UNITED STATES
NUCLEAR REGULATORY COMMISSION
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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

ROCHESTER GAS AND ELECTRIC CORPORATION

R. E. GINNA NUCLEAR POWER PLANT

DOCKET NO. 50-244

1.0 INTRODUCTION

By letters dated May 24, 1983, June 9, 1983, and June 14, 1983 Rochester Gas and Electric Corporation (RG&E) (the licensee) provided documentation regarding the changes made to the steam generator sleeving process previously reviewed and approved by the staff through the deletion of the 25-tube limit from the Ginna Inservice Inspection (ISI) program on April 1, 1983 (Reference 1).

The changes in the sleeving process were made as the result of the discovery that both axial and lateral movement of the steam generator tubes was restricted at the tube support plates resulting in a tube "lockup" situation. The staff was originally informed about the lockup during a telephone conversation on April 25, 1983. Additional information was provided during meetings between RG&E and the staff on May 12, 1983 and May 20, 1983. The formal submittals of May 24, 1983 and June 9, 1983 provided information regarding the basis for determining that the tubes were locked into the support plates, modifications made to the sleeving process and analysis and tests which have been performed related to the tube inspections and repairs. The licensee's letter of June 14, 1983 documented a commitment to improve the inspection techniques.

2.0 BACKGROUND

2.1 Steam Generator Tube Lockup at Ginna

The sleeving of steam generator tubes has been demonstrated to be an effective repair method for defective tubes. This method results in the defective tubes remaining inservice and forestalls the replacement and/or major repair of steam generators. Prior to April 1983, tube sleeving at Ginna had been approved on a limited basis (maximum of 25 tubes per steam generator per inspection) as an alternative to plugging. Based on the staff's analysis of additional information submitted to the licensee, the 25-tube limit was deleted from the Ginna ISI program by NRC letter dated April 1, 1983. A discussion of the approved sleeving process is included in the staff's Safety Evaluation enclosed with the April 1, 1983 letter.

Following approval of the sleeving process, and during the current outage, RG&E and Babcox and Wilcox (B&W) began sleeving the steam generator tubes. After the sleeving was complete, ultrasonic testing (UT) was used to determine the quality of the bonding. It was determined that poor bonding existed in several sleeves. Initially it was suspected that this was due to inadequate cleaning. Even with additional cleaning the quality of the braze joint continued to range from good to poor.

A similarity was noticed between the Ginna UT results and UT results from the locked tube tests at a non-domestic facility. [

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2.2 <u>Pretensioning Modification to the Sleeving Process</u>

The basic sleeving process is discussed in the staff's Safety Evaluation enclosed the the NRC's letter dated April 1, 1983.

Installation of a sleeve into a locked tube using the [ ] pretensioning process involved an additional step in the standard approved sleeve installation procedure. [

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The process of [DELETED] pretensioning the tube resulted in the tube going into compression and deforming slightly [DELETED]. After the [ ] was removed, the tube [ ] and a tensile load was introduced into the tube. [
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The pretensioning process was developed in the laboratory and implemented in the field. [

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A rebraze procedure was developed for tubes which had been brazed prior to discovering the locked tube situation.. [
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This rebraze procedure was successful in producing acceptable brazes (based on UT) on all except four tubes. These tubes and any tubes which were not accessible for UT were pressure tested [

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] The 1980 and 1981 sleeves that could not be UT tested or did not pass the test were also pressurized [
] If a leak at the braze existed and the original tube integrity was violated (three tubes are believed to have through wall indications), the leak could be detected. The 1980 and 1981 brazed joints passed a pressure test across the braze joint at the time of original installation.

The braze joint passed the pressure test if the pressure did not drop [DELETED] The seals were accepted, since no pressure drops [DELETED] were observed. Based on the work previously performed by B&W on locked tubes, work at the site was initiated using the revised process. In parallel, tests and analyses specific to the Ginna steam generator were performed. The results of this work are documented in the licensee's May 24, 1983 submittal (Reference 3).

