50-275/323-OLA-2
I-MFP-60

Dolie Feigel
Reporter

202672 026.1429

Pacific Gas and Electric Company

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Gregory M. Rueger
Senior Vice President and
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February 1, 1993

PG&E Letter No. DCL-93-026

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

Re: Docket No. 50-275, OL-DPR-80
Docket No. 50-323, OL-DPR-82
Diablo Canyon Units 1 and 2
Licensee Event Report 2-87-023-01 (Voluntary)
Accumulator Nozzle Cracking Due to Intergranular Stress Corrosion

Gentlemen:

PG&E is submitting a revision to voluntary Licensee Event Report 2-87-023-00 concerning intergranular stress corrosion cracking in both Units 1 and 2 accumulator nozzles. This revision is submitted to report the results of inspections and repair actions performed during the Unit 2 fourth refueling outage and the Unit 1 fifth refueling outage. This report is submitted for information purposes only as described in Item 19 of supplement 1 to NUREG-1022. Revision bars in the margin indicate the revised LER sections.

This event has in no way affected the health and safety of the public.

Sincerely,

Greg Rueger

Gregory M. Rueger

cc: Ann P. Hodgdon
John B. Martin
Mary H. Miller
Sheri R. Peterson
CPUC
Diablo Distribution
INPO

DC2-87-MM-N024
DC2-91-TN-N075

Enclosure

1091S/85K/JCN/2246

LICENSEE EVENT REPORT (LER)

202672

FACILITY NAME (1)	DOCKET NUMBER (2)	PAGE (3)
DIABLO CANYON UNIT 2	0 5 0 0 0 3 2 3	1 OF 10

TITLE (4) ACCUMULATOR NOZZLE CRACKING DUE TO INTERGRANULAR STRESS CORROSION

EVENT DATE (6)			LER NUMBER (8)			REPORT DATE (7)			OTHER FACILITIES INVOLVED (8)	
MON	DAY	YR	YR	SEQUENTIAL NUMBER	REVISION NUMBER	MON	DAY	YR	FACILITY NAMES	DOCKET NUMBER (S)
10	09	87	87	- 0 2 3 -	0 1	02	01	93	DIABLO CANYON UNIT 1	0 5 0 0 0 2 7 5
										0 5 0 0 0

OPERATING MODE (9): 1

POWER LEVEL (10): 1 0 0

THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR: (11)

____ 10 CFR ____

X OTHER - VOLUNTARY

(Specify in Abstract below and in text, NRC Form 366A)

LICENSEE CONTACT FOR THIS LER (12)

NAME	TELEPHONE NUMBER	
	AREA CODE	
DAVID P. SISK, SENIOR REGULATORY COMPLIANCE ENGINEER	805	545-4420

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

CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS		CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS

SUPPLEMENTAL REPORT EXPECTED (14)

		EXPECTED SUBMISSION DATE (15)	MONTH	DAY	YEAR
[ ] YES (if yes, complete EXPECTED SUBMISSION DATE)	[X] NO				

ABSTRACT (16)

This voluntary Licensee Event Report (LER) is submitted for information only as described in Item 19 of Supplement Number 1 to NUREG-1022.

Revision 0 of this LER described leaks in Unit 2 accumulator nozzles resulting from intergranular stress corrosion cracking (IGSCC) and a weld defect. This revision of the LER reports cracking in both Units 1 and 2 accumulator nozzles identified during planned refueling outage inspections as a result of using inspection techniques of higher sensitivity than those previously used.

The root cause of the flaws identified was IGSCC caused by a combination of factors during manufacture of the accumulators and a suitable incubation time.

All identified flaws were repaired or the nozzles were replaced, as appropriate. Attachments 1 and 2 provide a complete repair history of Units 1 and 2 accumulator nozzles.

TEXT (17)

I. Plant Conditions

Units 1 and 2 have been in various Modes and at various power levels with the identified flaws in existence.

