SAN ONOFRE NUCLEAR GENERATING STATION UNIT 1

SEISMIC PROGRAM FOR LONG TERM SERVICE

Prepared for:

NUCLEAR REGULATORY COMMISSION

Prepared by:

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1.0 INTRODUCTION

This document presents the program for the seismic review of San Onofre Nuclear Generating Station Unit 1 for Long Term Service (LTS), in response to the Nuclear Regulatory Commission's Systematic Evaluation Program.

In November 1984, the San Onofre Nuclear Generating Station Unit 1 (SONGS-1) was returned to service (RTS) after a lengthy outage. During the outage, many new hardware installations were made to upgrade the seismic capability of structures, piping and equipment. The NRC reviewed the seismic capability of SONGS-1 during this outage, and issued a Safety Evaluation Report (SER) documenting their findings [1]. Their findings state that the RTS structures, systems and equipment have adequate assurance of seismic capability to ensure public health and safety, to withstand a 0.67g Modified Housner Design Spectrum event. Other systems are similarly adequate to withstand a 0.50g DBE. The NRC stated that the design criteria and methodologies used for RTS were satisfactory for the continued operation of SONGS-1 for one refueling outage. For LTS, the NRC has required Southern California Edison (SCE) to demonstrate the seismic capability of SONGS-1 to a set of design criteria and methodologies suitable for long term operation of the station.

fuel cycle (?)

The design criteria and methodologies that SCE will use to demonstrate the seismic capability of SONGS-1 for LTS follow the philosophy proposed by Drs. Newmark and Hall in NUREG/CR-0098 [2].

> "It is well known that upgrading and retrofitting constitute expensive operations when they can be accomplished at all. In many cases it is economically, if not physically, impossible to carry out significant seismic upgrading improvements. In those cases, where it is possible economically it is desirable to take advantage of the latest concepts pertaining to development of seismic resistance. ...it is possible (and desirable) to take into account the modest amount of nonlinear behavior that can be permitted in many portions of systems without significant decrease in the margin of safety against safe shutdown or containment."
>
> It is observed that "the inherent seismic resistance of well designed and constructed systems is usually much greater than that commonly assumed, largely because nonlinear behavior is mobilized to limit the imposed forces and accompanying deformations. For such systems where the resistance is nondegrading for reasonable deformations the requirements for retrofitting may be nonexistent or at most minimal."

SCE believes that SONGS-1, in its current configuration, has the seismic withstand capability to meet its original design basis for a 0.50g DBE event. Based on the philosophy described above, SCE will use current methodologies and realistic criteria to demonstrate the seismic withstand capability of SONGS-1 to meet the current 0.67g Modified Housner Design Spectrum and will retrofit where necessary.

2.0 SCOPE

The Return to Service Program included structures and systems required to attain a hot standby condition. The scope of the Long Term Service Program will include all structures and systems previously evaluated and upgraded, with the addition of the South Extension of the Turbine Building. The previously established hot standby capability will be improved by reevaluating and, if necessary, upgrading the Refueling Water Storage Tank to provide the source of borated water for reactor coolant make-up (the Spent Fuel Pool will not be used). In addition, the hot standby capability will be augmented by upgrading systems and equipment necessary to achieve cold shutdown and to provide accident mitigation. This will include the replacement of the cast iron piping between the Saltwater Cooling pumps and the Component Cooling Water heat exchangers.

2.1 Structures

All major plant structures will be capable of withstanding a 0.67g Modified Housner Design Spectrum event, including:

- Reactor Building
- Containment Sphere
- Sphere Enclosure Building
- Reactor Auxiliary Building
- Ventilation Equipment Building
- Control and Administration Building
- Fuel Storage Building
- Seawall
- Intake Structure
- Turbine Pedestal and Turbine Building Extensions
- Diesel Generator Building
- Masonry Walls

2.2 Systems and Equipment

As a minimum, the following systems will be capable of withstanding a 0.67g Modified Housner Design Spectrum event:

- Reactor Coolant Pressure Boundary
- Main Steam and Main Feedwater Piping
- Atmospheric Steam Dump System
- Auxiliary Feedwater System
- Chemical and Volume Control System for Reactor Coolant Make-up
- Safety Injection System
- Containment Spray System
- Post-LOCA Recirculation System
- Saltwater Cooling System

Detailed system boundaries will be developed as part of the Long Term Service Program.

3.0 DESIGN CRITERIA

3.1 Large Bore Piping

The large bore piping criteria for LTS are based on the requirement that the piping systems remain functional during and after a 0.67g Modified Housner Design Spectrum event. Piping is functional if it maintains its rated flow. Two criteria can be used to evaluate piping capacity: a stress criterion and a strain criterion.

