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SUBJECT: LER 88-015-01:on 880507,RCP motor upper oil reservoir assemblies degradation attributed to metal fatigue.
W/8 ltr.

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TITLE: 50.73 Licensee Event Report (LER), Incident Rpt, etc.

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LICENSEE EVENT REPORT (LER)

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DIABLO CANYON UNIT 1	0 5 0 0 0 2 7 5	1 OF 1

TITLE (4) RCP MOTOR UPPER OIL RESERVOIR ASSEMBLIES DEGRADATION ATTRIBUTED TO METAL FATIGUE

EVENT DATE (5)			LER NUMBER (6)			REPORT DATE (7)			OTHER FACILITIES INVOLVED (8)	
MONTH	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	MONTH	DAY	YEAR	FACILITY NAMES	DOCKET NUMBER(S)
0 5	0 7	8 8	8 8	0 1 5	0 1	1 2	2 2	8 8	DIABLO CANYON UNIT 2	0 5 0 0 0 3 2 3
										0 5 0 0 0

OPERATING MODE (9): 5

POWER LEVEL (10): 0 0 0

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

X 10 CFR ______ VOLUNTARY REPORT

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

LICENSEE CONTACT FOR THIS LER (12)

NAME	TELEPHONE NUMBER
BRENT D. POGUE, REGULATORY COMPLIANCE ENGINEER	AREA CODE 8 0 5 5 9 5 - 7 3 5 1

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

CAUSE	SYSTEM	COMPONENT	MANUFAC TURER	REPORTABLE TO NPRDS	CAUSE	SYSTEM	COMPONENT	MANUFAC TURER	REPORTABLE TO NPRDS

SUPPLEMENTAL REPORT EXPECTED (14)

YES (If yes, complete EXPECTED SUBMISSION DATE) X NO

EXPECTED SUBMISSION DATE (15) MONTH DAY YEAR

ABSTRACT (16)

This voluntary LER is being submitted for informational purposes only as described in Item 19 of Supplement Number 1 to NUREG 1022.

On May 7, 1988, during routine outage maintenance of RCP motor 1-2, failed bolting was identified in the RCP motor lube oil flow chamber in the upper bearing assembly. Subsequent examinations also identified cracking in the flow chamber and leveling washer. RCP motors 1-1, 1-3 and 1-4 have been inspected and similar cracks have been identified in their flow chambers. Upon discovery of this condition, PG&E formed a team to investigate this situation and provide recommendations for its resolution.

During the Unit 2 refueling outage, which began September 17, 1988, bolting used to secure the flow chamber to the leveling washer within the upper lube oil reservoir was discovered to have failed on RCP 2-3.

Assessment of the cause indicated that metal fatigue from vibration was the likely primary or contributing factor. The Unit 1 RCP upper oil reservoir assembly components have been replaced or repaired and will be inspected at the next Unit 1 refueling outage. The Unit 2 RCPs were disassembled and inspected during the Unit 2 second refueling outage and the oil pumping systems were replaced by a new oil pumping system. A new oil lift system was also added.

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I. Initial Conditions

Unit 1 was in Mode 5 (Cold Shutdown) and Unit 2 was operating in Mode 1 (Power Operation) when the event was discovered. Both units have been operated at various modes and power levels while these cracks may have existed.

II. Description of Event

A. Event:

On May 7, 1988, during routine outage maintenance of Unit 1 reactor coolant pump (RCP) motor (AB)(MO) 1-2, the 3/8 inch bolting securing the flow chamber to the leveling washer (AB)(LW) within the upper lube oil reservoir was found to be damaged in an arc of about 150 degrees around the flow chamber flange. Bolts were broken, bent, or otherwise deformed, and the gasket material in the area of the damaged bolting was missing. Two cracks were also identified in the leveling washer section of the motor upper bracket.

On May 8, 1988, magnetic particle examination of the RCP 1-2 leveling washer cracks was performed. A magnetic particle examination of the RCP 1-2 lube oil flow chamber (AB)(BAF) was also performed. Ten cracks were identified in the flow chamber assembly welds. The flow divider plate in the flow chamber was broken or cracked in two places.

On May 10, 1988, RCP 1-4 was disassembled and a MT examination of the flow chamber and leveling washer was performed. No bolting damage or leveling washer cracks were identified, however, two cracks were found in the flow chamber welds.

