allowable stress 2.4 S_h). Under 4.0 Sy, no leakage occurred. Permanent deformations in several regions of the piping were ovserved, but there was no plastic collapse or loss of structural integrity in the pressurized piping, even under the extreme seismic input.

Based on the test data reported and strain levels achieved the 2 Sy stress limit represents a conservative, yet realistic criteria for piping systems at SONGS -1.

REFERENCES:

[1] Laboratory Studies: Dynamic Response of Prototypical Piping Systems, Report prepared by ANCO Engineers Inc. for the U.S. Nuclear Regulatory Commission and the Electric Power Research Institute, June 1984.

[2] "Quick Look Report: Dynamic Testing of a Pressurized Piping System Beyond the Elastic Limit," Report prepared by ANCO Engineers Inc. for the Electric Power Research Institute, October 1981.

[3] Sand, Lochan, Schoor, and Hass, "Experimental Study of Dynamic Behavior of Piping Systems Under Maximum Load Conditions - Analysis," Kraftwerk Union, Federal Republic of Germany, ASME 1982 Orlando Conference, 1982.

[4] Ibanez, P., Keowen, R.S., and Renty, P.E., "Experimental Study of Dynamic Behavior of Piping Systems Under Maximum Load Conditions - Testing." ANCO Engineers, Culver City, California, ASME 1982, Orlando Conference, 1982.

[5] "Proposed Code Changes to Place Seismic Loading in the Fatigue Category," PVPC Technical Committee on Piping Systems. July 11, 1984.

Table 1: Comparison of Analytical and Test Frequencies for 70-ft. Long, Six-inch, Schedule 40, Piping System

Analytical Mode No.	Direction of Max. Component Of Eigenvector	Analytical Freq. (Hz)	Test Freq. (Hz)	Test Mode No.
1	Y	4.18	4.62	1
2	Y	6.76	7.11	2
3	Z	8.66	---	2
4	X	8.70	9.16	3
5	X	11.57	11.66	4
6	X	14.53	13.54	5
7	Z	16.24	---	
8	Z	16.65	---	
9	X	17.86	17.71	6
		---	18.53	7
10	Z	21.68	---	
11	Z	24.24	23.94	8
12	X	25.72	25.87	9
13	Z	28.96	28.06	10
		---	29.30	11

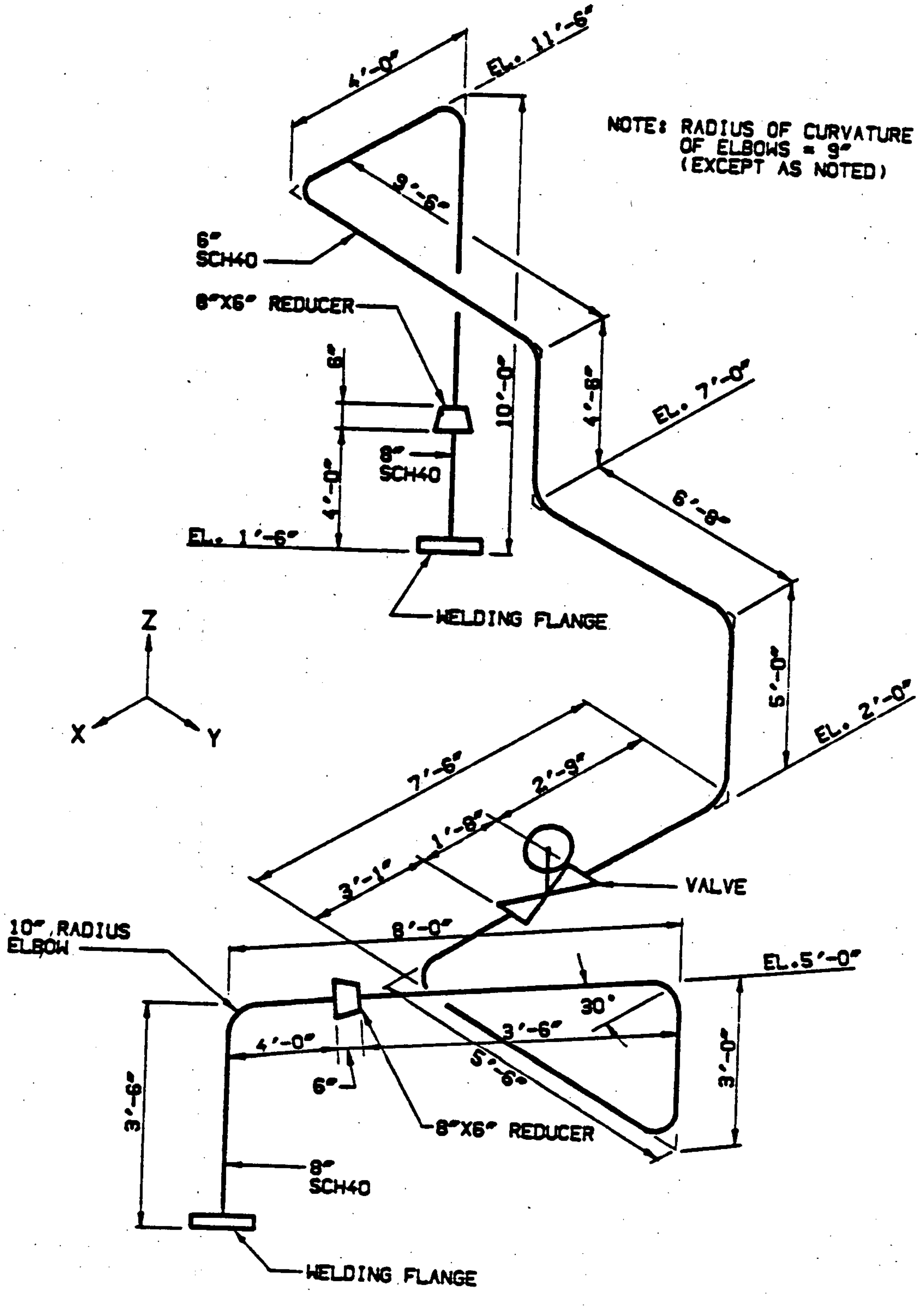


FIGURE 1 Pipeline Geometry

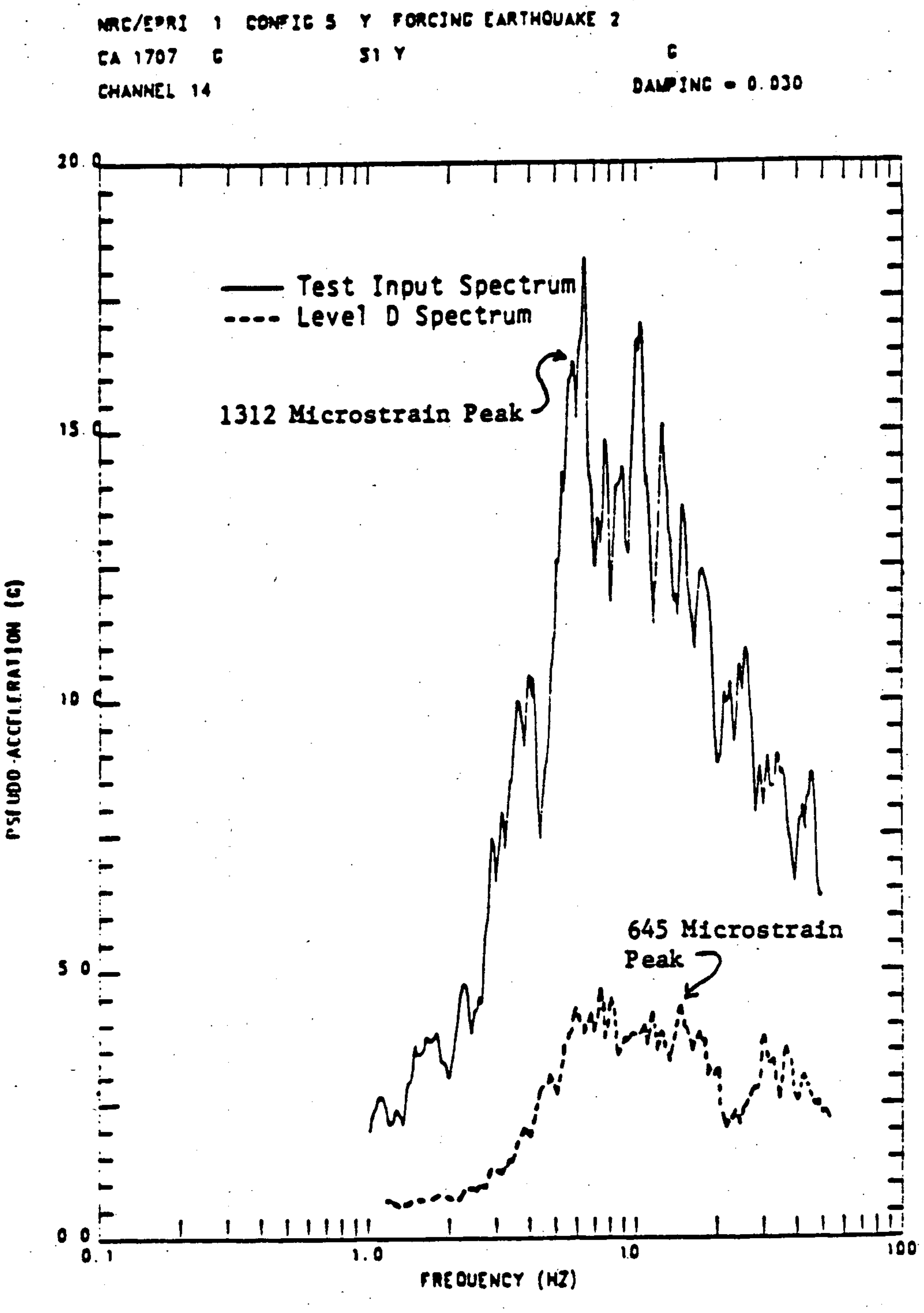
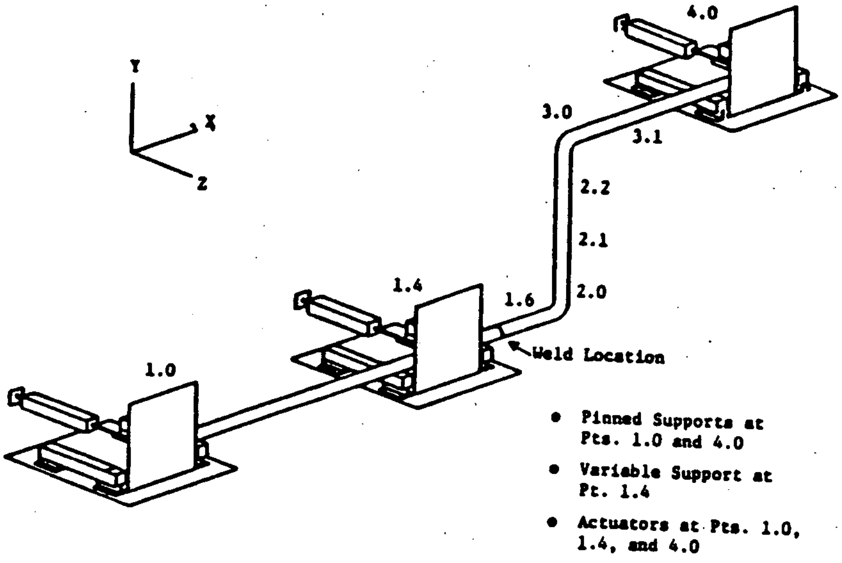


