UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION IV
611 RYAN PLAZA DRIVE, SUITE 400
ARLINGTON, TEXAS 76011-4005

May 8, 2003

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

SUBJECT: DIABLO CANYON POWER PLANT - NRC SPECIAL TEAM INSPECTION REPORT 50-323/03-09

Dear Mr. Rueger,

On February 28, 2003, the NRC completed an inspection at your Diablo Canyon Power Plant. The enclosed report documents the inspection findings, which the team leader discussed on April 30, 2003, with Dave Oatley, Vice President and General Manager, and other members of your staff.

This inspection examined activities conducted under your license as they relate to safety and compliance with the Commission's rules and regulations and with the conditions of your license. Within these areas, the inspection consisted of selected examination of procedures and representative records, observations of activities, and interviews with personnel.

The team identified no findings of significance. In accordance with 10 CFR 2.790 of the NRC's "Rules of Practice," a copy of this letter and enclosure will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of NRC's document system (ADAMS). ADAMS is accessible from the NRC Web site at http://www.nrc.gov/reading-rm/adams.html (the Public Electronic Reading Room).

Sincerely,

/RA/

Charles S. Marschall, Chief
Engineering and Maintenance Branch
Division of Reactor Safety

Docket: 50-323
License: DPR-82

Enclosure:
NRC Inspection Report
50-323/03-09

cc w/enclosure:
David H. Oatley, Vice President
and General Manager
Diablo Canyon Power Plant
P.O. Box 56
Avila Beach, California 93424

Lawrence F. Womack, Vice President, Power
Generation & Nuclear Services
Diablo Canyon Power Plant
P.O. Box 56
Avila Beach, California 93424

James R. Becker, Vice President
Diablo Canyon Operations and
Station Director, Pacific Gas and
Electric Company
Diablo Canyon Power Plant
P.O. Box 3
Avila Beach, California 93424

Dr. Richard Ferguson
Energy Chair
Sierra Club California
1100 11th Street, Suite 311
Sacramento, California 95814

Nancy Culver
San Luis Obispo Mothers for Peace
P.O. Box 164
Pismo Beach, California 93448

Chairman
San Luis Obispo County Board of
Supervisors
Room 370
County Government Center
San Luis Obispo, California 93408

Truman Burns\Mr. Robert Kinosian
California Public Utilities Commission
505 Van Ness, Rm. 4102
San Francisco, California 94102

Robert R. Wellington, Esq.
Legal Counsel
Diablo Canyon Independent Safety Committee
857 Cass Street, Suite D
Monterey, California 93940

Ed Bailey, Radiation Control Program Director
Radiologic Health Branch
State Department of Health Services
P.O. Box 942732 (MS 178)
Sacramento, California 94234-7320

Christopher J. Warner, Esq.
Pacific Gas and Electric Company
P.O. Box 7442
San Francisco, California 94120

City Editor
The Tribune
3825 South Higuera Street
P.O. Box 112
San Luis Obispo, California 93406-0112

James D. Boyd, Commissioner
California Energy Commission
1516 Ninth Street (MS 34)
Sacramento, California 95814

Electronic distribution by RIV:
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ENCLOSURE

U.S. NUCLEAR REGULATORY COMMISSION
REGION IV

Docket:	50-323
License:	DPR-82
Report No.:	50-323/03-09
Licensee:	Pacific Gas and Electric Company
Facility:	Diablo Canyon Nuclear Power Plant, Unit 2
Location:	7 ½ miles NW of Avila Beach Avila Beach, California
Dates:	February 17-28, 2003
Inspectors:	W. M. McNeill, Senior Reactor Inspector, Engineering and Maintenance Branch
	W. C. Sifre, Reactor Inspector, Engineering and Maintenance Branch
Accompanying Personnel:	C. B. Khan, Senior Materials Engineer, Materials and Chemical Engineering Branch Office of Nuclear Reactor Regulation
	M. C. Murphy, Materials Engineer, Materials and Chemical Engineering Branch Office of Nuclear Reactor Regulation
Approved By:	Charles S. Marschall, Chief Engineering and Maintenance Branch Division of Reactor Safety

SUMMARY OF FINDINGS

IR 05000323-03-09; Pacific Gas and Electric Company; 02/17-28/2003; Diablo Canyon Nuclear Power Plant, Unit 2; Special Inspection of Steam Generator Tubes.

