UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555

January 8, 2004

NRC INFORMATION NOTICE 2003-11, SUPPLEMENT 1: LEAKAGE FOUND ON BOTTOM-MOUNTED INSTRUMENTATION NOZZLES

Addressees

All holders of operating licenses or construction permits for nuclear power reactors, except those that have permanently ceased operations and have certified that fuel has been permanently removed from the reactor.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice (IN) to alert addressees to indications of leakage in the form of boron deposits discovered on bottom-mounted instrumentation (BMI) nozzles at South Texas Project Unit 1 (STP Unit 1). This supplement specifically provides additional information regarding the STP Unit 1 licensee's root cause analyses, as discussed in licensee's final licensee event report on this topic, dated October 15, 2003 (ADAMS Accession No. ML032950483). It is expected that the recipients of this IN will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this IN are not NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances

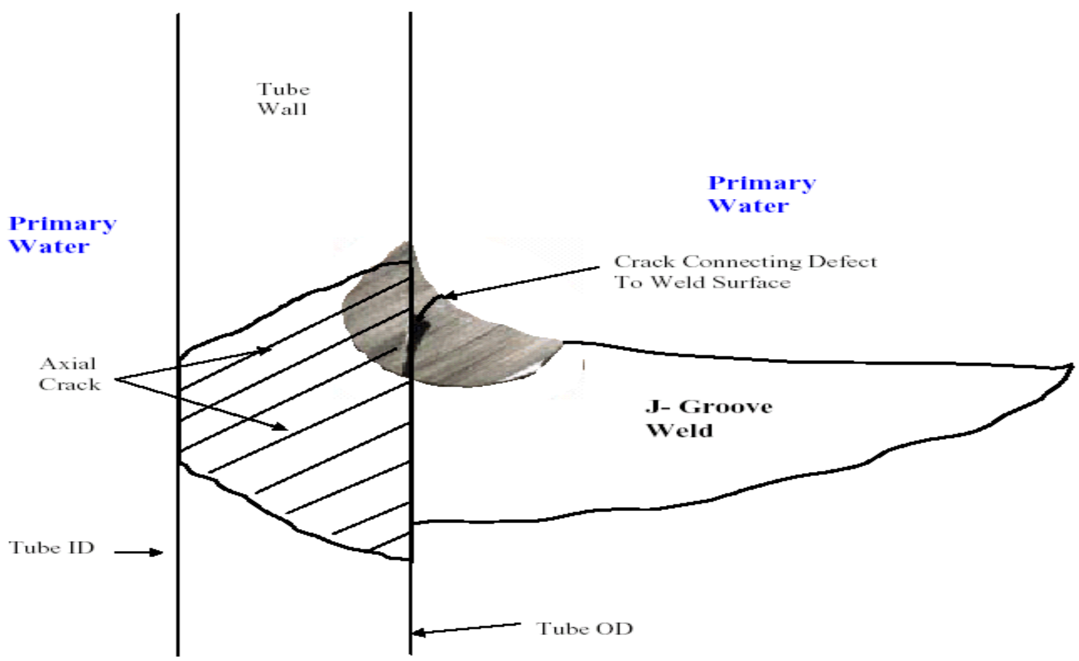
An extensive description of the STP Unit 1 BMI penetration leakage event was given in IN 2003-11, "Leakage Found on Bottom-Mounted Instrumentation Nozzles," dated August 13, 2003. The relevant pre-August 2003 information is summarized herein.

In April 2003, the STP Unit 1 licensee identified small boron deposits around two of the 58 STP Unit 1 BMI penetrations (penetrations 1 and 46), the only evidence of BMI nozzle penetration leakage reported by a U.S. facility to date. The STP Unit 1 BMI penetrations were constructed from an drilled Inconel 600 bar stock connected to the reactor vessel lower head by an Inconel 82/182 J-groove weld. The licensee's subsequent nondestructive examination (NDE) campaign, which included ultrasonic test (UT), visual, and eddy current testing, resulted in the identification of three axially oriented cracklike indications in the penetration 1 nozzle wall and two axially oriented cracklike indications in the penetration 46 nozzle wall. One of the indications in penetration 1 was characterized as an axial crack with a length of about 1.38 inches, surface-breaking on the outside diameter (OD) of the nozzle above and below the J-groove weld, as well as surface-breaking on the inside diameter (ID) of the nozzle. The other two indications in penetration 1 were characterized as being small, embedded cracks near the interface between the nozzle wall and the root pass of the J-groove weld. One of the indications in penetration 46 was characterized as an axial crack with a length of about 0.98 inches, surface-breaking on the OD of the nozzle above and below the J-groove weld. The other indication in penetration 46 was characterized as an embedded crack having an axial length of 0.95 inches.