FIGURE 2 Input Response Spectra Comparison



- Pinned Supports at Pts. 1.0 and 4.0
- Variable Support at Pt. 1.4
- Actuators at Pts. 1.0, 1.4, and 4.0

FIGURE 3. Tested Piping System

ANCO ENGINEERS

Test # 1 Run # 5 Time 15:20 Date 9/22/81 Recorded by KB Page # _____

Test Specimen: EPRI pipe test specimen 1a

Purpose of Test: attempted 800% of yield test

Direction: ±Z

Comments: Channel 3
Damping = 2%

—— Response Spectra for piping input, point 1.0

– – – Horizontal Response Spectra for plant sited in Southeast U.S.A. for safe shutdown earthquake

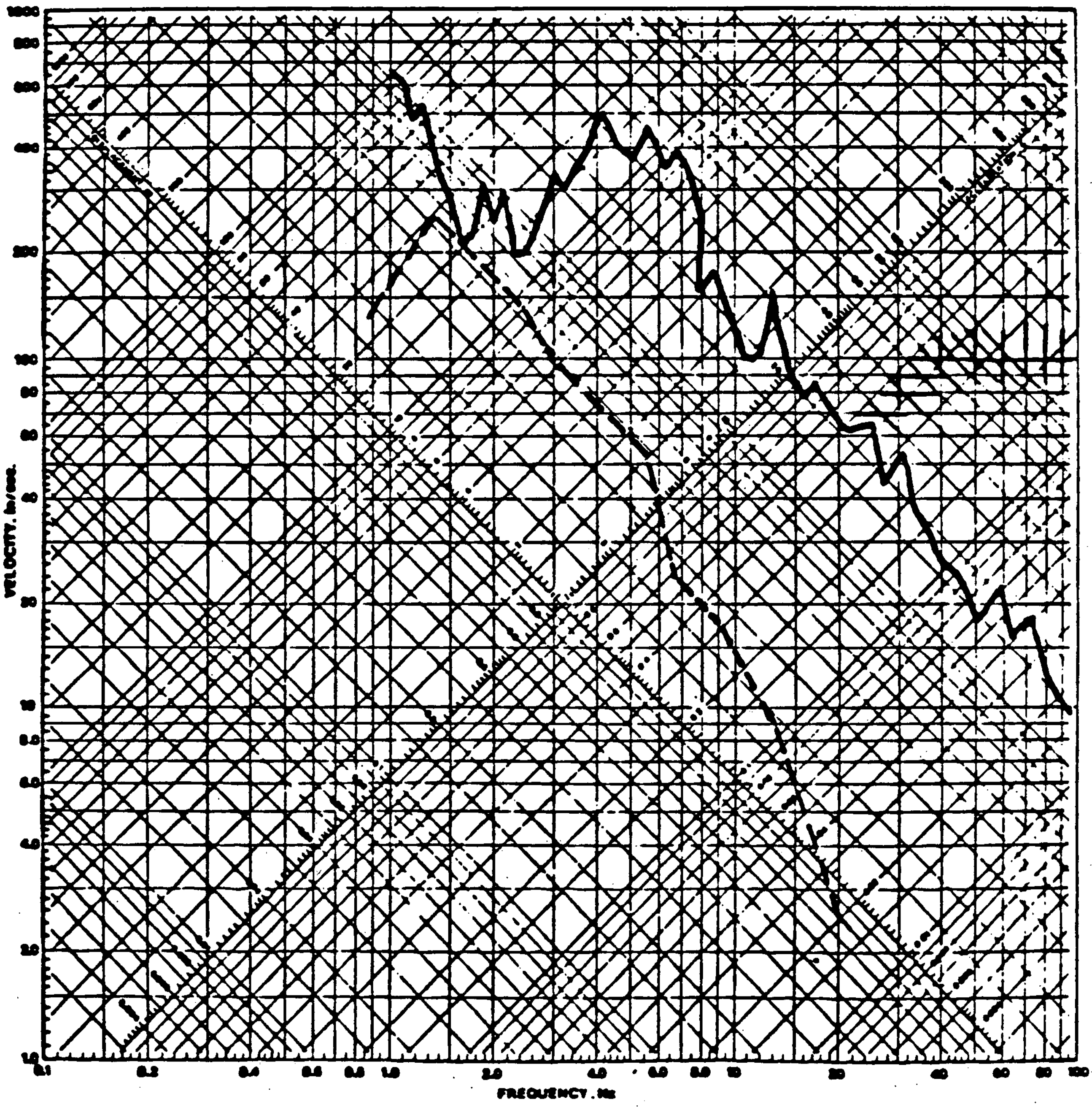


FIGURE 4

ANCO ENGINEERS

Test # 1 **Run #** 5 **Time** 15:20 **Date** 9/22/81 **Recorded by** KB **Page #** ______

Test Specimen: EPRI pipe test specimen 1a

Purpose of Test: attempted 800% of yield test

Direction: ±Z

Comments: Channel 3
Damping = 2%

—— Test Spectra

– – – Spectra to Generate Maximum Acceptable Stress Condition

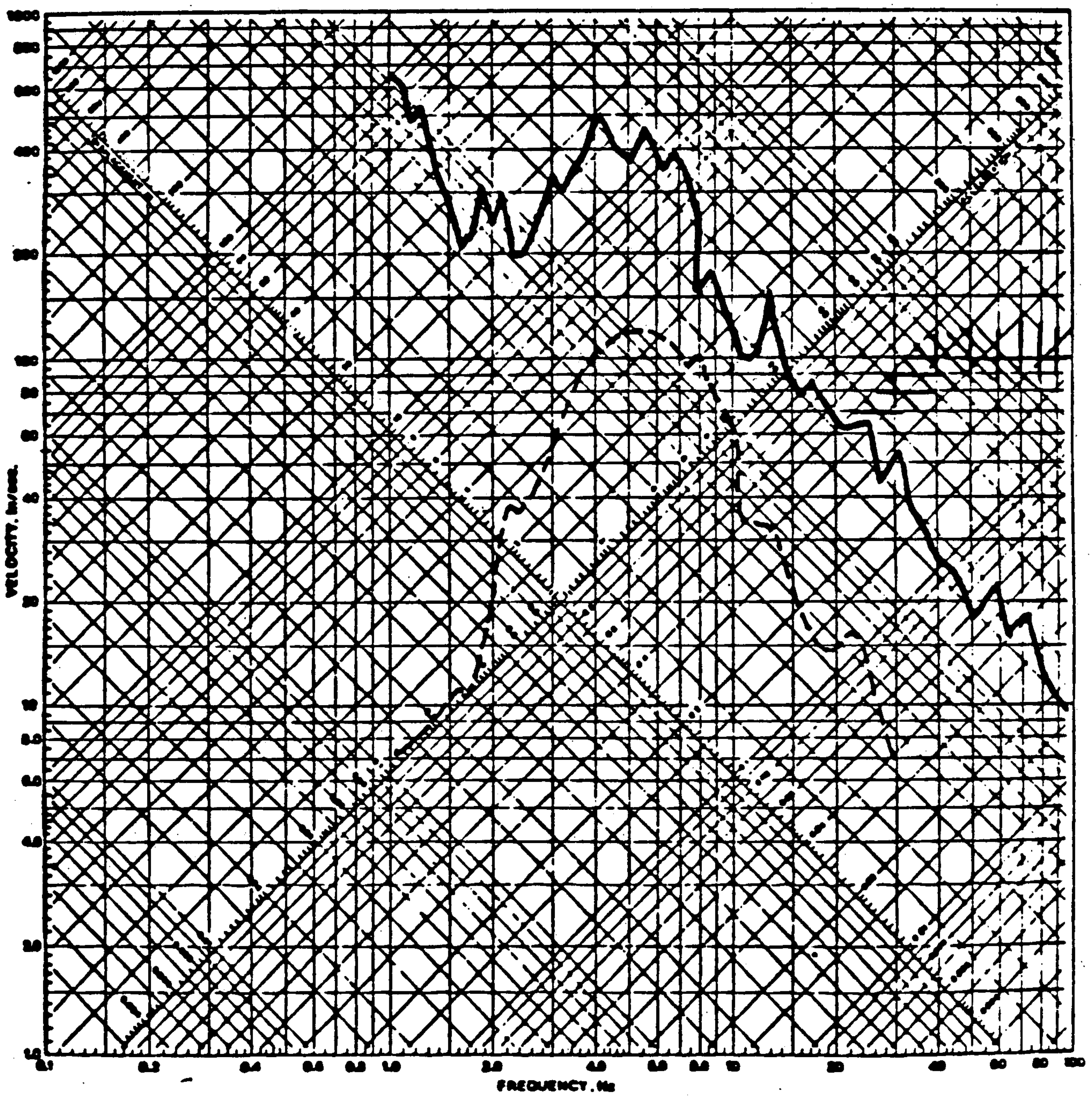


FIGURE 5 T1R5 Spectra Compared to that Which Would Product Maximum Acceptable Stress Condition

Section 5.c: Strain Limits for High Temperature Piping

Code Case N-47 [7] addresses the design and analysis of Class 1 components at elevated temperatures. Elevated temperatures are defined as temperatures exceeding those covered by the rules and stress limits of ASME Subsection NB and the tables in Appendix I. At these high temperatures, creep effects may become significant and the stress criteria are not appropriate. The rules of the Code Case guard against deformation-related failures, such as:

- Creep rupture from long term loadings
- Creep fatigue failure
- Loss of function due to excessive deformation
- Gross distortion due to incremental collapse and racheting.

Appendix T of Code Case N-47, "Rules for Strain, Deformation, and Fatigue Limits at Elevated Temperatures" provides the following strain limits:

1 percent	Averaged through thickness (membrane)
2 percent	Surface strain due to a linearized distribution through the thickness (membrane plus bending)
5 percent	Local strain at any point.

Although the strain criteria in the Code Case were developed for use at elevated temperatures, where stress criteria cannot be applied, the strain criteria can also be applied to the dynamic analysis of components at lower temperatures. In fact, Rodabaugh [5] refers to the Code Case N-47 strain limits in a discussion of Code Stress limits and inelastic analyses, including seismic analyses.

The strain limits presented provide assurance of the structural integrity of the piping and limit gross distortion (which is the phenomenon addressed in the seismic evaluation). The limits presented in the Code Case were developed for inelastic analysis methods, since elevated temperature conditions often result in stresses above the elastic range. Therefore, the strain limits which are developed in the Code Case out of necessity, to address creep and elevated temperature effects are applicable for use in the seismic evaluation for SONGS-1.

The classification of stress intensities, and therefore the classification of strains, is given in Table-3217-2 of Code Case N-47 and Table NB-3217-2 of Section III, Subsection NB. These tables are included on the following pages for information. A review of the tables shows that only internal pressure causes membrane (P_m) stresses and strains. Thus, the 1 percent limit is only applied to the portion of the strain caused by internal pressure. Stresses and strains due to mechanical loads, including gravity and seismic loading, are classified as bending (P_b). Therefore, the 2 percent strain limit for membrane plus bending is applicable to seismic loading.

REFERENCES:

[1] "San Onofre Nuclear Generating Station Unit 1 Functionality Criteria for Piping Systems in Response to the DBE Event," Impell Report No. 04-0310-0063, Revision 1, December 1983.