The stress criterion states that the elastically calculated piping primary stress, as defined in Equation 9 of the ASME Boiler & Pressure Vessel Code, Section III, Class 2/3 piping for Level D Service Condition, is to be compared to a stress limit of 2.0 times the yield strength (S_y) at the maximum operating temperature as follows (See also Section A.3.1):

$$\frac{PD_o}{4t} + 0.75\, i\, \frac{M_a+M_b}{Z} \leq 2.0\, S_y$$

where

P = Internal maximum operating pressure, psig
D_o = Outside diameter of pipe, in
t = Nominal wall thickness of pipe, in
Z = Section modulus, in^3
i = Stress intensification factor as listed in Appendix D of ASME B&PV, Section III, Subsection NC, 1980 Edition, Winter 1980 Addenda [4]. (This is the Code of Record for SONGS-1 Systematic Evaluation Program. This Code of Record will be applied to all tasks, except as noted.)
M_a = Resultant moment due to gravity loads, in-lbs
M_b = Resultant moment due to 0.67g Modified Housner Design Spectrum inertia, as calculated by linear elastic methods, in-lbs
S_y = Piping material yield strength at maximum operating temperature, psi (obtain S_y from Appendix I of ASME Code).

This applies to both carbon and stainless steel piping.

In cases where nonlinear analysis methods are used, the piping strain criterion can be used. The allowable strains in piping components are one percent and two percent strain for carbon and stainless steel, respectively.

In performing the piping analyses, the following criteria will be applied:

(1) Branch Pipe Decoupling Criteria: For branch lines whose nominal diameter is less than or equal to 1/3 of the run line nominal diameter, the branch line can be decoupled from the run line. For evaluation of the run line, ignore the branch line. For evaluation of the branch line, the run line may be considered as an anchor. Exceptions to this criteria will be taken in cases where an anchor

or rigid restraint on the branch line is located near the run pipe and significantly restrains the movement of the run line. For such cases, the branch line will be included with the model of the run line, up to the anchor point or up to and including the second support in each of three orthogonal directions.

As an alternative, the coupled run line and branch line analyses are acceptable.

(2) Seismic to Non-seismic Piping Decoupling Criteria: If a line contains a seismic to non-seismic boundary, the piping analysis will include a portion of non-seismic piping either to the next anchor point, or to the second support in each of three orthogonal directions, whichever is closer.

(3) Support Stiffnesses: Generic stiffness values (see Table 3.1-1) will be used to model pipe supports. These values reflect the lower bound support stiffnesses used for the typical pipe support design. They are compatible with the stiffness values used for other nuclear power plants. For cases where pipes are connected to flexible secondary structures, the influence of this flexibility will be assessed.

3.2 Small Bore Piping and Tubing

Walkdown and chart methods will be used to qualify small bore piping and tubing. This method will be validated by rigorous stress analysis methods, to meet the comments of the SER [1]. Generic configurations will be used for the validation.

Alternatively, rigorous stress criteria will be used to qualify small bore piping and tubing. These criteria are described in Section 3.1.

3.3 Pipe Supports

The pipe support criteria for LTS are developed for the following component types:

- Structural steel
- Concrete expansion anchor bolts
- Catalog items
- Welds

The criteria are presented in Table 3.3-1. The following subsections discuss the criteria in detail.

3.3.1 Structural Steel

The capacity of structural steel components will be obtained by applying the design requirements for structural steel members. These are described in the ASME Boiler & Pressure Vessel Code, Section III, 1983 Edition, and include the Summer 1983 Addenda for Level D loads (Summer 1983 Addenda has revised Level D allowables for structural steel).

In applying the Code rules, a departure from the Code will be taken for the qualification of steel supports. The Code values for material yield stress will be increased by 18 percent to represent the average rather than the lower bound yield stress. This overstrength is based on the yield stress test results reported in Reference [3]. This allowance will be credited for only those materials at SONGS-1 for which these test results are applicable. For steel components loaded at high strain rates, a 10 percent increase in yield stress will be taken. In combination, these two factors result in a 30 percent increase in yield stress. See also Section A.3.3.1 for further discussion.

Nonlinear criteria described in Section 3.4 may be used as an alternative to the above elastic stress criteria. In such cases, the effects of pipe support yielding on pipe functionality will be considered.

3.3.2 Concrete Expansion Anchor Bolts

The allowable loads for concrete expansion anchor bolts will be obtained by using the manufacturer's reported ultimate capacity with a minimum factor of safety of four on wedge type anchor bolts and five on shell type anchor bolts. On a case-by-case basis, a factor of safety less than four will be used to qualify existing supports. A factor of safety of less than four will only be used if the adjacent supports carrying load in the same direction are qualified elastically, and if there are a minimum of four support anchor bolts, not more than half the bolts are subjected simultaneously to tension loads.

3.3.3 Catalog Items

The manufacturer's load capacity data for Level D service conditions will be used to qualify supports. For existing supports, qualification by engineering analysis or by comparison to test results for these catalog items may also be used. In such cases, a minimum factor of safety of two will be maintained.

3.3.4 Welds

The allowable stresses for welds will be based on the design requirements as specified in the ASME Boiler & Pressure Vessel Code, Section III for Level D loads. For full penetration welds, the allowable stresses will be those of the base metal. The allowable stresses used for welds do not include the increases for material overstrength or strain rate effects.

