Southern California Edison Company

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June 27, 1995

WALTER C. MARSH
MANAGER OF NUCLEAR REGULATORY AFFAIRS

TELEPHONE
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U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Gentlemen:

Subject: **Docket Nos. 50-361 and 50-362**
Response to NRC Generic Letter 95-03, "Circumferential Cracking of Steam Generator Tubes"
San Onofre Nuclear Generating Station
Units 2 and 3

On April 28, 1995, the NRC issued Generic Letter 95-03, "Circumferential Cracking of Steam Generator Tubes" (GL 95-03). Enclosure 1 to this letter provides the Southern California Edison (Edison) response to GL 95-03.

GL 95-03 notified all holders of operating licenses or construction permits for pressurized water reactors of the recent steam generator tube inspection findings at Maine Yankee Atomic Power Station and the safety significance of these findings. The NRC requested that all addressees implement the actions described in the generic letter and submit to the NRC a written response to the generic letter regarding implementation of the requested actions.

Edison has worked in cooperation with the Nuclear Energy Institute (NEI), the Electric Power Research Institute (EPRI), and the Combustion Engineering Owners Group to develop generic information in support of the generic letter. Enclosure 2 provides an EPRI letter (C.S. Welty, Jr.) to NEI (R. Clive Callaway) dated May 26, 1995 which provides technical support for our response to GL 95-03.

The conclusion of our response to GL 95-03 is that inspections for steam generator tubing circumferential cracking in San Onofre Units 2 and 3 have been adequate and that safe operation can continue until planned inspections are conducted during the next scheduled refueling outages (Unit 3 in August 1995 and Unit 2 in the winter of 1996-7). Inspections of the San Onofre steam generators will continue to be done in accordance with the recommendations of the EPRI steam generator examination guidelines.

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If you have any questions or require further information, please let me know.

Sincerely,

Walter C. Marsh

Enclosures

State of California
County of San Diego
On JUNE 27, 1995 before me, ALBERT G. MELVILLE, NOTARY PUBLIC
personally appeared WALTER C. MARSH, personally known to me to be the person whose name is subscribed to the within instrument and acknowledged to me that he executed the same in his authorized capacity, and that by his signature on the instrument the person, or the entity upon behalf of which the person acted, executed the instrument.

WITNESS my hand and official seal.

OFFICIAL SEAL
ALBERT G. MELVILLE
Notary Public-California
ORANGE COUNTY
My Commission Expires
October 30, 1995

Signature Albert G Melville

cc: L. J. Callan, Regional Administrator, NRC Region IV
A. B. Beach, Director, Division of Reactor Projects, Region IV
K. E. Perkins, Jr., Director, Walnut Creek Field Office, NRC Region IV
J. A. Sloan, NRC Senior Resident Inspector, San Onofre Units 2 & 3
M. B. Fields, NRC Project Manager, San Onofre Units 2 and 3

Enclosure 1

Southern California Edison Response to Generic Letter 95-03

Southern California Edison Response to Generic Letter 95-03

The purpose of this report is to document the Southern California Edison Company response to U.S. Nuclear Regulatory Commission Generic Letter 95-03, "Circumferential Cracking of Steam Generator Tubes." This response is applicable to San Onofre Nuclear Generating Station (SONGS), Units 2 and 3.

Recent Operating Experience

The SONGS Units 2 and 3 steam generators were designed and fabricated by Combustion Engineering, Inc. (now ABB C-E). There are two model "3410" steam generators per unit. The model number, 3410, refers to the 3410 MW design thermal output of the units. Each steam generator has 9350 tubes and about 104,000 square feet of heat transfer area. The tubes were explosively expanded, "explanded," into the tubesheet during fabrication. The tube supports are all carbon steel lattice-bars, "egg crates." The design of the two steam generators in each plant is identical as it relates to factors that affect steam generator performance. With limited exceptions, the steam generators in both plants have been operated with the reactor outlet (hot-leg) temperature in the range of 607-609 °F.

