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CRITERIA FOR SEISMIC ANALYSIS OF SAFETY-RELATED MECHANICAL EQUIPMENT (SEP TOPIC III-6)

SEISMIC REQUALIFICATION OF ESSENTIAL PIPING SYSTEMS

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SPECIFICATION RELEASE RECORD

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CRITERIA FOR SEISMIC ANALYSIS OF SAFETY-RELATED MECHANICAL EQUIPMENT (SEP TOPIC III-6)

1.0 PURPOSE

The purpose of this document is to provide acceptance criteria to be employed for the Big Rock Point seismic requalification program (SEP Topic III-6). The criteria posed herein will be applied to safety-related piping and supports and the supports and pressure boundaries associated with specific mechanical equipment. Appendix A presents supplemental information concerning analysis and modeling techniques and standard procedures.

2.0 SCOPE

The scope of the equipment to which the proposed criteria apply includes safety-related piping (except primary coolant loop), pipe supports, selective tanks, heat exchangers, pumps and valves. The primary coolant loop is being evaluated as part of the building structural analysis. The tanks, heat exchangers, pumps and valves will be evaluated for pressure boundary and support integrity where appropriate. A list of systems to be evaluated is included in Reference (1). Certain items listed in Reference (1) will not be subject to the criteria proposed herein. These items are: Mechanical and electrical equipment supports considered under the scope of IE Information Notice 80-21 which will be addressed when the results of that work are reported; the fuel pool structure and spent fuel racks which will be evaluated separately under an ongoing program; the masonry walls which will be evaluated by an inelastic analysis associated with the reserve energy method, the results of which will be reported when complete; non ductile materials (e.g. cast iron) which will be handled on a case by case basis.

3.0 LOADING CONDITIONS

3.1 Piping and Equipment

All safety-related piping and pressure retaining mechanical equipment will be evaluated for the following loading conditions:

1. Deadweight combined with design pressure and other design mechanical loads.

2. Design temperature thermal expansion (piping systems) with thermal anchor movements due to design temperature.

3. Deadweight combined with operating pressure, operating mechanical loads, if any, and safe shutdown earthquake intertia (SSE) loads.

3.2 Piping and Component Supports

All safety-related piping and mechanical equipment supports will be evaluated for the following loading conditions:

1. Deadweight combined with loading due to restraint of design temperature free end displacements and design mechanical loads.

2. Deadweight combined with loading due to restraint of operating temperature free end displacement, operating mechanical loads and safe shut-down earthquake inertia (SSE) loads.

4.0 STRESS EVALUATION CRITERIA

4.1 Piping

Piping analysis that will be conducted for the Big Rock Point Plant Seismic Requalification will be based on the rules of the ASME Boiler and Pressure Vessel Code (ASME), Section III, Subsection NC, 1980 Edition, including Winter 1980 Addenda. Load combinations and the stress limits associated with piping are shown in Table 1. All safety related high temperature and some low temperature systems will be evaluated using the analysis guidelines in Appendix A. Design pressures and temperatures for piping will be taken from the Big Rock Point Plant Piping Materials Specification.

4.2 Small Bore Piping

Small bore piping is that piping which has a 2-1/2" nominal pipe size (NPS) or smaller. Chart methods will be prepared and are expected to be used for most small bore piping. Small bore piping will be dynamically analyzed if chart methods are impractical or if it is included as part of a large bore pipe model. Any chart methods to be used will ensure that the piping criteria of Table 1 are met. Charts may be employed for large bore, low temperature piping where applicable.

4.3 Equipment

Vessels, pumps and valves will be evaluated for pressure boundary integrity using stress acceptance criteria consistent with original design criteria, supplemented with criteria for faulted condition load combinations. Pressure boundaries of vessels and extended operator structures of active valves will be evaluated in accordance with the criteria of the 1980 Code, Section III, for Class 2 Components. No special consideration will be given to valve and pump bodies as the connecting pipe moment will be limited in accordance with standard valve and pump design practice. Table 2 summarizes loading combinations and stress limits for equipment.

Special consideration will be given to extended structures of active valves. The stress in active valve operator supports will be limited to the yield strength of the material.

In addition, the acceleration of active valve operators will be limited to 3 g's horizontal and 2 g's vertical.

The additional piping reaction loads on vessels due to SSE will be assumed to be acceptable if they are limited to 0.8 Sh (Normal loads + SSE $\leq$ 1.8 Sh).

4.4 Piping and Component Supports

Existing piping and component supports will be evaluated for loads produced by piping and equipment response to static and dynamic loadings specified in Paragraph 3.2 above.

Piping and component supports will not be analyzed if the original design load for the support is not exceeded by more than 10% for the load combinations described in Section 3.2.

