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OFFICE OF NUCLEAR REACTOR REGULATION
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NRC INFORMATION NOTICE 86-108, SUPPLEMENT 3: DEGRADATION OF REACTOR COOLANT SYSTEM PRESSURE BOUNDARY RESULTING FROM BORIC ACID CORROSION

Addressees

All holders of operating licenses or construction permits for pressurized-water reactors (PWRs).

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice supplement to alert addressees to two recent significant incidents of boric acid-induced corrosion of ferritic steel components on the pressure boundary of pressurized water reactors. These incidents indicate that there may still be a general lack of awareness of the ambient conditions that can lead to boric acid attack. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this information notice are not NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances

In February 1994, the licensee personnel at Calvert Cliffs Unit 1 found three nuts on an incore instrumentation flange that were corroded by boric acid, leaking past the flange gasket. The Calvert Cliffs reactors each has eight such flange assemblies. Each assembly is held together by eight carbon steel studs that are 33 cm [13 in.] long and have a diameter of 4.45 cm [1-3/4 in.]. During a subsequent inspection, the licensee found three more nuts on another incore instrumentation flange that were also corroded by the same mechanism. One of these nuts had failed completely, and the mating stud had dropped out of the flange. The two adjacent nuts had been significantly damaged.

On March 7, 1994, the licensee personnel at Three Mile Island Unit 1 were attempting to stop a small leak across the body-to-bonnet gasket of the pressurizer spray valve by tightening a bonnet stud, when the leak suddenly increased to 11 L/min [3 gpm]. The reactor was at 100 percent power at the time of the event. After reducing the power to 75 percent to reduce potential pressure surges that could occur without the aid of pressurizer spray, the licensee was able to isolate the leaking valve by closing other valves in the pressurizer spray line. When the workers continued to try to tighten the studs, one of the studs, with its nut still attached, came out in a worker's hand. The workers then found two more studs on the same side of the bonnet

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that had completely failed and a fourth one that was severely degraded. The cause of this damage was corrosion by boric acid. The damaged studs were among eight 5/8 in. nominal studs that join the bonnet to the body of the insulated 2.5 in. nominal motor-operated globe valve manufactured by Velan. The body and bonnet are both made of 316 stainless steel. However, the studs, which are threaded into the valve body, are made of ASTM A193 Grade B7 low alloy steel and the nuts are made of ASTM 194 Grade 2H low alloy steel. The licensee kept the plant at reduced power until March 17, 1994, then shut the plant down to repair the damaged valve.

Discussion

At both plants where the recent boric acid corrosion problems occurred, there were earlier indications of boric acid leakage from the components that were eventually damaged. In March 1993, the Calvert Cliffs licensee had discovered leakage from the Unit 2 ICI flanges. The licensee determined that the leakage was caused by inadequate gasket material and corrected this leakage by replacing the flange gaskets with thicker ones and by adding washers under the stud nuts to increase the tension on the studs.

In June 1993, the Calvert Cliffs licensee had also discovered evidence of leakage from the same cause on seven of the ICI flanges in Unit 1. After reviewing the problem, the licensee concluded that any corrosion from this leakage would be acceptably low and elected to defer the corrective actions for the Unit 1 flanges until the 1994 refueling outage. This conclusion was based on the assumption that the flange temperatures would be approximately 260 °C [500 °F]. At this temperature, any boric acid present would boil dry and result in corrosion rates of about 0.04 mm/month [1.6 mil/month]. Actual flange temperatures, measured during a startup after the damage was discovered, are in the range of 71 to 146 °C [160 to 295 °F]. These temperatures encompass the range where boric acid can remain in solution and become concentrated by evaporation. The temperatures also cover the range where the high corrosion rates identified by the Westinghouse tests (discussed below) can occur.

Workers had reported a body-to-bonnet leak from the pressurizer spray valve at Three Mile Island Unit 1 in November 1993. A work request was prepared to repair the leak. However, the licensee inspected the valve without removing all of the insulation and concluded that the boric acid crystals around the valve came from the valve packing rather than the body-to-bonnet joint. As a consequence the work request was cancelled.

Related Generic Communications

Boric acid coolant leaking onto hot carbon steel surfaces has significantly damaged reactor pressure boundary components at a number of plants in the past. As a result, the NRC has issued a number of generic communications dealing with this issue. The following are some of the more significant examples:

In 1980, Fort Calhoun personnel found in each of two separate pumps three reactor coolant pump studs whose diameter had been reduced from 3 1/2 in. nominal to between 2.5 and 3.8 cm [1 and 1.5 in.] by corrosion caused by boric acid leaking past the flange gaskets (Information Notice 80-27).