The inspection team consisted of two regional inspectors and two Office of Nuclear Reactor Regulation personnel. The NRC has described its program for overseeing the safe operation of commercial nuclear power reactors in NUREG-1649, "Reactor Oversight Process," Revision 3, dated July 2000.

The team identified no findings of significance during the examination.

SPECIAL INSPECTION ACTIVITIES

01 Background

During Unit 2 Operating Cycle 9, Diablo Canyon's operating staff identified a minor primary to secondary side leak in a steam generator (less than 0.10 gallons per day (gpd)). Diablo Canyon's operating staff unsuccessfully attempted to locate and correct the leakage in Refueling Outages 2R9 and 2R10. During Operating Cycle 11, the steam generator leak continued, and gradually increased to approximately 6.5 gpd. The licensee determined the source of the identified leakage as Steam Generator 2-4. During Refueling Outage 2R11, which began at the end of Operating Cycle 11 on February 3, 2003, the Diablo Canyon staff pressurized the secondary side of Steam Generator 2-4 to 800 pounds per square inch gauge. Test personnel did this in an attempt to locate the source of the steam generator tube leakage. The secondary side pressure test pressurizes the tubes from the outside rather than the inside and creates a lower differential pressure across the tubes than during normal operation. Diablo Canyon staff has found the test beneficial in helping to identify the location of leaking steam generator tubes.

Based on the secondary side pressure test of Steam Generator 2-4, the Diablo Canyon staff identified 4 steam generator tubes that leaked (i.e., dripping) and 11 additional tubes that they reported as moist. Moist meant to the Diablo Canyon testing staff that the layer of boron on the ends of the tubes appeared dark or damp. The Diablo Canyon staff elected to perform secondary side pressure tests on the other 3 Unit 2 steam generators. The Diablo Canyon testing staff found 3 additional moist tubes in Steam Generator 2-1.

Of the 18 leaking or moist tubes one (the tube in row 5 column 62 of Steam Generator 2-4) leaked from both the hot-leg and cold-leg sides of the tube, which indicated throughwall flaws in the U-bend region. The Diablo Canyon eddy current analysts examined the U-bend region of the tube in row 5 column 62 of Steam Generator 2-4, with a rotating probe. The eddy current analyst identified 18 circumferential indications initiating from the tube inside diameter. A visual inspection of the inside of the tube with enhanced video camera equipment aided the licensee in determining that stress corrosion cracks caused the circumferential indications. The Diablo Canyon staff concluded they had circumferential primary water stress corrosion cracking (PWSCC) in unexpected regions of the steam generator tubing.

The Diablo Canyon staff examined the remaining 17 tubes with a bobbin probe (part of the original inspection scope). They determined that a majority of the 17 tubes contained axial outside diameter stress corrosion cracking (ODSCC) at the tube-to-tube support plate intersection. One ODSCC indication measured 21.5 volts. During the previous outage inspection analysts identified and measured this flaw at 2.0 volts. This met the Technical Specification criteria to leave it in service. The licensee previously received NRC approval to implement a voltage-based alternate repair criteria, which allows the Diablo Canyon staff to leave certain axial ODSCC flaws at tube-to-tube support plate intersections in service based on bobbin coil voltage. The NRC discussed voltage-based

alternate repair criteria in Generic Letter 95-05, “Voltage-Based Repair Criteria for Westinghouse Steam Generator Tubes Affected by Outside Diameter Stress Corrosion Cracking,” dated August 3, 1995. The licensee did not expect the significantly larger than predicted voltage growth from 2.0 to 21.5 volts in one cycle. Other tubes exhibited axial ODSCC indications with larger than predicted voltages, in the range of 2 to 6 volts. The Diablo Canyon engineering staff had left these indications in service during the previous steam generator inspection in accordance with the Diablo Canyon Technical Specifications based on bobbin coil voltage. When the Diablo Canyon staff considered the voltage from these indications in the probability of burst calculation (a calculation required by the voltage-based alternate repair criteria), it exceeded the $1x10^{-2}$ Technical Specification 5.5.9.d.1.j reporting criteria. The licensee notified the NRC staff of this occurrence in accordance with 10 CFR 50.72. The Diablo Canyon staff concluded the steam generator tubes had axial ODSCC at tube-to-tube support plate intersections with higher than predicted voltage growth rates.

