ATTACHMENT

LaSALLE COUNTY NUCLEAR STATION
UNITS 1 AND 2

SNUBBER REDUCTION PROGRAM FOR NUCLEAR PIPING SYSTEMS

PREPARED FOR:

U.S. NUCLEAR REGULATORY COMMISSION

PREPARED BY:

COMMONWEALTH EDISON COMPANY

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List of Acronyms

Abs Sum - Absolute Summation

AIB - Arbitrary Intermediate Break

AISC - American Institute of Steel Construction

ASME - American Society of Mechanical Engineers

BOP - Balance - of - Plant

CECO - Commonwealth Edison Company

FSAR - Final Safety Analysis Report

HELB - High Energy Line Break

IGSCC - Intergranular Stress Corrosion Cracking

IHSI - Induction Heating Stress Improvement

ISI - Inservice Inspection

ISM - Independent Support Motion

NSSS - Nuclear Steam Supply System

OBE - Operating Basis Earthquake

ORE - Occupational Radiation Exposure

PVRC - Pressure Vessel Research Committee

RPV - Reactor Pressure Vessel

SRP - Standard Review Plan

SRSS - Square-root-of-the-sum-of-the-squares

SRV - Safety/Relief Valve

SSE - Safe Shutdown Earthquake

URS - Uniform Response Spectra

Executive Summary

This submittal describes the advanced piping analysis methodologies and changes in the existing design criteria which are to be implemented in the LaSalle County Nuclear Station snubber reduction program. The recommendations in this report are consistent with those in NUREG-1061, "Report of the U.S. NRC Piping Review Committee", and are proposed as an approach to minimize snubber related problems.

The LaSalle County Nuclear Station has more than 1200 safety-related snubbers on each of its two units. Snubbers are used to minimize piping response during postulated dynamic loadings such as earthquakes and BWR hydrodynamic events. The redundant and excessive conservatism existing in codes, regulations, and design techniques which were implemented to account for postulated dynamic events has resulted in an unmanageable population of snubbers.

Operating experience in the nuclear industry has shown that a large population of snubbers results in: 1) interference with inservice inspection (ISI) of the piping, 2) interference with other maintenance activities, 3) extensive and time-consuming visual inspection and functional testing, 4) high occupational radiation exposure (ORE) to plant personnel, and 5) reactor shutdowns required for snubber inspections.

Furthermore, evidence has accumulated that many snubbers presently installed are not necessary to provide adequate protection against postulated dynamic events and may act to decrease piping safety. The original design of LaSalle resulted in rigid piping systems which were thought to have higher safety margins than more flexible systems. However, examination of piping at fossil power plants and process plants subjected to earthquakes indicates that flexible piping systems respond less and incur less damage than more rigid piping systems. Also, snubbers installed to increase the dynamic rigidity of a system often fail to perform according to design specifications. When a snubber fails to move freely during thermal expansion of the piping or becomes locked-up, potentially damaging loads for which the piping was not designed may occur during heatup and cooldown.

Recent advancements in piping analysis methodology now enable piping behavior to be more realistically predicted. The excessive conservatisms in modeling dynamic events which led to the use of a large number of snubbers have been identified. Improvements have been recommended by PVRC and other technical groups in the manner of combining loads, handling of spectra broadening and, in particular, the use of new damping values for building filtered loads.

In seeking to reduce snubber related problems, the Commonwealth Edison Company (CECo) initiated a snubber reduction pilot program at LaSalle implementing new advancements in piping analysis. The results indicate that up to 80% of the snubbers can be removed from the plant while maintaining conservative design margins.

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CECo now seeks NRC approval of advanced piping analysis methodologies and realistic design criteria for use in the snubber reduction program at LaSalle County Nuclear Station Units 1&2. As in the original plant design, the two basic types of methodologies will be the response spectra and time history analyses.

The following modifications to response spectra analysis are proposed: 1) PVRC damping values, 2) PVRC spectral peak shifting, and 3) use of independent support motion techniques. Nonlinear time history analysis will be used in limited cases for the removal of problem snubbers.

Modifications will be made to load cases and load combinations used in the original design. For BOP piping, the SRV flow transient, SRV building inertial, and turbine trip loads will be decoupled. This is consistent with the original design of LaSalle's NSSS piping. The NSSS vendor has verified the loads are time phased and should not be contained in the same load case. Furthermore, the SRSS method of combining individual flow transient loads on the main steam headers is proposed as an alternative to the original design method. In addition, the analysis will decouple SRV (all) and SRV (asymmetric) loads, as these loads do not occur simultaneously.

For the subsystems that undergo re-analysis, the basic design criteria relating to piping and support design will remain as presently stated in the LaSalle 1&2 updated FSAR. Alternative design criteria will be applied to situations where their use permits the removal of problem snubbers.

CECo is investigating the use of strain criteria and dynamic stress as secondary stress criteria to evaluate piping. However, this alternative piping criteria will not be submitted for approval until industry groups such as the ASME verify their acceptability.

For the high energy line break (HELB) criteria, CECo proposes to maintain all existing break locations and not add any new breaks. The redundant conservatism in the break postulation criteria and the existing pipe-whip restraints ensure that reasonable protection will be maintained against HELB.

The pilot program indicated that low allowable nozzle loads on mechanical equipment are a factor leading to the large population of snubbers. Provisions are made to requalify nozzle loads to higher allowables. Nozzle flexibilities may also be included in the piping analysis.

Several options are proposed to requalify auxiliary and structural steel. Should actual material yield stress data be available, the actual yield stress may be used in the support calculation in lieu of the AISC allowable. Faulted multipliers and use of the plastic section modulus up to the allowable stated in the updated FSAR and Standard Review Plan 3.8.4 will be used. Limiting the ductility ratio to three is another alternative qualification technique proposed for auxiliary steel.

For cases where concrete expansion anchor bolts limit the removal of a problem snubber, the anchor bolts will be requalified to new factors of safety.

Even with the proposed changes, significant and adequate conservatisms remain in the piping design. Strain rate effects, which can significantly increase yield stress for dynamic loadings, are not considered. The OBE ground acceleration, presently required to be at least half the SSE level, has no technical basis and results in an overly conservative seismic design. Furthermore, the SRV (all) load case, representing the simultaneous firing of all eighteen SRV's, is currently placed in Service Level B loads. Based on probability of occurrence, however, Service Level C is a more appropriate category for the SRV (all) load. Considerable design margin exists by having an unrealistic load in Service Level B added to conservatisms inherent in developing the SRV (all) response spectra.