3.4 Secondary Steel Structures

Secondary steel structures are those components which do not contribute to the strength or stiffness of the primary structure, ie., they are not essential to the load carrying capacity of the main building structures. These components are typically light steel framing members spanning between girders, columns or concrete walls of the main structure to support loads from piping systems, conduit or cable trays.

The criteria for the secondary steel members will be the rules in the AISC Code [4]. Specific criteria for nonlinear evaluation are based on either ductility ratios or strain limits as given below.

The allowable ductility for steel members which require no upgrade is three. For cases where ductilities are over three, further evaluations will be made to determine if upgrades are required. The allowable strain for steel members and components in pure tension is one-half the ultimate uniform strain for the material.

The nonlinear values described in the previous paragraph may be obtained by the approach used for RTS. In this approach, ductility is calculated by comparing the elastically calculated loads to the resistance capacity of the member. The resistance capacity is based on the plastic moment capacity of the section.

In cases where a nonlinear approach is used to qualify a structural member, the effects of yielding on pipe functionality will be considered.

In applying the Code rules, departures from the Code will be taken for qualification of steel structures. Yield stress increases to account for material overstrengths and strain rate effects will be taken, as described in Section 3.3.1.

3.5 Mechanical Equipment (Pumps, Heat Exchangers, Filters)

The design criteria for mechanical equipment are developed for both pressure-retaining and non-pressure retaining parts.

3.5.1 Pressure-Retaining Parts

The design criteria for mechanical equipment will be based on the rules and criteria in the ASME, Boiler & Pressure Vessel Code, Section III, Subsection NC, 1983 Edition including Summer 1983 Addenda. The criterion specified for LTS is that components must maintain their structural and pressure integrity during and after a 0.67g Modified Housner Design Spectrum event. The Level D stress limits are specified for the evaluation of the equipment pressure-retaining parts. The criteria are defined in NC-3000 of the Code and are summarized below:

Catagory	Allowables
Primary membrane stress	$2.0\ S_h$
Primary membrane + bending stress	$2.4\ S_h$

where S_h = Component material allowable stress

These stress allowables are applicable to all pressure-retaining parts including shells and nozzles.

Alternatively, the criteria of NC-3200 and Appendix XIII may be used.

3.5.2 Non-Pressure Retaining Parts and Equipment Supports

The design criteria for non-pressure retaining parts and equipment supports will be based on the design requirements for structural steel members defined in Subsection NF and Appendix F of the ASME Code, Section

III, 1983 Edition, and include the Summer 1983 Addenda for Level D loads. This includes a check of the stresses for bending, axial and shear loads, as well as a check on stability, weld and anchor bolts. A summary of the support evaluation criteria is contained in Table 3.3-1.

All support loads will be combined as shown below:

Design loads for support = Gravity (signed) +
Nozzle (signed) +
0.67g Modified Housner Design Spectrum
Inertia ($\pm$)

Nozzle loads include gravity, thermal, hydraulic transients, seismic inertia, and seismic anchor motion effects. The seismic inertia and SAM loads will be combined by SRSS.

3.6 Valves

The design criteria for valves are developed for active and passive valves and for pressure and non-pressure retaining components.

3.6.1 Active Valves

The criteria are intended to ensure the structural integrity of the valve and its extended structure during and after a 0.67g Modified Housner Design Spectrum event. Seismic loads on the extended structure will be derived from valve accelerations, which will be calculated during the piping analyses.

Non-pressure retaining components, such as yoke legs, will be evaluated using Subsection NF of the ASME Code. All stresses in active valves will be limited to the elastic range. The Level C allowables of Subsection NF will be used, as they limit all primary stresses to below the yield point. The stress criteria for the non-pressure retaining parts are listed in Table 3.6-1.

Qualification of the valve body will be demonstrated by qualifying the welded joint between the valve body and the attached piping, including consideration of the appropriate stress concentration factors. Pressure retaining parts of the extended structure will be evaluated using NC-3500 of the ASME Code. Level C allowable stresses will be used and are summarized below.

Category	Stress Limit
Primary membrane stress	1.5 S
Primary membrane + bending stress	1.8 S

Pressure-retaining flanged connections are evaluated using the criteria of NC-3658 for Service Limit C.

The loads considered in the qualification of active valves are combined as shown below:

Design loads for valves = Gravity (signed) + Operational (signed) + 0.67g Modified Housner Design Spectrum Inertia (±)

In the pressure-retaining components, operational loads include thrust loads due to valve actuations and pressure loads.

3.6.2 Passive Valves

The criteria for passive valves are intended to ensure the structural integrity of the valve and its extended structure during and after a 0.67g Modified Housner Design Spectrum event. The general qualification approach will be the same as that used for active valves, except that the allowable stresses will be increased.

Non-pressure retaining components will be evaluated using Subsection NF of the Code modified appropriately by Appendix F. Table 3.6-1 shows the stress criteria for the non-pressure retaining parts.

