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NOVEMBER 21, 1975 MEETING BETWEEN MECHANICAL ENGINEERING BRANCH, DIVISION OF TECHNICAL REVIEW, NRR AND LICENSEE FOR SURRY UNIT 1 AND TURKEY POINT UNIT 4

This memorandum summarizes significant information presented at the meeting regarding a new type of imperfection discovered in recent eddy current inspections of steam generator tubes called "dent" and recommends action to answer unreviewed safety questions for operating reactors raised by this information. The principal spokesman for the NRC was R. R. Maccary and for the licensees (Virginia Electric Power Company and Florida Power and Light Company) it was Tom Anderson. The bulk of technical information was presented by Westinghouse (Doug Fletcher and Dr. Conway). The licensees have concluded that it is safe for the plants to continue to operate, but deemed it necessary to present the data in its evaluation and future inspection plans in view of NRC's responsibility to review safety significant matters and in view of the upcoming public hearing on steam generator tube integrity for Prairie Island.

SUMMARY

Significant information follows

(1) The discovery of dents has only been made in plants that have switched from phosphate treatment of secondary coolant to all volatile treatment (AVT) in the fall of 1974. The Robinson-2 plant that remained on phosphate treatment does not have dents and apparently does not have other significant defects caused by localized corrosion. Data on dents for Turkey Point 4 and Surry Unit 1 was presented. Data for Prairie Island Unit 1 inspection in May 1975 is still under review. A dent was defined as a reduction in tube diameter over a 3/4-inch length of tubing.

(2) Eddy current signals are quite sensitive to changes in the metallographic structure of the tube material caused by deformation.

(3) In the May 1975 inspection at Turkey Point-4, the eddy current signal interpreters determined that some deformation was taking place in the tubes at the tube support plates by the very large signal. In one steam generator, 2000 tubes were surveyed on the hot leg of each steam generator and 100 tubes through the 6th tube support. In addition, several undersized probes were used as gages to determine the inside diameter of the dents. Every tube inspected showed dents at supports with diameter decreases ranging up to 0.020 inches on the nominal tube I.D. of 0.775 inches.

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The plant was put back into operation.

(4) In July 1975 a leak of 0.03 gallons per minute (gpm) developed in steam generator "B" of Turkey Point-4. On August 3, the leak was 0.05 gpm and the plant was shut down to plug the tube. A few tubes around the leaking tube were probed but no unacceptable defects were found, other than the leaking tube which was plugged. The plant was put back into operation.

(5) On August 27, 1975 another leak of about 0.04 gpm developed. The leak increased to about 0.055 gpm on September 12 and to 0.067 gpm on September 17. The unit was shut down on September 21 and an eddy current inspection was performed. Three leaks were found in two adjacent tubes. One through wall crack was between the 2nd and 5th supports, but a more precise location could not be determined. The other two cracks were determined by eddy currents to be adjacent to dents at tube supports. The two leaking tubes were plugged. The eddy current inspection and tube gaging inspections indicated that between May and September 1975, the dent locations had increased from the support plate elevations in the hot leg side to the top support locations on the cold leg side. A tube having a diameter reduction of 0.025 inches was pulled for laboratory examination. The laboratory examination (a) confirmed the diameter reduction measured by the gages in the steam generator tube probing inspection, (b) found 0.002 inches wall thinning on the O.D. attributed to corrosion during operation with phosphate treatment, (c) measured hardness at a cross section through the dented region and through a non-dented region of the tube, and (d) performed chemical and metallographical examination of the dent. The Vickers hardness (200-gram load) for the dented section ranged from 270 to 310 at 1 mil from the outer surface, 210 to 220 at 4 mils, 200 to 240 at 7 mils, and 180 to 190 from 10 mils to the inner surface. The corresponding harness number ranges for the non-dented section were 220 to 260 at 1 mil, 210 to 220 at 4 mils, 200 to 250 at 7 mils, 180 at 10 mils, 240 from 15 mils to the outer surface. The average hardness near the outer surface was 290 in the dented section compared to 240 in the non-dented section. (Hardness numbers axially along the outer surface in the dented region and adjacent regions were not presented.

