AEOD ENGINEERING EVALUATION REPORT*

UNIT: Palisades
DOCKET NO.: 50-255
LICENSEES: Consumers Power Company
NSSS/AE: Combustion Engineering/Bechtel Corp.

EE REPORT NO. AEOD/E423
DATE: September 20, 1984
EVALUATOR/CONTACT: E. J. Brown

SUBJECT: FAILURE OF LARGE HYDRAULIC SNUBBERS TO LOCK-UP

EVENT DATE: September 17, 1983

SUMMARY

All 16 steam generator hydraulic snubbers at the Palisades plant were determined to have been inoperable (would not lock-up) since initial operation of the plant more than 10 years ago. Further investigation for additional events revealed that large hydraulic snubbers (load capacity greater than 50,000 pounds, 50 kips) at other plants have been found to be unable to provide the desired safety function because of failure to lock-up or inability to sustain loads below the rated load of the component. There have been at least 13 plants affected in which snubbers were supplied by five different manufacturers. The primary safety issue is that failure of these large snubbers to perform their design function could potentially result in an unanalyzed accident outside the plant design basis.

This study identified that deficiencies which led to snubber inoperability or delayed discovery of inoperability covered a broad spectrum of activities involving design, manufacture, functional qualification, service aging, and surveillance requirements. The primary issue with aging appears to be ethylene propylene rubber seals that fail to retain hydraulic fluid with an apparent shelf life of seven years. There was evidence that additional subcomponent deficiencies have been identified in one snubber design that failed a load test. These deficiencies were reported to cause inoperability, but the scope of the problem has not yet been established. Approximately 25 plants do not yet have technical specifications in place that require surveillance testing of these large snubbers. It was also determined that 23 of the 25 plants began commercial operation during or before 1977 which implies more than seven years service life. In many cases, inoperability was discovered during the first surveillance tests that were required by technical specification changes that were implemented in the last two years.

The evaluation concludes there is doubt relative to whether existing programs provide reasonable assurance that large hydraulic snubbers will operate to perform the intended design function. The report recommends that AEOD consider initiating a case study to determine generic implications and identify bases for changes to provide confidence in large snubber operability. It seems appropriate that preliminary, but immediate, NRC effort should address the following:

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*This document supports ongoing AEOD and NRC activities and does not represent the position or requirements of the responsible NRC program office.

1. Expedite the current program to implement proposed technical specification changes so that all operating plants will have surveillance test requirements for large snubbers.

2. Consider a requirement that initial surveillance tests should be completed on an accelerated basis rather than delayed as much as 18 months to two years after the technical specifications are in place.

3. Consider adding a new section to the technical specifications to require a test to confirm snubber load capacity (rating).

4. The Office of Inspection and Enforcement should issue an information notice to promptly disseminate this information about failures of large snubbers.

INTRODUCTION

The initial event under review was that of a large capacity hydraulic snubber that failed to lock-up during functional testing. This was reported in LER 83-063 (Ref. 1) for the Palisades plant. The snubber was one of 16 ITT-Grinnell snubbers installed to provide seismic restraint for the two steam generators. Functional testing of a second snubber revealed that both snubbers failed to lock-up as required. The cause was attributed to a manufacturing deficiency and a 10 CFR Part 21 Report (Ref. 2) was submitted on September 30, 1983. The manufacturing defect was determined to be insufficient counter boring of the snubber's valve block end-cap which inhibited the shuttle valve from properly closing the appropriate valve block port to provide lock-up of the snubber.

These snubbers had been in service for approximately 10 years and had not been tested since installation. Consequently, all sixteen(16) snubbers were assumed to have been inoperable. Subsequent review of this event was reported by Region III in Reference 3. That report indicated that the cause of failure to lock-up was that the control valve single piston used for closing and opening of the hydraulic ports, which was positioned by two springs (one on each end), could not travel sufficient distance to close the ports. The result was failure to lock-up in both the tension and compression dynamic loading condition. Examination revealed that piston/spring travel restraint was caused by an insufficient counter-bore depth at the two end caps where the springs seat.

