Safety Evaluation Report by the Office of Nuclear Reactor Regulation

Long Term Service Plan - SEP Seismic Reevaluation

Criteria and Methodology

San Onofre Nuclear Generating Station Unit No. 1

Docket No. 50-206

1.0 INTRODUCTION

This safety evaluation presents the results of the staff's review of the Long Term Service (LTS) Seismic Reevaluation Program Criteria and Methodology for San Onofre Unit 1. The licensee, Southern California Edison Company (SCE), has proposed to apply these criteria and methods to complete the seismic reevaluation and identify any necessary plant modifications to demonstrate that the safety-related structures, systems and components at San Onofre Unit 1 can withstand a 0.67g modified-Housner spectrum earthquake.

2.0 BACKGROUND

The history of the seismic reevaluation program for San Onofre Unit 1 is presented in the staff safety evaluation issued on November 21, 1984 (Ref. 1). As noted in that evaluation, the reevaluation and implementation of plant modifications has been completed in stages. One phase of this reevaluation effort, the Return to Service (RTS) Plan, consisted of a program to demonstrate the capability of the plant to achieve and maintain a hot standby condition following the postulated 0.67g modified-Housner spectrum earthquake, in order to justify plant operation until completion of the seismic reevaluation of the plant. The licensee proposed several evaluation methods and criteria as part of this RTS plan.

On February 8, 1984, (Ref. 2), the staff issued a safety evaluation report on the licensee's return to service plan and criteria. That evaluation addressed the acceptability of the reevaluation criteria both for short-term (one cycle) and for long-term operation.

On November 21, 1984, (Ref. 1), the staff issued a Contingent Rescission of Suspension and supporting safety evaluation report addressing implementation of the RTS plan and the capability of the plant to achieve a hot standby condition following a 0.67g modified-Housner spectra earthquake. That action authorized plant operation in accordance with its specified terms. In particular, the staff required that the seismic reevaluation program and resulting plant modifications be completed by the end of the next refueling outage unless a case-by-case justification for any further extension was provided. The plant is currently scheduled to shutdown for refueling in November 1985.

By letter dated March 12, 1985 (Ref. 3), the licensee submitted a report entitled "Seismic Program for Long Term Service," which presents the proposed criteria and methodology for completion of the seismic reevaluation of San Onofre Unit 1. Additional information relating to the licensee's proposal was provided in letters dated March 29, April 15, April 30, May 14, June 4, June 26, 1985, and July 19, and August 2, 1985, (Ref. 4-11), and in several meetings with the staff (Refs. 12-15).

The staff issued preliminary findings on the proposed criteria and methodology on March 27, 1985 (Ref. 16). The following evaluation is cross-referenced, as appropriate, both to the licensee's March 12, 1985 submittal (e.g., LTS Section 3.1) and to the staff's March 27, 1985 review (e.g., NRC item 1.1), with respect to specific methods or criteria proposed.

3.0 EVALUATION

3.1 Large Bore Piping

The licensee's proposed approach for large bore piping reevaluation is described in Reference 3 and also in enclosures to the April 15, 1985, and June 4, 1985 submittals (Refs. 5 and 8).

The basic approach is to specify methods and criteria which will account for the capability of piping systems to absorb energy when stressed beyond their elastic limit. To this end, the licensee has proposed to assess piping integrity by establishing strain limits of material to ensure that deformation of the pipe is sufficiently limited.

3.1.1 Acceptance Criteria for Piping (LTS Section 3.1, NRC items 2.1 and 2.3)

3.1.1.1 Strain

The licensee has proposed an acceptance criteria of 1% strain for carbon steel material and 2% strain for stainless steel. The licensee's basis is described in the March 12, 1985 (Ref. 3), April 15, 1985 (Ref. 5), and June 4, 1985 (Ref. 8) submittals, as well as during several meetings with the staff (Ref. 12 to 15).

Based on the review of this information, the staff concludes that an acceptance limit of 1% strain is acceptable for both carbon steel and stainless steel. This conclusion is based on favorable test results (such as ANCO, Ref. 7), operating experience and the recommendations of the NRC's Piping Review Committee in Volume 2 of NUREG-1061 (Ref. 21).

In specific cases, calculated strains of up to 2% may be appropriate for stainless steel, provided the following failure modes are adequately addressed:

(1) the onset of plastic tensile instability, (2) low-cycle fatigue or plastic ratcheting, (3) the onset of local or system buckling, (4) excessive deformation (resulting in more than a 15% reduction, or less as required by system performance, reduction in cross-sectional flow area), or (5) functional failure of pipe-mounted equipment.

Application of a 2% strain criterion will be reviewed on a case-by-case basis as part of the staff's implementation review.

3.1.1.2 Stress

In order to establish the ductile capability of a system, non-linear analysis techniques are commonly used. However, non-linear analyses are time consuming and expensive. To simplify the analysis process, the licensee proposed to establish an equivalent stress limit to be used with linear analysis methods to screen out the most critical cases for more detailed analyses. For purposes of performing linear piping analyses, the licensee proposed to use Equation 9 of the ASME Code (1980 Edition, Winter

1980 Addenda), Subsection NC, for Class 2/3 piping for Level D Service conditions with a limit of twice yield stress:

$$\frac{PDo}{4t} + .75\ i\ \frac{Ma+Mb}{Z} \leq 2.0\ Sy$$

Nozzles would be evaluated for level C limits in accordance with the ASME code.

The basis for the licensee's proposed limit of 2.0 Sy is presented in a report dated June 4, 1985 (Ref. 8), as well as in References 3, 5, and 14. The limit was chosen by correlating the calculated stress with the proposed strain limits based on a comparison of linear and non-linear analyses for two "typical" piping systems at San Onofre 1, and on experimental test results.