3.0 EVALUATION

3.1 Design Verification Testing

Testing performed to evaluate the locked tube condition included mock-up, full-size simulation of the Ginna first tube support span and sleeve. The tubes were fully restrained at the tubesheet and the first tube support plate measurements were taken with strain gages and thermocouples at various axial positions on the outside tube diameter to characterize the tube expansion. [
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] These are acceptable based on a code allowable

of 35 ksi for membrane plus bending stresses. [
DELETED] Detailed data from the test is presented in Table 4 of Reference 3.

The results of the testing provided stress information and geometry data on the pretensioned tubes. This data has been used to evaluate actual sleeve loads associated with pretensioning. Further, an evaluation of the expanded portion of the tube indicated that the expansion produced insignificant stress concentrations. The staff considers this acceptable.

3.2 Upper Joint Strength Testing

The sleeve upper joint qualification testing described in Reference 2 assumed that the steam generator tubes were not locked. Since sleeves installed prior to implementation of the pretensioning procedure could have some bulging in the braze area, additional tests were performed. The objective of these tests was to evaluate the load carrying capability of an upper sleeve and expansion joint made under locked conditions. The test procedure was similar to that used previously. [

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The tube/sleeve combination was exposed to the standard braze cycle used during the Spring 1983 outage at Ginna. [
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] All specimens successfully passed the specified fatigue cycles without failure. The conclusion from this test was that the [ ] pretensioning cycle do not affect the joint strength and fatigue life of the tube/sleeve assembly upper joint.

In another test series, the effect of the pretensioning procedure on the strength of the existing steam generator tube below the sleeve upper end joint was determined. Results of these tests indicated [
DELETED] minimal effect on the strength of the tubing.

A test was conducted to determine whether tubes in the Ginna steam generators were locked in a hot or cold condition. Although there is very little difference in tube stresses, it is necessary to know whether the tubes were initially locked in the hot or cold condition in order

to determine the proper [ ] procedure. [
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] Cold locking should yield a zero net residual load. It was postulated that, due to the hot condition residual tensile load, hot condition locking would yield little or no bulging during a [ ] thermal cycle. Previously, it has been demonstrated by tests that cold locking leads to bulging. [
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] No bulge occurred in the test specimen with a tensile load (i.e., locked hot condition). It was, therefore, concluded that the tubes that are locked in the hot condition will not bulge during the braze operation. Since the Ginna tubes experienced bulging it was deduced that they were locked in a cold condition. Thus, a pretensioning procedure as proposed by the licensee is considered appropriate for Ginna.

3.3 Evaluation of Analyses to Demonstrate Structural Integrity

All sleeve designs (28 inch sleeves, 36 inch sleeves, and tubesheet sleeves) were evaluated for the locked tube case. Table 7 and 8 of Reference 3 list the loadings calculated for the sleeve and tube for the analyzed thermal and pressure transients. The maximum load ranges for any of the sleeve types was used to determine the maximum sleeve and tube stresses and usage factors reported. Results of this evaluation demonstrate that all the sleeve designs can accept the design loadings without failure and are qualified as a primary pressure boundary.

The analysis of the locked tube condition indicates that the maximum primary stress range for the sleeve and tube are:

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where Sm is the code allowable stress intensity.

The maximum primary plus secondary stress range for the locked tube was calculated by using the maximum axial load range from Table 7 of Reference 3 and combining this longitudinal stress regardless of its sign with the tensile hoop pressure stress to satisfy the ASME Code allowable stress of 3Sm = 69.9 ksi. The stress intensities of the critical sections of the sleeve and tube have been provided for the locked tube. All of the stresses meet the ASME Code Section III allowables. [DELETED
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For the sleeve, the primary local membrane (P_L) and bending (Pb) stress plus secondary stress (Q) is (S)

[DELETED]

For the tube, the primary plus secondary stress P_L + Pb + Q
[DELETED]

3.4 Fatigue Evaluation

There were no significant changes in the fatigue results due to pretensioning. The loads and cycle were such that the usage factor did not change between a "free" tube and a "locked" tube. The fatigue calculations for the most severe conditions are provided in Tables 13 and 14 of Reference 3. [
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3.5 Evaluation for Faulted Conditions

The Main Steam Line Break (MSLB) loadings for the locked tubes are as follows; Wrapper load is 155 lbs, Differential pressure load is 65 lbs, Drag is 130 in-lbs, and Turbulence is 80 in-lbs. [
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] The locked tube case, therefore, need not be reevaluated for the MSLB faulted condition.

