

## LICENSEE EVENT REPORT (LER)

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## Title (4)

STRUCTURAL INTEGRITY OF STEAM GENERATOR SLEEVED TUBES FOR WHICH EDDY CURRENT TEST DATA DOES NOT SUPPORT THE PRESENCE OF A ROLL EXPANSION MAY HAVE BEEN COMPROMISED DUE TO LIMITATIONS WITH EDDY CURRENT TEST ANALYSIS METHODOLOGY

EVENT DATE (5)				LER NUMBER (6)			REPORT DATE (7)			OTHER FACILITIES INVOLVED (8)				
Month	Day	Year	Year	///	Sequential Number	///	Revision Number	Month	Day	Year	Facility Names	Docket Number(s)		
1   2	1   2	8   8	8   8	---	0   1   8	---	0   1	0   7	1   2	8   9	NONE	0   5   0   0   0   1		
OPERATING MODE (9)				5	THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10CFR (Check one or more of the following) (11)								0   5   0   0   0   1	
POWER LEVEL (10)	0   0   0	<input type="checkbox"/> 20.402(b) <input type="checkbox"/> 20.405(c) <input type="checkbox"/> 20.405(a)(1)(i) <input type="checkbox"/> 50.36(c)(1) <input type="checkbox"/> 20.405(a)(1)(iii) <input type="checkbox"/> 50.36(c)(2) <input type="checkbox"/> 20.405(a)(1)(iii) <input checked="" type="checkbox"/> 50.73(a)(2)(i) <input type="checkbox"/> 20.405(a)(1)(iv) <input checked="" type="checkbox"/> X 50.73(a)(2)(ii) <input type="checkbox"/> 20.405(a)(1)(v) <input type="checkbox"/> 50.73(a)(2)(iii)								<input type="checkbox"/> 50.73(a)(2)(iv) <input type="checkbox"/> 73.71(b) <input type="checkbox"/> 50.73(a)(2)(v) <input type="checkbox"/> 73.71(c) <input type="checkbox"/> 50.73(a)(2)(vii) <input type="checkbox"/> Other (Specify in Abstract below and in text)				

## LICENSEE CONTACT FOR THIS LER (12)

Name	TELEPHONE NUMBER
H. E. Morgan, Station Manager	AREA CODE 7   1   4   3   6   8   -   6   2   4   1

## COMPLETE ONE LINE FOR EACH COMPONENT FAILURE DESCRIBED IN THIS REPORT (13)

CAUSE	SYSTEM	COMPONENT	MANUFAC-TURER	REPORTABLE TO NFRDS		CAUSE	SYSTEM	COMPONENT	MANUFAC-TURER	REPORTABLE TO NFRDS	

## SUPPLEMENTAL REPORT EXPECTED (14)

Expected Submission Date (15)	Month	Day	Year

Yes (If yes, complete EXPECTED SUBMISSION DATE)  XX NO  
ABSTRACT (Limit to 1400 spaces, i.e., approximately fifteen single-space typewritten lines) (16)

On 12/12/88, with Unit 1 in Cold Shutdown, during the review of an evaluation which had been initiated several months earlier to determine the acceptability of sleeved steam generator (SG) tubes that did not have eddy current test (ECT) indications of roll expansions, it was concluded that the structural integrity of these sleeved tubes may not have been in accordance with design requirements.

Approximately 6500 sleeved tubes were placed in service in 1981. Subsequent evaluation of the baseline (1981) and subsequent ECT data of all in-service sleeved tubes determined that the ECT data did not support the presence of roll expansions in 156 sleeved tubes. These tubes, therefore, are conservatively assumed to have had inadequate structural integrity from the time of installation of the sleeves in 1981 until they were removed from service by plugging in 12/88.

The program to install the sleeves in 1981 included ECT to verify proper sleeve installation. However, recent ECT performed with state-of-the-art technology did not indicate the presence of roll expansions in the sleeves. It is therefore believed that limitations of the ECT technology resulted in misinterpretation of the ECT data in 1981.

An evaluation completed in 12/88 indicated that sleeves installed without roll expansions may not preclude tube pull-out under worst case accident conditions. However, testing has shown that an increase in sleeve diameter from the expansion process, although not detectable by ECT, may be acceptable.

