Snubber Reduction Program

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Technical Report

REPORT SUMMARY

SUBJECTS	Reliability, operations, maintenance, and human factors / Major components
TOPICS	Reactor piping Reactor safety Snubber reduction
AUDIENCE	Generation planners

Snubber Reduction Program

Snubbers in nuclear reactors cause operating and maintenance problems and raise both operating costs and radiation exposure levels for plant workers. Utilities can now plan and evaluate snubber reduction programs, using the information developed in this project. Such programs can include replacement of snubbers with rigid struts and use of increased damping.

BACKGROUND Piping system design in nuclear plants must consider seismic and other dynamic events, as well as pressure and thermal-expansion effects. Current regulations and the ASME code have led to conservatism in planning for these dynamic effects, resulting in the installation, maintenance, and inspection of more than 2000 snubbers in recently built plants. Improvements, such as the damping code Case N-411 (ASME Boiler and Pressure Vessel Code), make it feasible to remove some of the excessive conservatism if a utility engages in a snubber reduction program and obtains necessary regulatory approvals.

OBJECTIVES To summarize the status of current snubber use in nuclear power plants and to provide utilities with guidance and a preliminary plan for snubber reduction programs.

APPROACH Investigators surveyed utilities on their use of snubbers and snubber reduction and compiled the resulting information into a database. Using this information, they summarized and evaluated current available techniques for snubber reduction. They derived specific examples to show how current technologies can reduce both the number of snubbers and the obstacles to greater snubber reduction. The investigators also addressed documentation issues related to snubber reduction programs.

RESULTS Use of increased damping, based on code Case N-411, can effectively reduce the need for snubbers. Other techniques discussed and illustrated in this report include computer optimization, multiple-support motion analysis, and zero deflection criteria. Obstacles to greater snubber reduction included the effects of both increased loading on supports and nozzles and stress redistribution on the locations of pipe whip restraints. Recommendations, such as changing ASME code nozzle and support design rules, address these obstacles.

EPRI PERSPECTIVE

This report offers an overview of the snubber reduction problem. Together with NSAC 104, *Guidelines for Reducing Snubbers on Nuclear Piping Systems,* it provides technical guidelines for implementing snubber reduction programs. Snubber reduction is technically feasible; however, financial and regulatory obstacles must be taken into account in determining when a program should begin and what piping systems it should address. Ongoing EPRI research projects RP1543 and RP2689 are looking at ways to further reduce snubbers. Utilities should make flexible plans to take advantage of new methods as they become available.

PROJECT

RP1757-39
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Snubber Reduction Program

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ABSTRACT

This report is a non-proprietary, edited version of EPRI RP1757-39, originally prepared by Teledyne Engineering Services. It contains historical information leading to an understanding of why such a large number of snubbers are used in commercial nuclear power plants in the United States and outlines recent and anticipated criteria changes which can bring about a reduction in the number of snubbers. The report also describes the development of a data base which contains basic snubber data for many nuclear power plants. Current utility snubber-reduction programs, available snubber-reduction information, and examples from piping systems assembled specifically for this study are summarized. Anticipated changes to plant documentation which are a necessary part of a snubber reduction program are described. Finally, recommendations are made to keep the data base and the procedures current with industry practice.

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CONTENTS

SUMMARY

Using information on piping systems and snubbers obtained from a survey of several domestic nuclear power plants, a data base was created and queried in order to categorize and analyze the information. This report describes the data base and its development, lists and evaluates methods currently in use in snubber-reduction programs, outlines a preliminary plan for implementing a snubber-reduction program, and offers guidelines for utilities considering such a program, including the impact on licensing issues and plant documentation.

A review of plant-specific data and snubber-reduction methods leads to the following conclusions and recommendations:

1. Two simple techniques can be used to replace snubbers with rigid struts. These techniques are (1) small axial thermal displacement (1/8-inch or less, depending on the location in the piping system) and (2) the resultant deflection method.

2. The use of increased damping can be very effective in eliminating snubbers. The engineering costs associated with this approach can be high, but the construction costs (primarily associated with removing snubbers) should be minimal. In cases in which a system has a mixture of rigid supports and snubbers, load increases on the rigid support resulting from snubber removal may require modification of the rigid support.

3. Anticipated changes to Code requirements which would reclassify seismic interia stresses could result in elimination of most snubbers except those required for fluid transients (water/steam hammer). However, current limitations on equipment nozzle loads, pipe displacements, and loads on remaining supports tends to reduce the effectiveness of this approach.

4. A study is recommended for the purpose of standardizing nozzle and support loading criteria with the aim of increasing the allowable applied loading for the short-term dynamic effects associated with a seismic event.