The allowable stress associated with the equations in various editions of the ASME Code are established by consensus committee judgements. Similar judgements were used to develop the piping criteria in the September 1982 SEP Guidelines (Ref. 17). The acceptance criteria associated with specific linear analysis equations in the Code involve a relatively complex interrelationship of geometry, materials and environmental conditions, and infers elastic behavior. While the staff agrees that an equivalent stress can be developed from linear elastic analyses to estimate plastic behavior for specific circumstances, the staff does not believe that an adequate basis has been established to explain the relationship between the proposed general criterion of 2.0 Sy and the Code criteria, nor has the licensee established adequate constraints for the application of this criterion in conjunction with other proposed analysis methods. Therefore, the staff will require that the licensee use the piping acceptance criteria in the SEP Guidelines (i.e., 1.8Sh for Class 1 and 2.4Sh for Class 2/3). For cases that exceed the SEP Guidelines, additional analyses should be conducted to establish the capability of the specific piping configuration, as compared to the strain criteria previously discussed.

For example during the July 1-2, 1985 meeting (Ref. 15), the licensee proposed a formula to be used to calculate piping strain from elastically-calculated stress. The resulting strain would then be evaluated against the strain limits discussed above. The formula proposed by the licensee is of the form:

$$\varepsilon = \frac{K}{E}\,\sigma_e$$

where ε is the strain, σ_e is the elastically-calculated stress, K is an empirically-derived function which linearly approximates strain hardening, and E is Young's Modulus. The staff concludes that this approach is acceptable, provided that the method used to calculate the value of ε is consistent with Section NB of the ASME Code.

3.1.2 Branch Line Decoupling Criteria (LTS Section 3.1(1) and NRC item 2.2)

To simplify the analysis of large-bore piping with branch lines, the licensee proposed criteria which specify the manner by which the branch lines may be decoupled from the analysis without significantly influencing the results.

The staff's position on the branch line decoupling criteria is stated in the March 27, 1985 letter (Ref. 16). Specifically, the following rules apply:

1) if the moment of inertia ratio is 25 or more for a pipe diameter ratio greater than or equal to 3, the branch line may be decoupled;
2) decoupling is not allowed if there is an anchor or another branch line in close proximity; and
3) decoupling is not allowed if the pipe segment includes a termination which defines a reaction load.

The licensee agreed to this position in the June 4, 1985 submittal (Ref. 8). The staff concludes that these criteria are acceptable because they will ensure that only branch lines that do not significantly affect the response of large-bore piping may be decoupled from the analysis.

3.1.3 Seismic to Non-Seismic Decoupling Criteria (LTS Section 3.1(2) and NRC item 1.1)

For a line which contains seismic and non-seismic class piping, the piping analysis will include a portion of the non-seismic piping either to the next anchor or to the second support in each of the three orthogonal directions, whichever is closer. The staff concludes that these criteria are acceptable because they will ensure that the effects of the loading from the non-seismic line is adequately included in the analysis of the piping within the seismic reevaluation scope.

3.1.4 Support Stiffness (LTS Section 3.1(3) and NRC item 1.1)

As discussed in the proposed LTS criteria (Ref. 3), the licensee plans to use generic support stiffnesses to model pipe supports. For cases where pipes are connected to flexible secondary structures, the influence of support flexibility will be assessed. (See discussion in SER Section 3.13).

The piping response analyses are generally insensitive to wide variations in the support stiffness value; therefore, the staff concludes that the use of generic support stiffnesses is acceptable, except for the flexible secondary structures as described above.

3.2 Small Bore Piping and Tubing (LTS Sections 3.2 and 4.3 and NRC item 1.3)

Small bore piping will be evaluated using a walkdown method, in a manner similar to the RTS approach. The staff's November 21, 1984 SER (Ref. 1), noted that some additional guidance should be provided in the walkdown methods and criteria to ensure that sufficient horizontal and uplift supports are established. The walkdown criteria were also to be validated by stress analyses for representative configurations, to ensure proper treatment of valve eccentricity effects and anchor movement and to check the reduced span criteria for elbows and bends.

The LTS walkdown criteria and supporting analyses were presented to the staff during the April 30-May 1, 1985 meeting and were submitted on April 30, 1985 (Refs. 13 and 6).

A staff consultant participated in part of the walkdown of small bore piping at the site to observe how the criteria are implemented. In general, the staff concludes that the walkdown criteria for small-bore piping are adequate. The staff is continuing its review of the supporting analyses. The results of that review will be combined with the staff's audit of the implementation of these criteria; if necessary, additional confirmatory analyses may be required to demonstrate the seismic capability of unique piping configurations.

3.3 Pipe Supports

3.3.1 Structural Steel (LTS Section 3.3.1 and NRC items 2.6 and 3.1)

The licensee has proposed to apply the allowable values for structural steel (e.g., linear supports) that are presented in the ASME Code, Section III, including the Summer 1983 Addenda, for Level D loads.

Because the analyses for calculating stresses or deflections beyond the elastic limit are complex and time-consuming, the licensee proposed a 30% increase in the Code yield stress. This criterion is based on an increase of 18% for the average material yield stress, based on test results compared to the lower bound yield stress specified by the Code. An additional 10% increase in yield stress would be applied for steel components, to account for the strain-rate effect. This 30% increase of yield stress would only be applied to identify those supports which require more detailed non-linear analyses.

A ductility ratio of less than three would be applied when performing non-linear analyses, which would be compared to the Code yield stress, as discussed in Section 3.4. The staff requested that the licensee confirm that a 30% increase in yield stress results in a ductility ratio of less than three for representative configurations. These analyses were provided in the April 15, 1985 and June 4, 1985 submittals (Refs. 5 and 8); the ductility ratio was determined to be less than 1.7 for cases with both uniaxial and biaxial bending. These analyses demonstrate that the increased yield stress for linear analyses is comparable to a direct materials approach to ductile behavior. The non-linear analyses would be compared to a ductility ratio of three bassed on the Code yield stress.

Based on a review of the applicable test data, including specific material properties reported by the licensee for San Onofre 1, and the favorable comparison of the ductility ratios, the staff concludes that the proposed increase in the allowable yield stress to account for more realistic material capability is acceptable.

3.3.2 Concrete Expansion Anchor Bolts (LTS Section 3.3.2 and NRC item 3.2)

The licensee's proposed allowable loads for concrete expansion anchor bolts are the manufacturer's reported ultimate capacity with a minimum factor of safety (FOS) of 4 on wedge type anchor bolts and a FOS of 5 on shell type anchor bolts. These criteria are the same as those given in the SEP guidelines (Ref. 17) and, therefore, are acceptable to the staff.

