Revision 4

SAN ONOFRE NUCLEAR GENERATING STATION UNITS 2 AND 3

SNUBBER REDUCTION PROGRAM FOR NUCLEAR PIPING SYSTEMS

Prepared for

Nuclear Regulatory Commission

Prepared by

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1.0 INTRODUCTION

Recent operating experience of nuclear power plants has highlighted reliability and maintenance problems associated with the use of snubbers on nuclear power plant piping systems (References 1, 2 and 3). Additionally, concerns have been expressed by knowledgeable industry personnel that piping systems may be overly designed with respect to seismic and other postulated plant design events (i.e., high energy line break), at the expense of optimum plant design for normal operating events. Over-design of plant piping results in large numbers of unnecessary seismic supports (struts and snubbers), pipe whip restraints, and jet impingement barriers. Pipe supports, restraints and barriers not needed to provide adequate design margins for seismic and other plant design events can restrict free thermal expansion of the pipe, hinder inservice inspection (ISI) of piping welds and components, and increase occupational radiation exposure (ORE) to plant personnel.

These concerns of piping over design for the seismic event have resulted in both industry and regulatory (Reference 4) investigations into analytical methods, design criteria and industry practices used for piping design, fabrication and installation.

Southern California Edison Company (SCE) has been closely following these activities as principally conducted by the Nuclear Regulatory Commission (NRC), Pressure Vessel Research Committee (PVRC), American Society of Mechanical Engineers (ASME), and EPRI. Results of these activities to date have demonstrated that the seismic design of San Onofre Units 2 and 3 piping is excessively conservative and that many of the seismic supports (principally snubbers) are neither needed nor desirable to provide adequate design margins for the seismic events. Removal of these unnecessary seismic supports would result in piping systems of increased reliability, lower plant maintenance costs, and decreased occupational radiation exposure (ORE) to plant personnel.

Additionally, nuclear power plant operating experience, recent test data and analytical advances in the mechanisms of High Energy Line Break (HELB) have demonstrated that the HELB design criteria of San Onofre 2 and 3 is also excessively conservative. Although SCE is not proposing to remove any pipe whip restraints or jet impingement barriers at this time, SCE is proposing modification to HELB criteria that will facilitate removal of unnecessary snubbers. However, SCE is reviewing information concerning the elimination of pipe whip restraints associated with elimination of arbitrary intermediate pipe breaks (and associated pipe whip restraints) at the Catawba, Votgle, Byron and Braidwood nuclear power plants and may apply for restraint removal at a future date. 4

Scope of the snubber reduction program is presented in Section 2.0. Design criteria for piping, pipe supports, and in-line components is presented in Section 3.0. Analytical methodology that will be utilized for the seismic event is presented in Section 4.0.

2.0 SCOPE

Scope of the snubber reduction program includes all safety related plant piping systems, snubbers on the Control Element Drive Mechanisms (CEDM), but exclusive of the nuclear steam supply system (NSSS) piping equal to or greater than 30 inches in diameter. Also excluded are snubbers used for seismic support of anchored equipment such as the reactor pressure vessel, steam generators and reactor coolant pumps.

In the event that a later snubber reduction program is instituted for NSSS piping equal to or greater than 30 inches in diameter, or for anchored equipment, then a review will be performed to determine that snubber reductions performed under this program have not been invalidated.

3.0 DESIGN CRITERIA

Licensing commitments as provided in the San Onofre 2 and 3 Final Safety Analysis Report (updated FSAR) will be followed except as specifically noted below.

3.1 Piping

All non-NSSS piping will continue to be analyzed to the 1974 edition, summer 1974 addenda, of the ASME Boiler and Pressure Vessel Code, Section III (Reference 5). NSSS piping will continue to be analyzed to the 1971 edition of the ASME Section III Code. In special circumstances, later editions and addenda may be used provided that the new requirements are reconciled with the original design requirements as provided in Section XI of the ASME Code.

3.1.1 Design Allowables

All piping loads, load combinations and allowable stresses identified in the San Onofre 2 and 3 updated FSAR (Sections 3.9.3 and 3.9.4) will be complied with.

