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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION
NORTHEAST NUCLEAR ENERGY COMPANY, ET AL.
MILLSTONE UNIT 2
DOCKET NO. 50-336
1985 STEAM GENERATOR TUBE INSPECTION

1.0 Introduction

At a meeting in Bethesda on May 1, 1985 and by letter dated June 12, 1985, Northeast Utilities reported the preliminary results of the scheduled Technical Specification eddy current testing (ECT) of the steam generator tubes that was carried out at Millstone Unit 2 during the 1985 refueling outage. The purpose of the staff review was to determine if there were any unreviewed safety issues introduced as a result of chemical cleaning during the outage and if there were any changes to the conclusions in the staff's Safety Evaluation of December 30, 1983 regarding the approval of the repair of the steam generator tubes by sleeving.

2.0 Background

Millstone Unit No. 2 is a Combustion Engineering design, two-loop pressurized water reactor rated at 2700 megawatts thermal. The two steam generators are of the vertical shell U-tube type with each rated at 5,603,000 lb/hr steam flow at 870 psig. Each steam generator contains 8519 heat transfer tubes. The tube material is Inconel 600 with dimensions of 0.750 inch O.D. and .048 inch nominal wall thickness. The tubes are fully expanded into the tubesheet and seal welded. Millstone Unit No. 2 began commercial operation in December 1975. All volatile treatment (AVT) secondary water chemistry control has been used since initial operation. Full flow condensate polishing was introduced in November 1977.

Steam generator tube degradation experienced at Millstone has included tube support plate and eggcrate denting and tube pitting. Between November 1977 and December 1980, 361 tubes in steam generator #1 and 439 tubes in steam generator #2 were preventatively plugged because of denting. During the 1981/1982 refueling outage, eddy current examination of heat transfer tubing in both steam generators revealed indications of secondary side tube degradation in the hot and cold legs of both steam generators. The degradation was characterized by ECT as discrete, small volume defects (confirmed later as pits). The pits were located within the tube bundles between the tubesheet secondary face and the lowest eggcrate support. Estimated depth of the indications varied from less than 20 percent through-wall to essentially through-wall.

In 1983, the staff approved sleeving as an alternate method to plugging for steam generator tube repair. The sleeves were designed to span degraded regions of the tubes in order to maintain them in service. Degradation due to pitting attack has occurred in both the hot and cold legs of the tube bundle with most pits located on the cold leg and confined to a region approximately one foot above the tubesheet.

During the initial sleeving program in 1983, 2022 sleeves were installed in the cold legs of both steam generators (SG #1-894, SG#2-1128) and 192 tubes were plugged in both steam generators. Of the above, 77 tube ends were repaired due to distorted signals which could not properly be evaluated and three tubes were removed for non-destructive examination. The pits, ranging in size from 8 to 80 mils in diameter and 8 to 40 mils in depth, were located between the top of the tubesheet and the first support plate and are mostly in tubes in the center of the tube bundle.

3.0 Discussion of Current Inspection

In an initial attempt to conduct the required Technical Specification steam generator tube inspection, the licensee experienced a high degree of eddy current signal interference associated with copper deposits. This caused a large number of pitting defects to escape detection before the subsequent chemical cleaning removed copper containing sludge and deposits. The failure to detect small pit defects (less than 0.050" diameter) prior to chemical cleaning was attributed to the high noise signal level generated by the presence of highly conductive copper on the tube and in the sludge. Since ECT is sensitive to the reduced conductivity caused by degradation, increased conductivity caused by the presence of copper can mask defect signals.

Although the phenomenon of copper signal interference of eddy current data has long been recognized, this is the first time that chemical cleaning was reported to be necessary in order to obtain a valid eddy current test of steam generator tubes. It has always been assumed that other measures such as frequency mixing or specially designed coils would give an adequate sensitivity to the presence of significant defects in the presence of copper interference. In the case of Millstone 2, the licensee concluded that only pit defects smaller than 0.050" inch diameter were masked by the copper. The staff has not yet conducted an independent evaluation of the data to confirm this; however, a review of the eddy current test information on Indian Point 3, a plant which has experienced pitting and copper deposits, revealed that pits > 0.050 inch diameter and > 50% through-wall were detectable even in the presence of copper interference.

"Burst" tests (test loss of internal pressure) on tubes removed from the Indian Point steam generator and tubes having drilled, simulated pits demonstrated that loss of tube integrity was by a pin hole leak at the bottom of one pit and not failure through the full diameter of the pit. The burst tests also demonstrated that it would take >7000 psi differential pressure to cause an 0.050" diameter by 90% through-wall pit to leak. Burst tests performed in 1982 to address the type of pitting defects found in the Millstone 2 steam generators showed that 9000 psi differential pressure was required to induce failure. This was based on a tube that was removed from service containing an 83% through-wall eddy current field test indication which was subsequently pressurized to failure.

As a result of the 1985 tube inspection, 1,707 tube ends have been sleeved and 23 tubes plugged in steam generator #1 and 1211 tubes have been sleeved and 40 tubes plugged in steam generator #2. There were about 2200 tube ends with eddy current indications ranging from >0% to< 40% through wall that were not required to be repaired.

