CONNECTICUT YANKEE ATOMIC POWER COMPANY

SAFETY RELATED PIPING SEISMIC QUALIFICATION PROGRAM

CRITERIA DOCUMENT

REVISION 2

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PURPOSE OF REVISION

Revision 3

The purpose of this revision is to incorporate the currently accepted modal damping values and response spectrum analysis techniques into the Connecticut Yankee seismic evaluation methodology.

REVISION RECORD
CY CRITERIA DOCUMENT

Revision Number	Pages Revised and Description of Changes
3	Page 7 - Addition of SUPERPIPE to the list of computer programs used for analysis. - Incorporated PVRC damping, Independent Support Motion (ISM) and spectra peak shifting methods to response spectrum analysis procedure. Page 13- References added.

NORTHEAST UTILITIES

THE CONNECTICUT LIGHT AND POWER COMPANY
THE HARTFORD ELECTRIC LIGHT COMPANY
WESTERN MASSACHUSETTS ELECTRIC COMPANY
HOLYOKE WATER POWER COMPANY
NORTHEAST UTILITIES SERVICE COMPANY
NORTHEAST NUCLEAR ENERGY COMPANY

ANALYSIS OF SAFETY-RELATED PIPING SYSTEMS

A. SCOPE

The purpose of this document is to present the analytical methods and stress criteria which will be used for the Connecticut Yankee safety related piping seismic qualification program. The program will include static analysis of the piping system/support scheme for maximum operating thermal, pressure, and deadweight loads, along with dynamic analysis for seismic loads. Stress criteria will be presented for the piping and supports.

B. BACKGROUND

In the years since the Connecticut Yankee generating station was designed, seismic analysis methods have become more rigorous and the ASME Boiler and Pressure Vessel Code (BP&V) Section III, Nuclear Power Plant Components, has been published reflecting changes in analysis, design, and quality control techniques. The purpose of this criteria document is to establish requirements for performing the upgrading seismic analyses of safety related piping systems applying current technology.

The original design criteria used for analysis of this plant's safety related piping systems was the 1955 Edition of the American Standard Code for Pressure Piping, ASA B31.1.

For the purposes of this document, safety related piping shall be considered to consist of portions of those systems listed herein including connecting piping two and one-half inches (2½") or larger nominal pipe size, up to and including the first valve that is normally closed or is capable of automatic closure during all modes of reactor operation.

1. Reactor coolant loop attachments -- Up to first isolation valve.

2. Main steam -- Up to and including the outermost containment isolation valve.

3. Feedwater -- Up to and including the outermost containment isolation valve.

4. Auxiliary feedwater -- From the primary feedwater lines to the demineralized water storage tank.

5. Residual heat removal.

6. Low pressure safety injection -- Residual heat removal system up to the refueling water storage tank.

7. High pressure safety injection -- Reactor coolant loops up to the refueling water storage tank.

8. Chemical and volume control -- Reactor coolant loops up to the volume control tank, volume control tank up to the 2 isolation valves needed to maintain system integrity.

9. Service water -- Supply lines to safety related equipment.

10. Fuel oil -- Emergency diesel generators to the emergency diesel generator storage tanks (TK-33-2A and 2B).

11. Compressed air -- Emergency diesel generators starting air motors up to air compressors C-14-1A and 1B.

C. LOADING CONDITIONS

Plant safety related piping and associated supports/restraints will be analyzed for the following loading conditions.

1. Design pressure, deadweight, and maximum operating temperature range.

2. Safe shutdown earthquake (SSE) combined with operating pressure and deadweight.

3. Analyses will not consider coincident LOCA and SSE.

D. STRESS CRITERIA

1. Above Ground Piping

(a) General

The piping analysis that will be performed for the Connecticut Yankee evaluation is based on the rules of the ANSI B31.1 Power Piping Code, 1973 Edition, Summer 1973 Addenda.

The loading combinations and associated stress limits to be used for the piping systems, which are part of the seismic qualification program, are given in Table 1. The stress limits used for the SSE condition correspond to faulted condition allowables as defined in the ASME Section III Code. The piping stresses are to be calculated using formulas given in ANSI B31.1, 1973 Edition, Summer 1973 Addenda.

Piping materials are to be identified on the basis of the Connecticut Yankee piping line list and pipe fabrication specifications.

(b) Supports/Restraints

Existing supports/restraints will be evaluated using the as-built configuration to determine if the assembly is capable of sustaining the new piping analysis loads.

Where the new loads exceed the original design load, the support/restraint will be reviewed to determine if modifications are required.

