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DEVELOPMENT OF ALTERNATE VISUAL EXAMINATION REQUIREMENTS FOR DYNAMIC RESTRAINTS (SNUBBERS)*

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ABSTRACT

Current plant technical specifications require an initial inservice visual examination of safety related equipment dynamic restraints (snubbers) to provide assurance of operability. The time to the next examination is as short as 1 month if 8 or more snubbers are found to be inoperable. Plant operators have observed that as the snubber population of a plant increases, the current plan becomes burdensome by requiring frequent shutdowns for examination of snubbers. The Nuclear Regulatory Commission (NRC) has recognized the need and has sponsored a program to develop alternate visual examination criteria which would require examinations at constant intervals such as at refueling outages. Brookhaven National Laboratories (BNL) was selected by the NRC to conduct this program. Based on the review and evaluation of the information gathered to date, and the conclusions drawn from plant visits and the Snubber Utility Group (SNUG) data base, BNL has developed an alternate statistically-based plan which provides the permissible number of inoperable snubbers for constant and twice constant visual examination intervals for various snubber population groups.

NOMENCLATURE

Snubber Type - Snubbers of the same design and manufacturer irrespective of capacity.

Snubber Group - Snubbers are further categorized into inaccessible and accessible groups. Each of these groups may be inspected independently according to the schedule in the technical specification.

Hydraulic Snubber - A device in which the load is transmitted through a hydraulic fluid as shown in Figure 1.

Mechanical Snubber - A device in which the load is transmitted entirely through mechanical components as shown in Figure 2.

Inaccessible Snubber - A snubber that is in a high radiation area or other environment that would render it impractical for the snubber to be examined during normal plant operating conditions without exposing plant personnel to undue hazards.

Inoperable, Failed, Impaired and Unacceptable Snubbers - Inoperable, failed, impaired and unacceptable are essentially identical terms and are used interchangeably by plant personnel to indicate a snubber which does not meet the plant technical specification requirements for visual examination. Snubbers which appear inoperable, failed, impaired or unacceptable as a result of visual examination may be determined to be operable as provided for in the plant technical specification.

Examination and Inspection - Examination and inspection are essentially identical terms and are used interchangeably by plant personnel to indicate visual observation in compliance with the visual inspection requirements of the plant technical specification.

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INTRODUCTION AND OBJECTIVE

Periodic inservice visual examination of safety related nuclear power plant equipment dynamic restraints (snubbers) is required to be conducted throughout the life of the plant by each plant-specific technical specification to provide assurance of operability. An equipment dynamic restraint (snubber) is a device which supports the equipment during a seismic event by mechanical or hydraulic resistance to sudden motion but permits free motion due to the slow displacement of the equipment during thermal expansion/contraction. Examination consists of visual observation of the snubbers and is intended to detect failed, unacceptable, impaired and/or inoperable snubbers. Typically, checklist items require observation for: leakage; paint and/or corrosion; correct installation; broken, bent, loose or missing parts; binding; misalignment; deformation; and, for hydraulic snubbers, fluid supply.

Current plant-specific technical specifications are similar with respect to examination methods and acceptance criteria as shown below:

"Visual inspections shall verify that: (1) there are no visible indications of damage or impaired OPERABILITY, (2) attachments to the foundation or supporting structure are secure, and (3) fasteners for attachment of the snubber to the component and to the snubber anchorage are secure. If all snubbers of each type on any system are found OPERABLE during the first inservice visual inspection, the second inservice visual inspection of that system shall be performed at the first refueling outage. Otherwise, subsequent visual inspections of a given system shall be performed in accordance with the following schedule:"

No. of Inoperable Snubbers of Each Type on any System Per Inspection Period	Subsequent Visual Inspection Period
0	18 months ± 25%
1	12 months ± 25%
2	6 months ± 25%
3,4	124 days ± 25%
5,6,7	62 days ± 25%
8 or more	31 days ± 25%

The schedule in the technical specifications for subsequent visual inspections was developed in 1975 and was designed to provide a confidence level of 95% that 90% of the snubbers are operable during plant operation. However, plant operators have observed that as the snubber population of a plant increases, the subsequent examination period, which is based on the absolute number of inoperable snubbers found during the current examination period, becomes burdensome by requiring frequent shutdowns for examination of snubbers.

