February 07, 2001

Mr. Gregory M. Rueger
Senior Vice President, Generation and
Chief Nuclear Officer
Pacific Gas and Electric Company
Diablo Canyon Nuclear Power Plant
P. O. Box 3
Avila Beach, CA 93424

SUBJECT: REVIEW OF DIABLO CANYON NUCLEAR POWER PLANT, UNIT NO. 1 - REFUELING OUTAGE 9 STEAM GENERATOR INSPECTION 90-DAY REPORT (TAC NO. MA6240)

Dear Mr. Rueger:

By letter dated June 8, 1999, Pacific Gas and Electric Company (PG&E) submitted its steam generator (SG) 90-day report, "90-Day Report Generic Letter 95-05 Voltage-Based Repair Criteria - Diablo Canyon Power Plant Unit 1 Ninth Refueling Outage." The report was submitted in accordance with Generic Letter (GL) 95-05, "Voltage-Based Repair Criteria for Westinghouse Steam Generator Tubes Affected by Outside Diameter Stress Corrosion Cracking," as a result of implementing the voltage-based alternate repair criteria in the Diablo Canyon Nuclear Power Plant (Diablo Canyon), Unit No. 1 technical specifications (TS).

The amendment approving the use of voltage-based repair criteria for Diablo Canyon Unit No. 1 included a reporting threshold of 1×10^{-2} for the conditional probability of tube burst. PG&E estimated a conditional burst probability well below this threshold using an NRC staff-approved methodology. The estimates of the primary-to-secondary leak rate during a postulated main steam line break for Diablo Canyon Unit No. 1 were well below the 12.8 gpm value assumed in the licensing basis accident analyses and were determined using an NRC staff-approved methodology.

The staff identified two technical issues which PG&E should consider in future inspections and/or assessments. These issues along with the staff's review are discussed in the enclosed safety evaluation. The staff requests that PG&E address these issues within 180 days of

receipt of this letter. As discussed in the enclosed safety evaluation, the staff concludes that PG&E has reasonable assurance of tube integrity for this degradation mechanism over the next operating cycle.

Sincerely,

/RA/

Girija S. Shukla, Project Manager, Section 2
Project Directorate IV & Decommissioning
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket No. 50-275

Enclosure: Safety Evaluation

cc w/encl: See next page

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

OF THE STEAM GENERATOR 90-DAY REPORT

PACIFIC GAS AND ELECTRIC COMPANY

DIABLO CANYON UNIT 1

DOCKET NO. 50-275

1.0 INTRODUCTION

By letter dated June 8, 1999, Pacific Gas and Electric Company submitted for staff review the report for Diablo Canyon Unit 1, "90-Day Report Generic Letter 95-05 Voltage-Based Repair Criteria Diablo Canyon Power Plant Unit 1 Ninth Refueling Outage." The report was submitted in accordance with Generic Letter (GL) 95-05, "Voltage-Based Repair Criteria for Westinghouse Steam Generator Tubes Affected by Outside Diameter Stress Corrosion Cracking," as a result of implementing the voltage-based alternate repair criteria in the Diablo Canyon Unit No. 1 technical specifications.

GL 95-05 allows steam generator tubes having outside diameter stress corrosion cracking (ODSCC) that are predominately axially oriented and confined within the tube support plates to remain in service on the basis of, in part, bobbin coil voltage response. GL 95-05 specifies that inspection results and associated tube integrity analyses should be submitted within 90 days of each plant restart following a steam generator tube inspection. The report should include, at a minimum, projected end-of-cycle (EOC) calculations on voltage distribution, postulated tube leakage, and tube burst probability under main steam line break (MSLB) conditions.

2.0 GENERAL PLANT DESCRIPTION

Diablo Canyon Unit No. 1 has been in operation since May 1985. Diablo Canyon Unit No. 1 has four Westinghouse Model 51 steam generators. The tubes are ⅞-inch diameter and were fabricated from mill annealed alloy 600 material. The steam generators have drilled hole carbon steel tube support plates.

On March 12, 1998, the staff approved a permanent change to Diablo Canyon Unit Nos. 1 and 2 technical specifications which implemented a steam generator voltage-based alternate repair criteria in accordance with GL 95-05.

