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

SAFETY EVALUATION

STEAM GENERATOR INSPECTION

WISCONSIN ELECTRIC POWER COMPANY

POINT BEACH NUCLEAR PLANT, UNIT 1

INTRODUCTION

By letters dated November 11, December 3, December 9, and December 10, 1982 Wisconsin Electric Power Company (licensee) reported the results of their November 1982 Point Beach Unit 1 steam generator inspections. The NRC staff obtained further information via telephone conversations with the licensee between November 29, 1982 and December 8, 1982, in which certain points concerning debris removal and fluid elastic analyses were clarified.

The licensee reported that a total of eighteen tubes inspected on the cold leg side of the steam generators were mechanically plugged. This included all tubes having degradation greater than 40% through-wall plus several other tubes which showed signs of possible mechanical damage from foreign objects. The foreign objects were removed from the steam generators. During the removal efforts a small 7.3 gram steel pin broke loose from a retrieval tool and was left in the "A" steam generator. Attempts to locate and remove the pin were unsuccessful and the pin was believed to be lost in the sludge pile. An analysis showed that the pin would not cause tube damage even if it were to be released from the sludge pile where it was believed to be trapped. It should also be noted that the licensee plans to replace the Unit 1 steam generators during the Fall 1983 refueling outage.

Based on our review of the licensee's program of plugging degraded and damaged tubes and the recovery of all significant debris, we have concluded that Point Beach Unit 1 may continue to operate under the provisions of the existing plant Technical Specifications and effective Confirmatory Orders which were imposed for the operation of Unit 1 in late 1979 and early 1980.

BACKGROUND

Point Beach Unit No. 1 began commercial operation in December 1970 using sodium phosphate secondary water chemistry control until the changeover to all-volatile water chemistry treatment (AVT) in September 1974. Operation in this period was characterized by the accumulation of substantial amounts of sludge on the tubesheet and the occurrence of wastage and caustic stress corrosion attack of the tubes in both steam generators. (A definition of terms and general explanation of the corrosion phenomena discussed here may be found in NUREG-0886, Steam Generator Tube Experience, February 1982).

On February 26, 1975, following the changeover to AVT, a tube rupture occurred resulting in a 125 gpm primary-to-secondary leak. The tube failure was attributed to a combination of wastage and caustic stress corrosion cracking from previous phosphate chemistry operation. 157 tubes were plugged, bringing the total of plugged tubes to 353 in both generators. Subsequent operation under AVT has been comparatively free of wastage.

Denting was first detected in November 1975, but the degree of denting has been moderate with no flow slot hourglassing. Only eleven of about 100 affected tubes have been plugged since September 1978 indicating little progression of denting.

Both steam generators have experienced extensive intergranular attack and stress corrosion cracking in the tubesheet crevice which has resulted in the plugging of several hundred tubes. The "deep crevice cracking" was first detected in November 1977.

Steam generator inspections performed in December 1980 and July 1981 continued to show a decrease in the occurrence of newly degraded tubes. The operation of this Unit continues to be subject to a portion of the operating restrictions imposed by Commission Orders of November 30, 1979, January 3, 1980, and April 4, 1980. These Orders include requirements for more restrictive limits on primary-to-secondary leakage, hydrostatic testing of tube bundles during steam generator inspection outages, and additional reporting requirements concerning steam generator inspection results. In addition, these Orders require NRC written approval for restart, in the event that the Unit is shut down because of leakage in excess of the limits in the Technical Specifications. More restrictive reactor coolant iodine concentration limits were also imposed as well as restricting operation to 2000 psi primary system pressure and limiting the total number of tubes plugged in either steam generator to 18%.

In an effort to further reduce corrosion, the licensee began limiting hot leg temperature to 557°F in November 1979. This placed a practical limit of about 75% power on Unit 1. In July 1981, the licensee increased hot leg temperature to 575°F which corresponds to 85% power.

Both steam generators were inspected in November 1981 during refueling after an operating run of 14 weeks at 575°F and approximately 85% power. The number of tubes requiring plugging (16) suggested an increase in tube deterioration versus the previous operating run at 557°F. On restart in December 1981, Unit 1 continued at 575°F and came off-line in March 1982 for steam generator inspection after 15 weeks of operation.