Secondary water chemistry control meets the recommendations of the EPRI Secondary Water Chemistry Guidelines (Reference 1). Full flow condensate polishing demineralizer units are operated continuously in both plants resulting in steam generator ionic impurity concentrations (e.g., Na^+, Cl^-, and $SO_4^=$) that are routinely less than 0.2 ppb. Primary water chemistry is also maintained as recommended by EPRI guidelines (Reference 2).

SONGS Unit 2 is currently operating early in its eighth fuel cycle. The Unit 2 steam generators were inspected in March, 1995, after 8.62 effective full power years (EFPY) of operation. SONGS Unit 3 is nearing completion of its seventh fuel cycle. The Unit 3 steam generators were last inspected in November, 1993, after 7.13 EFPY.

A total of 691 tubes (out of 18,700) have been removed from service in Unit 2 and a total of 614 tubes have been removed from service in Unit 3. No sleeves have been installed in the steam generators of either SONGS Unit 2 or Unit 3.

Areas Susceptible to Circumferential Cracking

Circumferential cracking in steam generator tubes has occurred in steam generators fabricated by all three of the domestic nuclear steam supply system (NSSS) suppliers - B&W, ABB C-E and Westinghouse. In addition to the top of the hot-leg tubesheet (TSH), it has been detected at dented tube-support intersections, small radius U-bends, sleeved tubes, and top of the cold-leg tubesheet locations.

Industry experience with steam generators supplied by ABB C-E indicates that the area most susceptible to circumferential stress corrosion cracking (SCC) is in the expansion transition at the TSH location. The only circumferential SCC detected at the cold-leg transition of ABB C-E manufactured units was in the replaced steam generators at Millstone Unit 2 and one tube in the Maine Yankee unit. The only other circumferential SCC detected in ABB C-E steam generators was one tube in the replaced Millstone Unit 2 steam generators with a circumferential crack at a dented, drilled-hole tube support. For San Onofre, circumferential cracking has been detected only at the TSH location in SONGS Unit 2.

Historical Inspection Scope at SONGS Units 2 and 3

The scope of the inservice inspections of steam generator tubing in SONGS Units 2 and 3 have increased with each succeeding fuel cycle. During the Cycle 7 refueling outages (1993), more than 60% of the tubes in both units were inspected full length using a bobbin-coil eddy current probe and 100% of the tubes were inspected at the TSH location using a conventional (3-coil) motorized rotating pancake coil (MRPC) probe. The MRPC inspection was conducted specifically to identify tubes with circumferential SCC. During the Cycle 8 refueling outage in Unit 2, 100% of the tubes were inspected full length using a bobbin-coil eddy current probe and 100% of the tubes were inspected at the TSH location using a conventional MRPC probe. These inspections exceed the recommendations of the EPRI Steam Generator Inservice Inspection Guidelines (Reference 3). These inspections also meet the expanded recommendations included in a recent EPRI assessment (Reference 4) of these inservice inspection guidelines on the use of a conventional MRPC probe for the detection of circumferential SCC.

Reference 4 indicates that the qualification of the conventional MRPC technology for detection of >60% through-wall SCC (axial and circumferential) using a 0.80 inch diameter coil resulted in a probability of detection (POD) of 0.83 at a 90% confidence level. More recent work by EPRI, presented at a steam generator circumferential cracking workshop on June 14-15, 1995, indicates that the POD for >40% through-wall circumferential SCC using a 0.115 inch diameter pancake coil and a MIZ-30® system is 0.91 at the 90% confidence level. It is this configuration, including EPRI recommended techniques, that was used during the last inspection of the SONGS Unit 2 steam generators.

Inspection Results (related to circumferential SCC)

As a result of the SONGS Unit 2 steam generator inspections in March, 1995, 27 tubes were identified as having circumferential SCC at the TSH. During the previous inspection in June, 1993, after 7.16 EFPY, 12 tubes were identified as having circumferential SCC. No tubes in Unit 3 have been identified as having circumferential SCC. The results of these inspections (number of tubes with circumferential SCC indications) are summarized in Table 1.