Subsystems will be selected for re-analysis based on recommendations from LaSalle Station personnel. This input shall ensure that the re-analysis effort addresses snubbers which create the most problems at the station from maintenance, ISI, and ALARA standpoints. In addition, snubbers within each subsystem will be prioritized for removal before re-analysis.

The piping analysis methodologies and design criteria used to re-analyze subsystems during the snubber reduction program will be properly documented. After the stress report for a subsystem is finalized, all affected design documents will be updated.

1.0 Introduction

The LaSalle County Nuclear Station has more than 1200 snubbers per unit. This large number of snubbers has resulted from layers of conservatism in the original design via codes, regulations, and design techniques. The combination of these conservatisms produced piping systems that contain more snubbers than are necessary or desirable.

Since the original piping design at LaSalle, advances in piping analysis and operating experience indicate that snubbers are not necessary nor desirable for the following reasons:

1. Increased Ability to Predict Piping Response to Dynamic Events

   Research conducted by PVRC has resulted in the recommendation to use higher damping values to predict piping response to dynamic events. Furthermore, the excessive conservatism involved with using enveloped spectra and broadened spectra may be reduced by using newly developed independent support motion and peak shifting techniques. Use of the above damping values and analytical techniques more realistically models piping response behavior and indicates that many snubbers are not necessary.

2. Seismic Testing of Piping Systems

   Recently completed testing at ANCO laboratories (reference 1) and by Teidoguchi (reference 2) have demonstrated that piping systems can withstand earthquake excitations at least three to five times larger than permitted by the ASME Code without failure of the piping. The ANCO testing also demonstrated that failure of a snubber or support in the Z - bend system tested did not result in loss of piping pressure retaining integrity.

   Historical data of fossil power plants and process plants subjected to large earthquakes indicate that failure of major piping systems have not occurred (references 3 and 4). Piping systems in fossil power plants and process plants typically have low fundamental frequencies (for example 0.5Hz) as compared to nuclear plant piping. As a result, the response of these flexible systems to a seismic event is less severe.

3. Snubbers Perform Unreliably

   Operating experience at nuclear plants has demonstrated that snubbers perform unreliably in service and are subject to frequent failure. The functional test data from several plants indicates that snubber failure rates typically range from 5% to 20%.

   A snubber which does not perform according to design specifications may not only fail to provide adequate protection against postulated dynamic events, but may also introduce thermal stresses during normal operation for which the system was not designed.

4. Occupational Radiation Exposure of Plant Personnel (ORE)

The Technical Specification for LaSalle requires both visual inspection and functional testing of snubbers. These activities divert manpower resources from other maintenance areas in order to maintain the large population of snubbers at LaSalle. The inspection and testing of snubbers results in large ORE to the personnel who inspect the snubbers in the plant or remove, transport, and reinstall snubbers for functional testing.

5. Plant Availability

High snubber failure rates increase the frequency of required inspections. Approximately half of the snubber population is in the drywell and main steam tunnel, areas inaccessible during normal operation. Therefore, unit shutdowns are necessary for the sole purpose of snubber inspection.

6. Interference with Piping ISI

Snubbers decrease the accessibility to welds and impede ISI of the piping.

In seeking to reduce snubber related problems, CECo initiated a snubber reduction pilot program in early 1984. The purpose of the pilot program was to examine the feasibility of re-analyzing piping systems in order to remove snubbers.

The pilot program incorporated a variety of PVRC recommendations and made comparisons of alternative design criteria and load combination methods. PVRC damping values were used. The program also applied the independent support motion technique, comparing results of the Abs Sum method of combining group responses to the SRSS method. The advantage in using the dynamic stress as secondary stress criteria was evaluated. Load cases were modified to remove excessive conservatisms. Snubber optimization subroutines were used. The program utilized existing piping analytical models and minimized the conversion of snubbers to struts.

Results showed that 80% of the presently installed snubbers are unnecessary and could be removed. Only 14% of the removed snubbers required replacement by a rigid strut. Details of the pilot program are presented in Appendix A.

CECo now seeks approval to use the advanced piping analysis methodologies and modified piping design criteria outlined in the following sections. Improvement in plant safety and reliability, decreased ORE, and increased access for ISI are the sought after benefits.

2.0 Scope

The snubber reduction program will encompass snubbers on safety-related piping systems, including snubbers on NSSS piping. Snubbers used for the seismic support of equipment, other than piping, are excluded.

Not all safety-related subsystems will be re-analyzed to remove snubbers. Re-analysis will only be performed on subsystems where improvement in plant safety and/or ORE will result or where improvement in plant economics justify the effort.

3.0 Methodology

As in the original design, two general piping analysis techniques will be used in the snubber reduction program, the response spectra and the time history approaches.

The decision on which analysis technique to use is based upon the nature of the input loading. For the majority of subsystems to undergo re-analysis, the analysis techniques will follow the original plant design. The response spectra technique will be used for seismic (OBE and SSE) and BWR hydrodynamic, building-filtered loads (SRV building inertial, condensation oscillation, and chugging). The time history technique will be used for loadings characterized by an external forcing function time history (annulus pressurization, SRV thrust, and turbine trip). The time history technique may also be used for seismic and BWR building filtered loads for which time histories are available.

In exceptional cases, nonlinear dynamic analysis is proposed to justify the removal of problem snubbers. Problem snubbers are those snubbers which are difficult to access, cause high ORE during inspection and maintenance, and their removal is determined to be worth the effort of using advanced analytical techniques to show that the piping remains conservatively designed.

The following paragraphs describe in greater detail the specifics of the methodologies.

3.1 Response Spectra Method

Results of a response analysis are known to be overly conservative when compared to an equivalent time history analysis. The excessive conservatism leads to the use of unnecessary snubbers. CECo proposes to use the latest PVRC recommendations on damping and peak-shifting (Reference 5) as well as other advancements in response spectra analysis recommended in NUREG-1061 (Reference 6). The use of the following techniques will result in more realistic, yet still conservative, prediction of piping system response to seismic and BWR hydrodynamic events.

3.1.1 PVRC Damping

The PVRC damping recommendation allows the use of 5 percent of critical damping for piping frequencies up to 10 Hz, 2 percent of critical damping for frequencies between 20 Hz and 33 Hz, and a linear damping variation from 5 percent at 10 Hz to 2 percent at 20 Hz. The PVRC damping recommendation has been adopted as Code Case N-411 (Reference 7) by the ASME and the use of PVRC damping at the Byron, Braidwood, and Clinton (Illinois Power) nuclear stations has already been approved by the NRC.

PVRC damping will be used for the response spectra of all building-filtered loads. However, the building feedback response from BWR hydrodynamic events exhibits frequency content above 33 H_z. Therefore, 2 percent of critical damping will be used for all frequencies above 33 H_z. The 2 percent value was used in the original design for emergency and faulted condition dynamic loads.