3.6 Evaluation of the Vibrational Suitability of the Sleeved Tube

A locked tube with a sleeve installed has a higher margin to instability then the original analysis. The tensile load and fixed end conditions both serve to increase the natural frequency of the tube and therefore the margin to instability.

3.7 Evaluation of Plugging Criteria for Sleeved Tubes

The sleeve thickness required to meet the Level D conditions is [
DELETED] There is, however, no effect on the plugging criteria which remains at 30% of the sleeve wall [DELETED]

3.8 Corrosion Testing

By referencing published corrosion data, the licensee has shown to the staff's satisfaction that the locked tube situation does not invalidate the results of corrosion testing performed to date. Stress corrosion cracking will not occur as a result of the applied tensile load.

3.9 Inspection of Brazed Sleeves

An onsite review of inspection techniques was made by a consultant to the staff. The consultant's report (Reference 6) describes the results of that review.

The brazed region in the 28 and 36 inch long sleeves was tested using an ultrasonic technique. In addition, a baseline eddy-current inspection of the brazed region was performed using two differential radial [DELETED] coils rotated inside the tube. The entire length of each sleeve was also inspected using an annular [DELETED] differential eddy-current probe.

[

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] The annular differential probe [DELETED] is able to detect defects in the original tube and in the sleeve, as was demonstrated on a modified ASME Section XI drilled hole standard in regions below the braze. The sensitivity and noise levels for defects in the original tubing are not as good as can be obtained in an unsleeved tube, as would be expected. Extra holes were drilled in the standard to increase the magnitude of the signals.

[DELETED

] No attempt was made to use any type of multiple-frequency mix for any of these eddy-current tests. The defects in the sleeve produced larger signals and were much easier to detect and size.

The actual inspections with the annular coils provided acceptable results, except at the top of the sleeve (where the sleeve edge effect causes the signals to saturate), and in the braze region.

[DELETED

] When heated by an induction coil, the material flows into the [ ] gap between the tube and the sleeve and leaves an irregular cavity with some high conductivity material, which produces an eddy-current signal that is difficult to interpret.

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A differential radial probe was used to obtain baseline signals of the sleeved tube which it adequately does. However, the differential radial probe gave a signal that looked similar to a defect and was probably produced by variations in the thickness of the high conductivity material on the outer surface of the sleeve. The staff believes that multiple-frequency techniques could probably reduce this ambiguity and would also permit the inspection for outside diameter defects in the presence of inside diameter defects.

The probe gave large lift-off signals, with those inside the actual steam generator sleeve being larger than those inside the standard. The staff believes that this effect could also be reduced by multiple-frequency techniques.

The inspection of the rest of the tubing above the sleeve was performed from the cold side. The probe diameter, which determines fill factor and affects inspection sensitivity, is limited by the probe size that will pass through the U-bends [

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4.0 SUMMARY

The prestressing of steam generator tubes prior to sleeving appears to have no adverse consequences. The process development for the sealable sleeve was based on the previously approved requirements for the Ginna steam generators. The locked tube condition although not initially anticipated was compensated for by the [ ] pretension process. The licensee has demonstrated that the locked tube condition and other tube irregularities have been found to not adversly effect reliability of the sleeving process. While the pretensioning process is not within the bounds of the original qualification program, the licensee has demonstrated that pretensioning is acceptable.