Table 1

	Cycle 7		Cycle 8	
	EFPY	Tubes Affected	EFPY	Tubes Affected
Unit 2	7.16	12	8.62	27
Unit 3	7.13	0	Future	Future

All of the circumferential cracking indications detected in Unit 2 were located at the TSH. Further, they were all located in the central region of the TSH where corrosion products (sludge) tend to accumulate.

The ability to characterize circumferential cracks as to size and origin using nondestructive examination techniques is very limited. Specifically, depth (percent through-wall) sizing techniques are under development and have not been qualified for use in the field. Therefore, the depth of these cracks have not been determined for the SONGS Unit 2 steam generators. The origin of these flaws (inside diameter (ID) or outside diameter (OD)) based on the phase angle of the MRPC pancake coil has been evaluated, and it is estimated that about 75% were initiated from the ID.

The circumferential extent of these crack indications in SONGS Unit 2, however, can be estimated based on MRPC data. It has been determined that all 39 of these flaws are less than 240 degrees. The majority (all but 6) are less than 180 degrees in circumferential extent. The allowable circumferential extent based on a conservative assumption that the flaw is 100% through-wall for its full extent is greater than 270 degrees for steam generators fabricated by ABB C-E that are similar to the SONGS units.

All tubes in the SONGS steam generators with circumferential SCC indications have been removed from service by plugging.

Growth Rates

With the limited number of tubes identified with circumferential SCC in the SONGS Units 2 and 3 steam generators, growth rates have not been determined. Among the other units with ABB C-E steam generators, only one (Maine Yankee) has estimated the growth rate for circumferential SCC in its tubing. For Maine Yankee, the average growth rate for ID cracks was estimated at 11.17% per EFPY, with a 95%/95% (probability/confidence), and the upper limit growth rate was estimated at 40.23% per EFPY.

Justification for Continued Operation

Continued operation of both SONGS Units 2 and 3 is justified based on the inspections that have been conducted and the results obtained. These inspections exceeded the scope recommended in the EPRI steam generator inspection guidelines (Reference 3). As noted in Reference 4, the use of "conventional" MRPC probes in the manner recommended by Reference 3 "have adequately managed circumferential cracking." This is interpreted to mean that the number and size of leaks due to circumferential cracks has been limited and there is no indication that structural limits for in-service steam generator tubing have been violated. This is further supported by Reference 4 which states that available tube-pull and in-situ burst testing data indicate that structural limits have not been violated.

Continued operation of SONGS Units 2 and 3 is further supported by a state-of-the-art water chemistry program, full flow condensate polishing demineralizer systems, conservative leak response procedures, operator training in those procedures, and continuing efforts to participate in and benefit from industry steam generator activities.

Future Steam Generator Inspection Plans

Future inspections of the SONGS steam generators (Unit 3 in August 1995 and Unit 2 in the winter of 1996-7) will be done in accordance with the recommendations of the EPRI steam generator inspection guidelines (Reference 3). Specifically, Edison plans to use a rotating probe with a plus-point coil and a 0.115-inch pancake coil to inspect 100% of the SONGS Unit 3 tubes for circumferential SCC at the TSH location during the Cycle 8 refueling outage. In addition, the use of the most advanced technology will be considered for future outages.

References

1. PWR Secondary Water Chemistry Guidelines, Revision 3, EPRI Report TR-102134, May 1993.

2. PWR Primary Water Chemistry Guidelines, Revision 2, EPRI Report NP-7077, November, 1990.

3. PWR Steam Generator Examination Guidelines, Revision 3, EPRI Report NP-6201, November 1992.

4. Letter from EPRI (C.S. Welty) to NEI (C. Callaway) dated May 26, 1995; Subject: NDE/ISI for Circumferential Cracking.

Enclosure 2

Letter from EPRI (C. S. Welty, Jr.) to NEI (R. Clive Callaway), Dated May 26, 1995