3.1.2 High Energy Line Break Criteria

Arbitrary intermediate breaks need not be postulated for Class 1,
2 and 3 piping in which 1) stress corrosion cracking, large
unanticipated dynamic loads (such as water or steam hammer), or
thermal fatigue in fluid mixing situations are not expected to
occur, provided design requirements in Section 3.6 of Reference 7
are met and 2) all safety related equipment in the vicinity of the
piping have been environmentally qualified for the non-dynamic 4
effects of a non-mechanistic pipe break with the greatest
consequences for the surrounding equipment. However, pipe breaks
are required to be postulated at those locations where the

conditions as stated in Standard Review Plan (SRP) Section 3.6.2, Revision 1, B.1.c(2)(a)(b) and B.1.c(1)(a)(b)(c) exist (Reference 6.a). SCE will satisfy these conditions as stated in SRP 3.6.2, Rev. 1, and in Reference 7 except that arbitrary intermediate breaks may be eliminated in conformance and subject to the conditions as stated in the staff position in Reference 7. 4

3.1.3 Pipe Displacements

All pipe displacements which exceed those provided by the original design analysis will be checked to ensure that no interference occurs with plant structures or other plant equipment.

3.2 Piping Supports

3.2.1 ASME Class 1, 2 and 3 Pipe Supports

Load combinations, applicable Code edition/addenda and allowable stresses for NSSS and non-NSSS pipe supports are provided in Sections 5.4 and 3.9, respectively, of the San Onofre Units 2 and 3 updated FSAR. In special circumstances, later editions and addenda of the ASME Code may be used provided that the new requirements are reconciled with the original design requirements as provided in Section XI of the ASME Code.

The effects of both thermal anchor motion and seismic anchor motion will be considered as primary loads for evaluation of pipe supports and auxiliary steel.

3.2.2 ASME Welds

Weld allowables for ASME Class 1, 2 and 3 pipe supports will continue to be that provided by the applicable edition/addenda of Section III of the ASME Code.

3.2.3 Auxiliary Steel

For auxiliary steel, whose design loads are determined to be greater than current design loads, the load combinations and allowable stresses will be provided by Standard Review Plan 3.8.4 (Reference 6.b) as limited by the following:

1. The allowable limit for compression members during emergency and faulted condition loads will be 1.33S (S is the required section strength defined in Reference 6.b, p. 13). 4

2. For angle members, the maximum bending stress during normal and upset condition events will be limited to F_b*, where

$$F_b = \left[0.55 - 0.10 \frac{F_{ob}}{F_y}\right] F_{ob} \qquad \text{for } F_{ob} \le F_y$$

$$F_b = \left[0.95 - 0.50 \sqrt{\frac{F_y}{F_{ob}}}\right] F_y \qquad \text{for } F_{ob} > F_y$$

F_{ob} = elastic buckling stress

$$= \frac{\pi E}{2\sqrt{2.6}} \frac{t}{L} \quad \text{for equal leg angle members}$$

t = member thickness

L = unsupported length

For unequal leg angle members, design criteria will be provided by References 19 and 20.

*For normal and upset events these limits are based on the Australian code for angle members (Reference 15) which has been endorsed by AISC (Reference 16). The 0.66 F_y allowable for compact angle members (for normal and upset events) is also part of the Australian code and endorsed by AISC (Reference 16). For emergency and faulted events, the 0.95 F_y limitation provides approximately a 1.9 factor of safety against plastification (Reference 17).

For normal and upset events, F_b shall be limited as follows:

$b/t < 65/\sqrt{F_y}$ $\qquad F_b = 0.66\ F_y$

$65/\sqrt{F_y} \leq b/t \leq 76/\sqrt{F_y}$ $\qquad F_b = 0.60\ F_y$ 4

$b/t > 76/\sqrt{F_y}$ $\qquad F_b = 0.60\ Q_sF_y$

where: b = width of angle leg

Q_s is per Appendix C of AISC (Reference 18)

For emergency and faulted events F_b shall be the lower of the allowable as determined by Standard Review Plan Section 3.8.4 or 0.95 F_y.

In general, principal axes of the angle member will be used for determination of bending stress and in the design interaction formulas. However, stresses will be based on conventional beam formulas (geometric axes) at locations where the angle member has translational restraint in one direction only and is prevented from rotating by other structural members. Angle members subjected to axial tension, 4
compression and shear will be verified or designed according to the criteria in AISC or ASME Section III.