5. It is essential that a utility prepare a complete plan before implementing a snubber-reduction program. This report offers guidelines to the utility for collecting and reviewing plant-specific data so that the decision to implement such a program takes into account the economic impact of each step in the process. Once a decision is made to proceed with a snubber-reduction program, a detailed set of procedures, which are plant

specific, should be developed to address engineering, licensing, operation, and construction activities.

6. Plants which are under construction should make every effort to include the guidelines in this report in their ongoing design activities.

7. Reducing the number of snubbers in a system can result in changes in the locations of maximum pipe stresses which could necessitate redefining pipe break locations. New pipe break locations could cause the relocation of existing pipe whip restraints and/or the addition of new pipe whip restraints. Before relocating or adding pipe whip restraints, the utility should evaluate the overall pipe whip protection provided by existing restraints, regardless of break location, or should consider performing the required studies (fracture mechanics, tearing instability, etc.) necessary to apply "leak before break" criteria.

8. Snubber-reduction programs should focus on those piping systems that are not subjected to fluid transient loads. Systems which experience fluid transients (main steam relief, pressurizer relief, etc.) have a large number of snubbers which are necessary to accommodate those loadings. Because the snubbers are in place, they also serve to accommodate the seismic event. The use of higher damping values or reclassification of seismic stress will not result in replacement of those snubbers because they are needed for their primary function. Efforts are under way to address this type of dynamic loading, and it is anticipated that, in the future, higher damping values and stress reclassification may be appropriate for fluid transient loads.

9. Finally, it is recommended that the data base described in this report be updated as more plants complete snubber-reduction programs.

Section 1

INTRODUCTION

The use of snubbers in providing seismic protection for piping in nuclear power plants has evolved over the years as a result of increasing conservatism in Codes, Regulations and design techniques. These conservatisms have resulted in piping systems that are more rigid than experience indicates is necessary to provide a reasonable balance between normal operation thermal expansion, on the one hand, and the low probability seismic event, on the other. Recent surveys (1,2) demonstrate the ability of piping to resist seismic loadings which were of sufficient magnitude to damage general structures. Most of the piping surveyed was essentially unrestrained (flexible) and free to deflect. These characteristics are not generally found in nuclear power plant piping which is highly restrained and for which deflection is restricted as a result of the proximity of other piping, equipment, and structures. However, a number of recent and anticipated changes to criteria, loading considerations, and design techniques (3,4,5,6) have resulted in overall seismic design criteria that will allow the removal of a large number of snubbers from nuclear power plant piping. This will result in nuclear power piping having more of the characteristics which are representative of piping that has survived seismic loading. It is important that the industry approach the subject of snubber reduction as a planned process with a full understanding of the benefits of such reduction as well as the economic impact of reducing the number of snubbers in existing plants. A utility's failure to plan properly could result in excessive costs and numerous iterations without obtaining the full benefit of existing and potential changes in criteria.

Part of this report describes a data base which contains current industry information on the number of snubbers, their associated maintenance costs, and the status of snubber reduction programs at utilities in the United States. This data will be useful to utilities in determining the relative position of their plant with respect to the industry in planning a snubber-reduction program.

The data base was interrogated to develop a number of responses to various parameters which can be reviewed by utilities to determine their relative position. (Detailed results of the data base interrogation is included in an Appendix to the proprietary version of this report.) An obvious result of the interrogation is the trend toward an increase in the number of snubbers with the date of commercial operation. A not so obvious result is that the Code of record has significantly less impact than the date of commercial operation. This trend can be seen in those plants with B31.1-1967 Code of record that did not begin operating until the early 1980's. These plants have significantly more snubbers than those plants which began operation in the 1970's. This could have resulted from increased conservatism in Regulatory and Code criteria in the seismic area. Also, plant size (MWe) has an effect on the number of snubbers, which accounts for more large-bore piping with increased size. Increased size (MWe) would relate to date of commercial operation because the size of plants increased with time.

The snubber reduction techniques reportedly being used by utilities have been applied to a limited number of examples in an attempt to evaluate their effectiveness. The results of the examples selected indicate:

1. Increased nozzle loads, valve accelerations and remaining support loads are a concern when stress reclassification is applied;
2. Increased damping will significantly reduce the number of snubbers required for seismic protection of piping; and
3. Utilities with a large population of snubbers should review those systems that are essentially cold (<200°F) to determine thermal displacement at snubbers and the potential for the use of the "zero displacement technique."

