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OPERATING EXPERIENCE WITH SNUBBERS

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Division of Operating Reactors
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
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INTRODUCTION

Recent operating experience with hydraulic and mechanical snubbers has indicated that there is a need to evaluate current practice in the industry associated with snubber qualification testing programs, design and analysis procedures, selection and specification criteria, and the preservice inspection and inservice surveillance programs.

This report is written as partial fulfillment of Subtask 1 of Category A generic Task A-13 to provide a summary of operational experiences that represent problems that are generic throughout the industry. Generic Task A-13 is part of the NRC Program for the Resolution of Generic Issues Related to Nuclear Power Plants described in NUREG-0410. This report is based upon a rather large amount of data that have become available in the past four years. These data have been evaluated by the Division of Operating Reactors to develop a data base for use in connection with several NRC activities including Category A, Technical Activity A-13 (Snubbers); the Standard Review Plan; future Regulatory Guides; ASME Code provisions; and various technical specifications of operating nuclear power plants.

II. STATEMENT OF THE PROBLEM

2.1 Summary

Mechanical and hydraulic snubbers perform important safety functions during seismic events and other plant transients. They have been used extensively in the nuclear industry for several years and selectively as far back as the first licensed reactors. Historically, the reliability of these components has been somewhat less than expected.

Industry practice with respect to snubbers varies from conceptual design through in-plant service. Adequate guidance has not been developed to establish a comprehensive and consistent approach for the resolution of manufacturing, design and service problems that have historically affected snubber performance.

2.2 Historical Background

2.2.1 Evolution of Increased Snubber Usage

Only small numbers of snubbers were used to meet design requirements prior to the late 1960s. Figure 2.1 and Table 2.1 show a marked increase in the number of snubbers used in nuclear power plants that received operating licenses after 1971. Over these years, more stringent seismic design requirements were evolving as well as escalations of the ground motion input. While no direct correlation can be made regarding the impact of higher "g" levels on the number of snubbers incorporated in a design (see Figure 2.2 and Figure 2.3), current seismic design criteria generally dictate that more snubbers be used. In addition, snubbers have also been added as a substitute for more detailed analyses or with the intent of providing a more conservative design.

2.2.2 Chronology of Industry Awareness of Generic Problem Areas

Operational experience with hydraulic snubbers was highlighted in July 1973 when the AEC issued Regulatory Operations Bulletin 73-3 to alert the industry that certain Bergen-Paterson snubbers were subject to a loss of hydraulic fluid. The bulletin evolved out of an evaluation of a reported abnormal occurrence at Millstone 1 that revealed 51 of 112 hydraulic snubbers inspected had lost hydraulic fluid. In August 1973 Regulatory Operations Bulletin 73-4 followed, indicating that the fluid loss described in RO 73-3 was due to defective seals and that replacement of the seals with the original material was not likely to be a long-term solution. In October 1973, all affected licensees were directed to replace the seal material with material that was compatible with the hydraulic fluid and to implement technical specifications for inservice surveillance of snubbers.

Inspection and Enforcement Bulletin No. 75-05 was issued in April 1975 after eight hydraulic snubbers on the main steam line inside the containment of the Three Mile Island Unit 1 facility could not achieve lockup. All holders of construction permits and/or operating licenses were requested

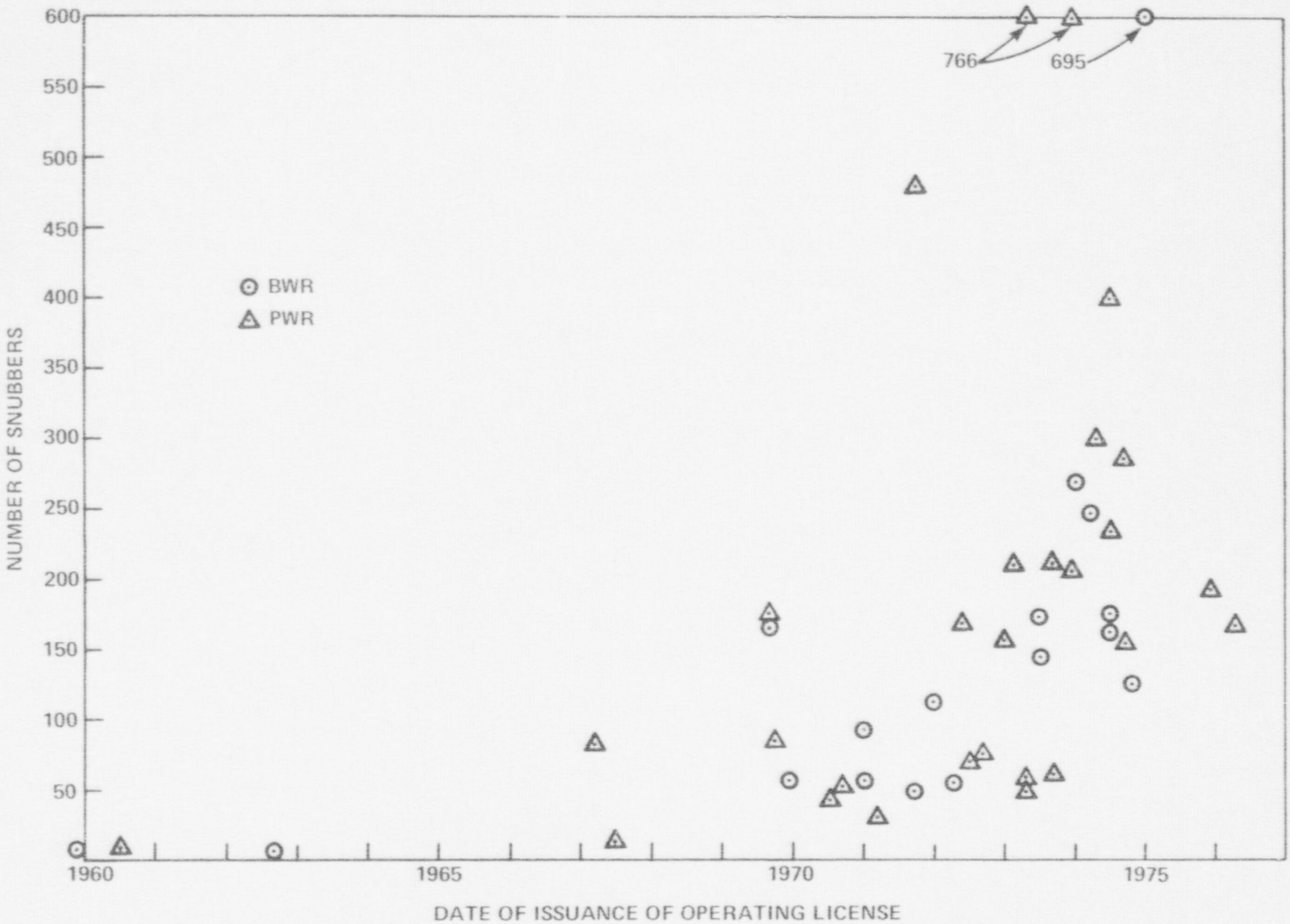


FIGURE 2.1 NUMBER OF SNUBBERS VS DATE OF O.L.

TABLE 2.1

SUMMARY OF NUMBER OF HYDRAULIC SNUBBERS IN SERVICE*

	REACTOR	OL	BERGEN-PATERSON	GRINNELL	OTHER
1.	DRESDEN 1 BWR	9/59		7	
2.	YANKEE ROWE PWR	12/63		8	
3.	HUMBOLDT BAY BWR	8/62			4
4.	SAN ONOFRE PWR	3/67		82	
5.	CONN. YANKEE PWR	12/74		8	4
6.	OYSTER CREEK BWR	4/69	149	25	
7.	NINE MILE PT. BWR	12/74	22	145	
8.	GINNA PWR	9/69	26	45	16
9.	DRESDEN 2 BWR	12/69	47	11	
10.	ROBINSON 2 PWR	9/70	3	17	22
11.	POINT BEACH 1 PWR	10/70		36	20
12.	QUAD CITIES 1 BWR	10/71	29	14	4
13.	MONTICELLO BWR	9/70	92		
14.	DRESDEN 3 BWR	1/71	47	11	
15.	PALISADES PWR	3/71	14	16	
16.	INDIAN POINT 2 PWR	10/71	456	24	
17.	QUAD CITIES 2 BWR	3/72	29	16	10
18.	SURRY 1 PWR	5/72	18	142	10
19.	PILGRIM 1 BWR	6/72	113		
20.	TURKEY POINT 3 PWR	7/72	70		
21.	MAINE YANKEE PWR	9/72		75	
22.	SURRY 2 PWR	1/73	18	136	10
23.	OCONEE 1 PWR	2/73		210	
24.	POINT BEACH 2 PWR	11/71		36	20
25.	TURKEY POINT 4 PWR	3/73	49		16
26.	BROWNS FERRY 1 BWR	6/73	146		
27.	OCONEE 2 PWR	10/73		211	
28.	ZION 1 PWR	4/73	16	750	
29.	ZION 2 PWR	11/73	16	750	
30.	PRAIRIE ISLAND 1 PWR	8/73			61
31.	KEWAUNEE PWR	12/73		200	8
32.	COOPER BWR	1/74	18	251	
33.	DUANE ARNOLD BWR	2/74	201		46
34.	THREE MILE ISLAND PWR	4/74		300	
35.	BROWNS FERRY 2 BWR	6/74	161		
36.	CALVERT CLIFFS 1 PWR	7/74		400	
37.	OCONEE 3 PWR	7/74		236	
38.	HATCH BWR	8/74	256	28	
39.	RANCHO SECO PWR	8/74	127	28	
40.	FITZPATRICK BWR	10/74	199	28	
41.	PRAIRIE ISLAND 2 PWR	10/74			61
42.	BRUNSWICK 2 BWR	12/74	695		
43.	TROJAN PWR	11/75	193		
44.	ST. LUCIE PWR	3/76	147	20	
45.	BROWNS FERRY 3 BWR	7/76	149		
46.	PEACH BOTTOM 2 BWR	8/73		162	8
47.	PEACH BOTTOM 3 BWR	7/74		162	8

*NOTE: This data was taken in a survey of licensees in May 1976. Plants not represented provided no response.