(6) In the current Surry Unit 1 inspection, an extensive eddy current examination and gaging inspection of steam generator tubes has been made. Three through wall cracks were found that had a combined leakage at operating conditions less than 0.1 gpm. Tubes in the center of the bundle have dents with diameter reductions ranging from 0.024 inches for a large number of tubes, 0.038 inches for several tubes, and 0.050 inches for the maximum dent in the center of the bundles. A few tubes at the edge of the bundle were found by gaging to have dented to the extent

that the maximum probe diameter that would pass through was 0.400 inches diameter (The nominal tube ID is 0.775 inches). A few more tubes at the edge have dents that will not pass probes larger than 0.549 inches. Two tubes were removed from the cold leg side for laboratory examination. No hardness measurements have been made yet on these tubes.

Several theories for the denting phenomena were considered by Westinghouse.

1. Flow-induced vibration - Westinghouse has concluded, based on examination of the outer surface of the dent and analyses of flow induced tube vibration that this is not the cause. They conclude the 0.002 inch wall thinning was caused by wastage-type corrosion and that a rubbed surface would have a different appearance than that found. The staff questioned whether hydraulice analyses were of significant value in reaching this conclusion.

2. A second mechanism, that is believed by Westinghouse to be the most likely cause, is that the deposits formed in the spaces between tube support plate holes and the tube O.D. during phosphate treatment has undergone a phase change when the water treatment was changed to AVT. This phase change results in a hardening of the deposits and a volume increase, similar to the volume increase when water goes from the liquid phase to the solid phase.

3. A third mechanism, accumulation of dirt is not believed a likely cause.

4. The fourth mechanism, oxide or scale buildup in the crevice may also be a contributing cause.

The staff questioned whether such oxide or scale formation would be removed from the gap by flow induced tube vibrations since it appears from laboratory examination that this type of deposit is quite brittle and easily removed. Westinghouse representatives stated that the volume increase of hard deposits in the gap is currently an unproved theory, although some laboratory tests with oxide formation in a simulated gap are in progess.

Westinghouse presented the results of a mechanical test of a dented section of the tubing pulled from Turkey Point Unit 4. A tight-fitting clamp was placed around the dent to simulate a support plate that has hard deposits between the support plate hole and the dent in the tube. The tube section was pressurized internally to a pressure of 3000 psig, then externally pressurized to 1500 psig, 5000 psig, and then 6000 psig when it collapsed at one end connection. Prior to collapse, no leaks were detected. Several tests of new tubing were also mentioned, including a squeezing to collapse, and

a bending at a simulated support. Westinghouse presented results of an analysis of tube sheet deformation based on the theory that the forces acting on the tube sheet holes due to growth of deposits in the gaps has distorted it. Pictures taken with a boroscope through the tube sheet hole where a tube was removed provide some support to the theory. These calculations also indicate that some of the edge tubes where probes larger than 0.4 inch diameter will not pass may have been reduced to a "cloverleaf" shape rather than a circular shape because the support plate in these locations is less flexible than in the central regions of the tube bundle. An analysis of the collapse pressure of these outer region tubes was made to determine the limiting pressure differential from secondary-to-primary side for hydrostatic leak tests subsequent to tube plugging operations. A limiting pressure for Surry Unit 1 of 800 psig was calculated for leak tests at 250°F or less, which has some margin below the calculated pressure that would collapse the worst tube found (0.400 inch diamter probe).

The licensee for Surry Unit 1 concluded that for short term operation of 6 months to 1 year, it is safe to operate the plant based on its judgement. They further conclude that tube bursting is unlikely during operation because leaks will occur prior to bursting and the plant can be safely shut down to plug the tubes.

The staff asked several questions about the capability to withstand design basis accidents such as the steam line breaks (SLB) and loss of coolant accident (LOCA) during the operating period between steam generator inservice inspections, particularly at the end of the operating period. Such determinations require (a) prediction of the progression of localized corrosion effects, such as denting, (b) calculating of the defect (due to denting) that would cause a tube to fail to perform its safety function of no leakage greater than Technical Specification limits during an SLB or LOCA, and (c) selection of acceptance criteria to be used in the next inservice inspection. The staff also asked about the safety significance of having degradation progressing at an equal rate on a large number of tubes.

The licensees for Turkey Point 4, Surry Unit 1 and representatives of Westinghouse did not have a basis for selecting a 6 month to 1 year operating period before the next inspection, other than judgement. They will consider the development of such a basis.