[2] Greenstreet, W.L., "Experimental Study of Plastic Response of Pipe Elbows," ORNL/NUREG 24, February 1978.

[3] Ishiki, Nishizawa, et. al., "Nonlinear Seismic Analysis and Test," 1979, U.S. - Japan Seminar on HTGR Safety Technology.

[4] Teidoguchi, H., "Experimental Study on Limit Design for Nuclear Power Facilities during Earthquakes," 1975.

[5] Rodabaugh, E.C., "Position Paper on Stress Allowables for Piping," included on NUREG-1061, *Report of the U.S. Nuclear Regulatory Commission Piping Review Committee Evaluation of Other Loads and Load Combinations.*

[6] Imazu, Sahahibara, Nagata and Hashimoto, "Plastic Instability Test of Elbows Under In-Plane and Out-of-Plane Bending" Paper E6/5, Sixth SMIRT Conference, Paris, France, August 1981.

[7] ASME Boiler & Pressure Vessel Code, Case N-47-21, "Class 1 Components in Elevated Temperature Service, Section III, Division I," approved December 11, 1981.

Table –3217-2

Classification of Stress Intensities in Piping, Typical Cases

Piping Component	Locations	Origin of Stresses	Classification[1]	Discontinuities Considered	
				Gross	Local
Pipe or tube, elbows, and reducers. Intersections and branch connections except in the crotch regions	Any, except crotch regions of Intersections	Internal pressure	P_m	No	No
			P_L and Q	Yes	No
			F	Yes	Yes
		Sustained mechanical loads including weight	P_b	No	No
			P_L and Q	Yes	No
			F	Yes	Yes
		Expansion	P_m, P_b and $Q^{1,2}$	Yes	No
			F	Yes	Yes
		Axial thermal gradient	Q^1	Yes	No
			F	Yes	Yes
Intersections, including tees and branch connections	In the crotch region	Internal pressure, sustained mechanical loads and expansion	P_L and Q^3	Yes	No
			F	Yes	Yes
		Axial thermal gradient	Q^1	Yes	No
			F	Yes	Yes
Bolts and flanges	Any	Internal pressure, gasket compression, bolt load	P_m	No	No
			Q	Yes	No
			F	Yes	Yes
		Thermal gradient	Q^1	Yes	No
			F	Yes	Yes
		Expansion	P_m, P_b and $Q^{1,2}$	Yes	No
			F	Yes	Yes
Any	Any	Nonlinear radial thermal gradient	F	Yes	Yes
		Linear radial thermal gradient	Q^1	Yes	No

[1] These classifications may be modified for purposes of certain criteria in Appendix T.
[2] See –3138 and –3213.8.
[3] Analysis is not required when reinforced in accordance with –3643.

Table 1 - Stress Classifications, excerpted from ASME Code Case N-47

TABLE NB-3217-2
CLASSIFICATION OF STRESS INTENSITY IN PIPING, TYPICAL CASES

Piping Component	Locations	Origin of Stress	Classification	Discontinuities Considered	
				Gross	Local
Pipe or tube, elbows, and reducers. Intersections and branch connections except in crotch regions	Any, except crotch regions of intersections	Internal pressure	P_m P_L and Q F	No Yes Yes	No No Yes
		Sustained mechanical loads, including weight	P_b P_L and Q F	No Yes Yes	No No Yes
		Expansion	P_e F	Yes Yes	No Yes
		Axial thermal gradient	Q F	Yes Yes	No Yes
Intersections, including tees and branch connections	In crotch region	Internal pressure, sustained mechanical loads, and expansion	P_L and Q [Note (1)] F	Yes Yes	No Yes
		Axial thermal gradient	Q F	Yes Yes	No Yes
Bolts and flanges	Any	Internal pressure, gasket compression, and bolt load	P_m Q F	No Yes Yes	No No Yes
		Thermal gradient	Q F	Yes Yes	No Yes
		Expansion	P_e F	Yes Yes	No Yes
Any	Any	Nonlinear radial thermal gradient	F	Yes	Yes
		Linear radial thermal gradient	F	Yes	No
		Anchor point motions, including those resulting from earthquake	Q	Yes	No

NOTE:
(1) Analysis is not required when reinforced in accordance with NB-3643.

Table 2 - Stress Classification, excerpted from Subsection NB

Section 5.d: El Centro Steam Plant Earthquake Experience

Earthquake Response of the El Centro Steam Plant during the October 15, 1979 Imperial Valley Earthquake

The El Centro Steam Plant was inspected by an NRC team following the October 15, 1979 Imperial Valley Earthquake [1]. The inspection was of interest to the NRC because the plant is similar to older operating nuclear power plants in both design and types of equipment installed. The NRC team observed only minor damage to the plant's structural and mechanical systems despite the estimated 0.5g peak horizontal ground acceleration produced at the site.

The large magnitude earthquake had its epicenter on the Imperial Fault, approximately 15 miles from the plant. When the earthquake occurred, Units 3 and 4 of the four-unit nonnuclear plant were operating. The operating units tripped off-line when the station's power was lost. Unit 3 was restored to service within 15 minutes after the main shock. Unit 4 was restored to service within 2 hours.

The plant's original design criteria specified a static lateral load equivalent to 20 percent of the dead and live loads. Following the earthquake, the NRC engaged LLNL to analyze Unit 4 [2]. To accurately predict the actual response of the Plant from the earthquake, the LLNL study used realistic assumptions for the analysis, thus eliminating many of the conservatisms that are used in the analysis of nuclear power plants. For example, in the soil-structure interaction analysis, soil damping ratios as high as 100 percent of critical were used. The use of these highly damped soil springs provided a reasonable estimation of the forces induced in the structure as evidenced by the close relationship of the design to predicted base shears. It should be noted that for SONGS-1, the soil damping was limited to a maximum of 20 percent of critical, when in fact, experimental testing supported the use of damping as high as 50 percent of critical. It is reasonable to conclude that as a result of limiting the soil damping alone, we are severely overestimating the response of SONGS-1 structures, piping and equipment.

The LLNL study concluded that the forces experienced by the plant equipment were on the order of 2 to 9 times greater than the 0.2g specified design load. The reserve seismic capacity in the plant equipment is then at least of the order of 200 percent. Note that because of the highly damped soil properties used in the SSI analysis, the forces calculated from analysis represent a low estimate, if compared with the forces that would be obtained using more conservative assumptions, as was done for SONGS-1. The reserve margin would be even greater if analysis techniques such as used for SONGS-1 were used.

The above conclusion was confirmed by observations of the actual response of piping systems at the plant. Post-earthquake inspection indicated that no high-temperature or high-pressure piping failed during the earthquake. Piping failures were observed only in two lines, at locations that had been either weld-repaired or had been excessively corroded.

We can conclude that operating nuclear power plant structures, equipment and piping, such as those in SONGS-1, have considerable seismic reserve margins capable of sustaining an earthquake which far exceeds its nominal design capacity.

REFERENCES:

[1] Levin H.A., Martore J.A., Reiter L., Jeng D., Heller L.W., "Reconnaissance Reports - Imperial Valley Earthquake, October 15, 1979," U. S. Nuclear Regulatory Commission, Washington D. C., Memorandum for Darrel G. Eisenhut (November 2, 1979).

[2] NUREG/CR-1665 "Equipment Response at the El Centro Steam Plant during the October 15, 1979 Imperial Valley Earthquake," prepared by LLNL for the Office of Nuclear Reactor Regulation, October 1980.

Section 5.e: A comparison of LTS and SEP methods for piping analysis.

RESPONSE:

Item	LTS	SEP
- Code Eqn. 9 (Level D) Allowable	$2.0S_y$	$-2.4S_h$ for Class 2/3 $-1.8S_m$ for Class 1 (or 3Sm using Class 1 rules)
- Envelope Response Spectra Method		
o Mode Combination	R.G. 1.92 or CQC	R.G. 1.92
o Damping	Code Case N411	R.G. 1.61
o Peak Shifting	R.G. 122 or Appendix N-1226.3	R.G. 122
- More accurate Methods Include MLRS, Time History and nonlinear analysis	May use.	Not specified.

Section 5.f: A list of piping materials with allowable stresses at maximum operating temperatures.

Material	Max. Operating Temp. (°F)	2.4 S_h (ksi)	Winter 1980 Code $2S_y$ (ksi)	$2.4S_h/2S_y$
A312 TP304L	200	37.68	42.60	.88
A312 TP304	575	38.16	37.00	1.03
SA312 TP316	570	41.52	38.26	1.08
A106 B	545	36.00	54.44	.66
A53 B	340	36.00	61.20	.59

The apparent anomaly occurring in the table above, in which 2.0 S_y is actually less than 2.4 S_h for two materials, is easily explained by considering the basis of the allowable stress S_h. As defined in Appendix III, Article III-3000 of the ASME Code, S_h is defined as the lowest of:

Carbon Steel
1) 1/4 S_u minimum (ambient temp.)
2) 1/4 S_u (operating temp.)
3) 2/3 S_y minimum (ambient temp.)
4) 2/3 S_y (operating temp.)

Stainless Steel
1) 1/4 S_u minimum (ambient temp.)
2) 1/4 S_u (operating temp.)
3) 2/3 S_y minimum (ambient temp.)
4) 0.9 S_y (operating temp.)

For SA 312 TP304 and SA 312 TP316, S_h is controlled by 1/4 S_u at operating temperature and 0.9 S_y, at operating temperature, respectively. In these cases, 2.4 S_h is actually higher than 2.0 S_y as shown below:

For A312 TP304:
S_h = 1/4 S_u @ 575°F = 1/4 (63.5) = 15.88 ksi
(Code uses 15.9 ksi)
2.4 S_h = 2.4 x 15.9 = 38.16 ksi
S_y @ 575°F = 18.5 ksi
2 S_y = 2 x 18.5 = 37 ksi

For SA312 TP316
S_y @ 570°F = 19.13 ksi
S_h = 0.9 S_y @ 570°F = 0.9 x 19.13 = 17.22 ksi
(Code uses 17.3 ksi)
2.4 S_n = 2.4 x 17.3 = 41.52 ksi
2 S_y = 2 x 19.13 = 38.26 ksi

ACTION ITEM 6: There are several versions of the Complete Quadratic Combination (CQC) method. Which version will be used for the LTS?

RESPONSE:

Impell Corporation proposes to use the CQC methodology developed by professor A. Der Kiureghian at the University of California, Berkeley. Details of this methodology for combination of modal responses can be found in the References 1, 2 and 3.

The effect of the high frequency modes will be taken into account by using the missing mass correction (4). In that way, all the modes beyond the frequency "cut off" will be concentrated in one fictitious mode. This mode and the modes with frequency below the frequency "cut off" will be combined using the CQC rule.

(1) Der Kiureghian, A., "On Response of Structures to Stationary Excitation," Report No. UCB/EERC-79/32, Earthquake Engineering Research Center, University of California, Berkeley, California, 1979.

(2) Der Kiureghian, A., "A Response Spectrum Method for Random Vibrations," Report No. UCB/EERC-80-15, Earthquake Engineering Research Center, University of California, Berkeley, California, 1980.

(3) Wilson, E.L., Der Kiureghian, A., and Bayo, E.P., "A Replacement for the SRSS Method in Seismic Analysis," Earthquake Engineering Structural Dynamics, Vol. 9, pp. 187-194, 1981.