EPRI
Electric Power
Research Institute *Leadership in Electrification through Global Collaboration*

May 26, 1995

Mr. R. Clive Callaway
Project Manager
Nuclear Energy Institute
1776 Eye Street, N.W., Suite 300
Washington, DC 20006-3708

Subject: Response to NRC Generic Letter 95-03, EPRI Input on NDE/ISI of SG Tube Circumferential Cracking

Dear Clive:

Attached is the EPRI input to the industry effort in support of the required response to NRC Generic Letter 95-03. The information is consistent with the current version of the "PWR Steam Generator Examination Guidelines" (Revision 3, 11/92), and reflects available industry practices. It is provided as reference material to be used by the utilities in developing responses to the Generic Letter.

Please contact me if you have any questions.

Sincerely,

/ Welty

C. S. Welty, Jr.
Manager, Steam Generator Program

cc: SGMP Utility Steering Committee

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NDE/ISI for Circumferential Cracking

May 19, 1995

The material below is provided to assist PWR operating utilities in preparing their response to NRC Generic Letter (G/L) 95-03, "Circumferential Cracking of Steam Generator Tubes". The material is provided in response to an action item from a May 9, 1995 meeting held under the auspices of the NEI Steam Generator Issues Working Group wherein the following three-point strategy for responding to the G/L was developed:

1. EPRI to document the current status of MRPC qualification relative to detection of circumferential cracks (including current specific POD and confidence level), and provide information to assist in responding to Item 3 of G/L 95-03 regarding future inspection plans based on Revision 3 of the PWR Steam Generator Examination Guidelines;

2. Each Owners Group and/or NSSS supplier to provide a compilation of recent operating experience relative to circumferential cracking (e.g., # of cracks as a function of location and EFPY, tube pull results, in-situ pressure test results, etc.);

3. Each utility to use the information provided in 1. and 2. to develop a plant specific response to G/L 95-03.

ISI Recommendations

Current recommendations relative to ISI effectiveness are based on conformance to the "PWR Steam Generator Examination Guidelines" (EPRI Report NP-6201, Revision 3, November, 1992). "Conformance" includes having a management/administrative structure that is responsible for implementing the "Steam Generator Examination Engineering" functions described in Section 2, Responsibility, of the Guidelines. Additionally, conformance leads to application of specific portions of Sections 3 and 4 (Guidelines Summary and Steam Generator Examination - Recommended Practice, respectively) that address, at a minimum, the following:

1. A "random" inspection sample scope (i.e., 20% tube-end-to-tube-end bobbin coil examination of all generators) and expansion rules;

2. An "augmented" inspection sample which factors in experience at the particular unit being inspected as well as other relevant industry experience;

3. The use of techniques that are qualified to Appendix H for the particular damage forms that might exist/be found during a specific inspection outage;

4. Data analysis, including;
   a. use of Qualified Data Analysts (QDAs);
   b. development and use of site-specific analysis guidelines;
      1 including the attached guidance "Points to Consider in Circumferential Crack Detection and Length Sizing" (2/21/95)
   c. use of site specific pre-ISI performance demonstration;
   d. analysis of all data;
   e. independent two-party review of data;

5. The use of supplemental NDE techniques and procedures to resolve anomalous/unexpected ISI results.

1. Tubesheet Expansion Zone Region (Including Top of Tubesheet [TTS])

The following discussion applies to the augmented ISI for expansion zone and TTS circumferential cracking. Since all TS expansion designs (explosive, hard-roll and hydraulic) in plants with mill-annealed (non-thermally treated) alloy 600 tubing have exhibited such cracking, both OD and ID initiated and in some cases with as little as ~2 EFPY, it would be expected that all plants with such material and expansion designs inspect a minimum of 20% of the HL transitions in each SG with "conventional" MRPC technology (see NDE Technique Qualification below). If cracking is found in the, the inspection scope should be expanded to 100% in the HL. (If HL cracking is widespread, or if comparison to industry experience indicates that the onset of the problem in the CL is imminent, a 20% CL sample should be done.) If there are geometric discontinuities beyond those found in "normal" transitions, supplemental techniques appropriate to the circumstances should be used to augment the conventional MRPC examination. (Note: absence of "formal" Appendix H qualification should not be considered an obstacle to the use/application of new and developing technologies and procedures [e.g., use of different diameter ECT coil, the use of new probes, etc.].)