The Nuclear Regulatory Commission (NRC) has recognized the need to develop alternate visual examination criteria which would require examinations at constant intervals such as at refueling outages and, at the same time, provide an equally reliable method for assuring snubber operability as that currently implemented by the technical specifications. The justification for development of a constant interval snubber examination plan is also based on observations that:

a) Snubber visual inspection requirements as currently implemented appear to be overly conservative especially for plants with large numbers of snubbers.

b) Frequent snubber visual inspections are costly in terms of money and personnel radiation exposure and result in poor plant performance.

c) The current visual inspection frequency table has served a useful purpose by providing a strong incentive to improve snubber performance and this has been accomplished by design changes and augmented inspection techniques and therefore the stringent inspection frequency requirements are no longer necessary.

d) The current visual inspection frequency requirements result in numerous licensee requests for waivers which require NRC staff review. This imposes a significant burden on the NRC by requiring expenditure of limited budgets and staff manpower for these reviews.

e) In addition to visual examination, functional testing of a representative sample of snubbers is required by the technical specifications and typically involves removing the snubber and testing it on a specially designed test stand to verify its ability to operate within specified performance limits. Functional testing alone provides a 95% confidence level that 90% of the snubbers are operable within acceptable limits.

f) Current snubber visual inspection failure rates are very low (less than 0.5% per year) as shown in Table 1 which summarizes the significant visual inspection results from the Snubber Utility Group (SNUG) data base for hydraulic, large hydraulic and mechanical snubbers.

A program to develop alternate snubber visual examination requirements was sponsored by the NRC. Brookhaven National Laboratories (BNL) was selected by the NRC to:

a) Review and evaluate existing plant data and reports on snubber performance including the SNUG data base.

b) Obtain detailed information on snubber performance and documentation by visiting operating plants.

c) Evaluate the data obtained and assess whether modifications of the current visual inspection frequency requirements in the technical specifications are feasible based on improved performance trends.

d) Develop an alternate plan requiring visual examination of snubbers at constant intervals such as at refueling outages.

Based on the review and evaluation of the information gathered to date, and the conclusions drawn from the plant visits and the SNUG data base, BNL has developed an alternate plan which replaces the schedule in the technical specifications with a table which provides the permissible number of inoperable snubbers for constant and twice constant visual examination intervals for various snubber population groups.

VISUAL EXAMINATION RESULTS

<u>Operating Plant Experience</u>

Visits were made to three operating plants in order to obtain first-hand, current snubber information which would be useful in developing alternatives to the snubber visual inspection frequency schedule in the plant technical specifications.

The following snubber information was reviewed during the plant visits:

a) Pertinent sections of the Technical Specifications
b) Inspection procedures
c) Maintenance procedures
d) Inspection reports
e) Inspection, test and maintenance history for each snubber
f) Record of snubber failures including service life, operating environment and type of failure
g) Resolution of specific failures, i.e., root cause determination, failure mode grouping, engineering evaluation
h) Service life monitoring program
i) Input to SNUG data base
j) List of snubbers including type, manufacturer, capacity and, location

The first plant visited had 2 units with a total of 1569 snubbers of which 923 are hydraulic and 646 are mechanical. The number of snubbers which have failed as a result of visual examination are shown in the table below.

Year	Unit 1		Unit 2	
	Hydraulic	Mechanical	Hydraulic	Mechanical
1979	[illegible]	-	-	-
1980	3	-	-	-
1981	2	-	-	-
1982	0	-	3	-
1983	1	0	2	0
1984	2	0	2	-
1985	0	0	0	0
1986	3	1	2	0
1987	-	-	1	0
1988	1	0	-	-

The second plant visited has two units with a total of approximately 2900 Pacific-Scientific (PSA) mechanical snubbers. The size distribution of the mechanical snubbers is:

40% small - sizes 1/4 and 1/2
55% medium - sizes 1, 3 and 10
5% large - sizes 35 and larger

The number of failed snubbers which have been found during visual examination are:

Year	Unit 1	Unit 2
	Mechanical	Mechanical
1985	[illegible]	-
1986	5	-
1987	[illegible]	[illegible]
1988	-	-

The technical specifications for this plant require that snubbers located on systems which have the potential for severe dynamic events (water hammer, etc.) be inspected at each refueling outage by manually "stroking" the snubbers through their full range of travel. On Unit 1, there are 624 snubbers located on these systems. This inspection is independent of any other inspections or tests. If a snubber is found to have failed, it is replaced before returning to power. Out of the total of 624 Unit 1 snubbers that were checked by stroking, there were 7 failures in 1986 and 4 failures in 1987.