For some highly insulated piping systems, the PVRC approved similar damping criteria beginning at 8% of critical damping in a meeting on January 27, 1986. It is our understanding that this will probably be endorsed by Section III through a Code Case. At that time, we intend to apply for use of these higher damping values on the applicable systems.

3.1.2 PVRC Peak Shifting

The PVRC peak shifting recommendation provides an alternate approach to the + 15% peak broadening guidelines required by Regulatory Guide 1.122 (Reference 8). The peak shifting alternative allows response spectra peaks to be shifted throughout the + 15% range, enveloping input responses rather than the inputs themselves. Peak shifting has been adopted by the ASME as Code Case N-397 (Reference 9).

3.1.3 Independent Support Motion (ISM)

The ISM method groups pipe supports by attachment points, where supports attached to a floor or structure with the same general translational motion (without rotation) are considered as a group. All support attachment points in a group will have the same response spectra. The piping response resulting from each group is calculated by keeping all other pipe support groups fixed. The total piping response is determined by combining the effects of all individual groups.

Original plant design enveloped all independent response spectra at the various attachment points of a given piping system into a single response spectra. The enveloped response spectra, also referred to as a uniform response spectra (URS), was used as the input for all attachment points. NUREG-1061 and NUREG/CR-3811 (Reference 10) have indicated that this practice considerably overestimates the response of piping systems in most cases and precludes providing a balanced design between seismic protection and normal system operation. Both NUREG-1061 and NUREG/CR-3811 recommend use of the ISM methods.

In order to apply the ISM methodology, the following approach will be used:

a. For the inertial component of response:

   i. Structural support points that are attached to a rigid floor or structure so that the same general translatory motion (without rotation) is experienced are considered as a group of supports.

   ii. Group responses for each direction will be combined by:

      1. SRSS for OBE and Service Level B Hydrodynamic Events.
      2. Abs Sum for SSE and Service Level C&D Hydrodynamic Events.

   iii. Modal and directional responses will be combined by the SRSS method without consideration of additional techniques for closely spaced frequencies.

b. For the static component of response:

   i. For each group, the maximum absolute response will be calculated for each input direction and the results combined by the Abs Sum method.

   ii. Directional responses will be combined by the SRSS rule.

c. Total response (inertial and static) will be combined by the SRSS rule.

The above approach is consistent with recommendations in NUREG-1061 except for a.ii. Approval to combine group responses for each direction using the SRSS method for OBE and Service Level B hydrodynamic events is requested. The basis is NUREG/CR-3811, a Brookhaven study which compared the results of the URS and ISM methods to best estimate time history analyses. The piping models were subjected to multiple earthquake motions and the group responses were combined using algebraic sum, SRSS, and Abs Sum methods. Data from the SRSS method are summarized in Table 4-1 of Appendix B.

The average group responses combined by SRSS were shown to be conservative when compared to time history analyses. The comparison is summarized as follows:

- Pipe displacements - 144% conservative
- Pipe accelerations - 859% conservative
- Pipe forces and moments - 152% conservative
- Pipe support loads - 120% conservative

It is recognized that there were a few cases where the ISM-SRSS combination underpredicted piping responses by up to 19%. Consequently, group responses from SSE and Service Level C & D hydrodynamic events will continue to be combined by the Abs Sum method. Additional studies presently being performed at Brookhaven National Laboratories on ISM using PVRC damping will hopefully prove that the SRSS method is valid in all cases. Other studies are being proposed which will use probabilistic analysis to justify SRSS.

Until the pending studies are completed, the proposed position on directional group response combination is justified by the following:

1. Service Level B allowables limit the piping near yield stress. Piping materials typically have a ratio of ultimate stress to yield stress of approximately 1.7, or 70% above yield. Thus, even if the SRSS group combination occasionally underpredicts responses by up to 20%, no failure of the pressure boundary will occur.

2. 10CFR100 requires nuclear plant piping be designed for an operating basis earthquake (OBE) and safe shutdown earthquake (SSE). The OBE is an earthquake which could reasonably be expected to occur at the plant site during the operating life of the plant. The SSE is based upon an evaluation of the maximum earthquake potential, considering the regional and local geology and seismology, and specific local subsurface characteristics. However, 10CFR100, Appendix A, Part V, "Seismic and Geological Design Basis," requires the OBE be at least one-half the magnitude of the SSE. This requirement is not consistent with the definition of the OBE and leads to an overly conservative design. Consequently, the OBE rather than the SSE often controls piping seismic design. Since designing piping systems to the SSE is sufficient to ensure safety, the OBE should not govern seismic design.

3. Until the conservatism involved with the ISM-SRSS method can be documented, group combinations for the SSE and other Service Level C&D hydrodynamic events will be combined using the Abs Sum method or otherwise the URS will be used.

3.1.4 Response Combination

3.1.4.1 High Frequency Modes

For subsystems affected by BWR hydrodynamic loads, all modes above 33Hz will be considered as high frequency modes. Algebraic combination will be used to combine high frequency modal effects. The total effect of all high frequency modes will be combined with the total effect of all modes less than 33Hz by using the SRSS method.

3.1.4.2 Closely-spaced Modes

As recommended in NUREG-1061, all modes less than 33Hz will be combined using the SRSS method without considering closely-spaced modes.

3.1.4.3 Sequence of Combinations

Any sequence of combinations between spatial and modal components may be used.

3.2 Time History Method

The time history method will be used to analyze piping systems subjected to dynamic loads characterized by external forcing functions. These include the SRV thrust loads, turbine trip transients, etc. The time history method may also be used for other dynamic loads such as seismic loads, SRV discharge (inertial), LOCA (inertial), annulus pressurization loads, etc.

Consistent with the recommendation of NUREG-1061, Reg. Guide 1.61 (Reference 11) damping values will be used in the time history analysis.

3.2.1 Multiple Input Time History Approach

The time history approach will be performed using the multiple input time history approach. This approach utilizes individual time histories at the various building attachment points. The building time histories are either obtained from the dynamic analysis of the building subjected to the particular dynamic load or obtained by synthesis of the broadened response spectrum.

The technical details of the multiple input time history methodology are already provided in Section 3.7.3.14.2 of the updated LaSalle FSAR (Reference 12).

3.2.2 Nonlinear Time History Analysis

Nonlinear time history analysis, which considers the effects of geometric and/or material nonlinearities, will only be used in select cases. The geometric nonlinearities include gaps between pipe supports and pipes and between pipe supports and building structure. Technical details of nonlinear dynamic analysis are well documented in literature. Specific approval will be sought on a case-by-case basis.