Another part of this report addresses the anticipated documentation changes which should occur with a snubber-reduction program. The amount and type of information that must be gathered and reviewed before making a decision to implement a program is discussed as well as those criteria which could result in plant licensing revisions. Finally, guidelines to utilities when planning a snubber reduction program are summarized based on the results of the work undertaken in this project.

Section 2

SCOPE OF WORK

The work performed under this program, sponsored by the Electric Power Research Institute (EPRI) and performed by Teledyne Engineering Services (TES), is separated into the following three tasks:

TASK 1 - DEVELOPMENT OF THE DATA BASE

A questionnaire was sent to each domestic nuclear power plant, requesting basic plant data, piping-design data, and snubber-reduction data. This data was compiled using a spreadsheet computer program, and preliminary results of trend analyses, using the available data, are presented.

TASK 2 - VALIDATION OF PROCEDURES

Using utility responses to the questionnaire, currently implemented programs are summarized and assessed. A summary of current techniques for snubber reduction is provided, and results of evaluation of these techniques are presented, using specific examples of piping systems from operating nuclear power plants.

TASK 3 - PLANT DOCUMENTATION

In order to implement a snubber-reduction program at a nuclear power plant, changes to documentation must be made, and the extent of these changes will vary with the characteristics of the program. The documentation anticipated to be changed, including drawings, analysis reports, and licensing-related documents, are discussed.

Based on the results of Tasks 1 through 3 above, important information is summarized in Section 4 of this report as guidelines to utilities when planning a snubber reduction program.

Section 3

RESULTS AND DISCUSSION

TASK 1 - DEVELOPMENT OF THE DATA BASE

A survey was made of U.S. utilities with operating nuclear power plants or plants under construction or on order. Responses were received from 27 utilities, representing 62 plant units, 47 of which are operating plants and 15 of which are under construction. The resulting data base represents approximately 59 percent of the total number of operating plants and 25 percent of plants under construction or on order in the United States as of February 1984. Data from individual plants was entered into a spreadsheet software program, SYMPHONY™.[1] This software provides a well-organized format and permits easy manipulation of data, the addition of new information, and straightforward interrogation by the user.

The data base contains information divided into three major subsets:

- Basic Plant Data;
- Plant Piping-Design Data; and
- Plant-Specific Snubber-Reduction Data.

The Basic Plant Data includes the name of the plant, date of commercial operation, containment type and manufacturer, net MWe, and the architect-engineer as well as the quantity of snubbers (inside and outside containment) and information on the type and manufacturer of the snubbers.

The Plant Piping-Design Data includes information on the seismic design loading, seismic design criteria (applicable Code, Addenda), allowable stress, and approximate amount of small- and large-bore piping.

The Plant-Specific Snubber-Reduction Data covers information relating to the approximate cost of snubber testing (inside and outside containment), the

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[1]SYMPHONY is a registered trademark of the Lotus Corporation.

snubber-reduction method used (such as deflection criteria, resultant deflection, damping, computer optimization and improved spectra) as well as the engineering, hardware and construction costs of the program.

Results compiled from the above data base are included in a more detailed proprietary (limited access) version of this report. Future surveys would be expected to provide additional information which will aid utilities in the development of cost-effective strategies for snubber reduction.

It is believed that the data presents a reasonable sample of the status of and the potential for snubber reduction in domestic nuclear power plants. One of the most significant trends from the data compiled to date is a general increase in the total number of snubbers with later dates of commercial operation, but a decline in the use of snubbers at the present time. A similar trend of an increase in the number of snubbers in larger plants (MWe) is apparent, but with a decline in the number of snubbers for the largest (MWe) plant. Also, a trend toward the use of fewer hydraulic and more mechanical snubbers is noted.

TASK 2 - VALIDATION OF PROCEDURES

Summary of Implemented Programs

Results of the industry survey undertaken in Task 1 above demonstrate that most snubber-reduction programs are in the planning stage. Overall, only 14 out of the 62 plants which responded to the survey presently have a snubber-reduction program or plan. Most such programs involve the use of deflection criteria or increased damping. The former requires a simple review of thermal deflections in the axial direction of the snubber and its replacement with a rigid strut, based on set guidelines. The use of increased damping to reduce the seismic response of the system requires reanalysis of piping and additional changes to documentation.

Current Methods for Snubber Reduction

Several effective methods with adequate technical bases to justify their use for snubber reduction are presently available. A brief summary of these methods follows. The current methods available for snubber reduction have varying degress of effectiveness, based largely on plant-specific factors. There are characteristics unique to every nuclear power plant which can help determine which snubber-reduction method (if any) can be implemented in the most cost-effective manner.

