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VERMONT YANKEE NUCLEAR POWER STATION

DESIGN CRITERIA
FOR
PIPE STRESS

YANKEE ATOMIC ELECTRIC COMPANY
FRAMINGHAM, MASSACHUSETTS

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1.0 SCOPE

The purpose of this document is to provide technical guidelines to perform pipe stress re-analysis of the Vermont Yankee Nuclear Power Station by Earthquake Engineering Systems, Inc., (EES) for Yankee Atomic Electric Company (YAEC). The systems that will require re-analysis shall be defined by the Project Engineer. Computerized piping stress analysis shall be done by nationally recognized, independently verified programs such as ADLPIPE (A.D. Little Co.), PIPESD (J.A. Blume & Associates) or NUPIPE (Nuclear (Services).

2.0 CODES

The following codes and standards shall be used in pipe stress analysis activities:

a) American National Standard Institute Code for Power Piping - ANSI B31.1 1977 Edition, hereafter referred to as ANSI B31.1

b) American Society of Mechanical Engineers ASME Boiler and Pressure Vessel Code - Section III (1977 Winter Edition)

c) Nuclear Regulatory Guideline 1.92 "Combining Modal Responses and Spatial Components in Seismic Response Analysis"

d) American Society of Mechanical Engineers - "ASME Boiler and Pressure Vessel Code, Section I & VIII, Division I; 1977 Winter Edition

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3.0 REFERENCE DOCUMENTS

The following reference documents shall be used in carrying out the pipe stress analysis activities:

a) Yankee Atomic Electric Company, "Final Safety Analysis Report, Vermont Yankee Nuclear Power Station"

b) Vermont Yankee Insulation Specification VYNP-III-I-1

c) Vermont Yankee Piping Specification "BWR-QC10"

d) Grinnel Pipe Hanger Catalog, PH-76

e) Vermont Yankee Nuclear Power Plant Flow Diagrams and Piping Drawings

f) YAEC Stiffness Coupling Criteria (letter MEG 58/81, dated 2/11/81)

4.0 DESIGN AND ENGINEERING

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4.1 Geometry Modeling:

The following considerations shall be made for geometry modeling.

Each problem shall be considered from anchor to anchor. If anchor to anchor exceeds program limitations, the following approach shall be considered in modeling:

- Overlapping in such a way that there is negligible migration of loads from one problem to another.

- Bracketing results of multiple computer runs to assess boundary conditions or loading conditions.

The geometry and restraint conditions shall be modeled in accordance with EES "As-Built" Isometrics.

The pipe material properties and analysis condition shall be considered as per YAEC's approved documentation such as the Vermont Yankee Piping Specification (BWR QC-10), YAEC flow diagrams, the Vermont Yankee Insulation Specification (VYNP-III-I-1) and Grinnel catalog data.

Branch lines will be considered coupled statically and dynamically to the main run pipe if the following requirement is met:

a) Branch lines with a nominal diameter greater than 2½ inches: Couple the systems if the ratio of moments of inertia (pipe/branch) is 25:1 or less

b) Branch lines with a nominal diameter 2 inches and less: Couple the systems if the ratio of moments of inertia (pipe/branch) is 10:1 or less

Equipment nozzles and penetrations shall be considered anchor points in the analysis. Loadings shall be summarized on EES Anchor Load Summary and Nozzle Load Summary forms and included in the Piping Analysis Summary calculation.

Valves shall be modeled as follows:

- Thickness of the valve body shall be assumed as twice the connecting pipe wall thickness

- Diameter of the valve body shall be modeled as 1½ times the matching pipe diameter

- Manually operated valves and check valves shall be modeled with the mass of the valve concentrated at the centerline of the pipe midway between the valve inlet and outlet.
- Motor and air operated valves shall be modeled as eccentric mass points. The total weight of the valve shall be concentrated at a point one-third (1/3) the distance between the centerline of the pipe and centerline of the operator assembly (one-third of the "stem length" measurement as noted on the valve data form)
- Body length of the valve shall be assumed as two (2) pipe diameters if not divisioned on the isometric drawing.

Seismic accelerations on the valves shall not be summarized.

As per ANSI B31.1 code requirements, bypass lines shall be assumed to be Schedule 80, and of a material of the same nominal chemical composition and physical properties as that used for the mainline, unless otherwise specified on YAEC flow diagrams or the VYNP piping specification.

Flanges shall be considered as additional weights. Flange thickness shall be assumed to be the same thickness as the connected pipe for purposes of modeling stiffness.

Stress intensification factors for tees, reducers, flanges, elbows and couplings (half and full) shall be considered as per code requirements (ANSI B31.1) and all applicable ASME and manufacturer's published test data.

