October 20, 1989

MEMORANDUM FOR: Charles E. Rossi, Director
Division of Operational Events Assessment, NRR

James E. Richardson, Director
Division of Engineering Technology, NRR

FROM: Thomas M. Novak, Director
Division of Safety Programs, AEOD

SUBJECT: SOME OBSERVED EROSION FAILURES MAY NOT BE ADDRESSED BY PROPOSED MONITORING PROGRAMS

A review of erosion induced failures from 1980 through 1988 is enclosed (E. J. Brown, "Excessive Valves Body Erosion at Brunswick," AEOD/E908, September 29, 1989). The study was initiated as a result of a valve body erosion event at Brunswick Unit 1 on December 14, 1988. In the report, we conclude there is a broad range of erosion induced problems, including cavitation induced valve body erosion, valve assembly degradation due to vibration, pipe support damage due to vibration, piping erosion downstream of throttled valves, severe degradation of pumps in the service water system and RHR service water system, low-flow-related damage to pumps in other systems, and corrosion/erosion fouling that may adversely impact heat transfer capability of service water system heat exchangers or piping rather than pump or valve operability.

The NRC has issued several generic communications addressing these issues. These include Information Notices 83-055, 89-001, 89-008; Bulletin 88-04; and Generic Letter 89-13. The Information Notices identify the technical concerns involving valve assembly vibration, piping support vibration, pump and valve erosion, and low flow pump erosion, but they don't include specific action. Bulletin 88-04 requests that licensees investigate parallel pump operation for dead-heading during miniflow operation and the adequacy of the miniflow line. Generic letter 89-13 essentially concentrates on heat exchangers in service water systems.

It appears there are two efforts established to address these problem areas. First, the BWR Owners Group (BWROG) has established an effort to cover "target" valves in systems such as RHR, HPCI, RCIC, and HPCS as well as two RHR service water system valves. This effort will concentrate on valve cavitation, but will not address pump degradation due to low-flow conditions. The second effort involves licensee response to Generic Letter 89-13 pertaining to service water systems. This review, too, will not address low-flow operation of pumps. Further, during NRC staff meetings with the BWROG, there were indications from

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a NUMARC representative that they would review these erosion concerns with separate PWR Owners Groups. We are not aware that generic PWR reviews have evolved from this process.

Therefore, it appears that low-flow-induced degradation of pumps will not be covered by either the BWROG effort or Generic Letter 89-13. This degradation cannot be detected by inservice testing programs in accordance with Section XI of the ASME Code. Thus, the only warning is pump failure. In addition, the industry effort for review of PWR system erosion does not seem to have resulted in a generic review of plants. We believe that NRR should pursue both low-flow pump damage and PWR plant monitoring issues.

Original Signed by:
Thomas M. Novak

Thomas M. Novak, Director
Division of Safety Programs, AEOD

Enclosure: As stated

cc w/enclosure:
L. Shao, RES

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

OCT 18 1989

MEMORANDUM FOR: Jack E. Rosenthal, Chief
Reactor Operations Analysis Branch
Division of Safety Programs, AEOD

AEOD/E908

THRU: Matthew Chiramal, Chief
Engineering Section
Reactor Operations Analysis Branch
Division of Safety Programs, AEOD

FROM: Earl J. Brown
Engineering Section
Reactor Operations Analysis Branch
Division of Safety Programs, AEOD

SUBJECT: EXCESSIVE VALVE BODY EROSION AT BRUNSWICK

A copy of a technical review report on excessive valve body erosion at Brunswick is enclosed for your information.

The report indicates there is a broad scope of erosion related problems that could have an adverse impact on safety related system operation or availability. The problems include cavitation induced valve body erosion, valve assembly degradation due to vibration, piping support damage due to vibration, piping erosion downstream of throttled valves, severe degradation of pumps in the service water system and RHR service water system, low flow related damage to pumps in other systems, and corrosion/erosion fouling that may adversely impact heat transfer capability of service water system heat exchangers or piping rather than pump or valve operability. The industry action by the BWR owners group will cover "target" valves, but not pumps. Thus, it appears that low flow damage mechanisms for pumps may not be adequately covered by either the BWR owners group or Generic Letter 89-13 for Service Water Systems.