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Plant: San Onofre Nuclear Generating Station

Unit: One

Reactor Vendor: Westinghouse

Event Date: 12/12/88

Time: 1300

A. CONDITIONS AT TIME OF THE EVENT:

Mode: 5, Cold Shutdown

B. BACKGROUND INFORMATION:

In 1981, in response to a concern regarding steam generator (SG) (EIIS Component Code SG) circumferential tube degradation at the top of the tube sheet due to intergranular attack (IGA) and intergranular stress corrosion cracking (IGSCC), a program was performed by Westinghouse Electric Corporation (WEC) to install sleeves on approximately 6900 SG tubes in the three Unit 1 SGs. In summary, the program replaced the pressure-retaining capability of the original tube with a sleeve inserted inside the tube. This would provide a restraint against double-ended failure of the original tubes at the top of the tubesheet and limit primary-to-secondary leakage should the original tube be penetrated in the region spanned by the sleeve.

Initially, the sleeving program included the installation of sleeves with leak-tight, brazed upper joints; however, it was determined that this program could not be successfully implemented. A leak-limiting, mechanically-bound upper joint process was therefore developed, qualified and applied to the majority (93%) of sleeves installed. The process used to install the sleeves is summarized below:

1. The inside of the tube was honed (cleaned) over the length of the tube to be sleeved.
2. Each sleeve was inserted into its selected tube. The sleeves are of several lengths and extend from the bottom of the tubesheet to a maximum distance of approximately 13 inches above the top of the tubesheet, thereby providing protection in the area where Intergranular Attack (IGA) is of concern.
3. A hydraulic expansion of the upper and lower joint area of the sleeve (located close to the upper and lower end of the sleeve) was performed to expand those regions of the sleeve into contact with the SG tubes.
4. A "roll expansion" (mechanical roll) within the sleeve joint areas (which were hydraulically expanded as described in 3 above) was performed to mechanically bind the sleeve to the SG tube by further expanding those portions of the sleeve against the tube.

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5. Eddy current testing (ECT) of the sleeve was performed to verify that steps 2, 3, and 4 were, in fact, properly performed. The presence of a successfully executed roll expansion is normally accompanied by a distinct indication when subjected to ECT. An ECT analyst reviewed the strip chart indication to determine the presence of roll expansions.
6. If step 5 identified a deviation from expected results, a Nonconformance Report (NCR) was generated. The disposition of the NCR typically included the following:
  - a) In most cases, steps 3, 4, and 5 were repeated as necessary to correct deficiencies.
  - b) Sleeved tubes which could not meet various acceptance criteria were removed from service by plugging. (Approximately 400 tubes were plugged as a result of this.)

After startup from the 1981 tube repair (sleeving) outage, primary-to-secondary leakage was observed. A steam generator leak test was performed in 1982 in conjunction with the Cycle 8 mid-cycle outage Technical Specification (TS) eddy current examination. Three sleeves in "C" SG exhibited minor leakage (one to two drops per minute). Although this leakage was within the acceptable amount for a leak limiting sleeve, all three sleeves were plugged. The results of the eddy current testing conducted on these sleeves indicated no abnormalities.

Limited primary-to-secondary leakage occurred again during Cycle 8 operation (1 gallon per day) and although a leak test was planned, it could not be conducted on the steam generators during the Cycle 9 refueling outage due to the water hammer repairs required on the feedwater system.

In February 1988, Unit 1 was shutdown for a mid-cycle 9 outage, during which a SG leak test was performed to identify (and plug) the SG tubes which were contributing to the approximately 70 gallons per day (gpd) primary-to-secondary leakage observed during the cycle. The leak test identified 19 leaking sleeved tubes and 1 leaking explosive plug. Each leaking sleeve was eddy current tested; the ECT data did not substantiate the presence of roll expansions on the upper joint of 5 sleeves and on the lower joint of 1 sleeve. All but two of the nineteen leaking sleeved tubes were determined to have a leakage rate within acceptable limits (210 drops per minute) specified in the design criteria for the sleeves. All leaking sleeves were plugged.

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An evaluation of the sleeves which were apparently missing roll expansions concluded that this condition was acceptable until the Cycle 10 refueling outage (approximately 3 Effective Full Power Months (EFPM)) based on: 1) all leaking sleeves had been removed from service; 2) the leakage experienced from these sleeves had increased slowly over the fuel cycle without exceeding technical specification limits; (3) the progression of IGA in the sleeved tubes was projected to be less than 1% per month, resulting in a high confidence that a significant number of tubes would not progress to through wall IGA during the remainder of the fuel cycle; and 4) those sleeves without roll expansions would provide an adequate primary pressure boundary in that if a primary-to-secondary leak developed due to a through-wall defect, the leakage would be within the TS limits. This evaluation was reviewed by WEC prior to plant startup from the mid-cycle 9 outage.

