**Analysis of Design Practices for Snubbers
(Report 3)**

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(REPORT 3)

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NOTICE: This document contains information of a preliminary nature. It is subject to revision or correction and therefore does not represent a final report.

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ANALYSIS OF DESIGN PRACTICES FOR SNUBBERS (REPORT 3)

J. H. Butler

ABSTRACT

In an effort to understand the expected performance of snubbers, a survey of current design methods was performed. Questionnaires were sent to the major snubber manufacturers requesting information on important phases of snubber analysis, testing, shipping, and handling. The elements of design considered in the questionnaire were derived from an evaluation of snubber failure histories and the performance requirements of snubber users. After careful examination of replies to the questionnaires, the author believes that the snubber manufacturers are making a conscientious effort to supply a product that will meet the needs of the power industry but, at the same time, are finding it difficult, if not impossible, to insure snubber performance in all applications. There are three reasons for this opinion. First the owners' design specifications are often vague and incomplete. Second, the stringent requirements for restraint systems in nuclear power plants have introduced relatively new design problems to the snubber manufacturers. Third, the manufacturers have had neither the time nor the resources to develop the data base required to answer recent questions on snubber performance from regulating agencies, utilities, and architectural and engineering firms.

Keywords: snubbers, spring constant, iterative motion, hydraulic fluid, load rating.

1. INTRODUCTION

The purpose of this report is to survey the design criteria of snubber manufacturers in an effort to understand their interpretation of snubber performance and to investigate standard procedures relating to installation, maintenance, shipping, and handling in order to reveal possible problems. A questionnaire concerning this information was sent to snubber manufacturers and the answers were tabulated. A comparison was then made regarding the manufacturers' methods of supplying data, performance data they felt was important, and their own interpretation of expected

snubber performance. These questions directed to the manufacturers were derived from problem areas revealed by the first two reports^{1,2} in this series as well as from consultation with experts in snubber design. The areas considered in the questionnaire were

1. shipping and handling,
2. installation,
3. maintenance,
4. seals,
5. fluids,
6. field failures,
7. snubber loads,
8. snubber ratchetting,
9. snubber testing,
10. snubber analysis,
11. calculated snubber spring constant,
12. snubber modeling.

A great deal of emphasis in the questionnaire was placed on the design criteria because it is apparent that the majority of users do not clearly understand these factors.

Response to the questionnaire consisted of only three replies out of seven requests for information. Nevertheless, these three replies indicated careful consideration of the questions and clearly revealed the manufacturers' interpretation of snubber performance and supplier problems as well as the differences in their design philosophies. The responses also provided insight into individual manufacturing design practices.

2. RESPONSES TO QUESTIONNAIRE

This section contains questions and answers (*italics*) derived from the supplier questionnaire. The manufacturers responding included two hydraulic snubber manufacturers and one mechanical snubber manufacturer, indicated by numbers 1, 2, and 3, respectively. At the end of each topic the author's commentary is presented to highlight important design practices and emphasize possible problems revealed by the questionnaire responses.

2.1 Shipping and Handling

A. How are your snubbers prepared for shipment?

1. *Snubbers are completely packaged in accordance with the current code or customer specification requirements.*
2. *Normal preparations for shipment include painting to customer specification, stamping mark numbers in a conspicuous place, attaching an acceptance tag that includes performance specifications, presetting to customer hot and cold position settings, and shrouding the piston rod. The units are then combined in their respective struts and blocked for shipment. However, we would prefer to ship the units in separate packaging to protect them from the handling that is usually associated with structural steel. Most of the time our procurement specifications require that the strut assembly be completed as much as is possible prior to shipment, thus precluding the ability to handle the hydraulic or mechanical snubbers on an individual basis.*
3. *Packaging and shipping are handled in accordance with the customer's requirements. Normally, small snubbers are first placed in a polyethylene bag and then packaged in a fiberboard container with suitable padding. Larger snubbers are mounted on wooden pallets on padded support blocks, and the skid is then sealed with a heavy fiberboard cover.*

B. What precautions are included in preparation for shipment to prevent the entry of air into the snubber fluid system during shipment, subsequent storage and handling, and installation?

1. *Shipping plugs are used.*
2. *No precautions are required due to the pressurized interface reservoir.*
3. *Not applicable (mechanical snubber).*

C. What precautions are taken in preparation for shipment to allow for the effect of temperature variation during shipment and subsequent storage?

1. *No precautions are required since fluid expansion is taken up by piston rod motion.*
 2. *The pressurized reservoir is equipped with an overfilled protection vent which relieves excessive fluid volumes caused by overfilling or temperature variation.*
 3. *Not applicable. Temperature has no material effect on the snubber.*
- D. **What special parts or devices used on snubbers during shipment are to be removed at the time of installation? What method is used to assure their proper removal and/or replacement?**
1. *Special parts used for shipment vary with the contract; generally, a shipping plug (red tagged) is used.*
 2. *The preset clamp, which is equipped with a warning tag indicating its removal after installation, restrains the piston rod to ease installation. The installation and maintenance manual also directs removal of the tag and preset clamp after unit installation.*
 3. *There are no special devices attached to the snubber for shipment.*
- E. **How is the snubber packaged for shipment and storage?**
1. *In accordance with shipment and storage procedures.*
 2. *Snubbers are blocked, strapped, and shipped in tri-wall construction containers.*
 3. *Requirements of Level C of ANSI N45.2.2 are met.*

2.1.1 Commentary

Shipping restraints and plugs introduce potential problems in snubber operation. Consultation with experts in snubber repair and installation has indicated that many snubbers are installed and placed in service without removing the clearly marked shipping restraints and plugs. These restraints may render the snubber inoperable and may even cause severe damage to the supported member during plant startup.

2.2 Installation

- A. Is a formal instruction manual furnished to your customers for the installation of snubbers?
1. Yes.
 2. Generally, formal instruction manuals are furnished as part of the contract's specification. If the contract does not specifically call for installation instructions or maintenance manuals, they are furnished upon request on a complimentary basis.
 3. An instruction manual is furnished along with the necessary design drawing and parts list.
- B. Do your personnel supervise installation of snubbers in the plant?
1. Yes.
 2. Normally installation of snubbers, struts, or other pipe-support equipment is by piping contractors who are competent in the installation of such equipment. With regard to snubbers, factory technical advisors do not usually supervise the installation of these units. Depending on the circumstances, factory personnel are available for assistance should the installer require help.
 3. We do not normally supervise the installation of snubbers; however, we provide advisory assistance if requested.
- C. Is it possible for the user to verify lockup and bleed rates for snubbers at the time of installation? How is this accomplished?
1. Yes. Rates can be verified by a testing device which our company supplies.
 2. Currently units are 100% factory tested and tagged with all pertinent performance information. Prior to actual installation, a unit may be retested on a hydraulic test stand designed by the utility, our company, or others.
 3. At the present time a snubber of our design can be checked in the field to insure that it moves freely within the specified friction levels allowed. On smaller units it can also be confirmed that the unit does apply resistance to abnormal accelerations above its threshold. The snubber cannot be quantitatively

measured in the field, but we currently have under development a means for quantitatively determining these values which should be available during 1977.