Qualification of the valve body will be demonstrated by qualifying the welded joint between the valve body and the attached piping. This includes the consideration of the appropriate stress concentration factors. Other pressure-retaining parts will be evaluated using NC-3500 of the ASME Code. Level D allowables will be used and will be summarized below:

Category	Stress Limit
Primary membrane stress	2.0 S
Primary membrane + bending stress	2.4 S

Pressure-retaining flanged connections will be evaluated using the criteria of NC-3658 for Level D Service Limits.

Design load for valves = Gravity (signed) + Operational (signed) + Modified Housner Design Spectrum inertia (±).

In the pressure-retaining components, the operational loads include thrust loads due to valve actuations and pressure loads.

3.7 Tanks

Design criteria for the Refueling Water Storage Tank will be described in a separate report. This report will be submitted to NRC by April 15, 1985.

3.8 Penetrations

The design criteria for the containment penetrations ensure the adequacy of the penetration structures to act as pipe supports and to verify the structural integrity of the containment structure. The stresses in the penetration structure will be reviewed against the applicable criteria for piping and pipe supports, as described in Subsections 3.1, 3.2 and 3.3. The stresses in the containment will be reviewed against the criteria in the ASME B&PV Code, Subsection NE for metal containment.

3.9 Electrical Raceways

The criteria for the evaluation of electrical raceways, which consist of cable trays and conduits, will be based upon the RTS Design Criteria for SONGS-1 [5]. The applicable criteria in Sections 3.3.1 (second paragraph) and 3.3.2 may alternatively be used to qualify raceway supports.

Table 3.1-1

GENERAL SUPPORT FLEXIBILITIES FOR VARIOUS PIPE SIZES

Pipe Diameter (inch)	Translational Flexibility (in/lb)
2-1/2	1.60×10^{-4}
3	1.11×10^{-4}
4	6.25×10^{-5}
6	2.78×10^{-5}
8	1.56×10^{-5}
10	1.00×10^{-5}
12	6.94×10^{-6}
14	5.10×10^{-6}
16	3.91×10^{-6}
18	3.08×10^{-6}
20	2.50×10^{-6}
24	1.74×10^{-6}
28	1.28×10^{-6}
30	1.11×10^{-6}

Table 3.3-1

DESIGN CRITERIA FOR PIPE AND EQUIPMENT SUPPORTS

Component Type	Stress Condition	Criteria
Structural Steel	Tension, Bending Shear Compression Web Crippling	1.18 x ASME Level D (2) 1.18 x ASME Level D (2) ASME Level D ASME Level D
Concrete Anchor Bolts	Shear, Tension, With Elliptical Interaction	F_u/F.S. where F.S. = 4 for wedge type = 5 for shell type (see note 3).
Catalog Items	All	Manufacturer's Load Capacity Data for Level D Service Conditions or Engineering Analysis with F.S.=2 or Test Data with F.S.=2.
Welds	All	ASME Level D

Where F_u = Ultimate strength at design temperature

F.S. = Factor of safety

Notes:

(1) The above criteria apply to elastically evaluated pipe supports.

(2) An additional 10 percent increase in yield stress due to strain rate effects may be taken.

(3) On a case-by-case basis, F.S. less than 4 will be used (see Section 3.3.2).

Table 3.6-1

DESIGN CRITERIA FOR VALVE CAPACITY - NON-PRESSURE RETAINING PARTS

Component Type	Stress Condition	Active Valves	Passive Valves
Structural Elements (Yoke Legs)	Tension	ASME Level C	ASME Level D
	Bending	ASME Level C	ASME Level D
	Shear	ASME Level C	ASME Level D
	Compression	ASME Level C	ASME Level D
Bolting	Tension	ASME Level C	ASME Level D
	Shear	ASME Level C	ASME Level D
Welds	All	ASME Level C	ASME Level D

4.0 METHODOLOGY

4.1 Load Generation

The in-structure floor response spectra currently defined for SONGS-1 will be used for subsystem analysis. Alternatively, for the Reactor Building, Containment Sphere and Turbine Building, these spectra may be refined by using the following methods. These methods reflect current day techniques not available at the time that the original analyses were performed.

4.1.1 Input Time History

A new artificial time history motion will be generated which matches the modified Housner 0.67g response spectrum.

4.1.2 Soil-Structure Interaction

SONGS-1 soil-structure interaction (SSI) analyses were based on the lumped parameter method, using frequency-independent soil springs. These analyses were performed in the 1975 to 1980 time frame. Since then, more refined SSI techniques have been developed.

For LTS, refined SSI analyses will be performed to generate new floor response spectra. These analyses will explicitly include a continuum representation for soil with frequency-dependent soil impedances, as, for example, included in programs CLASSI and SASSI. Soil material (hysteretic) damping will be limited to the damping value at 0.1 percent soil strain. The free field motion will be applied at the level of the foundation, both for surface-founded and embedded structures. Floor spectra will be broadened to include variations in soil properties.

4.1.3 Direct Generation Method

New floor response spectra will be calculated using the direct generation method. This method may consider the effects of tuned primary and secondary structures. This method has been validated by the time history method.

4.2 Large Bore Piping Analysis Methods

Large bore piping analyses will consider the effects of pressure, thermal, deadweight, hydraulic transients and seismic loadings. These loadings require consideration for pipe stress, pipe support loads, anchor loads and nozzle loads.