The licensee has proposed that for some special cases, existing anchor bolts may be qualified with a FOS less than 4, but greater than 2, provided that the overall FOS for the affected support meets the criteria (FOS of 4 or 5) and that all bolts on adjacent supports satisfy the FOS of 4 or 5 requirement. The licensee's approach is described in the March 12 and

June 4, 1985 submittals (Refs. 3 and 8). As noted in the staff's March 27, 1985 letter (Ref. 16) such applications will be evaluated on a case-by-case basis. In general, the staff concludes that a FOS greater than 2 for individual anchor bolts, in conjunction with an overall FOS of 4 or 5 for the entire support, is sufficient to ensure the integrity of the support, provided that load redistribution effects are adequately assessed.

3.3.3 Catalog Specifications (LTS Section 3.3.3 and NRC item 2.4)

The licensee proposed the use of manufacturers' load capacity data for component standard supports, based on Level D service conditions, to qualify new supports. For existing supports, the licensee has proposed qualification by analysis or comparison to test data, with a minimum FOS of 2.

Manufacturers' catalog specifications are generally established in a conservative manner, consistent with applicable quality assurance requirements for nuclear applications; therefore, the staff considers their use acceptable. For existing supports, the staff considers a minimum FOS of 2 acceptable, provided that the analysis appropriately considers uncertainties in the methods or data. Therefore, the staff will audit selected cases during implementation to ensure that uncertainties have been appropriately addressed.

3.3.4 Welds (LTS Section 3.3.4 and NRC item 2.5)

The licensee has proposed use of ASME level D stress criteria (1980 Winter Addenda) for pipe support welds. For full penetration welds, the base material allowable stresses would be used.

The staff finds these criteria acceptable, provided that the licensee can establish that the welding procedures and controls used during construction of the support provide reasonable assurance that weld strength is always greater than or equal to that of the base-metal. The licensee has committed to supply further information regarding welding practices.

3.4 Secondary Steel Structures (LTS Section 3.4 and NRC items 2.6 and 3.1)

The criteria for secondary steel structural members proposed by the licensee are the rules specified in the AISC Code. The licensee also proposed specific criteria for non-linear analyses i.e. a ductility ratio for flexible members up to 3 and strain limits for the members in pure tension.

The first step in the evaluation of highly-stressed secondary steel members would be a 30% increase in yield stress, on the same basis as that proposed for pipe supports (See Section 3.3.1), for screening the steel members to identify cases requiring a more detailed analyses. The ductility ratio criterion would then be applied to determine whether the member has adequate load-carrying capacity. If the member exceeds the ductility ratio criterion, a more detailed non-linear analysis may be performed.

During the RTS program evaluation, this issue was addressed in an August 7, 1984 staff evaluation (Ref. 18). The staff concluded that the ductility criterion is acceptable provided that all requirements specified in the staff's letter dated August 7, 1984 (Ref. 18) are met and an evaluation is performed on a system-wide basis of the piping, supports, and connections to confirm system integrity. The licensee has agreed to perform such system evaluations; the staff will review these cases as part of the implementation review.

As for the strain criteria, the staff concluded that to allow one-half the ultimate uniform strain for tension members is not acceptable. As discussed during the April 2-3, 1985 meeting (Ref. 12), and in the June 4, 1985 submittal (Ref. 8), this proposal has been withdrawn by the licensee.

3.5 Mechanical Equipment (LTS Sections 3.5 and 4.6 and NRC item 1.4)

The proposed criteria for mechanical components and equipment (pumps, heat exchangers, filters) are based on the requirements of the ASME Code, 1983 Edition, including Summer 1983 addenda, for Level D service conditions. The staff finds these criteria acceptable.

The mechanical equipment analyses will be conducted using equivalent static or dynamic analyses, consistent with current practice. Equipment nozzles will be analyzed by a Bijlaard technique (WRC Bulletin 107). The staff concludes that these methods are acceptable, provided that the limitations of the particular method (e.g., range of applicability) are appropriately considered. As noted in Section 3.8, the licensee has committed to address the applicability of this technique for the cases analyzed. The staff finds this approach acceptable and will audit the results during the implementation review.

3.6 Valves (LTS Sections 3.6 and 4.7 and NRC item 2.7)

Active valves, i.e., those required to operate following the seismic event, will be evaluated using the Level C service condition limits of Subsection NF of the ASME Code in order to demonstrate that the yoke remains elastic. Stresses will be limited to below the yield point so that no plastic deformation of the valve occurs. Valves that are not required to operate would be evaluated against the Level D limits of the ASME code in order to demonstrate structural integrity. The staff finds these criteria acceptable.

The valve analyses will be conducted using equivalent-static hand calculations which consider gravitational, operational and seismic inertial loads. The valve accelerations are obtained directly from the piping analyses. These methods are reasonably consistent with current analysis techniques and are, therefore, acceptable.

3.7 Refueling Water Storage Tank (RWST) (LTS Section 3.7 and 4.8)

An analysis report for the RWST, including the criteria and methodology description, was submitted on April 30, 1985 (Ref. 6).

The staff is currently reviewing that report. The results of this review will be included in the staff's evaluation of SCE's implementation of the LTS program.

3.8 Penetrations (LTS Sections 3.8 and 4.9 and NRC item 1.5 and 2.10)

The boundary definition for containment penetrations was provided in the licensee's response to Item 18 of the March 12, 1985 submittal (Ref. 3). Specific criteria and methodology for each element (i.e., piping segment or component support) are the same as those applied in general for piping and supports in the LTS evaluation. The induced load stresses in the containment structure will be compared to the criteria in subsection NE of the ASME Code, which is applicable to steel containments. The staff finds this approach acceptable.

As described in the licensee's June 4, 1985 submittal (Ref. 8), the containment penetrations will be analyzed using stress calculations, including textbook solutions, axisymmetric finite-element analyses, or the Bijlaard technique (see Section 3.5). The staff concludes that these methods are acceptable, provided that the limitations of the particular method (e.g., range of applicability) are appropriately considered. The licensee has committed to consider the limits of applicability (e.g., geometric configuration) of the various techniques for each application. The staff finds this approach acceptable and will audit the results during the implementation review.