The NRC initiated this special inspection because of the report by the Diablo Canyon staff of the secondary side pressure test results and subsequent eddy current test results. The NRC had concerns regarding the structural and leakage integrity of the steam generator tubes. The team used Inspection Procedure 93812, "Special Inspection Procedure" to further assess these concerns. The team reviewed the effectiveness of the examination methods used to examine steam generator tubes during the previous outage. The team did this to determine whether Diablo Canyon staff analysts missed any degraded tubes that should have been plugged during the previous outage. The special inspection team also evaluated the effectiveness of the examination methods used during the 2R11 outage. Specifically, the team evaluated the effectiveness of methods used to detect circumferential cracks in the U-bend region and to address the higher than predicted voltage growth rate of axial ODSCC flaws at tube-to-tube support plate intersections. The inspection team observed the in-situ pressure tests of select steam generator tubes to assure proper and correct testing. The team reviewed Diablo Canyon staff's preliminary root cause and risk evaluations for completeness and accuracy. Lastly, the team assessed the potential generic implications for the remainder of the industry related to the circumferential cracks in the U-bend region and to the higher than predicted growth rate of axial ODSCC flaws at tube-to-tube support plate intersections.

02 Special Inspection Areas

02.01 Effectiveness of Previous Examinations

a. Inspection Scope

In order to evaluate the effectiveness of previous examinations, the team reviewed the inspection scope, eddy current data and results from previous outages related to the inspection of the U-bend region and tube-to-tube support plate intersections. The team reviewed bobbin probe data and available rotating probe data. The team interviewed Diablo Canyon staff and eddy current analysts.

b. Findings

During previous steam generator inspections, the Diablo Canyon staff typically inspected the U-bend region of all tubes with the bobbin probe. At the same time Diablo Canyon inspected the rows 1, 2 and a sampling of row 3 ("low row") U-bend regions with a rotating probe. The licensee and industry experts consider the rotating probe more sensitive to degradation in the tight-radius of low row U-bends. The licensee qualified this probe for detection of circumferential flaws in the low row U-bend region. Diablo Canyon analysts and industry experts do not consider the bobbin probe qualified for detection of circumferential flaws. Based on plant-specific and industry experience, the Diablo Canyon steam generator inspection scope required examination of the row 1 and 2 U-bend regions and a sampling of row 3 with a rotating probe. Upon identification of flaws in the row 3 tubes, the licensee would expand the inspection with a rotating probe to a sampling of the higher numbered rows (4, 5, and beyond). Diablo Canyon and industry based this inspection and expansion plan on the assumption that the likelihood of circumferential degradation would decrease as the row number increased due to lower residual stresses in the tube from the bending process. The identification of circumferential cracks in a row 5 column 62 tube raised the licensee staff's concerns with this inspection and expansion plan since Diablo Canyon had not previously found degradation in rows beyond row 2 at Diablo Canyon.

The Diablo Canyon eddy current analysts reviewed the Unit 2 bobbin probe data from the tube in row 5 column 62 from eight previous outages (i.e., 1982 to the present outage). Diablo Canyon analysts had only collected bobbin probe data prior to the Operating Cycle 11 refueling outage. The analysts performed this review to determine if an analyst could detect the circumferential cracks based on the bobbin probe data. The analysts could detect only a handful of the indications previously identified with the rotating probe and only with special filtering of the raw data. They concluded from this review that the bobbin data could not be used to reliably detect these circumferential flaws in other tubes. The analysts do not normally use filters because of the tendency to filter out other valid indications. In addition, the analysts could only develop the filters used to identify the cracks in the tube in row 5 column 62 after an analyst had already determined the presence and location of the same flaw through rotating probe inspection. Based on the review of previous bobbin data, the analysts found some evidence of cracking as early as 1996 in the tube in row 5 column 62. An independent consultant for the NRC reviewed the bobbin probe data for the tube in row 5 column 62 from previous inspections. The NRC consultant agreed with the Diablo Canyon staff's assessment that the bobbin probe data could not be used to reliably detect circumferential flaws. Based on this, the NRC team concluded that Diablo Canyon analysts did not have an opportunity to identify the circumferential flaws in the tube in row 5 column 62 prior to Refueling Outage 2R11. In addition, the NRC team determined the Diablo Canyon staff's rotating probe inspection scope and expansion plans during Refueling Outage 2R10 and earlier outages were appropriate given the information available at the time.