(4) Powell, G.H., "Missing Mass Correction in Modal Analysis of Piping Systems," Transitions of the 5th International Conference on SMIRT, Vol. K(b), paper K 10/3, 1979.

ACTION ITEM 7: Provide a report summarizing the small bore piping criteria. The report should address the methods used to select the worst case configurations and should identify the number of confirmatory analyses.

RESPONSE:

SCE will submit a small-bore piping verification report to the NRC by April 15, 1985.

ACTION ITEM 8: Provide the LTS criteria for buckling of support and structural steel.

RESPONSE:

Buckling evaluations will be performed using the criteria in the ASME Code for Service Level D conditions as stated in Reference 1. No increase in material strength allowables will be used for buckling evaluations.

REFERENCES:

[1] "SONGS-1 Seismic Program for LTS," Impell Report No. 01-0310-1318, Revision 0, February 1985.

ACTION ITEM 9: Provide a detailed justification for the 10 percent strength increase for strain rate effects.

RESPONSE:

The strain response of ductile materials depends upon the loading rate. Review of literature shows that extensive data on the influence of rate of strain on the yield strength of mild steel is available [1, 2, 3]. The yield stress versus strain rate curves from these references show that there is a significant increase in yield strength with increased strain rates.

For pipe supports and supporting structural steel members, the seismic loading is a result of the pipe's excitation. Piping fundamental frequencies are usually in the range of 2-10 Hz. A typical pipe support reaction time history is shown in Figure 1. This shows the predominant response at about 6 Hz and a higher mode response superimposed at about 12 Hz. This figure demonstrates that the load rate (proportional to strain rate) is significant even at high load levels. A sample calculation is given below for this support's reaction time history to estimate the strain rate.

Minimum frequency of load = f_1 = 6 Hz

Young's Modulus E = 30×10^3 ksi

Static (Measured) Yield Strength = 30 ksi (mild steel - Reference 1)

Maximum stress in critical member = $_1$ = 30 ksi (assumed near yield)

Time required for the stress in member to increase

from 0 to $_1$: $T = \frac{1}{4f_1} = 0.042$ sec.

$$\text{Therefore, the Strain Rate} = \frac{}{T} = \frac{}{E\ T} = \frac{30\text{ ksi}}{30 \times 10^3 \times 0.042} = 2.4 \times 10^{-2}\ \text{in/in/sec.}$$

Figure 2 shows the effect of strain rate on yield strength of mild steel [1]. The strain rate obtained for the sample calculation is significant. At this strain rate, the increase in yield strength over the static yield strength is about 16 percent.

This analysis demonstrates that for typical piping system frequencies, the increase in yield strength as a result of strain rate effects is greater than 10 percent.

It should be noted that the 10 percent increase in yield strength for strain rate effects will be used on a case-by-case basis only for existing pipe supports, equipment supports, and structural steel members.

REFERENCES:

[1] Manjoine, M.J., "Influence of Rate of Strain and Temperature on Yield Stresses of Mile Steel," J. of Applied Mechanics, Volume 11. ASME Trans., Volume 66, pages A211-A218, 1944.

[2] Timoshenko, S., Strength of Materials, Part II, Third Edition, Van Nostrand, Princeton, New Jersey, 1956.

[3] Beedle, L.S., and Tall, L., "Basic Column Strength," Proceedings of ASCE, Volume 86 (ST-7), July 1960.

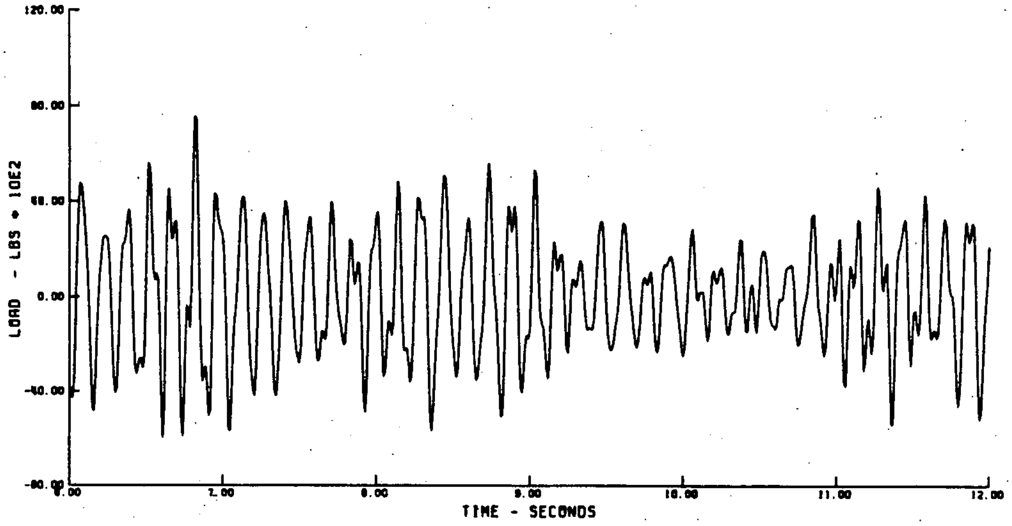


Figure 1 - Typical Support Reaction Time History

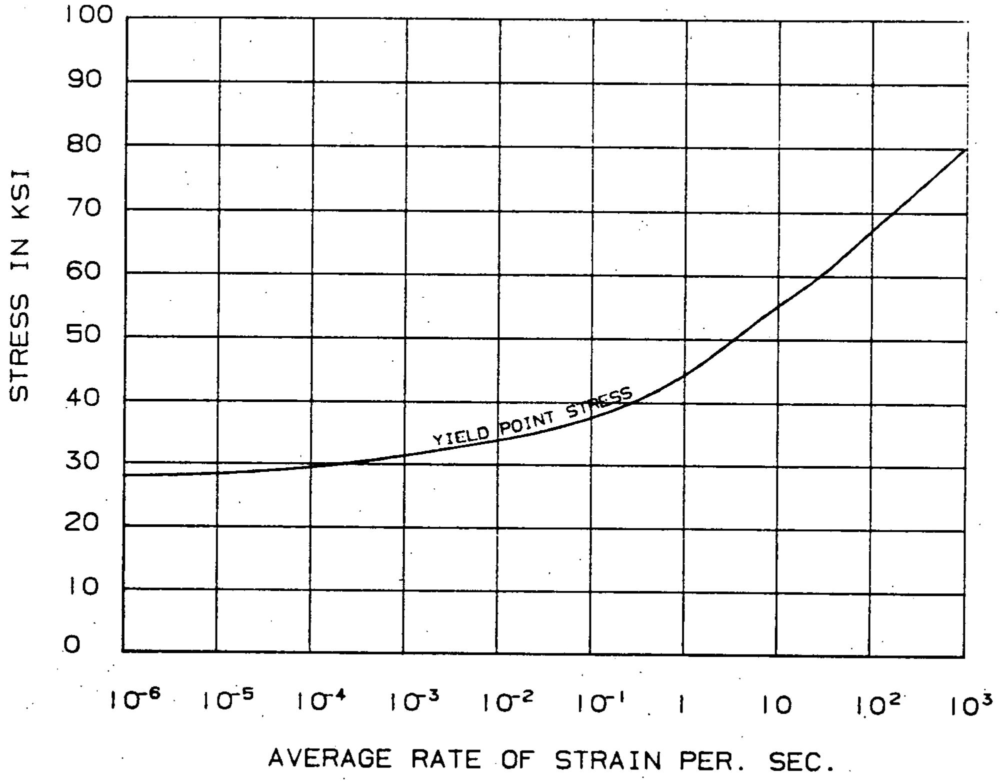


Figure 2 - Relationship Between Material Yield and Strain Rate for Mild Steel (Reference 1)

ACTION ITEM 10: Provide information on the 18 percent overstrength factor for structural steel. The presentation should include information on the statistical variation in the test samples.

RESPONSE:

Steel strength test data for the A36 structural steel used for all major structures at the V. C. Summer Nuclear Station, Unit 1 is available in Reference [1]. In summary, the average yield strength of the A36 structural steel for the plant was demonstrated to be 21 percent higher than the minimum specified yield strength. The coeffecient of variation on the samples was very low (0.09).

ASTM specifications for structural and reinforcing steels require that the specified yield value represents a 3-sigma lower bound from test results [2]. The effect of this requirement is illustrated in Figure 1, which shows a probability distribution for yield strength of A-7 (similar to A-36) structural steel taken from a large sample of mill tests. The average yield strength is about 21 percent greater than the specified minimum value.

In a report by Smith, et. al. [3], it is reported that the measured yield strength of over 60,000 specimens of mild steel was found to be, on the average, 18 percent greater than the ASME Code reported minimum yield strength.

It should be noted that the 18 percent increase in yield strength for material overstrength will only be used on a case-by-case basis for existing pipe and equipment supports. This factor was used very sparingly on the Return to Service pipe support qualification effort (on less than 7 percent of the supports evaluated).

There was no indication, in any of the test data reviewed, that age degrades material strength for mild steel.

REFERENCES:

[1] Applicant's Additional Testimony to the ASLB, South Carolina Electric and Gas Company, Docket No. 50/395 OL, December 18, 1981.

[2] "Structural Analysis and Design of Nuclear Plant Facilities," ASCE Manual on Engineering Practice, No. 58, 1980.

[3] Smith, P. D., Maslenikov, O.R., and Bumpus, S.E., "LLL/DOR Seismic Conservatism Program: Investigations in the Seismic Design of Nuclear Power Plants," UCRL-52716 (draft).

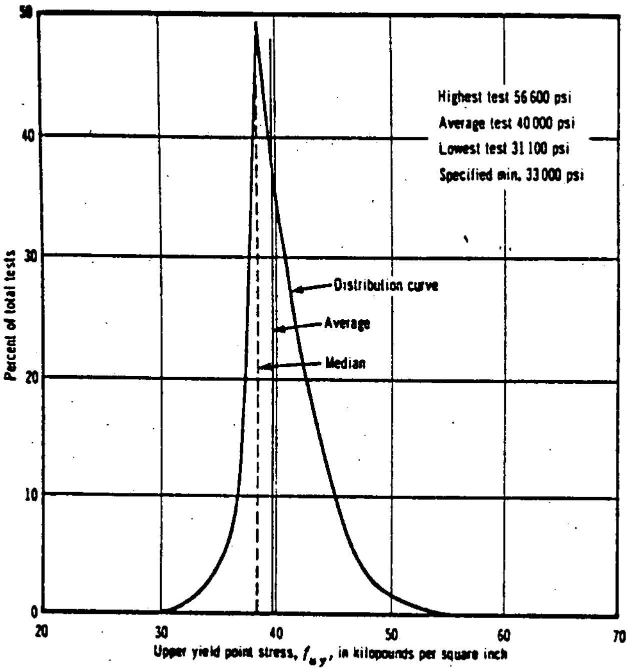


Figure 1 - Yield Strength Distribution for A-7 Steel
(Reference 4)

ACTION ITEM 11: Provide information on the factors of safety used with anchor bolts. Provide justification for any factors of safety less than 4.0.

