

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

March 17, 1988

ALL LICENSEES OF OPERATING PWRs AND HOLDERS OF CONSTRUCTION PERMITS  
FOR PWRs

GENTLEMEN:

Subject: BORIC ACID CORROSION OF CARBON STEEL REACTOR PRESSURE  
BOUNDARY COMPONENTS IN PWR PLANTS (GENERIC LETTER 88-05)

Pursuant to 10 CFR 50.54(f), the Nuclear Regulatory Commission is requesting information to assess safe operation of pressurized water reactors (PWRs) when reactor coolant leaks below technical specification limits develop and the coolant containing dissolved boric acid comes in contact with and degrades low alloy carbon steel components. The principal concern is whether the affected plants continue to meet the requirements of General Design Criteria 14, 30, and 31 of Appendix A to Title 10 of the Code of Federal Regulations (CFR) Part 50 when the concentrated boric acid solution or boric acid crystals, formed by evaporation of water from the leaking reactor coolant, corrode the reactor coolant pressure boundary. Our concerns regarding this issue were prompted by incidents in PWR plants where leaking reactor coolant caused significant corrosion problems. In many of these cases, although the licensees had detected the existence of leaks, they had not evaluated their significance relative to the safety of the plant nor had they promptly taken appropriate corrective actions. Recently reported incidents are listed below.

- (1) At Turkey Point Unit 4, leakage of reactor coolant from the lower instrument tube seal on one of the incore instrument tubes resulted in corrosion of various components on the reactor vessel head including three reactor vessel bolts. The maximum depth of corrosion was 0.25 inches. (IE Information Notice No. 86-108, Supplement 1)
- (2) At Salem Unit 2, leakage occurred from the seal weld on one of the instrument penetrations in the reactor vessel head, and the leaking coolant corroded the head surface. The maximum depth of corrosion was 0.36 inches. (IE Information Notice No. 86-108, Supplement 2)
- (3) At San Onofre Unit 2, boric acid solution corroded nearly through the bolts holding the valve packing follow plate in the shutdown cooling system isolation valve. During an attempt to operate the valve, the bolts failed and the valve packing follow plate became dislodged causing leakage of approximately 18,000 gallons of reactor coolant into the containment. (IE Information Notice No. 86-108, Supplement 2)
- (4) At Arkansas Nuclear One Unit 1, leakage from a high pressure injection valve dripped onto the high pressure injection nozzle. The maximum depth of corrosion was 0.5 inches, which represented a 67 percent penetration of the pressure boundary. (IE Information Notice No. 86-108)

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- (5) At Fort Calhoun, seven reactor coolant pump studs were reduced by boric acid corrosion from a nominal 3.5 inches to between 1.0 and 1.5 inches.(IE Information Notice 80-27)

Additionally, corrosion rates of up to 400 mils/month have been reported from an experimental program. (IE Information Notice No. 86-108, Supplement 2)

Although failure of the reactor coolant pressure boundary did not occur in every instance, all of these incidents demonstrated the potential adverse consequences of boric acid corrosion.

The corrosion caused by the leaking coolant containing dissolved boric acid has been recognized for some time. Since 1979, the NRC has issued five information notices (80-27; 82-06; 86-108; and 86-108, Supplements 1 and 2) and Bulletin 82-02 addressing this problem. In June 1981, the Institute for Nuclear Power Operations issued a report discussing the effect of low level leakage from the gasket of a reactor coolant pump and concluded that significant corrosion of the pump studs could occur during all modes of operation. In December 1984, the Electric Power Research Institute issued a summary report on the corrosion of low alloy steel fasteners which, among other things, discussed boric acid-induced corrosion. The information contained in these documents clearly indicated that boric acid solution leaking from the reactor coolant system can cause significant corrosion damage to carbon steel reactor coolant pressure boundaries.