Each outage, the Diablo Canyon staff typically inspected each steam generator tube with a bobbin probe from the tube-end on the hot-leg side to the tube-end on the cold-leg side as part of its standard inspection. This typical inspection included all tube-to-tube support plate intersections. During Refueling Outage 2R10, the Diablo Canyon staff found a slight increase in the axial ODSCC growth rate that they accounted for in their operational

assessment. In Refueling Outage 2R11, the Diablo Canyon analysts re-reviewed the Refueling Outage 2R10 bobbin data and voltage sizing of the larger axial ODSCC indications. The analysts did this to determine the correctness of voltage measurements during 2R10, and to insure that all tubes left in service under this voltage-based repair criteria met the Technical Specification requirements. The NRC team independently reviewed the 2R10 bobbin data from the tube in row 44 column 45 of Steam Generator 2-4 (the tube that contained the 21.5 volt flaw during Refueling Outage 2R11). The team determined that the Diablo Canyon staff had accurately measured 2.0 volts during Refueling Outage 2R10. The inspectors also concluded that the flaw did not exceed the Technical Specification limit for leaving the indication in service. In addition, the scope of bobbin probe inspections (i.e., 100 percent from tube-end to tube-end) also met the Technical Specification requirements.

The NRC team concluded the analysts did not miss an opportunity to identify the circumferential flaws in the tube in row 5 column 62. In addition, the NRC team determined the Diablo Canyon staff had appropriately inspected the steam generator tubes for the anticipated degradation mechanisms. The team also concluded that Diablo Canyon had appropriately considered plant-specific and industry operating and inspection experience during Refueling Outage 2R10 and earlier outages. The team determined that the 2R10 voltage measurement for the flaw in the tube in row 44 column 45 was accurate and did not exceed the Technical Specification criteria for leaving the indication in service. The scope of bobbin probe inspections (i.e., 100 percent from tube-end to tube-end) for detection of axial ODSCC at tube-to-tube support plate intersections met the Technical Specification requirements.

02.02 Effectiveness of Current Examinations

a. Inspection Scope

To evaluate the effectiveness of current steam generator tube examinations, the team reviewed the inspection scope, eddy current data and inspection results from Refueling Outage 2R11 for the U-bend region and tube-to-tube support plate intersections. The team reviewed a sample of bobbin probe data and available rotating probe data, and the eddy current analysis guidelines for Refueling Outage 2R11. The team interviewed the Diablo Canyon staff, eddy current analysts and industry personnel.

b. Findings

After the secondary side pressure test of Steam Generator 2-4, the Diablo Canyon eddy current analysts examined the U-bend region of the tube in row 5 column 62 with a rotating probe. The analysts inspected this tube because the tube leaked from both the hot-leg and cold-leg sides of the tube during the secondary side pressure test, which they considered indicative of throughwall flaws in the U-bend region. The Diablo Canyon staff initially identified approximately 18 circumferential cracks throughout the U-bend region initiating from the tube inside diameter. Because the licensee had determined the bobbin probe data could not be used to detect these circumferential flaws in the U-bend region, analysts increased the scope of the rotating probe inspection in the U-bend region of the four steam generators to 100 percent.

Diablo Canyon eddy current analysts identified additional tubes with circumferential cracks in the U-bend region. The inspections identified the following numbers of tubes with flaws in the U-bend region and the approximate number of flaws (mostly circumferential):

- 7 cracks in 1 tube in row 5 column 54 in Steam Generator 2-1;
- 23 cracks in 2 tubes (row 4 column 51 and row 10 column 19) in Steam Generator 2-2;
- 4 cracks in 3 tubes (row 3 column 86; row 3 column 93; and row 4 column 52) in Steam Generator 2-3; and
- 58 cracks in 6 tubes (row 5 column 60; row 5 column 62; row 5 column 68; row 6 column 23; row 6 column 53; and row 7 column 52) in Steam Generator 2-4;

As previously discussed, following the secondary side pressure test of all four steam generators, test personnel identified 17 additional tubes as either leaking or moist. In order to identify the degradation causing the leakage, the Diablo Canyon staff performed bobbin probe inspections on all of these tubes. The analysts identified axial ODSCC at tube-to-tube support plate intersections in the majority of these tubes.