The two units of the third plant visited use Pacific-Scientific mechanical snubbers for piping and ITT-Grinnell, Paul-Munroe and Taylor hydraulic snubbers for steam generators and reactor coolant pumps. Each unit has 220 mechanical and 20 hydraulic snubbers.

No snubbers have ever been declared inoperable at this plant due to visual examination and therefore the increased frequency of visual examination required by the technical specification has never been invoked.

The plant visual inspection procedure requires that each accessible mechanical snubber be manually exercised through its full range of travel (limited operability testing) at each inspection period. For large snubbers, a mechanical force multiplier is used.

Every significant failure, even if the snubber is not declared inoperable, is reported on a nonconformance report. If a failure occurs a second time at the same location, engineering is required to formally evaluate the snubber application.

BNL's review team was provided with visual examination results from two additional operating plants. The first plant has two units which have a total of 3441 snubbers of which 1035 are hydraulic and 2406 are mechanical (1040 are PSA-1/2 mechanical). The number of snubbers which have failed during visual examination and "stroking" are:

Year	Unit 1			Unit 2		
	Hydraulic	Mechanical	Stroking*	Hydraulic	Mechanical	Stroking*
1983	2	0	10	N/A	N/A	-
1984	0	0	1	N/A	N/A	-
1985	0	0	3	0	1	8
1986	N/A	N/A	-	0	0	18
1987	0	0	7	1	0	10
1988	N/A	N/A	-	0	0	5

*All mechanical snubbers were "stroked" to determine freedom of motion. Two-thirds of the "stroking" failures were small-size PSA snubbers.

The three units at the second plant have a total of 785 snubbers of which 340 are hydraulic (Grinnell) and 445 are mechanical (PSA). No snubbers have been declared inoperable at this plant as a result of visual inspections in the last 3 years.

Year	Unit 1		Unit 2		Unit 3	
	Hydraulic	Mechanical	Hydraulic	Mechanical	Hydraulic	Mechanical
1986	0	0	0	0	0	0
1987	0	0	0	0	0	0
1988	0	0	0	0	0	0

SNUG Data Base

A better perspective of the industry-wide visual inspection results can be obtained from the data base maintained by the Snubber Utility Group (SNUG). A summary of the significant results obtained from the data base for hydraulic, large hydraulic and mechanical snubbers is shown in Table 1. The results for hydraulic snubbers extend from 1977 to the present and show that the average rate at which snubbers failed visual examination is 0.3%. Large hydraulic and mechanical snubbers have an essentially zero percent failure rate due to visual examination.

Conclusions

Evaluation of the snubber examination records obtained from operating plants and the SNUG data base revealed that:

1) In recent years, relatively few snubber failures have been found as a result of visual examination as shown in the SNUG data base summary, Table 1. Even fewer snubbers have been classified as "inoperable" in the sense of requiring increased frequency of examination.

2) Visual examination is generally not effective in finding failed or inoperable mechanical snubbers. Therefore, other examinations are required to assure operability of these snubbers and are in fact done at some plants.

3) Small-size mechanical snubbers exhibit a high failure rate in functional and limited operability (stroking) testing, particularly in vibration environments such as near rotating equipment.

4) Formal snubber maintenance programs, other than seal replacement schedules, do not generally exist. However, the visual examination is performed by the Maintenance Group in most plants and is therefore considered as part of the maintenance program.

PLAN DEVELOPMENT

Methodology

Based on probabilistic and statistical methodologies, the permissible number of inoperable snubbers for various snubber populations and constant inspection intervals was calculated while maintaining the reliability of the snubber population at a 95% confidence level that a minimum of 90% of the snubbers of each type are operable at all times.