Office of Inspection and Enforcement (IE) Bulletin 82-02 requested licensees to identify all of the bolted closures in the reactor coolant pressure boundary that had experienced leakages and to inform the NRC about the inspections to be made and the corrective actions to be taken to eliminate that problem. However, the bulletin did not require the licensees to institute a systematic program for monitoring small primary coolant leakages and to perform maintenance before the leakages could cause significant corrosion damage.

In light of the above experience, the NRC believes that boric acid leakage potentially affecting the integrity of the reactor coolant pressure boundary should be procedurally controlled to ensure continued compliance with the licensing basis. We therefore request that you provide assurances that a program has been implemented consisting of systematic measures to ensure that boric acid corrosion does not lead to degradation of the assurance that the reactor coolant pressure boundary will have an extremely low probability of abnormal leakage, rapidly propagating failure, or gross rupture. The program should include the following:

- (1)A determination of the principal locations where leaks that are smaller than the allowable technical specification limit can cause degradation of the primary pressure boundary by boric acid corrosion. Particular consideration should be given to identifying those locations where conditions exist that could cause high concentrations of boric acid on pressure boundary surfaces.

- (2) Procedures for locating small coolant leaks (i.e., leakage rates at less than technical specification limits). It is important to establish the potential path of the leaking coolant and the reactor pressure boundary components it is likely to contact. This information is important in determining the interaction between the leaking coolant and reactor coolant pressure boundary materials.
- (3) Methods for conducting examinations and performing engineering evaluations to establish the impact on the reactor coolant pressure boundary when leakage is located. This should include procedures to promptly gather the necessary information for an engineering evaluation before the removal of evidence of leakage, such as boric acid crystal buildup.
- (4) Corrective actions to prevent recurrences of this type of corrosion. This should include any modifications to be introduced in the present design or operating procedures of the plant that (a) reduce the probability of primary coolant leaks at the locations where they may cause corrosion damage and (b) entail the use of suitable corrosion resistant materials or the application of protective coatings/claddings.

Additional insight into the phenomena related to boric acid corrosion of carbon steel components is provided in the attachment to this letter.

The request that licensees provide assurances that a program has been implemented to address the corrosive effects of reactor coolant system leakage at less than technical specification limits constitutes a new staff position. Previous staff positions have not considered the corrosion of external surfaces of the reactor coolant pressure boundary. Based on the frequency and continuing pattern of significant degradation of the reactor coolant pressure boundary that was discussed above, the staff now concludes that in the absence of such a program compliance with General Design Criteria 14, 30 and 31 cannot be ensured.

You are required to submit your response signed under oath or affirmation, as specified in 10 CFR 50.54(f), within 60 days of receipt of this letter. Your response will be used to determine whether your license should be modified, suspended, or revoked. Your response should provide assurances that such a program is in place or provide a schedule for promptly implementing such a program if one is not in place.

This information is required pursuant to 10 CFR 50.54(f) to assess conformance of PWRs with their licensing basis and to determine whether additional NRC action is necessary. The staff does not request submittal of your program. You shall maintain, in auditable form, records of the program and results obtained from implementation of the program and shall make such records available to NRC inspectors upon request.

This request for information is covered by the Office of Management and Budget under Clearance Number 3150-0011, which expires December 31, 1989.

Comments on burden and duplication may be directed to the Office of Management and Budget, Reports Management, Room 3208, New Executive Office Building, Washington, D.C. 20503.

Sincerely,

Frank Miraglia  
Associate Director for Projects  
Office of Nuclear Reactor Regulation

Attachment:  
As stated

## ATTACHMENT

### BORIC ACID CORROSION OF CARBON STEEL REACTOR COMPONENTS IN PWR PLANTS

Boric acid is used in PWR plants as a reactivity control agent. Its concentration in the reactor coolant ranges between 0 and approximately 1 weight percent. At these concentrations boric acid solutions will not cause significant corrosion even if they come in contact with carbon steel components. In many cases, however, coolant that leaks out of the reactor coolant system loses a substantial volume of its water by evaporation, resulting in the formation of highly concentrated boric acid solutions or deposits of boric acid crystals. These concentrated solutions of boric acid may be very corrosive for carbon steel. This is illustrated by recent test data, tabulated below, which were referenced in NRC Information Notice No. 86-108, Supplement 2.