Diablo Canyon staff found the voltage growth from 2.0 to 21.5 volts in one cycle unexpected and significantly larger than predicted by the Diablo Canyon staff for tube row 44 column 45 of Steam Generator 2-4. In addition, based on bobbin probe inspections in 13 tubes, the Diablo Canyon staff found that other axial ODSCC indications exhibited larger than predicted voltage growth rates, although none as large as the 21.5 volt flaw. The engineering staff previously had left these indications in service in accordance with the Diablo Canyon Technical Specifications based on bobbin coil voltage. In addition, the licensee factored the voltage growth rates into their operational assessment using the methodology approved by the NRC. Based on the size and growth rates of the flaws found during Refueling Outage 2R11 in these 13 tubes and in other tubes, the licensee reported to the NRC that they would exceed the $1x10^{-2}$ conditional probability of burst associated with the voltage-based alternate repair criteria.

In addition to the bobbin inspections, the Diablo Canyon staff performed rotating probe examinations of all axial ODSCC flaws greater than or equal to 1.0 bobbin volts at tube-to-tube support plate intersections. In addition, the licensee inspected 100 percent of the axial ODSCC at tube-to-tube support plate intersections less than 1.0 bobbin volts in Steam Generator 2-1 with a rotating probe. The licensee also inspected a sampling of ODSCC flaws at tube to tube support plate intersection with less than 1.0 volts in the other steam generators. These additional inspections went beyond that required by the Diablo Canyon Technical Specifications and the voltage-based alternate repair criteria methodology. The licensee performed these additional inspections in order to gather additional information about this degradation mechanism to aid them in determining the cause and appropriate corrective actions for the under predicted voltage growth rates.

The Diablo Canyon staff documented these two issues in Action Requests A0574268 for Unit 2 as: (1) a known defect mechanism, circumferential primary water stress corrosion cracking (PWSCC) operating at a new location, and (2) an increase in assumed crack

growth rate. They documented these issues in Action Request A0574572 for Unit 1 because of the potential generic implications to Unit 1. In addition, the licensee also documented these issues in a higher level corrective action document, Nonconformance Report N0002155.

The team did not identify any concerns with the inspection scope, and eddy current data analysis performed at Diablo Canyon, Unit 2, related to the inspections of the U-bend region and the tube-to-tube support plate intersections. The team determined the Diablo Canyon staff and eddy current contractors followed procedures and performed appropriate additional activities to help bound the scope of these two issues.

02.03 Evaluation of Diablo Canyon Staff's In-situ Pressure Test Activities

a. Inspection Scope

The team observed the in-situ pressure testing of steam generator tubes, and reviewed the results of the in-situ pressure tests to verify proper and correct testing.

b. Findings

The Diablo Canyon staff in-situ pressure tested the tube in row 5 column 62 of Steam Generator 2-4, and all other tubes with indications in the U-bend region. The Diablo Canyon staff concluded that all these tubes met the structural integrity performance criteria of a differential pressure equal to three times normal operating pressure. The tubes also met the leakage integrity performance criteria (which assesses tube leakage at main steam line break differential pressure). The Diablo Canyon staff in-situ pressure tested 14 tubes that contained axial ODSCC at tube-to-tube support plate intersections. Test personnel pressurized these tubes up to main steam line break differential pressure in an attempt to determine whether the flaws contributed to the leakage identified during normal operation. Based on the leakage values identified, Diablo Canyon staff determined that they probably did not contribute to the operating leakage identified during the previous cycle. The licensee hypothesized that, although the tubes leaked during the secondary side pressure test, the presence of the tube support plate and related corrosion products may have prevented the tube from leaking during normal operation. Test personnel only in-situ pressure tested the tube in row 44 column 45 of Steam Generator 2-4 up to normal operating differential pressure and experienced very minor leakage.

The Diablo Canyon staff pulled the tube in row 44 column 45 and the tube at row 35 column 57 of Steam Generator 2-4 to perform off-site laboratory tests (e.g., leakage, burst and metallurgical tests). The Diablo Canyon staff reported that the preliminary burst and leak tests of these tubes met their expectations for the size of the flaws in the tubes. The Diablo Canyon staff stated that when the results become available they intend to provide a formal report to the NRC.

The team observed the in-situ pressure testing and determined that the licensee performed the tests in accordance with plant procedures. The team considered the testing activities acceptable.