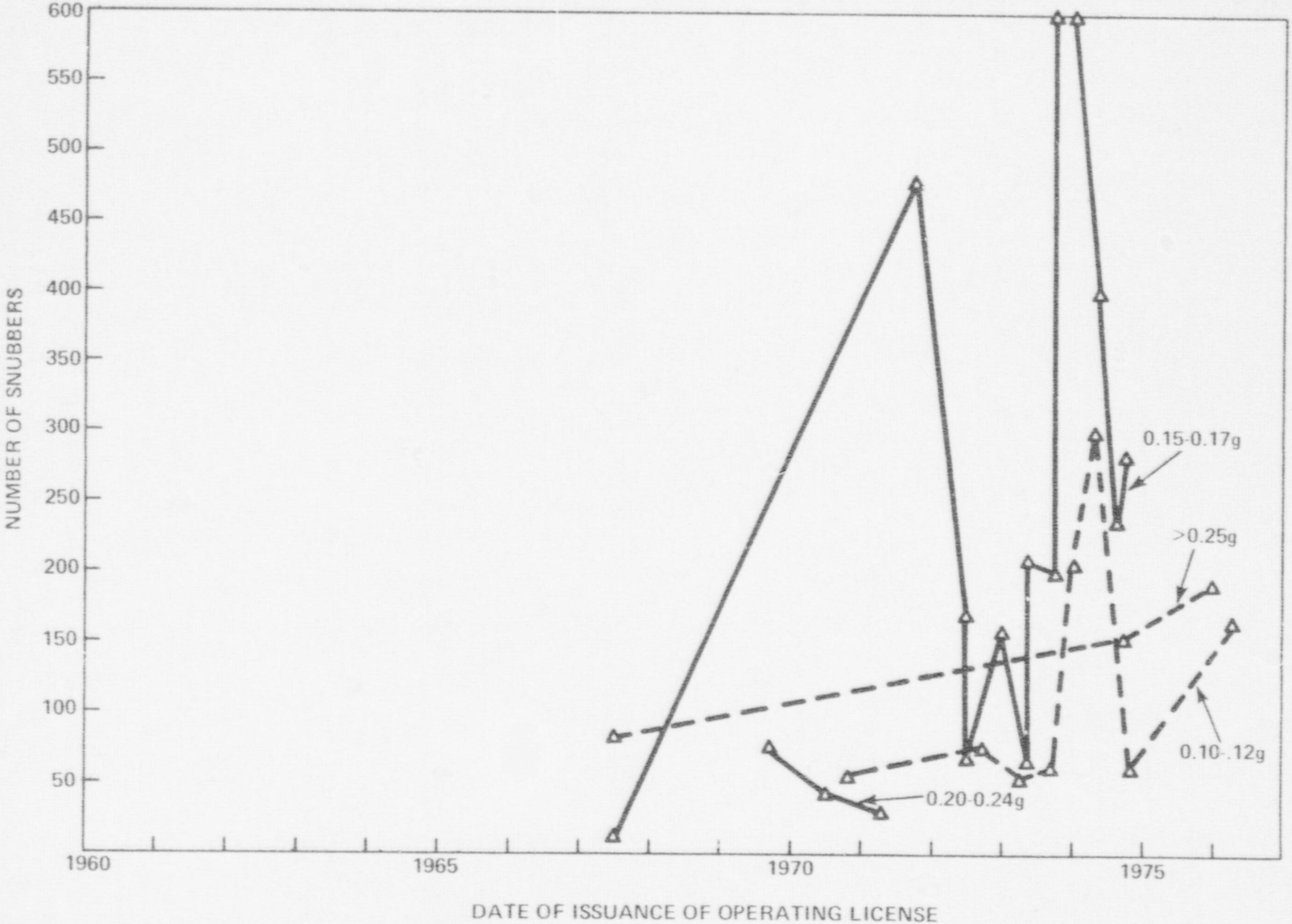


FIGURE 2.2 NUMBER OF SNUBBERS VS DATE OF O.L. FOR VARYING SSE 'g' LEVELS PWR's

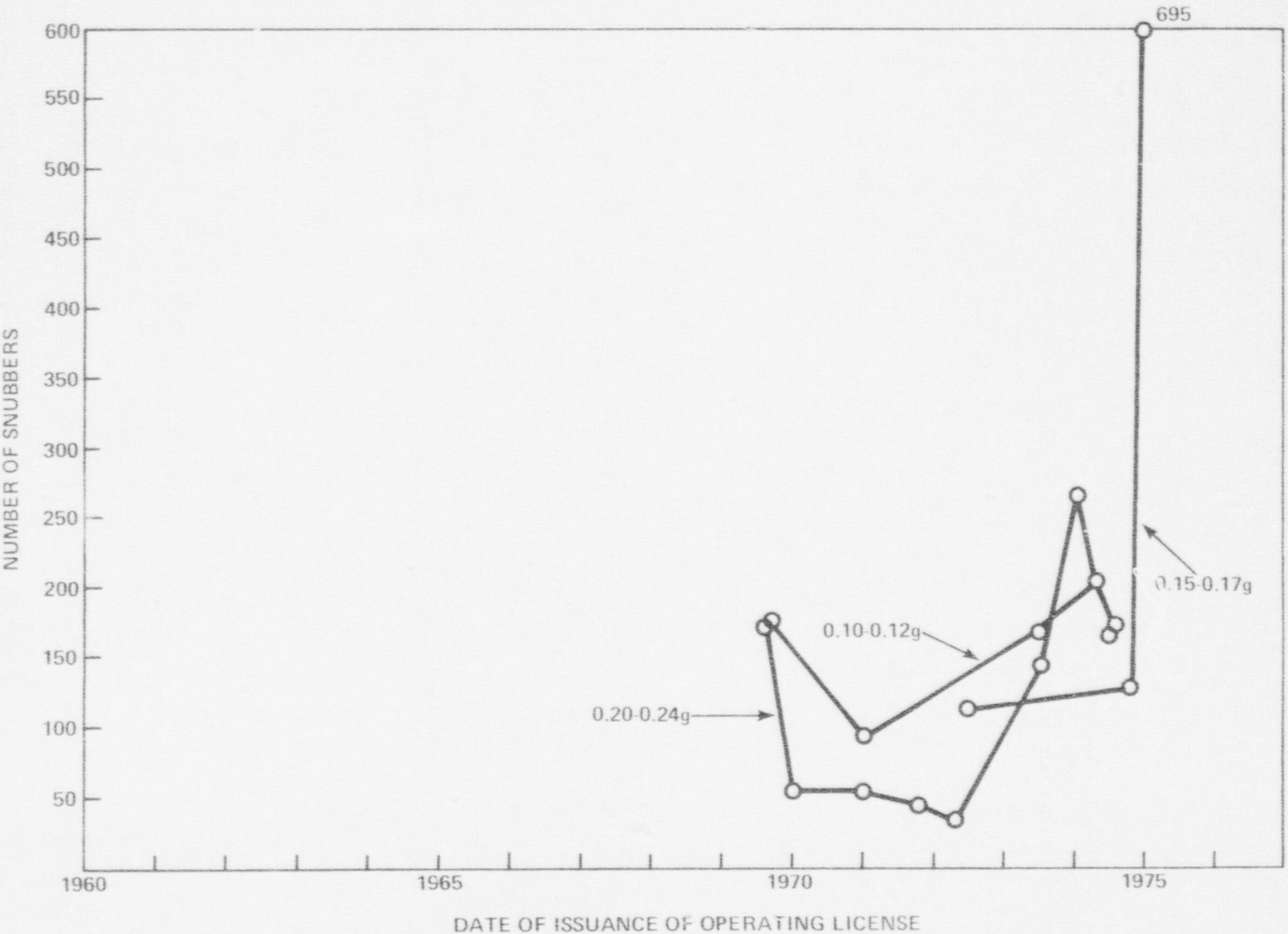


FIGURE 2.3 NUMBER OF SNUBBERS VS DATE OF O.L. FOR VARYING SSE 'g' LEVELS BWR's

to provide the original design requirements and inservice surveillance programs for snubbers installed in their plants. Based upon the responses to I&E 75-05, it was concluded that the lockup problem was caused by using the wrong hydraulic fluid and by contaminants in the fluid.

Inspection and Enforcement Circular No. 76-05 was issued in October 1976 to alert purchasers of certain Grinnell hydraulic snubbers that many were out of calibration when shipped from the Grinnell factory. The circular also alerted users that the proper lockup and bleed rate settings on snubbers with adjustable orifices might not be maintained if the seal material was changed in the field without a subsequent recalibration of the valve blocks on test equipment. Each affected utility was asked to provide information on any such snubbers.

Standardized snubber technical specifications evolved as a direct result of this operating experience and represent the only current NRC requirements and guidance concerning the use of snubbers. The model technical specifications were issued to licensees in December 1975 and at present all but three licensees have snubber technical specifications, most closely resembling the model technical specifications (see Appendix B).

2.3 Functional Requirements

Mechanical and hydraulic snubbers are primarily utilized as seismic restraints for piping and equipment. They are used in a limited manner as shock and vibration attenuators for safety relief valve thrusts, pipe whip, and water hammer induced thrusts. Snubbers are designed to allow free movement of the piping system or component when subjected to a non-dynamic application of load such as that imposed by thermal expansion during normal operation. When subjected to an impulsive dynamic load as may be expected during a seismic event, the snubber locks and controls motion of the system to which it is attached. The snubber is expected to lock when subjected to a specified minimum excitation. During normal operation the snubber should not inhibit free movement of the system above a specified minimum force. A summary of the operating characteristics of both hydraulic and mechanical snubbers is presented in Appendix A to this report.

Technical specifications require that hydraulic snubbers be functionally tested once each refueling cycle ($\sim$ 18 months) to verify the specified values of lockup velocity[1] and bleed rate.[2] Piston movement through full stroke

[1]Lockup Velocity - Threshold velocity of snubber piston needed to convert snubber from a nonload carrying device to a load carrying uniaxial strut.

[2]Bleed Rate - Velocity of snubber piston after the snubber has locked up; the bleed rate is proportional to the applied load.

is also verified to demonstrate unrestrained movement during normal thermal expansion. At the present time, there are no functional testing requirements for mechanical snubbers.

2.4 The Design Methodology

The piping design is one of the most iterative design problems in the plant. A fully optimized design requires a balance of flexibility for thermal considerations and stiffness for the restraint of dynamic loadings such as seismic induced motion. Limitations of available support locations place difficult constraints on the design, and the piping design and building design often proceed in parallel. As a consequence, available options for support locations are not fully known in advance.

Where possible, rigid supports are used. However, if resultant thermal expansion stresses are too high based upon a thermal flexibility analysis, a snubber is specified. Often times it has been the practice to specify snubbers rather than rigid seismic supports to preclude the need to redo thermal flexibility analyses. This approach is more expedient and often economically more viable. It is also more conservative assuming the snubber functions properly. Procedures such as these yielded adequate support under dynamic loadings and lower stress during normal operation. However, subsequent reliability questions about snubbers have created problems and an increased surveillance burden.

The changing seismic design methodology and efforts to provide added conservatism have also led to the use of more snubbers. It has often been the practice to design the seismic support system such that the piping natural frequency is placed in the rigid range of the floor response spectra, thus requiring more snubbers.

A penalty is paid for specifying unnecessary snubbers. Although the consequences of using snubbers are insignificant for normal operation, there is a basic inconsistency in such a practice for system response to an earthquake. Under such dynamic loadings the snubbers lock-up and stiffen the piping system. By increasing the stiffness, the relative displacement loads, resulting from differential support movements, rise. A balance must be developed in the design to control both the inertial loads and relative displacement loads. Adding more snubbers, while helping inertial loads, hurts the relative displacement loads.

Analytically, the snubber has been modeled as a rigid strut, flexible spring or gapped spring. The stiffness or spring rate of the hydraulic snubber varies in the compression and tension modes, while it is constant for mechanical snubbers. Additionally, the stiffness is a function of piston position, or fluid column length. Some designers have used equivalent stiffness representations to account for these variables and any lost motion in the component due to slop or lag until lockup. An equivalent spring rate representation has also been suggested to account for the viscous and hysteretic damping characteristics of the snubber.

In general, the snubber lockup and bleed characteristics should be consistent with the compatibility requirements of the system. The snubber should not lock up dynamically due to thermal expansion of the system. Therefore, the lockup velocity or acceleration should be greater than the highest thermal expansion velocity or acceleration. This objective has not been consistently attained in existing plant designs.

Hydraulic snubbers continue to displace at the bleed velocity following a lockup, the bleed velocity being a function of the magnitude of the applied load. The bleed provides a source of energy dissipation, which has not been analytically accounted for in the past and therefore represents a conservatism in the design. However, the bleed parameter controls to a large extent the total displacement seen by the system during the dynamic event. High bleed rates imply large displacements. These displacements may have an unanticipated impact in terms of high stress at various discontinuities such as support points or nozzles. The consequences of parametric changes in the bleed rate have only recently been evaluated.

In a limited number of applications such as safety relief valves, a snubber will dynamically lock up during blowdown and then be subjected to a thermal transient. The bleed can accommodate this thermal expansion if the piping displacement occurs concurrently with high dynamic load. However, this is difficult to predict and therefore the system usually must be designed to carry both the thermal and dynamic stress together.

In summary, the analytical treatment of snubbers throughout the industry has been inconsistent. There is an important need to parametrically evaluate the effects of varied snubber properties on the systems to which they are attached. A study is also required to provide a basis for a definition of functional operability.

2.5 Performance and Reliability

The reliability of snubbers has been less than expected and consequently, surveillance requirements have been imposed upon nuclear power plant licensees to assure operability of all safety-related snubbers. While increasing operational experience has helped eliminate many of the problem areas, it would still appear that increased use of snubbers could result in less reliable systems at this time.

A "frozen" snubber represents the highest potential for system degradation. The frozen snubber is one which inhibits the normal free expansion of the system during thermal loading. It will frequently cause an overstressed condition, because many times snubbers are specified because the system cannot take the stress associated with the use of a rigid restraint.

The second most serious operational problem for snubbers is fluid leakage that uncovers the hydraulic fluid reservoir in a hydraulic snubber. A snubber void of fluid will not satisfy the specified design requirements, although a partially voided snubber may provide some reaction during the dynamic event.

Another important issue is the effect of various combinations of adjacent snubber failures or partial failures on system performance during normal and faulted conditions. Such an evaluation has not been completed to date.

III SUMMARY OF NOTABLE OPERATIONAL EXPERIENCES

3.1 Calvert Cliffs Units 1 and 2

Summary of Types of Snubbers and Function

All snubbers at Calvert Cliffs were manufactured by Grinnell and most were delivered between mid-1969 and early 1972. Only a few were manufactured using the present Grinnell specification. Approximately half of the cylinders were manufactured by Lynair and half by Miller. The remaining few were manufactured by Tomkin - Johnson. The snubbers are equiped with both adjustable and preset valve blocks.

The snubbers were designed to attenuate the seismically induced motion of the system to which they are attached. A few snubbers were used to arrest motion caused by relief valve thrusts.

Design Specification Summary

No design requirements were specified for lockup and bleed rate by the original purchase specification; the manufacturer's standard settings were considered satisfactory for Calvert Cliffs.

The licensee, Baltimore Gas and Electric (BG&E), subsequently established lockup and bleed rates for each snubber in Units 1 and 2. Acceptable lockup rates for each snubber are between 6 and 23.5 inches/minute. The acceptance criterion for bleed rate is based upon the maximum thermal movement of the component to which the snubber is attached and varies from snubber to snubber. The minimum bleed rate is established to be just greater than the maximum thermal expansion, while the maximum bleed rate must be less than 23.5 inches/minute. The above criteria are based upon studies conducted by Bechtel, the architect-engineer, in 1976.

Notable Operational Experience

On November 4, 1976, BG&E reported that eight out of a sample ten hydraulic snubbers at Unit No. 2 failed to meet the manufacturer's stated specifications of lockup velocity and bleed rate. BG&E uncovered this deficiency during the initial surveillance testing conducted prior to entering Mode 4 of the reactor's initial criticality. Immediately, a functional testing program of 35 additional snubbers was instituted paralleled with a Grinnell factory recalibration of all 297 snubbers existing at Unit No. 2. Subsequent findings from the additional 35 snubbers indicated approximately the same incidence of failure (see Table 3.1).

BG&E postulated that a field modification to ethylene-propylene (E-P) seals without a subsequent recalibration caused the high "out of spec" rate. The licensee had previously conducted the seal modification as a result of I&E Bulletins 73-3 and 73-4 that alerted the industry to the possible deterioration of seal materials and the loss of hydraulic fluid. The modification included replacing the thread seals of the poppet valves

TABLE 3.1

SURVEILLANCE HISTORY
UNIT 1

SNUBBER ID #	SIZE BORE x STROKE	CYLINDER MODEL	TEST RESULTS ** LOCKUP T	LOCKUP C	BLEED T	BLEED C	MFG. SPECS LOCKUP	MFG. SPECS BLEED	BG&E CRITERIA LOCKUP	BG&E CRITERIA BLEED	MODIFICATIONS*	PROBABLE CAUSE OF FAILURE
1-12-4	1 1/2 x 5	Miller	22.7	15.5	0.1	0.1	10	0.125	6-23.5	>2	None	Note 1
1-63-10			21.4	19.0	0.1	0.1	10	0.125		>5/16	None	Note 1
1-71-2			9.1	12.6	0.1	0.1	10	0.125		>1/4	None	Note 1
1-71-2A			17.5	14.0	0.1	0.1	10	0.125		>1 1/4	None	Note 1
1-71-3			14.8	12.7	0.1	0.1	10	0.125		>1	None	Note 1
1-83-40A			13.5	15.5	0.2	0.1	10	0.125		>1/8	None	N/A
1-11-16	1 1/2 x 6	Lynair	6.3	4.9	0.1	0.1	10	0.125	6-23.5	>2	None	Bleed - Note 1 Lockup - Note 2
1-11-19			8.6	7.1	0.2	0.1	10	0.125		>2	None	Note 1
1-36-1A			30+	30+	24.5	29.0	10	0.125		>2	None	Loose fittings
1-26-3			30+	30+	30+	24.5	10	0.125		>2	None	Loose fittings Dry O-ring
1-52-74			30+	30+	30+	24.5	10	0.125		>1	None	Loose fittings
1-60-12			30+	30+	29.3	24.0	10	0.125		>1/8	None	Loose fittings
1-15-6A	2 1/2 x 5	Miller	16.1	18.2	0.1	0.1	10	0.125	6-23.5	>2	Thread Seals	Note 1
1-15-11			9.1	14.9	0.2	0.1	10	0.125		>2	None	Note 1
1-41-5			20.9	18.3	0.1	0.1	10	0.125		>2	None	Note 1
1-52-12			22.9	21.1	0.4	0.2	10	0.125		>1/4	Thread Seals	N/A
1-52-24			11.0	9.7	0.2	0.2	10	0.125		>1/2	None	Note 1
1-60-22			6.4	7.3	0.1	0.2	10	0.125		>1	Thread Seals	Note 1
1-64-13			30+	27.1	30+	24.5	10	0.125		>1/4	None	Loose fittings
1-64-23			11.1	14.0	0.2	0.2	10	0.125		>1/4	Thread Seals	N/A
1-83-75			11.1	7.8	0.1	0.2	10	0.125		>1/16	None	N/A
1-11-2	2 1/2 x 5	Lynair	30+	24.4	30+	24.4	10	0.125	6-23.5	>2	None	Loose reservoir
1-52-23			5.9	5.2	0.2	0.1	10	0.125		>1/4	None	Bleed - Note 1 Lockup - Note 2

Table 3.1 (Continued)
SURVEILLANCE HISTORY
UNIT 1

SNUBBER ID #	SIZE BORE x STROKE	CYLINDER MPDE1	TEST RESULTS ** Lockup T	Lockup C	BLEED T	BLEED C	MFG. SPECS LOCKUP	MFG. SPECS BLEED	BG&E CRITERIA LOCKUP	BG&E CRITERIA BLEED	MODIFICATIONS*	PROBABLE CAUSE OF FAILURE
1-52-23			11.7	11.1	0.1	0.1	10	0.125		>3/4	Thread Seals	Note 1
1-52-45			11.9	10.7	11.0	0.5	10	0.125		>3/8	Thread Seals	N/A
1-54-2			6.8	6.6	0.1	0.1	10	0.125		>3/4	Thread Seals	Note 1
1-54-14			11.3	30+	0.2	0.3	10	0.125		>2	None	Loose fitting Dry-rotted O-ring
1-60-13			8.7	6.0	0.2	0.1	10	0.125		>1 7/8	None	Note 1
1-61-7			7.5	7.7	0.2	0.2	10	0.125		>1 3/4	Thread Seals	Note 1
1-83-33			11.1	11.3	0.1	0.1	10	0.125		>1/3	None	N/A
1-52-75	3 1/4 x 5	Miller	9.7	9.6	0.1	0.1	5	0.125	6-23.5	>1	Thread Seals	Note 1
1-83-6	5 x 5	Tomkin - Johnson	7.5	9.4	0.1	0.1	3	0.125	6-23.5	>1/16	None	N/A
1-83-67	6 x 5	Tomkin - Johnson	7.2	7.1	0.1	0.1	2	0.125	6-23.5	>1/2	Thread Seals	Note 1

* - Field modifications conducted to change seals beneath adjusting screws on some snubbers.