On May 11, 1988, an Operations Shift Order was issued to require all control room operators to review the RCP annunciator response procedure and associated operating procedures. This order was intended to make the Unit 2 operations personnel aware of the conditions on Unit 1 and to insure that appropriate actions would be taken.

On May 12, 1988, RCP 1-1 was disassembled and an MT examination of the flow chamber and leveling washer was performed. No bolting damage or leveling washer cracks were found. Nine cracks were identified in the flow chamber welds. The flow divider plate in the flow chamber was broken or cracked in two places.

On May 13, 1988, RCP 1-3 was disassembled and an MT examination of the flow chamber and leveling washer was performed. No bolting damage or leveling washer cracks were found. Ten cracks were identified in the flow chamber welds.

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On May 25, 1988, a standing order was issued to ensure that operations personnel maintain an increased awareness of all Unit 2 RCP temperature and vibration alarms. The annunciator response procedure was revised to require that upon indications of multiple problems with an RCP, the reactor is to be tripped and the RCP shut down as soon as possible.

On September 17, 1988, Unit 2 was shut down for refueling. During the Unit 2 outage all RCPs were disassembled and inspected; failed bolting and a damaged flow chamber divider plate were discovered on RCP 2-3. The bolting is used to secure the flow chamber to the leveling washer within the lube oil reservoir. A severed oil lift line was also discovered. All Unit 2 RCPs had an oil viscosity pump modification installed during the outage. A new oil lift system was also installed.

B. Inoperable structures, components or systems that contributed to the event:

None

C. Dates and approximate times for major occurrences:

1. May 7, 1988: RCP 1-2 was being disassembled. Broken and/or damaged bolting was discovered in the upper lube oil reservoir of RCP 1-2.

2. May 8, 1988: Magnetic particle examination of RCP 1-2 leveling washer and flow chamber performed. Cracks discovered in flow chamber and leveling washer.

3. May 10, 1988: Unit 1 RCP 1-4 examined. Cracks discovered in the flow chamber.

4. May 11, 1988: PG&E notified NRC Region V and NRR.

5. May 11, 1988: Operations Shift Order issued to review annunciator response and associated operating procedures for the RCPs.

6. May 12, 1988: Unit 1 RCP 1-1 examined. Cracks discovered in the flow chamber.

7. May 13, 1988: Unit 1 RCP 1-3 examined. Cracks discovered in the flow chamber.

8. May 25, 1988: Standing order issued to ensure that operations personnel maintain an increased awareness of all Unit 2 RCP temperature and vibration alarms. Annunciator response procedure revised.

9. October 29, 1988: Work Order completion for the Unit 2 RCPs oil viscosity pump modification and new oil lift system.

D. Other systems or secondary functions affected:

None

E. Method of discovery:

During routine outage maintenance of Unit 1 RCP motors, failed bolting was identified on the RCP 1-2 motor lube oil flow chamber. Further examination identified a number of weld cracks in the RCP 1-2 flow chamber and leveling washer. Examination of other Unit 1 RCPs also identified flow chamber cracks.

F. Operator actions:

None.

G. Safety system responses:

None.

III. Cause of Event

A. Immediate cause:

The failed bolting of the RCP motor oil flow chamber and the flow chamber and leveling washer cracking was attributed to metal fatigue.

B. Root cause:

An extensive investigation of the failed bolting and the flow chamber and leveling washer was conducted by an interdisciplinary team including Westinghouse representatives. Evaluations which were conducted included:

1. Visual and magnetic particle examination of all four Unit 1 flow chambers and leveling washers.

   Magnetic particle examination of all four Unit 2 leveling washers and visual examination of all four flow chambers. No linear indications were found in any of the leveling washers. RCP 2-3 flow chamber had evidence of failure of the intermediate vane in two locations. The flow chamber was replaced with the installation of the new oil pumping system.

