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To: Wayne Schmidt
Date: Mon, Aug 7, 2000 3:02 PM
Subject: IP2

See attached.

6

A1154

Indian Point 2 Steam Generator Inspection Report Input
Rev. B, 8/6/2000

1RS3 Review of 1997 Steam Generator Conditions

.1 Review of 1997 U-Bend PWSCC Indications - Wayne

a. Inspection Scope

The team reviewed the actions taken upon discovery of a PWSCC flaw at the apex of SG 24 R2C67 during the 1997 inspection. As discussed above Con Edison used the Plus point technique to conduct the U-bend examination.

b. Issues and Findings

Upon discover of the apex indication neither Con Edison nor its contractor entered the issue into their corrective action programs.

The issue was reported by the contractor in the end of outage report and by Con Edison to the NRC in the technical specification (TS) required post outage report.

There was no specific review as to the significance of this flaw.

.2 Denting and Hour-glassing/Secondary Side Visual Exam

a. Inspection Scope

The team reviewed the TS, the submittal made in 1997 following completion of the outage SG inspection (date), NRC requests for additional information, Con Edison reposes _ list which ones -, and the Indian Point 2 Steam Generator Data Book, dated December 1, 1997, to assess SG conditions in 1997 relative to tube denting, hour-glassing and the secondary side inspections.

b. Issues and Findings

Tube Denting

A significant, contributing cause to the stress factor of PWSCC in the u-bend region of the tube is upper TSP flow slot hour-glassing which results from denting of tubes at the TSP as described below.

Denting of the tubes is the direct result of corrosion of the carbon steel tube support plates. When the SG is shutdown and cooled down, there is a circumferential gap between the tube passing through the TSP and the hole in the TSP through which the tube passes. The gap is there by design to allow for thermal expansion of the tube when the high temperature reactor coolant is pumped through the SG tubes. However, while the SG is shutdown corrosion products can form, based on water chemistry, and harden in that gap. When the SG is heated up for operation the tubes try to expand but are prevented from expanding at the TSP due to the hardened corrosion products in the gap. Since the tube cannot expand where it passes through the TSP, but does expand above and below the TSP, the tube becomes dented, circumferentially, where expansion is restricted by the hardened corrosion products and the TSP. The next time the SG is cooled down the tube contracts, the dent remains, and a gap is recreated. Again corrosion products can form in the gap (influenced by feedwater chemistry) and refill the gap. During the next SG heat-up, additional denting can occur as described above. This denting process can continue indefinitely until eventually the tube inside diameter is so restricted that an eddy current probe will not pass through and/or significant cracking of the tube is detected in the dented region, at which time the tube is plugged.

Tubes that did not pass the smallest eddy current probe (610 mil diameter) due to restrictions were plugged. Twenty (20) tubes were plugged in 1997 for restrictions (up from just one tube in 1995), bringing the total tubes plugged due to restrictions for all four SGs to three hundred and three (303).

Regarding the significant increase in the number of tubes plugged due to denting restrictions, Con Edison, in their June 19, 2000 response to Question 3 of NRC RAI Letter dated March 24, 2000, states that, "Restriction to the movement of an eddy current inspections probe can be from a variety of causes............ Examples are: Rotating coil probes may be used with motor that has a larger diameter than the test coil, and the motor may be obstructed rather that the probe head, though the effect is the same". Additionally, Con Edison states that the, "Rotating probe can sometime pass a restricted location as the probe is pushed into the tube indicating that the restriction has a larger diameter than the nominal probe size. However when the probe is spun and pulled through the tube to gather data the probe may become restricted or stop rotating"

However, denting is still the issue since it is the initial movement of the tube at the upper TSP due to denting and the associated hour glassing that generates the stress (as the tube bend radius is decreased) associated with PWSCC. In general, sufficient movement of the tube has occurred whether or not the probe used has a larger diameter motor.

.3 <u>Hour-glassing and Secondary Side Examinations</u>

a. <u>Inspection Scope</u>

b. <u>Issues and Findings</u>

<u>Hour-glassing</u>

The same forces that cause the tube to dent, as described above, also exert force against the TSP. These flow slots allow the secondary side feedwater, heated by the reactor coolant inside the tubes, to pass through the tube sheets. As the SG heats up, the forces that dent the tube also exert force on the TSP and, where the structural resistance is low, can cause deformation and/or cracking of the TSP. One area where the structural resistance is low is at the flow slots. There are six evenly spaced flow slots running along the diameter of each TSP. The flow slot openings are about 15 inches long (along the TSP diameter and spanning about twelve tubes) and about 3 inches wide. Though the forces on the TSP can exist at all locations where a tube passes through the TSP, the forces at the flow slots are of greater concern since the forces can cause hour-glassing of the flow slots which contributes to the stress in the tubes.