3.9 Electrical Raceways (LTS Sections 3.9 and 4.10 and NRC item 2.8)

The criteria and methodology for electrical raceways (cable trays and conduits) is based on the RTS criteria described in the licensee's October 2, 1984 and May 14, 1985 submittals (Refs. 19 and 7). In some cases, the pipe support criteria discussed above will be used to evaluate raceway supports. Raceway deflections will be limited to ensure electrical cable integrity.

In general, the staff concludes that the criteria and analysis methods proposed for electrical raceways are reasonable because they are consistent with current piping criteria and methods. Because of the continuing evolution of information related to the seismic evaluation of electrical raceways, the staff will review the licensee's raceway analyses as part of the implementation of the LTS program.

3.10 Load Generation Methods

For the LTS reevaluation, the licensee has proposed to generate new instructure response spectra for the analysis of the piping end equipment located in the reactor building and the turbine building. In other locations, the in-structure response spectra previously generated for San Onofre 1, as submitted on July 9, 1982 (Ref. 20), will be used.

3.10.1 Ground Motion Time History (LTS Section 4.1.1 and NRC item 1.2)

A set of new artificial time histories (three statistically independent components) of ground motion has been generated to match the 0.67g modified Housner response spectrum. The staff concluded on March 27, 1985 (Ref. 15), that the proposal to generate new artificial time histories is acceptable provided that the results satisfy the criteria in Section 3.7.1 of the Standard Review Plan (NUREG-0800).

By letter dated June 4, 1985 (Ref. 8), the licensee confirmed that the SRP criteria (e.g., suggested frequency increments, no more than five points of the time history results shall fall below, and no more than 10% below, the design response spectra) are generally met. As discussed during the July 1-2, 1985 meeting (Ref. 14), for some damping values or at some frequencies outside the range of interest, minor deviations from the SRP criteria occurred; for example, in the vertical direction with 2% damping, a difference of -11.5% occurs at 0.46 Hz. However, these deviations will not have a significant effect on the response because they occur at frequency ranges not relevant to the analyses. A plot of the results was presented during the April 30-May 1, 1985 meeting (Ref. 13). In response to a staff request, the digital results were provided during the July 1-2, 1985 meeting (Ref. 15).

Based on this information, the staff concludes that the artificial time histories generated for San Onofre 1 are reasonably consistent with current criteria and are, therefore, acceptable.

3.10.2 Reactor Building Soil-Structure Interaction (LTS Section 4.1.2 and NRC item 3.3)

For the containment/reactor building, the licensee proposed to generate new floor response spectra using a soil-structure interaction approach which reflects the state-of-the art.

3.10.2.1 Methodology

The floor response spectra for the containment/reactor building would be generated through a combination of the SASSI and CLASSI computer codes. This methodology was discussed during the April 2-3, 1985 meeting (Ref. 12). The SASSI code allows for three-dimensional modeling of the embedded containment structure and soil foundation. The impedances calculated by SASSI are then used in CLASSI to generate the floor response spectra.

Attachment 1 to this safety evaluation is a Technical Evaluation Report (TER) which describes a detailed evaluation of the SASSI/CLASSI methodology for the San Onofre 1 application, performed by an NRC contractor. That review considered the pertinent theory, methodologies computer codes, and application. In addition, a test problem was developed to compare the solution from the method proposed by the licensee with the solution from methods previously accepted by the staff. Based on the information presented in the TER, the staff concludes that the methodology is acceptable for use in the San Onofre 1 seismic reevaluation.

The SASSI/CLASSI in-structure response spectra peaks will be broadened by ± 15% to account for uncertainties in such parameters as the material properties of the structure, damping values, soil structure interaction methodology modeling techniques and soil variation, in accordance with Regulatory Guide 1.122.

3.10.2.2 Soil Parameters

Soil properties are important parameters in the SASSI code. The values originally proposed by the licensee are (1) a material damping of 11%; (2) a shear modulus of 1390 ksf, with soil variation studies to be done for a ± 10% variation; and (3) a Poisson ratio of 0.35.

The licensee provided additional justification for the soil parameters that they consider appropriate for this analysis in letters dated April 15, 1985 and June 4, 1985 (References 5 and 8). Supporting information was also provided in Reference 10. The staff is reviewing the proposed parameters relative to the soils evaluation that was conducted as part of the operating license application for San Onofre Units 2 and 3. The seismic analyses for San Onofre 2/3 did not use the soil properties in the same way as that proposed for the San Onofre 1 reevaluation and the staff has not yet reconciled the variations in the parameters proposed for this analysis. Consequently, the staff recommended that a material damping value of 8% be used for the SASSI analysis, consistent with the SEP Guidelines. The licensee has agreed. The staff's review of the San Onofre soil properties is continuing to confirm the parameter values.

3.10.3 Lumped-Parameter Time-History Method

In general, the response spectra for the turbine building were originally generated by the lumped-parameter, time history approach. As discussed in Reference 14, the licensee has explained that the three newly developed components of ground motion time history will be applied simultaneously to the turbine building model previously developed by Bechtel. This approach is reasonably consistent with current analysis procedures and is, therefore, acceptable.

3.10.4 Direct Generation Method (LTS Section 4.1.3 and NRC item 3.3)

For the turbine building, the licensee had proposed to use the direct generation method, using the FLORA computer code. In-structure response spectra are determined directly from the input ground response spectrum and the dynamic properties of the structure. This method considers the effects of interaction between the structure and subsystems, i.e., those where the frequencies of the two systems are close.

During the April 2-3, 1985 meeting (Ref. 12), the staff provided a test problem to be performed by the licensee for comparison to response spectra calculated by methods previously accepted by the staff. The results of this test problem were submitted by letter dated April 15, 1985 (Ref. 5). Attachment 3 to this evaluation is a TER, prepared by a NRC contractor, which provides the results of their review of the FLORA theory, intended application for the LTS program, and the test problem comparison. Based on results presented in the TER the staff concludes that the direct generation method using FLORA is acceptable for the proposed application.

Because of the cost required to use "FLORA" to generate floor response spectra for the entire turbine building (including deck extensions), the licensee proposed a modified time history analysis method during the July 1-2, 1985 meeting (Ref. 14). The floor response spectra are first generated by time history analysis and then these spectra are modified by multiplying a correction factor, calculated from FLORA results, to remove the conservatism due to the spectra-enveloping requirement. For cases where the interaction effect between the structure and subsystems is significant, the direct generation approach (i.e. "FLORA" computer code) will be applied for local areas to develop the floor response spectra.