2. Review of Westinghouse RCP operating experience history.

3. Review of the flow chamber and leveling washer material properties and fabrication processes.

4. Review of RCP modifications.

5. Review of RCP vibration history.

6. Metallography of a flow chamber weld cross section.

7. Fractography of the flow chamber divider plate crack.

8. Structural vibration testing of the flow chamber divider plates.

9. Structural vibration testing and analysis of the upper flow chamber assembly.

Based on investigations conducted, the following postulated sequence of events led to the cracking and other damage found in the RCP motor upper bracket assemblies. First, vibration of the oil pump assembly caused fatigue cracking of the flow chamber fillet welds (See Figure 1, note on the cross section of the RCP flow chamber that these are on the fillet welds that weld the turning vane to the top cover and bottom plate). Failure of these welds has several possible secondary effects: (1) it could cause a downward shift in the resonant frequency of the pump assembly as a result of reduced stiffness of the flow chamber; (2) it could result in increased relative motion between the flow chamber and leveling washer because of loss of preload compression due to a gap between the vanes and the face plates (See Figure 1 and the cross section of the flow chamber and leveling washer assembly); and (3) it could increase the stresses on the 3/8" bolts at the peripheral joint because of the increased flexibility from (1) and (2). Second, the 3/8" bolts at the outer periphery of the flow chamber loosened and broke as a result of fatigue stresses caused by the primary rocking motion and the secondary relative motion between the flow chamber and the leveling washer. Failure and loosening of these bolts is not the primary cause of damage in the assembly because two of the flow chambers had fillet weld cracking with no signs of bolt failure or loosening. Third, the leveling washer cracked at the welds attaching it to the columns (See Figure 2). The leveling washer cracking is apparently the last event in the sequence because it only occurred on the motor with the worst damage to the other oil reservoir assembly components.

In summary, the damage found in the Unit 1 and Unit 2 RCP 2-3 motor upper oil reservoir assemblies is fatigue damage resulting from vibration of the oil pump assembly (flow chamber and leveling washer). The most likely source of the vibration is the 180 hertz rocking motion of the pump assembly. It is also possible that a 140 hertz vertical vibration mode of the pump chamber

either contributed to or caused the observed damage. Gaps found between the top cover and bottom plate and the diverter vanes of the flow chambers (See Figure 1) are potentially a significant contributor to the failure by reducing the stiffness of the bearing assembly and by subjecting the fillet welds joining these three members to the cyclic tensile stresses from the pump vibration.

IV. Analysis of Event:

A. Postulated Failures

The observed lube oil flow chamber and leveling washer cracking hypothetically in the worst case could have lead to fragmentation or loss of integrity of the flow chamber, leveling washer, or the divider plate. The postulated modes of failure from the observed lube oil flow chamber and leveling washer cracking were: (1) failure of the flow chamber/leveling washer plate, (2) fragmentation failure of the flow chamber or leveling washer, or (3) concurrent flow chambers/leveling washers failures.

B. Potential Effects:

(1) Failure of the flow chamber/leveling washer

The portions of the RCP motor flow chambers and leveling washer which were discovered to be cracked are not structural components of the RCP motor and do not provide structural support to the RCP motor bearings. Therefore, failure of the upper flow chamber or leveling washer plate would not cause a loss of structural integrity to the motor bearing support structure.

(2) Fragmentation failure of the flow chamber or leveling washer leading to possible partial loss of Babbit material

Fragmentation failure of the flow chamber could have resulted in a failure to contain high pressure oil (30 psi) or generation of loose parts. Fragmentation failure of the leveling washer could have resulted in loose parts. If the flow chamber failed to contain high pressure oil, a loss of oil to the radial bearings and a loss of oil flow to the cooler would have resulted. Loose parts caused from either a flow chamber or leveling washer failure could have resulted in blocking of the cooler flow path, interruption of the guide bearing oil flow or introduction of particles to the thrust bearing surface.

The flow chamber is clamped in the bearing bracket. Large loose parts would have collected at the bottom of the oil chamber and upper oil pot. Therefore, these large parts due to their size and weight could not migrate to the bearing surface to cause bearing damage. Smaller parts could have entered the oil flow path. Additionally, particulate size pieces could be routed to the bearing surface area.

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TEXT (If more space is required, use additional NRC Form 366A's) (17)

The above scenarios could have resulted in wiping and partial degradation of the soft Babbit material which would have resulted in a high bearing temperature alarm. All four RCPs are equipped with the following detection circuitry: oil lift pump pressure, lower oil reservoir level, upper oil reservoir level, thrust bearing upper shoe temperature, thrust bearing lower shoe temperature, upper radial bearing temperature, lower radial bearing temperature, stator winding temperature, motor frame vibration, shaft vibration, and motor current. Upper and lower oil reservoir levels are sensed by level switches which actuate an annunciator on low level. Actual oil levels can be read locally at the pump.