The results of the licensee's UT inspection identified other features within the BMI penetrations which were deemed to be relevant by the licensee. UT reflectors were observed and characterized as "discontinuities" at the interface of the nozzle and the J-groove weld in all 58 of the STP Unit 1 BMI penetrations. These discontinuities were particularly evident in seven penetrations, including penetrations 1 and 46. The discontinuities in penetrations 1 and 46 were located in the same general azimuthal locations as the cracklike indications.

To further investigate the potential root causes of the STP Unit 1 BMI penetration cracking, the licensee attempted to cut material samples (known as "boat samples"), by means of a specially designed electrical discharge machining (EDM) tool, from STP Unit 1 BMI penetrations 1 and 46 for destructive examination. Due to the difficulties of the EDM cutting process, only one sample, from penetration 1, was successfully removed and destructively evaluated. The penetration 1 boat sample was taken from the same azimuthal location as the 1.38 inch flaw, was intended to sample the nozzle and J-groove weld material, and was intended to contain portions of the 1.38 inch flaw as well as one or more of the observed UT discontinuities at the nozzle-to-weld interface. Figure 1, discussed in more detail below, provides a composite overlay of the penetration 1 boat sample with the tube (nozzle) wall and the penetration 1 J-groove weld.

Figure 1 Overlay of cross section of boat sample from STP Unit 1 penetration 1 with drawing of penetration 1 tube and weld geometry.



The licensee's destructive examination of the STP Unit 1 penetration 1 boat sample provided the following information:

(1) The axial crack in the penetration 1 tube wall was entirely intergranular in nature and consistent with primary water stress corrosion cracking (PWSCC) as the mechanism of crack propagation. Essentially no PWSCC of the J-groove weld material was observed in the boat sample.

(2) The UT discontinuity at the tube-to-weld interface which was captured in the boat sample (the dark area in the boat sample in Figure 1) was confirmed to be a weld lack-of-fusion zone from initial fabrication. A weld material ligament of approximately 80 mils (0.080 inch) separated the weld lack-of-fusion zone from the surface of the J-groove weld. The length of the lack-of-fusion zone in the circumferential direction was about 0.2 inch. The axial PWSCC crack in the tube wall was located at one end of the lack-of-fusion zone.

(3) A second cracklike defect was observed in the weld material (the dark line in Figure 1), running in the circumferential direction. The length of this defect was about 0.2 inch, consistent with the length of the lack-of-fusion zone. This defect was completely through the 80 mil weld ligament and would have permitted primary water to leak into the lack-of-fusion zone. The precise mechanism for the initiation and propagation of this defect through the weld material could not be determined from the boat sample. However, its location and size relative to the associated lack-of-fusion zone suggest that the formation of this defect was also related to initial fabrication processes.

Based on this information, and the results of the licensee's NDE campaign, the licensee concluded that the following scenario most likely explains the PWSCC flaws observed at STP Unit 1:

(1) Initial fabrication of the STP Unit 1 BMI penetrations resulted in lack-of-fusion zones between the nozzle (tube) and the J-groove weld. In addition, in penetrations 1 and 46, conditions existed from initial fabrication which resulted in the formation of defects through the J-groove weld, subsequently allowing primary water to flood the embedded lack-of-fusion zones early in the facility's operating history.

(2) Primary water flooding of the embedded lack-of-fusion zones established conditions (i.e., a high-temperature, high-purity water environment, a susceptible material, and high local stresses) which are known to promote PWSCC.

(3) PWSCC flaws initiate "inside" the weld joint, adjacent to the lack-of-fusion zones, and propagate through the tube wall, eventually establishing a leakage path to the exterior of the reactor pressure vessel lower head.

In addition to the boat sample analysis discussed above, this scenario is supported by the observation that the large, 0.95 inch flaw in penetration 46 was not, based on NDE results, surface-breaking either on the ID of the nozzle wall or above the J-groove weld. Assuming that the same mechanism was responsible for all of the flaws observed in the STP Unit 1 BMI penetrations, this observation points toward a scenario which is not dependent on PWSCC initiation at a normally wetted surface.

Discussion

The NRC has closely monitored the inspections conducted at STP Unit 1 and the licensee's evaluation of the root cause for the observed cracking. At this time, the NRC staff has concluded that the scenario summarized above is the explanation which is most consistent with the available information from the licensee's NDE campaign and material sample testing. The NRC staff expects to further review details associated with the licensee's root cause determination as part of NRC's normal reactor inspection and oversight process. The NRC staff will consider the need to supplement this IN if additional information is discovered which may modify the NRC staff's assessment of the scenario described above.

The NRC staff expects that licensees whose facilities may be subject to conditions which could lead to degradation like that observed at STP Unit 1 will evaluate the information in this IN and determine what, if any, actions may be prudent to maintain the integrity of their facilities' reactor coolant pressure boundaries consistent with NRC regulatory requirements.

This IN 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 project manager.

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