02.04 Evaluation of Diablo Canyon Staff's Root Cause Evaluation

a. Inspection Scope

The team reviewed the facts and data, including draft versions of the root cause analysis for the U-bend circumferential cracking and the under predicted high voltage growth rate associated with axial ODSCC at the tube-to-tube support plate intersections.

b. Findings

The Diablo Canyon staff concluded the U-bend circumferential cracking was the result of primary water stress corrosion cracking (PWSCC). The principal factor indicated by the licensee for the susceptibility of the tubes to PWSCC resulted from the residual stress levels induced by the original tube bending operation. The licensee found it was not feasible during the 2R11 refueling outage for the plant to pull one of the tubes affected by the U-bend cracking to verify the root cause analysis. However, the engineering staff concluded that the factors necessary (tensile stress, susceptibility of mill annealed Alloy 600 to PWSCC, and chemical environment) for PWSCC were present in the U-bend region.

The Diablo Canyon staff investigated the under predicted high voltage growth rates for axial ODSCC at the tube-to-tube support plate intersections identified during Refueling Outage 2R11 and concluded that their observed voltage growth rates were normal when compared to industry data. With respect to the 21.5 volt flaw, when the analysts broke the growth into the components of through wall growth and flaw axial extension, the average through wall growth rate (in terms of percent through wall) was typical of industry growth rates. The licensee believes the flaw was nearly through wall during Refueling Outage 2R10, and the flaw grew in the axial direction during Operating Cycle 11. The licensee concluded that the large increase in voltage occurred because eddy current bobbin voltage rapidly increases as flaws go through wall and as the through wall extent increases in length. The licensee's root cause is based largely on the flaw depth and length sizing, for which the eddy current technique is not qualified. Information gathered from the destructive examination of this pulled tube may provide additional information in support of this root cause.

In addition to the 21.5 volt flaw, the licensee identified a second issue regarding under predicted high voltage growth rates. During Refueling Outage 2R10, the licensee used the methodology from the industry guidelines to develop voltage dependent growth rates for axial ODSCC. The licensee's root cause evaluation characterized the methodology identified in the industry guidelines for developing voltage dependent growth rates during the 2R10 as nonconservative. The engineering staff found that the combination of the methodology outlined in the industry guidelines and Diablo Canyon Unit 2's limited number of data points in the higher voltage range during Refueling Outage 2R10 resulted in the nonconservative growth rate predictions. The methodology requires a minimum number of data points to be included in a set of data. Because Diablo Canyon Unit 2 steam generators contained a small number of higher voltage data points in 2R10, the licensee was required by the industry methodology to combine lower voltages with the higher voltage data. The lower voltage data points (with lower growth rates) overwhelmed the higher voltage data points (with higher growth rates), resulting in a nonconservative

combined growth rate when applied to the higher voltage data points. The licensee stated their intent to raise this issue with the industry. The licensee indicated that this was not a continuing concern because they now have more high voltage data points for Diablo Canyon Unit 2.

The team found no major concerns with the root cause evaluations performed to date.

02.05 Evaluation of Diablo Canyon staff's risk analysis

a. Inspection Scope

The team reviewed the Diablo Canyon staff's risk evaluation of the current problems with U-bend PWSCC and axial ODSCC at tube-to-tube support plate intersections to assure the completeness and accuracy of the evaluation.

b. Findings

The Diablo Canyon staff found the in-situ pressure testing for tubes with U-bend PWSCC indicated that the steam generator tubes met the leakage and structural integrity performance criteria. For the axial ODSCC at tube-to-tube support plate intersections, the Diablo Canyon performed laboratory burst and leakage tests on two tubes. One of these tubes contained the 21.5 volt flaw which the licensee believed posed the greatest potential to challenge the structural and leakage integrity performance criteria. The laboratory test results indicated both tubes satisfied the performance criteria. The unit did not exceed the Technical Specification operational leakage limits during the last cycle. The Diablo Canyon staff concluded that the as-found flaws had minimal risk impact.

The team considered Diablo Canyon's analysis acceptable. The team determined that the in-situ and laboratory burst and leakage testing results demonstrated that the flaws imposed very low risk to plant operation.