2. Dented Support Intersections

For plants with dented tube support intersections (eddy current indications greater than 5 volts), the above discussion relative to techniques, initial augmented sample and expansion to 100% of the dented region (intersections greater than 5 volts) if cracking is found applies (unless the plant is governed by use of interim tube plugging criteria and inspection requirements consistent with Generic Letter 95-XX). The initial 20% augmented sample can be confined to the lowest HL support, applies only to those intersections with

>5 volt dents, and need only be expanded if cracking is found in that region. It should be noted that dents generally imply substantial geometric discontinuities where the application of supplemental technologies would be recommended.

3. Inner-row U-bends

For plants with tubing susceptible to inner-row (small radius) U-bend PWSCC, 100% of the susceptible population should be examined with conventional MRPC technology until/unless U-bend stress relief has been applied in which case a 20% initial sample may be applied (note: conventional MRPC coil[s] are generally configured on a special probe to allow passage through the U-bend region). If cracking is found the sample should be expanded to 100% of the susceptible tubes.

4. Sleeved Tubes

For plants with sleeved tubes, 20% of the HL sleeved tubes should be examined to verify the integrity of the sleeve-to-tube joint(s). If cracking is found the sample should be expanded to 100% of the HL sleeved tubes. (For plants with CL sleeves, if HL sleeve cracking is widespread, or if comparison to industry experience indicates that the onset of the problem in the CL sleeves is imminent, a 20% sample of CL sleeves should be done.) Since the sleeve-to-tube joint generally presents a substantial geometric discontinuity one of the supplemental technologies is recommended for this inspection. At least two of these (the Cecco probe and the Plus Point probe/coil) are currently undergoing peer review for formal qualification to the requirements of Appendix H of the Examination Guidelines, and are expected to be formally qualified by the end of May 1995 (see discussion on technique qualification below).

<u>NDE Technique Qualification</u>

Currently (May 19, 1995) conventional MRPC technology is qualified to Appendix H of the "PWR Steam Generator Examination Guidelines" for **detection** of stress corrosion cracks on the primary side (PWSCC) and secondary side (ODSCC). Conventional refers to a pancake coil with mid-range frequency response around 300 KHz. The following two configurations have been formally qualified per Appendix H:

a. 0.080 inch diameter coil at 200 and 100 KHz

b. 0.080 inch diameter coil at 300 and 200 KHz

"Qualification" requires that a technique demonstrate, at a minimum, a probability of detection (POD) of 0.80 at a 0.90 confidence level for flaws $\geq$ 60%

thru-wall depth on a suitable specimen set as defined by Table S2-2 of Appendix H. The actual field performance for qualified techniques is expected to exceed the minimum criteria, which is in fact the case for the use of conventional MRPC for detection of circumferential cracks based on the field data for the pulled tube specimen set shown below where POD is 83% at 90% confidence level.

Identification	Mode	ID/OD	Max. Depth %	Circum-ferential (Met.) Extent	EC Det.
25-58TTS	Circ.	OD	68	50	Y
39-37TTS	Circ.	OD	20	20	N
20-100TTS	Circ.	OD	28	180	N
23-145TTS	Circ.	OD	64	210	Y
25-19TTS	Circ.	OD	100	330	Y
22-52TTS	Circ.	OD	91	280	Y
23-44TTS	Circ.	OD	100	340	Y
14-118TTS	Circ.	OD	71	350	Y
75-34TTS	Circ.	ID	100	360	Y
13-147TTS	Circ.	OD	100	360	Y
36-130TTS	Circ.	OD	100	360	Y
55-63TTS	Circ.	OD	100	360	Y
64-48TTS	Circ.	OD	100	360	Y
79-83TTS	Circ.	OD	71	360	Y
40-47TTS	Circ.	OD	100	360	Y