D. Does the installation manual contain limitations for the angular orientation of snubbers when installed?

1. *Yes.*
2. *There are no mounting limitations for our hydraulic shock and sway arrestor units.*
3. *The snubber itself is not orientation limited and can be installed in any angular position. The only limitation is to ensure that the self-aligning ball bushing has proper freedom of movement after installation.*

E. Does the installation manual recommend any post-installation testing? How is this accomplished?

1. *Yes. Post-installation testing is accomplished by whichever test is defined in the specifications.*
2. *No post-installation testing is required.*
3. *Omitted.*

F. How do the instructions in the installation manual provide for continuous maintenance of proper fluid level in the snubber and the reservoir during snubber installation?

1. *The instructions provide for proper fluid level by specific orientation methods.*
2. *All units furnished to date have been equipped with a fluid-level indicator as a design standard. This feature, coupled with the air-oil piston interface reservoir, provides a means for exact determination of the proper fluid level at all times. Only our company offers the calibrated indicator plate, which indicates fluid level as a function of piston position. This information is also included in the service and maintenance manual.*
3. *Not applicable.*

G. How does the installation manual provide for the removal of shipping devices (e.g., the reservoir vent plug) and the installation of appropriate operating parts?

1. *This information is defined in the installation instructions.*
2. *There are no vent plugs to be checked; however, the preset clamp must be removed. The installation manual has instructions indicating that the clamp is to be removed along with the red warning tag attached to the clamp itself and to each unit.*
3. *There are no shipping devices involved.*

H. Do you have information indicating a significant number of snubber failures due to improper installation or handling prior to installation?

1. *No.*
2. *Only a small number of failures have been reported and documented.*
3. *To date we have not had a significant number of failures due to improper installation or handling. Some time ago we did find a few small snubbers that had been mishandled during installation. The installation between the pipe clamp and the wall brackets was not well aligned and we found that field personnel had used a large wrench in their attempts to twist the self-aligning bearing lug into alignment. There is a very simple way to make this alignment properly. As a result of these cases, we now attach a sticker which warns against this procedure across the self-aligning bearing of every unit shipped.*

I. In your experience, what snubber problems are most frequently encountered as a result of improper installation or handling during installation? How can these problems be prevented?

1. *The most frequent problem is failure to remove the reservoir shipping plug.*
2. *Improper clearance around the unit impeding its rotation has been a problem resulting from improper installation.*

3. *To date we have not encountered problems in installation or handling. However, we have followed up to find out if there were any problems and have not been apprised of any.*

J. With reference to hydraulic snubbers, what precautions are recommended in your manual to prevent the entry of air into the snubber during installation?

1. *Two precautions are recommended: (1) remove the shipping plug, and (2) do not invert the snubber.*
2. *No precautions are necessary because of the air-oil interface design. As an additional precaution, the unit is pressurized to exclude any additional air entering the system. If the port plugs are not tampered with, no air will be introduced into the system.*
3. *Not applicable.*

2.2.1 Commentary

The instruction manuals provided by the manufacturers appear to cover installation requirements adequately. Since these manuals provide the normal means of communication for snubber installation, it is imperative that personnel who are thoroughly familiar with these procedures supervise installation. It appears that in many cases the instruction manuals are not used during installation.

2.3 Maintenance

A. Are customers provided with a formal maintenance manual?

1. *Yes.*
2. *Yes. As an added precaution, a periodic general mailing is made to ensure that all our customers have maintenance manuals.*
3. *An installation and maintenance manual is furnished to our customers. We plan to expand this manual as necessary to incorporate in-service inspection, tools, and techniques as well as field repair.*

B. What is the nature and frequency of maintenance inspection recommended by your manual?

1. *Yearly inspection is recommended.*
2. *We recommend periodic logged-in inspection on a yearly basis or as it coincides with long-term scheduled shutdowns. The Nuclear Regulatory Commission (NRC) directive 75-05 (see Ref. 1, Appendix E) is also to be considered. Inspection plans are left to the discretion of the individual owner. As a minimum, inspection should include the general appearance of the unit fluid level and the hot or cold position. Additional recommendations are included in the maintenance manual and in additional kit instruction sheets contained in each ethylene-propylene master kit.*
3. *To date we have not established in our manual a formal frequency for maintenance and inspection. We have maintained contact with the utilities using our snubbers and as yet have not found a need for maintenance to any units that have been placed in service.*

C. Can any maintenance required during the design life of your snubbers be performed by a customer using your maintenance manual?

1. *Yes.*
2. *Yes, this has been successfully demonstrated by many owner/operators. However, some owners do prefer factory overhauls, and this service is also provided.*
3. *At the present time our maintenance manual does not provide for complete repair and maintenance throughout the design life of the plant. Our plan is to maintain surveillance of our customers so that we can have first-hand knowledge of the snubber's performance and whatever maintenance may be eventually required. We plan to incorporate this information into our maintenance manual and to institute an immediate updating of the manual as this material becomes available.*

D. What is the nature and extent of snubber maintenance services that you offer, including lead time and scheduled time requirements?