Reference 3 concluded that failure of the 16 snubbers to be operable since installation more than 10 years ago was the result of inadequate control during manufacturing. It was also determined that the snubbers were designed and purchased by Combusiton Engineering, Inc., for Consumers Power Corporation. The design specification apparently did not specify either acceptable lock-up and bleed rate ranges or proof testing of snubber assembly function. Additional NRC investigation was conducted by the Vendor Program Branch and reported in Reference 4. It was concluded that failure to lock-up was caused by a combination of two problems. The first problem was a revision to the original specification to change the end spring to a stiffer spring. Secondly, ITT-Grinnell changed the cylinder cap bolt from one with a 0.25 inch counter bore to one having a 0.38 inch counter bore. When the Palisades snubbers were assembled October 17, 1968, the original 0.25 inch counter bored cylinder cap bolt was used rather than the new cap bolt with the 0.38 inch counter bore. It was concluded that the snubber spring and incorrect counter bore restrained piston travel to prevent snubber lock-up.

DISCUSSION

The initial interest in this event was primarily concerned with the fact that these were large snubbers that failed to lock-up under conditions similar to seismic loadings. In addition, they had been in service for more than 10 years, had not been tested during that time span, and would not have performed their design function. A review of past NRC requirements for snubbers indicates that the situation where large snubbers would not have been tested

is related to an exemption from snubber surveillance test requirements in plant technical specifications. In general, snubbers larger than 50,000 pounds (50 kips) were exempted from test requirements (possibly on the basis that equipment was not available to apply the necessary load or lock-up velocity). This fact was understood by NRC staff and efforts to correct the situation have been in progress for several years.

The specific NRC corrective efforts are described in References 5 and 6. Reference 5 addresses technical specification changes in snubber surveillance programs. The NRC suggested changes were primarily to cover mechanical snubbers in the technical specifications for the first time, but they also removed the previous provision to exempt snubbers greater than 50 kips from surveillance testing. In a related effort, Reference 6 was a proposed draft regulatory guide to cover qualification and acceptance tests for all snubbers. The guide was never issued.

The primary safety issue is that failure of these large snubbers to lock-up during seismic events, loss of coolant accidents, or main steam line breaks could potentially result in accidents outside the plant design basis. Possible scenarios are that postulated accidents such as a LOCA or MSLB could lead to concurrent failure of a primary pipe and a secondary line break or blowdown of two steam generators inside containment if the snubbers do not perform their restraint function. These potential concurrent breaks are unanalyzed events and in excess of current design basis accidents.

Thus, the event at Palisades in conjunction with the previous NRC efforts was the impetus to search for other events involving large snubbers. It is important to realize that a general search of the LER data base files would not be expected to yield the desired events because there were no technical specification requirements to test large snubbers prior to 1980 and those plants that have implemented updated technical specifications (Palisades on 3/12/82) have only recently begun to test these large snubbers.

Snubber Events

Palisades

The condition of the snubbers at Palisades was discovered because of surveillance testing requirements implemented with updated plant technical specification requirements in response to Reference 5. The NRC investigations into the event also revealed weaknesses in the original specifications in that lock-up requirements were not specifed and functional tests were not required. Also, there may have been weaknesses in manufacturing procedures to control parts and/or design changes. However, the investigation (Reference 4) concludes that the Palisades plant was probably the only plant affected. This "qualified" conclusion was based on information that only two other nuclear plants could have been affected (Nine Mile Point 1 and Oyster Creek), but only one shop order could be found and it was marked "No Special Requirements". The report further indicates that ITT-Grinnell personnel believed this was the usual course of business, except for Palisades, during the 1968-1970 time period.

The primary emphasis during this study to identify other snubber problems was to restrict the search to large snubbers only. These would normally be used on steam generators, main steam lines or possibly feedwater lines. Several events were found documented in LERs, IE Inspection Reports, 10 CFR Part 21 reports, and a PNO. Each event appears to be somewhat special yet indicative of possible generic importance and is therefore discussed separately.