3.0 STAFF ASSESSMENT

3.1 Inspection Scope and Results

In accordance with the alternate repair criteria (ARC) guidance provided in GL 95-05, the EOC-9 inspection of the Diablo Canyon Unit No. 1 steam generators (SGs) consisted of a complete, 100 percent eddy current (EC) bobbin probe, full length examination of the tubes in all Unit 1 SGs except for the U-bend portion of the tubes in rows 1 and 2 which were inspected with a rotating +point probe. The +point probe was also used to examine the tubes at the tube support plate (TSP) intersections in support of the voltage-based ARC. The +point examination at the TSP intersections encompassed: 100 percent of the distorted OD support (DOS) signal with possible indication signals greater than two volts called by bobbin; 100 percent of the TSP bobbin dent indications; 100 percent of the DOS indications in the defined cold leg thinning region; 100 percent of the ID distorted support signals (DIS); 100 percent TSP dent indications detected during the bobbin probe examination up to the TSP elevation where primary water stress corrosion cracking (PWSCC) had been detected in each specific steam generator, plus a 20 percent sample at the next highest TSP elevation; all TSP indications containing mix residual signals exceeding a voltage threshold that could mask a 1.0 volt bobbin outer diameter distorted signal; intersections with suspected TSP ligament cracking; intersections with DOSs in the wedge regions; and indications that may extend outside the TSP crevice.

PG&E detected a total of 179 intersections (of tubes that were in service during cycle 9) with DOS plate signals that were candidates for the ARC during 1R9 inspection. Twenty-one of the DOS indications were located in the cold leg and 158 were in the hot leg region. Of the 179 indications, 18 were greater than 1.0 volt as determined from the bobbin coil and only one indication was greater than the 2.0 volt lower repair limit. There were no indications that exceeded the upper repair limit of 4.9 volts. A total of 13 tubes were removed from service (12 ODSCC indications confirmed by plus point required repair and one tube was pulled in support of the ARC). PG&E determined that 19 of the cold leg indications were located in the cold leg thinning region.

During the ninth refueling outage (1R9), 35 tubes previously plugged in the eighth refueling outage (1R8) were deplugged, re-inspected, and returned to service. These 35 tubes contained 52 ODSCC indications at TSPs.

In accordance with GL 95-05, PG&E calculated the upper repair limit using the more conservative of the plant-specific average growth rate per effective full power year (EFPY), or 30 percent per EFPY. PG&E documented in its report the average growth rates from cycle 9 to verify that the 30 percent per EFPY value is bounding for Diablo Canyon Unit 1 at this time. PG&E calculated the upper repair limit to be 4.9 volts. This value was calculated prior to 1R9 inspection in accordance with GL 95-05 instructions.

Based on the number of tubes returned to service with bobbin coil indications and the indication bobbin voltages, steam generators 1-2 and 1-3 are considered to be the limiting steam generators for cycle 9 operation. As discussed in Section 3.2.3 of this safety evaluation, this

conclusion is supported by the calculated estimate of accident tube leakage. A total of 203 ODSCC bobbin indications were returned to service for cycle 10.

3.2 Evaluation of Probabilistic Methodologies for Estimating Conditional Probability of Burst and Total Leak Rate Under Postulated Steam Line Break Conditions

Acceptable tube integrity at the conclusion of Cycle 9 operation is demonstrated, in part, by a calculated conditional probability of tube burst for the limiting steam generator less than the reporting threshold indicated in GL 95-05 and an estimated accident-induced steam generator tube leak rate from ODSCC at tube support plate intersections below plant-specific reporting thresholds. Three distinct probabilistic calculations are necessary to determine these results. The following summarizes the staff's evaluation of the results reported on these calculations.

3.2.1 Projected End-of-Cycle Voltage Distribution

In order to perform the first implementation of the ARC at Diablo Canyon Unit No. 1, PG&E performed a review of 1R8 data to assess the voltage growth. PG&E deplugged 35 tubes that were plugged during 1R8 for ODSCC at the TSPs. These 35 tubes contained 52 indications that will be returned to service.

The composite average growth rate for Diablo Canyon Unit No. 1 during cycle 9 was 0.187 volts resulting in an average Cycle 9 growth rate of 29.6 percent, which is equivalent to 0.102 volts per EFPY (based on 1.62 EFPY for cycle 9). This growth rate for Unit 1 appears to be much higher than the growth rate for Unit 2. PG&E has not determined why the growth rate for Unit 1 appears to much higher than Unit 2. PG&E stated that no significant differences in design, operation, or material construction exists between the units. No comparisons for growth rates can be made to previous Unit 1 cycles at this time since 1R9 is the first implementation of the voltage-based alternate repair criteria at Unit 1. GL 95-05 states that if the growth rate distribution consists of fewer than 200 indications, a bounding probability distribution function of growth rates should be used based on consideration of experience to date at similarly designed and operated plants. In order to obtain the most conservative results with respect to the growth rate distribution used in Monte Carlo simulation, PG&E utilized the more conservative industry average growth rate distributions.