Based on the favorable results of the sample problem analysis and the sound theoretical basis of the FLORA code, the staff concludes that these approaches are acceptable. During the implementation review, the staff will audit the modified time history analyses and the modeling and results of the local applications of FLORA.

3.11 Linear Piping Analysis Techniques

Linear analysis of piping systems will be performed and the resulting stresses will be compared to the stress criteria previously discussed, to identify those areas for which further analysis or support modifications may be necessary.

3.11.1 Envelope Response Spectra Method (LTS Section 4.2.1.1 and NRC item 1.1)

Most of the large bore piping analysis will be performed with the envelope response spectra method. The responses to the three components of the earthquake will be combined by square-root-of-the-sum-of-the-squares (SRSS), as recommended in Regulatory Guide 1.92. Therefore, the staff finds this combination acceptable. Modal responses will be combined either by one of the combination rules in RG 1.92 or by the Complete Quadratic Combination (CQC). The neglected mass effect for modes in the rigid range will be considered.

Supporting information on the CQC method was submitted by letter dated March 29, 1985 (Ref. 4). A test problem was developed by the staff to evaluate this technique. The results of the licensee's analyses were submitted on April 15, 1985 (Ref. 5), as supplemented June 4, 1985 (Ref. 8). Attachment 2 to this evaluation is an NRC contractor's evaluation of the CQC technique. Based on review of the CQC theory, its intended application in the LTS program, and the results of the test problem comparison, the staff concludes that this technique is acceptable for modal combination with the envelope response spectra method.

The licensee has proposed to use the damping values recommended by the Task Group of the Pressure Vessel Research Committee (PVRC) of the Welding Research Council (WRC). As discussed in the staff's February 8, 1984 SER (Ref. 2), the use of these damping values with this method is acceptable.

In general, the response spectra peaks are broadened ± 15% to account for uncertainties. As an alternative, the spectral peak shifting method may be used in some cases. This technique is also acceptable, as described in the staff's February 8, 1984 evaluation (Ref. 2).

The licensee has proposed to combine seismic anchor movement effects with inertia effects by the SRSS method. The staff concludes that this is acceptable, based on the recommendation of the Piping Review Committee in NUREG-1061 (Ref. 21).

3.11.2 Multiple-Level Response Spectra Piping Analyses (LTS Section 4.2.1.2 and NRC item 1.6)

The envelope response spectra method, when applied to a piping system whose support members are attached to different structures or on different levels within a structure, results in an overprediction of the piping response. The multiple-level response spectra (MLRS) method allows the appropriate floor response spectra to be input at the point of attachment on the piping system. The overall response of the pipe is then calculated considering the dynamic (inertial) and pseudostatic (seismic anchor motion) components of the motion.

The licensee has proposed to use this method for selected piping analyses, when the input spectra at different levels in a structure or between buildings have wide variations.

The licensee has also proposed to use many of the same techniques for the MLRS method as were discussed above for the envelope response spectra method. However, as noted in the June 4, 1985 submittal (Ref. 8), peak shifting and CQC modal combination will not be used with the MLRS method. The staff agrees.

For combination of pipe system responses at the different levels of input motion, SRSS will be used if it can be shown that the correlation coefficient of the inputs is between plus or minus 0.16; otherwise, the absolute summation will be used. This approach deviates from that recommended in NUREG-1061 (Ref. 21), which would require absolute summation for all such cases. However, the staff agrees that SRSS is an appropriate combination method when the inputs are uncorrelated. Therefore, the staff will review the applications of SRSS, in this context, to ensure that the inputs are uncorrelated.

The responses to the three components of the earthquake of motion will be combined by SRSS. Modal response combination will be in accordance with the combination rules of Regulatory Guide 1.92.

The MLRS analysis will be performed with the SUPERPIPE computer code. This option of SUPERPIPE has not previously been bench-marked and approved by the NRC. A test problem was developed by the NRC's consultant to examine the floor response spectra calculated from FLORA, considering the piping-structure interation, and multiple-level piping response calculated with the SUPERPIPE code. The licensee's results for the test problem were submitted in letters dated April 15, 1985 and June 4, 1985 (References 5 and 8). Attachment 4 to this evaluation summarizes the results of the staff's review of the test problems. As discussed therein, the staff found the results inconclusive for purposes of establishing acceptability of the MLRS option of SUPERPIPE. It was concluded that the simplified test problems may not be representative for this method.

Therefore, the staff has provided to the licensee the generic test problems used for benchmarking of piping analysis computer codes. Results of the licensee's analyses for the benchmarking problems were discussed during the June 11, 1985 meeting (Ref. 14) and were submitted on August 2, 1985 (Ref. 11). Although the benchmarking review for the MLRS option of SUPERPIPE is continuing, the staff believes that an adequate basis for the application of MLRS can be developed subject to the limitations described below. Alternatively, independent confirmatory analyses may be used to establish whether there is sufficient margin for the MLRS cases.

The use of FLORA with the MLRS method is acceptable (subject to SUPERPIPE benchmarking) if RG 1.61 damping is used. The staff will review any such cases to evaluate how the effective mass (m_{ik}) is calculated, which accounts for pipe-structure interaction.

The licensee has proposed to use PVRC damping values with both FLORA and the MLRS method. Based on the analysis comparisons supporting the PVRC damping values, the staff concludes that the use of PVRC damping with FLORA is acceptable. However, the staff believes that, under certain circumstances, the combination of PVRC damping with the MLRS method may not include sufficient conservatism to offset the uncertainties associated with the combination of these approaches; therefore, any application of PVRC damping with the MLRS method (including decoupling and load combination assumptions) will be reviewed on a case-by-case basis during implementation. Similarly, the application of PVRC damping when the MLRS method is used in combination with FLORA is even more complex and less likely to include sufficient conservatism to offset the associated uncertainties; therefore, this combination of methods should not be used.

1.3 Time History Piping Analyses (LTS Section 4.2.1.3 and NRC item 1.7)

In some cases, the licensee may perform piping analyses with the time history method. The maximum responses from the three components of earthquake motion will be combined by SRSS. This is consistent with RG 1.92, and is acceptable to the staff. Damping values presented in RG 1.61 will be used with the time-history method. As discussed in NUREG-1061 (Ref. 21), PVRC damping is not considered suitable for use with the time-history analyses.