1. *Because they are defined in the customer's specification, lead time and scheduled time requirements vary from contract to contract.*
2. *Factory service available to the owner includes complete overhaul, reconditioning, and performance testing. Field service technical advisors are available to assist the owner in all aspects of service, including advice on equipment requirements. Special factory tools are available for sale to the plant operator, and occasionally factory calibration equipment is brought to the site for field use.*
3. *As stated, no maintenance has been required to date on our snubbers. We would prefer, for a period of time, to have any snubbers needing maintenance returned to us for repair so that we can fully test and examine the unit in our facility and obtain an in-depth knowledge of its service performance. We can offer this service to our customers on an expedient turnaround basis. As we learn the nature of the maintenance that might be required, we will supplement our maintenance manual so that maintenance can be performed in the field. We believe the snubber can be completely overhauled in the field and spare parts can be made available for that purpose.*

E. Do you maintain a stock of seal kits for all models of snubbers, including models no longer produced?

1. *Yes.*
2. *Yes, we adopted a master kit philosophy which includes seals to overhaul any unit manufactured since 1967. Prior to 1967, only 200 units, designated as prototypes, were sold. These units had rod-packing seals with a chevron configuration which cannot be molded into ethylene-propylene E740-75 type compounds. This fact is the only reason that not all of our snubbers can be overhauled.*
3. *Not applicable.*

F. What type of in-plant maintenance testing is recommended by your manual?

1. *Leak checks are recommended and checks for tampering.*
2. *No maintenance testing is currently recommended in the present manual, but a section in the revised manual will direct itself to field testing.*
3. *At present, it is recommended that inspections be made to determine if the arrestor remains free to function as intended. Frequencies and sampling techniques are not specified.*

G. In the event of a major revision to your maintenance manual, are the users of your snubbers advised of this revision? If so, how is this accomplished?

1. *Yes. This is accomplished by an official letter.*
2. *Once units have been furnished to a plant, the manual in effect at the time of manufacture is furnished. If a customer requests more current information, the request is generally forwarded to the Engineering or Product Engineering Departments.*
3. *As updated issues of our maintenance manual are produced, they will be furnished to our customers.*

H. Do you offer a training program to your customer's plant personnel for the maintenance of your snubbers?

1. *Yes. At present the program is for in-house personnel.*
2. *A training program is offered. Most of these seminars are conducted at the site when requested by the plant engineer. A factory training program is also offered on a request basis.*
3. *We have offered no formal training program, but we have no objection to doing so.*

I. Does your maintenance manual contain a formal procedure for filling and bleeding hydraulic snubbers?

1. *Yes.*
2. *Yes, specific details are outlined in the manual.*
3. *Not applicable.*

J. Does your maintenance manual contain specific instructions for compliance with existing NRC inspection and test requirements?

1. *Enough information is provided to comply with these requirements.*
2. *The existing manual does not contain this information, but the revised manual will.*
3. *The maintenance manual currently does not specifically comment on NRC inspection test requirements.*

2.3.1 Commentary

Currently yearly snubber inspection is not adequate. All snubbers capable of visual inspection should be inspected monthly for fluid containment, attachment integrity, and piston position. A plant startup surveillance of snubber operation and piston position is essential.

Owner maintenance has revealed problems in seal replacement. TVA has indicated problems in snubber overhaul as illustrated in report 1 of this series.¹ It is necessary that only qualified individuals with proper tools be allowed to overhaul and test snubbers. To perform these tasks, the owners need to use factory services or qualified consultants who have demonstrated to regulating agencies their proficiency by meeting certain minimum requirements such as completion of factory training programs.

2.4 Seals (Hydraulic Snubbers Only)

A. Do your snubbers employ an elastomeric seal compound for the primary seals? Specify the compound by number and manufacturer.

1. *Yes. Compound number and manufacturer are in-house classified information.*
2. *Yes, ethylene propylene. Manufacturers are Parker Seal and Parker Packing Company for all seals except the filler-plug seals, which are made by Molded Rubber Products Company, Butler, Wisconsin. No other vendors are used.*
3. *Not applicable.*

- B. Have you performed independent tests on the seal material used in your snubbers to determine such characteristics as fluid compatibility, radiation resistance, shelf life, etc.? Describe any testing conducted and state whether or not formal test reports are available.
1. *Yes. This testing was accomplished under a contract for a specific customer. Information related to the testing must be obtained through that customer.*
 2. *Yes, testing was conducted by such companies as Desogrim Industries, Reznord, Inc., Parker Seal Companies, Westinghouse, and others. A generic report was issued to Mr. K. R. Goller, Assistant Director for Operating Reactors for the Atomic Energy Commission (AEC) on October 7, 1974.³*
 3. *Not applicable.*
- C. According to your design criteria, what degree of seal degradation is tolerable before the seal is considered failed?
1. *This information can be obtained through various seal manufacturers.*
 2. *Degradation after 1×10^7 rads is normally considered failed, but the ultimate test is whether the seal retains fluid.*
 3. *Not applicable.*
- D. What maximum compression set is tolerable in your seals?
1. *This information can be obtained through seal manufacturers.*
 2. *Up to a maximum of 90% compression set is considered tolerable.*
 3. *Not applicable.*
- E. What certified data do you furnish to the users of your snubbers to establish seal characteristics?
1. *We furnish testing reports.*
 2. *We will certify the data provided in the seal technical bulletin.*
 3. *Not applicable.*

2.4.1 Commentary

Seal integrity is essential for proper snubber performance; report 1 (Ref. 1) has shown 513 snubber abnormalities caused by leaky seals and loss of hydraulic fluid. For the most part, these seal failures were due to fluid-seal incompatibility and subsequent seal deterioration. The seal materials have since been changed to ethylene propylene (EP). Some EP seals have been in service for up to three years with no adverse effects to date. The author has not discovered a single snubber failure due to seal degradation in snubbers incorporating EP seals. Nevertheless these points should be considered. First, service data on EP seals are incomplete. Second, the relationship between EP seal degradation and radiation coupled with other environmental conditions has not been clearly established. A quotation from the Oct. 7, 1974, report to the AEC reaffirms this.

Note that one of the tests reported here shows the effects of radiation, while the other shows the effects of temperature and fluid. We have not tested the combined effect of all three, but we anticipate that the loss in physical properties may be greater than a simple addition of the separate effects.³

Third, seal wear and fatigue data are limited and this information is required for snubbers that are subject to system vibration.

2.5 Fluids

A. What fluid does your snubber normally contain?

1. G.E. fluid SF 1154.
2. Standard fluid is General Electric; silicone fluid is SF 1154 for all applications.
3. Not applicable.

B. How is fluid cleanliness maintained in your plant?

1. Fluid cleanliness is maintained by a control procedure.
2. All fluid is filtered through a 10- μ filter prior to filling a unit. Material is segregated to prevent combination.
3. Not applicable.