RESPONSE:

In general, the allowable loads for concrete expansion anchor bolts will be obtained by using the manufacturer's reported ultimate capacity with a minimum factor of safety (FS) equal to 4.0 or 5.0 for wedge or shell type anchors respectively. On a case-by-case basis, a FS less than 4.0 or 5.0 will be used to qualify existing supports. However, a FS less than 4.0 or 5.0 will only be used if:

1. The adjacent supports, carrying load in the same direction, are qualified elastically, with a FS = 4.0 or 5.0 (if they have expansion anchors), and
2. If there are a minimum of four anchor bolts in the same base-plate for the support in question, not more than 50 percent of the bolts are subjected simultaneously to tensile loads. In no case will an FS less than 2.0 be used.

Available test data on concrete expansion anchor bolts [1] indicate that the distribution of data is reasonably close to Gaussian (or normal) distribution with a coefficient of variation of about 0.27. Since an FS less than 4.0 or 5.0 will only be used if the two constraints specified above are met, this will preclude any potential for a "zippering" effect on supports.

It should be noted that for the Return to Service support qualification effort, a factor of safety less than 4.0 or 5.0 was used very sparingly (on less than 5 percent of the supports evaluated).

REFERENCE:

[1] "Realistic Seismic Design Margins of Pumps, Valves and Piping," NUREG/CR-2137, prepared by Battelle Labs/ORNL for the NRC, June 1981.

ACTION ITEM 12: Define "Ultimate Uniform Strain". Explain and justify its application to the LTS effort.

RESPONSE:

Ultimate uniform strain (Euu) for steel is defined as that strain equal to one-half the ultimate strain (Eu) [2]. Ultimate strain is defined by the appropriate ASTM standard for the material under review.

One-half of ultimate uniform strain (1/2 Euu) is an upper bound limit to be used in the nonlinear evaluations of mild steel members. This criteria will only be applied for secondary steel members under tension [1].

One-half ultimate uniform strain is considered more conservative than the standard practice of limiting axial ductility to ratio of 0.5 Eu/Ey criteria [3] since the one-half ultimate uniform strain limit equates to a 5 percent strain for A-36 steel, and the ductility ratio of 0.5 Eu/Ey equates to a strain limit of 10 percent.

REFERENCES:

[1] Standard Review Plan, Section 3.6.2, U. S. Nuclear Regulatory Commission, NUREG-0800, Revision 1, July 1981.

[2] Babcock & Wilcox, "Effects of Asymetric LOCA Loadings," Phase II Analysis, B&W 177-FA Owners Group, BAW-1621, July 1980, Lynchberg, VA.

[3] ASCE, Structural Analysis and Design of Nuclear Plant Facilities, Manuals and Reports on Engineering Practice No. 58, New York, NY, 1980.

ACTION ITEM 13: Determine if the support anaylsis methods to be used for LTS will vary from the SEP guidelines. Justify any variances.

RESPONSE:

See our response to Action Item 3.

ACTION ITEM 14b: Provide additional information for the valve qualification.
Provide the LTS criteria position on valve stem analysis.

RESPONSE:

The active valve stress criteria is established such that the stresses in the extended structure will be below the material yield point. This ensures that all deformations are elastic and no plastic deformations will occur during or after the postulated 0.67g Modified Housner Ground Motion.

The Level C limits of the ASME Code, Subsection NF, are selected for evaluating the non-pressure retaining parts of the extended structures. These limits were selected because, as shown below, the allowable stresses are below the yield point:

$$F_b = 1.50\ (.66\ S_y) \quad \text{(Compact Sections)}$$
$$= .99\ S_y$$

$$F_t = 1.50\ (.60\ S_y)$$
$$= .90\ S_y$$

Under seismic loading, the stresses in the yoke legs of a valve are much greater than the stresses in the valve stem. The moment of inertia of the yoke legs is generally much greater than the moment of inertia of the valve stem. In addition, the yoke legs are rigidly attached to the valve operator and to the bonnet, while the stem is supported by the relatively flexible valve packing and operator bearings. Because of their much greater stiffness, the yoke legs carry the majority of the seismic loading, and the stresses in the yoke are correspondingly high. The load carried by the stem is low compared to the load supported by the yoke legs. Also, because of the difference in end conditions, a displacement which causes stresses near the yield point in the yoke legs will cause much lower stresses in the stem. In fact, because the contribution of the stem to the valves seismic capacity is so low, in many cases the stem can be neglected and the capacity can be conservatively based only on the yoke legs. When stresses in the stem are calculated, seismic inertia and operational thrust loads will be considered. As stated above, stresses will be maintained below the material yield point.

Additional conservatism is obtained by using Code minimum yield strength values. No credit is taken for material overstrength or strain rate effects.

Provide additional information for the valve qualification.

ACTION ITEM 14c: Provide the existing valve body integrity analysis.

ACTION ITEM 14d: Explain why piping end loads are not listed in the design loads for valves in Section 3.6.1 of the LTS criteria and methodology report (Impell Report No. 01-0310-1368, Rev. 0, dated 2/1/85).

RESPONSE:

The design loads in Section 3.6.1 of the Impell report (Report No. 01-0310-1368) are gravity, operational, and seismic inertia. These loads are applied to the extended structure of the valve. The operational load includes the stem thrust due to opening or closing the valve and, in pressure retaining parts, the internal pressure load. The inertia load is found by factoring the weight of the extended structure by the maximum accelerations at the center of gravity of the extended structure. The accelerations are determined during the piping analysis. Qualification is then determined by comparing the stresses resulting from the design load to the criteria established in the report (see response to item 14b).

The stress in valve bodies is addressed in a generic analysis comparing stresses in the valve bodies to stresses in the attached piping. The piping stresses include the effects of piping loads (gravity, pressure, seismic inertia, etc.), as well as the loads caused by excitation of the valves extended structure, including the valve operator.

The discussion on the three following pages compares stresses in valve bodies to stress in the connected piping, including the appropriate concentration factors. The comparisons are based on the ratio of the section modulus of the valve body to the section modulus of the piping. The geometry of the valve bodies is based on data obtained from an Impell study of valve body/piping interfaces performed for Class 1 analyses at other nuclear power plants. The comparison shows that all valve body stresses are below yield.

VALVE BODY STRESSES

The piping in the Return to Service (RTS) Scope at SONGS-1 was evaluated using equation (9) of NC-3652 [1]. The piping evaluations considered pressure, deadweight, and seismic inertia loads. The effects of valves on the piping system was addressed by including the valve body in the piping model. A lumped mass is included at the CG of the valve extended structure. The primary stresses in the piping, including the effects of the stress intensificaiton factors of Figure NC-3673.2 (b)-1 [1], were limited to $2.0S_y$.

Seismic qualification of valves is performed in two parts; evaluation of pressure retaining components and evaluation of non-pressure retaining parts.

Non-pressure retaining components, such as yoke legs and yoke to bonnet bolting are evaluated as linear type supports using Subsection NF or Appendix XVII of [1]. Passive valves are not required to operate during (or after) the DBE, therefore, gross structural deformations in the extended structure are acceptable.

The pressure retaining parts of the valve, including the body and bonnet, are evaluated according to the rules of NC/ND-3500 of [1]. These rules require that the valve body be stronger than the attached piping (NC-3521(a) of [1]). The weakest section of the valve body is at the welded joint to the pipe. At this section the valve body thickness is reduced to match the thickness of the attached piping. In the RTS piping evaluations the valve to pipe welded joints were qualified to the functionality limits. This demonstrates the pressure integrity of all the valve bodies in the RTS Scope.

In addition to demonstrating pressure integrity, the BOPMEP criteria for SONGS-1 require that stresses in the bodies be limited to yield for active valves and to Level D limits for passive (inactives) valves ([3], Table 3).

The following paragraphs discuss the evaluation of stresses in the bodies of the valves in the RTS Scope at SONGS-1. In each case the primary stress at the pipe/valve interface is conservatively assumed to be $2.0S_y$. Valves are connected to the piping systems using butt welds, flanges, or socket welds. These three connections are described below:

1. Socket Welds - For the small valves, including solenoid valves, a stress intensification factor of 2.1 is applied to socket welded joints. In addition, a comparison of the section modulus of standard 3000# socket weld fittings [2] with the section modulus of standard weight piping shows that the couplings have a moment capacity from 4.8 (for 1/2") to 3.1 (for 2") greater than the piping. Consideration of these two factors gives the maximum primary stress in the valve body:

$$S_{Valve} = \frac{2.0S_y}{(.75\text{x}2.1)(3.1)} = .41S_y$$

   Review of the stress qualification concluded that with this magnitude it reserves sufficient margins for the secondary stresses (thermal and SAM) and the total stress in the valve body is less than yield.

2. Flanged Ends - Relief valves are commonly constructed such that the limiting secion is the flanged ends. The valves in the RTS scope with flanged ends were qualified by evaluating the loads in the flanged connections using the rules of NC-3658. All connections were qualified to Level A or B service limits for all loading. This demonstrates that the stresses in the valve body are below yield, since the level A and B stress limits are approximately equal to the yield stress.

3. Butt Welded Ends - Control and motor operated valves greater than 2" NPS generally used butt welding ends. Butt welds are generally included in the piping model as as-welded butt welds using stress intensification factor of 1.8 or as tapered transitions using stress intensification factors of 1.5 to 1.9.

   A detailed review of 7 valve/pipe interfaces in 3 plants was performed in [4]. The sizes ranges from 2" NPS to 6" NPS. The data from [4] is summarized in Table 1. This data shows that the ratio of valve section modulus to pipe section modulus ranges from 4.18 to 7.36. Consideration of the stress intensificaton factors and the difference in section moduli reduces the stress of $2.0S_y$ to:

   $$S_V = \frac{2.0S_y}{(.75x1.5)(4.18)} = .43S_y$$

   Again, this reserves enough margins for the secondary stresses. Hence the total stress in the valve body is less than yield.

Conclusion:

Stress in valve bodies have been calculated based on pipe end loads (for flanged valves) or by assuming a primary stress of $2.0S_y$ in the attached piping. In all cases the basic stress in the valve body was found to be less than S_y. Therefore, the stresses in all valve bodies satisfy the requirements of the BOPMEP criteria for the RTS scope.

REFERENCES

1. ASME Boiler and Pressure Vessel Code, Section III, Subsection WC, 1983 Edition.

2. "Forged Steel Fittings, Socket-Welding and Threaded," AWSI Standard B16.11-1973, ASME, New York.

3. "Balance of Plant Mechanical Equipment and Piping Seismic Reevaluation Criteria (BOPMEP Criteria)," San Onofre Nuclear Generating Station Unit 1, dated May 20, 1983, Bechtel Power Corp. Job No. 14000-300/339.

4. "A Review of the 1-D and 2-D Thermal Transient Analysis of Piping Components," EDS Nuclear Report No. 01-9602-1113, July 2, 1981.

TABLE 1

Case	MPS	t_{pipe}	t_{valve}	Z_v/Z_p (Note 1)
1	2"	.343	.922	4.18
2	2"	.343	.922	4.18
3	3"	.438	1.390	5.08
4	3"	.438	1.688	7.10
5	3"	.438	1.688	7.10
6	4"	.531	2.00	6.53
7	6"	.718	3.00	7.36

Note 1: $$\frac{Z_v}{Z_p} = \frac{(Do^4 - Di^4)\ do}{(do^4 - di^4)\ Do}$$

Where: Do and Di are OD and ID for valve.
do and di are OD and ID for pipe.

ACTION ITEM 15: Provide an explanation of the energy balance method. Include examples of its use in other types of analysis (such as waterhammer).

RESPONSE:

A) A brief description of the energy balance method is provided in the attached paper entitled "Energy Balance Method."