3. For auxiliary steel subject to eccentric load application, uniform torsional stress, warping shear stress and warping normal stress will be determined and included for comparison with appropriate allowables.

3.3 Mechanical Equipment

Load combinations, allowable stresses and applicable Code versions identified in Sections 3.9 and 5.4 of the updated San Onofre 2 and 3 FSAR will be met for mechanical equipment. This includes vessels, pumps, heat exchangers, tanks, valves and containment penetrations.

4.0 METHODOLOGY

Methodology that will be utilized by SCE in performing the snubber reduction program will include one or more of the following:

4.1 Response Spectra Method

Piping response to the inertia portions of the seismic input may be
determined by either the uniform method (envelope spectrum approach) 4
or the Independent Support Motion (ISM) method. ISM is also
referred to as multiple support motion or multiple input response
spectra analysis in the literature. Acceptable analytical
techniques include those defined in Appendix N of the 1983 edition
of ASME Section III.

For the ISM method, each pipe support will be identified with a group experiencing a common response spectra and common seismic anchor movement (pseudo static component of the seismic response) according to its attachment point to the structural (building) model.

For the uniform method, the response spectra of all applicable pipe supports will be enveloped to determine the response spectra to be utilized for the entire piping subsystem. Each piping support will also be identified with the applicable seismic anchor movement.

4.1.1 Modal Combinations

As demonstrated and recommended in NUREG/CR-3811 (Reference 9)
modal and directional responses will be combined by the square
root of sum of the squares (SRSS) method without considering
closely spaced frequencies. This is consistent with the design
practices of non-NSSS San Onofre 2 and 3 piping (FSAR Section
3.7B.5). For NSSS piping, as in the original design, closely
spaced modes will be combined by the absolute sum method as 4
described in FSAR Section 3.7.3.7.

If including piping system modes above 33 Hz would increase the system response by more than 10%, their effect will be included by using the missing mass correction as described in Reference 21. 4

4.1.2 Sequence of Combinations

As demonstrated and recommended in NUREG/CR-3811 (Reference 9), any sequence can be selected for combining modal and spacial components.

4.1.3 Combination of Group Responses for Independent Support Motion (Inertia Contribution)

For the ISM method, group responses for each direction will be combined by the absolute sum method, as specified in Reference 8.c. Modal and directional responses will be combined by the SRSS method (Reference 8.c). 4

4.1.4 Combination of Group Responses (Anchor Motion Contribution)

Per the recommendations of Reference 9, pseudo static movement of each pipe support group will be combined by the absolute combination procedure to determine the seismic anchor movement response, as is the current design practice of San Onofre Units 2 and 3.

4.1.5 Combination of Directional Components

Results from each direction of earthquake (X, Y and Z directions) will be combined by the SRSS method to determine total seismic response. This is consistent with the current design practices of San Onofre Units 2 and 3 piping (FSAR Section 3.7B.5).

4.1.6 Combination of Inertia and Anchor Motion Contributions

Seismic design loads on pipe supports and reaction loads on in-line components will be determined using an SRSS combination of inertia and anchor motion contributions. This procedure is in accordance with the recommendations of the Brookhaven study.

For evaluation of pipe stress, the seismic inertia contribution will continue to be classified as a primary load and seismic anchor motion will continue to be classified as a secondary load. This is consistent with the current design basis of San Onofre 2 and 3 piping.

4.2 Time History Method

As an alternate to the response spectra method defined in Section 4.2, piping system response may be determined by the time history method. Inertia and anchor motion contributions will be combined by the SRSS method, as discussed in Section 4.1.6.

4.3 Damping

For seismic analysis using the uniform response spectra method (envelope spectrum approach), the damping will be specified in 4
accordance with ASME Code Case N-411 (Reference 11). This damping will be used in its entirety for all applicable analysis and not be mixed with that provided in Table 3.7-22 of the FSAR.

For piping frequencies in the range of 10 Hz to 20 Hz, a linear interpolation of 2% and 5% response spectra is considered an acceptable approximation of the response spectra which would be generated by utilizing the Code Case N-411 frequency variable 4
damping.