It may be prudent for utilities to implement snubber-reduction methods at the present time which do not require reanalysis, such as the zero deflection criteria. Then, if some form of seismic stress reclassification gains Code and Regulator approval, reanalysis of piping systems for snubber reduction could be implemented utilizing all the available techniques discussed in this section, such as computer support optimization and Multiple Support Motion (MSM) methodology.

Zero Deflection Criteria Method. The Zero Deflection Criteria are described in detail in Reference (3). When the calculated axial thermal displacement of a snubber is 1/16-inch or less, it can be considered insignificant, and the snubber can therefore be replaced with a rigid strut. Larger calculated thermal displacements may also be considered insignificant with adequate technical justification. As described in Reference (3), thermal displacements of 1/8-inch can be insignificant, based on the nominal pipe size and the distance to adjacent supports. This technique requires a review of the snubber pipe-support drawings and the piping analysis to determine movement of the snubber as a result of piping thermal expansion. When the displacement criteria are met, a rigid strut must be designed using the design loads specified for the snubber.

The Zero Deflection Criteria Method is a simple and effective way to justify the replacement of snubbers with rigid struts. However, the replacement of the snubber with a strut may cause operational problems in the system. Careful review of the piping thermal expansion analysis and hot inspection of the snubber locations may be warranted. Also, the Zero Deflection Criteria should be cautiously applied to systems in which computer modeling refinements, such as the modeling of actual snubber stiffnesses or equipment nozzle flexibilities, have been used.

In operating plants, piping systems with low operating temperatures (such as component cooling, service water, etc.) should be reviewed because these systems are the most likely candidates for snubber removal. If a significant number of snubbers exist on low-temperature systems, it will be worthwhile to broaden the review because their presence indicates that the design practices used did not consider snubber minimization. In new plants, the design practice of not specifying snubbers on low-temperature lines must be emphasized to the organization responsible for piping design.

PVRC Damping and Peak-Shifting Rules Method. The use of new seismic damping and response spectra peak-shifting criteria is another method which permits snubber removal. Current damping values used in the design and analysis of nuclear power plant piping systems are based on US NRC Regulatory Guide 1.61, published in 1973, and it is believed to have contributed substantially to the excessive use of snubbers. In order to provide more realistic damping values, a task group on damping was formed under the Technical Committee on Piping Systems of the Pressure Vessel Research Committee (PVRC) of the Welding Research Council (WRC). Code Case N-411 of the ASME Boiler and Pressure Vessel Code, Section III, (6) allows the use of PVRC damping for piping systems. The application of the PVRC frequency-dependent damping to actual nuclear power plant piping systems has shown significant reductions in both pipe stress and in the number of restraints and snubbers required to meet Code criteria.

The response spectra peak broadening requirements of US NRC Regulatory Guide 1.122 have also contributed conservatism to seismic analysis of piping systems, resulting in the excessive use of snubbers. The spectra peak shifting method requires enveloping results of shifted spectra rather than enveloping of inputs (as done per US NRC RG 1.122). Analyses performed on piping systems with the peak-shifting method have shown moderate reductions in pipe stress and in the number of supports (3). The variation in effectiveness of peak shifting is related to the frequency characteristics of the piping model. A piping system with a single dominant mode near the response spectra peak is least affected, while systems with several dominant modes are most benefited.

The use of PVRC damping and response spectra peak shifting requires a computer seismic reanalysis of the piping system in order for them to be used as snubber-reduction tools. Obviously, for a new design, these methods can be part of the original design criteria, thereby providing a more realistic approach to seismic evaluation which will result in a reduction in the number of snubbers.

Before implementing PVRC damping and response spectra peak shifting, it is important to consider the following. Response spectra curves for 5% damping, which are unbroadened, must be available. Most plants have curves available for 0.5%, 1.0%, and 2.0% critical damping. Theoretically, an artificial time history can be generated from a response spectra curve. This procedure can be cumbersome and requires careful implementation. Otherwise, seismic reanalysis of the building model must be performed. A total reanalysis is not required if acceleration time histories are available for each floor (lumped mass point).

Recently, the NRC staff has raised some concerns about the use of PVRC damping. These concerns are related to a number of issues that are either generic or are under study by the staff. For instance, the NRC staff considers that, for operating plants, the use of the PVRC damping method is unacceptable unless current regulatory defined seismic spectra are used and that it is also unacceptable for use with cracked piping (IGSCC).

Reclassification of Seismic Stress Method. The reclassification of seismic interial stresses in the evaluation of piping in nuclear power plants appears to be a successful snubber-reduction tool. However, there are significant limitations related to nozzle load allowables and remaining support loads. This method is presently under consideration by Code committees and the regulatory agency.