In order to determine if there were additional sleeves without ECT data supporting the presence of roll expansions, Allen Nuclear Associates (ANA) was tasked with reevaluating the baseline (1981) eddy current data on all in-service sleeved tubes. This effort utilized the best available analysis techniques and equipment, the DDA-4, which was a significant improvement over the strip chart method used in 1981. The results of this reevaluation, which was completed in September 1988 and which utilized inspection criteria different from that used for initial acceptance by WEC, indicated that there were approximately 600 sleeves for which ECT data did not support the presence of roll expansions (further evaluation, described in Section E.1, later reduced this number to 156 tubes). It is very important to note that these issues concern the absence of ECT indications of a roll rather than indications of an inadequate roll in several steam generator tube sleeves.

Using the above ANA evaluation results, WEC initiated an evaluation of these sleeves to determine their acceptability for the remaining life of the SGs. This evaluation was to determine whether the sleeves required rework (rerolling), removal from service (plugging), or additional ECT, or could be accepted as-is. Initial results from this evaluation indicated that the sleeves could be accepted as-is based on primary-to-secondary leakage rates calculated during normal operation and accident conditions. However, when these sleeves were evaluated regarding structural integrity in December 1988, it was concluded that the sleeves could not meet the design requirements for structural integrity. Specifically, it was concluded that there is a potential for tube pull-out (i.e., a tube severing at the tubesheet and pulling off of the end of the sleeve).

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C. DESCRIPTION OF THE EVENT:

1. Event:

On December 12, 1988, following a phone notification from WEC regarding their ongoing evaluation of sleeves with apparently missing roll expansions, it was determined that upper roll expansions are necessary to preclude SG tube pull-out following postulated accidents. Sleeved SG tubes that are apparently missing upper roll expansions are, therefore, assumed to have had inadequate structural integrity from the time of installation of the sleeves in 1981 until Unit 1 entered its Cycle 10 refueling outage in November 1988. The suspect tubes were plugged in December 1988.

2. Inoperable Structures, Systems or Components that Contributed to the Event:

Not applicable.

3. Sequence of Events:

DATE      ACTION

1981      Approximately 6500 sleeved SG tubes placed in service in 3 SGs.

2/88      Unit 1 shutdown for mid-cycle outage. Leak test completed which identified 19 leaking sleeved tubes.

3/88      SG tube inspection complete. Roll expansions discovered to be apparently missing in 6 sleeves.

SCE initiates a safety evaluation for continued operation with the above condition.

4/6/88      The safety evaluation is completed. The evaluation concludes that continued operation is acceptable since there was assurance that sleeved tubes not having indication of an upper roll expansion would provide adequate leak limiting integrity for the remainder of the fuel cycle (-3 EFPM).

4/10/88      A program is initiated to review the adequacy of the 1981 SG tube sleeving and the impacts of potentially missing upper sleeve rolls for the life of the SGs.

5/2/88      SCE requests that WEC evaluate the adequacy of the safety evaluation.

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<u>DATE</u>	<u>ACTION</u>
5/9/88	WEC comments on the safety evaluation are received. The comments pertain to the limiting event (MSLB) and the effect of thermal hydraulic response of the SG tubes on leakage during an MSLB.  SCE concludes that the existing safety evaluation bounds the WEC comments and is sufficient for the next 3 EFPM.
5/19/89	WEC completes an investigation of the 19 leaking SG sleeves and concludes (based on in-plant test results and 1981 rework records) that the absence of an ECT roll expansion indication does not mean that the roll expansion was not performed.
8/5/88	Unit 1 returns to service from the mid-cycle outage.
11/22/88	Unit 1 is shutdown for the Cycle 10 refueling outage which lasted until 5/25/89.
12/12/88	At 1300, following a phone notification from WEC, it is determined that the presence of an upper roll expansion is necessary to preclude tube pull-out following certain postulated accidents.
12/24/88	All sleeved tubes without ECT indication of a roll expansion are re-examined using modern ECT technology. All SG tubes without indication of an upper roll expansion are plugged.

4. Method of Discovery:

Refer to Section C.1.