Earl J. Brown

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AEOD TECHNICAL REVIEW REPORT

UNIT: Brunswick 1
DOCKET NO.: 50-325
LICENSEE: Carolina Power and Light Company
NSSS/AE: General Electric/UE&C

TR REPORT NO.: AEOD/E908
DATE: September 29, 1989
EVALUATOR/CONTACT: E. J. Brown

SUBJECT: EXCESSIVE VALVE BODY EROSION AT BRUNSWICK

EVENT DATE: December 14, 1988

SUMMARY

Excessive valve body erosion was discovered in the LPCI injection valve, E11-F017B, at Brunswick Unit 1. The licensee investigation indicated that valve throttling was a major contributor to the erosion. A review of previous AEOD reports, the Sequence Coding and Search System, and NPRDS identified four previous AEOD reports that addressed erosion events and more than 200 other erosion events. The event data indicate a pattern of erosion damage and degradation of components in several safety systems (RHR, HPCI, RCIC, service water, and RHR service water). The primary causes appear to be cavitation related to either throttling devices such as valves, orifices, and reducers or low flow conditions. An NRC information notice, IN 89-01, was issued on the valve erosion event and Generic Letter 89-13 was issued on service water system problems. It appears that action by the BWR owners group will concentrate on "target" valves in various systems. However, it appears that low flow damage mechanisms for pumps may not be adequately covered by either the BWR owners group action or Generic Letter 89-13 for service water systems. Also, it is not clear that industry efforts to monitor PWR plants have evolved as anticipated.

DISCUSSION

On December 14, 1988, the licensee discovered excessive erosion of the valve body downstream of the seat during disassembly of the LPCI injection valve, E11-F017B, for Brunswick Unit 1. The valve disassembly was being conducted as part of the plant long term maintenance program. The valve body had erosion pockets with a minimum wall thickness of 1.7 inches. The original wall thickness was between 3.5 and 4 inches. Inspection of the identical valve, E11-017A, on the other LPCI train revealed a wall thickness of 1.4 inches in the same area of the valve body. Preliminary investigation by the licensee indicated that a major contributor to the erosion of these valve bodies could be the throttling operation of the valves. The licensee discovered erosion in other throttle valves in the LPCI system. NRC Information Notice IN 89-001 (Ref. 1) was issued on this event.

The effort to ascertain the extent of this problem included a review of previous AEOD reports, a search of the SCSS LER database, and a search of the NPRDS equipment failure database. This review identified three engineering evaluation (EE) reports that addressed erosion and effects of valve throttling in nuclear plants and one case study that included erosion as a degradation

mechanism. The three EE reports are: "Misuse of Valve Resulting in Vibration Damage to the Valve Assembly and Pipe Supports," E315 (Ref. 2); "Erosion in Nuclear Power Plants," E416 (Ref. 3); and "Pump Damage Due to Low Flow Cavitation," E807 (Ref. 4). The case study report was: "Service Water System Failures and Degradations In Light Water Reactors, C801 (Ref. 5). The LER search using the Sequence Coding Search System (SCSS) identified 64 valve erosion events from 1980 through 1988. The NPRDS search identified over 140 events covering the period from 1985 to 1988.

AEOD Reports

° AEOD/E315

This report was an evaluation of two events involving operation of the residual heat removal system (RHR) in the shutdown cooling mode at the Susquehanna Unit 1 plant. The F017B valve (the same valve with erosion at Brunswick) was used to throttle flow in the shutdown cooling mode of the RHR system. This valve was observed vibrating severely. The packing was lost, the position indicator had fallen off, the adjacent pipe hanger had two broken welds, and another pipe hanger had cracked welds. Several pipe hanger weld cracks were observed on the other train also. Four months later the valve disc separated from the stem. The investigation found that RHR flow for the shutdown cooling mode could be distributed as a minimum 1/4 heat exchanger flow and 3/4 bypass flow. This flow distribution in combination with a very low level of decay heat created a situation in which it was desirable to reduce flow through the RHR heat exchanger, but this could only be accomplished by throttling valve F017B.