The motor thrust bearing has thermocouples embedded in one upper thrust shoe and in one lower thrust shoe. The motor bearing thermocouples are monitored by the plant computer and are annunciated in the control room. The annunciator actuates when the temperature reaches 200°F. The upper and lower motor radial bearings also utilize embedded thermocouples to measure bearing temperature. These detectors actuate the same annunciator at 200°F as above.

Each pump is equipped with a set of proximity probes and velocity transducers which measure pump motor shaft, and motor frame vibration in two radial directions. This vibration information is transmitted to an instrument rack for operator viewing and to a host computer for trend analysis. This system is also equipped with an alarm relay which when activated sends an input signal for the control room annunciator.

Westinghouse evaluated the potential for a thrust bearing failure as a result of the flow chamber problems noted herein and concluded that such a failure is highly unlikely. This conclusion was based on operating experience that shows that under normal operating conditions particulate size matter that finds its way to the bearing surface does not cause excessive bearing degradation. The maximum size of such particulate is on the same order as the oil film thickness on the bearing surface (approximately 1.5 mls). Also, there would have been no loss of oil as a result of any postulated flow chamber problem. This is because the flow chamber is located inside the oil reservoir and is completely bathed in oil. Note that since the thrust bearing will remain operable, the necessary clearances would have been maintained such that the reactor coolant pump seals would not be affected by any postulated flow chamber problems.

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In the unlikely event that a thrust bearing failure were to occur, this would have allowed the RCP shaft to move upward the thickness of the Babbit material and affect the No. 1 seal. Continued operation of the reactor coolant pump could have failed the No. 1 seal and resulted in a high leak-off flow alarm. If no operator actions were taken, failure of the No. 2 seal could be postulated and resultant loss of coolant accident.

To assure appropriate and immediate action, operators were notified and operator annunciator response procedures were revised to require that upon indications of multiple problems with a RCP (such as bearing problems with concurrent pump seal alarms), the reactor was to be tripped and the reactor coolant pump shut down as soon as possible.

The scenarios described above postulate bearing damage to the extent that Babbit material is degraded and/or failed. A loss of coolant accident due to thrust bearing failure and subsequent reactor coolant pump seal failure is extremely unlikely based upon the basic thrust bearing design further supported by operator action. Instantaneous locked rotor would not have occurred. Therefore FSAR Section 5.5.1.3.5 which states that there are no credible sources of shaft seizure other than impeller rubs remained valid.

Since any postulated failure of components discussed above would be internal to the RCP motor, no new leakage paths for hot oil are formed. Therefore, no new fire protection concerns were introduced.

(3) Concurrent flow chambers/leveling washers failures

Concurrent failures of RCP motors due to degraded oil flow chambers or leveling washer plates is highly unlikely. As discussed above, operator response to indications of multiple problems with a RCP was to trip the reactor and shut down the RCP as soon as possible. Upon entry into Mode 3, the locked rotor accident is no longer a concern. Because of the short duration of time it would take to shutdown the plant, it was highly unlikely that another pump would have failed. Additionally, no failure modes were identified that would have caused a simultaneous failure of RCP motors. In addition the plant has been designed and tested to be brought to cold shutdown with no RCPs available.

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V. Corrective Actions

A. PG&E's metallurgical specialists examined the RCP 1-2 failed bolting, flow chamber and the leveling washer and RCP 2-3 failed bolting to determine the cause of the cracking.

B. New flow chambers were installed in the Unit 1 RCP motors. The new flow chambers are fabricated from A36 carbon steel rather than the A514 carbon steel used in the original flow chambers. The new material is more weldable than the original material.

The new flow chambers are also of a more recent design which has a 3/4 inch thick divider plate rather than the 1/4 inch thick divider plate used on the original flow chamber.

C. The RCP 1-2 leveling washer cracks were weld repaired. The repair was nondestructively examined to verify its integrity. Structural deformation of the leveling washer due to the crack and to the weld repair of the crack was performed by precision machining of the leveling washer to flow chamber flange and the leveling washer to flow chamber machined mating surface.

D. Before RCP reassembly, Mechanical Maintenance Procedure (MP) M-7.46, "Reactor Coolant Pump Motor Inspection and Maintenance", was revised. This revision provides additional guidance to ensure proper bolt reinstallation in the RCPs.

E. All four of the Unit 2 RCP motors were disassembled; the oil pumping systems were replaced by a new oil pumping system and a new oil lift system was added. The flow chambers of the Unit 2 RCP motors were deleted as part of the new viscosity oil pump system motor modification.