Additional piping support/restrain functions that are identified in the piping analysis shall be designed to meet the required load capacity.

Supports with expansion type anchor bolts, shall be designed utilizing I&E Bulletin 79-02 criteria. 2

Evaluation of component standard supports will be performed using manufacturer's published allowable load data. Piping support/restraint structural steel will be reviewed/designed in accordance with the AISC Specification, "Manual for Steel Construction", 7th Edition, 1970.

The effects of friction shall be considered where the thermal movement of the pipe relative to the piping support exceeds one-sixteenth inch (1/16"). The coefficient of friction to be used in this analysis is 0.3 for steel-on-steel. The frictional force acting on the structure shall be equal to the greater of the deadweight load or the deadweight plus thermal load, multiplied by the coefficient of friction.

(c) Small Bore Piping

Small diameter (2½" nominal and less) piping systems needed for the safe operation of the plant may be reviewed using chart 2
methods which are demonstrated to result in piping stresses within Code allowable limits; i.e., same as D.1. Computer analyses may be performed on select small bore lines.

Vent, drain, and sampling lines which are not considered vital to safe system operation are not included in this program.

2. Underground Piping

The analysis of underground piping conforms to the criteria outlined by Newmark and Hall[A] and to the method proposed by E. C. Goodling[B], and by Shah and Chu.[C]

This method addresses primarily the axial stresses induced in pipe runs which are parallel to the direction of soil strain as recommended by Wang.[D] Since a buried pipeline reacts to seismic inputs through the medium of the surrounding soil, its response behavior is influenced by its physical parameters and by the governing geotechnical and seismological parameters. These parameters are manipulated to determine the forces, moments, and stresses on the pipe element. This method neglects strains induced by ground curvature as recommended by Newmark. Also, since the dynamic effects on buried piping response have been found to be negligible, they are not considered.

This analysis method involves four (4) distinct phases.

1. Physical, geotechnical, and seismological data are assembled. The physical and seismological data are readily available, but because Connecticut Yankee was designed before the emphasis on rigorous seismic analysis developed, there may be some difficulty obtaining the geotechnical data from the plant site. However, using engineering judgements, data available from a geologically similar site, will be combined with tabulated parameter values for the soil covering the pipes to form the geotechnical data base.

2. Intermediate parameters such as the soil pipe interaction constant and maximum length, L', over which friction effects are important, are calculated.

3. Pipes are then classified as long or short based on the magnitude of L' relative to the length at which there is negligible additional influence on the forces and moments. This classification allows for flexibility assumptions which will facilitate the evaluation of stresses.

4. Finally, deflections, forces, moments, and code stresses are calculated and compared to allowables.

E. ANALYSIS PROCEDURES

1. Computer Codes

In general, the following QA qualified computer codes will be utilized in this analysis.

Piping Stress	ADLPIPE	Version 1D
	SUPERPIPE	Version 15C or later
Support/Restraint Structure	STRUDL	Version 2 Model 2

3

If necessary, other QA qualified programs may be employed.

2. Response Spectrum Analysis Procedures

Analysis will be performed assuming that the seismic event is initiated with the plant at normal full power condition. The SSE damping values used[(E)] are 3% for nominal pipe diameter greater than 12" and 2% for nominal pipe diameter equal to or less than 12" except that increased damping values may be applied on an as-needed basis in accordance with ASME Code N-411[(G)] (Figure - 1). 3

When piping system support points are located in different parts of the structure or in separate building structures, the response spectrum in each direction shall be an envelope of the applicable peak broadened floor spectra. Alternatively, a multiple excitation method, called the "Independent Support Motion (ISM)" response spectrum method as outlined in NUREG 1061[(H)] Volume 4, Section 2.4 may be utilized. 3

The floor response spectra* utilized in the Connecticut Yankee analysis is based on ground response spectra previously submitted for NRC review.[(F)] These spectra were peak broadened

*The ground response spectra used to develop the floor response spectra is very close to the Staff's ground response spectra forwarded by D. M. Crutchfield's letter to all SEP owners (except San Onofre) on June 8, 1981.

± 15 percent to account for the uncertainties in the calculated values of structural frequencies. The spectra peak shifting method as described in Appendix - N, N1226.3, Section III, ASME B&PV Code Case Number N-397, will be utilized on an as-needed basis. 3

The analysis shall be performed with a simultaneous input of the two (2) horizontal components and one (1) vertical component of the earthquake. The modal response for each item of interest (i.e., force, displacement, stress) shall be obtained by the square root of the sum of the squares method.