The report suggested that an information notice be issued. IE IN 83-055 (Ref. 6) was issued on the event. It was concluded that the severe damage to the LPCI system injection valve, F017B, was directly related to RHR system flow limitations that result from a combination of system design, configuration, flow control, and the low level of decay heat. The report suggested that NRR review system operation for compatibility of valve assembly design and qualification including frequency of operation and vibration, together with the adequacy of the shutdown cooling mode system flow control.

° AEOD/E416

This study was an evaluation of more than 140 reports involving erosion in pumps, valves, heat exchangers, and piping. There were 31 reports about valves (a report may include several valves) distributed among 11 PWRs, 19 BWRs, and 1 HTGR. The erosion events involved both steam and water systems. The erosion problems included wear through the wall of valve bodies, deterioration of rubber seats, and wear of retaining devices. A major finding was that "erosion events appear related to the specific water source with suspended solids (raw water, radwaste, etc.), the use of throttling devices (valves and orifices), or a combination of these effects." This study also indicated that piping erosion events were related to use of throttling devices such as valves, orifices, and reducers. Approximately 40 percent of the 60 piping erosion reports were related to flow throttling. Thus, if valve throttling is used, the program to monitor erosion should include both the valve and downstream piping.

The report concluded that constructive actions to address erosion problems could include: (1) cognizance of the phenomenon for certain systems and sites, (2) identification of specific plant equipment and physical configurations that may be susceptible to erosion, and (3) implementation of monitoring programs to detect degradation of equipment (pumps, valves, heat exchangers, and piping).

° AEOD/E807

Erosion and vibration resulted in failure of an emergency service water pump at Susquehanna Unit 1. Subsequent disassembly of the pump revealed that the bottom portion of the pump suction bell had separated from the body and had fallen into the pump pit. Inspection of the residual heat removal service water pumps revealed cavitation damage similar to that found in the service water pumps. The cavitation was caused by flow recirculation due to operating the pumps at low flow rates. The RHRSW pumps had been operated at less than 50 percent flow most of the time. A search of operational experience database files identified similar pump degradation from low flow operation at Vermont Yankee, H. B. Robinson 2, Turkey Point 3, Haddam Neck, and a foreign plant.

The study concludes that operation of centrifugal pumps at low flow conditions for extended periods of time can cause cavitation damage from flow recirculation. The cavitation erodes the impeller and the internal pump casing wall. The low flow conditions could occur during performance of the inservice surveillance tests by restricting flow through the mini flow bypass line, or running the pumps in a low flow mode for a system designed for a wide range of flows. NRC Bulletin 88-04 (Ref. 7) addressed the miniflow test configuration. NRC Information Notice 89-008 (Ref. 8) was issued to highlight pump damage caused by low-flow operation.

° AEOD/C801

This report was a comprehensive review and evaluation of service water system failures and degradations observed in LWRs from 1980 to 1987. The causes of failures and degradations include various fouling mechanisms (sediment deposition, biofouling, corrosion and erosion, pipe coating failures, calcium carbonate, foreign material and debris intrusion); single failure and other design deficiencies; flooding; multiple equipment failures; personnel and procedural errors; and seismic deficiencies. Of 980 operational events during this period, 276 were deemed to have potential generic safety significance. A majority (58 percent) of the events involved system fouling. The fouling mechanisms included corrosion and erosion (27 percent), biofouling (10 percent), foreign material and debris intrusion (10 percent), sediment deposition (9 percent), and pipe coating failure and calcium carbonate deposition (1 percent).

The recommendations from the study were:

(1) Conduct, on a regular basis, performance testing of all heat exchangers which are cooled by the service water system and perform a safety function to verify heat exchanger heat transfer capability.

(2) Require licensees to verify that their service water systems are not vulnerable to a single failure of an active component.

(3) Inspect, on a regular basis, important portions of the piping of the service water system for corrosion, erosion, and biofouling.

(4) Reduce human errors in the operation, repair and maintenance of the service water system.

Generic Letteer 89-13 (Ref. 9) was issued July 18, 1989 to address the issues identified in Case Study C801.