This inspection was to verify Unit 1 steam generator tube integrity prior to Unit 2 being shut down for its annual refueling outage. The inspection consisted of hydrostatic tests and eddy current tests of essentially 100% of all the tubes in both steam generators. A 800 psid secondary-to-primary hydrostatic test indicated five leaking tubes, four of which were from leaking plugs. As a result of hydrostatic and eddy current tests, 39 tubes in the A steam generator and 14 tubes in the B steam generator were plugged. The leaking plugs were weld repaired. The total number of tubes requiring

plugging (53 total, 33 with indications of intergranular attack, or IGA, within the tubesheet crevice) indicated an upward trend in crevice corrosion compared with that experienced in 1980 and early 1981 while operating at 557°F. Therefore, at restart in April 1982, the licensee elected to return to 557°F operating temperature. As was the practice since early 1980, crevice flushing was performed to minimize crevice hot leg IGA corrosion. Following the April 1982 restart, the primary-to-secondary leak rate was measured to be approximately one gallon per day (1 gpd) and this low rate continued until the Unit came down for the annual refueling 28 weeks later on October 22, 1982.

During the October 1982 outage, an eddy current inspection was performed on the hot leg side of all readily accessible tubes up to the first support plate. All tubes containing sleeves were eddy current inspected up through the sixth support plate on the hot leg side. U-bend eddy current inspection was conducted on 3% of the tubes from the hot leg side. Additionally, 2000 psid primary-to-secondary and 800 psid secondary-to-primary hydrostatic tests were performed.

Following the hot leg eddy current inspection, an annular search of the steam generator's secondary side was conducted for loose parts. The search was done through the handholes using fiberoptics to scan the region above the tubesheet and between the tubes and the steam generator shell. Loose parts and debris were observed in both the "A" steam generator (cold leg side) and the"B" steam generator (hot and cold leg sides).

Because of indications of damage to three tubes on the cold leg side of the "A" steam generator an eddy current examination of peripheral tubes in the cold leg side of both steam generators was performed. All outermost peripheral tubes on the cold leg sides of the steam generators were inspected over the U-bend through the top support plate on the hot leg side. To verify that there was no mechanical damage to hot leg peripheral tubes the eddy current tapes of those tubes were re-examined.

DISCUSSION AND EVALUATION

Leak Test

During the October 1982 refueling outage, a 2000 psid primary-to-secondary hydrostatic test and an 800 psid secondary-to-primary leakage check were performed on both steam generators. Visual inspection, with the aid of remote video equipment, identified leakage from previously plugged tubes. Explosive plugs were found to be leaking at a very low rate (approximately two drops per minute). The licensee elected not to repair these plugs during this outage. This decision was based on the consideration of personnel radiation exposure associated with performing weld repairs, the low primary-to-secondary leak rate (less than 10 gallons per day) prior to the outage, and the planned steam generator replacement scheduled in 1983.

In view of the limited period of operation until the replacement of all tubes and the small primary-to-secondary leak rate (10 gallons per day versus the 250 gallons per day limit specified by the Technical Specifications), we consider the licensee decision not to repair the leaky plugs acceptable. In

addition, the Technical Specifications call for a shutdown if an upward trend of leak rate exceeds 15 gallons-per-day per day when primary-to-secondary leakage in either steam generator is over 150 gallons per day.

Eddy Current Examination

The eddy current inspection program performed during this outage consisted of the following:

1. Inspection of essentially all readily accessible tubes to the first support plate in the hot legs of both steam generators.

2. Inspection over the U-bend from the hot leg side of greater than 3% of the tubes in each steam generator.

3. Inspection up to the sixth support of the hot leg tubes containing sleeves.

4. A special inspection of all the sleeves in both the hot leg and cold leg.

5. Inspection of tubes previously identified as containing degradation.

Of the 2,809 open tubes in the "A" steam generator, 2,769 were inspected and 2,787 of the 2,837 open tubes in the "B" steam generator were also inspected. Four tubes in the "A" steam generator and three in the "B" steam generator contained indications exceeding the 40% plugging limit. Of the seven indications exceeding the plugging limit, one is a new indication in the "A" steam generator and two are new indications in the "B" steam generator. The other indications identified were either previously noted as undefinable indications or defects that previously existed, but were not identified in previous inspections. As in the past, all indications had a small volume and originated from the tube's outside diameter.

The seven tubes containing indications greater than the plugging limit have been mechanically plugged. Correct plugging was independently verified by visual means. In addition, the eddy current inspection program identified a total, for both steam generators, of 71 tubes that are restrictive to a 0.720" diameter probe at the first support plate on the hot leg side. Of the 71 restrictions, 20 are in the "A" steam generator and 51 are in the "B" steam generator. The majority of these restrictions are located in the periphery tubes near the "wedge" areas.