The following probability model and assumptions were used in the calculations. Let n denote the total number of snubbers in the group. Let X denote the random variable representing time-to-failure (or operable life span) of any individual snubber in the group. Let P_f denote the probability that any individual snubber in the group fails in the next inspection cycle with inspection period T_f. That is:

$$P_f = P\,(X \leq T_f) \qquad (1)$$

Let Z be the random variable denoting the number of failed snubbers in the group in the next inspection cycle with inspection period T_f. Since the time-to-failure of each individual snubber in the group takes place independently of the other, the random variable Z follows the binominal distribution:

$$P\,\{Z \leq z\} = \sum_{i=0}^{z} \binom{n}{i} P_f^{\,i}\,(1 - P_f)^{n-i} \qquad (2)$$

The snubber reliability criterion of having a 95% confidence level that there are a minimum of 90% of the snubbers (of the type) operable in the next inspection cycle with inspection period T_f, is equivalent to having a 95% confidence level that there are less than 10% of the snubbers (of the type) inoperable. Therefore we require that:

$$P\,\{Z \leq s\} = \sum_{i=0}^{s} \binom{n}{i} P_f^{\,i}\,(1 - P_f)^{n-i} \geq 0.95, \qquad (3)$$

where s is the largest integer that is less than n/10. Equation (3) will be the basis for the reliability analysis to develop the maximum permissible number of inoperable snubbers for various snubber populations and constant inspection intervals.

The maximum permissible number of inoperable snubbers was calculated for different populations and for next inspection intervals equal to 2/3, 1 and 2 of the past inspection interval and the results are shown in Columns B, A and C respectively in Table 2. The results shown in Table 2 are based on the assumptions that the distribution of the failure time random variable X of the snubbers does not change over two consecutive cycles, and that the distribution of the random variable X follows an exponential distribution.

Both assumptions are reasonable since the failure rate can always be assumed to be constant over a short period of time (that is the distribution of X is exponential). It is emphasized that based on the reliability analysis in this study, the maximum permissible number of inoperable snubbers satisfying the reliability criterion depends on the group size and the future inspection interval.

Outage Based Plan

In Table 2, Column A represents the baseline results for the permissible number of inoperable snubbers for constant inspection periods, e.g., inspections each outage. Column B represents an increased permissible number which may be used if the subsequent inspection interval is 2/3 of the past inspection interval, e.g., if the past operational cycle was 18 months long and the next outage is scheduled to occur in 12 months. Column C is a decreased permissible number which may be used if the subsequent inspection interval is twice the past inspection interval, e.g., if the past operational cycle was 18 months long and the next inspection is to be performed in 36 months thereby skipping an inspection during the next outage.

If the number of inoperable snubbers for the group exceeds the value given in Col. (A) but is equal to or less than the value in Col. (B), then;

(a) the inoperable snubbers are to be repaired or replaced, and an engineering review and evaluation is to be performed to justify continued use of the snubbers; or

(b) the inoperable snubbers are to be repaired or replaced and the next inspection period shall be decreased. Col. (B) represents 2/3 of the past inspection period; interpolation between Cols. (A) and (B) is permissible.

If the number of inoperable snubbers for the group exceeds the value in Col. (B), then both 2(a) and 2(b) shall be performed.

If the number of inoperable snubbers for the group is equal to or less than the value in Col. (C), then the inoperable snubbers shall be repaired or replaced, and the next inspection period may be increased to twice the past inspection period, i.e., the next inspection may be skipped, and the snubbers in the group shall be visually examined only every other outage as long as the results of the visual examination meet the requirements of Col. (C). No more than one outage may be skipped in visually examining any snubber population group.

If the number of inoperable snubbers exceeds the value in Col. (C) but is equal to or less than the value in Col. (A), then the inoperable snubbers are to be repaired or replaced, and the next visual inspection shall be conducted at the next outage (constant inspection period).

RECOMMENDATIONS

1) Consider the use of Table 2 for visual examination on an interim basis.