4.0 Design Criteria

Licensing commitments stated in the updated FSAR (Reference 12) will be followed except as specifically noted below.

4.1 Load Combinations

4.1.1 SRV Thrust, Turbine Trip, and SRV Building Inertial Loads

The SRV lines attached to the Main Steam (MS) system are subjected to both fluid transient loads (SRV thrust and turbine trip) and vibratory loads from building feedback (SRV induced inertial loads). Since the time duration of these loads do not overlap, the SRV thrust, turbine trip, and SRV inertial loads were not combined together for NSSS piping. This fact is reflected in the current stress reports for the NSSS portion of MS subsystems.

For the BOP piping (refer to Table 3.9-16, sheet 3 of 9 in the updated FSAR), a more conservative approach was followed; namely, SRV thrust and SRV building inertial loads were combined by the SRSS methods. To be consistent with the NSSS piping, sheet 4 of 9 in Table 3.9-16 for BOP piping is being modified by the addition of a footnote to the load acronym 'TR'. The footnote will clarify that SRV thrust loads shall not be combined with SRV inertial loads since these loads are time phased. Likewise, the SRV thrust loads shall not be combined with the turbine trip fluid transient loads nor shall the turbine trip fluid transient loads be combined with SRV inertial loads.

However, the SRV thrust, SRV inertial, and the turbine trip loads shall be individually combined with seismic loads (OBE and SSE).

4.1.2 SRV Thrust Effects

To determine the total effect of SRV discharges on the main steam header, the NSSS vendor simultaneously applied all individual thrust force time histories. The piping response was determined as a function of time. The maximum piping response was used in the load combinations. This approach is overly conservative since the simultaneous discharge of all SRVs is highly improbable considering the different set points, variations in valve opening times, and discharge pipe routing.

Another alternative approach is to decouple the SRV discharge piping from the main steam header piping and perform an individual analysis for each SRV discharge piping.

The load from SRV discharge is then imposed on the header piping. Because of the difference in the SRV set points, variation in the valve opening time and discharge pipe routing, CECo will combine the maximum response due to the individual application of SRV discharge load on the main steam header by the SRSS method.

4.1.3 SRV (all) and SRV (asymmetric) Loads

The BOP piping at LaSalle was originally designed by enveloping the SRV (all) and SRV (asymmetric) response spectra. The NSSS piping, however, was designed by performing separate analysis to obtain the SRV (all) and SRV (asymmetric) loads.

In the snubber reduction program, CECo will use separate analyses to obtain the SRV (all) and SRV (asymmetric) loads on the BOP piping, as was done for the NSSS piping. The envelope of the individually obtained SRV (All) and SRV (asymmetric) loads will be used in the applicable load cases as the SRV (all/asy) load.

4.2 Allowable Loads and Stresses

All piping and supports, NSSS and BOP, will continue to be designed to the original Code of Construction, the 1974 ASME B&PV Code, Section III (Reference 13). 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 (Reference 14)

4.2.1 Piping

The snubber reduction pilot program results have indicated that allowable loads on supports and mechanical equipment nozzles are the most common factor limiting snubber removal, not allowable pipe stress. However, special cases may arise where the removal of problem snubbers may be possible if and only if alternative piping stress criteria are used. For these special cases, alternative piping design criteria based on allowable strain and classifying dynamic stress as secondary stress are currently being developed. After industry recommendations have been evaluated and the alternative criteria are complete, the alternative criteria may be forwarded in a separate submittal.

4.2.1.1 Strain Criteria

The strain criteria will be used as acceptance criteria when inelastic response analyses are performed. The strain criteria will also be used with psuedolinear-elastic estimation methods. NUREG-1061, Volume 5 concludes that since the SSE is a low-probability event, it is prudent to account for the energy absorption and dissipation capacity of piping by accepting some inelastic behavior.

4.2.1.2 Dynamic Stress as Secondary Stress

CECo is aware of ongoing industry discussions among ASME and PVRC committees concerning a modified dynamic stress criteria. The modified dynamic stress criteria is based on the classification of seismic loads as secondary, accounting for the energy absorption capacity of the piping, and considering the seismic loads in a separate fatigue evaluation. CECo will consider using the modified criteria when its acceptability is proven for both seismic and BWR hydrodynamic loads.

4.2.2 Pipe Supports

Standard pipe component supports for NSSS and BOP safety-related piping were designed in accordance with Subsection NF of the ASME B&PV Code, Section III or ANSI B31.1 as appropriate. Non-standard pipe supports were designed in accordance with AISC requirements. The same acceptance criteria will be used in the snubber reduction program.

4.3 Miscellaneous Piping Criteria

4.3.1 As-Built Tolerances

Any as-built configuration which does not meet the tolerance band stated on design drawings, but was reconciled, will be used to update the piping analytical model during the snubber reduction program.

4.3.2 Pipe Dynamic Displacements

Pipe dynamic displacements will be checked after snubber optimization to ensure that interaction with surrounding structures, piping, ductwork, cable trays, and equipment does not occur.

The interaction check will be performed either by limiting new displacements to less than or equal the previously existing pipe displacements or performing a field walkdown to confirm acceptable clearance.

4.3.3 Functional Capability - Essential Piping

For essential piping, the original functional capability acceptance criteria as stated in the Mark II-DAR (Reference 19) will be met.

Should piping acceptance criteria based on strain be implemented, the functional capability acceptance criteria shall also be changed accordingly.

4.3.4 High Energy Line Break (HELB) Criteria

Design criteria for the selection of postulated locations of HELB are provided in Section 3.6.2 of the updated FSAR and were based upon Regulatory Guide 1.46 (reference 15), NRC Branch Technical Position APCSB 3.1, Appendix B, and as expanded in NRC Branch Technical Position MEB 3-1. These criteria require postulated HELB locations at terminal ends and at two or more intermediate locations. Evolution of these criteria has been summarized in NUREG-1061. The conclusion is that current nuclear power plants have too many pipe whip restraints and jet impingement barriers for extremely low probability HELB events.

For the snubber reduction program no new HELB locations will be added, unless it becomes necessary to satisfy stress and cumulative usage factor (CUF) limits. The usage factor to be used will follow recommendations in letter N. Hou, NRC to J. Fox, Chairman of the ANS-58.2 Working group, dated October 1, 1985 (Reference 20). In that letter, Mr. Hou suggests a CUF of 0.4 instead of the 0.1 factor presently used, based on the implementation of ANSI/ASME Standard OM-3, "Requirements for Pre-Operational and Initial Startup Vibration Testing of Nuclear Power Plant Piping Systems", which reduced the uncertainties associated with vibratory loads. Pre-operational and startup vibration testing programs consistent with this standard have been performed at LaSalle Units 1 & 2. The purpose of the programs was to ensure that the operational vibration levels did not exceed allowable stress amplitudes nor caused undesirable system responses.