All of the restrictions, except for the two in the "B" steam generator, passed a 0.0650" diameter probe. The two restrictions noted above passed a 0.610" diameter probe. Thirteen of the twenty restrictions in the "A" steam generator were present during previous inspections. Forty-two of the 51 restrictions in the "B" steam generator were present during previous inspections. In addition to a slight increase in the total number of restrictions, a slight increase in the extent of the restrictions in some of the tubes previously noted as containing restrictions was experienced. All tubes that restricted a 0.700" probe at the first support were probed through the sixth support with a 0.650" or 0.610" probe. Only minor denting was noted at the higher supports.

Twelve tubes had been sleeved during the October 1981 refueling outage. Eleven of these were eddy current inspected during this outage (one sleeved tube was plugged and removed from service in March 1982). An eddy current signal was identified in the sleeved region of one tube.

This signal was believed to be an indication of a deposit on the ID of the sleeve wall. Evaluations of this signal included reprobing of this sleeved tube before and after brushing and honing of the sleeve wall.

A decision was made to remove the sleeve from this tube for further examination of this indication. The bottom 19-7/8" section of the sleeve was removed for laboratory nondestructive and destructive examination. The hot leg and cold leg ends of tube R28C58 were subsequently mechanically plugged.

Laboratory eddy current inspection confirmed the indication at 10.5" and studies with a pancake probe showed the indication was on the ID and more pronounced in 0-90-180^{0} circumferential location. A detailed examination of the OD at up to 60X at this location and OD diametral measurements identified no cause for the indication and showed a constant OD value of 0.740".

Double wall x-ray radiographs were done at 0^{0}, 45^{0}, 90^{0}, and 135^{0}. Only a shallow circumferential mark at 10.5" was detected at 45^{0}, 90^{0}, and 135^{0}. The mark was not found at 0^{0}.

To facilitate further examination a tube section extending from 9 to 12" was removed and split longitudinally along 0^{0} and 180^{0}. At 10.5", a shallow circumferential mark was observed and found to be more pronounced at 0^{0}-90^{0}-180^{0}. Wall thickness measurements indicated no localized wall reduction at this location. In addition, the section was searched for localized ferromagnetism because of a possible contribution of a ferromagnetic material to the EC signal. No ferromagnetic phase was detected with the instrument used.

The sample was further reduced in size for studies with the scanning electron microscope with the energy dispersive x-ray spectrometer. The 9-12" tube section from 0-180^{0} was cut transversely one half-inch below and above the 10.5" indication and longitudinally at 90^{0}. A scanning electron microscope montage through the indication location shows scratches but otherwise appears featureless. The microstructures at the indication and away from the indication are similar and were as expected from the in-plant wire brushing and honing. The Inconel 600 matrix composition along with Si and Al were found. The latter may have come from the honing.

The above section from 10-11" and 0-90^{0} was cut longitudinally at 45^{0}. On the 0-45^{0} section, energy dispersive x-ray spectrometer area analyses were made at 10.4-10.55" (EC indication) and at 10.6-9" (away from EC indication). The Inconel 600 matrix composition and Al plus Si were found in both areas.

Elemental mapping for Ni and Fe was done in the above areas as part of an evaluation of the variation in the concentration of elements that might contribute to magnetic permeability. The concentrations of each element in the two areas are similar.

Metallography was performed on the 45° surface of the 45-90° section at 10.5". The wall is uniform in thickness and the structure appears normal.

The roll transition and brazed areas of the tube sleeves were also inspected using the same eddy current parameters as used during the baseline inspection of 10/81. The data resulting from this inspection was compared to the baseline data. No noticeable changes in the eddy current signals were observed. In addition to the sleeve inspections, the hot leg tubes containing sleeves were inspected through the sixth support from the hot leg side. This inspection was performed with normal eddy current parameters and a 0.650" diameter probe. No indications were identified.

Inspection and Removal of Debris

After eddy current testing was completed, sludge lancing was performed as a part of normal refueling activities and in preparation for an annular search of the steam generator secondary side. The annular search was done through the handholes using fiberoptics to scan the region above the tubesheet and between the tubes and the steam generator shell.

The annular search of the "A" steam generator identified the following objects, all on the cold leg side:

one six-inch "C" clamp with swivel pad missing

one "C" clamp swivel pad

one three-inch stainless steel hose clamp

pieces of lockwire along with residual scale and sludge

The "C" clamp was leaning against two tubes which showed signs of mechanical damage. A third tube in the area also appeared to have damage although not as severe as the damage to the first two tubes.

The annular search of the "B" steam generator was performed on November 6, 1982 and the following items were found on the hot leg side:

one rod bar 1/4 inch x 3/8 x 58 inches long

one piece of metal 1-1/4 inch x 2-1/4 inches x 6-1/2 inches
(a second piece identical to the one above was later found as the objects were being removed)

pieces of weld rod

pieces of lockwire along with residual scale and sludge

On the cold leg side of the "B" steam generator, the only item found was a piece of slag, which was originally described as 1/2 inch in diameter and one inch long.