4.2.1 Linear Analysis Methods

In general, the envelope response spectra method will be used. Should more precise analysis methods be warranted, then either the multiple level response spectra or time history methods will be used. Similarity analysis may be used when justified, on a case-by-case basis.

4.2.1.1 Envelope Response Spectra Method

This method is the most commonly used method of piping analysis.

Mode/Direction Combinations

Modes will be combined using any of the combination rules provided in Regulatory Guide 1.92 or by the Complete Quadratic Combination (CQC) technique. The three directions of earthquake motions will be combined by SRSS, as per Regulatory Guide 1.92. A missing mass correction for modes in the rigid range will be made. See Section A.4.2.1.1 for further discussion.

Peak Shifting

The spectra peak shifting methodology, as outlined in Reference [7], and accepted in [8], may be adopted in this analysis.

Damping

PVRC recommended damping values, as outlined in Reference [9], and accepted in [8], will be used in this analysis.

Seismic Anchor Motions

Seismic Anchor Motion (SAM) effects on pipe stresses will be evaluated. SAM effects on pipe support loads will be combined with inertia effects by SRSS method.

Coupled Pipe-Structure Analysis

Piping may be supported on structures which are not rigid. In such cases, pipe-structure coupling may occur.

A rigid structure is one that has its first mode frequency over 33 Hz, or into the rigid range of the acceleration spectrum defined at the base of the structure. Alternatively, a structure can be considered rigid if it deflects less than one-eighth inch under the 0.67g Modified Housner Design Spectrum pipe support reaction load.

For non-rigid structures, an equivalent stiffness of the structure will be incorporated into the piping model.

4.2.1.2 Multiple Level Response Spectra Method

This method is a commonly used method of piping analysis. The method will remove some conservatism introduced in the envelope response spectra method, when the input spectra at different levels in the structure have wide variations.

Mode/Direction/Level Combinations

Modes will be combined using any of the combination rules provided in Regulatory Guide 1.92 or by CQC. The three directions of earthquake motions will be combined by SRSS, as per Regulatory Guide 1.92. The pipe system responses due to individual levels of input motions will be combined by absolute summation. A missing mass correction for modes in the rigid range will be made.

The pipe system responses due to individual levels of input motions will be combined by SRSS, if it is shown that individual input motions are independent of each other. Independence will be demonstrated by showing that the correlation coefficient for the input motions is between plus or minus 0.16.

As an alternative to the above procedures, mode and level combinations may be combined using a random vibration method. This method uses correlation coefficients calculated from separate pipe and structure models to combine model and level responses. This technique has been validated by the multiple level time history technique.

Peak Shifting

The methodology described in Subsection 4.2.1.1 may be used.

Damping

The methodology described in Subsection 4.2.1.1 will be used.

Seismic Anchor Motion

The methodology described in Subsection 4.2.1.1 will be used.

Coupled Pipe-Structure Analysis

The approach described in Subsection 4.2.1.1 will be used.

4.2.1.3 Time History Method

General

In lieu of the response spectrum approach, time histories of support motions will be used as excitation to the piping system. If the motions at the different support locations are distinct, multiple time histories will be used to perform the analysis. The input motions will include both acceleration and displacement motions of the supports.

Direction Combinations

The three directions of earthquake motions will be combined by SRSS, as per Regulatory Guide 1.92.

Damping

The damping values in Regulatory Guide 1.61 will be used.

4.2.1.4 Similarity Analysis Method

For piping systems which are similar to systems which have previously been evaluated, a similarity analysis will be used to qualify the piping system. The similarity evaluation will focus on pipe routing, pipe support scheme, and location of equipment. By evaluating the effect of minor changes between systems, the similarity analysis will provide an economic means of evaluating the piping system.

4.2.2 Nonlinear Analysis Methods

4.2.2.1 Time History Method

General

The nonlinear time history analysis will account for nonlinearities in the piping system due to material nonlinearity. The material nonlinearities are included for piping, pipe supports or support structures. Input time history motions are taken from appropriate locations of the structural analysis models.

Damping

The damping used in the nonlinearity analysis will be Rayleigh type damping. The hysteretic behavior due to material yielding will also be factored into the evaluation.

4.2.2.2 Energy Balance Method

General

The energy balance method will compare the earthquake energy input to the piping to the strain capacity of the piping. If the pipe strains meet the criteria, the pipe will be shown to be functional, otherwise the pipe support scheme must be revised.

Damping

The method described in Subsection 4.2.1.1 will apply.

4.2.2.3 Secant Stiffness Method

In some cases, secondary steel beams support the piping systems. When inelastic behavior is exhibited, the impact of this behavior on the piping systems will be evaluated.

The nonlinear behavior will be approximated using an iterative linear analysis approach. The secant stiffness of the yielding support system will be used as input to the piping analysis. Iterations will be performed until converged pipe support reactions and pipe stresses are reached.