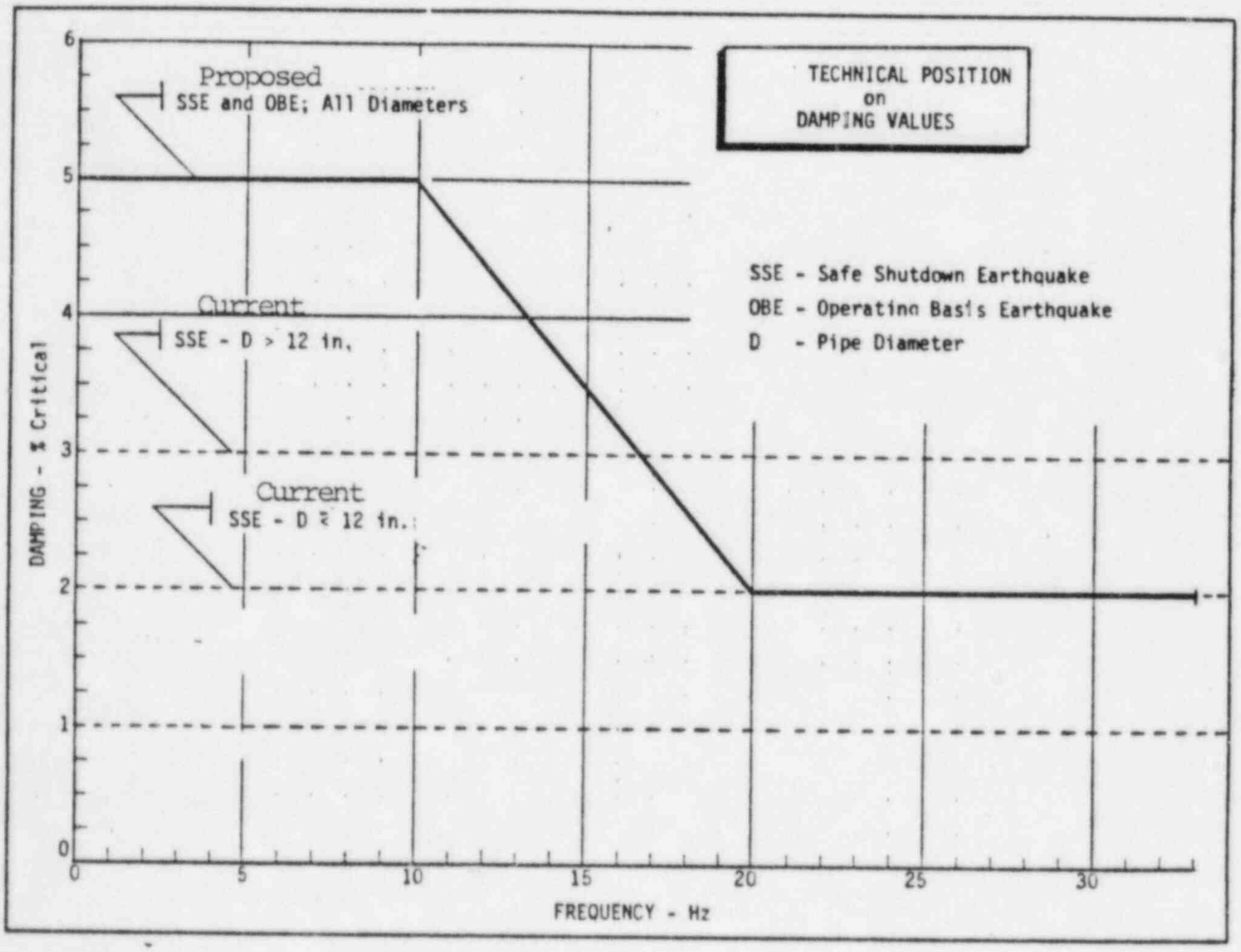

FIGURE 1

Page added by Revision 3

$$R_T = \{ \sum_{i=1}^{3} R_i^{\,2} \}^{1/2}$$

where: $$R_i = \{ \sum_{j=1}^{N} R_{ij}^{\,2} \}^{1/2}$$

where: R_T = total combined response at a point

R_i = value of combined response of direction i

R_{ij} = absolute value of response for direction i, mode j

N = total number of modes considered

For systems having modes with closely spaced frequencies, the above method shall be modified to include the possible effect of these modes. Combined total response for system which have such closely spaced modal frequencies will be obtained in accordance with Regulatory Guide 1.92.

F. MODELING TECHNIQUES

The piping system and support scheme are to be represented by an ordered set of data which numerically describes the physical system.

