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UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF INSPECTION AND ENFORCEMENT
WASHINGTON, D.C. 20555

June 2, 1982

IE BULLETIN NO. 82-02: DEGRADATION OF THREADED FASTENERS IN THE REACTOR COOLANT PRESSURE BOUNDARY OF PWR PLANTS

Addressees:

All pressurized water nuclear power reactor facilities holding an operating license (OL), for action. All other nuclear power reactor facilities holding an operating license or construction permit (CP), for information.

Purpose:

The purpose of this bulletin is to: (1) notify licensees and construction permit holders about incidents of severe degradation of threaded fasteners (bolts and studs) in closures in the reactor coolant pressure boundary (RCPB), and (2) to require appropriate actions. A response to this bulletin is required from pressurized water reactors (PWRs) holding an operating license as discussed below.

Description of Circumstances:

In May 1980, Omaha Public Power District (OPPD) submitted a special maintenance report to the NRC about the significant corrosion wastage experienced with closure studs in the reactor coolant pumps at its Fort Calhoun facility. The corrosion wastage was attributed to boric acid attack as a result of leakage at flexitallic gasketed joints between the pump casing and pump cover. These closure studs are 3.5 inches in diameter, and are manufactured of SA 193-B7 (AISI 4140) low-alloy, high-strength steel. Accordingly, the NRC issued Information Notice No. 80-27 on June 11, 1980 to all PWR licensees about the potential for undetected boric acid corrosion wastage and emphasized the need for supplemental visual inspection of pressure-retaining bolting in pump and valve components. Subsequently, similar occurrences of corrosion wastage from borated water leakage have been identified at other PWR plants, as discussed below.

On March 10, 1982, the NRC was notified by Maine Yankee Atomic Power Company and Combustion Engineering (C-E) that during routine disassembly of a steam generator primary manway at Maine Yankee, 6 of the 20 manway closure studs failed and another 5 were found, by ultrasonic examination using specialized techniques, to be cracked. Leakage had been noted from this manway during the current operating cycle and several efforts were made to eliminate the leakage. These efforts involved increasing the joint operating compression through torquing the studs to hydrotest levels and repeatedly injecting Furmanite sealant. Normal plant operation continued until a planned maintenance outage.

Preliminary results of a metallurgical analysis C-E performed on the affected studs have indicated that the failure mode was stress-corrosion cracking (SCC). By Information Notice No. 82-06 (issued March 12, 1982), the Office of Inspection and Enforcement notified all licensees and construction permit holders about this degradation to emphasize the increased potential for studs to fail by the joint action of stud preload, material conditions and a corrosive environment generated by the presence of primary coolant leakage. As a follow-up to the information notice, the utility established that the root cause of leakage was due to an interference contact between the gasket retainer lip and vessel cladding which prevented proper compression of the flexitallic gasket during reinstallation of the manway cover. This problem was corrected and all 20 studs were replaced. Magnetic particle and ultrasonic examinations of the studs in manways of the other two steam generators identified no other failures.

In the last several years a significant number of incidents have been reported of bolts and studs that have failed or become severely degraded because of boric acid corrosion wastage or SCC mechanisms. Preliminary results of an NRC staff review of threaded fastener experience in operating nuclear power plants have identified that specific generic actions need to be taken before the study is complete. The staff review identified 44 incidents of threaded fastener degradation since 1964. From Table 1 it can be seen that since 1977, 15 incidents related to primary coolant pressure boundary application have been recorded. These incidents involved 9 PWR plants. Of concern is that degradation and failure of such threaded fasteners constitute a potential loss of RCPB integrity and, in the extreme case, a loss-of-coolant accident could occur, should extensive fastener failures in a pressure-retaining closure not be detected.

In some instances, it has been reported that sealant compounds have been injected into bolted closures in the RCPB as a means of convenient maintenance to control leakage. A review of the limited chemical analysis available on Furmanite indicates it has a variable composition with respect to concentration of chlorine, fluorine, and sulfur which are leachable and well recognized promoters of SCC. Consequently, prolonged exposure of this sealant to leakage and high temperature conditions causing a gradual release of its potentially corrosive ions must be taken into account.

Also, certain lubricants may be formulated with molybdenum disulfide ($MoS_2$) which contains a significant level of sulfide constituent. Experience suggests that $MoS_2$ has a pronounced tendency to decompose in the presence of high temperature and moisture conditions to release sulfide which is a known promoter of SCC.