In 1982, the Maine Yankee licensee reported that 6 of the 20 primary manway closure studs on one steam generator had failed. Five more of the studs were cracked. The studs had surface corrosion wastage caused by boric acid leaking past the studs. The final failure mechanism was stress corrosion cracking that may have been aggravated by the injection of Furmanite sealant and the additional torquing that was applied in an effort to stop the initial boric acid leakage (Information Notice 82-06).

In June 1982, the NRC Office of Inspection and Enforcement issued Bulletin 82-02, which summarized the problems with threaded fasteners in the reactor coolant pressure boundary. This bulletin gave 11 examples of boric acid corrosion of closure studs. The bulletin required licensees to establish maintenance procedures to ensure the integrity of such threaded fasteners. It also requested licensees to identify all bolted closures in the reactor coolant pressure boundary that had leaked and to describe corrective measures taken to eliminate the problems.

In October 1986, personnel at Arkansas Nuclear One Unit 1 discovered 1.3 cm [1/2 in.]-deep wastage on the "A" high-pressure injection (HPI) nozzle caused by boric acid leaking from an HPI manual isolation valve and running down the stainless steel HPI line onto the carbon steel nozzle. The boric acid had corroded two-thirds of the way through the nozzle, which was attached to one of the four reactor cold legs (Information Notice 86-108).

In March 1987, personnel at Turkey Point Unit 4 discovered over 227 kg [500 lb] of boric acid crystals on the reactor vessel head and in the exhaust cooling ducts of the control rod drive mechanisms. The boric acid crystals had precipitated from reactor coolant that had leaked from an instrument tube seal. The boric acid had severely corroded three of the reactor vessel head bolts, the control rod drive shroud support, and the leaking instrument tube seal clamps. All of these items, including the entire control rod drive shroud, had to be replaced (Information Notice 86-108, Supplement 1).

In August 1987, personnel at Salem Unit 2 discovered a pile of rust-colored boric acid crystals 0.9 m by 1.5 m by 0.3 m [3 ft by 5 ft by 1 ft] high on the reactor vessel head as well as a boric acid coating on other areas of the head and control rod drive mechanism. The boric acid had precipitated from reactor coolant leaking through pinholes in a seal weld at the base of a thermocouple connection. The boric acid had corroded nine pits, ranging in depth from 0.9 to 1 cm [0.36 to 0.4 in.], in the surface of the reactor vessel head (Information Notice 86-108, Supplement 2).

Also in August 1987, personnel at San Onofre Unit 2 broke off the packing plate hold-down bolts of a 10-in. nominal isolation valve in the shutdown cooling system while attempting to open the stuck valve manually. The resulting leak of approximately 230 to 380 L/min [60 to 100 gpm] spilled 68 kl [18 k gal] of reactor coolant into the containment. Boric acid leaking from the valve had corroded the valve packing plate hold-down bolts, which were made of carbon steel (Information Notice 86-108, Supplement 2).

Information Notice 86-108, Supplement 2 also discussed a series of tests performed by Westinghouse that showed that high concentrations (15 to 25 percent) of aerated or dripping boric acid could corrode carbon steel surfaces at rates as high as 10 mm/month [400 mil/month] in 93 to 99 °C [200 to 210 °F] environments.

In March 1988, the NRC staff issued Generic Letter 88-05 in which it requested licensees to institute a systematic program to monitor locations where boric acid leakage could occur and to provide measures to prevent degradation of the reactor coolant pressure boundary by boric acid corrosion.

The latest two incidents of boric acid-induced corrosion indicate that, although PWR licensees have generally become sensitive to the possibility damage from boric acid leakage, there may still be a lack of awareness of the conditions that can lead to boric acid attack. The wide range of ambient conditions around reactor primary coolant leak sites with the resulting wide variation in boric acid corrosion rates make it difficult to predict the likelihood of corrosion damage when a leak is present. This is particularly true of components such as insulated flanges and valve bonnets that are somewhat isolated from the areas of heat input from the reactor coolant and may experience large temperature variations.

The primary defense against boric acid corrosion, previously discussed in Information Notice 86-108, remains the same; i.e., minimize leakage, detect and stop leaks soon after they start, and promptly clean up any boric acid residue.

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact one of the technical contacts listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

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Attachment:
List of Recently Issued NRC Information Notices