4.0 Chemical Cleaning of the Steam Generators

The chemical cleaning process which was used has been under development for approximately 10 years. During the development period and prior to the cleaning, the staff received information through EPRI reports and meetings with the licensee which demonstrated that the cleaning process did not significantly degrade Inconel 600 tubing. The chemical cleaning process was further tested on tubes which had been removed from the Millstone 2 steam generators. In these tests, no evidence of pitting corrosion was detected. Additionally, during the actual cleaning process, test specimens of Inconel 600 were used and the post-cleaning general corrosion was measured at $\leq$0.003 mils with no observable pitting attack.

The licensee concluded that the chemical cleaning process did not result in pitting attack of the tubes. However, it did remove sludge deposits which had caused interference with detectability of small volume pits. Based on the developmental programs, the staff has reasonable assurance that the chemical cleaning process at Millstone 2 did not cause pitting corrosion of the Inconel 600 tubing.

5.0 Staff Evaluation

In the safety evaluation approving the sleeving of tubes as an acceptable alternate method of repair, the staff noted that the licensee had made a commitment that his ECT techniques would incorporate the most recent state-of-the-art technology for inspection of the sleeved assembly and that as improved techniques are developed they would be utilized. The staff's major concerns were directed toward the adequacy of ECT methods in detecting defects in the vicinity of geometrical discontinuities in the sleeve-tube combination. At that time, the possibility of interference or masking due to the presence of copper was not recognized.

In accordance with the licensee's previous commitment, an advanced multi-frequency ECT method was used during the present inspection outage. Eddy current testing was performed using the ZETEC MIZ-18 digital inspection system in combination with a DDA-4 digital data analysis system. A high frequency, narrow-focus, bobbin probe, designed to optimize pit identification in the presence of copper was used for the majority of the inspections. However, other probes, optimized for specific applications such as hot leg, cold leg, U-bend, sleeves or top of tubesheet were also utilized. These specialized probes matched the fill factors, magnetic saturization characteristics, focus ability and frequency mix ability with the specific needs of the application. For example, a jointed flexible coil was used for the U-bend region while an eight-coil pancake surface riding array was used for the inspection of the top of the tubesheet.

The licensee has stated that he believes that a conventional ECT program, without chemical cleaning, meets the intent of current Technical Specification requirements. To support this conviction, the licensee cites data in which he says it was shown that several, large-volume, large-depth, drilled holes (0.125 inch diameter by 88 percent depth) were required to violate the structural requirements defined in Regulatory Guide 1.121. An ECT amplitude of about 14 volts is associated with one such defect, a size which should be detected even in the presence of copper. Laboratory tests conducted by Combustion Engineering using drilled holes have shown that pits as small as 0.075 inches in diameter by 40 percent depth are detectable by ECT in the presence of a 4 mil layer of copper, whereas an 0.030 inch diameter by 40 percent deep pit was not detectable. The staff has not completed its review of this information. The staff has requested that their eddy current consultant at Oak Ridge National Laboratory review this data and provide the staff with his conclusions and recommendations as to the validity and applicability of this data to Millstone 2. In the meantime, reasonable assurance that no significant pit could develop, go undetected, and eventually lead to tube rupture during operation is provided by the Technical Specification primary to secondary leakage rate limit of 0.5 gpm, since that level of leakage is equivalent to leakage from an 0.025 inch diameter hole.

The licensee has further stated that pitting is expected to greatly decrease and essentially cease at Millstone Unit 2 as a result of aggressive countermeasures which are expected to remove or greatly improve the "local-chemistry environment" responsible for the pitting. These countermeasures include removing "sludge," aggressive control of oxygen leaks and condenser tube leaks (including a 100 percent ECT inspection), replacing copper alloy tubes in feedwater heater, and numerous improvements in secondary chemistry control practices and equipment. The effectiveness of these countermeasures at Millstone 2 and the licensee's conclusions as to the reduced potential of pitting corrosion as a degradation mechanism will be best evaluated after the inspection at the completion of the next cycle of operation.

6.0 As Low As Reasonably Achievable (ALARA) Considerations

The licensee, in their July 12, 1985 letter, provided actual radiation exposures for the entire Steam Generator Sleeving Program including tube sleeving, chemical decontamination, eddy current testing, chemical cleaning, etc. The person-rem exposure for tube sleeving was 526 while the balance of the jobs were completed with an exposure of 435 person-rem. This ALARA effort was done by (1) mock-up training, (2) extensive shielding in loop areas and decontamination areas, (3) use of ROSA (Robot) in the cold legs, and (4) chemical decontamination of the steam generator. Sufficient detail has been provided by the licensee for us to conclude that the NNECO 1985 sleeving operation is acceptable to assure that occupational radiation exposure will be ALARA.

7.0 Environmental Considerations

Because the exposures are ALARA, the conclusions made in the December 30, 1983 Safety Evaluation contained in Amendment 89 to Facility Operating License No. DPR-65, which approved sleeving as an acceptable repair method, remains valid. That is, an environmental impact statement or negative declaration and environmental impact appraisal need not be prepared in connection with the sleeving operation.

8.0 Conclusions

We have concluded, based on the information cited above, that the chemical cleaning of the Millstone 2 steam generators enabled a more valid eddy current inspection of the steam generator tubes to be conducted and that there is reasonable assurance that the chemical cleaning process did not cause further pitting corrosion of the Inconel 600 tubing. We further conclude that our previous favorable evaluation of the acceptability of sleeving as a method of steam generator tube repair remains unchanged.

Principal Contributors:
H. Conrad
J. Minns
F. Witt
D. Osborne

Date: August 19, 1985