The analysis criteria for piping in nuclear power plants have typically required that moments resulting from seismic interial loadings be considered as primary loadings (non-self-limiting) and that they be evaluated in conjunction with internal pressure and deadweight stresses in order to meet static load allowables which would preclude gross collapse. However, it is felt that earthquakes provide limited energy input to piping systems in nuclear power plants and, therefore, gross plastic deformations and primary collapse mechanisms will not occur. A recommendation has been made to remove earthquake moments from the primary stress piping equations of the ASME B&PV Code, Section III. Similar recommendations are under consideration also for the ASME B&PV Code, Class 2, 3 or B31.1.

Because the primary stress limits presently provided by piping Codes generally control support selection, it is felt that a change to the seismic stress criteria, as described above, will have an effect on snubber reduction. Snubbers required to provide protection against fluid-dynamic-type loadings would not be affected. Computer seismic evaluation would be required to utilize this method. A deflection check may need to be performed on piping which undergoes this reduction technique since the removal of snubbers may result in large calculated seismic displacements which could affect adjacent equipment.

Multiple Support Motion Analysis Method. The seismic evaluation of piping is normally performed by using a response spectra dynamic analysis on a computer finite element model. Response spectra are generated as input to this analysis from a computer model of the building containing the piping, and they are subjeced to a base time history representing an earthquake of some postulated magnitude. Responses can be generated at various elevations in the building in the form of acceleration versus time histories or response spectra at various damping values. For piping systems which span several elevations of a building, the response spectra are conservatively enveloped and then used in the piping computer analysis. To determine the total seismic response of a piping system, the effects of both interial loading and support point displacements must be considered. The inertial effects are usually determined using enveloped response spectra which can be very conservative.

Multiple Support Motion (MSM) methodology can be used to remove conservatism and reduce the number of snubbers. MSM requires that support points be grouped by elevation and that response spectra applicable to that elevation be applied to those supports and, subsequently, to that portion of the piping. This procedure will result in the application of multiple spectra to the system. The evaluation of support point displacement effects or seismic anchor motions is normally performed by applying the peak displacements to the piping computer model. Removal of snubbers, particularly near anchor points or equipment, should result in reduced pipe stress as a result of support point displacement effects.

Analysis examples from Reference (7) indicate that the MSM method can be as effective as the increased damping method for piping systems which span different elevations or different structures in a building. For piping systems which are basically at one elevation, the MSM method will not be as effective as the increased damping method. MSM analysis requires computer evaluation and the use of a program having this capability.

Currently, the NRC staff is resisting the use of MSM in combination with the damping values allowed by Code Case N-411. It is anticipated that NRC staff approval for combined usage will not occur until more definitive results are available from current EPRI/NRC research activities and until the ASME B&PV Code, Section III Committee adopts definitive damping and dynamic analysis application technology for all dynamic loading and equipment.

Computer Optimization Method. Computer software for the optimization of piping supports can be used in a snubber-reduction program. Typically, these computer programs are design aids which cannot, by themselves, perform a complete piping evaluation. The approach used with this method is to create a finite element model of the piping system and designate several potential support locations. Seismic response spectra and thermal expansion temperatures are also specified as input. The software will try various combinations of support configurations until an optimum solution is reached with a minimum number of supports, particularly snubbers. This method can be very effective in reducing the number of snubbers in a new design and layout of piping in a nuclear power plant.

Additional Techniques for Consideration. There are several additional techniques for snubber reduction which are less rigorous than the methods previously described. For instance:

(1) Elimination of lightly loaded snubbers. It is recommended that hand calculations be performed to evaluate pipe stress and load redistribution in order to justify removal of the snubber.

(2) Elimination of snubbers at locations where seismic displacements are too small to initiate lockup; e.g., close to rigid restraints, anchors, or equipment nozzles. Some reevaluation should be performed on pipe stress and load distribution.

Evaluation of Methods Using Sample Piping Systems

A review was made of three actual plant piping systems which were all supported for earthquake events by analyses using a significant number of snubbers. None of these systems previously benefited from any current snubber-reduction methodology. The results of the analyses of the three piping systems, including isometrics, seismic spectra and other pertinent data, may be found in Appendix C of the proprietary version of this report. A discussion of the results is contained in the following paragraphs.

Elimination Through Zero Deflection Criteria Method. The component cooling water system (CC) was evaluated using the zero deflection method for elimination of snubbers. The CC system was chosen because it was a relatively cold system and therefore appeared to be a candidate for snubber reduction through review of the thermal displacements at the support location, as suggested by WRC Bulletin 300 (3). This system included a total of ten snubbers at seven support locations on 10- or 12-inch-diameter piping with a system operating temperature of 110°F. Piping system design was based on the 1967 B31.1 Code, using a seismic design loading of 0.06 g OBE and 0.12 g DBE and design pressure of 150 psi.