02.06 Evaluation of Diablo Canyon Staff's Corrective Actions

a. Inspection Scope

The team reviewed the facts and data on corrective actions for the U-bends and tube-to-tube support plate issues. The team also reviewed preliminary corrective actions for both issues to determine if the licensee planned to take full and complete corrective action.

b. Findings

For the circumferential cracks identified in a tube in the outer row U-bend region (row 5 column 62), the Diablo Canyon staff took the following actions during Refueling Outage 2R11:

- Inspection of 100 percent of the tubes in all four steam generators in the U-bend region with a rotating probe to ensure identification of all tubes with circumferential cracks;

- Inspection of a subset of tubes with the a newer probe design to determine the flaw position, the existence of tube ovalization, and to gather data for possible future use and qualification of the newer probe design;

- Visual inspection of the inside of the steam generator tubes with enhanced video camera equipment; and

- Additional review of bobbin probe inspection data from previous outages for the tube in row 5 column 62 to determine whether the analysts missed flaws during previous cycles.

The Diablo Canyon staff indicated that in future outages they intended to continue to inspect outer row tubes with inspection techniques capable of detecting circumferential flaws. The licensee has yet to determine the scope of these inspections.

For the under predicted growth rate of axial ODSCC indications at tube-to-tube support intersections, the Diablo Canyon staff took the following actions during Refueling Outage 2R11:

- Plugged all tubes with axial ODSCC indications greater than 1.2 bobbin volts (Technical Specifications 5.5.9.d.1.j requires the licensee to plug all axial ODSCC indications greater than 2.0 bobbin volts that are also detected with a rotating probe);

- Inspected all axial ODSCC indications greater than 1.0 bobbin volts with a rotating probe in all 4 steam generators;

- Inspected all axial ODSCC indications less than or equal to 1.0 bobbin volts with a rotating probe in Steam Generator 2-1;

- Inspected a sample of axial ODSCC indications less than or equal to 1.0 bobbin volts with a rotating probe in Steam Generators 2-2, 2-3 and 2-4;

- Performed detailed flaw profiling using rotating probe inspection data for a significant number of the larger bobbin voltage flaws to enable preventive removal of incipient throughwall flaws from service (see discussion in Section 02.07);

- Utilized the voltage dependent growth rate distribution in the Operational Cycle 12 assessment because it was more conservative than a non-voltage dependent growth rate distribution, which is discussed in Generic Letter 95-05;

- Submitted a license amendment request to use a probability of detection (POD) of 1.0 for the tube in row 44 column 45 (i.e., the 21.5 volt flaw), in lieu of a POD of 0.6, the currently approved value. The Diablo Canyon staff concluded it was unrealistic to use a 0.6 POD for the 21.5 volt flaw (they do not believe analysts would miss a 21.5 volt flaw). The Diablo Canyon staff indicated that approval of this request, in conjunction with other corrective actions, would justify plant operation for at least 120 days;

- Pulled portions of two tubes containing significant axial ODSCC flaws to enable laboratory burst, leakage and metallurgical tests.

The Diablo Canyon staff notified industry of the new information on U-bend and ODSCC flaws via an industry report. In addition, Diablo Canyon assessed the potential applicability of these two issues to Diablo Canyon Unit 1 and found no additional problems or issues.

The team considered the corrective actions appropriate.

02.07 Evaluation of Generic Issues

a. Inspection Scope

The team assessed the potential generic implications for the remainder of the industry related to the circumferential cracks in the U-bend region and to the under predicated growth rate of axial ODSCC flaws at tube-to-tube support plate intersections.

b. Findings

The Diablo Canyon staff identified three generic issues. The first of these issues dealt with the discovery of flaws from a known cracking mechanism, PWSCC, in U-bend regions in higher numbered rows of the steam generator than previously observed. The second and third issues were associated with the ODSCC found at tube to support plate intersections. The second issue related to a greater voltage response than expected in a 21.5 volt flaw that grew in the axial direction after it grew throughwall. The third issue dealt with the higher than expected growth rate of axial ODSCC flaws at the tube-to-tube support plate intersections.

The Diablo Canyon staff has preliminarily concluded that they observed the same cracking mechanism previously identified in rows 1 and 2 at Diablo Canyon in the outer row U-bends during Refueling Outage 2R11. Analysts found the degradation in new and unexpected locations, such as rows 3-10. Before this issue came to light, analysts did not anticipate circumferential cracks in the U-bend region of the outer row tubes. The analysts did not use inspection techniques capable of detecting circumferential flaws in this region. This issue has potential generic implications because; 1) the scope of eddy current inspections previously performed at Diablo Canyon, Unit 2, is similar to the scope of inspections typically performed in the steam generators at other pressurized water reactors, and 2) the cause for PWSCC (i.e., residual stresses stemming from tube design and tube bending processes) is not unique to Diablo Canyon, Unit 2. The Diablo Canyon staff notified the industry of this issue via an industry report.