Existing linear piping and component supports will be analyzed in accordance with the stress criteria from ASME, Section III, Subsection NF and Appendix XVII, 1980 Edition, Winter 1980 Addenda.

Plate and shell piping and component supports will be evaluated to the criteria of the ASME Code, Section III, Subsection NF, 1980 Edition, Winter 1980 Addenda.

Most piping and component supports at Big Rock Point are attached to building steel. The attachment to this steel will be evaluated in accordance with the requirements of the ASME Code, 1980 Edition, Winter 1980 Addenda. Concrete embedments and anchor bolts will be evaluated in accordance with the criteria given in Table 3.

Loading combinations and stress limits for piping and component supports are summarized in Table 3.

TABLE 1

LOADING COMBINATIONS AND STRESS LIMITS FOR PIPING

Loading Combinations	Stress Limits
1. Normal	
(a) PD + D (1)	≤ Sh
(b) TD + TAM	≤ Sa
2. Faulted	
P + D + SSE	≤ 2.4 Sh

Where:

PD	=	Design Pressure Stress
D	=	Deadweight Stress
TD	=	Thermal Expansion Stress due to Design Temperature
TAM	=	Stress due to Design Temperature Thermal Anchor Displacements
SSE	=	Stress due to Safe Shutdown Earthquake Inertia Loads
Sa	=	Allowable Stress Range, f(1.25 Sc + 0.25 Sh), where f = 1.0
Sc	=	Cold Material Allowable Stress from ASME, Section III, 1980 Edition, Winter 1980 Addenda or ANSI B31.1, 1980 Edition (2)
Sh	=	Material Allowable Stress at Maximum Operating Temperature from ASME, Section III, 1980 Edition, Winter 1980 Addenda or ANSI B31.1, 1980 Edition (2)

NOTES: (1) If required, any design mechanical loads will be included in this combination.

(2) Material allowables will be taken from B31.1 if they are not available in Section III.

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TABLE 2

LOADING COMBINATIONS AND STRESS LIMITS
FOR VESSELS, PUMPS AND VALVES

Loading Combination	Stress Limit (1)
PD + D + FD	$S1 \leq 1.0\ S$ (3)
	$S1 + S2 \leq 1.5\ S$ (3)
PN + D + FN + SSE	$S1 \leq 2.0\ S$ (4)
	$S1 + S2 \leq 2.4\ S$ (5)

Where:

PD	=	Design pressure
PN	=	Normal operating pressure
D	=	Deadweight
FD	=	Design mechanical loads from connecting piping excluding earthquake
FN	=	Operating mechanical loads from connecting piping including earthquake inertia loads
SSE	=	Safe Shutdown Earthquake Inertial Loading
S1, S2	=	Membrane stress and bending stress as defined in the ASME Code, Section III, NF-3522
S	=	Allowable stress intensity from ASME Code, 1980 Edition with Addenda through Winter 1980, Table 1-7 or 1-8

NOTES:

(1) Valve and pump bodies are considered stronger than connecting pipe and therefore analyses of valve and pump bodies will not be performed.

(2) For active valves, the extended operator support structure stress will be limited to Sy and the valve operator acceleration will be limited to 3 g's horizontal plus 2 g's vertical.

(3) This limit may be considered to have been satisfied by the original designer of the component.

(4) For active valves and pumps, this limit shall be 1.5 S.

(5) For active valves and pumps, this limit shall be 1.8 S. This limit may be satisfied by limiting the pipe stress at the point of attachment to the component to 1.8 Sh.

TABLE 3

LOADING COMBINATIONS AND STRESS LIMITS FOR SUPPORTS (1, 2, 3, 6)

Loading Combination	Linear Type Support Limits	Plate and Shell Support Limit
D + TD	F all	$S1 \leq 1.0\ S$
		$S1 + S2 \leq 1.5\ S$
D + TO + SSE	1.2 Sy but not	$S1 \leq 1.5\ S$ (4)
	> 0.7 Su (7, 8, 9)	$S1 + S2 \leq 2.25\ S$ (5)

Where:
- D = Deadweight Stress
- TD = Stress induced by restraint of free end thermal displacement due to design temperature
- TO = Stress induced by restraint of free end thermal displacement due to operating temperature
- SSE = SSE inertia loads
- Sy = Material yield strength at temperature
- F all = Allowable stress value from ASME Code, Section III, XVII-2000.
- S1, S2 = Membrane stress and bending stress as defined in the ASME Code, Section III, NF-3321.
- S = Allowable stress from the ASME Code, Appendix I

NOTES:
(1) Compressive axial member loads shall be kept to less than 0.67 times the critical buckling load.
(2) Includes Component Standard Supports designed by analysis.
(3) For linear as well as plate and shell support analyses, use ASME Code, 1980 Edition with Winter 1980 Addenda.
(4) Not to exceed 0.4 Su.
(5) Not to exceed 0.6 Su.
(6) Supports may also be designed by load rating per Section III, NF-3360.
(7) As an alternative, the criteria of F-1370 may be used.
(8) Concrete embedded anchors will be evaluated for the same loading combinations using a limit of 0.7 Su.
(9) Anchor bolts will be evaluated for the same loading combinations using a limit of 0.25 Su for wedge type and 0.20 Su for shell type (as specified by manufacturer).