H. B. Robinson and Point Beach

A 10 CFR Part 21 Report (reference 7) identified failure of a large snubber at H. B. Robinson while undergoing testing. This was one of 12 snubbers at the plant supplied by Ebasco Services. This testing was part of the surveillance test requirements in response to new technical specifications implemented on March 3, 1982 and apparently was the first testing of these snubbers since installation in 1969. The hydraulic snubber failed at 412 kips, which is below the specification of 470 kips, when one of the self aligning ball bushings failed (Torrington part number 30SBB48). At the time of manufacture, the load rating for this part was 899 kips and one of the 12 snubbers was tested successfully at the 470 kips specification. Subsequent to manufacture, the Torrington bearing (30SBB48) rating was revised downward to 300 kips from the original 899 kips (Reference 7 does not identify when the downrating occurred).

This hydraulic snubber was manufactured by Anchor-Holth which has withdrawn from the design of new snubbers. However, as of May 31, 1984, all design rights, documents and data were formally conveyed to Paul-Munroe Hydraulics, Inc., 1701 West Sequois, Orange, California 92668. The corrective action recommended by Paul Munroe, Inc. was to replace the existing self aligning ball bushing with a new self aligning ball bushing with a static radial load rating exceeding the load rating of the snubbber, using Paul-Munroe part number PA-89467.

The failure of this type of bushing was also reported to affect the Point Beach plants which have 12 snubbers of a 500 kip rating with an original manufacture date of 1969. The Point Beach plants are two loop, Westinghouse PWRs. Each steam generator has three snubbers for both Units 1 and 2. A review covering these plants also identified that two 800 kip snubbers are installed on each main steam line. These 800 kip snubbers contain a Torrington bushing that originally was rated at 1600 kips that was down rated to 533 kips. A licensee evaluation apparently determined that all snubber loads at Point Beach were less than the 412 kips which caused failure of the H. B. Robinson snubber. As a result, a decision was made on June 8, 1984 that snubbers are operable at Point Beach and no immediate action was required. However, during discussions with the resident inspector it was revealed that current licensee plans are to replace the bushings at the next outage for each plant (planned for September, 1984 for Unit 2 and April, 1985 for Unit 1).

A subsequent letter from Paul-Munroe Hydraulics, Reference 8, identified further concern about the design and construction of these snubbers. Their analysis and evaluation has revealed that some components of the snubber (Blind End Cover and Piston Rod Eye) can experience stresses that exceed their respective material yield points at loads below the specified faulted load of 470 KIPS force. Hence, this condition causes plastic deformation of these components. The resultant safety hazard caused by the deformation was stated as total inoperability of the snubber. The letter indicates further investigation is proceeding to review the potential impact of other snubbers originally manufactured by Ankor-Holth and installed in nuclear plants.

These events at Robinson and Point Beach identify weaknesses in original design, functional qualification testing, and procedures to control and notify users of changes (down rating) in equipment capability. The testing that was done apparently was to satisfy a specification limit rather than the actual load rating of the component. This aspect could have ramifications pertaining to definition of an acceptable surveillance test when the qualification testing has not been conducted. These deficiencies were discovered through required testing as part of new surveillance requirements in updated technical specifications at H. B. Robinson. However, the load capacity testing that was conducted appears to be more than the technical specifications require. Although the technical specifications at Point Beach were updated in May of 1982 (two months after H. B. Robinson), we have not been able to confirm whether any of the subject snubbers have been tested or have been scheduled for testing.

Salem 1 and 2

During surveillance testing of hydraulic snubbers in late October, 1982, four 100 kip steam generator snubbers were found out of specification on either the bleed rate test or acceleration tests (References 9 and 10). Subsequent testing determined that all 16 snubbers failed the bleed rate tests and six had excessive lock-up velocities. These snubbers were Rexnord, Inc., 16 inch bore, 100 kip hydraulic snubbers. These snubbers had originally been exempted from surveillance testing and this first testing was in response to new technical specification requirements implemented in February, 1982. The snubbers were manufactured in 1974.

The cause of the snubber failure to lock-up was apparently fluid leakage past deteriorated seals. The piston seals are made of ethylene propylene (EPR) rubber material. Reference 10 indicates the manufacturer suggested shelf life of the EPR rubber seals is seven years.