The flow slots have low structural resistance to lateral forces in the middle of their long dimension where the ligaments (TSP steel between the rectangular flow slot and circular tube penetration) have less support. The same forces that cause tube denting where the tube passes through the TSP also push against the support plate steel between tube being dented and the flow slot opening. This happens on both sides of the flow slot forcing the sides of flow slot inward at the middle of the flow slot causing the previously rectangular shaped flow opening to develop the shape of an hour-glass. Cracking of the TSP can and has occurred both near flow slots and at other locations in conjunction with tube denting forces in the TSP. This deformation of the flow slots reduces the flow area. But more significantly, when this hour-glassing occurs at the top TSP it causes the hot and cold legs of the short radius u-bend tubes to be forced closer together at the top TSP reducing the bend radius of the u-bend. This places additional stress on the associated u-bend which, in turn, contributes to and has resulted in PWSCC, the cause of the tube failure in SG24 on February 15, 2000.

As stated in Con Edison's "Indian Point 2 Steam Generator Data Book," dated December 1, 1997, "Con Edison performed visual spot checks at the top support plate in the wedge area of SGs 22 and 23." Additionally, in conjunction with their response in Attachment 1 to the u-bend CMOA provided to the NRC June 2, 2000, Con Edison included the following statements: "Based on the stress model, it is believed that very minor hour-glassing, which is not visible during visual inspections, was most likely reached during the initial active-denting years of the IP2 steam generators." "Con Edison performed visual inspections of all upper support plant flow slots, and these flow slots all appeared to be similar (i.e., hour-glassing was not visually detected, implying that the extent of hour-glassing is minimally low)." "Since hour-glassing is not visually apparent or minimal after 25 years of service at Indian Point 2, and since leg displacement beyond that necessary to induce PWSCC is conservatively assumed, there would be no benefit to establishing an hour-glassing "base-line" for postulating additional hour-glassing effects during the next cycle."

In the 1997 SG tube inspection there were twenty (20) restrictions at the upper TSP. The team concluded that Con Edison did not sufficiently assess those eddy current probe restrictions in the upper support plate, commonly caused by tube denting, during the 1997 steam generator inspections, with respect to the potential for flow slot hour-glassing adversely impacting tubes beyond row 1. Con Edison did conduct visual inspections but did not, though required by their TS, have an accurate method of measuring nor did they have any documented criteria for determining when significant hour-glassing of the upper tube support plates had taken place. As such, Con Edison could not effectively assess the impact the denting and the flow slot hour-glassing would have on short radius u-bend tubes over the next operation cycle.

Also, the team found the extent of condition evaluation conducted by Con Edison for the flaw they detected in 1997 in the R2C67 tube in SG 24 was inadequate regarding the potential for increased apex stresses and PWSCC that would result from flow slot hour-glassing. The conditions that contributed to the cause of the flaws in the R2C67 tube in SG24, which was detected in 1997, were essentially the same conditions that caused the flaws in four other tubes, including the tube that failed (R2C5 tube in SG24), that were not detected in 1997 but, based on a reanalysis of the 1997 data tapes in 2000, should have been detected. The finding of the flaw in R2C67 in SG 24 was the first PWSCC, low radius u-bend, apex flaw and should have been treated as the detection of a new, significant failure mechanism requiring a more thorough eddy current inspection of all tubes with the same susceptibility, particularly in light of the low signal to noise ratios being experienced in the 1997 eddy current testing program.

.4 Outside Diameter Stress Corrosion Cracking (ODSCC) and Secondary Side Examinations

a. Inspection Scope

b. Issues and Findings

ODSCC

Sludge and other deposits on the tubes have played a key role in eddy current testing results. As stated in Con Edison's "Indian Point 2 Steam Generator data Book," dated December 1, 1997, "Since the early years of operation at Indian Point 2, a relatively large amount of sludge has been accumulation in the steam generators. Sludge development started during the early years of plant operation, when industry guidelines on pH and dissolved oxygen were different than the current limits." "In 1978, a sludge lancing program was initiated. Since then sludge lancing has been performed during each outage. The amount of sludge removed during each outage was typically 200 lb./SG. Much of the sludge accumulated in the steam generators was usually hard (Rockwell T 60-80). Unlike the deposits in other plants, the deposits around the steam generator tubes at Indian Point 2 contain large amounts of hematite (Fe_2O_3), interspersed with metallic copper." "In general, development of tube deposits and hard sludge was not found to promote severe tube corrosion."

Con Edison went on to say that, "In addition to the extensive conventional sludge lancing performed during each outage, Indian Point 2 developed and implemented the CECIL robotic system for inspection and removal of hard sludge." "No removal of hard deposits from the upper bundle is expected because of the absence of corrosion evidence on the tubes. The risks of damage to the tubing and support plates outweigh the benefits of hard sludge removal or chemical cleaning. This deposit does not appear to cause significant reduction in heat transfer. In general, development of tube deposits and hard sludge was not found to promote severe tube corrosion. The accumulation of deposits has not resulted so far in degradation to the thermal performance of the steam generators. Thus, neither corrosion issues nor heat transfer issues justify chemical cleaning at Indian Point 2. The use of enhanced techniques of chemical cleaning, such as pressure pulsing or high temperatures, is likely to pose severe hazards to vulnerable components, such as the tube support plates which are already damaged."

However, Con Edison failed to address the fact that deposits on the outside diameter of the SG tubes is one of the primary contributors to the noise observed during eddy current testing. So even though the deposits may not promote severe tube corrosion, these same deposits can create the high noise levels that mask the detection of tube flaws that, if detected, would require that the degraded tube be plugged.