Each system will be analyzed by one or several stress problems. In general, the analytical terminal points for each stress problem will be one of the following, based upon engineering judgement.

1. Equipment nozzle.

2. Piping interface where the moment of inertia of the run pipe exceeds that of the connecting line by a minimum factor of ten.

3. An anchor; i.e., a six-way restraint.

4. Two or more restraints in proximity such that the effects of the piping on either side of the support group are isolated.

The spatial geometric description of the model is to be based upon the as-built isometric piping drawings developed under the I&E Bulletin 79-14 program. Node point coordinates and incremental lengths of the members are determined from these drawings. The geometrical properties along with the modulus of elasticity, E, the coefficient of thermal expansion, α, the average temperature changes from the ambient temperature, ΔT, and the weight per unit length, ω, are specified for each element. Supports are represented by a stiffness applied in the appropriate direction to define the restraint characteristics of the supports.

The models used in the static analyses are to be modified for use in the dynamic analyses by including the mass characteristics of the piping. The lumping of the distributed mass of the piping systems is to be accomplished by locating the total mass at points in the system which will approximately represent the response of the distributed system.

The effect of eccentric masses, such as valves and extended structures, are considered in the seismic piping analyses. These eccentric masses are modeled in the system analysis and the moments caused by them are evaluated and included in the total

system response. The total response must meet the limits of the criteria applicable to the safety class of the piping.

TABLE 1

LOADING COMBINATIONS AND STRESS LIMITS FOR PIPING

LOADING COMBINATIONS	STRESS LIMITS	
1. Normal:		
(a) Design Pressure + Deadweight	$\leq S_h$	
(b) Maximum Operating Temperature + Seismic Anchor Movements	$\leq S_A$	
or		
Design Pressure + Deadweight + Maximum Operating Temperature + Seismic Anchor Movements	$\leq (S_H + S_A)$	
2. SSE:		
(a) Maximum Operating Pressure + Deadweight + Maximum Potential Earthquake Loads (SSE)	$\leq kS_H$	2

Where: S_A = allowable stress range

= $1.25\ S_c + .25\ S_h$

S_c = material allowable stress at minimum temperature from ANSI B31.1, 1973 edition, summer 1973 addenda

S_h = material allowable stress at design temperature from ANSI B31.1, 1973 edition, summer 1973 addenda

k = 1.8 for Class I piping systems and 2.4 for Class II, III, and B31.1 piping systems 2

TABLE 2

LOADING COMBINATIONS AND STRESS LIMITS FOR SUPPORTS

LOADING COMBINATION	LINEAR TYPE SUPPORT LIMITS[3]	PLATE AND SHELL SUPPORT LIMIT
Greater of:		
D + T or D	Working Stress[4]	$P_m \leq 1.0\ S_m$
		$P_m + P_b \leq 1.5\ S_m$
Greater of:		
D + T + E or D + E	Within lesser of:	$P_m \leq 1.2\ F_y$[1]
	$\frac{1.2\ F_y}{F_t}$ or $\frac{0.7\ S_u}{F_t}$	$P_m + P_b \leq 1.8\ F_y$[2]
	times working limits[4]	

Where: D = deadweight

T = thermal maximum operating temperature

E = SSE

F_y = material yield strength

F_t = allowable tensile stress per ASME Section III, Appendix XVII

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[1]Not to exceed $0.7\ S_u$

[2]Not to exceed $1.05\ S_u$

[3]Compressive axial member loads should be kept to less than .67 times the critical buckling load 2

[4]Working stress allowables per Appendix XVII of ASME III.

REFERENCES

A. Newmark, N. M., and Hall, W. J., "Development of Criteria for Seismic Review of Selected Nuclear Power Plants", N. M. Newmark Consultant Engineering Services, Urbana, Illinois, 1977.

B. Goodling, Jr., E. C., "Flexibility Analysis of Buried Pipe", American Society of Mechanical Engineer, New York, 1978.

C. Shah, H. H., and Chu, S. L., "Seismic Analysis of Underground Structural Elements", Journal of the Power Division, Proceedings of ASCE, Vol. 100, No. P01, July 1974.

D. Ru-Liang Wang, L., "Some Aspects of Seismic Restraint Design of Buried Pipelines", Presented at Third National Congress on Pressure Vessels and Piping, San Francisco, California, 1979.

E. "Damping Values of Nuclear Plant Components", Regulatory Guide 1.61.

F. W. G. Counsil letter to D. M. Crutchfield, dated September 15, 1980.

G. ASME BP & V Code, Section III, Appendix - N, Code Cases N-397 & N-411. 3

H. NUREG-1061, Vol. 4, December 1984.