For time history analysis or response spectra analysis using the ISM method, damping values provided in Table 3.7-22 of the San Onofre 2 and 3 FSAR will be used. These are identical to those recommended in Regulatory Guide 1.61 (Reference 12).

4.4 Peak Shifting

To account for uncertainties in the natural frequencies of the piping system, either the peak broadening procedures of Reference 13 or the peak shifting procedures of References 10 and 14 may be used. For the case of peak shifting, shifting will be performed about a minimum of two peaks of the response spectra.

5.0 REFERENCES

1. U.S. Nuclear Regulatory Commission, IE Bulletin 81-1, "Surveillance of Mechanical Snubbers," January 27, 1981

2. U.S. Nuclear Regulatory Commission, IE Information Notice 84-67, "Recent Snubber Inservice Testing with High Failure Rates," August 17, 1984

3. U.S. Nuclear Regulatory Commission, IE Information Notice 84-73, "Downrating of Self-Aligning Ball Bushings Used in Snubbers," September 14, 1984

4. U.S. Nuclear Regulatory Commission, memorandum from H. Denton and R. Minogue to W. Dircks, "Proposal for Reviewing NRC Requirements for Nuclear Power Plant Piping," July 13, 1983

5. American Society of Mechanical Engineers, "Section III - Nuclear Power Plant Components," 1974 Edition including Addenda through Summer 1974

6. U.S. Nuclear Regulatory Commission, NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," July 1981

    a. Standard Review Plan 3.6.2, "Determination of Rupture Locations and Dynamic Effects Associated with the Postulated Rupture of Piping," Revision 1, July 1981

    b. Standard Review Plan 3.8.4, "Other Seismic Category 1 Structures," Revision 1, July 1981

7. NUREG-0954, Supplement No. 2, Safety Evaluation Report, Catawba Nuclear Station, Units 1 and 2, June 1984, Section 3.6

8. U.S. Nuclear Regulatory Commission, NUREG-1061, "Report of the U.S. Nuclear Regulatory Commission Piping Review Committee"

   a. Volume 2, "Evaluation of Seismic Designs - A Review of Seismic Design Requirements for Nuclear Power Plant Piping," April 1985

   b. Volume 3, "Evaluation of Potential for Pipe Breaks," November 1984

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   d. Volume 5, "Summary - Piping Review Committee Conclusions and Recommendations," April 1985

9. Brookhaven National Laboratory, NUREG/CR-3811, "Alternate Procedures for the Seismic Analysis of Multiply Supported Piping Systems," August 1984

10. Welding Research Council, Bulletin 300, December 1984

11. ASME Code Case N-411, "Alternative Damping Values for Seismic Analysis of Piping Section III, Division I, Class 1, 2 and 3"

12. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," October 1973

13. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.122, "Development of Floor Design Response Spectra for Seismic Design for Floor-Supported Equipment or Components," Revision 1, February 1978

14. ASME Code Case N-397, "Alternative Rules to the Spectral Broadening Procedures of N-1226.3 for Classes 1, 2 and 3 Piping"

15. Australian Institute of Steel Construction, Australian Standard AS 1250-1975

16. Letter from G. Haaijer, American Institute of Steel Construction, to T. Longlais, Sargent and Lundy Engineers, dated January 15, 1986

17. Letter from T. Galambos, University of Minnesota, to T. Longlais, Sargent and Lundy Engineers, dated January 9, 1986

18. American Institute of Steel Construction, "Specification for the Design, Fabrication and Erection of Structural Steel for Buildings," Eighth Edition

19. J. M. Leigh and M. G. Lay, "Laterally Unsupported Angles with Equal and Unequal Legs," BHP Melbourne Research Laboratory Report MRL 22/2, July 1970

20. B. F. Thomas and J. M. Leigh, "The Behavior of Laterally Unsupported Angles," BHP Melbourne Research Laboratory Report MRL 22/4, December 1970

21. G. H. Powell, "Missing Mass Correction in Modal Analysis of Piping Systems," 5th International Conference on Structural Mechanics in Reactor Technology, Paper K10/3, Berlin, Germany, August 1979

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