✔ Dr. Conway of Westinghouse estamated from his curves developed for hydrostatic testing, that for a limiting condition in a LOCA with 1100 psig (safety valve setpoint) on the secondary side and 550°F tube temperatures, tubes that passed a probe 0.550-inch diameter or larger would not collapse. A few tubes would collapse in the Surry 1 steam generators under LOCA conditions. Leakage of the collapsed

tubes is not expected based on the mechanical test described above. Tom Anderson of VEPCO indicated that the effect of collapsed tubes on steam binding during LOCA reflood would be small. A reduction in peak power ratio of a few tenths would offset this effect on steam binding to maintain calculated peak cladding temperature at 2200°F.

Dr. Conway presented results of differential pressure acting on tube sheets during a steam line break. Plastic deformation of tubes by supports was simulated for new tubing in which a simulated support plate was deformed to a greater extent than calculated, without leakage developing in the tube. (Dented sections of pulled tubes have not been tested in this manner.) Based on these new tube tests and the ~~300~~ 3000 psig internal pressure test of a dented section of a pulled tube, with a tight fitting support in the dented region, Westinghouse representatives have concluded that no tubes would burst in the Surry 1 plant in a steam line break.

In response to staff's question, licensee said that no tubes have been plugged at Turkey Point 4 because of denting. However, they have not defined an unacceptable defect resulting from denting nor determined an acceptance criteria for plugging that would provide adequate safety margin for LOCA and SLB and other accident and normal operating conditions, as defined by the staff in Prairie Island Hearing Testimony for wastage and crack type defects identified in prior PWR operation.

In response to staff's questions regarding eddy current inspection of steam generators with dented tubes, Westinghouse said that cracks or wastage at dented sections cannot be detected because of the much larger effect on the signal due to metallographic structure changes. The accuracy of detection of cracks and wastage in sections of the tube above the first tube support is less than in the section above the tube sheet because the smaller probes required introduce an error due to the larger gap (probe wobble). Probes of 0.640 inch diameter have been used previously to allow traversing of the U-bend The smallest probe now used is 0.400 inches diameter.

Westinghouse said that they believe an adjustment to the all volatile treatment for secondary coolant may be desireable to eliminate the denting mechanism of tube degradation.

Recommendation

Based on the information presented at this meeting and previous information obtained in my coordination of the steam generator tube integrity contention for the Prairie Island plant hearing, I recommend that the following unreviewed safety questions for Turkey Point 4 and Surry Unit 1 be investigated by Reactor Systems, Containment Systems, and

Accident Analysis Branch of the Division of Technical Review. They are already under investigation by Engineering, DTR.

1. For the 6-month to 1-year operating period recommended until the next inservice inspection, will the safety margins in steam generator tube strength remain adequate to assure no tube failures and no leakage in excess of Technical Specification limits during accidents, including steam line breaks, feedwater line breaks, and loss of coolant accidents? The staff raised several aspects of this question that were not answered in the meeting including the specification of an unacceptable defect due to denting and the method of determining acceptable progression of the denting phenomena for the recommended operating period.

2. In light of the proposed limitation of 800 psig hydrostatic test pressure from secondary-to-primary, what confirmation will be made that tubing and plugs (particularly in tube sheet holes where the tube is removed) have been properly welded and have not corroded to the extent they would not hold the maximum pressure differential that could occur in a LOCA (1100 psig)?

3. In light of the expected collapse of tubes during a LOCA, how many tubes are predicted to degrade to the point of collapse for LOCA conditions at the end of the 6-month or 1-year operating period recommended and what is the effect of these collapsed tubes on steam binding during the reflood phase of a LOCA?

4. What is the potential for leakage or failure of many tubes with dents during anticipated operational occurrences, including a spurious closure of steam line isolation valves and water hammer in the feedwater piping?

5. What constitutes an acceptable location and number of tubes for eddy current inspection, gaging with undersized probes, laboratory examination of tubes for determination of unacceptable defects in light of (a) the occurence of denting in all tubes inspected, (b) the inability of eddy currents to detect cracks or wastage at dented locations, and (c) the reduced accuracy of measuring depths of penetration of cracks or wastage at locations above the first tube support due to use of smaller probes?

6. What are the interim conclusions regarding the Prairie Island Unit 1 inspection data of May 1975 that is still under review with respect to any denting phenomena?

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