B) Similar types of analyses using energy balance methods for loss of pipe support capacity involve hydrodynamic events such as waterhammer. These types of analyses have been performed and approved on the following plants and pipelines.

Hydrodynamic Events

Client	Description	Date
CECo	Dresden 3 Reactor Water Cleanup Waterhammer	1980
CECo	Dresden 2 HPCI Turbine Steam Supply Hydrodynamic Loads due to Insufficient Drainage	1981
CECo	Dresden 2 Containment Cooling Service Water Drain Down and Check Valve Slamming	1981
CECo	Dresden 2 Main Steam Hydrodynamic Loads Related to Reactor Flooding	1984

ENERGY BALANCE METHOD

The energy approach compares the earthquake kinetic energy input to the piping system, versus the strain (potential) energy capacity of the piping. If the earthquake energy input exceeds the strain energy capacity, the system will fail. However, if the piping system is capable of absorbing more energy than is provided by the earthquake phenomena, failure does not occur and the piping system remains functional. The strain energy capacity of a piping system is a direct function of maximum response displacement. By accounting for the pipe's actual plastic deformation, it can be shown that piping systems are capable of absorbing a significant amount of input energy before any failure mechanism can occur.

The energy approach concept is described below for a single-degree-of-freedom (SDOF) system. This procedure is then extended for multiple-degree-of-freedom (MDOF) systems. Consider a SDOF system of mass M and stiffness K. The maximum kinetic energy input to the system can be conservatively estimated from the maximum response of the system. The maximum kinetic energy input is given by:

$$KE = \frac{1}{2} M\dot{U}^2$$

where $\dot{U}$ = maximum response velocity

For the same system, the maximum strain energy capacity is given by:

$$PE = \frac{1}{2} KU^2$$

where U = maximum response displacement.

By equating the maximum kinetic energy input to the strain energy of the system, the maximum response displacement U can be estimated as

$$U = \frac{\dot{U}}{\omega}$$

where ω is the system's natural frequency in radians per seconds.

If U is less than some measured displacement capacity, then the SDOF system is capable of absorbing the maximum energy input. Using the same analogy for piping systems (MDOF), an evaluation is performed where the energy input to the piping is equated to the pipe strain energy. The maximum strain in the system is then computed for the maximum deformation state defined by the absorption of the kinetic energy. The maximum strain, including elastic and plastic strains, is compared to the limiting allowable strains. If the calculated strains are below the allowables, the piping remains functional.

The maximum kinetic energy, which is the maximum earthquake energy input to the system, is computed by integrating the maximum pipe velocity over the length of pipe:

$$KE = \frac{1}{2} \int_0^L M\dot{U}^2 \, dL$$

when M = mass per unit length of pipe.

It should be noted that the maximum velocity can be determined in several ways: direct time integration, Fourier Transform, or response spectrum analysis. If the maximum velocity is conservatively computed, the upper bound of the maximum energy input is obtained, regardless of the method of analysis. For large bore piping, the more conservative response spectra approach is used to compute the maximum velocity for computing the maximum energy input. This conservatism simplifies the peak response analyses, since the floor spectra are readily available for all elevations. Additional conservatism is introduced by using the elastic response spectra with damping values corresponding to elastic systems, thereby overpredicting the piping maximum velocity. In this case, the computed kinetic energy is a conservative bound on the earthquake energy input to the piping system. As a conservative approach, the computation of the maximum velocity and the pipe frequency assume a pin-ended beam to maximize the estimation of the input kinetic energy.

ENERGY BALANCE METHOD

The pipe strain (potential) energy is computed by integrating the strain energy per unit volume over the entire volume of the pipe material:

$$PE = \int \sigma \epsilon \quad dv$$

where σ = stress per unit volume

ϵ = strain per unit volume

The maximum strain energy capacity of the piping system is the amount of energy required to cause plastic hinges along the pipe span to form a mechanism. Failure occurs if the computed kinetic energy exceeds this maximum capacity. However, if the earthquake kinetic energy input is less than the maximum strain energy capacity, then maximum resulting strain is computed by equating the two energies. This strain value is then compared to the allowable limits to determine whether the pipe functionality is maintained. As a conservative approach, a fixed-ended beam is used to model the piping system (as compared to a pin-ended beam). This is due to the fact that a fixed-ended model goes through less deformation than a pin-ended model before reaching a limiting strain allowable, when both are subjected to the same amount of input kinetic energy; therefore, less potential (strain) energy gets absorbed in a fixed-ended model.

In summary, assumptions in the evaluation procedure are made to maximize the estimation of the input earthquake energy and to predict the minimum strain energy capacity of the piping system. The energy balance method is used to evaluate pipe functionality in cases where isolated supports are found to be overstressed.

ACTION ITEM 16: Provide a sample calculation to show the application of the energy balance method and load redistribution from a failed pipe support.

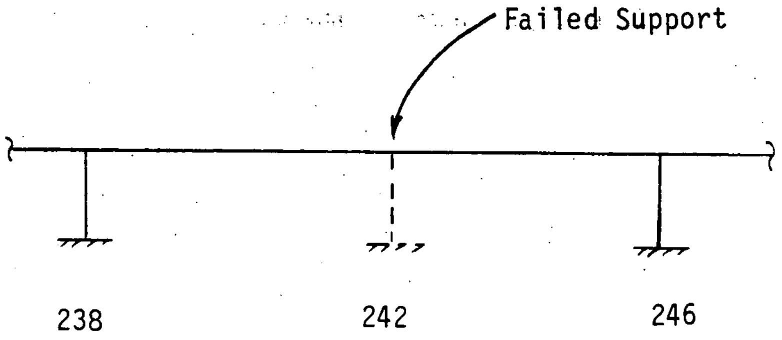
RESPONSE:

Attachment 1 is a typical example problem of the energy balance method, and the redistribution of loads from a failed support to it's adjacent supports for a SONGS-1 Piping system (Problem FW-07).

ATTACHMENT 1 - EXAMPLE CALCULATION

PROBLEM

A rigid Y support at data point 242 fails. Show pipe functionality without this support. In addition, evaluate increased support loads on adjacent Y supports.



Properties:

2" diameter (Schedule 80) pipe
E = 27.0 x 10^3 ksi
Sy = 27.2 ksi

Evaluation of Pipe Functionality

Applying the energy balance method, evaluation is performed in the following steps:

1. Evaluate a lower-bound conservative frequency for the span without the failed support.

$$f = \frac{\pi}{2L^2}\sqrt{\frac{EI}{m}} = 12.4 \text{ Hz.}$$

2. Determine kinetic energy (KE), input into the system. This is maximized by assuming a simply-supported beam model. Then a uniform load (w_1) related to this energy is determined.

$$KE = \frac{1}{2} MU^2$$

$$w_1 = 4.7 \text{ lb/in}$$

3. Evaluate the strain energy capacity (SE) of the pipe. This is minimized by assuming a fixed-ended beam model. Then a maximum uniform load (w_{1max}) related to this energy is determined.

$$SE = \frac{1}{2} KU^2$$

$$w_{1max} = 28 \text{ lb/in}$$

4. Since $w_1 < w_{1max}$ (KE < PE), an equivalent load to absorb all kinetic energy is

$$w_{eq} = w_1 = 4.7 \text{ lb/in}$$

5. Evaluate an upper-bound rotation in pipe by assuming a simply-supported beam model.

$$= \frac{w_{eq} L^3}{24 EI} = 0.012 \text{ rad.}$$

6. Using ϵ-θ curves for elbows, evaluate the maximum strain (ϵ) in the pipe.

$$\epsilon = 0.14\% < 1\% \quad \text{(allowable for carbon steel)}$$

Failure (or deletion) of Support #SI-01-0342-H342 would not impair the functionality of the piping system.

Load Redistribution to Adjacent Supports

1. Evaluate increased gravity and seismic loads on adjacent supports at data points 238 and 246. To evaluate the new seismic load, estimate the revised piping frequency without the support at data point 242. Using this frequency, estimate the seismic spectral acceleration from the floor spectra and evaluate the new seismic load.

At data point 238, $F_{seismic} + F_{gravity} = 429$ lb.

At data point 246, $F_{seismic} + F_{gravity} = 304$ lb.

2. Since a support at data point 242 is deleted, thermal and SAM loads will remain the same or decrease. Conservatively, the same loads are used.

   At data point 238, $F_{SAM} = 0$ lb.

   $F_{thermal} = -95$ lb.

   At data point 246, $F_{SAM} = 3$ lb.

   $F_{thermal} = 5$ lb.

3. Combine loads to obtain total load

   $F_{total} = F_{seismic} + F_{gravity} + F_{thermal} + F_{SAM}$

   At data point 238, $F_{total} = 429/-524$ lb.

   At data point 246, $F_{total} = 312/-304$ lb.

ACTION ITEM 17: Provide reasons for using the Summer 1983 Code Addenda for structural steel strength.

RESPONSE:

The use of the ASME S'83 Addenda is preferred because the S'83 Addenda provides more detailed guidelines for the determination of Level D allowable stresses than previous editions of the Code. In addition, the S'83 Addenda provides guidelines for the combination of stresses which were not provided in earlier editions. The actual allowable stresses determined using the S'83 and previous editions of the Code are not significantly different. Any differences in the S'83 and previous Codes are discussed in the following paragraphs. Examples of the stress allowables using the two codes are presented for comparison.

The allowable stresses for components (including structural members) subjected to Level D loads are addressed in Appendix F of the Code. For the S'83 Addenda, Appendix F was revised in its entirety. Prior to the S'83 Addenda, Level D loads for component supports were addressed in F-1370. This subarticle established factors to be used for development of Level D allowable stresses based on the Level A allowable stresses presented in Appendix XVII of the Code. These factors, which are listed in Table 1A, were intended to be used for tensile, bending, and shear stresses. Appendix F did not provide allowable stresses for structural bolts or provide interaction requirements.

The S'83 Addenda provides an expanded discussion of the Level D criteria for linear type supports in paragraph F-1334. This paragraph provides general factors similar to those in earlier codes for calculating Level D allowables from Level A allowables. It also provides specific relationships for calculating allowables for shear, tensile, and bending stresses. The S'83 version of Appendix F provides specific guidelines for calculating Level D allowables for structural bolts and for interaction of tension and bending stresses, as well as compressive and bending stresses.

The relationships used to calculate allowable stresses before and after the S'83 Addenda are listed in Table 2. This table shows that the allowable stresses of the S'83 Addenda are equal to, or more restrictive than, earlier editions of the Code. Table 3 lists the yield stresses for SA-36 structural steel at various temperatures. These values have not changed since they were first published.

In summary, the S'83 Addenda version of Appendix F will be used because it provides a more detailed definition of Level D criteria than previous Codes. The allowable stresses of the S'83 Addenda are equal to, or less than, the allowables in previous editions of the Code.

Table 1A

Factors used to calculate Level D allowables based on Level A allowable stress - Prior to Summer 1983.

The minimum of: $1.2\ (S_y/F_t)$ or $0.7(S_u/F_t)$

Table 1B

Factors used to calculate Level D allowables based on Level A allowables stresses - Summer 1983

For $S_u > 1.2S_y$
The minimum of: $1.67\ (S_u/S_y)$ or 2.0

For $S_u \leq 1.2S_y$: 1.4

where: S_y = Yield strength at temperature
S_u = Ultimate strength at temperature
F_t = Allowable tensile strength at temperature.