4.3 Small Bore Piping and Tubing

The small bore piping and tubing analysis for RTS was performed with walkdowns and chart methods. For LTS, these methods will also be used. These methods will also be verified by generic piping calculations and will include the effects of anchor motions for support design.

As an alternative, small bore piping and tubing may be evaluated using the analysis methods described in Section 4.2.

4.4 Pipe Supports

Pipe supports will be evaluated against the criteria in Section 3.3. If a support has yielded or failed, the piping will be reevaluated to determine whether it can maintain functionality. The adjacent supports will be reevaluated to determine whether they can support the additional load.

Structures supporting more than one pipe will be evaluated to withstand the total loads from all the pipes. Components loaded by more than one pipe will be evaluated by considering the SRSS combination of seismic responses of the different pipes.

4.5 Secondary Steel Structures

The methodology used for RTS [10] will be used to evaluate the secondary steel members. The criteria described in Section 3.4 will be used to qualify the components.

As an alternative, structures may be evaluated directly from coupled pipe-structure analyses. For nonlinear structures so evaluated, the calculated responses are compared directly against the design acceptance criteria.

All yielding members will be evaluated for end connection strength, as well as secondary failure modes (eg. lateral torsional buckling, flange buckling).

4.6 Mechanical Equipment

The evaluation of mechanical equipment (heat exchangers, pumps and filters) will be performed using equivalent static analysis and dynamic analysis techniques.

4.7 Valves

Equivalent static analysis will be performed to calculate stresses in critical sections of the valve based on the total loads (seismic, gravity and valve operation). The calculated stresses will be compared to the allowables.

4.8 Tanks

The evaluation of RWST will be addressed in a separate report.

4.9 Penetrations

The penetration components will be evaluated using stress calculations which will include textbook solutions, axisymmetric finite element or Bijlaard solutions.

4.10 Electrical Raceways

The methodology described in Reference [5] will be used to evaluate the conduit and cable tray supports. Maximum support deflections will be restricted to four inches to ensure circuitry continuity [11].