- C. What procedure is used for eliminating entrained air from the fluid contained in a snubber?
1. *Vacuum purge.*
 2. *Units are equipped with a fluid-bleed screw located at the highest point when the unit is in the horizontal position. The technique for bleed is similar to that for bleeding an automotive brake system.*
 3. *Not applicable.*
- D. Do you have a method for determining the amount of entrained air contained in a fluid sample?
1. *Yes, but we do not have a production procedure.*
 2. *Our experience with hydraulics does not indicate a requirement for determining the amount of entrained air in the fluid. A detrimental amount of trapped air will show itself at performance testing by spongy hydraulic response and poor test characteristics. Units failing the test criteria are reworked.*
 3. *Not applicable.*
- E. Does your control valve contain filters to prevent contamination from entering the control valve orifices?
1. *No.*
 2. *To be effective, fluid filters must be located upstream of the control orifice. A hydraulic system, like any other, is subject to wear and subsequent particulate contamination. When filters become clogged, the unit becomes ineffective. We have furnished all hydraulic snubbers with a self-cleaning orifice design which is flow cleaned during reverse cycles or reverse thermal growth activation. Our design philosophy is to provide a flow-control valve which requires no maintenance other than periodic seal overhaul.*
 3. *Not applicable.*
- F. Have you conducted independent testing to determine fluid characteristics such as viscosity, viscosity index, bulk modulus, etc.?

1. *Yes.*
 2. *No.*
 3. *Not applicable.*
- G. Have you conducted independent radiation testing on your fluid?
1. *Yes.*
 2. *No.*
 3. *Not applicable.*
- H. Does your snubber system use a pressurized accumulator or an atmospheric reservoir?
1. *The system uses an atmospheric reservoir.*
 2. *The snubber uses a pressurized reservoir system which provides the ability to mount the unit in any spatial orientation, an air-oil interface to eliminate oxidation degradation of the fluid, and a positive interface to prevent entrainment of air during thermal growth or seismic response.*
 3. *Not applicable.*
- I. If your system uses a reservoir vent, describe it. Is this vent filtered?
1. *Yes, it is a filtered vent.*
 2. *Not applicable.*
 3. *Not applicable.*
- J. Does your maintenance manual recommend periodic fluid testing? Please describe any tests recommended?
1. *No.*
 2. *Not required. The fluid itself has been found to be completely stable.*
 3. *Not applicable.*
- K. How many snubbers are usually serviced by a single reservoir of an accumulator?
1. *Normally only one, but more than one snubber can be serviced by a single reservoir.*

2. *For Standard Units, classified as Component Standard Supports, one reservoir per snubber; for Steam Generator and Reactor Cooling Pump Motor Support units, generally considered special designs, up to eight reservoirs.*
 3. *Not applicable.*
- L. Is the fluid compressibility (bulk modulus) affected by temperature changes and/or the presence of contaminants? Please describe these effects.
1. *Yes. We have preliminary information and will have more extensive information after a full testing program has been completed.*
 2. *Bulk modulus is affected by temperature and contaminants. Solvents destroy the chemical structure of the silicone molecule and change the viscosity and general characteristics of the fluid. They also act as chain extenders and are generally interstitial in nature. The result is a density change which directly affects bulk modulus. Temperature affects bulk modulus by changing the density of the fluid (mass per unit volume). At a higher temperature, the density will decrease, which is a direct reduction in bulk modulus.*
 3. *Not applicable.*

2.5.1 Commentary

Fluid contamination is a problem as illustrated by the contaminated snubbers found at Three Mile Island (see Ref. 1). Fluid should be examined for particular matter at installation and at specified inspection intervals.

The effect of fluid property changes due to temperature changes as related to snubber performance has not been thoroughly investigated. Also, cleaning solvents can have a detrimental effect on snubber performance if they contaminate the hydraulic fluid. This problem can be avoided by having qualified personnel supervise snubber overhaul and installation.

2.6 Field Failures

A. Do you employ a system for the retrieval of field failure data for your snubbers? Describe your system.

1. *We do this on an individual basis by close contact with customers, but we do not have a formal system.*
2. *The most common information concerning field failures is in the form of customer complaints which require advice on corrective action or on service, parts, etc. Responses are compiled according to product lines as in the case of hydraulic snubbers and the hydraulic shock and sway arrestor file. Most complaints lead to product redesign and are acted upon by engineers who are now part of the product development group (Product Engineering Department). The hydraulic shock and sway arrestor has recently entered its third-generation design. The goal of our company is to provide a product which is as trouble-free as possible.*
3. *We periodically contact users of our snubbers, but as yet have not had field failures.*

B. Have you, as a result of the investigation of field failures, defined snubber problems which could be described as generic in nature? Describe any such problems and the corrective action taken.

1. *Yes. We have a specific shop tolerance associated with factory setting the bleed and lockup rates. These tolerances are: lockup rates, 8 ± 2 in./min; and bleed rate, 4 ± 2 in./min. These are factory-set tolerances and do not reflect what should and can exist in field installation. If the bleed and lockups fall outside the original shop tolerance level, it does not mean that the snubber is inoperable. We have found by extensive testing and analysis that the lockup and bleed rates of hydraulic snubbers can vary distinctly from the manufacturing shop tolerance. After it has finished its formal testing, our company will publish bleed-rate ranges and lockup ranges.*

2. *Yes. Two examples of such generic problems are seal failures and manifold leaks and others. Our failures have been well documented by the NRC and are available to all interested parties in the industry. Corrective action taken includes a major seal redesign as a result of changing polyurethane seals to ethylene propylene seals to plant environmental and configuration changes.*
3. *No failures have been found to date.*

C. **Do you maintain records of field failure data?**

1. *We do not maintain an official system of records; however, pressurized and nonpressurized leakage are the major criteria.*
2. *Field failure data are included in the hydraulic shock and sway arrestor file. Field failures are also documented by the NRC and the vendor inspection status report and published on a periodic basis.*
3. *No failures have been found to date.*

2.6.1 **Commentary**

Field examination has demonstrated that many hydraulic snubbers have bleed and lockup rates that vary considerably from manufacturers specifications. In the author's opinion these specifications are out of control at the present time. The effect of this variance on snubber performance during a seismic event is unclear and will remain unclear until the proper specification tolerance can be established.

Since the manufacturers are relying primarily on customer complaints for design improvement, it is essential that a formal procedure, regarding snubber abnormality reporting and failure mode evaluation be required by the regulating agency.