Therefore, care should be exercised in the selection and application of lubricants and injection sealants to minimize the risk of SCC from potentially corrosive ions due to the gradual breakdown and/or synergistic interaction of such materials with prolonged exposure to leakage conditions. This would be of

particular concern for fastener materials made of high-strength low-alloy steels and, austenitic and martensitic stainless steels (i.e., 304, 316, 416, 17-4 PH, etc.) which are known to be susceptible to halogen/sulfide SCC degradation.

The above concerns are further compounded by the fact that under the present ASME Code Section XI inservice inspection rules ultrasonic examination is not required on threaded fasteners in sizes 2 inches and less in diameter (e.g., Table IWB-2500-1). However, except for the reactor coolant pump stud wastage, most failures have occurred in fastener sizes 2 inches and smaller. Furthermore, experience has clearly shown that Code-specified ultrasonic testing (UT) methods are not singularly adequate to detect corrosion wastage conditions. Moreover, the present Code UT procedures are not sufficiently sensitive to detect initiation of stress corrosion cracking (SCC) but requires the use of specialized UT techniques and calibration standards based on notch reflectors simulating critical flaw parameters to enhance reliability of detection. At the present time, visual examination (e.g., IWA 2210, VT-1) appears to be the only method to detect borated water corrosion wastage or erosion-corrosion damage and may require insulation removal and/or disassembly of the component, in some cases, in order to have direct visual access to the threaded fasteners. Therefore, degradation could go undetected when there is no clear evidence of leakage in the surrounding area. Similarly, the reliability of visual examination alone is questionable in detection of SCC initiation of threaded fasteners either in-situ or removed. Accordingly, it is necessary that a combination of nondestructive examination techniques (UT, VT-1, MT, PT) be employed to the maximum extent practical to enhance detection of the degradation mechanisms discussed above.

Actions To Be Taken by PWR Facilities Holding Operating Licenses:

The scope of action items listed below is limited to the RCPB. Included are the threaded fasteners (studs or bolts) in (1) steam generator and pressurizer manway closures, (2) valve bonnets, and pump flange connections installed on lines having a nominal diameter of 6 inches or greater and (3) control rod drive (CRD) flange and pressurizer heater connections that do not have seal welds to provide leak-tight integrity. That is, CRDs having an omega seal weld design are excluded from this bulletin action. The reactor vessel head closure studs are also excluded for those PWR licensees committed to the provisions of Regulatory Guide 1.65, "Materials and Inspection for Reactor Vessel Closure Studs."

Action Item 1 is to be completed prior to the performance of the subsequent action items. Action Item 2 is to be performed within the next cycle, but no later than the completion of the next refueling outage that is initiated after 60 days from the date of this bulletin. The report requested by Action Item 3 is to be submitted within 60 days from the date of this bulletin.

1. Where procedures do not exist, develop and implement maintenance procedures for threaded fastener practices. These procedures should

include, but not limited to the following: (1) maintenance crew training of proper bolting/stud practices, tools application, specifications and requirements, (2) detensioning and retensioning practices (torque iteration), specified tolerances, and other controls for disassembly and reassembly of component closure/seal connections, (3) gasket installation and controls, and (4) retensioning methods and other measures to eliminate reactor coolant leakage during operations.

Quality assurance measures should also be established for proper selection, procurement, and application of fastener lubricants and injection sealant compounds to minimize fastener susceptibility to SCC environments.

2. Threaded fasteners of closure connections, identified in the scope of this bulletin, when opened for component inspection or maintenance shall be removed*, cleaned, and inspected per IWA-2210 and IWA-2220 of ASME Code Section XI (1974 edition or later) before being reused.

3. NRC Information Notice Nos. 80-27 and 82-06, and similar INPO (Institute of Nuclear Power Operations) correspondence (with recommendations) have been issued in regard to corrosion problems associated with bolts/studs in RCPB closures (INPO/NSAC SER 81-12). To assist the Nuclear Regulatory Commission in its ongoing review and assessment of the scope of the problem you are asked to provide the following information for closures and connections within the scope of this bulletin:

   a. Identify those bolted closures of the RCPB that have experienced leakage, particularly those locations where leakage occurred during the most recent plant operating cycle. Describe the inspections made and corrective measures taken to eliminate the problem. If the leakage was attributed to gasket failure or its design, so indicate.

   b. Identify those closures and connections, if any, where fastener lubricants and injection sealant materials have been or are being used and report on plant experience with their application particularly any instances of SCC of fasteners. Include types and composition of materials used.

4. A written report signed under oath or affirmation under provisions of Section 182a, Atomic Energy Act of 1954 as amended, shall be submitted to the Regional Administrator of the appropriate NRC Regional Office within 60 days following the completion of the outage during which Action Item 2 was performed. The report is to include:

   a. A statement that Action Item 1 has been completed.