Similarly, Reference 11, reports failure, during test, of two steam generator hydraulic snubbers to meet requirements for both acceleration and bleed rate tests for Salem Unit 2 in February, 1983. The reported cause of failure was excessive leakage past the piston seals which had deteriorated due to aging. These snubbers were also Rexnord, Inc., 16 inch bore, 100 kip hydraulic snubbers. The corrective action for both Unit 1 and Unit 2 snubbers was to disassemble and refurbish them with piston seals and parts that were identical with the original designs. The snubbers

were retested and satisfactorily achieved lock-up and bleed rate velocities within specification requirements. However, there was no information relative to testing concerning load capability or capacity of the snubbers.

The Salem events appear to illustrate failure to operate as designed because of component deterioration since original manufacture in 1974. The distinction between time since manufacture rather than plant operating time or component service time appears significant. Unit 1 became operational in 1977 (approximately 5 years of operation up to 1982) and Unit 2 became operational in late 1981 (approximately 1 1/2 years of operation up to early 1983). Therefore, these events illustrate potential snubber inability to lock-up due to component degradation or aging during either operation or simply shelf time without use. The stated shelf time was seven years. For Unit 1, reference 10 indicates that failure of all 16 snubbers would result in permanent damage to the system, but the system would perorm as analyzed in the FSAR. We do not have the detailed report which was the basis for this conclusion.

Davis Besse

During a plant inspection by NRC staff prior to plant startup after an outage, four of the six large bore steam generator hydraulic snubbers were observed to have damaged piston rod wiper seals (Reference 12 and 13). These snubbers were manufactured by ITT-Grinnell. The licensee subsequently removed all six, 20 inch steam generator snubbers and eight, 8 inch primary coolant pump snubbers and returned them to ITT-Grinnell for overhaul.

Specific information on the piston rod wiper seal material was not stated. However, the time when leakage occurred was approximately five years after the original scheduled date of commercial operation. Hence, this may indicate a situation similar to that observed at Salem pertaining to seal shelf life.

Zion 1 and 2

References 14 and 15 discuss excessive leakage discovered on large bore hydraulic snubbers at Unit 1. During routine surveillance, excessive leakage was identified with three of the 16 large bore, Bergen-Patterson snubbers installed on the four steam generators inside containment. Disassembly of the snubbers at the site revealed significant gouging of the piston rod (ram) and gland seal surfaces above and below the horizontal position. During discussions with the manufacturer, it was learned that similar gouging had been experienced at the Surry Nuclear Power Plant on large bore snubbers. Although that damage had been initially thought to be due to a weld or fluid contamination, the gouging was subsequently attributed to close proximity components (the piston rod and gland) that were manufactured from materials with a similar surface hardness.

The resolution to permit Units 1 and 2 to return to power involved several corrective actions including both surveillance during operation and development of methods to verify function of the snubbers. There were several actions imposed to verify snubber reservoir levels such as on a weekly basis,

immediately following an earthquake, and after every 100°F temperature change. In addition, a procedure was to be developed to functionally test these 12 inch Bergen-Patterson snubbers. All 16 of the Unit 2, 12 inch Bergen-Patterson snubbers were to be inspected, repaired, and modified during the May 1980 refueling outage. Further, Reference 15 identified areas for evaluation which included improper function of the bleed valve pressure compensator; particles in the hydraulic fluid; and observations during the extended LOCA steam test that included fluid leaking out of the reservoir, leaking at the flange seal, and corrosion at the bleed valve area within the control valve block.

These events at Zion raise concerns relative to initial design, materials and functional qualification of this equipment. Discovery of the situation in 1979 and 1980 was approximately seven years after initial commercial operation.

Byron, Braidwood, Marble Hill

The snubbers in question were manufactured by Boeing and were to be used at the Byron, Braidwood and Marble Hill plants. Reference 16 identifies that three steam generator snubbers from the Braidwood facility were tested at the ITT-Grinnell facility in Warren, Ohio and all three failed to meet the test criteria. During testing, the metallic seals failed to hold snubber hydraulic fluid at loads less than 10 percent of the snubber rated capacity. Each steam generator would have two snubbers to protect the steam generators from excessive movement in the event of an earthquake and loss of coolant accidents. There are four steam generators for each plant. Reference 16 indicates that Region III will continue to monitor the licensee's evaluation of these snubbers. However, preliminary indications suggest that corrective efforts will include redesign and modification of the snubbers. The test results appear to raise several concerns relative to original design and functional qualification programs.