The snubber loadings ranged from a low of 75 pounds to a maximum of 1206 pounds. The thermal displacements axial to the snubbers at all locations were found to be less than the allowable, leading to the conclusion that all snubbers could be replaced by rigid struts. Also, it was found that the system would be a candidate for seismic reanalysis because a number of snubbers were lightly loaded and could probably be removed without being replaced by rigid struts.

Elimination Through PVRC Damping Method. Two piping systems, Residual Heat Removal (RH) and Safety Injection (SI) were chosen for snubber reduction evaluation using Code Case N-411 damping values. These systems have design temperatures greater than 550°F, are not subjected to fluid transient (water/steam hammer) loads, and each system has at least ten snubber locations.

The RH and SI systems were analyzed for the following cases:

Case	Description	Damping
1	Includes Existing Snubbers	CC N-411
2	Excludes All Snubbers	CC N-411
3	Excludes All Snubbers	1% Horizontal 1/2% Vertical
4	Includes Existing Snubbers	1% Horizontal 1/2% Vertical

Results of the stress analyses for these cases indicated that pipe stress alone is an insufficient measure for determining the potential effectiveness of snubber reduction programs. For the SI system (under Cases 2 and 3), the remaining rigid restraints and the accumulator tank nozzle were found to be overloaded and, under current criteria, would require redesign. An alternative to redesigning both the restraints and the nozzle would be to retain some of the snubbers. Therefore, for this system, the effectiveness of snubber reduction would be driven by equipment and rigid restraint designs and criteria.

Elimination Through Reclassification of Seismic Stress Method. A current test program at EPRI is aimed at determining the failure mode of piping due to dynamic loading and at providing sufficient data to justify reclassification of dynamic stresses. If successful, this reclassification would essentially result in removing the dynamic intertia moments from the occasional loading category and considering them only as fatigue stresses.

The RH system was used to demonstrate the effect of seismic stress reclassification on snubber reduction. The RH system with all snubbers removed was analyzed using FSAR spectra and classifying seismic stress as fatigue stress. The allowable pipe stresses were exceeded by 10 percent but, more importantly, the loads on anchors, rigid supports and nozzles increased dramatically. A comparison of the results with the results using N-411 damping values indicated that higher damping is more effective than stress reclassification when considering the loads on equipment, anchors and remaining supports.

Elimination Through Computer Optimization Method. Computer optimization programs have been written which provide a means of performing snubber reduction, primarily for the new design of piping systems. The design and layout of piping in a nuclear power plant is generally performed by trial and error--the process of selecting locations and types of pipe supports is an iterative procedure. The piping analyst uses a finite element piping program and engineering judgment to develop a support configuration, which could be far from optimum, based on individual talents and the practices and procedures of the organization in charge of design. An optimum support configuration is one which minimizes the overall piping costs, including design, construction, and maintenance as well as the costs related to potential failures.

An example of a computer pipe support optimization program is HANGIT (8), which has been used in the nuclear industry both in the United States and England. The strategy used by HANGIT closely parallels what an experienced piping designer would do with support optimization in mind. The piping designer must review the results of the computer optimization and decide on a support system. Then a rigorous evaluation can be performed using a pipe stress analysis program. The result should be a system which meets all applicable design criteria with the smallest number of snubbers.

An example of the use of computer optimization for snubber reduction is provided in a paper by J. Thorp of Great Britain (9). Comparisons between conventionally designed piping systems and those in which HANGIT was used show reductions of 35 snubbers to 8 (Case 20) 16 snubbers to 3 (Case 19) and so forth.

As is evident from the above description, the use of the computer optimization method is recommended for the initial design of piping support systems. For existing systems, a computer optimization program could be used to select those snubbers that are good candidates for removal.

TASK 3 - UPDATING PLANT DOCUMENTATION

Developing a Program

When a utility considers implementing a snubber-reduction program, one of its major concerns is the number of changes to documentation which will be required if the program is implemented. It is therefore important to identify all documentation which must be changed before initiating a program. The first step is development of a program plan or procedure which addresses the following topics:

1. Basic Background Data: Number of snubbers, type, location, costs associated with maintenance, applicable Codes and Standards.
2. Specific Piping Data: Piping isometrics and computer stress models, snubber support drawings, and a compilation of the number of snubbers per piping stress model, as well as P&ID drawings which can be used to determine thermal modes.
3. Piping Design Data: All data necessary to perform a pipe stress reanalysis--system design and operating temperatures, pressures, seismic spectra, and design specifications.
4. Description of Method: The approach to be used to reduce the number of snubbers, with a specific sequence of steps. Any particularly troublesome snubbers identified by the plant should be targeted as a priority.
5. Documentation Requirements: For each step specified in No. 4 above, identify the specific documents which must be generated or changed. These may include drawing revisions, analysis report revisions, changes to the FSAR or the Technical Specification, Plant Design Change Packages, etc.