Note that the increase in allowable CUF from 0.1 to 0.4 affects only postulated HELB locations on Class 1 piping. New postulated HELB's, if any, will be evaluated to demonstrate that plant protection requirements have been satisfied.

Rev. 1 to SRP 3.6.2 (Reference 16) states that it is not required to relocate arbitrary intermediate breaks (AIB's) each time the piping stress pattern changes, provided that specified stress and usage factor limits are satisfied. AIB's are those breaks postulated to provide a minimum of two breaks between terminal ends even though required stress limits and usage factors are met. Furthermore, CECo has received permission from the NRC in the LaSalle County Station Units 1 and 2, "Safety Evaluation for the Elimination of Arbitrary Intermediate Pipe Breaks", September 1985, to physically remove pipe-whip restraints associated with AIB's on Class 1 piping, except for one AIB on piping susceptible to IGSCC.

For piping systems susceptible to intergranular stress corrosion cracking (IGSCC), the LaSalle County Nuclear Station has performed induction heating stress improvement (IHSI) on Unit 1 to mitigate IGSCC effects. Most susceptible welds on Unit 2 have also undergone IHSI. The remaining welds (approxiately 40) will undergo IHSI during the first refueling outage of Unit 2 in September, 1986.

IHSI has proven to be an acceptable remedy for IGSCC. IHSI converts the welding residual stress at the inside surface of the pipe from tension to compression, thereby eliminating the major stress factor contributing to IGSCC.

Consequently, IHSI reduces IGSCC concerns regarding the elimination of arbitrary intermediate breaks. For this reason, CECo proposes not to postulate AIB's on piping that is no longer susceptible to IGSCC.

4.3.5 Pipe-Whip Restraint Gaps

Pipe-whip restraint gaps will be checked in all directions after snubber optimization. The check will ensure that the piping will not contact pipe-whip restraints during normal, upset, and emergency modes of plant operation.

4.4 Mechanical Equipment

Load combinations on nozzles to mechanical equipment will remain the same as presently stated in the updated FSAR except as modified by section 4.1 of this report. Mechanical equipment includes vessels, pumps, heat exchangers, tanks, valves, and containment penetrations.

4.4.1 Allowable Loads

Present allowable loads on nozzle connections to mechanical equipment will often limit the removal of snubbers. NUREG-1061 acknowledges that low allowable nozzle loads generally used today contribute to the stiffening of piping systems by requiring snubbers whose sole purpose is to keep loads on nozzles extremely low. In CECo's snubber reduction pilot program, the low allowable load on a RPV nozzle was the limiting factor to further snubber removal in a standby liquid control subsystem.

In cases where a low allowable nozzle load is identified as the limiting factor to further snubber removal, CECo may pursue the requalification of the nozzle to higher allowable loads. The original equipment vendor or a qualified engineering firm will be requested to perform the nozzle qualification calculation using advanced stress analysis techniques. Should allowable nozzle loads be increased, all affected mounting and structural calculations will be verified for acceptability.

4.4.2 Nozzle Flexibility

For the original design, piping system flexibility calculations (used for evaluating both static and dynamic loadings) did not always consider the flexibility of component nozzles. Nozzle flexibilities may be calculated and included in piping system flexibility calculations during the snubber reduction program.

4.4.3 Valve Accelerations

Valve operator accelerations shall not exceed the qualified allowables specified in existing stress reports.

4.5 Structural Evaluation

Auxiliary steel is the steel used to support loads from piping systems, conduit or cable trays, and does not contribute to the strength or stiffness of the primary structure. Auxiliary steel is not essential to the load carrying capacity of the main building structures and typically consists of light steel framing members spanning between girders, columns, or concrete walls.

Structural steel members carry the primary building loads.

Both the auxiliary steel and structural steel components were designed in accordance with the 1969 AISC Manual of Steel Construction (Reference 18) and other codes listed in Sections 3.8.3 and 3.8.4 of the updated FSAR.

For the majority of the piping subsystems undergoing re-analysis, loads on the auxiliary and structural steel components will be limited to a value less than or equal to existing qualified loads. However, in cases where an existing qualified load precludes removal of a problem snubber, the following techniques may be used to requalify the component to a higher allowable load.

4.5.1 Auxiliary Steel

4.5.1.1 Actual Material Yield Stress Data

The steel used in auxiliary steel components typically has an actual yield stress, based on tests, higher than the yield stress specified in the AISC Manual. If Certified Material Test Reports (CMTR's) are available for the steel, the actual minimum yield may be used in lieu of the yield stress specified in the AISC Manual for the material type.

4.5.1.2 Standard Design Practices

When qualifying auxiliary steel to higher allowable loads, excessive conservatisms in the original design, additional to those inherent in SRP 3.8.4 (Reference 16), will be removed. Thus, auxiliary steel design will remain in accordance with SRP 3.8.4.

The auxiliary steel at LaSalle Units 1&2 was originally designed with an increase factor of 1.33 for faulted allowables versus design allowables. SRP 3.8.4 allows up to a 1.7 increase factor and the updated FSAR allows up to a 1.6 increase factor (Table 3.8-9).

However, the original FSAR criteria will be retained for structural shapes with no axis of symmetry (angle sections).

Furthermore, SRP 3.8.4 allows the use of the plastic section modulus in computing the strengths of auxiliary steel for emergency and faulted conditions (Service Levels C and D) when LOCA and SSE loads are combined.

The effect of auxiliary steel yielding on the piping system response will also be evaluated.

4.5.1.3 Ductility Ratio

As an alternative to the elastic criteria for auxiliary steel design, an inelastic approach allowing support yielding will be followed. In this approach, the allowable ductility ratio is limited to three, where the ductility ratio is defined as the ratio of the elastic to elastic/plastic deflection at the pipe attachment point.

In these cases where a ductility ratio of three is used, no increase in material yield (as described in 4.5.1.1) will be used. Also, the ductility approach will be used only if the connection is stronger than the member.

The effect of auxiliary steel yielding on the piping system response will also be evaluated.

4.5.1.4 Dynamic Displacement

For the majority of cases, dynamic displacement of auxiliary steel is limited to less than or equal to ± 1/4 inch. If the dynamic displacement exceeds ∓ 1/4 inch, then the effect of the larger displacement on the piping will be evaluated. If necessary, the steel stiffness will be modeled in the piping evaluation.