** - T indicates movement in tension, C indicates movement in compression.

NOTE 1: Initial bleed settings not satisfactory per new BG&E criteria.

NOTE 2: These snubbers may still be considered as operable as long as the lockup is greater than the thermal growth rate. These low settings cannot be attributed to any obvious flaw.

and bleed orifice set screws. The proper settings of these screws were altered when the new seal material was installed. The reworked snubbers should have been recalibrated to spec following the seal modification.

During the scheduled January 1977 refueling outage at Unit No. 1, BG&E conducted an augmented functional testing program as a result of the experience at Unit No. 2. Thirty-three snubbers were tested for "as found" data (see Table 3.2). Additionally, all of the snubbers (352) in the plant were either monitored or te-ted to verify that they would not inhibit free thermal expansion of the systems to which they are attached. Over 90% of the sample failed to meet the manufacturer's specification. Seal modifications had been performed on about a third of these snubbers. All of the snubbers sampled were purchased during the period from mid-1969 to early 1972. They all were of mid-vintage with old specifications (see Table 3.3, "A Chronology of Specifications for Grinnell Shock Suppressors for Nuclear Power Plants").

Conclusions, Recommendations and Future Course of Action

The Calvert Cliffs facilities contain several vintages of Grinnell snubbers, each with their own specification for lockup velocity and bleed rate. The specification and its associated tolerances were devised as manufacturing limits but have been used by the utility as acceptance criteria during the functional surveillance testing. The tight tolerances in the specifications led to high failure rates. The licensee therefore instituted an analytical program to arrive at a new set of acceptance criteria with larger tolerance levels based upon actual system design requirements. Each snubber in the plant now has its own specified values of lockup velocity and bleed rate.

The system unique type of analysis should have been completed during the original design of the plant to assure compatibility of the snubber and system. The specification should evolve from a detailed dynamic and thermal analysis of the system and should address the following:

1. Maximum frictional resistance under normal conditions.

2. Maximum sum of lost motion.

3. Snubber sti'fness in compression and tension modes.

4. Lockup velocity.

5. Bleed rate.

6. Overload protection.

TABLE 3.2

SURVEILLANCE HISTORY
UNIT 2

SNUBBER #	SIZE	CYLINDER MODEL	VALVE STYLE	TEST RESULTS LOCKUP T	TEST RESULTS LOCKUP C	TEST RESULTS BLEED T	TEST RESULTS BLEED C	MANFR. LOCKUP	SNUBBER BLEED	BG&E CRITERIA LOCKUP	BG&E CRITERIA BLEED	MODIFICATION	PROBABLE CAUSE OF FAILURE
2-15-3	2 1/2 x 5	LYNAIR	OLD	>33	>33	-	-	10	1/8	6-23.5	>0	Note 1	Thread seal mod. altered lockup settings
2-52-6	3 1/4 x 5	LYNAIR	OLD	9.2	8.7	.1	.2	5	1/8	6-23.5	>3/8	None	Initial bleed settings not satisfactory per new BG&E criteria
2-11-9	2 1/2 x 5	LYNAIR	OLD	11.2	14.8	32.9	27	10	1/8	6-23.5	>0	Note 1	Thread seal mod. altered settings
2-15-1	2 1/2 x 5	LYNAIR	OLD	INOPERABLE				10	1/8	6-23.5	>0	Note 1	Unknown
2-83-3	5 x 5	TOMPKIN-JOHNSON	OLD	0	.1	16	7.1	3	1/8	6-23.5	<1/16	Note 1	Thread seal mod.
2-83-1	5 x 5	THOMPKIN-JOHNSON	OLD	6.7	10.2	.1	.1	3	1/8	6-23.5	>1/16	Note 1	N/A
2-52-41	2 1/2 x 5	MILLER	NEW	7.7	7.6	2.1	1.4	8 ± 2	4 ± 2	6-23.5	>1/4	Note 2	N/A
2-83-2A	5 x 5	MILLER	NEW	6.4	7.3	2.4	1.8	8 ± 2	4 ± 2	6-23.5	>3/16	Notc 2	N/A
2-83-4A	5 x 5	MILLER	NEW	6.5	6.1	2.9	2.1	8 ± 2	4 ± 2	6-23.5	>1/8	Note 2	N/A
2-52-26	1 1/2 x 5	MILLER	NEW	6.1	4.7	2.6	3.1	8 ± 2	4 ± 2	6-23.5	>2 1/4	Note 2	Fitting leakage
2-64-11	1 1/2 x 5	MILLER	NEW	9.5	6.3	1.6	4.9	8 ± 2	4 ± 2	6-23.5	>1 1/2	Note 2	N/A
2-83-B3	1 1/2 x 5	MILLER	NEW	8.8	8.2	1.9	2.8	8 ± 2	4 ± 2	6-23.5	>3/16	Note 2	N/A
2-54-5	1 1/2 x 5	MILLER	NEW	8.2	7.1	2.4	2.4	8 ± 2	4 ± 2	6-23.5	>2	Note 2	N/A
2-52-30	1 1/2 x 5	MILLER	NEW	7.9	7.2	1.9	2.3	8 ± 2	4 ± 2	6-23.5	>1/32	Note 2	N/A

Table 3.2 (Continued)
SURVEILLANCE HISTORY
UNIT 2

SNUBBER #	SIZE	CYLINDER MODEL	VALVE STYLE	TEST RESULTS LOCKUP T	TEST RESULTS LOCKUP C	TEST RESULTS BLEED T	TEST RESULTS BLEED C	MANFR. LOCKUP	SNUBBER BLEED	BG&E CRITERIA LOCKUP	BG&E CRITERIA BLEED	MODIFICATION	PROBABLE CAUSE OF FAILURE
2-64-6	1 1/2 x 5	MILLER	NEW	6	6	2	1.1	8 ± 2	4 ± 2	6-23.5	>1	Note 2	N/A
2-64-5	1 1/2 x 5	MILLER	NEW	6.1	2.8	1.8	0	8 ± 2	4 ± 2	6-23.5	>2.5	Note 2	Unknown
2-83-2	5 x 5	MILLER	NEW	8.1	6.7	4.6	2.7	8 ± 2	4 ± 2	6-23.5	>3/16	Note 2	N/A
2-52-63	2 1/2 x 5	MILLER	OLD	23.8	>33	1.3	-	10	1/8	6-23.5	>7/8	Note 1	Thread seal mod. altered settings
2-12-4	2 1/2 x 5	MILLER	OLD	26.2	11	.2	.5	10	1/8	6-23.5	>0	Note 1	Thread seal mod. altered settings
2-52-4	2 1/2 x 5	MILLER	OLD	10.3	10.6	4.8	.3	10	1/8	6-23.5	>1/2	Note 1	Initial bleed settings not satisfactory per new BG&E criteria
2-64-34	2 1/2 x 5	MILLER	NEW	8.1	7.9	3.9	3.1	8 ± 2	4 + 1	6-23.5	>1	None	N/A
2-52-43	2 1/2 x 5	MILLER	OLD	INOPERABLE				10	1/8	6-23.5	>1/4	Note 1	Unknown
2-12-2	2 1/2 x 5	MILLER	OLD	INOPERABLE				10	1/8	6-23.5	>0	None	Unknown
2-11-15	2 1/2 x 5	MILLER	OLD	INOPERABLE				10	1/8	6-23.5	>0	None	Unknown
2-12-1	2 1/2 x 5	MILLER	OLD	INOPERABLE				10	1/8	6-23.5	>0	Note 1	Unknown
2-64-38	2 1/2 x 5	MILLER	NEW	9.0	5.4	3.9	3.0	8 ± 2	4 + 1	6-23.5	>2 1/2	None	N/A
2-52-24	2 1/2 x 5	MILLER	OLD	INOPERABLE				10	1/8	6-23.5	>4 9/16	Note 1	Thread seal mod. altered settings
2-52-2	2 1/2 x 5	MILLER	OLD	INOPERABLE				10	1/8	6-23.5	>4 9/16	Note 1	Thread seal mod. altered settings

Table 3.2 (Continued)
SURVEILLANCE HISTORY
UNIT 2

SNUBBER #	SIZE	CYLINDER MODEL	VALVE STYLE	TEST RESULTS LOCKUP T	TEST RESULTS LOCKUP C	TEST RESULTS BLEED T	TEST RESULTS BLEED C	MANFR. LOCKUP	SNUBBER BLEED	BG&E CRITERIA LOCKUP	BG&E CRITERIA BLEED	MODIFICATION	PROBABLE CAUSE OF FAILURE
2-64-45	5 x 3 3/4	MILLER	OLD	7.9	7.9	0	0	3	1/8	6-23.5	1/8	Note 1	Thread seal mod. altered settings
2-64-2	2 1/2 x 5	MILLER	NEW	9.1	7.9	3.7	3.3	8 + 2	4 + 2	6-23.5	>1	None	N/A
2-11-4	2 1/2 x 5	MILLER	OLD	12.3	12.7	.1	.1	10	1/8	6-23.5	>0	None	N/A
2-52-8	2 1/2 x 5	MILLER	OLD	10.1	21.5	.1	.1	10	1/8	6-23.5	>3/8	Note 1	Initial bleed Setting not satisfactory per new BG&E criteria
2-11-5	2 1/2 x 5	MILLER	OLD	14.5	11.2	.2	.2	10	1/8	6-23.5	>0	None	N/A
2-83-28	1 1/2 x 5	MILLER	OLD	19.6	12.8	.2	1.6	10	1/8	6-23.5	>3/16	None	N/A
2-61-8	2 1/2 x 5	MILLER	OLD	14.2	12.3	.2	.2	10	1/8	6-23.5	>4	Note 1	Initial bleed setting not satisfactory per new BG&E criteria
2-61-6	2 1/2 x 5	MILLER	OLD	14.7	9.5	.2	.2	10	1/8	6-23.5	>3 7/16	Note 1	Initial bleed setting not satisfactory per new BG&E criteria
2-61-7	2 1/2 x 5	MILLER	OLD	7.0	13.1	13.1	.2	10	1/8	6-23.5	>1 7/8	Note 1	Initial bleed setting not satisfactory per new BG&E criteria
2-61-11	2 1/2 x 5	MILLER	OLD	12.0	11.9	.3	.2	10	1/8	6-23.5	>3 1/32	Note 1	Initial bleed setting not satisfactory per new BG&E criteria

Table 3.2 (Continued)
SURVEILLANCE HISTORY
UNIT 2

SNUBBER #	SIZE	CYLINDER MODEL	VALVE STYLE	TEST RESULTS LOCKUP T	TEST RESULTS LOCKUP C	TEST RESULTS BLEED T	TEST RESULTS BLEED C	MANFR. LOCKUP	SNUBBER BLEED	BG&E CRITERIA LOCKUP	BG&E CRITERIA BLEED	MODIFICATION	PROBABLE CAUSE OF FAILURE
2-61-21	2 1/2 x 5	MILLER	OLD	14.9	14.1	.2	7.8	10	1/8	6-23.5	>1 3/16	Note 1	Initial bleed setting not satisfactory per new BG&E criteria
2-61-12	2 1/2 x 5	MILLER	OLD	4.0	15.0	.3	1.8	10	1/8	6-23.5	>3 7/8	Note 1	Thread seal mod. altered settings
2-61-13	2 1/2 x 5	MILLER	OLD	11.1	10.0	.2	1.4	10	1/8	6-23.5	>4 3/8	Note 1	Initial bleed setting not satisfactory per new BG&E criteria
2-52-15	2 1/2 x 5	MILLER	OLD	4.8	3.0	.3	.3	10	1/8	6-23.5	>3/8	Note 1	Thread seal mod. altered settings and excessive air present
2-11-14	2 1/2 x 5	MILLER	OLD	12.7	8.3	.2	.2	10	1/8	6-23.5	>0	Note 1	N/A
2-61-4	1 1/2 x 5	MILLER	OLD	INOPERABLE				10	1/8	6-23.5	>1	Note 1	Thread seal mod. altered settings
2-52-52	1 1/2 x 5	MILLER	NEW	6.7	9.2	2.2	3.7	8 ± 2	4 ± 2	6-23.5	>2 1/4	Note 2	Modified settings not satisfactory per new BG&E criteria

NOTE 1 - Field modification conducted to change seals beneath adjusting screw lock nuts.

NOTE 2 - Field modification conducted on series "B" valves. Precalibrated velocity barrels and bleed pins were installed.