* Fasteners "seized" or designed with interference fit, may be inspected in place.

b. Identification of the specific connections examined as required by Action Item 2.

c. The results of the examinations performed on the threaded fasteners as required by Action Item 2. If no degradation was observed for a particular connection, a statement to that effect, identification of the connection and, whether the fasteners were examined in place or removed is all that is required. If degradation was observed, the report should provide detailed information.

5. A written report signed under oath or affirmation under provisions of Section 182a, Atomic Energy Act of 1954 as amended, shall be submitted to the Regional Administrator of the appropriate NRC Regional Office within 60 days of the date of this bulletin. The report is to provide the information requested by Action Item 3.

Potential occupational exposure of personnel as a result of the above requirements should be considered in the program formulation process in an effort to maintain incurred exposures as low as reasonably achievable. Personnel exposure-savings techniques such as use of steam generator primary manway cover-handling fixtures offer substantial time and man-rem savings.

This request for information was approved by the Office of Management and Budget under clearance number 3150-0086. Comments on burden and duplication should be directed to the Office of Management and Budget, Reports Management, Room 3208, New Executive Office Building, Washington, D.C. 20503.

While no specific request or requirement is intended, the following information would be helpful to the NRC in evaluating the cost of this bulletin:

1. Staff time to perform requested inspection.
2. Radiation exposure attributed to requested inspections.
3. Staff time spent to prepare written responses.

If you have any questions regarding this matter, please contact the Regional Administrator of the appropriate NRC Regional Office, or this office.

Richard C. DeYoung, Director
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Attachments:
1. Table 1
2. List of Recently Issued IE Bulletins

TABLE 1. SUMMARY OF DEGRADED THREADED FASTENERS IN REACTOR COOLANT PRESSURE BOUNDARY

| Degraded Reactor Coolant Pressure Boundary Threaded Fasteners | No. of Reported Incidents | Plants (Year Incident Reported) & Reactor Vendor | Mode of Failure* |
|---|---|---|---|
| Pressurizer manway closure studs | 2 | Calvert Cliffs 2 (1981) C-E<br>St. Lucie 1 (1978) C-E | BC<br>BC |
| Steam generator manway closure studs | 7 | Maine Yankee (1982) C-E<br>Oconee 3 (1980) B&W<br>Arkansas 1 (1978) B&W<br>Arkansas 1 (1980) B&W<br>Calvert Cliffs 1 (1980) C-E<br>St. Lucie 1 (1977) C-E<br>San Onofre 1 (1977) W | SC<br>SC<br>BC<br>SC<br>BC<br>BC<br>SC |
| Reactor coolant pump closure studs | 5 | Ft. Calhoun (1980) C-E<br>Calvert Cliffs 1 (1980) C-E<br>Calvert Cliffs 2 (1981) C-E<br>Oconee 3 (1981) B&W<br>Oconee 2 (1981) B&W | BC<br>BC<br>BC<br>BC<br>BC |
| Safety injection check valve studs | 1 | Calvert Cliffs 2 (1981) C-E | BC |

*SC = stress corrosion; BC = borated water corrosion.

Attachment 2
IEB 82-02
JUne 2, 1982

LIST OF RECENTLY ISSUED IE BULLETINS

| Bulletin No. | Subject | Date of Issue | Issued to |
|---|---|---|---|
| 82-01 Rev. 1 | Alteration of Radiographs of Welds in Piping Subassemblies | 05/07/82 | All power reactor facilities with an OL or CP |
| 82-01 | Alteration of Radiographs of Welds in Piping Subassemblies | 03/31/82 | The Table 1 facilities for action and to all others for information |
| 81-02 Supplement 1 | Failure of Gate Type Valves to Close against Differential Pressure | 08/18/81 | All power reactor facilities with an OL or CP |
| 81-03 | Flow Blockage of Cooling Water To Safety System Components by CORBICULA SP. (ASIATIC CLAM) and MYTILUS SP. (MUSSEL) | 04/10/81 | All power reactor facilities with an OL or CP |
| 81-02 | Failure of Gate Type Valves to Close Against Differential Pressure | 04/09/81 | All power reactor facilities with an OL or CP |
| 81-01 Rev. 1 | Surveillance of Mechanical Snubbers | 03/04/81 | Specific power reactor facilities with a CP |
| 80-17 Supp. 5 | Failure of Control Rods to to Insert During a Scram at a BWR | 02/13/81 | To all specified BWRs with an OL & All BWRs with a CP |
| 81-01 | Surveillance of Mechanical Snubbers | 01/27/81 | All power reactor facilities with an OL and selected power reactor facilities with a CP |

OL = Operating License
CP = Construction Permit