2.7 **Snubber Loads**

A. **What types of loading are considered in your snubber design?**

1. *The same types as specified in Subsection NF of the ASME Boiler and Pressure Vessel Code, Sect. III or as defined in customer specifications.*

2. *Axial loads with consideration for moments and temperature effects.*
 3. *Our design and analysis are in accordance with ASME Sect. IV Subsection NF.**
- B. For the case of engineered hanger contracts how do you determine snubber load?**
1. *Load is determined as specified in customer specifications.*
 2. *We use a combination of computer analysis for various vibratory and shock loading conditions in accordance with the architect-engineer's instructions.*
 3. *We do not engage in engineering hanger contracts.*
- C. In the case of engineered hanger contracts what other criteria are used for snubber selections?**
1. *Space availability along with loading criteria.*
 2. *Other criteria are a combination of computer analysis for various vibratory and shock loading conditions in accordance with the architect-engineer's instructions.*
 3. *We do not engage in engineering hanger contracts.*
- D. In the case of engineered hanger contracts what snubber load rating is used as a selection criterion?**
1. *All three ASME, Sect. III loading conditions are considered, both primary and secondary.*
 2. *Units are selected for design load and checked for other pertinent criteria.*
 3. *We do not engage in engineering hanger contracts.*

2.7.1 Commentary

Consideration of normal upset and emergency loads as described in ASME, Sect. III, Subsection NF should provide an adequate basis for structural evaluation of snubbers. The problem with snubber load specifications is that the analysts do not have an adequate data base to determine accurate snubber load-deflection characteristics. Approximating the snubber as

a pure elastic spring does not include the effect of the dead band on snubber loading which could result in underestimating peak load due to high impulse loading conditions.

2.8 Snubber Ratchetting

A. Is your snubber subject to ratchetting phenomenon as a result of a cyclic load input?

1. Yes.
2. *Although our company declines to comment technically on this subject at this time, we would add that ratchetting is not generic to snubbers alone. The "walking" phenomenon has been observed in cylinders, shock absorbers, and other reciprocation-type devices. The effect may be due to differences in momentum and load impulses which result in an apparent acceleration and subsequent deflection in one direction. Our company is scheduling further dynamic tests and will attempt to theorize this phenomenon.*
3. *The motion of the snubber under cyclic loading is shown in Test Report TR 80J.⁵ Note that the behavior of the snubber does not change materially with frequency until the frequency is below 3 Hz. Below 3 Hz, it will allow greater displacement of the restrained component. The amount of displacement is a function of the "g" sensitivity and frequency and will be greater the lower the frequency. However, the displacement results in energy being absorbed by the snubber rather than a lowering of the spring rate. The actual motion can be predicted. This is best described in an article we wrote called "Aerospace Technology Applied to Nuclear Power Plant Problems." (This article and all the information we have furnished here is available upon request to our customers for use in their analysis.) In some cases we have been requested to furnish snubbers which require the "g" setting to be as low as 0.001. This permits the snubber to react at one or two cycles in the same manner as it does at*

higher frequencies. The reason for this is explained in the above mentioned article.

B. What is the worst ratchetting event that can be experienced by your snubber? What conditions must prevail to cause this event?

1. To date the mechanics as to why ratchetting occurs have not been fully defined. It is theorized that this phenomenon is the result of unequal fluid deflections within the cylinder between tension and compression when the cylinder is tested dynamically in load controls (equal tension and compression loads). Using this theory, the snubber will ratchet to the point of equal fluid deflection when such loading is applied. Analytically, any snubber will ratchet to a point where the following condition exists when equal tension and compression cyclic loads are applied:

$$\frac{L_t}{D_p^2 - D_r^2} = \frac{L_c}{D_p^2},$$

where

L_t = length of tension-fluid column,

L_c = length of compression-fluid column,

D_p = nominal piston diameter,

D_r = nominal rod diameter.

2. See A, Sect. 2.8.

3. See A, Sect. 2.8.

C. What is the minimum ratchetting motion event that can be experienced by your snubber? What conditions must prevail for this event to occur?

1. Same as B, Sect. 2.8.

2. See A, Sect. 2.8.

3. See A, Sect. 2.8.

D. What is your understanding of the mechanics of ratchetting motion in your snubber?

1. Same as B, Sect. 2.8.
2. See A, Sect. 2.8.
3. See A, Sect. 2.8.

E. What information do you present to your customers regarding the phenomenon of ratchetting motion in your snubbers?

1. Same as B, Sect. 2.8.
2. See A, Sect. 2.8.
3. See A, Sect. 2.8.

2.8.1 Commentary

Ratchetting is a phenomenon inherent in hydraulic snubbers that has not been evaluated to date. Conceivably the random ground motion encountered in a seismic event could result in possible unequal loads on the snubber in tension and compression and cause it to ratchet to a piston position that could result in damage to the supported member.

2.9 Snubber Testing

A. What prototype testing do you perform for your snubber designs?

1. Testing to verify lockup and bleed rate. On large-bore snubbers we perform testing to verify both lockup and bleed and spring rate.
2. Load rating, functional, performance, elevated temperature, and endurance testing.
3. In the development of a snubber design, numerous engineering experimental tests have been performed both on completed snubbers and on parts of snubbers. These tests consist of environmental testing for rust and corrosion as well as dynamic and static testing to confirm engineering designs. Over the past few years we have performed a number of qualification-type tests for specific customers. In addition, in 1976 we ordered from our own production facility one snubber of every size. These

were ordered to meet full NF certification. The units were randomly selected from production lots of snubbers by the state inspector and the complete data package was required. Each of these units was then subjected to qualification testing.

- B. What testing is performed as a matter of production procedure?
1. Lockup and bleed rate.
 2. Functional, drag-load (bind) and performance testing.
 3. Every snubber that is shipped must pass an inspection test procedure.
- C. Do you, as a matter of production procedure, remove occasional fluid samples from snubbers and test for entrained air, contaminants, etc.?
1. No.
 2. Not normally.
 3. Not applicable.
- D. What records of production testing are maintained?
1. Records to verify lockup and bleed rate.
 2. Any test performed becomes a permanent record against the serial number.
 3. Copies of the inspection test procedure results of each snubber are furnished to the customer, and the originals are kept as a permanent record in our quality control file.
- E. To what extent have you performed dynamic snubber testing under cyclic loading conditions?
1. The full range of cyclic testing will be completed by the end of the third quarter of 1977.
 2. To comply with General Electric specification 21A9251 Rev. 3. Additional testing is scheduled to qualify the ASME Sect. III, Subsection NF⁴ snubbers with the most current specification.
 3. Test Report TR-809, Rev. 0,⁵ contains a typical example of the dynamic testing performed on a snubber. In addition to these formal reports, numerous tests have been done for experimental purposes and for specific customers.

