52-001

October 16, 1992

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U.S Nuclear Regulatory Commission
1155 Rockville Pike
Rockville, MD 20852

Dear Shou:

Enclosed are responses to the Piping Design Audit open items A-12 and A-25. If you have any questions, please call me (408-925-4824) or Maryann Herzog (408-925-1921).

Sincerely,

Jack Fox

Jack N. Fox
Advanced Reactor Programs

cc: Chet Poslusny (NRC)
Giuliano DeGrassi (BNL)

17-126

D050

ABWR CERTIFICATION PROGRAM
PIPING ANALYSIS

ITEM NO. : A-12

Combination of Inertia & Relative Support Motion Effects

GE RESPONSE

by

DK HENRIE

October 1992

GE NUCLEAR ENERGY

SAN JOSE, CALIFORNIA

1.0 DESCRIPTION OF CONCERN

ITEM NO. : A-12. "2. Provide justification for SRSS combination of inertia and displacement effects.

2.0 GE NUCLEAR ENERGY RESPONSE

"The inertia (primary) and relative support displacement (secondary) stresses are dynamic in nature and their peak values are not expected to occur at the same time. Hence, combination of the peak values of inertia stress and anchor displacement stress quite conservative. In addition, the anchor movement effects are computed from static analyses in which the support displacements are applied to produce the most conservative loads on the piping. In view of this, the combination of primary and secondary stresses shall be by SRSS".

3.0 THEORETICAL BASIS

Piping systems which experience Independent Support Motion (ISM) excitations are analytically benchmarked by linear, ISM, time history analyses in which each support degree-of-freedom undergoes an independent acceleration time history excitation. The theoretical basis for the benchmark linear, ISM, time history analysis is derived in Attachment A. The resulting equations are valid for any multi-supported structural system which undergoes ISM excitation. All terms which appear in the development are defined in the Nomenclature section (i.e., Section 1.0) of Attachment A.

The dynamic mode nodal displacement time history vector due to ISM excitation is given by Equation (27) of Attachment A. The corresponding nodal acceleration time history vector is given by Equation (28). The components of both the nodal displacement and the nodal acceleration vectors are absolute quantities relative to an inertial reference systems. The equations are general and apply to any multi-supported system including piping systems. The following comments are specifically directed to the ISM analysis of piping systems.

The piping model member end loads (shears, moments, axial, torsional), hence stresses, are obtained as the matrix product of the piping stiffness matrix and the piping nodal displacement vector given by Equation (27). That is

$$\underline{f} = \underline{\underline{K}}_{11} \, \underline{x}^{1}(t) = \underline{\underline{K}}_{11} \left[\underline{\phi} \, \underline{q}(t) - \underline{\underline{K}}^{-1} \underline{\underline{K}}_{1e} \, \underline{x}^{e}(t) \right] \quad \ldots (27\text{-}1)$$

The dynamic part of the response is given by the first term on the right side of both Equations (27) of Attachment (A) and Equation (27-1) above. The pseudo-static part of the response due to the relative anchor motion is given by the second term on the right side of both equations.

To justify the combination of the dynamic (inertia) and the pseudo-static (relative anchor motion) contributions to obtain the total response, it is sufficient to refer to only Equation (27) of Attachment A.

The following observations are made based on Equation (27):

1) For each degree-of-freedom i, the dynamic and the pseudo-static contributions are time inconsistent; i.e., their peak

values do not occur at the same instant in time.

2) In general, the combined response peak value is time inconsistent with both the dynamic peak value and the pseudo-static peak value. That is the combined response peak value occurs at a time different from that of either the dynamic or the pseudo-static peak values.

3) Consequently, it is inordinately conservative to combined the peak value of the dynamic response with the peak value of the pseudo-static response by the absolute sum method.

4) A more representative (i.e., a much better statistical representation of the) combined peak response is given by the SRSS combination of the peak dynamic and the peak pseudo-static values.

In addition, the piping analysis nodal displacements (hence member end loads, hence member stresses) are obtained by the model superposition, response spectrum methodology. Consequently, the peak values of the dynamic response part of Equation (27) are obtained by conservative response spectrum analysis. Furthermore, the pseudo-static peak responses, corresponding to the second term on the right side of Equation (27), are obtained by separate, very conservative static analyses in which the non time consistent, maximum relative anchor support displacements are applied to produce the most conservative loads on the piping model.

In summary, in the benchmark ISM time history analysis the dynamic and pseudo-static peak values are not time consistent with each other

nor are either time consistent with the corresponding combined response peak value given by Equation (27). Furthermore, the peak values of the dynamic responses are obtained from conservative response spectrum analyses and the peak values of the pseudo-static responses due to relative anchor motion are obtained from very conservative, independent static analyses as described above. Consequently, the resulting peak dynamic (inertia) and the peak pseudo-static (relative anchor motion) responses can be conservatively combined by the SRSS method.

One final note, the nodal absolute acceleration time history vector given by Equation (31) includes both the dynamic (inertia) and pseudo-static (relative anchor motion) contributions. Consequently, the Amplified Response Spectra (ARS) corresponding to, and generated from, the Equation (31) acceleration time histories will also include the inertia and the relative anchor motion contributions.

(END)