Because of apparent damage to three tubes on the cold leg side of the "A" steam generator, WEPCO performed an eddy current examination of the cold leg peripheral tubes in both steam generators. All of the hot leg peripheral tubes had been inspected previously through the first tube support plate during the normal eddy current inspection. To verify that there was no mechanical damage to tubes on the hot leg sides, eddy current tapes of the hot leg peripheral tubes were re-examined with no defects found.

All outermost peripheral tubes were inspected over the U-bend through the top support plate on the hot leg side. Also, all tubes within two tube row depths of the periphery were inspected through the first tube support plate. The results from this inspection showed the existence of mechanical damage to several tubes. In addition, there were several tubes with signs of degradation which was not related to mechanical damage from foreign objects. Because of these indications, the eddy current inspection program in each steam generator was expanded to include a minimum of 600 additional tubes. This inspection was not required by the Plant Technical Specification requirements to go to an expanded sample size, based upon the number of defect indications found in the initial sample. A total of about 1000 tubes per steam generator were inspected.

As a result of this inspection, 18 tubes were plugged as per the Plant Technical Specification. Three tubes having indications less than 40% through wall were not plugged. Two tubes in the "A" steam generator cold leg had observable damage from the "C" clamp and had been previously plugged. One was plugged in February 1978 after Unit 1 was shut down with a 130 gallon-per-day primary-to-secondary tube leak. The other was plugged in May 1978 after Unit 1 was shut down with a 145 gallon-per-day primary-to-secondary leak.

Fluid-elastic Analysis

Using fiberoptic photographs to determine defect size, the licensee performed an analysis to determine the fluid-elastic response of the two damaged tubes for stability with respect to flow-induced vibration and fatigue. At our request, on December 8, 1982, the licensee provided further information that confirmed the acceptability of the analysis to us. The tube was assumed to be dented and fixed at the first support (conservative for a worst-case analysis). Under the influence of normal operating fluid and thermal-mechanical loadings, the damaged tubes were determined to be structurally stable.

Loose Parts Removal

All of the objects were removed from the "B" steam generator on November 16, 1982, except for several pieces of light-weight lockwire which extended between tube columns and appeared to be fixed in the sludge. The 1/4 inch x 3/8 inch x 58 inch rod which was removed was carbon steel and showed no

signs of wearing against the tubes. The rod is estimated to have been in the steam generator for at least five years and could probably have been in the steam generator since before the unit was placed in service in 1970. The two metal blocks (carbon steel) were identified as items used in the wrapper support structure. The blocks did not show signs of ever being installed, and a remote visual inspection verified that there were no support blocks missing. Thus, the blocks were extraneous and have been in the steam generator annulus since fabrication.

All of the items were removed from the "A" steam generator. The "C" clamp handle had to be cut before the clamp could be maneuvered out of the steam generator. It is believed that the "C" clamp could have fallen into the steam generator in October 1977 when the downcomer flow resistor plate modification was performed. The origin of the hose clamp is unknown. During the retrieval efforts, a pin 1/4 inch in diameter by 1-1/2 inches long was lost from one of the retrieval tools. Attempts to locate the pin were unsuccessful.

At our request the licensee performed an analysis of the effect of leaving the pin in the steam generator. They calculated that the threaded pin, having a mass of only 7.3 grams, could achieve a maximum kinetic energy of less than 1 foot-pound. It therefore could not cause damage to the tubes if it became free from the sludge site in which it is believed to be trapped.

After retrieval of the foreign objects was complete, a visual inspection of the tubes in the area which could have been affected by the foreign objects was performed. The fiberoptics, which has a magnification capability of 14X, showed only slight scratches and scraping of a limited number of tubes.

SUMMARY AND CONCLUSIONS

We have reviewed the results of Wisconsin Electric Power Company's tenth refueling outage steam generator inspection as reported in their letters of November 15, December 3, December 9, and December 10, 1982. We also had the benefit of telephone conversations with WEPCO during the period of November 29, 1982 to December 8, 1982, in which certain points concerning the debris removal and fluid-elastic analyses were clarified.

All indications greater than 40% found during this inspection were confined to the tubesheet region. All tubes identified during this inspection as degraded beyond the plugging limit in the Technical Specification (>40%) were mechanically plugged. In addition, several other tubes which showed signs of possible mechanical damage were also plugged. All potentially dangerous foreign objects were removed from the steam generators. The structural integrity of tubes in the vicinity of the loose parts has been examined and found to be acceptable.

As a result of our review we have determined that Point Beach Unit 1 may continue to operate under the provisions of the existing Technical Specifications.

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