TABLE 3.3

A CHRONOLOGY OF SPECIFICATIONS FOR GRINNELL SHOCK SUPPRESSORS FOR NUCLEAR POWER PLANTS*

Cyl. Bore Inches	Normal Max. Oper. Load Pounds	Locking Velocity In/Min
THRU MID 1969		
2-1/2	11,000	30
3-1/2	21,000	15
4	35,000	12
5	50,000	9
6	72,000	6
8	130,000	3
10	200,000	1.5
MID 1969 - EARLY 1972		
1-1/2	2,190	10
2-1/2	11,000	10
3-1/4	21,000	5
4	35,000	4
5	50,000	3
6	72,000	2
8	130,000	1
10	200,000	0.5
EARLY 1972 - PRESENT		
1-1/2	4,500	8
2-1/2	12,500	8
3-1/4	21,000	8
4	32,000	8
5	50,000	8
6	72,000	5
8	128,000	3
10	200,000	3

*Bleed rate is currently 4 inches/minute. Prior to November 1974, the bleed rate was 0.125 inches/minute.

7. Piston setting (hot and cold)

8. Material requirements

BG&E is currently reevaluating each snubber installation in both units to delete those which are unnecessary. It is felt that many of the original snubbers were added without a detailed justification for their use. The many units pose a great surveillance burden to the utility. A systematic plan is in progress to reduce this burden.

3.2 Edwin I. Hatch Unit No. 1
Summary of Types of Snubbers

There are a total of 270 snubbers at Hatch, all of which are hydraulic. The original plant design incorporated 256 Bergen-Paterson snubbers and 28 Grinnell snubbers. Fourteen units were subsequently removed following the removal of a piping run that was no longer needed. The sizes range from a 1-1/2" to 10" diameter bore.

Design Specification Summary

The selection and specification criteria were established by Southern Services, the architect-engineer. Each unit was specified for size and stroke based upon the standard available unit having the necessary load and movement capabilities. No specifications were explicitly made regarding the required limits for lockup velocity and bleed rate. The units as supplied were designed for a lockup velocity of 10 $\pm$2 inches per minute and a bleed rate of 4 to 6 inches per minute.

Notable Operational Experience

During the first inspection and functional testing of the snubbers, as required by the technical specifications that were implemented in October 1976, a failure rate of greater than 20% was observed. The high failure rate required the licensee, Georgia Power Company (GPC), to functionally test 100% of the snubbers in the plant. Additionally, GPC was required to implement a 31-day visual inspection interval.

A total of 54 snubbers failed either the visual or functional surveillance criteria. The data indicate that 30 snubbers failed the functional test and at least 30 snubbers failed the visual examination for low oil level. All of the inaccessible Bergen-Paterson snubbers (those in the drywell) had been reassembled by the manufacturer to install E-P seals prior to initial startup and had been periodically inspected as a part of drywell closeup operations. The accessible snubbers never had any modification or surveillance of any kind. These data are summarized in Table 3.4 and cover approximately 32 months of operation.

TABLE 3.4

HYDRAULIC SNUBBER INSPECTION AND TEST DATA
E. I. HATCH UNIT NO. 1

SNUBBER NO.	SIZE	INDICATION OF FAILURE	SPECIFIC FAILURE IF NOTABLE	ACCESSIBILITY
RHRH 237	3	Excess Bleed Ten/Insufficient Bleed Comp.		A
RHRH 286B	3	Excess Bleed Tension		A
RHRH 192	3	Excess Bleed Tension		A
RHRH 207	3	Excess Bleed Tension	Accumulator Hole Mislocated Piston and Cylinder Scored	A
RHRH 202	3	Excessive Bleed Tension		A
RCSEH 2	10	Low Oil	Bad O-Ring	A
SS 41	10	No Lockup Tension	Mislocated Relief Ball	I
FDH 14	10	Low Oil	Trash in Oil	I
MVVH 35	10	Low Oil		I
FDH 19	10	Low Oil		I
FDH 25	10	Low Oil	Trash Under Poppet	I
RHRH 217	10	Low Oil		A
RHRH 212	10	Low Oil/Insufficient Bleed Compression	Decomposed O-Ring	A
HPSEH 8A	10	Low Oil		A
HPSEH 2	10	Low Oil		A
HPSEH 12	10	Low Oil	Cylinder Scored	A
RHRH 323A	10	No Lockup Comp.	Broken Poppet Spring/Chip in Accumulator Wall/Scored Piston Rod	A
RHRH 325	10	Low Oil		A
RHRH 189	10	Excessive Bleed Tension	Cylinder Scored	A
RHRH 187B	10	Low Oil		A
HPSEH 13A	10	Low Oil		A
RCSEH 23A	10	Low Oil		A
HPSEH 13B	10	Low Oil		A

TABLE 3.4 (Continued)

HYDRAULIC SNUBBER INSPECTION AND TEST DATA
E. I. HATCH UNIT NO. 1

SNUBBER NO.	SIZE	INDICATION OF FAILURE	SPECIFIC FAILURE IF NOTABLE	ACCESSIBILITY
RHRH 282	10	Insufficient Bleed Comp.	Rusted Accumulator Spring/ Pitted Accumulator Tube	A
RHRH 242	10	Insufficient Bleed Comp.		A
RHRH 250A	10	Low Oil		A
RHRH 279B	10	Low Oil		A
HPCIH 9	20	Low Oil	Cylinder Scratched	A
RHRH 214	20	Low Oil		A
SS 23	30	No Lockup	Relief Ball Missing	I
RHRH 310	3	Excessive Bleed Tension	Trash Under Poppet	A
RHRH 213	3	Insufficient Bleed Comp.		A
SS 19	3	Excessive Bleed Tension		I
SS 44	3	Excessive Bleed Tension		I
SS 46	3	Low Oil	Relief Valve Mislocated	I
RHRH 199	3	No Lockup Tension	Position Ring Chipped/ Cylinder Scored	A
RHRH 193	3	No Lockup Tension	Relief Ball Misplaced	A
RHRH 210A	3	No Lockup Tension	Accumulator Relief Hole Mislocated	A
RHRH 218	3	Low Oil	Accumulator Relief Hole Mislocated/Compression Poppet Scored/Bad O-Ring	A
RHRH 286A	3	Low Oil/Excessive Bleed in Comp.		A
RHRH 225	3	No Lockup Tension	Relief Ball Missing	A
RHRH 348A	3	Low Fluid - Excessive Bleed Tension		A
RHRH 231A	3	Escessive Bleed Tension	Accumulator Relief Hole Mislocated	A
RHRH 231B	3	Low Oil		A

TABLE 3.4 (Continued)

HYDRAULIC SNUBBER INSPECTION AND TEST DATA
E. I. HATCH UNIT NO. 1

SNUBBER NO.	SIZE	INDICATION OF FAILURE	SPECIFIC FAILURE IF NOTABLE	ACCESSIBILITY
RHRH 348B	3	Low Oil - Excessive Bleed Tension	Accumulator Relief Hole Mislocated	A
RHRH 186A	3	Low Oil	Accumulator Relief Hole Mislocated	A
RHRH 322A	3	Low Oil - Excessive Bleed Tension	Accumulator Relief Hole Mislocated/Poppet Scored by Spring	A
RHRH 322B	3	Low Oil - Excessive Bleed Tension		A
RHRH 240A	3	No Bleed Tension or Comp.		A
RHRH 332	3	Low Oil		A
RHRH 186B	3	Excessive Bleed Tension	Accumulator Hole Mislocated	A
RHRH 240B	3	Low Oil	Accumulator Hole Mislocated/ Accumulator Spring Broken/ Cylinder Scored	A
RHRH 238A	3	Insufficient Bleed Comp.		A
RHRH 238B	3	Insufficient Bleed Comp.		A

Figures 3.5, 3.6 and 3.7 show the failure rates by rated load capacity for all snubbers, inaccessible and accessible. A correlation between failure rate and snubber size is demonstrated in Figure 3.5. It should be noted that the sample size for the larger snubbers was small.

The failure rate for the accessible snubbers and inaccessible snubbers was greater than 30% and less than 9%, respectively. Only 5% of the inaccessible snubbers failed due to hydraulic fluid leakage. The improved performance can possibly be explained by the seal modification program conducted prior to initial unit startup. In addition, any problems associated with poor QC in manufacture would have been corrected at that time.

It is also of interest that 28 Grinnell snubbers have been installed in the drywell with polyurethane seals for approximately 32 months and have performed without any leakage. The temperature within the drywell can be as high as 165 degrees Fahrenheit with the radiation flux as high as 100 rads per hour.

Conclusions, Recommendations and Future Course of Action

The inaccessible snubbers, which were subjected to the more "hostile" drywell environment, seem to have performed more reliably than the accessible snubbers. This unpredictable performance can be attributed to the seal modification program conducted prior to initial startup. In effect, the accessible snubbers acted as a control and would indicate that the seal change provided a significant improvement in performance.

3.3 Indian Point No. 2

Summary of Types of Snubbers

There are approximately 400 hydraulic snubbers located inside containment. All units under 50 kips are Bergen-Paterson. There are also several 250-500 kip snubbers in service manufactured by Grinnell.

Design Specification Summary

The snubbers were purchased under the Bergen-Paterson standard shelf specifications (lockup velocity = 10+2 in./min., bleed rate = 4-6 in./min.). The design criteria as specified by United Engineers, the architect-engineer, were based upon keeping system frequencies in the rigid range. If by judgment there was thought to be a thermal problem, a snubber was used rather than a rigid restraint.

Notable Operational Experience

In March 1977, the licensee, Consolidated Edison Co. (Con Ed), requested a license amendment to permit the deletion of 31 hydraulic snubbers from various piping systems in the plant. The purpose of the amendment was to improve the reliability of the systems. Con Ed felt that the hydraulic

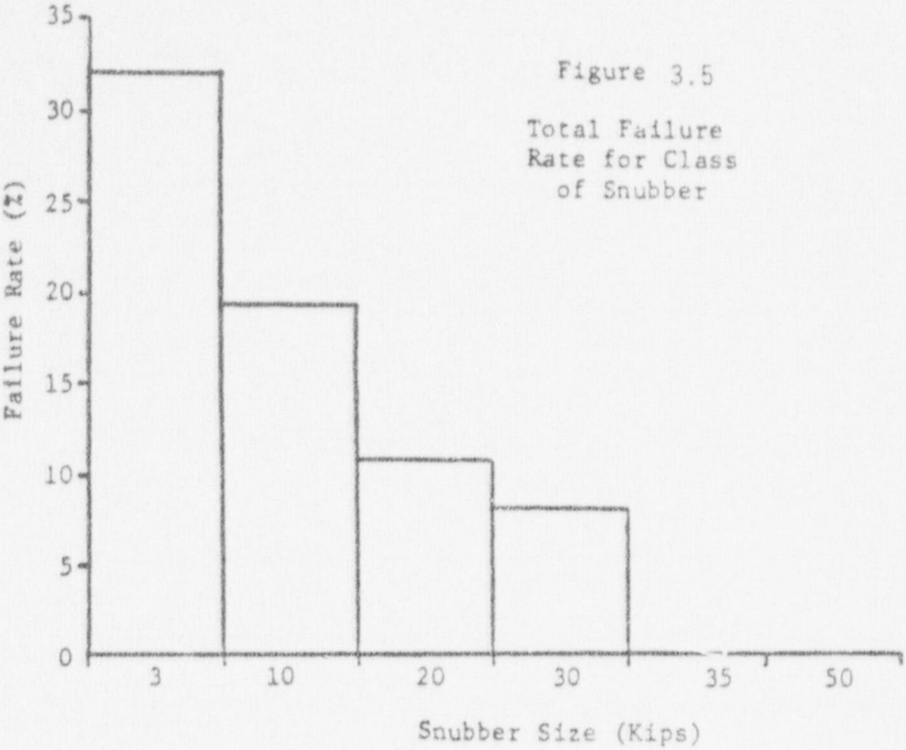


Figure 3.5
Total Failure Rate for Class of Snubber
Failure Rate (%)
35
30
25
20
15
10
5
0
3
10
20
30
35
50
Snubber Size (Kips)

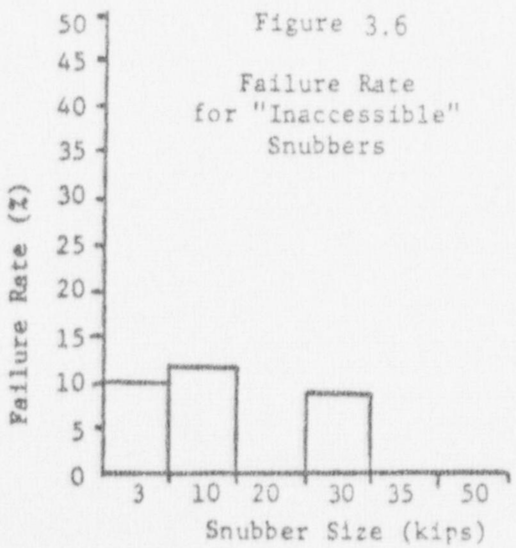


Figure 3.6
Failure Rate for "Inaccessible" Snubbers
Failure Rate (%)
50
45
40
35
30
25
20
15
10
5
0
3
10
20
30
35
50
Snubber Size (kips)

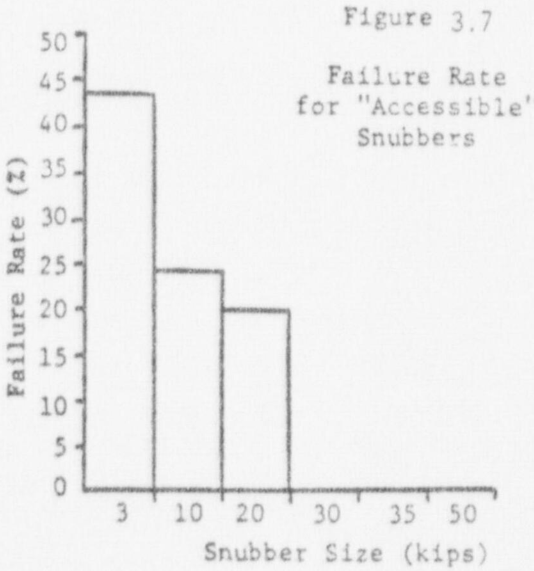


Figure 3.7
Failure Rate for "Accessible" Snubbers
Failure Rate (%)
50
45
40
35
30
25
20
15
10
5
0
3
10
20
30
35
50
Snubber Size (kips)

snubbers imposed a severe surveillance burden on plant personnel and that a system with snubbers is inherently less reliable than one with rigid restraints or none at all.

In the original design of the plant, snubbers were used more extensively than would be dictated by a rigorous design methodology. While Indian Point Units 2 and 3 are geometrically similar, Unit No. 2 has 400 snubbers while Unit No. 3 has 150.

The redesign of the support system at Unit No. 2 was based upon the Unit No. 3 analysis. The similarity of the geometry and operating conditions of the lines were studied to validate the analysis.