5. Personnel Actions and Analysis of Actions:

Since Unit 1 was in Cold Shutdown on December 12, no action was required.

6. Safety System Responses:

Not applicable.

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D. CAUSE OF THE EVENT:

1. Failure to Detect Potentially Missing SG Tube Roll Expansion:

The root cause of the potentially missing SG tube sleeve roll expansions is associated with the analysis methodology of ECT data applied during the original roll expansion process in 1981. That methodology, for a variety of reasons, permitted interpretation of ECT data to conclude the presence of a roll expansion contrary to the results obtained when a more advanced ECT analysis methodology is applied to the same ECT data. The methodology in use at the time of the sleeving project relied upon the interpretation by data analysts of eddy current strip chart traces generated by electronic data processing equipment. When the same data is subjected to state-of-the-art ECT analysis equipment (as was done during this evaluation), the strip chart trace is expanded, thereby facilitating the discrimination of various false indications, such as random noise. It is believed that such false indications could have misled the analyst using the older methodology to the erroneous conclusion that an expansion roll was present.

Notwithstanding these limitations, it is also believed that in some cases, errors may have been made on the part of the analysts. This belief is based upon the recent review of original strip chart traces for which there are no apparent indications of the roll expansion. The ECT data analysis process was contracted under Westinghouse as part of the sleeving project.

It is not clear why some tubes were documented as having acceptable roll expansions in 1981 when a review of the same data today does not result in the same conclusion. Due to the passage of time (i.e., > 8 years), the WEC process records and personnel actions cannot be reconstructed completely. Thus, WEC is not able to offer a conclusive explanation for this difference. It is possible that the ECT analysts considered production and/or rework records in their evaluation of the ECT data.

2. Inadequate Safety Evaluation Performed in March 1988:

The objective of the safety evaluation performed in March 1988 was to determine if the tube sleeves, which did not have an ECT indication of an upper roll expansion, would continue to provide assurance that any leakage would remain below applicable limits for the remainder of the fuel cycle (-3 EFPM). The evaluation determined that the sleeves, even without an expansion roll, would provide an adequate leak limiting primary pressure boundary for 3 EFPM.

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The need to consider structural integrity issue of SG tube pull-out in the March 1988 safety evaluation was not apparent since the WEC "Steam Generator Repair Report, San Onofre Unit 1," (Revision 1, dated March 1981) focuses on leakage and does not clearly identify structural integrity of the upper roll expansions as a design criterion. As a result, the NCR disposition and the safety evaluation concentrated on the leakage issues.

Following completion of the safety evaluation, it was provided to WEC for review. The WEC response (in May 1988) did not specifically address the acceptability of the safety analysis. It did, however, provide two comments on the safety evaluation:

1. The bounding event was a postulated MSLB.
2. The thermal hydraulic response of a sleeved tube during a MSLB may result in stretching of the existing cracks thus increasing the leak paths and possibly the leak rate. An assessment of the thermal hydraulic response would be required to address the consequences of an MSLB.

Both comments were valid. However, based on the operational leak rate of 70 GPD at 1300 PSID, a full 360 fold increase in the leakage would be required prior to reaching the MSLB leak limit of 18 GPM. SCE did not believe this to be credible due to the fact that the leak limiting orifice effect of the affected joint (upper or lower) would still significantly limit the leakage even though the MSLB stretched the tube crack and opened the leak path. Therefore, the NCR and the safety evaluation were not modified as a result of the WEC comments.

As a result of the investigation into the adequacy of the safety evaluation, WEC subsequently provided the following information concerning their review of the SCE safety evaluation:

1. WEC considers that their review was not a technical review but only a review of "form and structure" based on their understanding of the SCE request. The review focused on the licensing bases cited in the evaluation.
2. Had the WEC cognizant engineers been involved in the review, WEC would have concluded (based on the evidence available) that the roll expansions had actually been done but were not detectable by ECT. They disregarded the fact that ECT indication of rolls was the final acceptance criterion for the sleeves.
3. WEC did not understand SCE's position that the absence of an indication of a roll should be conservatively considered the absence of the roll itself. Therefore, WEC did not advise SCE of the structural integrity criterion for the sleeve rolls.