II. Description of Event

A. Event:

From October 1985 until April 1987, Unit 2 had experienced several very small leaks on the emergency core cooling system accumulator tank (BP)(ACC) sample and fill line nozzles (BP)(NZL). These leaks were all minor, resulting in only small deposits of boric acid precipitates. The leaks resulted from intergranular stress corrosion cracking (IGSCC) with the exception of one leak which resulted from a weld defect introduced during manufacturing. All leaking nozzles were identified and successfully repaired or replaced, and surveillance inspection frequency was increased.

In November 1985, PG&E informed Westinghouse of leaking nozzles on Accumulators 2-1 and 2-3. Accumulator 2-1 was found to be leaking at the socket weld connection on the 4-inch diameter fill line nozzle (nozzle G). A visual and dye penetrant examination indicated that the leak was the result of lack of fusion between the socket weld and nozzle. This defect was removed and weld repaired. Accumulator 2-3 was found to be leaking at nozzle G above the socket weld connection. Dye penetrant examination and investigative grinding revealed parallel longitudinal linear indications around the nozzle circumference. The location of these indications precluded weld repair and the defective portion of the nozzle was replaced. Data at that time indicated that the leakage was due to poor fabrication and the use of dissimilar metal in the nozzle socket; IGSCC had not yet been considered as a possible cause.

In October 1986, Accumulators 2-2 and 2-4 experienced very small leaks at the socket region of the 3/4-inch diameter sample line nozzles (nozzle D). No previous history of leaking had been noted on Accumulator 2-4; however, the nozzle on Accumulator 2-2 had previously leaked and had been weld repaired in February 1986.

During the Unit 2 first refueling outage (2R1), the D nozzles were removed from Accumulators 2-2 and 2-4 and a detailed metallurgical examination was performed to ascertain the root cause of the leaks. Sensitization testing using ASTM A-262 Practice A was performed and both nozzles were found to have heavily sensitized microstructures. IGSCC was found in the socket region of the nozzle D from Accumulator 2-2. Crack propagation was from the nozzle inside diameter to outside. Though no cracking was found on Nozzle D from Accumulator 2-4, IGSCC was not ruled out because this leak was extremely small, not easily detectable, and evidence of IGSCC may have been cut out when the nozzle was cut off the accumulator. Chemical analysis in the socket region of both nozzles indicated primarily sulfur and some chloride contamination. Sulfur and chlorides were also found in the 2-2 IGSCC crack region. A design change was implemented to replace the socket weld nozzles with butt weld end (BWE) nozzles of Type 304L.

The accumulators were manufactured by Delta Southern of Baton Rouge, Louisiana, under Westinghouse Specification No. 676441, and supplied as part of the Nuclear Steam Supply System Contract Scope.

An investigation by Westinghouse determined that 38 Westinghouse NSSS-supplied plants have been supplied with accumulators from the same supplier (Delta Southern). Westinghouse had no evidence at that time that the IGSCC observed at DCPP had been experienced by any of the other utilities supplied with these vessels.

On January 30, 1991, NRC Information Notice No. 91-05, "Intergranular Stress Corrosion Cracking in Pressurized Water Reactor Safety Injection Accumulator Nozzles," was issued. This Information Notice informed licensees of problems involving IGSCC of pressurized water reactor safety injection accumulator nozzles.

Prior to the Unit 2 fourth refueling outage (2R4), an ASME Code Case removed hydrostatic testing as a requirement for accumulator inspection. PG&E's Inservice Inspection (ISI) personnel performed a walkdown on September 1, 1991, with the system at normal pressure and found a small trace of boron at the Accumulator 2-2 nozzle C-B upper connection. A snoop test found no trace of an active leak.

On September 2, 1991, using high level magnification, traces of a linear indication were noted. Ultrasonic testing (UT) inspections were performed on accumulator couplings for indication of cracking. Indications of cracking were found on Accumulator 2-2 upper nozzle C-B. An action plan was generated to investigate the indications on Accumulator 2-2 and to additionally inspect other accumulator nozzles.

Further inspections revealed indications on Accumulator 2-1 lower nozzle C-A, Accumulator 2-3 skirt coupling G, and multiple indications on Accumulator 2-3 bottom nozzle D.