Conclusions, Recommendations and Future Course of Action

We concur with Con Ed's decision to systematically eliminate as many snubbers as possible from Unit 2. An arbitrary design in the rigid range is costly and may not be prudent since the necessary snubbers could cause high relative displacement loads during a seismic event.

In the design of piping systems, "judgment" is not an appropriate basis to determine whether a snubber or rigid restraint should be employed. This determination should be made using the guidance of a detailed thermal analysis. If a snubber is selected, the thermal analysis should again be consulted to verify that the snubber lockup and bleed settings are appropriate and unanticipated restraint to thermal motion is not imposed.

3.4 Zion Units 1 and 2

Summary of Types of Snubbers

Each unit has a total of 766 hydraulic snubbers, of which 750 are Grinnell and 16 are Bergen-Paterson snubbers. Originally, 500 snubbers were classified as "safety-related." Subsequently, this number was revised to about 325.

Design Specification Summary

All snubbers were purchased under the standard manufacturer specifications. Information regarding the design methodology is not available.

Notable Operational Experience

The licensee, Commonwealth Edison Company (CECo), has experienced repeated leaking of the hydraulic snubbers (12) located in the pressurizer cubicle. This area experiences the highest temperatures inside containment. The top enclosure of the cubical has been removed to provide improved circulation; however, this remedy has not worked adequately. CECo plans to replace the pressurizer snubbers with mechanical snubbers during the next scheduled refueling outage. There is evidence that hydraulic fluid is leaking from around the adjustment screws under the valve block. It has not been determined whether or not any of the leakage is due to failed seals.

CECo has recently submitted a proposal for their initial snubber technical specifications. It was proposed that snubbers be classified into groups identifying the type of application and general environment. Snubbers within a group would be subject to inspection independently so that when a failure occurs in that group, subsequent inspections would concentrate on those snubbers with similar characteristics. CECo has proposed that only 5 snubbers be tested each refueling cycle as opposed to the requirement of 10 or 10%, whichever is less, as prescribed in the standard technical specifications (see Appendix A). Additionally, it has been proposed that the inaccessible snubbers be subject to a less frequent inspection interval as determined by the failure rate.

Conclusions, Recommendations and Future Course of Action

The Zion plants exceed the average number of snubbers used in other nuclear plants, and therefore impose a greater surveillance burden on CECo. A design reevaluation to reduce the number of snubbers would be a possible alternative to the request for less frequent surveillance testing.

3.5 Duane Arnold

Summary of Types of Snubbers and Function

There are 201 Bergen-Paterson hydraulic snubbers and 46 International Nuclear Safeguards (INS) mechanical snubbers at Duane Arnold.

Design Specification Summary

Not available.

Notable Operational Experience

On March 27, 1977, the licensee, Iowa Electric Light and Power Co. (IELP), reported that 13 INS mechanical snubbers had frozen on instrumentation lines at Duane Arnold. IELP had their architect-engineer, Bechtel, perform an analysis to determine if damage to the system may have resulted. Bechtel determined that 14 welds may have exceeded code allowables. The welds were subsequently examined by liquid penetrant testing to verify their integrity.

IELP performed an inspection of the internal mechanisms of the subject snubbers. Examination revealed large amounts of oxidation on the thrust bearings which had been fabricated from carbon steel. INS had previously recommended coating the bearing surfaces with Molt-Kote #321. There was no evidence, however, of any coating on the roller bearings, which had "frozen" in place and were responsible for the failure. Corrosion was also in evidence on the ball screw and adapter assembly. Additionally, brinelling was detected at the point of contact between the ball bearings and OD of the adapter. IELP replaced all of the INS snubbers with Pacific Scientific mechanical snubbers.

Conclusions, Recommendations and Future Course of Action

The frozen snubber represents a potential for system overstress. There were approximately 7,000 INS snubbers with carbon steel bearings manufactured. INS has informed their customers that these units are subject to this type of failure. Four utilities have reported 41 failures in this mode. However, since there is no requirement to inspect mechanical snubbers, licensees are unlikely to detect such problems in a systematic and timely manner. INS has since changed their design to all stainless steel.

IV. SUMMARY OF ABNORMALITIES

4.1 Introduction

Abnormal occurrences and unusual events that take place during the term of the operating license are filed by licensees in licensee event reports (LERs). A summary of these reports from 1969 to the present is given in Table 4.1. As will be noted, there are few entries prior to 1974. Before this time, the significance of various snubber-related problems was unclear. In general, there is also a wide variation in the completeness of these reports. The data are presented to serve only as a broad indication of the problem areas.

The total number of affected snubbers in each category does not provide an accurate indication of the actual magnitude of the problem. Intensive surveillance for each plant was initiated only as recently as the technical specification dates shown in Table 4.2. In many cases the licensee has chosen to rework large portions of the snubbers in the plant without collecting additional "as found" data. Therefore, the LER data base is probably only useful as an indication of the most prevalent problem areas and should not form the basis for a quantitative reliability assessment.

It should be emphasized that failures of snubbers to meet design performance specifications are not necessarily indicative of a total inability to perform the intended design function. Partially drained hydraulic snubbers can provide some restraint and if the reservior is not uncovered, full restraint would probably still be available.

4.2 Abnormality Analysis

A total of 292 entries for 50 plants were reported in LERs. Table 4.2 lists the number of LERs filed for each facility, the date of operating license issuance and the date of adoption of the snubber technical specifications. Of 64 operating plants, 14 have not reported any snubber-related abnormal occurrences. One facility has made 19 reports. The disparity is not necessarily an indication of the reliability of the snubbers at a particular plant. However, a general correlation can be made for the increased frequency of reports and the issuance of the technical specifications. Prior to the technical specifications, there were no mandatory surveillance requirements and, therefore, there was no systematic identification of snubber-related problems.

Table 4.1 is presented as a matrix of "year" by "type of problem." Entries are filed using the standard facility abbreviation followed by the number of affected snubbers, if available. For the three categories that involve a loss of hydraulic fluid, the location of the snubber and an indication of the presumed cause of failure is included.

TABLE 4.1

SUMMARY OF LICENSEE EVENT REPORT DATA FROM 1969 TO PRESENT

YEAR	LOSS OF HYDRAULIC FLUID			RESERVOIR EMPTY			LEAKING SNUBBER			OUT OF CALIBRATION	INSTALLATION
	FACILITY & NUMBER	LOCATION	CAUSE	FACILITY & NUMBER	LOCATION	CAUSE	FACILITY & NUMBER	LOCATION	CAUSE	(i.e., LOCKUP, BLEED)	ERROR
1970											
1971											
1972											OCP1-1
1973	MNS1-51/112	ECCS&CONT	S				OPIC23/66	IN. DRYWELL	S		
							20/72	OUT. DRYWELL	S		
	OCP1-1	ST. LINE	S								
1974	OPC1-6	CORE SPRAY	S	CPR1-4	ECCS&CONT	LP	BRF2-11	ECCS	A		MNPI-NA
	-4	ISOL. COND.	S	MNS1-7	ECCS&CONT	S	CPR1-2	ECCS&CONT	LP		TMI 1-1
	-3	M.S., FEEDWATER	S	PBS2-1	N.A.	LP	DRS2-12/31	ECCS&CONT	S		
	TMI-4	M.S. SUPPLY	LP	TMI 1-3		S, LP	DAC1-1	ST. LINE	A		
	-1	S.F. POOL COOL. SUPPLY	LP				IPS2-5/540	ECCS&CONT	LP		
							OCP1-12	ECCS&CONT	S		
							-3	RECIRC&CONT	S		
							TMI 1-4	M.S. SUPPLY	LP		
							-1	M.S. SUPPLY	S		

A - ASSEMBLY ERROR
S - SEAL FAILURE
LP - LOOSE PARTS
N.A. - NOT AVAILABLE

YEAR	DAMAGE FROM UNANTICIPATED TRANSIENT	MANUFACTURING ERROR - M INADEQUATE DESIGN - D		ADMINISTRATIVE, MISC., EXTERNAL
1970	DRS2-1 HPCI VALVE CLOSURE			
	MNS1-1 M.S.			
1971	DDS2-3/ECCS			
1972	QAD1-1/RHR	OCP1-NA	D	
1973		BRF1-NA	D	
		FCS1-NA	D	
		HBR2-1	D	
1974	DAC1-NA/HPIC VALVE CL.	OCP1-1	M	BRF2-11/14
		TPS4-NA	M	
		CCN1-NA	D	
		DPS1-ALL	D	
		PBS3-3	D	

SUMMARY OF LICENSEE EVENT REPORT DATA FROM 1969 TO PRESENT (Continued)

YEAR	LOSS OF HYDRAULIC FLUID			RESERVOIR EMPTY			LEAKING SNUBBER			OUT OF CALIBRATION	INSTALLATION
	FACILITY & NUMBER	LOCATION	CAUSE	FACILITY & NUMBER	LOCATION	CAUSE	FACILITY & NUMBER	LOCATION	CAUSE	(i.e., LOCKUP, BLEED)	ERROR
1975	DRS3-2/35	HPCI, FEEDWATER	S	PBS2-7	OESFS	S	BRF2-4	COOL. SUBSTS & CONTROL	S	TMI1-8	CPR1-1
	-2	OESFS	S	PBS3-1	OESFS	S	DRS3-8/35	DRYWELL	S	YKR1-8	DAC1-2
	MNS1-2	OESFS	S	QAD2-2	OESFS	S	-3	CLEANUP SYS	S		EIH1-5
	MNP1-1	OESFS	S	-2	OFSFS M.S. DRAIN C1. PUMP SUCT.	LP	JAF1-2	DRYWELL	S		MNS2-1 FROZEN
	QAD2-2	OESFS COOL RECIRC	LP	-3	RECIRC BYPASS	LP	FCS1-2	MS SUPPLY	S		MNP1-1
	-2	SYS & CONT	LP				MNP1-1	LPCI	A		PBS3-1
	TMI1-1	ECCS & CONT	LP								TMI1-1
1976	BEP2-3	RHR RV HEAD PIP.	S	ARK1-12	OESFS	S	BEP2-N.A.	OESFS	S, LP	CCN2-10	CPR1-1
	-10	M.S. TUNNEL	S	CPR1-1	RHR	LP, S	CRP3-N.A.	OESFS	S	DCC1-10/10	MYP1-2 MNS2-NA
	CPR-16	RHR	LP, S	DRS1-3	ECCS	S	FCS1-2	NA	A		PBS2-3
	-4	ECCS & CONT	LP, S	MYP1-2	M.S. FEEDWATER	S	IPS2-1	OESFS	LP		
	DRS2-2	OESFS	S	PBS2-12	M.S. REL. VAL	S, LP	SLS1-5	SAF. INJ. COOL	LP		PBS3-1 SGS1-10 FROZEN
	FCS1-9/99	OUTSIDE S. WALL	LP	-7	M.S., HPCI	S	VYS1-2	RECIRC DISCH	S		ARK1-3
	-1/66	INSIDE S. WALL	LP	PBS3-14	CRD, HPCI	S					
	MNS1-1	RECIRC. LINE	S		M.S., REL VALVE LINES						
	DRS3-30	OESFS	S								

YEAR	DAMAGE FROM UNANTICIPATED TRANSIENT	MANUFACTURING ERROR - M INADEQUATE DESIGN - D		ADMINISTRATIVE, MISC., EXTERNAL
1975	JAF1-4/HIPCI	MNS2-NA	D	RSS1-NA
	-2/CONT	PAL1-135	D	TMI 1-1
		TMI 1-NA	D	
		DRS3-1	M	
		TMI 1-6	M	
1976	BEP2-1/NA	CPR1-1	D	SGS1-10 <u>FROZEN</u>
	DCC1-2/S.G.			SLS1-5 <u>FROZEN</u>
				CPR1-1

SUMMARY OF LICENSEE EVENT REPORT DATA FROM 1969 TO PRESENT (Continued)

YEAR	LOSS OF HYDRAULIC FLUID			RESERVOIR EMPTY			LEAKING SNUBBER			OUT OF CALIBRATION	INSTALLATION
	FACILITY & NUMBER	LOCATION	CAUSE	FACILITY & NUMBER	LOCATION	CAUSE	FACILITY & NUMBER	LOCATION	CAUSE	(i.e., LOCKUP, BLEED)	ERROR
1976	MNS2-2	M.S.	LP	QADI-4	CORE	S					
(Cont.)					SPRAY						
					RECIRL						
					DISCH						
					RHR						
				TMI1-1	DECAY	LP					
					HEAT						
					PUMP						
					SUCT.						
				-1	PRES.	S					
					SPRAY						
1977	PBH2-1	PRES.SRV	S	FSV1-1	COND.	LP, S	DAC1-11	N.A.	S	DAC1-15	BRF3-2
	MNS2-1	ECCS	LP		FEED, M.S.		BRF2-4	N.A.	LP		
	Z1S1-1	ECCS	S	PBS2-2	REL. VAL	LP	BRF3-6	N.A.	LP, S	MYP1-8	BEP1-1
	CCN2-8	S.GEN.	LP		RWCU		DRS2-2	FEEDWATR.	LP	NMP1-4	
	MNS2-1	ECCS	LP	-4	CORE	S	DAC1-5	N.A.	S	TMI1-45	BEP2-1
	RSS1-1	RCP	S		SPRAY		EIHI-30	N.A.	S	EIHI-32	
	Z1S1-1	RCP COOL	S	PBS3-9	M.S.,	S	IPS2-4	FEED;M.S.	S	JAFI-57/230	DCC1-1
	-1	RHR	S		HPCI		PAL1-1	M.S.	S	MNS2-4	CRP3-1
	-1	MS	S		FEEDWATER		Z1S1-2	ECCS, RHR	S	RSS1-35/81	FSV1-11
	-1	FEEDWATER	S	QAD2-5	N.A.	S	DRS2-2	FEEDWATER	S	SPS2-N.A.	PSB3-1
	-10	PRESIZR.									
		SPRAY	S	Z1S1-NA	N.A.	S	DAC1-5	N.A.	A	BVS1-13	DBS1-3
				NMP1-4	ECCS&CONT	S	FCS1-16	N.A.	S,LP	FCS1-90%	CPR1-1
				PSB3-2	ECCS	LP				HNP1-8	JAF1-21
				REG1-2	M.S.	S				PBH1-1	MNS1-4
				VYS1-3	COOL.REC.	S				VYS1-28	SPS1-1
				SPS1-1	M.S.	LP					
				BEP1-1	RCIC	N.A.					
				FSV1-5	N.A.	LP					

SUMMARY OF LICENSEE EVENT REPORT DATA FROM 1969 TO PRESENT (Continued)