Overview

The events cited illustrate operational deficiencies with large hydraulic snubbbers that affected 13 Nuclear power plants (not all plants are operational and at least one has been cancelled). The snubbers were manufactured by five different companies. The snubber manufacturers and affected plants are as follows:

Snubber Manufacturer	Nuclear Plant Using the Snubbers
ITT-Grinnell	Palisades, Davis Besse
Anchor-Holth (Paul Munroe)	H. B. Robinson, Point Beach 1 & 2
Rexnord	Salem 1 & 2
Bergen-Patterson	Zion 1 & 2, Surry
Boeing	Byron, Braidwood, Marble Hill

A review of the available event data suggests several deficiencies have occurred that have rendered large, hydraulic snubbers inoperable. The failure mode of concern has been one of inability to lock-up under seismic or dynamic loads. The apparent deficiencies are as follows:

1. inadequate design
2. inadquate control of design changes
3. inadequate control of manufacturing procedures to implement design changes
4. indaequate functional specifications
5. lack of requirements for functional qualification testing
6. derating of subcomponents after equipment was placed in service
7. component aging during service or shelf life
8. questionable qualification testing
9. exemption of large snubbers from surveillance testing requirements in technical specifications

It appears significant that many of these deficiencies were eventually discovered because of snubber failures during testing required by recent changes in technical specifications for some plants.

The effort to implement changes in technical specifications has been ongoing since 1980. We understand from discussions with NRR staff that this effort is generally divided between hydraulic snubbers and mechanical snubbers for control purposes. Also, for some plants, the Regional Offices have the lead to implement the technical specification changes. One reason for the grouping is that some plants may have only hydraulic snubbers and no mechanical snubbers or vice versa. For hydraulic snubbers, it appears that techncial specification changes to remove the exemption from surveillance testing of snubbers greater than 50 kips were implemented in 1982 and 1983 for most of the plants that have taken this step. Therefore, only a very few plants have actually tested these large snubbbers. In addition, approximately 25 operating plants still have not implemented the new technical specifications (we understand approximately 6-8 plants may complete this by the end of 1984). Hence, testing for these plants may not take place until two years after the implementation date of the technical specification.

The events cited in this report have all been for hydraulic snubbers. Furthermore, we would expect that most older operating plants have used hydraulic snubbers because mechanical snubbers have been a relatively recent introduction. However, there are some plants with large mechanical snubbers. We believe there are approximately 20 plants that still have not implemented new technical specifications to incorporate surveillace testing for mechanical snubbers.

FINDINGS

This study has identified several events that involved failure of large, hydraulic snubbers to lock-up when subjected to seismic or dynamic load conditions. This phenomenon represents inability of the snubber to perform its major safety function which is to provide restraint and prevent motion of large components such as steam generators when subjected to seismic loads or main steam line break loads. The current study pertains to hydraulic snubbers with rated loads greater than 50 Kips.

As a result of the evaluation, the following findings are provided:

1. Testing of large hydraulic snubbers in current service in operating plants has demonstrated they were unable to provide the desired safety function because of failure to lock-up or inability to sustain loads below the rated load of the component. These snubber events impact at least 13 plants.

2. All 16 steam generator snubbers at Palisades were determined to have been inoperable since initial operation of the plant more than 10 years ago. These snubbers have recently been repaired to meet requirements of the plant.

3. The snubbers that failed in the events reviewed by this study were made by five different manufacturers (ITT-Grinnell, Anchor-Holth, Rexnord, Bergen-Patterson, and Boeing).

4. The deficiencies that either led to inoperability of these large snubbers or delayed discovery of inoperability cover a very broad program spectrum involving design, manufacture, functional qualification, service aging, and surveillance. The specific weaknesses identified are: (a) inadequate design, (b) inadequate control of design changes, (c) inadequate control of manufacturing procedures to implement design changes, (d) inadequate functional specification, (e) lack of requirements for functional qualification testing, (f) derating of subcomponents after equipment was placed in service, (g) component aging during service or shelf life, (h) questionable qualification testing, and (i) exemption of large snubbers from surveillance testing requirements in technical specifications.