On September 26, 1991, dye penetrant testing (PT) found indications on Accumulator 2-1 interior weld-to-clad material transition area just below the nozzle C-B bore and in the nozzle bore. Grinding out the indications revealed significant cracks in the cladding down to the base metal. PT of the weld-to-clad transition areas of the nozzles in all four Unit 2 accumulators was begun.

On September 30, 1991, all Unit 2 PTs were completed. Three additional weld-to-clad transition areas were found to have indications. The areas were adjacent to Accumulator 2-2 nozzle B, Accumulator 2-3 nozzle A, and Accumulator 2-4 nozzle A. Nozzles A and B are in the upper head of the accumulators.

All Unit 2 accumulator nozzles that had indications were replaced with 304L stainless steel nozzles, and all other indications found during the inspections were repaired during 2R4.

On September 13, 1992, during planned Unit 1 UT of Accumulator 1-4, as part of the Unit 1 fifth refueling outage (1R5), unacceptable indications were identified in nozzle C-B, C1-B and skirt coupling G. These were replaced and the accumulator returned to service.

B. Inoperable Structures, Components or Systems That Contributed to the Event:

None.

C. Dates of Occurrences:

1. February 18, 1985: Accumulator 2-2 nozzle D had linear indications. Nozzle D was weld repaired.

2. October 5, 1985: Accumulator 2-1 nozzle G had linear indications. Nozzle G was weld repaired.

3. October 5, 1985: Accumulator 2-3 nozzle G had linear indications. Nozzle G was replaced.

4. October 29, 1986: Accumulator 2-2 nozzle D was leaking. Nozzle D was replaced.

5. October 29, 1986: Accumulator 2-4 nozzle D was leaking. Nozzle D was replaced.

6. September 1, 1991: Accumulator 2-2 nozzle C-B was leaking. Nozzle C-B was replaced. (See Attachment 2 for Unit 2 accumulator repair history.)

7. September 13, 1992: Accumulator 1-4 nozzle C-B had an indication. Nozzle C-B was repaired. (See Attachment 1 for Unit 1 accumulator repair history.)

D. Other Systems or Secondary Functions Affected:

None.

E. Method of Discovery:

Small leaks were discovered at various times during visual examinations and system walkdowns. Planned inspections during refueling outages identified additional nozzle cracking.

F. Operator Actions:

Not applicable.

G. Safety System Responses:

None required.

III. Cause of Event

A. Immediate Cause:

The sample line nozzle (D) on Accumulators 2-2 and 2-4 leaked as a result of IGSCC. Fill line nozzle (G) on Accumulators 2-1 and 2-3 leaked. Accumulators 2-1 and 2-3 leaked as a result of lack of fusion between the socket weld and the nozzle and as a result of IGSCC, respectively.

Subsequent cracking identified with more sensitive inspection techniques was a result of IGSCC.

B. Root cause:

Although the fill line nozzle samples from Accumulators 2-1 and 2-3 are not available, based on the available evidence in 1987, the most probable cause of leakage for Accumulator 2-1 was a weld defect. For Accumulator 2-3 the most probable cause was IGSCC. This conclusion was based on the dye penetrant and investigative grinding results which revealed parallel longitudinal linear indications like those of Accumulator 2-2. Metallographic examinations performed on nozzle D of Accumulators 2-2 and 2-4 revealed IGSCC on the Accumulator 2-2 nozzle. Review of manufacturing, installation, and operating records supports the conclusion that, with the exception of nozzle G on Accumulator 2-1, the Unit 2 sample and fill line nozzles leaked as a result of small base material intergranular stress corrosion cracks.

Cracking most likely was initiated because (1) sulfur and chloride contamination was present in the socket region of the nozzles, (2) the nozzles were highly sensitized, (3) the necessary aqueous environment was present, and (4) residual tensile stresses were present.

The basis for this conclusion is:

1. DCPP accumulators were supplied with the fill and sample lines between the vessel and skirt coupling installed by the vendor. Contaminants, most likely introduced as a result of fabrication (cutting oils, forming compounds, etc.) or contaminated hydrostatic testing water, were not removed during subsequent flushing because of the tight crevice between the pipe and the nozzle socket. Moreover, the tight controls on water chemistry at DCPP for hydrostatic testing, startup flushing, and accumulator inventory preclude the introduction of contaminants subsequent to manufacture.