LER SCSS Search

All LERs were searched using the automated database (SCSS) to identify those LERs in which the words "erosion" and "valves" both appear. Sixty-four LERs from 1980 through 1988 were identified. About half the events identified by this search occurred after our 1984 study of erosion, E416. These events did not appear to include excessive wear similar to that reported at Brunswick. In general, the data was similar to that reviewed in the E416 study. There were many events with valves that failed leak rate tests due to erosion of the disc. This was corrected by lapping. Other reported causes were erosion due to steam cutting, and expansion of a small leak from a gasket, "O" ring, or steam packing.

NPRDS Search

The search strategy for the NPRDS was to identify valves with normal/abnormal wear. It was further refined with a narrative search for the word "erosion." There were over 140 reports identified from 1985 through 1988 for all safety classes (1, 2, 3, and 4). The type of reported erosion was similar to that in the AEOD studies and the recent SCSS review. There were no narrative descriptions that indicated erosion as extensive as that at Brunswick Unit 1. However, there were reports that identified other valves in the RHR system with erosion damage. Some of the valves were F015B (this valve is in series with F017B), F024B (RHR test line control valve), 1001-28A and B (outboard isolation valves), and 1001-36A (RHR pump test line). Thus, the events reported to NPRDS illustrate erosion patterns similar to those previously identified in the AEOD reports E315, E416, and E807.

Industry Program

The BWR Owners Group (BWROG) has established an effort to address valve erosion due to cavitation induced by valve throttling. The BWROG objective is to "Provide a guidance document for individual utilities to establish and implement a valve assessment/inspection program in order to eliminate valve erosion problems." The BWROG program is a multistep process including meeting with NRC staff to present the plan, schedule, and discuss results prior to final disposition for use by licensee; surveying all BWROG participating utilities to identify safety-related valves used for throttling; request/collect data on cavitation erosion; identify methods used by utilities to eliminate erosion problems; and prepare a BWROG Guidance Report. Information about the program was presented to ACRS on April 27, 1989.

Based on data reviewed to date, the effort has identified approximately 15 or 16 "target" valves in BWR safety-related water systems. The appropriate number of valves depends on whether the BWR has HPCI or HPCS. The approach addresses eight valves in the RHR system, two in the RHR service water system, two in the core spray system, one to three in the HPCI/HPCS systems, and one in the RCIC system. For all systems other than RHR, the "target" valves are test return valves except for two heat exchanger flow control valves.

AEOD staff have participated with NRR during the BWROG presentations. The previously cited AEOD reports E315, E416, and E807 were identified for industry information. The concerns expressed by AEOD were that cavitation induced damage has exhibited a broader scope than simple valve body erosion. In addition to valve body erosion, the AEOD studies have identified cavitation induced damage as valve assembly degradation due to vibration, piping support damage due to vibration, piping erosion downstream of throttled valves, severe degradation of pumps in the service water system and the RHR service water system, and low flow related damage to pumps in other systems. It is our understanding that the BWROG program will be limited to "target" valve body erosion. Further, it was indicated by the BWROG that pumps will not be addressed and, if service water pumps are a concern, they should be covered as part of any NRC action related to service water systems. In addition, a representative from NUMARC indicated that efforts to address erosion in PWR plants would be reviewed with the various owners groups. We are not aware of subsequent action (after April 1989) by any PWR owners group.

OVERVIEW

The AEOD reports have identified a relatively broad scope of erosion related problems involving the RHR system, service water system, and RHR service water system. The problems include cavitation induced valve body erosion, valve assembly degradation due to vibration, piping support damage due to vibration, piping erosion downstream of throttled valves, severe degradation of pumps in the service water system and RHR service water system, low flow related damage to pumps in other systems, and corrosion/erosion fouling that may adversely impact heat transfer capability of service water system heat exchangers or piping rather than pump or valve operability. NRC generic communications that pertain to these issues include Information Notices 83-055, 89-001 and 89-008; Bulletin 88-04, and Generic Letter 89-13.

It appears that there are two efforts established to address these problem areas. First, the BWROG has established an effort to cover "target" valves in systems such as RHR, HPCI, RCIC, and HPCS as well as two RHR service water system valve. This BWROG effort appears to be a thorough effort that will concentrate on valve erosion and cavitation but will not address other components. Presumably, if valve cavitation is reduced, there is the potential for beneficial reduction in vibration problems with piping supports and valve assembly operation.