2) Continue work on the final phase of this program. The tasks during the final phase will consist of: (a) a more detailed review of the SNUG data base; (b) a detailed review of snubber failure by type and cause; (c) a review of the technical specification differences with respect to the requirements for declaring snubbers inoperable and reporting visual examination results; (d) development of a service life monitoring program; and (e) a study to determine if there is an adequate and reliable substitution for visual examination of mechanical snubbers. The objective of the final phase work is to determine the feasibility of further decreasing or eliminating snubber visual examinations and to evaluate the possibility of substituting alternate and equally (or more) reliable methods for assuring snubber operability. Methods to be considered include service life monitoring, sample stroking plans for mechanical snubbers, root cause determination and engineering evaluations of suitability for the intended service.

REFERENCES

1. U.S. Nuclear Regulatory Commission (NRC), "Standard Technical Specifications," Plant Systems, 3/4.7.9 Snubber, Plant Specific, Various Issue Dates.

2. Snubber Utility Group (SNUG), "Snubber Visual Inspection Reports," Transmitted to Brookhaven National Laboratories by the U.S. Nuclear Regulatory Commission, 1989.

3. Sargent and Lundy, "Increased Acceptance Criteria for Snubber Functional Testing," Presented at Snubber Utility Group Summer 1988 Meeting.

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TABLE 1

SUMMARY OF SIGNIFICANT VISUAL INSPECTION RESULTS FROM SNLG DATA BASE

HYDRAULIC, LARGE HYDRAULIC AND MECHANICAL SNUBBERS

Snubber Type	Year	Number of Snubbers Inspected	Number Failed	% Failed
HYDRAULIC SNUBBERS	1977	670	0	0
	1978	1,186	5	0.4
	1979	1,601	6	0.4
	1980	2,135	11	0.5
	1981	2,596	19	0.7
	1982	2,851	5	0.2
	1983	2,632	13	0.5
	1984	2,995	14	0.5
	1985	3,605	8	0.2
	1986	5,090	8	0.2
	1987	4,705	11	0.2
	1988	3,850	3	0.1
	Grand Total	33,716	103	0.3
LARGE HYDRAULIC SNUBBERS	1986	1,017	0	0
	1987	211	0	0
	1988	198	0	0
	Grand Total	1,426	0	0
MECHANICAL SNUBBERS	1982	1,425	0	0
	1983	5,676	4	0.1
	1984	4,306	0	0
	1985	10,340	2	0
	1986	14,124	3	0
	1987	15,337	1	0
	1988	10,458	3	0
	Grand Total	61,660	13	0

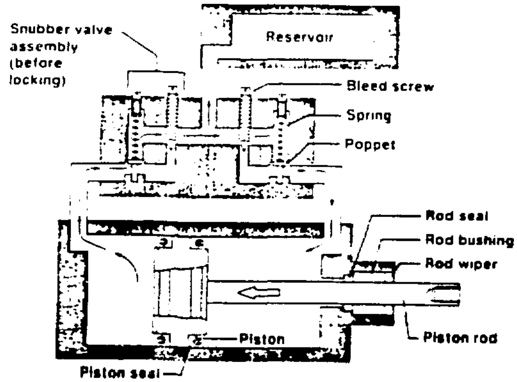

FIGURE 1 HYDRAULIC SNUBBER SCHEMATIC [3]

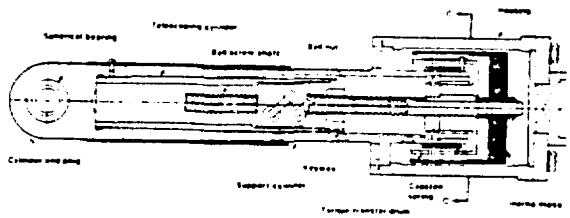

FIGURE 2 MECHANICAL SNUBBER SCHEMATIC [3]

TABLE 2

Outage-Based Visual Examination Table

Permissible Number of Inoperable Snubbers for Various Snubber Populations

Snubber Type Population Size N	Col. (A) Permissible Number of Inoperable Snubbers for Constant Inspection Periods	Upper/Lower Bound Limits on Number of Inoperable Snubbers Col. (B)	Col. (C)
1	0	1	0
80	1	2	0
100	2	4	0
150	4	8	1
200	8	13	2
300	16	25	6
400	23	36	10
500	31	48	14
750	51	78	23
1000	71	109	33