2. The austenitic stainless steel nozzles were type 304 (i.e., not a low carbon grade) and were welded into the vessel prior to vessel post weld stress relief heat treatment. Consequently, the nozzles underwent a heat treatment during stress relieving that would cause significant sensitization (carbide precipitation at the grain boundaries).

3. Sensitized type 304 stainless steel in stagnant 2000 ppm borated water systems at room temperature has been shown to be highly susceptible to IGSCC in the presence of trace amounts of chlorides and sulfur oxyanions. The primary contaminant identified was sulfur, along with some chlorides.

4. High local residual tensile stresses were present. These stresses were yield-stress-magnitude and were sufficient to initiate IGSCC given the conditions of contaminates and sensitized structure. The stresses resulted from differential contraction between the stainless steel nozzle and the carbon steel vessel during cooling (nozzle to vessel welds; vessel was stress-relieved with nozzles in place) and from solidification and shrinkage stresses from welding (socket welds).

5. The orientation of the identifiable indications responsible for leakage were longitudinal for all leaks except for nozzle G on Accumulator 2-1. In that case, the leak is believed to have been caused by a weld defect (lack of fusion); in addition, the orientation was circumferential. Unlike the leaks for the D nozzles on Accumulators 2-2 and 2-4, there was no recurrence of

leakage after weld repair.

6. With the exception of the nozzle G leak identified above, leaks that were initially stopped after being repaired with weld metal leaked again seven months following repair.

IV. Analysis of Event

The sample and fill lines are anchored to the accumulator nozzles and skirt, forming a stiff piping segment. Seismic loads would be expected to be low due to this stiff configuration, the anticipated response spectra, and no relative seismic displacement between the skirt and vessel nozzle. Thermal stresses are negligible because the service temperature of the accumulator inventory is essentially at containment ambient temperature. The applied stress at the IGSCC location will, therefore, be primarily the result of pressure stress and should not exceed approximately 1500 psi tension and 870 psi shear. Accordingly, self-limiting residual stresses, rather than applied loads, contribute to crack initiation. Defect propagation beyond the shoulder region of the socket was not likely to occur as substantiated by the characteristics of the leaks observed and the very low service stresses.

Joint loads due to accumulator internal pressure are significantly less than the expected shear capacity of the socket and neither defect propagation nor catastrophic failure (separation of pipe and nozzle) would be expected as the result of applied loads. The consequences of the defect going undetected would be limited to a continued very small leak. Early detection of a drop in accumulator level and/or pressure is provided by two channels for level detection and alarms. It is concluded that the leaks and associated defects would not preclude delivery of sufficient accumulator inventory to the reactor coolant system. The accumulators would continue to perform their intended safety function.

Therefore, there were no adverse safety consequences or implications resulting from this condition.

V. Corrective Actions

The leaking nozzle D on Accumulators 2-2 and 2-4 have been redesigned and replaced. The new design utilizes a butt welded connection and type 304L base material. The defective weld (lack of fusion) on nozzle G of Accumulator 2-1 has been weld repaired with no subsequent leakage. The leaking nozzle G on Accumulator 2-3 was repaired by replacement of defective nozzle material.

Attachments 1 and 2 summarize repairs performed on Units 1 and 2 accumulator nozzles during the 1R5 and 2R4 refueling outages, respectively.

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TEXT (17)

An enhanced periodic inspection program for accumulator nozzles is being developed and will be performed during future refueling outages.

VI. Additional Information

A. Accumulator tank data:

Manufacturer	-	Delta Southern
Vendor	-	Westinghouse
Material	-	Carbon steel, with 304 stainless steel liner
Size	-	1350 cubic feet

B. Previous LERs on similar events:

None.