All sleeve designs (28 inch sleeves, 36 inch sleeves and tubesheet sleeves) were evaluated for the locked tube case. The results of the evaluation demonstrate that the maximum primary stress intensity range at the most critical sections of the tube and sleeve meet the ASME Section III Code allowable for normal operation as well as faulted conditions. The fatigue evaluation based on both analysis and testing indicates that the fatigue usage factors are well within acceptable limits. The margin to instability of the sleeved tube under locked conditions due to vibration, was found to be adequate. The plugging limit of 30% of the sleeve wall thickness has been shown to be adequate for both the free and locked tubes. Based on the above evaluation, the staff concludes that all the sleeve designs can accept the design loadings without failure and are qualified as a primary pressure boundary.

In addition, the test data confirms that the Ginna steam generator tubes were locked in a cold condition. The staff has determined, on the basis of available test data and analysis, that the pretensioning procedure to allow for [ ] growth is appropriate for the Ginna steam generator tubes.

During the review, a number of questions concerning the adequacy of the inspectability of the part of the original steam generator tube located behind the upper braze joint transition end of the brazed sleeve were developed. The staff believes that the inspection procedures used this time were adequate to ensure tube integrity for this outage and base-line sleeve inspection but that a more effective inspection technique will be needed at future outages.

The licensee has recognized the need for further development of the inspection system, but believes that adequate detection of the presence of flaws can be accomplished with the present system. However, in a June 14, 1983 letter the licensee documented the fact that improvements in the sensitivity of the inspection techniques are being pursued. The improved inspection techniques will be used at the next refueling and maintenance outage. If applicable, the improved techniques will be used with the data from the current outage to provide a baseline prior to the next refueling outage. The results of the investigations will be discussed with the staff before the next refueling outage.

The staff has previously approved the tubesheet sleeve design and installation process as described in the "Steam Generator Rapid Sleeving Program Design Verification Report," dated August 1982. The licensee has demonstrated that the modified sleeve brazing and installation procedures are bounded by the analyses and tests described in that report and in current submittals. Review of the brazed sleeve installation procedure as required by Plant Technical Specification 6.5 was performed prior to their installation.

5.0 CONCLUSIONS

Based on the considerations above, the staff has concluded that the pretensioning modification to the approved sleeving process is acceptable. The inspection techniques and procedures performed at this outage were adequate for baseline inspection of the sleeves.

The staff concludes that the licensees commitment to pursue improvements in the inspection techniques to be satisfactory.

6.0 ACKNOWLEDGEMENTS

The following individuals contributed to this evaluation:

H. Conrad
J. Rajan
G. Dick

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REFERENCES

1. Safety Evaluation by the Office of Nuclear Reactor Regulation, Rochester Gas and Electric Corporation, R. E. Ginna Nuclear Power Plant, Docket No. 50-244, April 1, 1983.

2. Steam Generator Repair Sleeving Program Design Verification Report (R. E. Ginna Nuclear Power Plant) August 1982, prepared by Babcock & Wilcox.

3. Steam Generator Evaluation, Spring 1983 Outage, R. E. Ginna Nuclear Power Plant, Docket No. 50-244. May 24, 1983.

4. J. Blanchet, H. Coriou, L. Grall, C. Mahieu, C. Otter, G. Turluer, "Influence de Divers Parametres Sur La Fissuration Integranulaire Des Alliages Inconel 600 et X750 Dans l'Eau Pure a Haute Temperature," Proceedings of the International Conference on Stress Corrosion Cracking and Hydrogen Embrittlement of Iron Base Alloys, Firminy, France (June 1973), National Association of Corrosion Engineers, Houston, Texas (1977).

5. G. J. Theus, "Stress Corrosion Cracking Tests of Alloy 600," Workshop Proceedings; U-Bend Tube Cracking in Steam Generators," EPRI WS-80-136 Proceedings, Palo Alto, California (1981) June.

6. ORNL Intra-Laboratory Correspondence, C.V. Dodd to R. W. McClung, "Travel to Rochester, N.Y., May 13, 1983," memorandum dated May 16, 1983.