The Diablo Canyon staff determined two separate issues existed, with separate causes, for the axial ODSCC flaws at tube-to-tube support plate intersections. The first ODSCC issue related to the tube in row 44 column 45 in which they discovered a 21.5 volt flaw. Diablo Canyon analysts determined the flaw was nearly through wall during Refueling Outage 2R10, and that the flaw grew in the axial direction during Operating Cycle 11. They concluded that this combination of conditions (going through wall, then growing axially) led to the large increase in voltage (i.e., 2.0 volts to 21.5 volts) between 2R10 and 2R11. They concluded this was because eddy current bobbin voltage rapidly increases as flaws go throughwall and as the throughwall extent increases in length. The Diablo Canyon staff concluded that inspection with a rotating probe for further flaw characterization is necessary at Diablo Canyon Unit 2 for axial ODSCC flaws with larger bobbin voltages (greater than 1.2 volts) left in service under the voltage-based alternate

repair criteria. Based on this flaw characterization and its similarity to that present in tube row 44 column 45 during 2R10, they would consider preventive plugging for tubes with similar flaw profiles to that of the flaw in the tube in row 44 column 45 in Refueling Outage 2R10. This issue has potential generic implications because, 1) other licensees have approval to use the voltage-based alternate repair criteria, and 2) the licensee concluded that this issue is related to the behavior of incipient throughwall axial ODSCC flaws.

A second ODSCC issue was identified that pertained to an overall higher than expected growth rate of axial ODSCC flaws at Diablo Canyon, Unit 2. The Diablo Canyon staff utilized a widely available industry standard methodology for determining flaw growth rate. The staff found that the methodology was highly dependent on sample size. The Diablo Canyon staff also found that because they had a small number of data points in certain voltage ranges in Refueling Outage 2R10, they had under predicted the overall flaw growth rate. The industry methodology did not identify the dependence on sample size or the possibility for inaccurate growth prediction for small sample sizes. This issue has potential generic implications because the industry guidance is widely used. The Diablo Canyon staff issued an industry report to address this issue.

The team concluded that potentially generic issues regarding both the circumferential PWSCC in the U-bend region and the increased growth rate of axial ODSCC indications existed at Diablo Canyon. The team will refer these issues to the NRC, Office of Nuclear Reactor Regulation for consideration of NRC generic communications.

4OA6 Meetings, including Exit

Exit Meeting Summary

The team leader and NRC management representatives presented the special inspection results telephonically to Mr. Pat Nugent, NSSS Engineering Manager and other members of Diablo Canyon staff management on April 30, 2003. The staff did not identify any proprietary information supplied to the team.

ATTACHMENT

KEY POINTS OF CONTACT

Diablo Canyon staff

J. Becker, Vice President, Operation & Station Director
S. Chestnut, Director, Engineering Services
L. Exner, Project Manager, Engineering Services
G. Gilles, Director, Site Services
J. Hays, Director, Maintenance Services
S. Kettleson, Manager, Regulatory Services
D. Miklush, Director, Projects
P. Nugent, NSSS Engineering Manager
D. Oatley, Vice President & General Manager
P. Roller, Director, Operations Services
D. Taggart, Manager, Nuclear Quality Services
J. Tomkins, Director, Nuclear Quality Analysis and Licensing
D. Vosburg, Engineering Manager, Strategic Projects
R. Waltos, Director, Outage Management
L. Womack, Vice President, Nuclear Services

DOCUMENTS REVIEWED

The team selected and reviewed the following documents to accomplish the objectives and scope of the inspection and to support any findings:

Procedures

NDE ET-7, Eddy Current Examination of Steam Generator Tubing, Revision 2 with "on the spot change"

NDE ET-8, Site Specific Performance Demonstration for Eddy Current Examination of Steam Generator Tubing, Revision 01

96012.1, Examination Technique Specification Sheet, Revision 6

Reports

Diablo Canyon Unit 2 Refueling Outage 2R11 February 2003 Steam Generator Tubing Degradation Assessment, Revision 0

Special Report 02-01: Results of Steam Generator Tube Eddy Current Inspection During Unit 2 Tenth Refueling Outage, dated May 28, 2002

Generic W* Tube Plugging Criteria for 51 Series Steam Generator Tubesheet Region Wextex Expansions