- F. What tests have you performed to verify snubber spring rate under static and dynamic loading conditions?
1. *Both static and dynamic tests.*
 2. *Spring rate data are generated during cyclic loading. The definition of spring rate, however, is still a matter of discussion between the snubber manufacturers and suppliers.*
 3. *Test Report TR-809, Rev. 0, shows oscillograph traces of the snubber under dynamic loading conditions.*
- G. How closely do the results of deflection testing correlate with your deflection analysis?
1. *As of this date we cannot officially verify deflection testing. Our present program will accomplish this.*
 2. *Our experience is that they correlate quite well.*
 3. *An analytical deflection analysis has not been made.*
- H. What tests have you performed on snubbers that have been in service for one year or longer? What conclusions can you draw from the results of these tests?
1. *Lockup and bleed rate testing has been done. Conclusions that can be drawn are lockup and bleed can deviate from manufacturing tolerance and this deviation will not cause inoperability of the snubber. We are finding that both the lockup and bleed can vary throughout a large range and still not affect the performance of the snubber.*
 2. *No tests. Units are normally not returned for testing.*
 3. *We have only had a few cases of snubbers that have been in service for a year. No conclusive comments can be made; however, in no case has a snubber failed to meet the original inspection test requirements after having been in service.*
- I. What lockup and bleed rate calibration tests are performed for your snubber?
1. *As defined in our calibration testing procedure.*
 2. *Activation level (lockup) is recorded in tension and compression per serial number as specific temperature. Release rate (bleed)*

is recorded at unit design load or 50,000 lb (whichever is lower) and at the current ambient temperatures for component standard-support-type products. Large bore units, however, are tested at design load plus 10% or as indicated by the purchase specification. Loads as high as 2,000,000 lb have been applied to these units.

3. *The mechanical equivalent of this type of test is conducted in our own inspection test procedure.*

J. Have you performed fatigue testing of your snubbers?

1. *We are in the process of conducting these tests.*
2. *No actual tests. Design is predicted on a 3600-psi industrial cylinder which has been fatigue tested to meet 1×10^7 cycles at design load. The safety margin for hydraulic units is in the vicinity of 4:1 to meet ultimate tensile failure. This type of engineering results in ultimate life designs. See Sect. 2.10.*
3. *We will comment on fatigue testing in Sect. 2.10.*

K. What sampling method do you use for production testing to assure that the test results are typical of prototype units?

1. *Each snubber shipped from our company is completely tested for lockup and bleed.*
2. *Production units are pulled at random for additional testing. Since the basis of manufacture is by tight tolerance control, the components of one unit are interchangeable with others. These units are not custom fit, thereby resulting in performance repeatability.*
3. *We have commented earlier that the qualification testing was done with the State Inspector randomly choosing a snubber for testing from production lots.*

L. What testing have you performed that establishes the extent of ratchetting under various loading and installation conditions for your snubbers?

1. *Characteristic test units are randomly selected from production. The extent of ratchetting will be verified with future testing.*

2. *No comment at this time.*
3. *Test Report TR-309 (Ref. 5) shows the performance.*

2.9.1 Commentary

Some snubber designs are not evaluated under simulated seismic conditions. All design prototypes should be subjected to simulated seismic loading in order to determine performance characteristics, and fluid should be checked on production units for contamination. Dynamic load-deflection data are required for snubber modeling methodology development. Recommendations have been made to NRC to determine the correct method of snubber modeling. Presently it is questionable whether or not any method of spring-constant approximation of snubber load-deflection characteristics offers conservative system response results.

As stated previously, bleed rate and lockup velocity specifications appear out of control. Snubber manufacturers cannot rely solely on customer complaints for snubber service evaluation, and for this reason, sample snubbers should be retrieved from service periodically for a complete overhaul and a performance evaluation at the factory. Also, fatigue, piston-ring, and seal wear tests should be performed on prototype snubbers.

2.10 Analysis

A. Specifically what stress analyses do you perform for your snubber? Please furnish a sample analysis.

1. *Detail stress reports in accordance with ASME, Sect. III, Sub-section NF.*
2. *All components except the flow control body are stress analyzed. The flow control body is load tested.*
3. *A typical copy of our stress analysis is enclosed.*

B. Specifically what deflection analyses do you perform for your snubber? Please furnish a sample analysis.

1. *Only when required.*
2. *Deflection analysis is provided only upon request. One reason for this is the variance in deflection interpretation by the*

~~architect-engineers or stress analysts.~~ The deflection equation is given by

$$WL = \frac{PL}{K},$$

where P = fluid, L = column length, and K = bulk modulus.

3. Deflection is measured by static tests and dynamic tests.
- C. For purposes of your analysis, is your snubber considered Class I equipment?
1. Yes.
 2. Our company does not usually perform the analysis of the systems, but the current units (snubbers only) are manufactured to NF Class I criteria only.
 3. Our snubbers are considered Class I supports.
- D. Have you performed a fatigue analysis for your snubber?
1. No.
 2. We have not performed fatigue testing for the snubber specifically, but such testing has been performed on the components of the main cylinder. This effort was based on nonpioneered designs and more than 30 years of high-pressure technology.
 3. We have not performed an analytical fatigue analysis; however, we have done considerable fatigue testing, and these tests are continuing.
- E. Describe the fatigue and stress criteria used as a basis for your analysis.
1. As required in most specifications, 10,000 cycles.
 2. Omitted.
 3. In our fatigue testing, we have isolated the point of fatigue failure. This consistently has been the tangs of the capstan springs. The Qualification Test Report, TR-809, Rev. 0,³ shows proof that the snubber at full rated load is capable of carrying the loads required without failure that might occur in operating-basis earthquake (OBE) or safe-shutdown earthquake (SSE) incidents. We recommend to our customers that if a particular

snubber installation is frequently required to restrain significant loadings such as water or steam hammers, blowdown, etc., the next larger size snubber be used. This, in effect, lowers the rating of the snubber to about 30% of its normal design upset rating, the point at which the fatigue loading approaches infinite life. This recommendation is made by virtue of having fatigue tested the spring tangs at various loadings and obtaining results which show that they follow a classical load vs cycle life-fatigue curve.

F. Have you performed detailed stress and deflection analyses for clamps and brackets? If so, please include sample analyses.