4.5.1.5 Weld Attachment Capacity

The weld attachment capacity will be based on AISC allowables for the upset condition and 1.6 of AISC allowables for emergency and faulted conditions.

4.5.2 Building Structural Steel

When structural steel is requalified to higher allowable loads, the actual material yield strength data (as described above in 4.5.1.1) and SRP 3.8.4 (Same as 4.5.1.2) will be used. The ductility ratio approach shall not be used.

4.5.3 Concrete Expansion Anchor Bolts

The allowable loads for concrete expansion anchor bolts were obtained by using the manufacturer's reported ultimate capacity with a minimum factor of safety of four on wedge type anchor bolts. On a case-by-case basis, a factor of safety of two (2) will be used to requalify existing supports. A factor of safety of two will only be used if there are a minimum of four support anchor bolts, with not more than half the bolts subjected simultaneously to tension loads, and if the adjacent supports carrying load in the same direction are qualified elastically.

5.0 Conservatisms

5.1 General Conservatisms

Even though the approaches being employed in the snubber reduction program are more realistic methods of evaluating piping systems, significant conservatisms remain in this approach which are not quantifiable and are usually not considered in evaluating piping system safety margins. These conservatisms can be classified in three categories, as follows:

1) Analytical simplifications of complex phenomena in piping behavior.

   A. Strain rate effects, which can significantly increase yield stress for dynamic loadings, are not used.

   B. As used in the primary load equations for linear elastic analysis, stress intensification factors are extremely conservative. Use of these factors predicts yielding earlier than would naturally occur in components like elbows and tees; furthermore, no analytical mechanism exists for the redistribution of stress to other components after initial yielding.

   C. Current Code allowables for dynamic loading are conservative. Current Code thinking may eventually result in modifications to the criteria, such as the consideration of seismic stresses as secondary. Pending future developments in dynamic stress criteria, the conservatisms may become quantifiable and CECo will take credit for them.

2) Simplified modeling of real piping system geometric and material properties.

   A. Piping material actual yield strengths are generally at least 10% greater than Code specified minimums. In some cases, this conservatism will be accounted for in requalifying auxiliary and structural steel.

3) Conservative hand calculations and component allowables for pipe supports.

   A. Hand calculations of structural components and anchor bolt loads are conservatively performed.

   B. The load capacity of catalog items, as given by the vendor, are conservatively provided to A/E organizations.

Thus, the CECo approach includes conservatisms beyond the conservatism inherent in the ASME Code. At the same time, the piping systems will be made more reliable for normal system operation.

5.2 Specific Conservatisms at LaSalle

In addition to generic conservatisms inherent in the piping stress analysis, additional conservatisms exist in the basic loading inputs. It should be noted the following conservatisms will remain in the plant design after the snubber reduction program is complete.

1) The OBE site acceleration level of 0.10g for LaSalle is extremely conservative. The excessive conservatism arises because the OBE is coupled to the SSE and must be at least one-half of the SSE site acceleration level. NUREG-1061 recognizes that this requirement is overly conservative and has no technical basis. The OBE level should be based on a more reasonable level of occurrence, consistent with OBE loads being classified as Service Level B, and be independent of the SSE level.

2) The results of in-plant SRV tests (CECo proprietary) indicate that significant margin exists between the BWR hydrodynamic, analytically-predicted response spectra used for design and the actual measured responses. The margin in the structural responses stem from the inherent conservatisms in the structural modeling and analysis techniques. Consequently, the affected piping systems are designed for vibratory loads larger than those that actually occur.

3) The SRV load case for the upset plant condition (Service Level B) is the envelope of the SRV (all) and SRV (asy) cases. The SRV (all) load case represents the simultaneous discharge of all 18 SRV's.

   The probability of the SRV (all) load case occurring, however, is extremely low. While performing closure tests on the MSIV's at 95% reactor power, the SRV (all) case never occurred when the MSIV's were instantaneously shut. Based on the probability of occurrence, Service Level C is a more appropriate category for the SRV (all) load case.

   Therefore, maintaining the SRV (all) load case in Service Level B is overly conservative. Considerable design margin exists by having an unrealistic load case in Service Level B added to the conservatisms inherent in developing the SRV (all) and SRV (asy) response spectra.

4) Even with the proposed improvements, the response spectra technique generally results in a higher energy input into the piping model than time history analysis. The higher energy input translates into added conservatism in the piping design. The time history analysis is used as the basis for comparison because it is considered to be the most accurate method of predicting piping response.

When re-analysis is performed, the majority of subsystems will continue to use the response spectra analysis for building-filtered loads (seismic and BWR hydrodynamic), as was done in the original design. Therefore, the added conservatism introduced through the response spectra method will continue to prevail in the design of piping systems at LaSalle.

6.0 Implementation

After the proposed changes to design criteria and analysis methodologies have been approved by the NRC, CECo will begin the snubber reduction program at the LaSalle Nuclear Station. CECo will implement the snubber reduction program using a systematic approach to rank subsystems for priority of re-analysis. Engineering consulting firms will be screened for competence in applying the proposed analysis methodologies as well as for quality engineering procedures.

1) Snubber Prioritizing

Snubber prioritizing is a technique used to emphasize the removal of problem snubbers before others in a given subsystem. Problem snubbers are those which are inaccessible, in a high radiation area, or in a high temperature environment. Snubbers are given a priority level of 1 to 4. Attempts to remove priority 1 snubbers must be made before removing any priority 2, 3, or 4 snubbers. This process provides a benchmark for the piping analyst to use in iterative support optimization techniques, where many approaches and solutions for each subsystem are possible.

2) System Prioritizing

Systems which contain the highest number of priority 1 snubbers, or those systems which have had the highest number of snubber failures, will be grouped for re-analysis first. The station shall initiate modifications to implement the needed changes to plant systems using the same criteria.

The benefits of reduced ORE and increased plant reliability will be maximized by re-analyzing the subsystems containing the greatest amount of problem snubbers as soon as possible.

3) Snubber Removal/Conversion to Struts

Snubber removal and the conversion of snubbers to struts may begin once the new stress report and support arrangement have been finalized for a subsystem.

For subsystems which require only snubber removal, and no other alterations, the snubbers may be removed at any time which is safe for personnel to perform the work.

Subsystems which require the conversion of snubbers to struts will be declared inoperable before the conversion work is performed. Much of this work will occur during refueling outages. Before the subsystem is declared operable, the new support arrangement must be inspected and documented as complete.

4) Documentation

The FSAR will be updated to identify those piping systems which have been re-analyzed as a result of the snubber reduction program. Also, the specific design criteria and methodologies used in the snubber reduction program will be identified for each system. In addition, the required ASME Section III Stress (Design) Reports will be revised to reflect the new pipe support configuration.