A comprehensive plan, containing the information listed above, will facilitate the initiation of a snubber-reduction program.

Compiling the Required Data

At the earliest stage in the development of a snubber-reduction program, it is necessary to compile some basic plant-specific data in order to determine the methods and scope of the program and to determine whether or not it is economically justified to proceed. It is recommended that an engineer with some piping design experience be charged with the task of accumulating and organizing the basic data because a great deal of insight can be gained from performing this task. The data to be collected should include the following:

1. Snubber List: A comprehensive listing of all snubbers in the plant, indexed to the support drawing number, the piping-system designation (isometric drawing number) and the individual snubber designation.

2. Snubber Characteristics: A listing for each snubber, providing design loads, thermal deflection in three spatial directions and resolved to the axial direction, type of snubber, manufacturer, catalog number, and load rating.

3. Piping Characteristics: For each piping system which contains one or more snubbers, obtain the pipe stress calculation, including stress summary, support loads, loading conditions that are considered deadweight, thermal expansion temperatures, specific seismic spectra used, and other loads such as fluid dynamics.

4. Design Input Information: Obtain the seismic building analysis report with all response spectra as well as other loadings specified, such as building filtered LOCA loads. Determine the availability of variable damping spectra.

5. As-built Drawings: Compile as-built support drawings of all snubbers and as-built piping isometrics for each piping system containing snubbers.

6. Inspection Data: Obtain inspection and repair records and determine the associated frequency of each for every snubber. Also obtain costs associated with testing and replacement.

After the data is compiled, the most cost-effective snubber-reduction methods should become evident. By reviewing the tabulation of data from Steps 1 and 2, the usefulness of pursuing a zero deflection criteria approach should be clear. Consider the data compiled in Steps 3 and 4 to judge the possibility of success of an analytical approach such as PVRC damping or computer optimization. The inspection data (Step 6) will provide critical cost information to determine the economic benefit of the program.

Plant Licensing Issues

The implementation of a snubber-reduction program based on the recommendations in this report (including any future changes to seismic stress reclassification) will result in licensing issues for most of the plants in operation today. With regard to the following six methods of snubber reduction: (1) zero deflection criteria, (2) damping values, (3) response spectra shifting, (4) multiple support motion analysis, (5) seismic stress reclassification, and (6) computer optimization, the following comments may be noted. Items (1) and (6) are engineering approaches and do not represent licensing issues. These can be implemented today without modification to the plant SAR. Items (2), (3), (4) and (5) generally will require modification to the plant SAR and are therefore licensing issues. For some units, Item (4) may be found in the SAR under that portion applicable to the Nuclear Steam Supply System. Those items which represent licensing issues were identified and are presented in the proprietary (limited access) version of this report in a form that can be followed by a specific utility for submittal to the regulatory authorities.

Changes to Piping Documentation

The level of effort required to properly document a modification may be greater than that needed to justify the change. At a minimum, the removal of a snubber or replacement with a strut requires drawing revisions and a calculation package which documents the justification for the change. The original snubber pipe-support drawing will have to be revised, replaced, or voided. Also, the piping isometric drawing will have to be revised to show the correct support configuration.

Where a seismic computer reanalysis has been performed, a new or revised pipe-stress calculation will have to be created, incorporating the new computer runs. As a result of the new support configuration, some of the following parameters may have to be evaluated: (1) new loads on remaining supports, (2) allowable nozzle loads, (3) valve accelerations, and (4) piping deflections. For an ASME B&PV Code, Class 1 System, a revision to the Code-required certified stress report is necessary.

Where it is economically justified to implement a major snubber-reduction program involving seismic reanalysis of many systems, consideration should be given to an integrated computerized approach. If computer models of the as-built piping system exist, then these can be used in the snubber-reduction program. If models are not available, piping model generators are available which can quickly create a piping geometry model and translate this data to input for a piping analysis program. The geometry data can also be used to create a piping isometric drawing.