During recent inspections in some plants with 7/8-inch SG tubes, relatively high growth rates were observed for indications in tubes deplugged and returned to service at the beginning of their last operating cycle. Some licensees also noted an increase in growth rate with an increase in beginning-of-cycle (BOC) voltage. Since this is the first cycle to implement the voltage based repair criteria and it is the first time that tubes have been returned to service based on the voltage-based repair criteria, Diablo Canyon Unit No. 1 data thus far does not show either effect.

According to the Westinghouse ARC methodology (presented in WCAP-14277, Revision 1), PG&E should use the larger of the plant composite growth rate or the SG specific growth rate when projecting SLB leak rate and tube burst probability for each individual SG. GL 95-05 provides guidance for instances when the plant's growth rate distribution, or combined

distribution from two cycles, consists of fewer than 200 indications. A bounding probability distribution function of growth rates should be used based on consideration of experience to date at similarly designed and operating plants. Since this is the first cycle for the application of the voltage based repair criteria at Diablo Canyon Unit No. 1, which only has 159 indications in its Cycle 9 growth rate distribution, PG&E conservatively applied in accordance with GL 95-05, a bounding probability distribution function of growth rates based on similarly designed and operated units in predicting EOC-10 conditions.

Using the inspection findings in the EOC-9 inspection, PG&E calculated the projected EOC-10 voltage distribution for bobbin coil probe TSP indications. Based on the overall number of indications anticipated at the EOC-10, the 1-2 steam generator is the limiting steam generator for the next cycle of operation. The staff independently verified PG&E's calculations by completing a Monte Carlo simulation to estimate the EOC-10 voltage distributions. The results of these calculations confirm that the predictive methodology used by PG&E to estimate the EOC voltage distributions is consistent with the guidance provided in GL 95-05.

3.2.2 Conditional Probability of Tube Burst

Conservatively using the bounding industry average growth rate distributions as opposed to the growth rate distribution determined for each steam generator, PG&E reported the projected EOC-10 conditional tube burst probabilities. The calculated probability of tube burst for steam generators 1-1, 1-2, 1-3, and 1-4 were determined to be 2.4×10^{-4}, 3.1×10^{-4}, 2.5×10^{-4}, and 6.7×10^{-5}, respectively. The projected values are well below the GL reporting threshold, and therefore, the estimated tube burst probability due to ODSCC at tube support plates is well within acceptable limits for Cycle 10 operation.

3.2.3 Steam Line Break Leak Rate Projection

The staff evaluated the steam line break leak rate reported by PG&E. PG&E determined the steam line break leak rate for SG 1-1, 1-2, 1-3, and 1-4 to be 0.210, 0.275, 0.276, and 0.038 gpm (at room temperature). The staff performed confirmatory calculations and were in agreement with PG&E's values. PG&E's values are less than the Diablo Canyon Unit No. 1 steam line break leak rate limit of 12.8 gpm (at room temperature). Therefore, the projected tube leakage integrity for ODSCC indications is well within the allowable limit established for Diablo Canyon Unit No. 1.

3.3 Database for Tube Integrity Calculations

In order to calculate the conditional tube burst probabilities and postulated steam line break primary-to-secondary leak rate, the methodology approved for GL 95-05 requires the use of burst and leak rate data obtained from model boiler tubes and tubes removed from actual steam generators. The industry has developed correlations relating bobbin coil voltage to the measured leak rate, probability of burst, and burst pressure through testing of these tubes. The leak and burst correlations utilized in PG&E's analyses were based on the Addendum 2 to the Steam Generator Degradation Specific Management (SGDSM) database, "Steam Generator Tubing Outside Diameter Stress Corrosion Cracking at Tube Support Plates Database for

Alternate Repair Limits" submitted to the NRC on June 5, 1998 by the Nuclear Energy Institute (NEI). The NRC staff completed its review of the database and associated correlations for ⅞- inch diameter tubes and concluded that they were acceptable in a letter to NEI dated November 20, 1998. Therefore, the staff finds the ARC correlations utilized by PG&E acceptable.

3.4 Tube Pull Results

GL 95-05 requires periodic tube specimen removals to monitor the morphology of ODSCC degradation at tube support plate intersections and to obtain additional data for inclusion in the correlations relating bobbin coil voltage amplitude to tube burst pressure, probability of leakage, and leak rate. The removal of two tubes during the EOC-9 refueling outage satisfies the periodic degradation monitoring requirements specified in GL 95-05.