Concentration of boric acid Corrosion rate (percent) mils/month		Condition	Temperature (<deg>F)
25	Aerated	200	400
25	Deaerated	200	250
15	Aerated	200	350-400
15-25	Dripping	210	400

If all of the water evaporates and boric acid crystals are formed, the corrosion is less severe. However, boric acid crystals are not completely benign toward carbon steel, and at a temperature of 500<deg>F, corrosion rates of 0.8 to 1.6 mils/month were obtained in the Westinghouse tests referenced in the generic letter. Corrosion by boric acid crystals was observed in Turkey Point Unit 4 where more than 500 pounds of boric acid crystals were found on the reactor vessel head. After these crystals were removed, corrosion of various components on the reactor vessel head was observed.

The most effective way to prevent boric acid corrosion is to minimize reactor coolant leakages. This can be achieved by frequent monitoring of the locations where potential leakages could occur and repairing the leaky components as soon as possible. Review of the locations where leakages have occurred in the past indicates that the most likely locations are (1) valves; (2) flanged connections in steam generator manways, reactor head closure, etc.; (3) primary coolant pumps where leakages occur at cover to-casing connections as a result of defective gaskets; and (4) defective welds.

In many of these locations the components exposed to boric acid solution are covered by insulation and the leaks may be difficult to detect. If leak detection systems have been installed in the components (e.g., reactor coolant pumps from certain vendors), they should be used to monitor for leakage.

It is important to determine not only the source of the leakage but also the path taken by the leaking fluid by evaluating the mechanism by which leaking boric acid is transported. In some cases boric acid may be entrained in the steam emerging from the opening in the pressure boundary that subsequently condenses inside the installation thus carrying boric acid to locations that are remote from the source of leakage.

Boric acid corrosion can be classified into two distinct types: (1) corrosion that actually increases the rate of leakage and (2) corrosion that occurs some distance from the source of leakage and hence does not significantly affect the rate of leakage. An example of the first type is the corrosion of fasteners in the reactor coolant pressure boundary, for example, in reactor coolant pumps. This type of corrosion can lead to excessive corrosion of studs. The second type of corrosion can contribute significantly to the degradation of the reactor coolant pressure boundary. At Arkansas Nuclear One Unit 1, a leak developed in a high pressure injection isolation valve located 8 feet above the high pressure injection nozzle which was made of carbon steel. Accumulation of boric acid resulted in an approximately 1/2-inch-deep corrosion wastage adjacent to the stainless-to-carbon steel weld. Other locations of the nozzle exhibited corrosion to a lesser degree. Corrosion of the reactor vessel head was observed at Salem Unit 2. Corrosion pits were 1 to 3 inches in diameter and 40 to 300 mils deep. The source of this corrosion was a defective seal weld in one of the instrument penetrations. These examples indicate that the corrosion produced by boric acid could degrade even relatively bulky components. At Fort Calhoun, the diameter of a reactor coolant pump closure bolt was reduced from 3.5 inches to 1.1 inches by boric acid corrosion. At San Onofre Unit 2, boric acid corrosion of the valve bolts was responsible for the failure of the valve and the discharge of 18,000 gallons of primary coolant into the containment.

Because of the nature of the corrosion produced by boric acid, the most reliable method of inspection of components is by visual examination. Ultrasonic testing performed in accordance with Section XI of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code may not be sensitive enough to detect the wastage. At Fort Calhoun, two successive ultrasonic tests failed to detect corrosion of the reactor pump closure studs. When ultrasonic testing is used, the licensee should provide assurances that the results are reliable.