The results of the reanalysis can be printed through a post-processing program and included in a standardized documentation package. New or revised support drawings can also be generated using a computer-aided design program. Thus, a snubber-reduction program can be accomplished using state-of-the-art integrated computer-aided engineering software to facilitate the creation of new documentation. The end result is an updated data base containing the piping system model, isometrics, and supports. If additional changes to a piping system need to be made in the future, the data base is readily available. The cost to perform the work using this approach is somewht higher than conventional methods; however, future benefits can be substantial.

Once the engineering and engineering-associated documentation is planned for, it is time to consider the effect of implementing the modification in the plant. The requirements for documenting actual modification of supports are plant specific but, at a minimum, address the following:

- Owner's Specification;
- Plant Design Change Package;
- Safety Evaluation;
- Procedures, Purchase Specifications;
- Constructibility Review;
- Examination and Testing Requirements;
- QA Requirements;
- As-Built Documentation.

These installation documentation requirements can also be generated through the use of computer-aided engineering software.

Section 4

GUIDELINES TO UTILITIES

The following is a summary of the information contained in this report which a utility should consider before initiating a snubber reduction program.

PROPER PLANNING

Utilities are considering snubber reduction programs because of the costs associated with inspecting, testing and repairing existing snubbers and because of the increased exposure of plant personnel to radiation that results from performing these activities. However, if the utility does not understand all of the requirements necessary to plan, implement and document a snubber reduction program, they may find costs are far in excess of those anticipated, and the conservatisms appropriate to nuclear power plant design could be violated for their unit. In addition to recognizing the technical issues involved, the utility must address planning, documentation and licensing issues. The costs associated with documentation requirements are significant and should not be overlooked.

CRITERIA FOR DYNAMIC ANALYSIS

Seismic floor response spectra, corresponding to Code Case N-411 damping values, are not available for many nuclear units. In fact, spectra at 5% constant damping are unavailable for many units. Consequently, it may be necessary to regenerate the appropriate floor response spectra. This can be a costly and time-consuming task which should be evaluated in order to justify a snubber reduction program.

The subject of damping values is under consideration by many in the international nuclear community. For example, many European utilities are considering modifying damping values, and the Germans, in particular, have adopted a constant 4% damping value for seismic events. The Japanese are considering increased damping for certain piping systems, depending on the number and types of supports.

Intensive work is under way in the United States to deal with the issue of stress criteria associated with dynamic loading as well as minimizing the requirements for consideration of the Operating Basis Earthquake (OBE). The current damping values specified in Code Case N-411 were developed in recognition of this activity and, rather than being absolutely representative of damping values at the strain levels associated with the OBE, are better described as correlation factors which result in the design of piping systems that are acceptable today and can accommodate the criteria changes anticipated in the future. When the ongoing efforts of the technical community and the current research activity sponsored by EPRI and the NRC are completed, it is anticipated that the approach to the design of piping for dynamic loading will be modified. These modifications could result in the following changes:

1. Elimination of the OBE as a design consideration;
2. Recategorization of dynamic stresses to better address the real failure mode;
3. Modification of support criteria to allow yielding and to take advantage of the associated energy dissipation; and
4. Modification of Code Case N-411 damping data.

It is important to recognize that the adoption of all of these changes by the Code and the regulator would not negate any current effort at snubber reduction using Code Case N-411 damping, multi-support motion analysis, or any of the other alternatives discussed in this report and its associated references. As stated above, the damping values proposed by PVRC and adopted in Code Case N-411 were tentative values which recognized that there was the potential for changes in criteria in the areas of seismic level and stress categorization. For example, should stress recategorization occur and the OBE be maintained, it is anticipated that the damping values for OBE could be reduced. However, the combination of recategorization and lower damping values would result in at least the same margin on failure as the use of the current Code Case N-411 damping and would not negate any snubber reduction activities under way or completed. If all of the above changes occur, it is quite likely that the number of snubbers can be reduced further.

The point of the above discussion is to make utilities aware of the potential for modifications to current criteria. However, the adoption of any of the modifications will <u>not</u> negate the snubber reduction activities of utilities planning or implementing a snubber reduction program. At best, the modifications will allow further snubber reduction and, at worst, the modifications will result in the acceptability of current programs.

SEISMIC STRESS RECLASSIFICATION

Although the specific Code rules related to this approach have not been developed, it is important for the utility to recognize that stress reclassification without increased damping will not be very effective in reducing snubbers because of the current limitations on equipment nozzle loads and remaining support and anchor loads.

MULTIPLE SUPPORT MOTION ANALYSIS

This technique can be very successful in reducing snubbers, particularly for systems which span different elevations. Although not approved by the NRC staff, combining MSM with increased damping provides the most effective current approach to snubber reduction. The industry should provide the appropriate resources to obtain approval of combining MSM and increased damping.

Section 5

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