YEAR	LOSS OF HYDRAULIC FLUID			RESERVOIR EMPTY			LEAKING SNUBBER			OUT OF CALIBRATION	INSTALLATION
	FACILITY & NUMBER	LOCATION	CAUSE	FACILITY & NUMBER	LOCATION	CAUSE	FACILITY & NUMBER	LOCATION	CAUSE	(i.e., LOCKUP, BLEED)	ERROR
1977 (Cont.)				PBS3-2	FEED,ECCS	LP					
				REG1-1	S.GEN.	S					
				VYS1-6	COOL. RECIRC.	S					
				ARK1-1	COOL. RECIRC.	S					
1978				DRS1-1	ECCS	LP	EIH-1	HPSI	S		
TOTALS	154 SEALS 52 LOOSE PARTS			115 SEALS 34 LOOSE PARTS			149 SEALS 17 LOOSE PARTS 20 POOR ASSEMBLY			~ 286	82 (11 FROZEN) SET SCREWS NOT REMOVED

YEAR	DAMAGE FROM UNANTICIPATED TRANSIENT	MANUFACTURING ERROR - M INADEQUATE DESIGN - D		ADMINISTRATIVE, MISC., EXTERNAL
1977	BEP1-2/RHR	BVS1-6	D	PBS3-1
	DCC1-2/S.G.	DAC1-1	D	DAC1-2
	BEP2-1/RHR	IPS2-1	D	DAC1-13 FROZEN
	DAC1-1/RHR	DBS1-2	D	ZIS1-2
		REG1-5	D	SPS1-3
		SPS1-2	M,D	PPS1-1
		BEP2-5	M	
1978		EIH1-2	M	
TOTALS	21	N.A.		50 (28 FROZEN) DUE TO CORROSION

TABLE 4.2

SUMMARY OF NUMBER OF ABNORMAL OCCURRENCE REPORTS
AS OF NOVEMBER 21, 1977

FACILITY	ABBR.	OL ISSUED	TECH SPECS ISSUED	NUMBER OF ABNORMAL OCCURRENCE REPORTS
Dresden 1	DRS1	09-28-59	8/76	2
Yankee Rowe	YKR1	07-09-60	7/76	1
Indian Point 1	IPS1	03-26-62	N.A.	0
Humboldt Bay	HMB1	08-28-62	3/76	0
Big Rock Point	BRP1	08-30-62	N.A.	0
San Onofre	SOS1	03-27-67	7/76	1
Haddam Neck	HNP1	06-30-67	9/75	1
LaCrosse	LBR1	07-03-67	N.A.	0
Oyster Creek 1	OCP1	04-09-69	12/76	11
Nine Mile Point	NMP1	08-22-29	10/75	4
Ginna 1	REG1	09-19-69	6/77	3
Dresden 2	DRS2	12-22-69	9/76	7
H. B. Robinson 2	HBR2	07-31-70	8/76	1
Monticello	MNP1	09-08-70	10/76	4
Point Beach 1	PBH1	10-05-70	6/76	1
Millstone 1	MNS1	10-07-70	8/75	8
Dresden 3	DRS3	01-12-71	9/76	5
Palisades	PAL1	03-24-71	1/77	3
Quad Cities 1	QAD1	10-07-71	10/76	3
Indian Point 2	IPS2	10-19-71	10/76	8
Point Beach 2	PBH2	11-16-71	6/76	1
Vermont Yankee	VYS1	03-21-72	7/76	1
Quad Cities 2	QAD2	03-31-72	10/76	6
Surry 1	SPS1	05-25-72	9/76	5
Pilgrim	PPS1	06-08-72	9/76	1
Turkey Point 3	TPS3	07-19-72	1/78 Ten.	0
Maine Yankee	MYP1	09-15-72	7/76	4
Surry 2	SPS2	01-29-73	9/76	2
Oconee 1	NEE1	02-06-73	10/76	0
Zion 1	ZIS1	04-06-73	1/78 Ten.	11
Turkey Point 4	TPS4	04-10-73	1/78 Ten.	1
Ft. Calhoun	FCS1	05-24-73	7/77	4
Browns Ferry 1	BRF1	06-26-73	8/76	1
Peach Bottom 2	PSB2	08-08-73	6/76	15
Prairie Island 1	PIN1	08-09-73	8/76	0
Oconee 2	NEE2	10-06-73	10/76	0
Zion 2	ZIS2	11-14-73	1/78 Ten.	0
Fort St. Vrain	FSV1	12-21-73	N.A.	7

TABLE 4.2 (Continued)

FACILITY	ABBR.	OL ISSUED	TECH SPECS ISSUED	NUMBER OF ABNORMAL OCCURRENCE REPORTS
Kewaunee	KNP1	12-21-73	3/77	0
Cooper	CPR1	01-18-74	6/76	9
Duane Arnold	DAC1	02-22-74	6/76	12
Three Mile Island	TMI1	04-19-74	5/77	13
Arkansas 1	ARK1	05-21-74	4/77	3
Browns Ferry 2	BRF2	06-28-74	8/76	3
Peach Bottom 3	PBS1	07-02-74	4/77	19
Oconee 3	NEE1	07-19-74	10/76	0
Calvert Cliffs 1	CCN1	07-31-74	2/77	1
Hatch 1	EIH1	08-06-74	10/76	3
Rancho Seco	RSS1	08-16-74	1/77	3
Fitzpatrick	JAF1	10-17-77	12/76	8
Cook 1	DCC1	10-25-74	3/76	4
Prairie Island 2	PIN2	10-29-74	8/76	0
Brunswick 2	BEP2	12-27-74	11/76	8
Millstone 2	MNS1	08-01-75	6/76	10
Trojan	TNP1	11-21-75	1/78 Ten.	0
Beaver Valley 1	BVS1	01-30-76	4/76	2
St. Lucie 1	SLS1	03-01-76	3/76	2
Indian Point 3	IPS3	04-05-76	1/77	0
Browns Ferry 3	BRF3	07-02-76	8/76	2
Salem 1	SGS1	08-13-76	8/76	2
Calvert Cliffs 2	CCN2	08-13-76	11/76	2
Brunswick 1	BEP1	09-08-76	11/76	5
Crystal River 3	CRP3	12-03-76	12/76	2
Davis-Bessee 1	DBS1	04-22-77	4/77	4

The unanticipated transients category pertains primarily to a waterhammer induced failure of a seismic snubber, and the affected system has been indicated in each case. Indications of frozen snubbers are flagged because of the potential significance of this type of failure during normal operating conditions.

It appears that frozen snubbers have been limited to International Nuclear Safeguards mechanical snubbers and that the frozen condition has resulted from corrosion of the internal mechanism. A few cases have occurred because shipment set screws have not been removed prior to installation. Approximately 7,000 of these units are in service today.

The most chronic operability problem to date has been seal deterioration. Experimental work and preliminary operational experience indicate, however, that the new seal materials (ethylene-propylene) being used today are superior. The change to new seals in the field, however, has resulted in miscalibration problems at operating facilities where the modifications were conducted by inexperienced personnel. The miscalibrations were uncovered through routine surveillance as specified in the technical specifications. Other seal materials are also available which have performed reliably for many years. Emphasis should be placed on material compatibility analyses for the service environment during the design stage to enhance overall snubber reliability.

Table 4.3 summarizes defects attributable to field installation errors and manufacturing errors. As will be observed, a wide variety of defects have been encountered leading to snubber failures. These types of defects can be minimized through improved QA/QC programs in the shop, in shipment and in the field.

4.3 Conclusion

Accurate assessments of overall system reliabilities are difficult due to uncertainties in the design bases for the support system. Since snubbers have often been included that are not required for safety, failures of certain snubbers may be inconsequential because of added conservatism and design redundancies. On the other hand, where redundant snubbers have been specified, a penalty may be incurred due to increased system stiffness. Given the existing design practice, it would appear that system reliabilities could be improved through tighter QA/QC procedures during installation and an improved surveillance program during service.

TABLE 4.3(a)

SUMMARY OF OBSERVED FAILURE MODES

MANUFACTURING DEFECTS

1. Burrs on main position rod (damage to U-cups)
2. Fillings from set screw boring at piston-piston rod interface left in cylinder (damage to piston seals)
3. Poppet scored by spring
4. Accumulator relief holes mislocated
5. Reservior too small to accommodate full piston stroke
6. Uneven mating surfaces in reservoir construction
7. Misalignment of seals
8. Cylinder scored
9. Relief ball missing
10. Piston rod scored
11. Low viscosity oil
12. Accumulator spring broken
13. Missing O-rings
14. Cut seals
15. Components out of tolerance

TABLE 4.3(b)

INSTALLATION ERRORS

1. Rotated reservoirs (hydraulic fluid could not reach valve blocks)
2. Piston shaft painted (caused frozen condition)
3. Units installed upside down
4. Site glass broken
5. Installed with preset locking screws for shipment (caused a frozen condition, screws must be removed before service)
6. Hydraulic fluid lines placed too close to hot pipe causing the lines to burst
7. Snubber placed in wrong location
8. Clevis pins not attached to anchor
9. Snubber not installed at correct piston position
10. Bent piston rod
11. Welding arc across capstan spring and mandrel in mechanical snubber caused a frozen condition

TABLE 4.3(c)

DEFECTS ATTRIBUTIVE TO INSERVICE VIBRATION, POOR ASSEMBLY, EXTERNAL CAUSES, OR REASSEMBLY

1. Corrosion of internal mechanisms of mechanical snubbers (caused a frozen condition)
2. Loose housing screws, cylinder tie nuts, etc.
3. Broken holddown screws, accumulator springs, etc.
4. Loose retaining nuts on reservoir end caps
5. Loose adjustment screws on poppet and bleed values
6. Nicked or split O-rings
7. Leaking hydraulic fittings
8. Corroded accumulator tube, accumulator spring
9. Contaminated hydraulic fluid
10. Incompatible seal material and hydraulic fluid
11. Leakage through compression set seals (piston seals, thread seals)

V. CONCLUSIONS AND RECOMMENDATIONS

5.1 Technical Issues

The following technical issues have been identified which merit further evaluation:

1. Operability and performance criteria

2. Methods of analysis and design

3. Inspection and maintenance programs.

Each of these issues is discussed in more detail in the following sections.

5.1.1 Operability

Additional guidance should be developed on operability acceptance criteria. Since the definition of operability is the responsibility of the architect-engineer, he must establish the snubber design parameters along with a specification of the range by which these parameters can vary and still satisfy the design requirements. The inservice inspection program should be established consistent with these results.

The design specification is one vehicle by which the architect-engineer can establish the required operating limits of the component he specifies. Information from this specification should be inserted into the plant inspection and maintenance manuals to provide a set of acceptable criteria for operating personnel. The following items are examples of what should be addressed.

1. The required reservoir fluid level as a function of piston setting for operability.

2. The required functional testing parameters (lockup velocity and bleed rate) at test temperature to assure performance at operating temperature.

3. The required hot and cold piston settings.

4. The required maintenance and reconditioning (seals, etc.).

5. The required fluid viscosity.

6. The specified environmental conditions.

7. The tolerances on attachments .

8. Frictional resistance.

The Division of Operating Reactors has developed dynamic performance criteria for hydraulic snubbers for routine implementation in licensing actions and for the interpretation of technical specifications in the interim until more formal guidance is established. These criteria are based in part upon an experimental program conducted by ITT Grinnell that is documented in Technical Report PHD 7579-5-1, "A Parametric Study of the Effect of Locking Velocity and Bleed Rate Setting on the Dynamic Performance of ITT Grinnell Fig. 200 and Fig. 201 Hydraulic Snubbers," dated October 1977. The DOR criteria are contained in Appendix C.

5.1.2 The Calibration Problem

All licensees have initiated some type of seal modification program as a result of I&E Bulletins 73-3 and 73-4. Over 26 utilities have purchased seal kits from Grinnell for the purpose of converting to ethylene-propylene seal material. In the case of Grinnell snubbers, miscalibrations of the lockup velocity and bleed rate set screws following a thread seal replacement have been encountered.

It is suspected that this problem is generic to the industry.

All operating reactor facilities that have conducted a seal modification program without a recalibration should functionally test all of the affected snubbers in the plant. If required, each snubber should then be placed in calibration.

5.1.3 The Frozen Snubber Problem

All cases of frozen snubbers involve International Nuclear Safeguards mechanical snubbers. There are 7,000 snubbers of this design in use at operating nuclear plants.

Licensees with INS snubbers should institute a program to verify that no frozen snubbers exist in their facilities. The utilities should qualify each suspected snubber for continued use and then follow up with a surveillance program to verify continued operability.

Inservice surveillance procedures should be established to verify that snubbers have permitted free movement of the attached piping during the last thermal cycle. In addition, each snubber should be monitored during hot functional testing to obtain initial hot and cold piston settings. The data obtained will verify free movement at startup and serve as a basis for comparison to predicted movement and movement measured during service.

5.1.4 The Technical Specifications

For the limited time that the standard technical specifications have been in use, they have been effective in uncovering operability problems. Several improvements can be made to create a more workable spec based upon both technical and operating experience considerations. These are outlined below:

1. The present STS require a visual inspection of 100% of the snubbers at the interval defined in Table 4.7-4 of Appendix A. The interval is based upon the number of previous failures within two defined groups of snubbers: those which are accessible and those which are inaccessible during normal operation. While this approach is appropriate for problems that may be generic to all snubbers, it may be unreasonable to require a 100% inspection for isolated cases of failure. An alternate approach would be to group snubbers according to the location, function and environment of each snubber. Subsequent inspections should then be governed by matching the type of problems previously uncovered (e.g., fluid leakage, painted piston rod, etc.) to affected groups of snubbers. It may also be necessary to review the inspection interval table to determine if it meets the particular requirements of each plant.

2. A sampling plan should be developed for use in the functional testing program. The number of snubbers to be sampled should be related to the number installed at each facility and the level of performance required in achieving a given level of protection. The sample should not exclude any particular class of snubber and should consider both mechanical and hydraulic snubbers. There should not be a general exemption for snubbers with a capacity of greater than 50,000 pounds, since large bore hydraulic snubber valve blocks can be tested on smaller cylinders on the standard test rig and new testing equipment is being developed to test these units in place. The sample should include snubbers of varying design and of different manufacturers. A provision should also be included in the STS to allow a utility that has reworked its snubbers to have an increased inspection interval.

3. The STS indicates that ethylene-propylene is a compatible seal material and that all other materials must be demonstrated to be compatible and approved by the NRC. It would be preferable to have a snubber-specific seal material compatibility analysis where the use and environment of the seal would be considered and an estimate made of its service life. No particular favor should be given to E-P over another material since the important issue is performance during a specified amount of time.

4. Snubber operability criteria should be considered for inclusion into the technical specifications.

5. Verification of freedom of movement during a thermal cycling should be a part of a snubber operability inspection.

5.2 Safety Significance

While snubber-related problems are of potential safety significance, the following factors would tend to mitigate an immediate concern:

1. Most snubbers are in service to mitigate the effects of an earthquake, a low probability event.

2. While substantial numbers of snubbers have failed to meet operability specifications during surveillance testing, in many instances it has been due to overly restrictive limits rather than truly inoperable components. In addition, snubbers which are technically inoperable would often still provide a significant degree of system restraint.