Table 2

Comparison of Level D Allowable Stresses

Stress Condition	Allowable Stress Pre Summer 83 Addenda	 Summer 83 Addenda
Tensile Stress	Min $(1.2S_y, .7S_u)$	Min $(1.2S_y, .7S_u)$
Shear Stress	Min $(0.8S_y, .467S_u)$	Min $(.72S_y, .42S_u)$
Bending Stress	Varies depending on member type (i.e. compact, etc.)	Varies depending on member type and/or plastic shape factor.
Compression	0.67 critical buckling	.67 critical buckling

Notes:

1. All relationships are simplified based on a Level A tensile allowable of $0.6S_y$.
2. S_y = Yield strength at temperature
   S_u = Ultimate strength at temperature

Table 3

Comparison of Yield Stress vs. Temperature for SA-36 Steel

	Allowable Stress	
Temperature	W73 Code	S83 Code
100°F	36.0 KSI	36.0 SKI
200°F	32.8 KSI	32.8 KSI
300°F	31.9 KSI	31.9 KSI
400°F	30.8 KSI	30.8 KSI
500°F	29.1 KSI	29.1 KSI
600°F	26.6 KSI	26.6 KSI
650°F	26.1 KSI	26.1 KSI
700°F	25.9 KSI	25.9 KSI

Note:

All values from Table I-13.A, "Yield Strength Values, S_y, for Ferritic Steels and Copper Alloys for Classes 1, 2, 3, and MC Linear Type Component Supports." This table first appeared in the W'73 Addenda to the 1971 Code. These original values are listed above. Typographical errors in the W73 Code for 300 and 400°F have been corrected (21.9 vs. 31.9 KSI and 20.8 vs. 30.8 KSI).

ACTION ITEM 18: Provide a definition of the boundaries to be used for seismic analysis of the containment penetrations.

RESPONSE:

The boundary definition for seismic analysis of the penetrations follows the guidelines provided in the ASME Boiler & Pressure Vessel Code, Subsection NE, Article NE-1000. Impell classifies the piping and integral flued head as piping components subject to the rules for Class 2 piping (NC-3600). The section of the penetration at the containment is classified as an MC component subject to the rules of Subsection NE. The intermediate portion of the penetration is classified as Class 2, or MC by the ASME Code. For the SONGS-1 long term service seismic evaluations, Impell considers this segment a pipe support and applies the rules of subsection NF.

The evaluation techniques applicable to each section are:

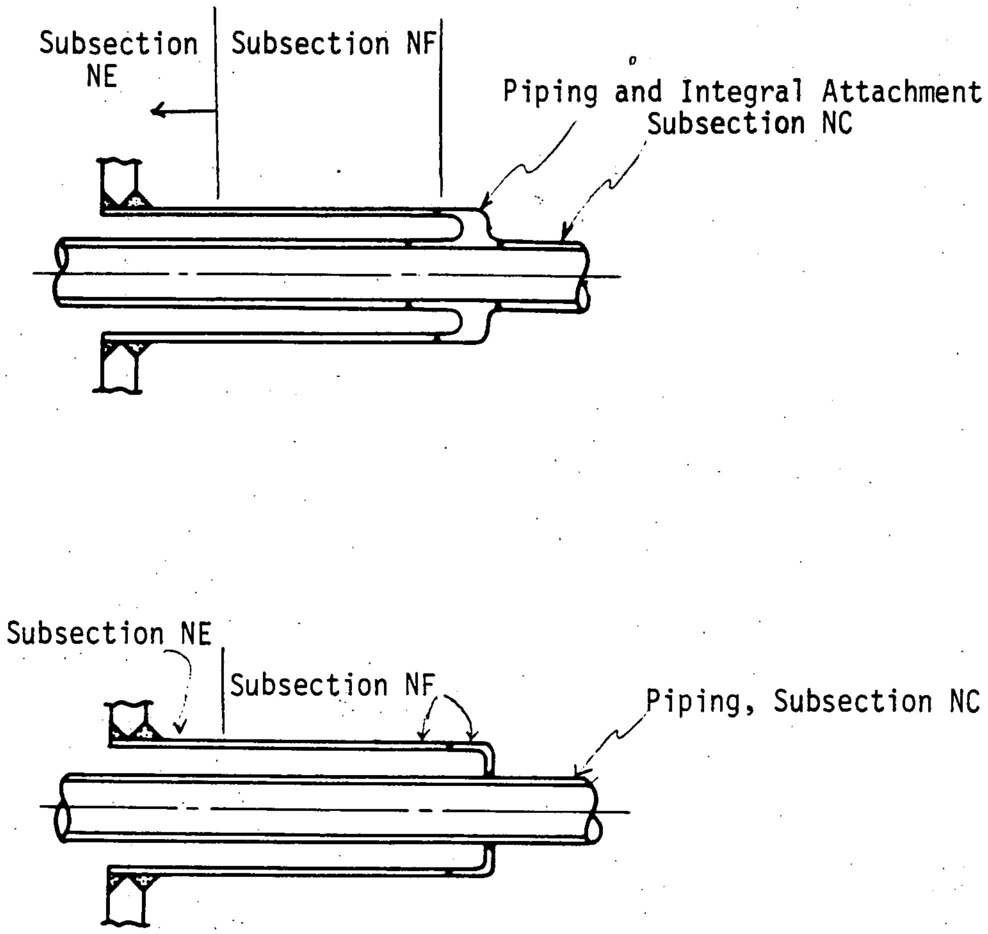
(a) Piping Segment: The piping analysis criteria and methodology developed for LTS will be utilized.

(b) Containment Penetration Segment: The criteria of NE-3200 are applicable and standard analysis techniques (finite element, WRC-117) will be used to evaluate the penetration.

(c) Intermediate Portion: The criteria and methodology for evaluating component supports developed for LTS will be utilized.

This approach will provide for the Code qualification of the containment penetration, the qualification of the piping, and demonstrate the load-carrying capability and structural integrity of the penetration to act as a piping support. The diagrams on the following page show the boundary definitions for criteria and analyses. The MC boundary extends a reasonable distance from the containment to ensure the integrity of the containment. In addition, for penetrations which include expansion joints, the displacement limits of the bellows are determined and the penetration will be evaluated to ensure that the displacement limits are satisfied.

Figure 1. Definition of Boundaries for Containment Penetration



ACTION ITEM 19: Make references in the criteria document to "0.67 Modified Housner Spectrum."

RESPONSE:

Done.

ACTION ITEM 20: Document the criteria used for qualification of piping systems using the similarity method.

RESPONSE:

If the similarity method is used, it will only be used on a case by case basis and will be identified to the NRC.

ACTION ITEM 21: Define the basis and procedures for the secant stiffness method.

RESPONSE:

If the secant stiffness method is used, it will only be used on a case by case basis and will be identified to the NRC.

ACTION ITEM 22: Provide a comparison of the loads generated by Impell (i.e., response spectra) with the existing spectra.

RESPONSE:

The comparison will be made following completion of the load generation task.

ACTION ITEM 23: Provide justification for the 11 percent damping value used for soil material in the SSI.

RESPONSE:

The damping-strain relationship (shown in Figure 1) for the San Mateo sand at the SONGS site was developed by Woodward-McNeill & Associates (Reference 1). The soil material (hysteretic) damping was measured by cyclic triaxial testing in the laboratory and by field attenuation tests performed at the site.

For the 0.67g Modified Housner event, major principal soil strains are expected to be on the order of .2 percent (Reference 2). As seen from Figure 1, this corresponds to soil material damping of approximately 12 percent. Per Impell's long-term criteria document (Reference 3), soil material hysteretic damping will be limited to the damping value at 0.1 percent soil strain, which corresponds to 11 percent soil damping from Figure 1. This approach is justified because of the inherent conservatism it provides to any soil-structure interaction analysis.

REFERENCES:

1. "Development of Soil-Structure Interaction Parameters," Proposed Units 2 and 3, San Onofre Generating Station, Report prepared for SCE by Woodward-McNeill & Associates, January 1974.

2. "Addendum 2 to Report on Soil Backfill Conditions, Appendix F: Variation of Modulus and Damping with Strain, Density and Peak Ground Acceleration," San Onofre Nuclear Generating Station, Unit 1, September 14, 1983.

3. "Seismic Program for Long Term Service," San Onofre Nuclear Generating Station Unit 1, Impell Report No. 01-0310-1368 Revision 1, February 1985.

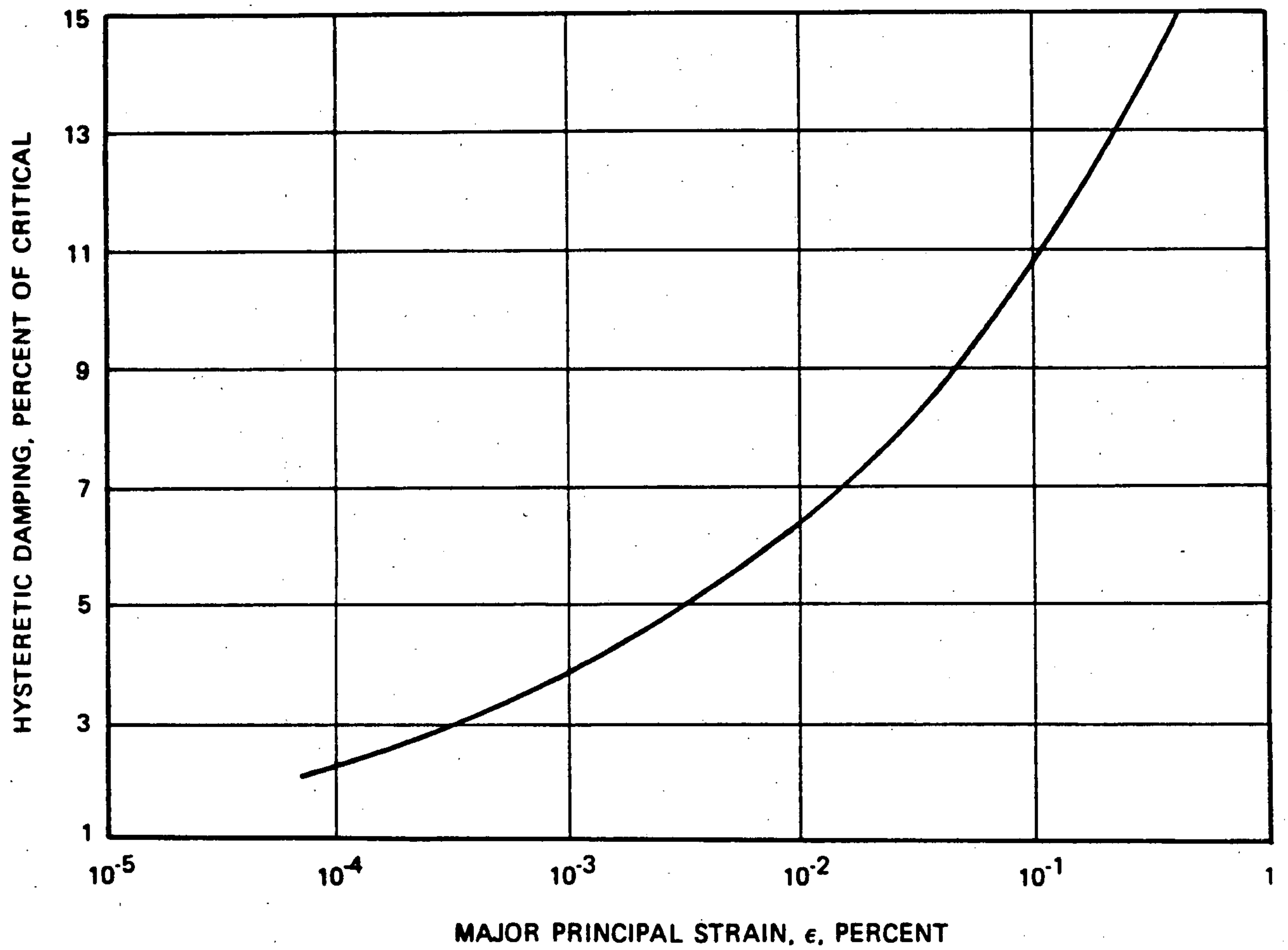


FIGURE 1

Project: **Project No.**	SONGS UNIT 1 SEISMIC RE-EVALUATION 413521	DAMPING RATIO VS MAJOR PRINCIPAL STRAIN SAN MATEO FORMATION SAND

WOODWARD–CLYDE CONSULTANTS

ACTION ITEM 24: Provide a copy of the RV-SUPERPIPE paper by Asfura, A., and A. Der Kiureghian, "A New Floor Response Spectrum Method For Seismic Analysis of Multiply Supported Secondary Systems," Report No. UCB/EERC-84/04, University of California, Berkeley.