Note that in the above table, the only two cracks that were not detected are the ones whose maximum depth is less than 30% through wall. This technique has been qualified since 1992, and has completed "peer review" and incorporation in the industry Performance Demonstration Database. It is currently in version 1.08 of the Qualified Data Analyst (QDA) material, issued in 1994. (The peer review process specified in Appendix G of the Guidelines for a technique's inclusion in the Performance Demonstration Database is a formal review/demonstration of the technique by a minimum of 5 industry QDAs.)

Several utilities are now using a 0.115" D pancake coil which, due to its larger diameter, is considered to be equivalent to or better than the 0.080" D coil for detection of OD flaws (though the advantage in detection may be offset by a loss in sensitivity to spatial resolution). The peer review process for qualification of this coil is in process, and is expected to be completed by the end of May 1995.

Summary

In summary, the PWR Steam Generator Examination Guidelines, Revision 3 (11/92), provide the protocol for developing and applying technology appropriate to manage both existing and emerging damage forms, including circumferential cracking. Within this protocol conventional MRPC technology has been formally qualified since 1992 for detection of stress corrosion cracks (irrespective of orientation - axial or circumferential); and field tube-pull data (shown above) indicate that, for circumferentially oriented stress corrosion cracks, the performance exceeds the minimum requirements of Appendix H of the Guidelines. Experience data provided by the utility owners groups and NSSS vendors indicate that this technology and protocol have adequately managed circumferential cracking. This is supported by: (1) the fact that the recent tube leak at Maine Yankee in July 1994 was due to a "missed" indication from a previous inspection; and (2) available tube-pull and in-situ burst testing data that indicate structural limits have not been violated.

Points to Consider in Circumferential Crack Detection and Length Sizing

1 All tube with distorted expansion transition signals should be re-examined with probes qualified for examination of expansion transitions, if not already so tested.

2 Data should be collected on a push to eliminate the drop through effect at the expansion transition. An axial position encoder may also aid in verifying probe translation quality.

3 Note should be taken of the fact that small cracks in the presence of conductive deposits can yield signals with relatively poor phase correlation between base frequencies.

4 Geometry variations may mask ID initiated cracks. The use of oriented coil voltage ratios may be used to differentiate geometry variations from ID cracks.

5 It may, at times, be beneficial to view C-scan data with the cross hatch turned off.

6 As a minimum, unfiltered data should be reviewed in both the X - Y and C-Scan modes.

7 Filtered data may aid in removing geometric and high frequency noise conditions. Filtered data should not be used to disposition indications from the raw unfiltered frequencies to no-detectable-degradation (NDD).

8 When screening RPC data for circumferential flaws, the screen display should be set such that a signal from a 40% circumferential EDM notch can be clearly seen.

9 When measuring the extent of circumferential cracks, the screen display parameters should be set such that a signal from a 40% circumferential EDM notch will occupy 50% of the X-Y screen. This can result in a clipped C-scan signal, but should ensure that small signals will not be reduced in size such that they might be incorrectly measured.

Note: These parameters may be established using artificial flaws other than a 40% circumferential EDM notch provided the ratio of signal amplitudes between the alternative flaw and the 40% circumferential EDM notch has been established.

10 To measure the circumferential extent of the crack , rotate the C-scan to achieve the best view (typically an end view). With the increased span , determine the end points by viewing a return to null condition. This may require using more than one scan line if geometric offsets exist. The total length should be inclusive of the multiple scan lines.

11 Volumetric calls at the top of tubesheet may represent mixed mode cracking. Indications should be investigated to determine that cracking is not present prior to accepting a volumetric call.

12 Consider the use of alternate probes if detection is compromised by local conditions.

13 Qualified confirmation tools to improve confidence in crack length measurement techniques should be developed.