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APPENDIX A

ANALYSIS GUIDELINES

A-1. Computer Codes

Where either static or dynamic computer analysis is required, QA qualified computer codes will be employed. Typical programs that may be employed are:

PIPE STRESS:	NUPIPE
COMPONENTS AND SUPPORTS:	ANSYS SAP (SAP 80) STRUDL

Other qualified programs will be employed where required.

A-2. Dynamic Analysis Guidelines

a. With the exception of the main reactor coolant and small bore piping, analysis of components and piping for a seismic event will be done by the response spectrum method. The seismic event will be expected to occur with the plant at normal operation. The response spectra to be employed are generally expected to be those resulting from the present analysis of the plant structures, Reference (2). However, revised amplified floor spectra resulting from an analysis using the site specific spectra of Reference (3) may be employed.

b. Damping values will be as recommended in NUREG/CR-0098, Reference (4). Damping for all sizes of piping will be 3 percent. Equipment damping will be 7 percent.

c. Response spectra associated with different pipe support locations within the structures will be enveloped where a single response spectrum is to be used in an analysis. However, should multiple input spectra be judged necessary, they will be used.

d. Analysis will be performed with a simultaneous input of all response spectra in the global or any convenient local coordinate system.

e. The maximum value of a response component (e.g. x, y, or z) will be determined by taking the SRSS sum of the individual modal responses for each component. The total response will then be taken as the SRSS sum of the individual maximum component responses, in accordance with Regulatory Guide 1.92.

f. The analysis of many mechanical equipment items are expected to be conducted by simplified static coefficient methods. A 1.5 factor for the multi-modal response of flexible equipment systems will be employed where analysis or testing cannot ensure that the equipment can be represented as a single-degree-of-freedom system.

g. Ductility, if used, will be accounted for in accordance with the NRC letter from D. M. Crutchfield to D. J. Van de Walle, dated June 23, 1982.

A-3. General Modeling Guidelines

a. The analysis models to be incorporated in the computer analyses will be conventional in nature. Dimensional isometrics of essentially all safety-related piping exist. These isometrics were generated during the implementation of IE Bulletin 79-14 work and include support locations and support drawings (in most cases).

b. Engineering judgment will be employed to decouple large systems into smaller piping stress problems where possible. Decoupling will be employed at large equipment nozzles, at six-way restraints (wall and floor penetrations) and at pipe interfaces where the moment of inertia ratio of run to connecting pipe is ten or greater.

c. Extremely large systems may be analyzed by overlapping models, e.g., a large portion of the piping may appear on both models.

d. Floor-mounted pumps will be modeled as anchors. Valves will be modeled as pipes with three times the torsional and flexual section moduli of the connecting pipe. Valve operators and other eccentric masses will be modeled as beams, with the properties of the connecting pipe, attached to the valve or in-line component with the eccentric mass at the estimated center of gravity location.

e. Variable support hangers will be input as spring constants for all static and dynamic analysis.

f. Constant support hangers will be modeled as forces for static deadweight analysis.

g. Rod type hangers will be modeled based upon anticipated response.

h. Stiffness for structural piping supports (stanchions, U-bolts, etc.) will be included in the structural models as appropriate.

i. A friction factor of .3 for pipes moving relative to a sliding support will be considered in support loadings when the relative movement exceeds 1/8 inch for piping systems which are dynamically analyzed.

REFERENCES

1. Letter from R. A. Vincent to D. M. Crutchfield, SEISMIC DESIGN CONSIDERATIONS, DATED 27 JULY 1981.

2. Letter from R. A. Vincent to D. M. Crutchfield, SEISMIC DESIGN CONSIDERATIONS, (transmittal of D'Appolonia Report), dated 26 August 1981.

3. Letter from d. M. Crutchfield to all SEP Owners, SITE SPECIFIC GROUND RESPONSE SPECTRA FOR SEP PLANTS LOCATED IN EASTERN UNITED STATES, 17 JUNE 1981.

4. Newmark, N. M., and W. J. Hall, "Development of Criteria for Seismic Review of Selected Nuclear Power Plants," NUREG/CR-0098, May 1978.

5. Ridall, R., and N. M. Newmark, "Statistical Analysis of Response of Nonlinear Systems Subjected to Earthquakes," Department of Civil Engineering Report UILU 79-2016, University of Illinois, August 1979.