RESPONSE:

A copy of this paper has been informally submitted to NRC on 3/6/85.

ACTION ITEM 25: Provide references for applications of the CLASSI, SASSI, and FLORA computer codes.

RESPONSE:

CLASSI

- GESSAR - Confirmatory Analyses; reviewed and accepted by NRC. Reference NUREG 0979, Supplement #2
- BYRON - On behalf of the NRC, Brookhaven used CLASSI to perform confirmatory SSI analyses to audit the design-based SSI analyses.
  - The design-based SSI analyses, performed by the A-E, were done using the frequency-dependent soil impedance method - the same technique used by CLASSI.
  - All SSI work has been reviewed and accepted by the NRC
- NRC - SSMRP selected CLASSI as the state-of-the-art SSI analysis technique and used it as a tool for evaluating SSI effects.

  NRC sponsors the development of SMACS (with CLASSI SSI capabilities) to be located at Argonne Computer Code center for public domain use.
- HTGR - GA Technology (General Atomic) has used CLASSI in all of the preliminary design work for the HTGR

We are continuing to collect and review SERs and NRC documents for other instances where CLASSI was used.

FLORA has been used in the following projects

- AEP - Report 02-0120-1258 Rev. 0, 1985
  "Donald C. Cook Nuclear Plant Units 1&2
  Generation of Required Response Spectra for
  AGASTAT 9400 Series Timing Relays"
- GPU - Oyster Creek

  Report No. 02-0370-1192 Rev. 0, Nov. 1984
  "Qualification of Standby Gas Treatment Panel"

  Report No. 02-0370-1193 Rev. 0, Nov. 1984
  "Oyster Creek Nuclear Generating Station Qualification of Control Room Panel 1F/2F"

  Report No. 02-0370-1165 Rev. 0, Nov. 1984
  "Dynamic Qualification of Standby Gas Treatment System Electrical Cabinets"

- PP&L - Report No. 02-0162-1162 Rev. 1, April 1984 "Susquehanna Steam Electric, Station Units 1&2 Generation of Required Response Spectra for the Mode Switch and other Components located in Panels 1C/2C-651"

Rancho Seco - Reference:

1) Seismic Evaluation of HVAC panels H4ACA and H4ACB at Rancho Seco NGS, Report No. 01-0790-1358, Rev. 1, Nov. 1984.

2) Seismic Evaluation of the Control Rod Drive AC & DC Breaker Cabinets at Rancho Seco Nuclear Generating Station. Report No. 01-0790-1361, Rev. 0, Dec. 1984.

THORP/British Nuclear Fuels - Impell Report Feb. 1985 "Vertical Seismic Analysis of the Main Hall"

SASSI

- N-Reactor/DOE - Impell has used SASSI in the seismic reevaluation for the N-Reactor. Reference: Impell Report No. 01-2520-1370, Rev. 0, "Seismic and Pressure Tube Rupture Evaluation of DOE N-Reactor, Phase I - Analyses and Evaluations," February 1985.
- HWU (Germany Company) for Iranian Plant under construction
- Trachionel (Belgium Company) for several European Plants
- Heyham & Torness/CEGB - Impell is the seismic consultant on the building and reactor core seismic analysis. Impell is developing soil structure interaction models using the SASSI code.
- Thorp/BNFL - Impell is the seismic consultant for the analysis of the THORP fuel reprocessing plant. SSI analysis for all major building of the plant are being performed with the SASSI Code.
- ABWR/Toshiba - Impell performed a series of soil-structure interaction analyses to evaluate the various site characteristics and analytical methods using the SASSI Code.

ACTION ITEM 26: Define the correlation coefficient used in the Multiple Level Response Spectra (MLRS) analysis method and in RV-Superpipe. Is it identical to the definition in R.G. 1.92?

RESPONSE:

The correlation coefficients used for each method are defined as follows:

A. Multiple Level Response Spectra Method is governed by the following combination rules:

- For the combination of modes, we will use R.G. 1.92 or CQC methods
- For the combination of levels or if between buildings, we will use SRSS method if the correlation coefficient is $-0.16 \leq P \leq 0.16$

where P is the correlation coefficient representing the statistical dependence between two time histories. It is evaluated as follows:

$$P = \frac{\sigma_{ij}^2}{\sigma_i \sigma_j}$$

where

σ_{ij}^2 = covariance of time histories at levels i and j.

σ_i, σ_j = standard deviations for time histories at levels i and j, respectively

The value of 0.16 is an acceptable measure of a statistical independence as per ASME Code, Appendix N.

B. RV-Superpipe

RV-Superpipe uses correlation coefficients to combine the level and modal responses simultaneously. Those correlation coefficients define the phasing of two modal responses subjected to two different level excitations.

The correlation coefficients are evaluated by using random vibration theory. They are a function of the modal properties of the structure and of the ground excitation which can be characterized by its response spectrum. Details of correlation coefficients in the framework of random vibration can be found in the following references:

- Asfura, A. and Der Kiureghian, A., "A New Floor Response Spectrum Method for Seismic Analysis of Multiply Supported Secondary Systems," Report No. UCB/EERC-84/04, Earthquake Engineering Research Center, University of California, Berkeley, California, June 1984.

- Asfura, A. and Der Kiureghian, A., "Floor Response Spectrum Method for Seismic Analysis of Multiply Supported Secondary Systems," paper submitted to Earthquake Engineering and Structural Dynamics.

Basically the correlation coefficients can be expressed by

$$P = \frac{\sigma^2_{ikjl}}{\sigma_{ik} \cdot \sigma_{jl}}$$

where

σ^2_{ikjl} is the covariance of modal response i due to excitation at level k and modal response j due to excitation at level l.

σ_{ik} is the standard deviation of modal response i due to excitation at level k.

σ_{jl} is the standard deviation of modal response j due to excitation at level l.

The RV superpipe correlation coefficients consider both modal combinations and multiple-level combinations simultaneously where as the Regulation Guide 1.92 is only applicable for modal responses.

ACTION ITEM 27: What combination method is used for piping loads on gang supports. Provide justification for the method used.

RESPONSE:

Gang supports supporting more than one pipe will be evaluated to withstand the total loads (gravity + thermal + seismic) from all the pipes. Components of the support structure, which are loaded by more than one pipe will be evaluated by considering the SRSS combination of seismic responses of the different pipes. The square root of the sum of the squares (SRSS) method of combination will only be used for those pipes whose fundamental frequencies are not grouped within a 10 percent range (Grouping Method), as defined in the NRC Regulatory Guide 1.92.

This procedure is much more realistic than the procedure wherein the seismic loadings from all pipes on the gang support are assumed to act in phase. In reality, piping systems with different configurations will generally have different dynamic characteristics. As a result, the probability of the pipe's peak seismic responses occurring simultaneously will be small. For piping systems whose fundamental frequencies are closely-spaced, the seismic responses as a result of loadings from these piping systems will be absolutely summed. If the piping frequencies are not closely-spaced, the responses will be combined using the SRSS technique. For gravity and thermal loads, the total loads from all piping systems will be used to evaluate the gang support.

This technique of combining responses from multiple piping has been approved by the NRC for a functionality evaluation of the Control Rod Drive Hydraulic System (CRDHS) insert and withdraw piping at Quad Cities Units 1 and 2, and Dresden Unit 2 for DBE level loading [1, 2]

REFERENCES:

1) "Dresden Unit 2, Control Rod Drive Hydraulic System Insert and Withdraw Piping Functionality Study, Addendum No. 1 to EDS Report No. 04-0590-03, Revision 0," EDS Nuclear Report No. 04-0590-15, Revision 0, August, 1981.

2) "Quad Cities Units 1 and 2, Control Rod Drive Hydraulic System Insert and Withdraw Piping Functionality Study, Addendum No. 1 to EDS Report No. 04-0590-02, Revision 0," EDS Nuclear Report No. 04-0590-14, Revision 0, August, 1981.

ACTION ITEM 28: Provide justification to use same allowable 2.0 S_y for Class 1 and Class 2/3 piping.

RESPONSE:

For the Class 2/3 faulted condition primary stress check (Equation 9), the SEP criteria specified that Class 1 piping systems meet a 1.8 S_h (or 3.0 S_m if Class 1 rules are used) allowable, as opposed to the 2.4 S_h allowable applied to Class 2/3 piping. For the SONGS 1 Long Term Service Program, the proposed criteria would require the satisfaction of this same equation, but calculated stresses would be compared to a 2.0 S_y allowable for both Class 1 and Class 2/3 piping alike. Present design practice, according to NB-3600 for Class 1 piping, includes a faulted condition primary stress intensity check essentially equivalent to the faulted primary stress check of NC-3600 for Class 2/3 piping. NB-3600's Equation 9 (faulted) must be compared to 3.0 S_m whereas NC-3600's Equation 9 (faulted) must be compared to 2.4 S_h as follows:

Class 1: $B_1 \frac{PD_o}{2t} + B_2 \frac{D_o}{2I} M_i \leq 3.0\ S_m$

Class 2: $\frac{PD_o}{4t} + 0.75i \frac{M_a + M_b}{z} \leq 2.4\ S_h$

From the definition of S_m in Article III-2000 of Appendix III of the ASME Code, 3.0 S_m is equivalent to 2.0 S_y for most Class 1 materials. By imposing the 1.8 S_h allowable stress to Class 1 piping using Class 2/3 rules, it is more restrictive than directly performing a Class 1 evaluation with 3.0 S_m as the allowable stress.

SONGS-1 was originally designed per ANSI B31.1 rules. The B31.1 code does not differentiate Class 1 piping from Class 2/3 piping. Identical code equations are checked for both Class 1 and Class 2/3 piping using Class 2/3 rules. In the nonlinear analysis performed for SONGS-1 by Impell, Class 2/3 Code Equation 9 was used to correlate the results of linear versus nonlinear methods (see response to Action Item 5e). As a conclusion of this study, 2.0 S_y was confirmed as the adequate allowable for the faulted primary stress check, using linear elastic analysis approach for both Class 1 and Class 2/3 piping alike.