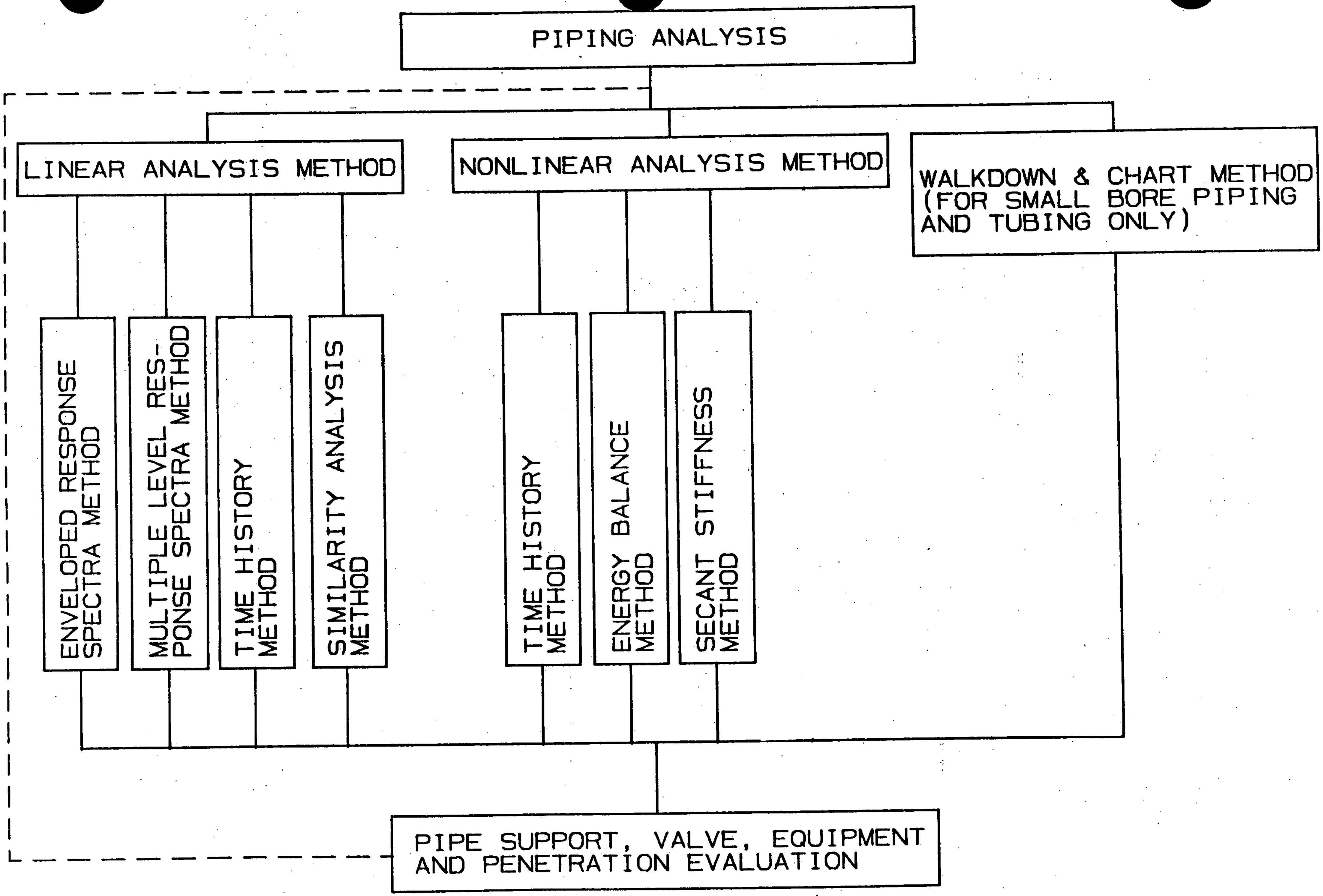

FIGURE 4.2 SUMMARY CHART FOR PIPING ANALYSIS METHOD

5.0 REFERENCES

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5. Bechtel Power Corporation, Return to Service Design Criteria for SONGS-1, Design of Raceway Support Modifications, Revision 0, May 9, 1984, Job No. 15691-308.

6. SCE Letters to NRC, from K. Baskin to D. Crutchfield, dated March 25, 1981, May 29, 1981, June 28, 1981, and April 12, 1982.

7. PVRC Technical Committee on Piping Systems of the Pressure Vessel Research Committee, Proposed Revision Regulatory Guide 1.122, 1983b (Incorporated to N-1226.3 of Appendix N of the ASME B&PV Code Section III, Summer 1984 Addenda).

8. "Proposed Restart Plan for Songs-1", Letter from the NRC (H. R. Denton) to SCE (K. Baskin), Docket No. 50-206, LS05-84-02-021, dated February 8, 1984.

9. PVRC Technical Committee on Piping Systems of the Pressure Vessel Research Committee, Progress Report on Damping Values, 1983a (Incorporated to ASME B&PV Code, Code Case No. 411).

10. Bechtel Power Corporation Project Design Criteria, Subjob 430-471, Revision 2.

11. "Electrical Raceway Support Implementation Plan for Return to Service, SONGS-1", SCE Letter dated October 2, 1984 from M.O. Medford to W.A. Paulson (NRC).

Appendix A: Commentary

A.3.1 Large Bore Piping

The piping stress criterion provides for a stress allowable of 2.0 S_y for the ASME Code Equation 9 primary stresses. In lieu of this stress criterion, a piping strain criterion may be used. The allowable strains in piping components are one percent and two percent strain for carbon and stainless steel, respectively. A justification for these values is based on the following factors:

Nonlinear Analysis

Nonlinear analyses of representative piping systems have been performed for SONGS-1 [A.1]. The analyses demonstrated that the 2.0 Sy stress allowable corresponds to very limited deformations and no impairment to functionality. Similar nonlinear analyses have also been performed at Commonwealth Edison's Dresden and Quad Cities plants to successfully license the 2.0 S_y stress limit as part of their IE Bulletin 79-14 program [A.2].

Testing Programs

Numerous testing programs have been conducted, or are in progress, to study the behavior of piping systems under severe seismic or other dynamic loading.

High-excitation testing to benchmark dynamic nonlinear analysis methods for piping is currently being conducted for EPRI [A.3]. One test has been completed on a 4-inch Schedule 40 ferritic steel piping system. The primary purpose of this initial test was to demonstrate the functional response of dynamically exciting piping systems to levels far in excess of current Code allowables. The maximum dynamic excitation level corresponded to seven to eleven times a typical 0.67g Modified Housner Design Spectrum event for a plant in a low to moderate seismic region. This excitation level results in stresses which exceed Level D Code allowable stress limits by a factor greater than three. Permanent and visible deformations were observed, but there was no plastic collapse or loss of structural integrity in the pressurized piping. Input accelerations were greater than 14g, and response accelerations were greater than 21g in one elbow.

A limited amount of dynamic component testing has also been conducted [A.4, A.5, A.6]. A Japanese experimental study tested carbon and stainless steel elbows and tees well into the plastic range with harmonic excitation. No failure or structural instability was observed in any of these tests.

Dynamic versus Static Loadings

Current ASME Code elastic analysis stress response acceptance criteria do not differentiate between dynamic (such as seismic) and static loading events. Inelastic response of piping systems to seismic and other dynamic loadings is significantly different than inelastic response to static loadings of the same magnitude. Studies have demonstrated that the margin against failure of piping systems is significantly greater for dynamic loads than for static loads when the elastically computed responses are held to the same allowable stresses [A.7].

Operating Plant Experience

The El Centro Steam Plant [A.8] has been subjected to strong (over 0.5 g) earthquake motion without disruption to operation. Similarly, Lawrence Livermore Laboratory and the Hamaoka Units in Japan have been subjected to moderate earthquake motion without disruption of operation. Numerous other electrical and process plants have been subject to earthquakes with no failure of piping systems, as supported by the ongoing findings of the SQUG program. SRV discharge piping systems in both PWR and BWR plants have also been subjected to dynamic loads without damage, where conventional analysis indicates dynamic stresses well above current Code allowables.