7.0 References

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4. Lawrence Livermore Laboratory, NUREG/CR-1665, "Equipment Response at the El Centro Steam Plant During the October 15, 1979 Imperial Valley Earthquake", October 1980.

5. Welding Research Council, Bulletin 300, December 1984.

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

   c. Volume 4, "Evaluation of Other Dynamic Loads and Load Combinations", December 1984.
   d. Volume 5, "Summary - Piping Review Committee Conclusion and Recommendations", April 1985.

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

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16. 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".
    b. Standard Review Plan 3.8.4, "Other Seismic Category 1 Structures", Revision 1, July 1981.

17. U.S. Nuclear Regulatory Commission, NUREG/CR-2136, "Effects of Postulated Event Devices on Normal Operation of Piping Systems in Nuclear Power Plants", May 1981

18. American Institute of Steel Construction "Manual for Steel Construction", 1969 Edition.

19. LaSalle County Station Mark II Design Assessment Report, Rev. 10, 9/82.

20. Letter Shou N. Hou, U.S. Nuclear Regulatory Commission, to Jack N. Fox, of General Electric Co., Chairman of the ANS-58.2 Working Group, October 1, 1985 Subject: "Comments on Draft Revision 2 of ANS-58.2".

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Appendix A

Snubber Reduction Pilot Program

The pilot program was divided into two phases. Phase I evaluated design optimization techniques by considering basic static and dynamic (response spectra type input) load cases. Phase II completed the design re-evaluation by examining all load cases, including postulated transients and fatigue, and all calculations and verifications required by the ASME Code.

Portions of the residual heat removal (RH), standby liquid control (SC), and main steam (MS) systems were selected as sample subsystems.

This Appendix describes these subsystems, and briefly addresses the methodology and, the acceptance criteria, and the results.

1.0 System Description

1.1 Subsystem MS-03

Line MS-03 consists of 26" diameter piping conveying steam from the reactor pressure vessel to the turbine. Isolation valves are located inside and outside the containment. Additionally, there are five, 8 inch diameter safety/relief valves connected to the main steam line. Downstream of each SRV there is 12" diameter piping which carries steam to the suppression pool during SRV opening. For the pilot study, the MS line and only two of the five SRV's were included, the other three were modeled only approximately. These lines have 30 snubbers, 6 rigid supports, and 6 variable or constant spring hangers.

1.2 Subsystem SC-02

The standby liquid control system is designed to shut the reactor down from full power to cold shutdown and maintain the reactor in a sub-critical state at atmospheric temperature and pressure conditions by pumping sodium pentaborate, a neutron absorber, into the reactor.

The manual start controls of the SLC system are interlocked with the reactor water clean-up system such that initiation of either standby liquid control channel will act to close the outboard RWCU system isolation valve. This isolation function prevents undesirable dilution or removal of neutron absorber from the reactor vessel during SLC operation. The SC-02 subsystem is a Class I piping system, anchored at the reactor pressure vessel nozzle at one end and a penetration at the other end. The subsystem has 4 snubbers, 15 rigid supports, one variable spring hanger and three valves.

1.3 Subsystem RH-19

Line RH-19 is part of the residual heat removal system (RHR) which serves the following purposes:

a. To remove decay heat and sensible heat from the reactor during normal shutdown and refueling.

b. To restore and maintain reactor vessel water level during a loss of coolant accident (LOCA).

c. To remove heat added to the pressure suppression pool water during hot standby operation.

RH-19 is a low flow bypass line used to control flow and pressure in the RHR system. The subsystem is Class 2, anchored at the header and penetration. It has 12 snubbers, 4 rigid supports, 2 variable spring hangers and one valve.

2.0 Criteria

The following criteria were utilized for the pilot program.

a. Pipe stresses for all Phase II loads, load combinations, and service levels were to meet the requirements of the ASME Section III Code, 1974 edition, with no addenda.

b. For subsystem MS-03, only relief lines 1MS04BC-12 and 1MS04BN-12 were to be modeled in detail.

c. Valve operator accelerations were to be within the allowable values.

d. The following changes to original plant design load combinations documented in the FSAR were made:

   1. SRV fluid transient loads, SRV inertia loads (building response spectra), and turbine trip fluid transient loads were to be decoupled from each other.

   2. For the SRV inertia event, SRV symmetric and SRV asymmetric response spectra were not enveloped. Rather SRV symmetric and SRV asymmetric responses were computed independently, and the larger of the two results used.

e. Phase II pipe support loads were within qualified levels provided by the pipe support design drawings as modified by the allowable margin factors and the combination method of references 3, 9 and 13. Any deviation from these allowable loads was to be justified.

f. Pipe reaction loads on equipment nozzles, containment penetrations, and headers were held within qualified levels. Load combinations and directional combinations were the same as in the original design with exceptions noted.

g. All remaining pipe supports were to:

   1. Remain at same location.
   2. Have same type and component sizes.
   3. Have same supporting structure.
   4. Have same weld sizes.

h. Efforts were to be made to keep system modeling the same as that used by Sargent and Lundy in the PIPSYS analysis. This includes:

   1. Valve modeling
   2. Support modeling
   3. System operating conditions
   4. Branch line modeling
   5. Modal combination procedures
   6. Frequency cutoff criteria

i. The pipe functionality criteria specified in the Mark II DAR, Rev. 10 was to be maintained.

j. Pipe seismic movements were to be less than $\pm$ 3 inches and auxiliary steel seismic movements were to be less than $\pm$ 1/4 inch, (original design criteria).

k. There was to be no change to existing pipe break locations documented in references 19 and 20. Pipe break locations were retained as per the original design.

l. Significant system as-built differences documented in reference 12 were to be included in the final pipe stress analysis. This included:

   1. As-built pipe support location deviations of one pipe diameter or greater.
   2. As-built spring hanger set load deviations of 2% or greater.
   3. As-built pipe support angular deviations of 3 degrees or greater.

m. Pipe movements (thermal plus deadweight plus dynamic) were to be such that the pipe did not interfere with the pipe whip restraints.

n. All remaining supports were to accommodate the new pipe movements.

o. Snubber removal priorities were considered based on plant input as follows:

PRIORITY 1: EVERY EFFORT IS TO BE MADE TO REMOVE THIS SNUBBER, INCLUDING CHANGES TO EXISTING HARDWARE IF REQUIRED. THERE ARE SERIOUS STATION CONCERNS ASSOCIATED WITH THIS SNUBBER REMAINING IN PLACE.