3.11.4 Similarity Method (LTS Section 4.2.1.4 and NRC item 3.4)

The licensee has proposed that for piping systems that are similar to systems that have been previously analyzed, the system will be evaluated by assessing the effect of the small changes, such as in routing or support configuration, on the system. If this approach is used, the licensee must completely establish establish the similarity of the systems. Because of the wide variety of configurations and, consequently, means to establish similarity, these analyses will be reviewed by the staff on a case-by-case basis during implementation.

3.11.5 Non-linear Analysis Techniques

The licensee has proposed to perform nonlinear analyses for some piping systems to account for plastic behavior of the system. These techniques would be used with the strain criteria discussed in Section 3.1.1.1.

3.11.5.1 Non-linear Time History Analyses (LTS Section 4.2.2.1 and NRC item 3.5)

A non-linear time history analysis was proposed as an alternative method by the licensee. In the March 27, 1985 letter (Ref. 16), the staff noted that generic studies performed in conjunction with Unresolved Safety Issue A-40 suggest that at least seven "real" time histories are necessary to adequately assess the phase relationships and that "artificial" time histories should not be used for non-linear analyses. In the June 4, 1985 submittal (Ref. 8), the licensee stated that a report describing the basis and application for this method would be provided at a later date.

The staff believes that, in selected cases, a single artificial time history may be sufficient to estimate a non-linear response. Therefore, the staff will review any such applications of non-linear time history analyses on a case-by-case basis.

3.11.5.2 Energy Balance Method (LTS Section 4.2.2.2 and NRC item 3.6)

The licensee has proposed the energy balance method to evaluate piping capability, such as in the area of an overstressed ("failed") pipe support. The basic approach is to develop a simplified model of the piping system so that hand calculations can be used to assess whether the piping can absorb the earthquake energy without excessive deformation. The energy balance method compares the maximum kinetic energy input from the earthquake to the minimum strain energy capacity of the piping. If the kinetic energy is less than the capacity of the piping, the load on the beam and resulting plastic hinge rotation is calculated. Experimental test relationships between rotation and strain are used to determine maximum strain for comparison to the strain limit as discussed in Section 3.1.1. The load redistribution to the supports adjacent to the "failed" support is then evaluated to ensure these supports remain elastic.

The application of this method has been discussed extensively between the staff and licensee and is described in the licensee submittals of March 12, 1985 and April 15, 1985 (Refs. 3 and 5). This method was also used on a limited basis for the RTS program.

As discussed in the staff's February 8, 1984 SER, (Ref. 2) the staff agrees that the energy balance theory is reasonable for assessing the impact of potential support failures on the integrity of the piping. In this respect, the energy balance method is analogous to the ductility criterion. However, care must be taken in its application to ensure conservative results.
The kinetic energy is calculated from the spectral acceleration corresponding

to the piping frequency. The acceleration at the lowest frequency is selected to maximize the kinetic energy. For very flexible piping (i.e., fundamental frequency less than that corresponding to the spectral peak), the peak acceleration should be used to bound the kinetic energy.

Some specific considerations regarding the energy balance methods were discussed during the June 10-11, 1985 meeting (Ref. 14). For instance, the means for considering the three dimensional responses, seismic anchor motion and thermal cycles were discussed.

The energy balance method uses simplified models to evaluate strain in the piping. Because of the uncertainty arising from this approach, it is the staff's position that when applying the energy balance method, the damping values in Regulatory Guide 1.61 or NUREG/CR-0098 (Ref. 24) should be used rather than PVRC damping. Further, the pipe-structure interaction effect should not be applied when using this approach.

During the audit reviews, the staff will review the application of the energy balance method, including development of the piping model, assessment of piping frequency, and the rotation-strain relationships, to ensure that strain in the piping remains within acceptable limits.

3.11.5.3 <u>Secant Stiffness Method (LTS Section 4.2.2.3 and NRC item 3.7)</u>

The secant stiffness method is described in the April 15, 1985 (Ref. 5) and the June 4, 1985 (Ref. 8) submittals. An example of its use was provided in an October 25, 1984 submittal (Ref. 22), which was supplemented by a June 26, 1985 report (Ref. 9).

A secant stiffness evaluation is an energy-based technique used to approximate the non-linear behavior of a piping support interaction with a quasi-linear elastic model. It is an iterative approach to establish an equivalent linear stiffness for the piping analysis that corresponds to the displacement from the yielding support. The theory associated with the secant stiffness method appears to be reasonable. Because of the variety in the configurations and uncertainties the staff will audit the application of this method during the implementation review.

3.12 Pipe Support Analysis Methods (LTS Section 4.4 and NRC items 3.8 and 3.9)

Pipe support loads will be calculated from dynamic piping analyses. These methods are reasonably consistent with current practice and are, therefore, acceptable.

As discussed in the licensee's June 4, 1985 submittal (Ref. 8), a snubber is considered to be inactive in pipe support analyses if it is in close proximity to a rigid support in the same direction. The specific "closeness" criteria are those that were accepted by the staff for Diablo Canyon (Ref. 23), and are therefore considered appropriate for the San Onofre 1 review as well.

For supports bearing multiple pipes, the licensee has proposed to combine the reaction loads on the support using the procedure described in their June 4, 1985 submittal (Ref. 8): (1) review the most significant modal frequencies of each pipe; (2) for those frequencies that are within 10% of each other, combine the support loads by the absolute summation method; (3) combine the previous result with the remaining loads by SRSS. If the frequencies are not closely spaced (i.e, all greater than 10%), all support loads would be combined by SRSS.

The staff believes that multiple-pipe supports should be analyzed assuming the individual pipe reaction loads are additive, particularly if the pipes are anchored in about the same location (i.e., similar input motion). However, if the licensee conservatively calculates the significant modal frequencies so that the pipe-to-pipe frequency differences are minimized and they are still greater than 10%, the staff agrees that SRSS is an appropriate method for combining the reaction load because they would be relatively independent loading functions as compared to the definition of "closely-spaced frequencies" in SRP Section 3.7.3. In view of the complexity in the assumptions involved, the staff will review any applications of this method on a case-by-case basis during implementation.