Strain Limit for High Temperature Piping

In Code Case N-47 titled "Class 1 Component in Elevated Temperature Service" of ASME Boiler and Pressure Vessel Code [A.9], the deformation and strain limits for structural integrity are two percent strain at the surface due to bending.

Categorization of Seismic Loading

In current ASME Code rules, seismic inertia stress is categorized as the primary stress and evaluated in the Code Equation 9. Studies have been performed, or are in progress, to investigate the licensing support for the elimination of the primary stress requirement for seismic loading on piping [A.10]. If seismic inertia stress is categorized as the secondary stress, the 2 S_y allowable represents a conservative limit for "shakedown" to elastic action when the yield stress is surpassed in an ideally plastic material.

A.3.3.1 Structural Steel

In a report by Smith et. al. [A.11], it is reported that the measured yield strength of over 60,000 specimens is found to be, on the average, 18 percent greater than the ASME Code reported minimum yield strength. Material overstrength is also substantiated in other references [A.12, A.13, A.14]. These allowances will be credited for those materials at SONGS-1 for which the test results are applicable.

Seismic loading is a high frequency event, and imposes higher strain rates on supports. These strain rates increase the yield stress by 10 percent or higher. Test data supporting these observations are given [A.15, A.16]. A 10 percent yield stress increase has previously been adopted for evaluation of the Rancho Seco, Davis Besse, Oconee, Arkansas Nuclear One Unit 1, Crystal River and Three Mile Island nuclear stations [A.17].

A.4.2.1.1 Complete Quadratic Combination

The Complete Quadratic Combination (CQC) method is an accurate method to combine modal responses. The method is documented in [A.19]. The method has been validated by time history methods, and is found to give more accurate responses of closely spaced laterally-coupled modes than do the Regulatory Guide 1.92 methods. Higher modes in the rigid range of the input spectra are included using the missing mass correction.

Appendix A: References

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[A.2] "Quad Cities Unit 1 Functionality Study of Piping Systems in Response to the Modified Housner Design Spectrum Event", EDS Report No. 01-0590-1135, Revision 0, December 1980.

[A.3] "Quick Look Report: Dynamic Testing of a Pressurized Piping System Beyond the Elastic Limit", Preliminary Report, ANCO Engineers, Culver City, California, prepared for EPRI, October 1981.

[A.4] Greenstreet, W.L., "Experimental Study of Plastic Response of Pipe Elbows", ORNL/NUREG 24, February 1978.

[A.5] Ishiki, Nishizawa, et. al., "Nonlinear Seismic Analysis and Test", 1979, U.S. - Japan Seminar on HTGR Safety Technology.

[A.6] Teidoguchi, H., "Experimental Study on Limit Design for Nuclear Power Facilities During Earthquakes", 1975.

[A.7] Campbell, R. D., Kennedy, R. P., and Thrasher, R. D., "Development of Dynamic Stress Criteria for Design of Nuclear Piping Systems", Structural Mechanics Associates, Inc., Report SMA 17401.01, November 1982.

[A.8] "Equipment Response at the El Centro Steam Plant During the October 15, 1979 Imperial Valley Earthquake", NUREG/CR-1665, October 1980.

[A.9] ASME Boiler & Pressure Vessel Code, Code Case N-47, "Class 1 Component in Elevated Temperature Service", dated December 11, 1981.

[A.10] "Proposed Code Change to Place Seismic Loading in the Fatigue Category," PVRC Technical Committee on Piping Systems, dated July 11, 1984.

[A.11] Smith, P.D., Maslenikov, O.R. and Bumpus, S.E., "LLL/DOR Seismic Conservatism Program: Investigations in the Seismic Design of Nuclear Power Plants," UCRL-52716.

[A.12] Galambos, T.V., Ravindra, M.K., "Properties of Steel for Use in the LRFD," Journal of the Structural Division, ASCE, September 1978.

[A.13] "Final Report on Bar Tests for the Committee of Reinforcing Bar Producers, AISI," by Wiff, Janney, Elstner and Associates, April 1970.

[A.14] "Comparative Tests of Physical Properties of No. 18 Reinforcing Bars, AISI," by Wiff, Janney, Elstner and Associates, January 1971.

[A.15] Timoshenko, S., Strength of Materials, Part II, Third Edition, Van Nostrand, Princeton, N.J., 1956.

[A.16] Beedle, L.S., Tall, L., "Basic Column Strength," Proceedings of ASCE, Vol. 86 (ST-7), July 1960.

[A.17] Effects of Asymmetric LOCA Loads, B&W 177-FA Owners Group, by Babcock and Wilcox and EDS Nuclear, BAW1621, July 1980.

[A.18] "Realistic Seismic Design Margins of Pumps, Valves and Piping," NUREG/CR-2137, Prepared by Battelle Labs/ORNL for the NRC, June 1981.

[A.19] Wilson, E.L., Der Kiureghian, A., Bayo, E.P., "A Replacement for the SRSS Method in Seismic Analysis", Earthquake Engineering and Structural Dynamics, Vol. 9, 1981.