C. Attachments:

1. Accumulator Nozzle Repair - Unit 1

2. Accumulator Nozzle Repair - Unit 2

ATTACHMENT 1

ACCUMULATOR NOZZLE REPAIR - UNIT 1

ACCUMU-LATOR	NOZZLE	CARBON CONTENT	REPAIR HISTORY	TEST HISTORY
1-1	A	.05	NONE	NRI[1]
1-1	B	.05	NONE	NRI
1-1	C-A	.028	NONE	NRI
1-1	C-B	.028	NONE	NRI
1-1	C-1A	.028	NONE	NRI
1-1	C-1B	.028	NONE	NRI
1-1	D	.004	NONE	NRI
1-1	E	[2]	NONE	NRI
1-1	G	.05	NONE	NRI
1-2	A	.05	NONE	NRI
1-2	B	.05	NONE	NRI
1-2	C-A	.027	NONE	NRI
1-2	C-B	.027	NONE	NRI
1-2	C-1A	.027	NONE	NRI
1-2	C-1B	.027	NONE	NRI
1-2	D	.004	NONE	NRI
1-2	E	[2]	BUFFED	1-IND
1-2	G	.05	NONE	NRI
1-3	A	.05	NONE	NRI
1-3	B	.03	NONE	NRI
1-3	C-A	.047	NONE	NRI
1-3	C-B	.047	NONE	NRI
1-3	C-1A	.047	NONE	NRI
1-3	C-1B	.047	NONE	NRI
1-3	D	.004	NONE	NRI
1-3	E	.024	NONE	NRI
1-3	G	.03	NONE	NRI
1-4	A	.05	NONE	NRI
1-4	B	.03	NONE	NRI
1-4	C-A	.047[3]	NONE	NRI
1-4	C-B	.047[3]	REPLACED	2-IND
1-4	C-1A	.047[3]	NONE	NRI
1-4	C-1B	.047[3]	REPLACED	3-IND
1-4	D	.004	NONE	NRI
1-4	E	.024	NONE	NRI
1-4	G	.03	REPAIRED	ROUNDED IND
1-4	G (skirt cpl)		REPLACED	1-IND

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1 No recordable indications

2 Recorded data believed to be for F nozzle instead of E nozzle and, therefore, data may be in error.

3 Questionable or illegible

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ATTACHMENT 2

ACCUMULATOR NOZZLE REPAIR - UNIT 2

ACCUMU-LATOR	NOZZLE	CARBON CONTENT	REPAIR HISTORY	TEST HISTORY
2-1	A	[1]	NONE	NRI[2]
2-1	B	[1]	NONE	NRI
2-1	C-A	.05	REPLACED	1-IND
2-1	C-B	.05	[3]	NRI
2-1	C-1A	.05	NONE	NRI
2-1	C-1B	.05	NONE	NRI
2-1	D	.05	NONE	NRI[4]
2-1	E	.061	NONE	NRI
2-1	G	[1]	REPAIRED	NRI[4]
2-2	A	.04	NONE	NRI
2-2	B	.04	REPAIRED	1-IND
2-2	C-A	.05	NONE	NRI
2-2	C-B	.05	REPLACED	3-IND
2-2	C-1A	.05	NONE	NRI
2-2	C-1B	.05	NONE	NRI
2-2	D	.05	REPLACED	NRI[4]
2-2	E	.061	NONE	NRI
2-2	G	.053	NONE	NRI[4]
2-3	A	.04	REPAIRED	1-IND
2-3	B	.04	NONE	NRI
2-3	C-A	.05	NONE	NRI
2-3	C-B	.05	NONE	NRI
2-3	C-1A	.05	REPAIRED	NRI
2-3	C-1B	.05	REPAIRED	NRI
2-3	D	.05	REPLACED	2-IND
2-3	E	.061	NONE	NRI
2-3	G	.04	NONE	NRI
2-3	G (skirt cpl)		REPLACED	1-IND
2-4	A	.04	REPAIRED	1-IND
2-4	B	.04	NONE	NRI
2-4	C-A	.05	NONE	NRI
2-4	C-B	.05	NONE	NRI
2-4	C-1A	.05	NONE	NRI
2-4	C-1B	.05	NONE	NRI
2-4	D	.05	REPLACED	NRI[1]
2-4	E	.061	NONE	NRI
2-4	G	.04	NONE	NRI[4]

1 Questionable or illegible

2 No recordable indications

3 Linear indication in 1985. Accepted-as-is.

4 Limited examination due to bottom curvature. Generally, only 180^{0} scanned.

1091S/85K