3.13 Secondary Steel Structures Analysis Methods (LTS Section 4.5 and NRC item 2.6)

Either simple hand calculations or computer codes would be used to calculate the support loads. These methods are reasonably consistent with current practice and are, therefore, acceptable.

When non-linear behavior of the beam results, the effect on the piping will be calculated either by the secant stiffness method or by coupled pipe/structure interaction analysis (i.e., FLORA).

As discussed under SER Section 3.1.4, generic support stiffnesses are used in the piping analyses. For non-rigid structures, or for yielding support structures, these stiffnesses may not be sufficiently representative such that the effect of the more flexible support on the piping must be evaluated. One method of evaluation is the secant stiffness method (see SER Section 3.11.5.3).

The licensee has defined a rigid structure as one that has its first mode frequency over 33 Hz or that deflects less than 1/8" under the seismic loading. The staff agrees that this is an appropriate evaluation criterion to identify flexible supports, provided that the dynamic nature of the loading is considered in the deflection calculation.

4.0 IMPLEMENTATION

As discussed during the June 10-11, 1985 meeting (Ref. 14), the licensee will prepare, for each piping system or component within the review scope, a summary table identifying which criteria and methods were applied to the seismic reevaluation and the resulting actions required, if any.

Figure 1 summarizes the interrelationships among the proposed criteria and methods for the evaluation of piping and supports. The purpose of this figure is to simply illustrate the wide variety of alternative methods that may be employed to evaluate the seismic capability of the safety-related systems. Moreover, as discussed in this safety evaluation, some criteria and analysis methods are appropriate for use only under certain conditions or in combination with others. The staff intends to select specific cases to audit, including an independent confirmatory analysis, as part of the review of the licensee's implementation of the LTS program.

5.0 CONCLUSION

The staff concludes that the methods and criteria proposed for the Long Term Service (LTS) program, as modified by and with the reservations and limitations noted in the foregoing evaluation, provide a reasonable basis to complete the seismic reevaluation of San Onofre 1 and to design any plant modifications necessary to ensure the plant's capability to withstand a 0.67g modified-Housner ground response spectrum earthquake.

The staff's review of the following related aspects of the seismic reevaluation is continuing; however, the staff belives that the methods and criteria involved are adequate to proceed with implementation:

- Soil Parameters for the soil-structure interaction analyses
- Confirmatory analyses for small bore piping
- Raceway analysis methods and criteria
- Refueling water storage tank analysis
- Benchmarking of MLRS option of SUPERPIPE

The staff will review the implementation of the modified methods and criteria to determine whether they have been appropriately applied. By that time, the related ongoing reviews should be complete. The staff's implementation review will pay particular attention to the following areas:

- large bore piping with calculated strains that exceed 1%
- concrete expansion anchor bolts with factor of safety less than 4
- existing support qualification (catalog items) with factor of safety near two
- weld material strength
- system-wide response evaluation for ductile secondary steel supports
- application of FLORA to local areas in the turbine building, including "correction factors" applied to floor response spectra from the lumped-parameter time-history analysis

- results of multiple level response spectrum analyses
- application of energy balance method
- analysis of penetrations
- application of secant stiffness method
- non-linear time history analyses
- application of the similarity method
- multiple-pipe supports

6.0 REFERENCES

1. Letter, D. G. Eisenhut (NRC) to K. P. Baskin (SCE), dated November 21, 1984, transmitting Contingent Rescission of Suspension and supporting Safety Evaluation Report.

2. Letter, H. R. Denton (NRC) to K. Baskin (SCE), dated February 8, 1984, Subject: Proposed Restart Plan for San Onofre Nuclear Generating Station, Unit No. 1.

3. Letter, M. O. Medford (SCE) to J. A. Zwolinski (NRC), dated March 12, 1985, Subject: Long Term Seismic Criteria and Methodology.

4. Letter, M. O. Medford (SCE) to J. A. Zwolinski (NRC), dated March 29, 1985, transmitting reports on FLORA, Correlation Coefficient for Combination of Piping Response, and Complete Quadratic Combination Technique for Modal Response.

5. Letter, M. O. Medford (SCE) to J. A. Zwolinski (NRC) dated April 15, 1985, transmitting Responses to Open Items from the April 2-3 Meeting and the Methodology Test Problems.

6. Letter, M. O. Medford (SCE) to J. A. Zwolinski (NRC) dated April 30, 1985, transmitting "Review and Development of Small Bore Piping and Tubing Criteria" and "Evaluation of the Refueling Water Storage Tank for Long-Term Service."

7. Letter, M. O. Medford (SCE) to J. A. Zwolinski (NRC) dated May 14, 1985, transmitting reference documents.

8. Letter, M.O. Medford (SCE) to J. A. Zwolinski (NRC) dated June 4, 1985, transmitting 1) Long Term Service Status Report, 2) Technical Basis for Piping Strain Limits and Development of Linear Elastic Analysis Methodology, 3) Revised Test Problems and 4) Report on Studies of Soil Modulus and Damping.

9. Letter, M. O. Medford (SCE) to J. A. Zwolinski dated June 26, 1985, Subject: Summary report on the Evaluation of Interaction of Piping and Structures, San Onofre Unit 1 Return-to-Service.

10. Letter, M. O. Medford (SCE) to JZwolinski (NRC), dated July 19, 1985, Subject: Soil Damping - Experimental and Analytical Results.

11. Letter, M. O. Medford (SCE) to J. A. Zwolinski (NRC), dated August 2, 1985, transmitting SUPERPIPE Benchmark Problem Results.

12. Summary of April 2-3, 1985 Meeting, E. McKenna/T. Cheng to C. Grimes, dated April 15, 1985.

13. Summary of April 29-30, 1985 Meeting, C. Grimes to D. Crutchfield, dated June 12, 1985.

14. Summary of June 10-11, 1985 Meeting, C. Grimes to D. Crutchfield, dated July 11, 1985.

15. Summary of July 1-2, 1985 Meeting, T. Cheng to C. Grimes, dated July 22, 1985.

16. Letter, D. Crutchfield (NRC) to K. Baskin (SCE), dated March 27, 1985, Subject: Seismic Criteria and Methodology - San Onofre Nuclear Generating Station, Unit 1.