The second effort involves licensee response to Generic Letter 89-13 pertaining to service water systems. As previously indicated, the corrosion/erosion aspect of this effort appears to emphasize fouling that may impact heat transfer capability rather than degradation of components such as pumps and valves. Thus, it would seem that low flow pump erosion may not receive appropriate monitoring to address the concerns identified in E807 (Ref. 4).

FINDINGS

1. AEOD studies have identified a broad scope of cavitation related component damage. These include valve body erosion, valve assembly degradation due to vibration, piping support damage due to vibration, piping erosion downstream of throttled valves, severe degradation of pumps in the service water system and RHR service water system, low flow damage to pumps in other systems, and service water system failures and degradations involving fouling mechanisms that include corrosion and erosion.

2. The conclusions, suggested actions, and recommendations in AEOD reports E315, E416, E807, and C801 appear to be reasonable approaches to minimize effects of this damage in the future.

3. NRC has issued several generic communications addressing these erosion issues. These documents are Information Notices 83-055, 89-001 and 89-008; Bulletin 88-04; and Generic Letter 89-13.

4. The BWROG effort appears to be a thorough effort pertaining to erosion of "target" valves. NRR is following this effort. We understand the effort will not include monitoring of pumps.

5. It does not appear that any formal effort has been established by PWR owners groups to review these erosion issues.

6. The damage mechanism to centrifugal pumps under low flow conditions identified in E807 (Ref. 4) does not appear to be appropriately addressed by either the BWROG action or Generic Letter 89-13.

CONCLUSIONS

The event data from 1980 through 1988 exhibit a consistent pattern of erosion damage and degradation of components in several safety related systems. The primary causes appear to be cavitation related to either throttling devices such as valves, orifices, and reducers or low flow conditions. This results in either long term erosion wear or a more immediate destructive vibration problem. However, the root causes leading to erosion or cavitation damage appear related to system flow limitations with special concern at low flows relative to full system capacity. A combination of system design, configuration, flow control and low flow requirements conspire to cause equipment damage. The conclusions, suggested actions and recommendations in AEOD reports E315, E416, E807, C801, and the NRR Generic Letter 89-13 appear useful to monitor damage and degradation due to erosion. However, it appears that flow damage mechanisms for pumps may not be adequately addressed by either the BWROG or GL 89-13. Also, it is not clear that industry efforts to monitor PWR plants has evolved as anticipated.

REFERENCES

1. U.S. Nuclear Regulatory Commission, NRC Information Notice No. 89-001, Valve Body Erosion," January 4, 1989.

2. U.S. Nuclear Regulatory Commission, E. J. Brown, "Misuse of Valve Resulting in Vibration and Damage to the Valve Assembly and Pipe Supports, "AEOD/E315, July 7, 1983.

3. U.S. Nuclear Regulatory Commission, E. J. Brown, "Erosion in Nuclear Power Plants," AEOD/E416, June 11, 1984.

4. U.S. Nuclear Regulatory Commission, C. Hsu, "Pump Dmage Due to Low Flow Cavitation," AEOD/E807, October 18, 1988.

5. U.S. Nuclar Regulatory Commission, P. Lam and E. Leeds, "Service Water System Failures and Degradations In Light Water Reactors," AEOD/C801, August 1988.

6. U.S. Nuclear Regulatory Commission, IE Information Notice 83-055, "Misapplication of Valves by Throttling Beyond Design Range," August 22, 1983.

7. U.S. Nuclear Regulatory Commission, NRC Bulletin No. 88-04, "Potential Safety-Related Pump Loss," May 5, 1988.

8. U.S. Nuclear Regulatory Commission, NRC Information No. 89-008, "Pump Damage Caused by Low-Flow Operations," January 26, 1989.

9. U.S. Nuclear Regulatory Commission, J. G. Partlow to All Licensees, "Service Water System Problems Affecting Safety-Related Equipment (Generic Letter 89-13)," July 18, 1989.