3. The thermal overstressing of a system due to a frozen snubber should not cause an immediate failure. Thermal stresses are generally self-relieving and failure is dependent upon the number of thermal cycles. However, frozen conditions may go undetected and there can be uncertainty regarding the number of thermal cycles a system has undergone.

5.3 Future Course of Action

The Division of Operating Reactors will continue to monitor operating experience with snubbers. New problems have been uncovered at an accelerated frequency over the last six months as a result of the implementation of the technical specifications. The DOR staff will actively follow up on any new problems brought to our attention.

Recommendations for corrective and preventative action will be provided for input to the licensing process. The DOR staff has provided guidance to various snubber manufacturers for the development of parametric data that will help the NRC and the industry better evaluate snubber performance. The DOR staff will also continue the review of improved analytical techniques for the evaluation of operating data.

Further, as part of generic Task A-13,[1/] the NRR staff will utilize the information and recommendations presented in this report in conjunction with additional studies, to perform a comprehensive evaluation of current industry practice associated with snubber qualification testing, design and analysis procedures, selection and specification criteria and preservice and inservice inspection programs. Based on this evaluation, the NRR staff will develop any needed modifications to the technical specifications, standard review plan and/or regulatory guides for future use in the licensing process in assuring a high-level of snubber operability.

[1/] Task A-13, "Snubber Operability Assurance" is a Category A generic task in the NRC Program for the Resolution of Generic Issues Related to Nuclear Power Plants as described in NUREG-0410.

APPENDIX A

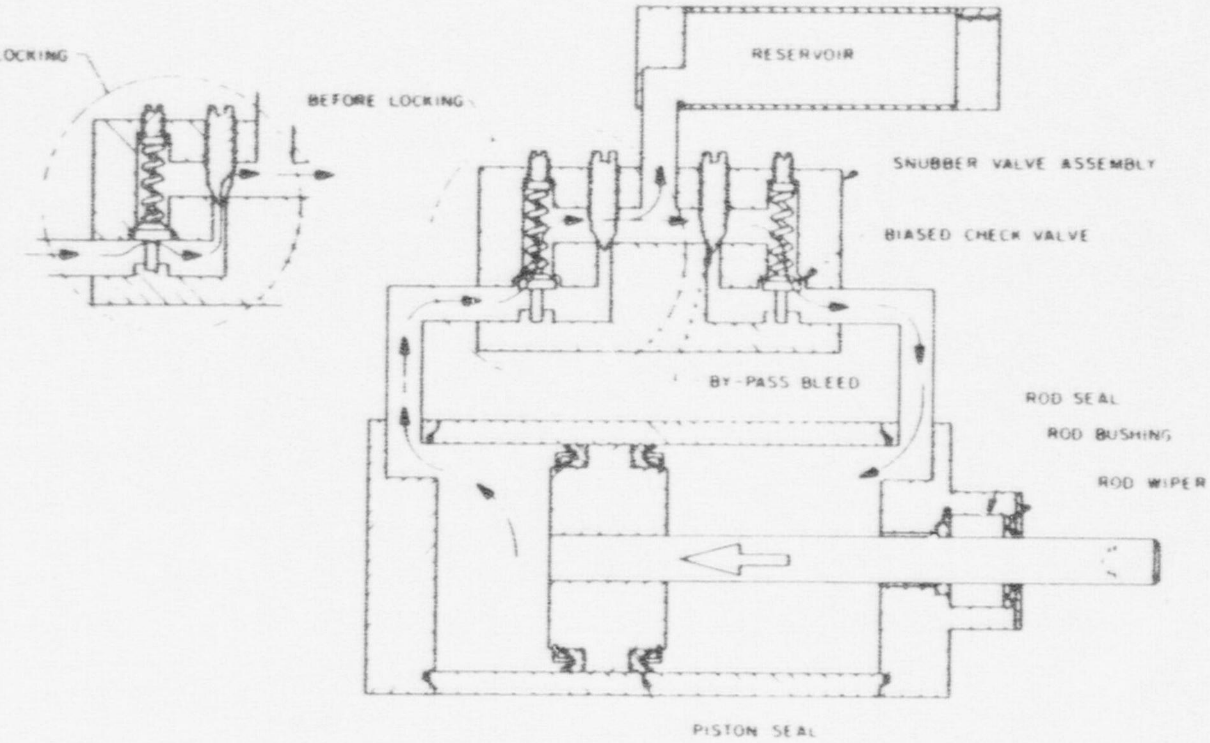
SUMMARY OF OPERATIONAL CHARACTERISTICS OF HYDRAULIC AND MECHANICAL SNUBBERS

Hydraulic Snubbers

The mechanistic mode of operation of the hydraulic snubber centers around the control valve. The control valve converts the snubber from a free acting device to a strut with a given stiffness. When the snubber is subjected to motion exceeding the lockup velocity (usually 8-10 inches/minute), the poppet valve closes due to the flow of hydraulic fluid (a pressure drop is created across the valve) and subsequent flow is directed to the smaller bleed orifice. The snubber is then able to carry a load because of the restricted flow. The load is resisted by both the fluid column and structural elements. The snubber endpoints continue to translate at the bleed velocity (usually 4-6 inches/minute) as the load is resisted. The bleed velocity is proportional to the magnitude of the applied load. In general, the stiffness of the snubber and the peak-to-peak displacement it sees under dynamic load are a function of the bleed rate and lockup velocity. The lockup velocity and bleed rate are very sensitive to the viscosity of the hydraulic fluid. A schematic illustration of a snubber in operation is presented in Figure A.1.

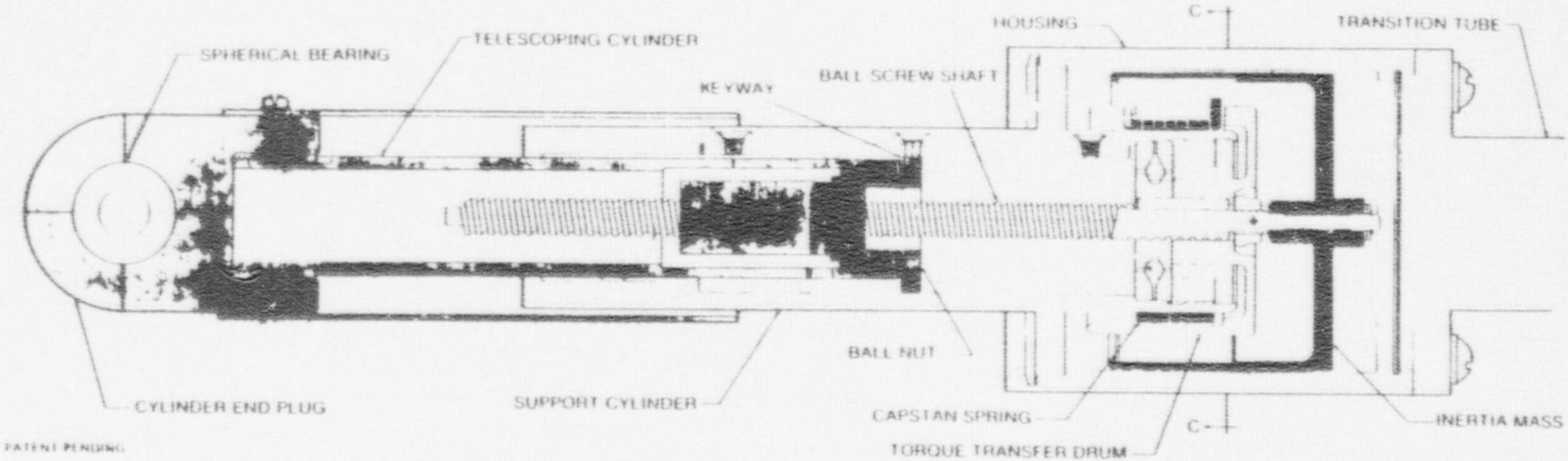
Mechanical Snubbers

There are two types of mechanical snubbers. The first and most common type arrests motion to a specified maximum acceleration. The second type senses motion above a specified threshold and then becomes an elastic strut. The second type ceases to translate in resisting the load. The first type continues to "bleed" as it resists load. The basic concepts of operation are similar for all mechanical snubbers. Linear motion is mechanically converted into angular motion through the rotation of the ball screw shaft. Attached to the shaft are a torque transfer drum and an inertia mass that rotate along with the shaft. Enclosed within the torque transfer drum is a capstan spring. Tangs on the capstan spring project through the torque transfer drum. The tangs engage the inertia mass. Under a slowly applied load, the entire mechanism rotates freely. However, excessive axial acceleration will cause the inertial mass to lag behind the torque transfer drum. The inertia mass then catches the tangs of the capstan spring and winds the spring up around a stationary mandrel. The load is then mechanically resisted. The mechanical advantage is on the order of 50,000 to one. A schematic illustration of a mechanical snubber is shown in Figure A.2.



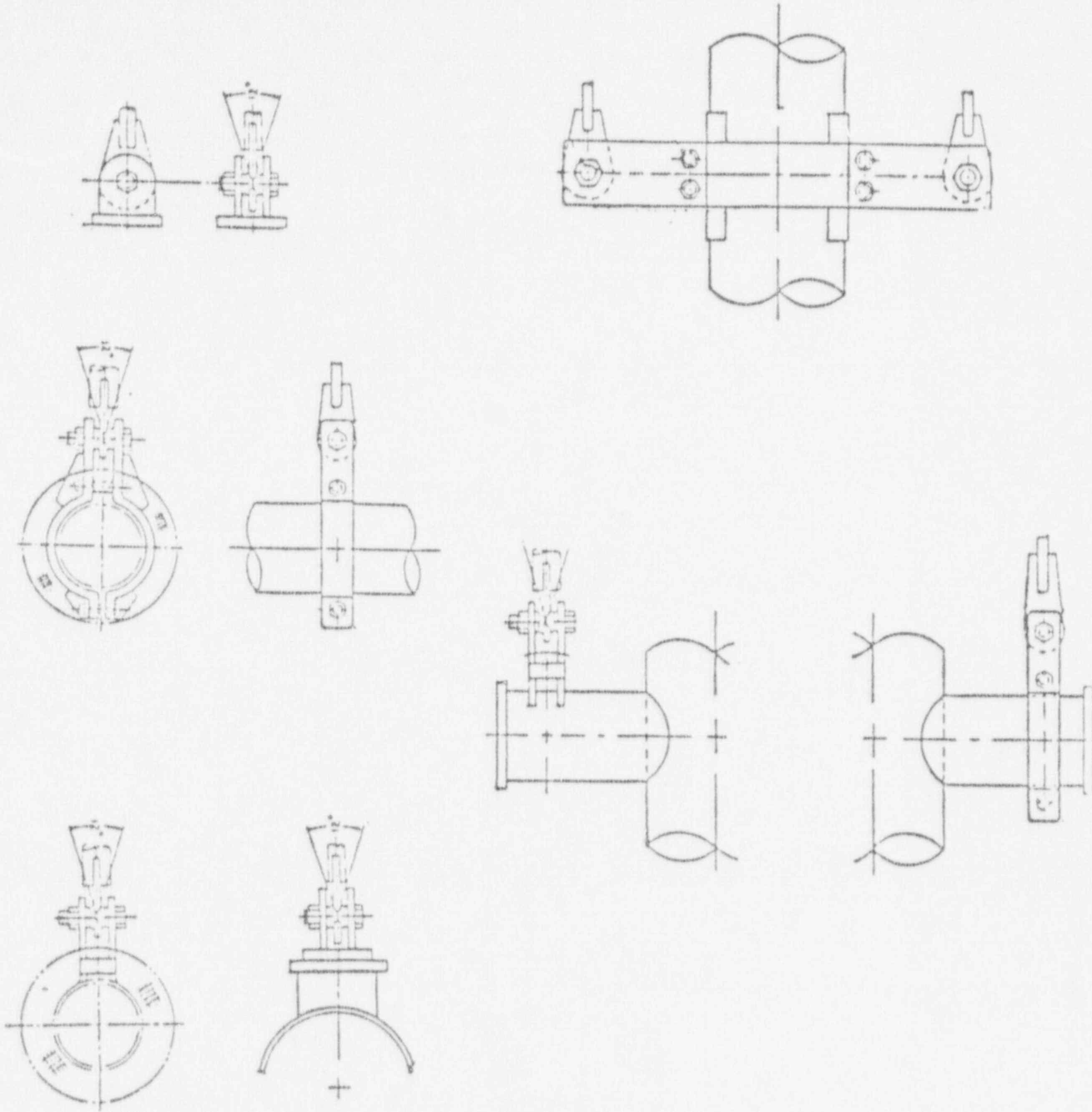
Schematic illustration of a hydraulic shock arrestor in operation. Drawing courtesy of ITT-Grinnell.

Figure A.1



Schematic illustration of a mechanical shock arrestor.
Drawing courtesy of Pacific Scientific.

Figure A.2



TYPICAL PIPE ATTACHMENTS FOR SNUBBERS

Figure A.3

3/4.7.9 HYDRAULIC SNUBBERS

LIMITING CONDITION FOR OPERATION

3.7.9.1 All hydraulic snubbers listed in Table 3.7-4 shall be OPERABLE.

APPLICABILITY: MODES 1, 2, 3 and 4.

ACTION:

With one or more hydraulic snubbers inoperable, replace or restore the inoperable snubber(s) to OPERABLE status within 72 hours or be in at least HOT STANDBY within the next 6 hours and in COLD SHUTDOWN within the following 30 hours.

SURVEILLANCE REQUIREMENTS

4.7.9.1 Hydraulic snubbers shall be demonstrated OPERABLE by performance of the following augmented inservice inspection program and the requirements of Specification 4.0.5.

a. Each hydraulic snubber with seal material fabricated from ethylene propylene or other materials demonstrated compatible with the operating environment and approved as such by the NRC, shall be determined OPERABLE at least once after not less than 4 months but within 6 months of initial criticality and in accordance with the inspection schedule of Table 4.7-4 thereafter, by a visual inspection of the snubber. Visual inspections of the snubbers shall include, but are not necessarily limited to, inspection of the hydraulic fluid reservoirs, fluid connections, and linkage connections to the piping and anchors. Initiation of the Table 4.7-4 inspection schedule shall be made assuming the unit was previously at the 6 month inspection interval.

b. Each hydraulic snubber with seal material not fabricated from ethylene propylene or other materials demonstrated compatible with the operating environment shall be determined OPERABLE at least once per 31 days by a visual inspection of the snubber. Visual inspections of the snubbers shall include, but are not necessarily limited to, inspection of the hydraulic fluid reservoirs, fluid connections, and linkage connections to the piping and anchors.