PG&E removed the first hot leg tube support plate intersection from tube R16C57 and the first, second and third tube-to-tube support plate intersections from tube R37C32. The first TSP intersection of tube R16C57 was expected to have primary water stress corrosion cracking (ID cracking). The third TSP intersection of tube R37C32 was expected to have ODSCC. The removed tube sections were examined by nondestructive and destructive examination techniques. The destructive examination confirmed the presence of ODSCC at all tube support plate intersections of tube R37C32 and ID and OD cracking at the first TSP intersection of tube R16C57. PG&E concluded the ODSCC morphology is consistent with the morphology of the degradation used in the GL 95-05 databases.

3.5 Probe Wear Criteria

PG&E used alternative probe wear criteria as opposed to the method outlined in GL 95-05. The method was developed by NEI and was found acceptable by the NRC staff as discussed in a letter from Brian Sheron of the NRC to Alex Marion of the Nuclear Energy Institute dated March 18, 1996. Diablo Canyon was given approval to use this alternative method in the staff's safety evaluation for amendment number 124 dated March 12, 1998.

The alternative method involves re-inspecting, with an acceptable probe, all tubes with indications above 75 percent of the lower voltage repair limit which had been inspected subsequent to the last successful probe wear check. That meant, for Diablo Canyon Unit No. 1, all tubes containing indications above 1.5 volts that were originally inspected with a worn probe were to be re-inspected with a new probe. During 1R9, two tubes required retesting to satisfy the bobbin probe wear criteria because they had indications with voltages above 1.5 volts and were found by a worn probe. The re-inspection with a "non-worn" probe resulted in similar voltages to the original readings (i.e., within 6 percent). The staff finds this acceptable.

4.0 IMPLEMENTATION ISSUES

As a result of the staff's review of PG&E's submittal, the staff identified the following two technical issues. Although the staff believes PG&E should address these issues promptly, the staff believes at this time it will not have a significant effect on the results of the analysis (i.e.,

conditional probability of burst and/or primary-to-secondary leakage under postulated accident conditions) given the current state of degradation in the Diablo Canyon Unit No. 1 steam generators. The issues are:

1. In at least 3 instances axial ID and OD cracking was located at the same tube support plate intersection. Based on the material provided, it appears these indications were identified by bobbin as OD indications (i.e., DOS indications) and when inspected with a plus point coil, PG&E identified both ID and OD cracking. PG&E did not discuss whether denting was occurring at these intersections and/or the voltages associated with these dents. Although these indications were removed from service, PG&E should evaluate the need to inspect all bobbin indications with voltages below the 2.0 volt threshold to confirm that ID and OD cracking are not occurring at the same intersection. PG&E's dent inspection program may be addressing this concern; however, the submittal was not clear on this respect. The staff's concern is that PG&E may be applying a voltage based repair criteria to an ID flaw with no supporting correlations and/or methodology. It is also unclear whether PG&E addresses this degradation in the condition monitoring and operational assessment.

2. PG&E evaluated the alternate probe wear criteria to determine if there was a disproportionate number of new indications being found in tubes inspected during a prior outage with a probe that failed the probe wear criteria (i.e., 15 percent). PG&E's evaluation indicated that approximately half of the new indications were in tubes that previously failed a probe wear check and that probe wear was not considered to be the dominant reason for the new indications.

   The staff believes that PG&E should consider evaluating the alternate probe wear criteria by comparing the percentage of intersections previously inspected with probes that failed the probe wear check and developed new indications to the percentage of intersections previously inspected with probes that passed the probe wear check and subsequently developed new indications. The staff recognizes assumptions regarding when the probe actually failed the probe wear check would need to be made (i.e., an estimate of the point between the calibration runs when the probe crossed-over the 15 percent criteria would need to be made) during this evaluation.

   The staff's concern is illustrated in the following hypothetical example. Suppose 20 new indications were detected during the outage. Further, suppose that of these 20, 10 were associated with a probe that failed the probe wear check during the prior inspection and 10 were associated with a probe that passed the probe wear check during that prior inspection. Also, suppose that during the prior outage a total of 100 intersections were inspected with a probe that failed the probe wear check and 10,000 intersections with a probe that passed the probe wear check. In this case, 10 percent of the intersections inspected with a "worn probe" developed new indications whereas only 0.1 percent of the intersections inspected with a "non-worn probe" developed new indications. This may indicate that the alternate probe wear criteria is resulting in missing degradation.

5.0 CONCLUSION

The projected EOC-10 conditional probability of burst and projected MSLB leak rate were less than the GL 95-05 criteria. The staff has reviewed PG&E's methodology, has performed confirmatory calculations, and has found PG&Es methodology and results acceptable. However, as discussed above, the staff has identified two issues as a result of its review. The staff requests that PG&E respond to these issues within 180 days.

Principal Contributor: A. Keim

Date: February 07, 2001