For the purpose of analysis, penetration shall be treated as follows:

- Grouted penetrations: A two-way restraint condition shall be assumed to exist on either side of the penetration for all load cases. Axial restraint of the pipe shall not be considered unless a welded collar is indicated on the pipe and embedded in the penetration.
- Ungrouted penetrations: At ungrouted penetrations, deflection of the pipe $\leq$ ¼" shall be considered acceptable. Where deflections exceed ¼", further review of actual penetration clearances shall be initiated: Deflections shall be based on the combined thermal and seismic conditions.

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4.2 Dead Weight Analysis

- Dead weight analysis shall be performed considering weight of the pipe, contents, insulation, concentrated masses (other pipes supported off pipe, flange etc.). Dead weight analysis stress results exceeding 1500 psi shall be brought to the attention of the P.E.

4.3 Thermal Analysis:

- Thermal analysis of the piping system shall be performed based on maximum design temperatures as designated on YAEC flow diagrams. Overstresses due to thermal considerations shall be brought to the attention of the P.E. Subsequent thermal analysis may be initiated on a reduced temperature as directed/approved by YAEC.

- Thermal anchor movements at nozzles and penetrations shall be indicated on the as-built isometrics and shall be based upon original Ebasco Design Isometrics as defined in Work Instruction 1.

4.4 Application of Spectra:

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For each earthquake condition, three directions of earthquake will be considered. (Two horizontal components and one vertical component). The total response due to each of the three (3) components of earthquake shall be calculated first. These responses shall then be combined by the SRSS method (Square Root of the Sum of Squares). The procedures to be used in combining the modal responses and responses due to spatial components of earthquake shall be as follows:

1. The modal responses for each component of earthquake shall be combined by taking into consideration the modes with closely spaced frequencies in accordance with NRC Regulatory Guide 1.92 Rev. 1, February 1976 Subsections 1.2.1, 1.2.2, or 1.2.3.

2. The total systems responses due to the three (3) spatial components of earthquake are then combined by the SRSS method.

The responses of the Yankee site specific load case shall be used to evaluate the piping system and its support. For piping systems spanning several floors or with pipe supports connected to support structures attached to different floors, the response spectra for the analysis of the piping system shall be the envelope of the floor response spectra of all the floors involved.

Sustained Loading Stress Evaluation

The effects of pressure, deadload and other sustained mechanical loads shall satisfy:

$$\frac{PD_o}{4t_n} + \frac{.75i\ M_a}{Z} \leq 1.0\ S_h \qquad \text{(Eq. 5.2)}$$

Where:

P = internal design pressure, psig

D_o = outside diameter of pipe, inches

t_n = nominal wall thickness of component, inches

M_a = resultant moment loading on cross section due to weight and other sustained loads, inch - lbs

Z = section modulus, inches^3

i = stress intensification factor. The product of .75i shall not be taken as less than 1.0.

S_h = basic material allowable stress at maximum (hot) temperature; from ANSI B31.1 allowable stress tables

5.2 Occasional Loading Stress Evaluation

The effects of pressure, weight, other sustained loads, and occasional loads including earthquake shall satisfy:

$$\frac{PD_o}{4t_n} + \frac{.75i\ M_a}{Z} + \frac{.75i\ M_b}{Z} \leq k\ S_h \qquad \text{(Eq. 5.3)}$$

Terms are the same as previously described, except:

k = 1.2 for evaluation of loading considering the OBE

k = 1.8 for evaluation of loading considering the SSE

M_b = resultant moment loading on the cross section due to earthquake inertia only

5.3 Additive Stress (thermal) Evaluation

The requirements of either equation 5.3(a) or 5.3(b) shall be satisfied:

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- Thermal expansion alone -

$$S_e = \frac{i\,M_c}{Z} \leq S_a \quad \text{Eq. 5.3(a)}$$

Terms are as previously described, except:

M_c = range of resultant moments on the pipe cross section due to thermal expansion of the system and thermal anchor movements. Consider moment effects of earthquake anchor displacements (SSE only) as full range and combine with thermal moments

S_a = The allowable stress range for thermal expansion stresses, where:

$$S_a = f\ (1.25\ S_c + 0.25\ S_h)$$

S_c = basic material allowable stress at system minimum (cold) temperature from the ANSI B31.1 Allowable Stress Tables

S_h = as previously described

f = stress range reduction factor for cyclic conditions. (This will always be assumed as 1.0 for Vermont Yankee analysis)

- Sustained Plus Thermal Expansion Stress -

$$\frac{PD_o}{4t_n} + \frac{0.75i\,M_a}{Z} + \frac{i\,M_c}{Z} \leq (S_h + S_a) \quad \text{(Eq. 5.3(b))}$$

Terms are as previously described. Use only if Eq. 5.3(a) fails.