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Concerns related to the structural integrity issue did not emerge until December 1988 during the ongoing evaluation of the tube sleeve upper roll expansion issue. The structural integrity became apparent during a comparison of the ECT data base collected by ANA with WEC records. This comparison revealed that there were some locations for which WEC could not retrieve microfilm records to verify the completion of the sleeve installation. Thus, for these tubes, the issue of sleeve structural integrity was only then raised by WEC as a potential issue since the documentation of completion of the upper roll expansions was unavailable.

Nonetheless, since the March/April 1988 SCE safety evaluation considered impact of the absence of ECT indication of an upper roll expansion on leakage, it should have also considered the potential for degraded structural integrity. As mentioned above, WEC did not consider the absence of ECT indication of an upper roll expansion as indication of the absence of structural integrity.

Factors contributing to the inadequate safety evaluation of the absence of roll indications (completed in April 1988) are as follows:

1. Documentation of the design criteria applicable to the tube sleeves was not clearly presented in the WEC SG Repair Report. Specifically, structural integrity was addressed in the "Development and Qualification" section of the report rather than in the "Design Criteria" section.
2. During preparation of the safety evaluation, SCE's review of the WEC SG Repair Report for design criteria applicable to the upper roll expansions was not thorough as it did not include a review of the "Development and Qualification" section.
3. In its request to WEC to perform a technical review of the safety evaluation, SCE did not clearly communicate the type of review to be performed. In the same interchange, WEC was not sufficiently thorough in its response to the SCE request.
4. In its review of the WEC comments on the safety evaluation, SCE accepted a less than definitive assessment of the WEC comments.

The root cause of the inadequate safety evaluation of the absence of roll indications is a lack of thoroughness on the part of SCE. In assessing this emerging issue, inadequate communications between SCE and WEC (in particular, a failure to identify and assure resolution of technical differences of opinion) compounded the problem.

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E. CORRECTIVE ACTIONS:

1. Corrective Actions Taken:

- a. Each of the approximately 600 sleeved tubes that were identified by ANA as apparently missing roll expansions were eddy current tested by CONAM Inspection utilizing state-of-the-art technology. The ECT data was analyzed by three separate parties, including WEC, ANA, and CONAM Inspection. The results of this analysis identified 156 tubes that did not exhibit the ECT signature characteristic of an upper roll expansion. These tubes were removed from service by plugging. In addition, 12 other sleeved tubes that were identified to have primary-to-secondary leaks were plugged. All sleeves that remain in service have been verified by ECT analysis to have the required upper and lower roll expansions.
- b. It is the belief of SCE that improvements made in its quality assurance and control programs since 1981 are sufficient to prevent recurrence of this type of problem. For example, ECT technology and the practices currently in effect to assure quality (e.g., two party analysis and remotely operated systems (robots)) will prevent recurrence of this problem. Further, the improved quality of procedures and the required attention to procedural detail that have been implemented at San Onofre since 1981 will also prevent recurrence of this type of problem.
- c. Regarding the inadequate technical evaluation performed in March/May 1988 which permitted restart of Unit 1, a critical self-assessment and review has been conducted by the engineering personnel (including management) involved.

As a result of this assessment the responsible personnel have become more sensitive to the following aspects of evaluating technical issues:

- 1) The need for a more thorough review of design criteria during the performance of technical and safety evaluations.
- 2) The need to be more specific in communicating requests for evaluations by organizations providing technical support.
- 3) The need to assure that differences of opinion between SCE and its supporting contractors are resolved and that both the basis for and the results of technical evaluations be mutually understood and agreed upon.

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2. Planned Corrective Actions:

None.

F. SAFETY SIGNIFICANCE OF THE EVENT:

Absence of a roll expansion results in a sleeve configuration that is not in accordance with the design assumptions of the sleaving project.

Analysis has shown that during certain postulated accidents (e.g., main steam line break), sleeved tubes without roll expansions may not provide sufficient load-carrying capability to preclude tube pull-out. The pull-out of one or more tubes could result in primary-to-secondary leakage sufficient to exceed allowable offsite dose limits. However, although tube pull-out was considered in the sleeve design criteria, it is not believed to be a credible event due to the physical restraint provided by surrounding tubes. Further, absence of a roll indication by ECT does not preclude the presence of a roll expansion. Recent testing by WEC has concluded that an increase in sleeve diameter from the expansion process, although not detectable by ECT, may be acceptable.

G. ADDITIONAL INFORMATION:

1. Component Failure Information:

Not Applicable.

2. Previous LERs on Similar Events:

None.

3. Results of NPRDS Search:

Not Applicable.