1. *Yes. In-house classified information can be obtained through major architect-engineers.*
2. *See Load Capacity Data Sheets for such equipment.*
3. *A sample analysis of a bracket is enclosed. We do not manufacture pipe clamps.*

G. Does your snubber deflection analysis take into account the deflection of anchor bolts?

1. *If required by the customer.*
2. *No.*
3. *To date, our designs of wall brackets have not used anchor bolts.*

H. Do you perform any stress or deflection analysis for other than axial snubber loading? Describe.

1. *Yes. Seismic side loading and jet-impingement loading.*
2. *No, the snubber only sees axial loads. The moments introduced by unit dead weight and hinge friction are normally not significant.*
3. *We have performed analysis to limit the overall length of the snubber support and extension. In some limited cases, we have done analysis considering dynamic side loading on the snubber simultaneously with axial loading.*

I. Have you defined snubber load ratings as a result of your analyses? Define your load ratings in terms of ASME, Sect. III loading definitions.

1. Yes, as defined in ASME, Sect. III, Subsection NF normal and upset, emergency and faulted.
2. Design, rated, normal, and upset loads are the same as design load. Emergency is the same as design load. Faulted is $1.5 \times$ design load.
3. The snubber load ratings in accordance with ASME, Sect. III* are defined in the stress analysis. For catalog publication purposes, in most cases we have rounded these numbers to a slightly lower value.

J. Do you analyze clamps and wall brackets to take into consideration snubber angular orientation with respect to the pipe axis or wall surface?

1. If requested by customer.
2. Yes; the loading condition for the worst case is used in the analysis.
3. Our wall brackets have been analyzed for angular orientation of the axial load.

2.10.1 Commentary

Stress analysis as prescribed in ASME, Sect. III, Subsection NF should reveal any problems due to component overstress. Stress analysis of the entire snubber system should be performed, including control valve assemblies (if applicable) and the means of attachment.

2.11 Calculated Snubber Spring Constant

A. To what tolerance (calculated vs demonstrated) are you able to calculate snubber spring constants?

1. We are not presently in the position to state what tolerance level we can produce on spring rate constants for snubbers. We do feel, however, that with our present testing program under

way, we will have accurate information by the end of the third quarter 1977.

2. We do not normally apply a tolerance level to spring rates of the snubber.
3. See Sect. 2.12.

B. At what piston position do you calculate snubber spring constants?

1. At either the midstroke setting or the position indicated in the customer's specification.
2. Spring rates are normally calculated at midposition of stroke, but analytical data can be provided in any fluid-column length. A comparison of calculated vs actual spring rates is shown below:

<u>Model</u>	<u>Calculated^a</u>		<u>Actual^b</u>	
	<u>Ext</u>	<u>Comp</u>	<u>Ext</u>	<u>Comp</u>
HSSA-10	183,300	275,000	166,700	250,000
-20	366,700	158,300	307,700	540,600
-30	550,000	687,500	300,000	483,900

^aCalculated spring rate is based on an adiabatic bulk modulus at atmospheric pressure of 165,000 psi at 70°F for SF 96-200 silicone fluid. Pressures used in the calculations are those produced by the various differential areas necessary to obtain design load. (Units - lb/in.).

^bActual test data with mean-response values analyzed. Test data generated during double load qualification tests at room temperature and unit-design loads using GE SF 96-200 silicone fluid.

3. See Sect. 2.12.

C. Do you calculate spring constants for the clamp, snubber, and bracket as an assembly?

1. Yes.
2. Spring constants are normally calculated for the snubber alone and not particularly calculated for the clamp and the bracket as an assembly. These components are considered as structural

steel, and their deflection analysis and associated spring rates are based on typical deflection analysis equations.

3. *See Sect. 2.12.*

D. Is the calculated spring constant for the clamp, snubber, and bracket assembly significantly affected by the angular orientation of the snubber as it is installed? If so, how do you describe this effect in your information to the user?

1. *Yes. We describe this by a detailed deflection analysis.*

2. *Special orientation of the snubber has no effect on the snubber's spring rate. This definition of spring rate is the axial load/unit deflection applied to a strut in a piping system. The vector component of the load must be considered and accounted for in the system analysis.*

3. *See Sect. 2.12.*

2.11.1 Commentary

The correct method of spring-constant approximation of snubber non-linear load-deflection characteristics exhibited during seismic-type loading has not been established. The difference in load-deflection characteristics between compressive and extension forces is illustrated in the preceding table. It is apparent from the answers to the questions in this section that the problems associated with spring-constant approximations have not been resolved.

2.12 Snubber Modeling

A. How do you suggest that your snubber be modeled in a structural dynamics analytical program?

1. *This should be separated into three categories. For equipment snubbers we recommend that the snubber should be handled as a linear spring. For class 1 nuclear piping, they should be represented as a linear spring. For class 2, 3, and MC piping, they should be represented as rigid.*

2. Our company normally does not perform dynamic analysis of piping systems and we are therefore unable to provide information on snubber modeling. However, we would suggest that architect-engineers or piping-systems design analysts be contacted concerning their usage of modeling systems in snubber piping calculations.
3. This writer was assigned by the ASME Snubber Task Force the job of suggesting the wording for the spring rate of snubbers. In the most recent meeting of the task force, January 10, there was no objection raised to this wording except for comments that perhaps the task force should recommend a preferred means of choosing a spring rate. This meeting was brief because it preceded the NF Committee Meeting. The subject will be discussed in much greater detail in a tentative meeting of the task force in Chicago on February 1-2, 1977.

We feel quite strongly that the comments in this exhibit should not be oversimplified by restricting the systems analyst to a specific means of arriving at the spring constant or for modeling of the snubber in his program. We feel this is an area of expertise which belongs in the hands of the systems analyst and that he should have the knowledge and freedom to model the snubber in as sophisticated a manner as necessary to provide an acceptable analysis to the NRC. Conversely, in a great many snubber applications, it may not be necessary to use an extremely sophisticated model with the attendant complexities and cost related to development of a completely safe and conservative analysis. For example, snubbers that restrain primary safety components where dynamic behavior and deflections may be extremely critical could require very serious study by the systems analyst to be sure that his model will provide conservative answers. In some cases a conservative answer may be arrived at by considering the lowest possible spring rate, including lost motion as part of the spring rate. In others, the conservative answers may be derived by considering the highest possible

spring rate that could occur. Only the overall systems analyst has access to the detailed knowledge of the system, structural behavior of the attach points that go beyond NF, etc.

It also should be considered that a great many snubbers, particularly the smaller sizes, are used on the systems where the spring rate or deflection are not particularly critical and will permit much simpler analysis and modeling of the snubber.