5. There are indications that additional subcomponent design deficiencies are present (other than the subcomponent that failed during test), that could result in plastic deformation and subsequent inoperability of snubbers manufactured by Anchor-Holth (Reference 8). This issue is apparently under review, but we have no information relative to the affected snubbers or plants.

6. In many of the events, snubber inoperability was discovered during the first surveillance tests that were required by technical specification changes implemented in the last two years. Previous technical specifications exempted these snubbers (greater than 50 KIPS) from surveillance testing.

7. The primary aging mechanism reported involved failure of ethylene propylene (EPR) rubber seals to retain hydraulic fluid. The stated shelf life was seven years.

8. Approximately 25 plants do not have updated technical specifications that require surveillance testing of all snubbers; i.e., remove the previous exemption for surveillance testing for snubbers with rated loads greater than 50 KIPS. A review indicates that 23 of the 25 plants began commercial operation in or before 1977 and have been in service for seven years or more.

9. Some snubbers have failed when subjected to loads less than the rated load of the equipment or less than maximum plant loads. Since initial functional qualification has not been demonstrated, it appears that the currently proposed updated technical specifications should be amended to include a maximum load test in addition to the activation rate and bleed or release rate tests.

CONCLUSIONS AND RECOMMENDATIONS

This evaluation demonstrates that many large, hydraulic snubbers, installed in operating plants, would not have functioned properly to perform their intended safety function. These snubbers were supplied by five different manufacturers and the deficiencies span the complete spectrum from initial design to manufacture, qualification, and surveillance. Furthermore, at least 13 plants have been impacted. This evidence points toward a conclusion that doubt exists relative to whether existing programs can provide reasonable asssurance that large, hydraulic snubbers will operate to provide the intended design function of restraint during seismic or other dynamic load conditons.

The primary safety issue is that failure of these large snubbers to perform their design function (restraint) could potentially result in accidents outside the plant design basis such as a combined primary break and steam generator blowdown or blowdown of two steam generators. AEOD should consider initiating a case study to determine possible generic implications and identify bases for changes that will lead to confidence in large snubber operability.

It would seem that preliminary NRC efforts should address the following:

1. Expedite the current program to implement proposed technical specification changes so that all operating plants will have a requirement to perform surveillance tests on large snubbers.

2. Consider that initial surveillance tests should be completed on an expedited basis rather than delayed as much as 18 months to two years after the technical specifications are in place.

3. Consider adding a new section to the technical specifications to require a test to confirm snubber load capacity (rating).

4. The Office of Inspection and Enforcement should issue an information notice to promptly disseminate this information.

Although further evaluation via an AEOD case study is being considered, there are several aspects of the situation that could possibly be handled more efficiently and effectively if the problem could be addressed by an industry group on a generic basis. The operational events cited in this report illustrate a need for action to assure snubber operability. However, the breadth of the problem in terms of numbers of manufacturers and affected plants suggests that review on an individual basis may not be an efficient approach. In particular, it appears that several plants have had failures and are aware of some corrections that licensees not yet aware of the situation could find extremely helpful in resolving the issue. Attention by an owners group or other industry group could heighten awareness of the problems by all licensees, and lead to timely acceptance and implementation of the new technical specifications for plants that have not yet completed that effort.

REFERENCES

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3. NRC, Inspection Report No. 50-255/83-25, Nov. 25, 1983

4. NRC, Inspection Report 99900282/84-01, "Inspection of ITT-Grinnell; Warren, Ohio," August 13, 1984.

5. Letter from D. G. Eisenhut, NRC, to all power reactor licensees (except SEP licensees) dated November 20, 1980, Subject: Technical Specification Revisions for Snubber Surveillance.

6. USNRC, "Qualification and Acceptance Tests for Snubbers Used in Systems Important to Safety," USNRC Draft Regulatory Guide SC 708-4, Rev. 1, February 1981.

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12. NRC, Inspection Report 50-346/79-33, February 12, 1980.

13. NRC, Inspection Report 50-346/80-22, August 18, 1980.

14. NRC, Inspection Report 50-295/79-26; 50-304/79-25, February 7, 1980.

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