SURVEILLANCE REQUIREMENTS (Continued)

c. At least once per 18 months during shutdown, a representative sample of at least 10 hydraulic snubbers or at least 10% of all snubbers listed in Table 3.7-4, whichever is less, shall be selected and functionally tested to verify correct piston movement, lock up and bleed. Snubbers greater than 50,000 lb. capacity may be excluded from functional testing requirements. Snubbers selected for functional testing shall be selected on a rotating basis. Snubbers identified as either "Especially Difficult to Remove" or in "High Radiation Zones" may be exempted from functional testing provided these snubbers were demonstrated OPERABLE during previous functional tests. Snubbers found inoperable during functional testing shall be restored to OPERABLE status prior to resuming operation. For each snubber found inoperable during these functional tests, an additional minimum of 10% of all snubbers or 10 snubbers, whichever is less, shall also be functionally tested until no more failures are found or all snubbers have been functionally tested.

TABLE 3.7-4

SAFETY RELATED HYDRAULIC SNUBBERS*

SNUBBER NO.	SYSTEM SNUBBER INSTALLED ON, LOCATION AND ELEVATION	ACCESSIBLE OR INACCESSIBLE (A or I)	HIGH RADIATION ZONE** (Yes or No)	ESPECIALLY DIFFICULT TO REMOVE (Yes or No)

* Snubbers may be added to safety related systems without prior License Amendment to Table 3.7-4 provided that safety evaluations, documentation and reporting are provided in accordance with 10 CFR 50.59 and that a proposed revision to Table 3.7-4 is included with the next License Amendment request.

**Modifications to this table due to changes in high radiation areas shall be submitted to the NRC as part of the next License Amendment request.

TABLE 4.7-4

HYDRAULIC SNUBBER INSPECTION SCHEDULE

NUMBER OF SNUBBERS FOUND INOPERABLE DURING INSPECTION OR DURING INSPECTION INTERVAL*	NEXT REQUIRED INSPECTION INTERVAL**
0	18 months $\pm$ 25%
1	12 months $\pm$ 25%
2	6 months $\pm$ 25%
3 or 4	124 days $\pm$ 25%
5, 6, or 7	62 days $\pm$ 25%
≥ 8	31 days $\pm$ 25%

* Snubbers may be categorized into two groups, "accessible" and "inaccessible". This categorization shall be based upon the snubber's accessibility for inspection during reactor operation. These two groups may be inspected independently according to the above schedule.

** The required inspection interval shall not be lengthened more than one step at a time.

temperature for continuous duty rating for the equipment and instrumentation cooled by this system and 2) the control room will remain habitable for operations personnel during and following all credible accident conditions. The OPERABILITY of this system in conjunction with control room design provisions is based on limiting the radiation exposure to personnel occupying the control room to 5 rem or less whole body, or its equivalent. This limitation is consistent with the requirements of General Design Criteria 10 of Appendix "A", 10 CFR 50.

3/4.7.8 ECCS PUMP ROOM EXHAUST AIR CLEANUP SYSTEM

The OPERABILITY of the ECCS pump room exhaust air cleanup system ensures that radioactive materials leaking from the ECCS equipment within the pump room following a LOCA are filtered prior to reaching the environment. The operation of this system and the resultant effect on offsite dosage calculations was assumed in the accident analyses.

3/4.7.9 HYDRAULIC SNUBBERS

The hydraulic snubbers are required OPERABLE to ensure that the structural integrity of the reactor coolant system and all other safety related systems is maintained during and following a seismic or other event initiating dynamic loads. The only snubbers excluded from this inspection program are those installed on nonsafety related systems and then only if their failure or failure of the system on which they are installed, would have no adverse effect on any safety related system.

The inspection frequency applicable to snubbers containing seals fabricated from materials which have been demonstrated compatible with their operating environment is based upon maintaining a constant level of snubber protection. Therefore, the required inspection interval varies inversely with the observed snubber failures. The number of inoperable snubbers found during an inspection of these snubbers determines the time interval for the next required inspection of these snubbers. Inspections performed before that interval has elapsed may be used as a new reference point to determine the next inspection. However, the results of such early inspections performed before the original required time interval has elapsed (nominal time less 25%) may not be used to lengthen the required inspection interval. Any inspection whose results require a shorter inspection interval will override the previous schedule.

BASES

To provide further assurance of snubber reliability, a representative sample of the installed snubbers will be functionally tested during plant shutdowns at 18 month intervals. These tests will include stroking of the snubbers to verify proper piston movement, lock-up and bleed. Observed failures of these sample snubbers will require functional testing of additional units. To minimize personnel exposures, snubbers installed in high radiation zones or in especially difficult to remove locations may be exempted from these functional testing requirements provided the OPERABILITY of these snubbers was demonstrated during functional testing at either the completion of their fabrication or at a subsequent date.

3/4.7.10 SEALED SOURCE CONTAMINATION

The limitations on removable contamination for sources requiring leak testing, including alpha emitters, is based on 10 CFR 70.39(c) limits for plutonium. This limitation will ensure that leakage from byproduct, source, and special nuclear material sources will not exceed allowable intake values.

APPENDIX C

DYNAMIC PERFORMANCE CRITERIA FOR HYDRAULIC SNUBBERS

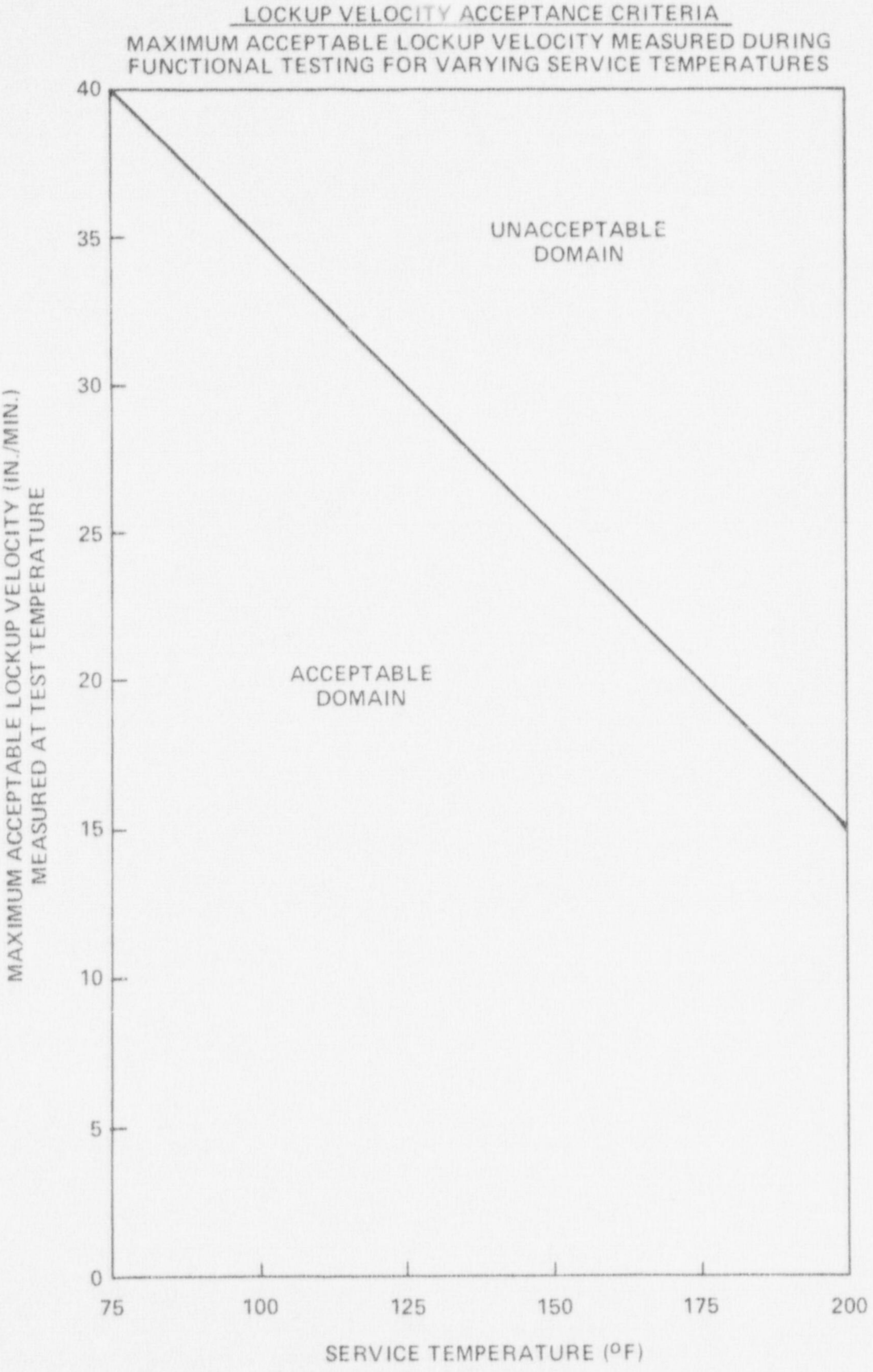
1. A snubber shall be considered operable under normal operating conditions if it permits thermal movements of the piping system and/or equipment without applying a resisting force greater than one percent of the rated load of the snubber.

2. A snubber shall be considered operable under dynamic conditions if it restricts movement of the piping system and/or equipment to the limits assumed in the dynamic analysis.

   a. For seismic snubbers these limits are assured by maintaining the lockup velocity and bleed rate within the acceptable domain of Figures 1 and 2.

   b. For snubbers designed to attenuate various thermal-hydraulic thrusts, the limits defined in Figure 1 are acceptable. However, the bleed rates specified in Figure 2 may be modified if concurrent thermal movement of the piping system and/or equipment is designed to be accommodated by the bleed during the dynamic event. Thermal movement occurring during the unlocking period may be significantly resisted because the bleed rate decreases under dissipating loads. Such thermal movement may not be accommodated and shall be considered in the design.

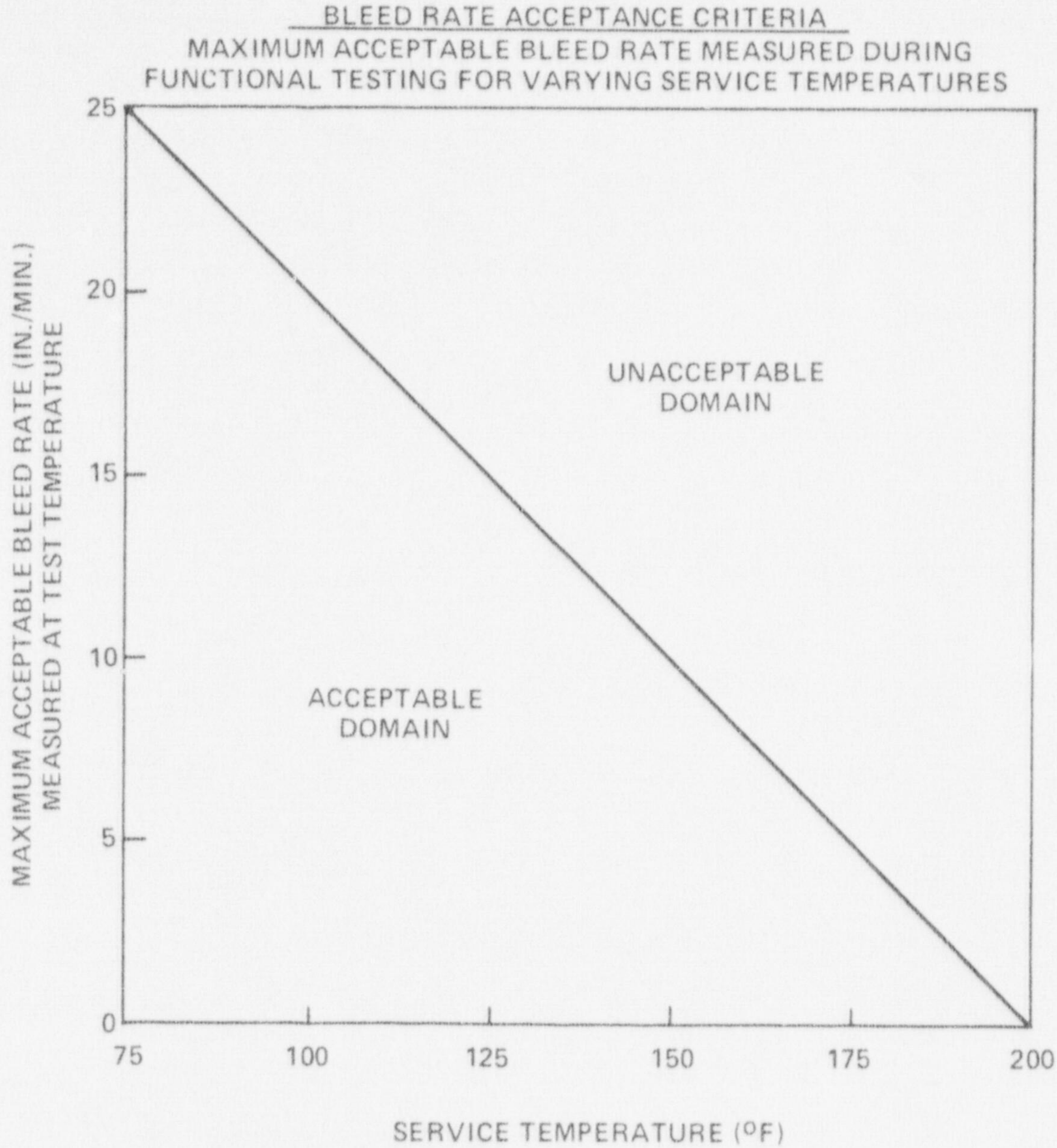
FIG. 1



NOTES:

1. Test Temperature = 75° ± 5°F
2. The Minimum Acceptable Lockup Velocity Shall Always Exceed the Maximum Predicted Thermal Expansion Velocity of the System

FIG. 2



NOTES:

1. Test temperature = 75° ± 5° F
2. For Standard Factory Bleed Rate Calibrations, the Following Service Temperatures Represent an Upper Bound
   - Grinnell - 180°F
   - Bergen - Paterson - 175°F

   Higher Service Temperatures Warrant a Reduction of the Bleed Rate Calibration
3. A Minimum Bleed Rate Greater that 0.1 In./Min. Must be Verified During Functional Testing
4. Bleed Rates for Non-Seismic Snubbers may Exceed the Limits Specified in this Diagram if an Appropriate Analysis is Completed

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Summary of operating experience with hydraulic and mechanical snubbers. Provides an evaluation of current practice with respect to snubber qualification testing programs, design and analysis procedures, selection and specification criteria, and preservice and inservice surveillance programs.

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