17. Letter, W. Paulson (NRC) to R. Dietch (SCE), dated September 20, 1982, Subject: Staff Guidelines for Seismic Evaluation Criteria for SEP Group II Plants.

18. Letter from D. M. Crutchfield (NRC) to K. P. Baskin (SCE), dated August 7, 1984, Subject: Seismic Evaluation of Structural Elements.

19. Letter, M. O. Medford (SCE) to W. Paulson (NRC) dated October 2, 1984, Subject: Electrical Raceway Support Implementation Plan for Return to Service.

20. Letter, K. Baskin (SCE) to D. M. Crutchfield (NRC), dated July 9, 1982, transmitting Instructure Response Spectra.

21. NUREG-1061, Volumes 2 and 4 "Report of the U.S. Nuclear Regulatory Commission Piping Review Committee", April 1985 and December 1984 (respectively)

22. Letter, M. O. Medford (SCE) to J. A. Zwolinski (NRC), dated October 25, 1984, Subject: Evaluation of Piping and Structures, San Onofre Unit 1, Return to Service.

23. NUREG-0675, Supplement No. 25, "Safety Evaluation Report Related to the Operation of Diablo Canyon Nuclear Power Plant, Units 1 and 2", July 1984.

24. NUREG/CR-0098, "Development of Criteria for Seismic Review of Selected Nuclear Power Plants", May 1978.

25. NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, LWR Edition," July 1981.

7.0 Attachments

1. Technical Evaluation Report for the Licensee's Proposed Soil-Structure Interaction Analysis Techniques for Long-Term Service Seismic Reevaluation: San Onofre Unit 1, June 1985.

2. Technical Evaluation Report for the Licensee's Proposed Modal Response Combination Techniques for Long-Term Service Seismic Reevaluation: San Onofre Unit 1, June 1985.

3. Technical Evaluation Report for Direct Generation of Floor Spectrum for Long-Term Service Seismic Reevaluation: San Onofre Unit 1, June 1985.

4. Technical Evaluation Report for MLRS Piping Response Analysis Technique for Long-Term Service Seismic Reevaluation: San Onofre Unit 1, June 1985.

SAN ONOFRE 1 SEI[illegible]NALYSIS METHODS

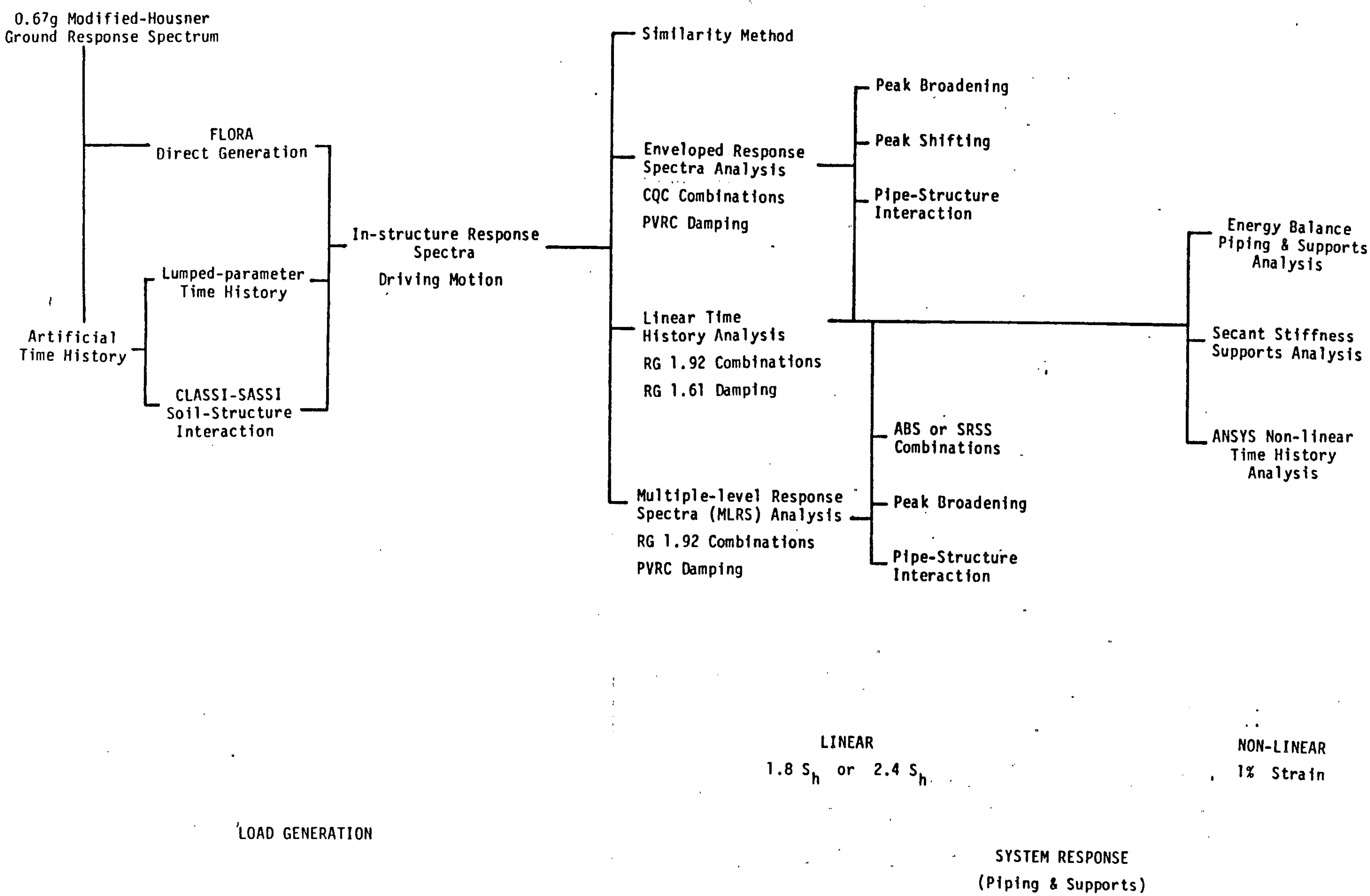

Figure 1.