PRIORITY 2: VERY DESIRABLE TO REMOVE THIS SNUBBER. ATTEMPT IS TO BE MADE TO REMOVE THIS ONE RATHER THAN ANY PRIORITY 3 OR 4 UNITS ON THE SYSTEM. SMALL POSSIBILITY THAT MINOR HARDWARE CHANGES WILL BE ACCEPTABLE TO THE STATION.

PRIORITY 3: DESIRABLE SNUBBER TO COME OUT AS REMOVAL WITHOUT HARDWARE CHANGES. THERE IS ONLY A REMOTE POSSIBILITY THAT HARDWARE CHANGES TO REMOVE THIS SNUBBER MAY BE ACCEPTABLE TO THE STATION.

PRIORITY 4: SNUBBER REMOVAL WITHOUT HARDWARE CHANGES ONLY.

3.0 Methodology

The following methods and techniques were used for the snubber reduction pilot program.

3.1 PVRC Damping

PVRC damping values (frequency dependent, 2% - 5%) were used for the response spectra. For time history analysis, FSAR damping values were used.

3.2 Independent Support Motion (ISM)

ISM was used, support group excitations were combined by both SRSS and NUREG-1061 methods. Modal and directional combinations also followed task force guidelines in NUREG-1061.

3.3 Seismic Anchor Motion (SAM)

Values of horizontal seismic anchor motion (SAM) were determined from the building seismic time history response. Each pipe support was identified with the motion of a corresponding building mode. Maximum values were determined, conservatively ignoring time phasing between individual maxima. SAM values determined for the SSE event were larger than those for the OBE and were also used for the OBE event.

3.4 Annulus Pressurization (AP)

Time histories of the AP load were applied to the steel to restraint attachment points to the building steel. For attachment points which were not radially in line with the nozzle, direction cosines of the restraint attachment points with respect to the line extending radially from the nozzle were computed. No attenuation factors were used between the containment wall and the sacrificial shield wall; instead, sacrificial shield wall time histories were directly used for all attachments between the containment and the shield wall.

3.5 Combination of Seismic Inertia and SAM

Seismic inertia loads on piping were considered as primary stresses. Seismic anchor motions were considered as secondary stresses for the piping. For evaluation of pipe supports, equipment nozzles, penetrations and structural anchors, both seismic inertia and seismic anchor motion were considered primary loads. These loads were combined by the SRSS method.

3.6 Load Combinations for MS-03 and SC-02 Subsystems

As indicated under Criteria, more realistic load combinations were applied to the MS-03 and SC-02 subsystems as follows:

- o SRV thrust forces were decoupled from SRV induced building inertial loads.
- o Turbine trip forcing functions were developed from both the SRV thrust forces and SRV induced building inertial loads.
- o SRV symmetric and asymmetric response spectra.

3.7 Comparison of Response Spectra Methodologies

Selection of the response spectra methodology was found to be a controlling parameter in determining the number of snubber required for each subsystem. Three methodologies were utilized in this study:

a. Independent Support Motion with results from each pipe support group combined by the absolute sum method (ISM-Absolute).

b. Independent Support Motion with results from each pipe support group combined by the square-root-of-sum-of-squares method (ISM-SRSS).

c. A uniform response spectra determined by enveloping all pipe support group individual response spectra (envelope).

The ISM-Absolute method generally resulted in responses approximately 50% greater than the ISM-SRSS method, and approximately 30-50% greater than the envelope method. Since the ISM-SRSS method is not presently recommended in NUREG 1061, the envelope method was used for the remainder of Phase II work.

3.8 Dynamic Stresses as Secondary

It is well recognized piping systems rarely fail in actual earthquakes and the limitation of calculated stresses in piping to levels well below the yield strength is very conservative. In the pilot program, CECo attempted to quantify the benefits of reclassification of dynamic stresses as secondary. This study was performed for line MS-03 system.

The criteria used were similar to those recommended in NUREG-1061. The stresses due to building inertial loads (seismic and BWR hyrodynamic events) were removed from the code primary stress equations. The stresses due to the inertial loads and the relative anchor motions were limited to stress levels of 1.0 to 1.2 times the yield strength limited by fatigue considerations.

However, since the snubber reduction in the MS-03 system was limited by the pipe support/building allowables rather than pipe stresses, there was no advantage in the reclassification of dynamic stresses as secondary.

4.0 Results

The results of the snubber reduction pilot study on three piping subsystems are summarized in the following table. As noted in the table, the percentage of snubbers removed ranges from 70% to 100% per subsystem.

Subsystem	Original Configuration No. of Snubbers	Optimized Configuration Snubbers Retained1	Snubbers to Rigids	Percent Removed %
Main Steam MS-03	30	9	2	70
Standby Liquid Control SC-02	4	0	1	100
Residual Heat Removal RH-19	12	2	2	83
Total	46	11	5	76

APPENDIX B

TABLE 4-1

SUMMARY OF BROOKHAVEN ISM EVALUATIG.' USING SRSS
COMBINATION OF GROUP RESPONSES (INERTI..L COMPONENT)

Pipe Displacement[1]

Model	Highest	% Conservative Lowest	Mean
RHRSI1[2]	217	4	147
AFWSG1[2]	129	23	68
ZBEND	82	-19	39
BM1	601	8	176
BM2	607	-14	305
BM3	673	5	131
		Ave.	144

Pipe Accelerations[1]

Model	Highest	% Conservative Lowest	Mean
RHRSI1[2]	1,390	144	365
AFWSG1[2]	728	72	240
ZBEND	579	17	115
BM1	482	57	253
BM2	14,618	109	2,571
BM3	47,893	60	1,612
		Ave.	859

Notes

1. All results are from Brookhaven case 3, which is representative of the SRSS group combination procedure results.

2. Results from RHRSI1 and AFWSG1 systems are mean results from 33 earthquakes. Thus, highest is highest mean, lowest is lowest mean, and mean is mean of means.

TABLE 4-1 (continued)

SUMMARY OF BROOKHAVEN ISM EVALUATION USING SRSS COMBINATION OF GROUP RESPONSES (INERTIAL COMPONENT)

Pipe Moment and Forces[1]

	% Conservative		
Model	Highest	Lowest	Mean
RHRSI1[2]	237	34	164
AFWSG1[2]	130	53	89
ZBEND	61	23	34
BM1	345	11	172
BM2	417	90	3167
BM3	336	37	137
		Ave.	152

Pipe Support Loads[1]

	% Conservative		
Model	Highest	Lowest	Mean
RHRSI1[2]	210	11	137
AFWSG1[2]	128	26	69
ZBEND	66	-19	39
BM1	228	9	115
BM2	597	-13	270
BM3	181	5	88
		Ave.	120

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