I believe to cover this very important subject in your report, recognition should be given to the fact that modeling of the snubber for major components such as steam generators, pumps, main steam lines, etc., may require different degrees of analysis than those for other applications. Note that the snubber spring constant is different in tension and compression and is also a function of the amount of extension. Although this is a general answer to Sects. 11 and 12, we believe it provides the basic background and that the actual measurements and test data are shown. The spring constant of a mechanical snubber does not change significantly. Dynamic testing at various temperatures has not shown a significant difference in performance.

B. At what piston position do you calculate snubber spring constants?

1. Our calculated spring constant does not account for loss of motion or nonlinear piston displacement. This type of analysis would be extremely cumbersome, time consuming, and expensive.
2. See Sect. 2.12.
3. See Sect. 2.12.

C. Is your suggested snubber model dependent upon a specific piston position?

1. Yes.
2. See Sect. 2.12.
3. See Sect. 2.12.

- D. How does your suggested snubber model account for changes in snubber spring constant resulting from changing load directions?
1. *It does not. Again this would be very time consuming, expensive, and would have to be done with a time-dependent computer program. To our knowledge, this type of analysis is not being done on a production basis.*
 2. *See Sect. 2.12.*
 3. *See Sect. 2.12.*
- E. Does your snubber spring constant change significantly as a result of temperature variation?
1. *The snubber spring constant changes as a result of two major factors. It changes as a function of temperature and bulk modulus changes. We are presently engaged in extensive testing on both large-bore and small-bore snubbers to develop a technique by which we can accurately predict spring-rate characteristics.*
 2. *See Sect. 2.12.*
 3. *See Sect. 2.12.*
- F. Do you have test data to support your modeling suggestion? If so, what is the nature and extent of this data?
1. *Yes. We have extensive analysis that backs up spring-rate characteristics of both large-bore and small-bore snubbers. Furthermore, we are presently engaged in large-bore and small-bore testing to verify analysis techniques.*
 2. *See Sect. 2.12.*
 3. *See Sect. 2.12.*

2.12.1 Commentary

Load-deflection characteristics of snubbers change with piston position, load, temperature, frequency, and snubber size. A linear approximation of snubber nonlinear load-deflection characteristics (see Ref. 2) provides a simpler model and method of analysis for the systems analyst.

The question is whether or not this type of approximation provides conservative system response results because the methods used to model snubber nonlinear response with a linear approximation for a given snubber yield results that vary as much as 300%. Snubber modeling is presently in the hands of the systems analyst as recommended by the ASME Task Group on Snubbers. The problem is that the analysts do not have the data required to determine an accurate model for the snubber in their analysis because load-deflection data is incomplete or not available. The analysts have not determined the effect of snubber nonlinear characteristics on system response. As a result, most analysts are using spring constants supplied by the manufacturers in their analysis. It is interesting to note that due to the complexity of systems analysis, the manufacturers are recommending that the analysts establish their own snubber model while the analysts are actually using the snubber model recommended by the manufacturers.

3. RECOMMENDATIONS AND CONCLUSION

The preceding questionnaire was directed to the manufacturers in an effort to determine the basis for snubber design as well as manufacturing and installation problems. The problems revealed by the responses to the questionnaire, along with recommendations for corrective action, are summarized below.

<u>Problem</u>	<u>Corrective actions</u>
A. Shipping restraints and plugs are not always removed from snubbers before plant startup.	<ol style="list-style-type: none"> 1. Only qualified personnel should supervise snubber installation. 2. A plant startup snubber surveillance to indicate piston position, fluid containment, and attachment integrity at each thermal plateau should be mandatory. 3. Training programs for snubber installation and maintenance should be provided.

- B. Bleed rate and lockup rates for some snubber designs may vary greatly from published specifications.
1. The maximum allowable tolerance for bleed rate and lockup velocity should be determined and specified by the owners.
 2. Bleed rate and lockup tests should be performed on all snubbers by the manufacturers before shipment and by qualified personnel at the installation site before installation.
 3. Snubber lockup velocities and bleed rates should be determined for all snubbers during plant shutdown.
 4. Snubber lockup velocities and bleed rates should be determined for selected snubbers at selected intervals between outages.
 5. A complete design analysis of control valve configurations should be performed by the manufacturers.
- C. Yearly snubber inspection is inadequate.
1. All snubbers capable of visual examination should be inspected monthly for fluid containment, attachment integrity, piston position, and general appearance.
 2. Snubber lockup velocities and bleed rates should be determined for selected snubbers at selected intervals between outages.
 3. Selected snubbers should be examined for fluid contaminants at selected intervals.
- D. Snubber maintenance is many times inadequate.
1. Only qualified personnel with appropriate tools and equipment should supervise snubber maintenance overhaul and testing.
- E. Performance data on ethylene propylene seals are incomplete.
1. Research should include fluid compatibility, environmental effects, fatigue, and wear.

- 2. Selected snubbers should be withdrawn from service and evaluated as to seal performance.
- F. Fluid contamination does occur.
 - 1. Selected snubbers should be examined for fluid contaminants at selected intervals.
 - 2. All snubbers should be inspected for fluid contamination before shipment and at installation.
 - 3. Only qualified personnel should supervise overhaul, bleeding, and testing of snubbers to eliminate the possibility of fluid contamination from cleaning solvents.
- G. A formal procedure for evaluation of field failures does not exist.
 - 1. Regulating agencies should require formal failure evaluations to complement abnormal occurrence reports.
- H. An adequate data base to develop snubber modeling methodology is not available.
 - 1. Research.
- I. The ratchetting phenomenon is not understood.
 - 1. Research.
- J. Some snubber designs are not evaluated under simulated seismic conditions.
 - 1. Design prototype performance should be evaluated under all types of probable service loading including seismic and system vibration.

It is apparent from the answers to the questionnaire that the manufacturers have different interpretations of many aspects of snubber performance and design, including spring constant determination and snubber modeling. The ASME Working Group on Component Supports issued a document on Feb. 1, 1977, entitled *Snubber Design Criteria*. This document defines pertinent areas of snubber performance and, in the author's opinion, offers for the first time the basic information required by the buyers to communicate effectively with the suppliers regarding performance. The problem that will arise as a result of this document is that the data required to answer adequately many questions regarding the specifics of

performance (e.g., ratchetting, spring constants, environmental effects, fatigue) are presently not available as responses to the questionnaire indicate.

In summary, snubber designs have not been fully characterized with regard to expected performance. The manufacturers are making a conscientious effort to supply this information but, due to previously mentioned barriers, they are finding the task difficult, if not impossible. The preceding analysis has revealed problems in snubber design, shipping, handling, maintenance, and installation and has made recommendations for corrective action.

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