Similar modifications for the Unit 1 RCPs will be completed during the next Unit 1 refueling outage.

F. The annunciator response procedures were revised to require that upon indications of multiple problems with a RCP, the reactor is to be tripped and the RCP shut down as soon as possible.

VI. Additional Information

A. Failed components:

None.

B. Previous LERs on similar events:

There have been no previous LERs on problems with RCP upper bearing assemblies.

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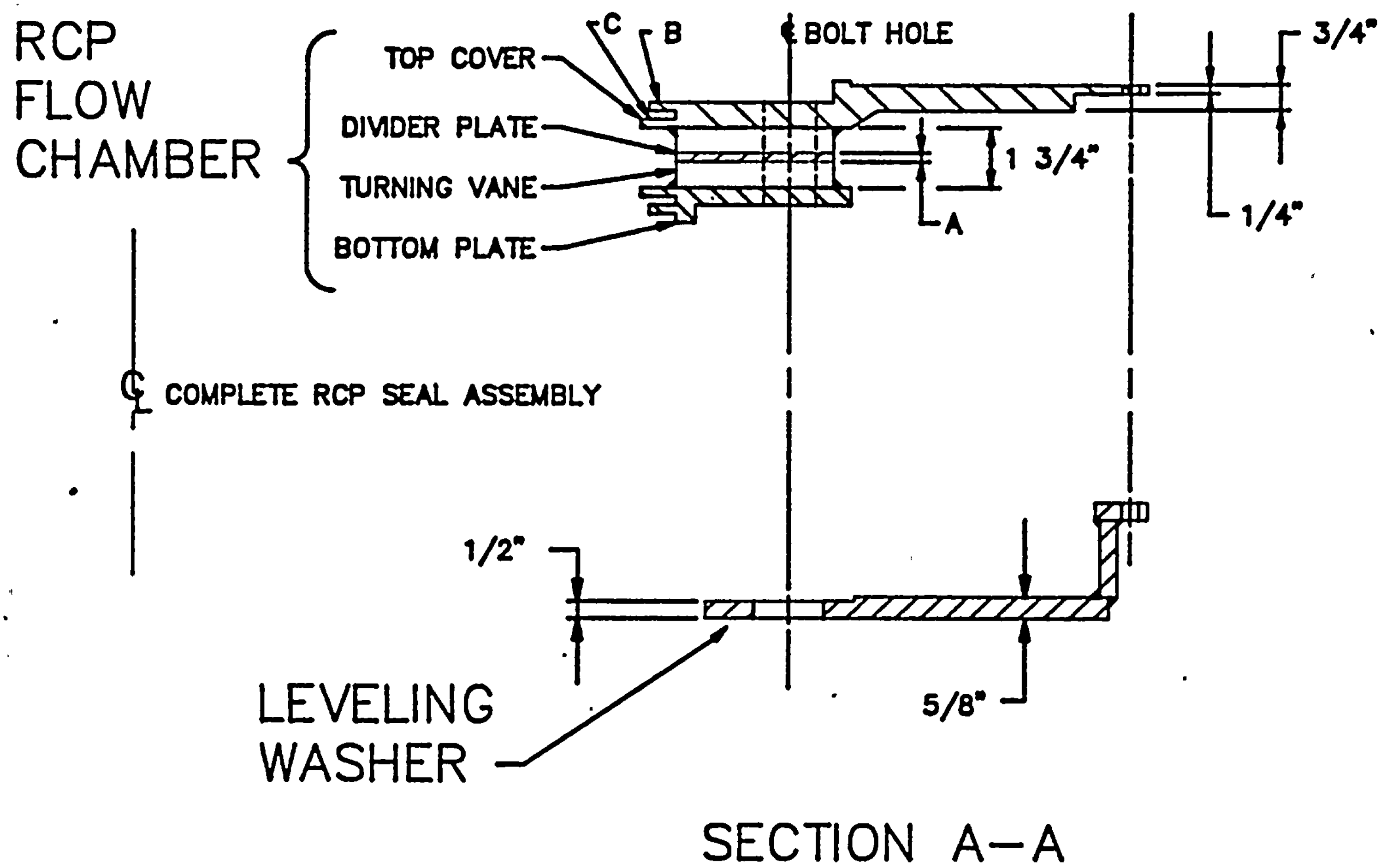
TEXT (If more space is required, use additional NRC Form 366A's) (17)

FIGURE 1

FLOW CHAMBER SECTION



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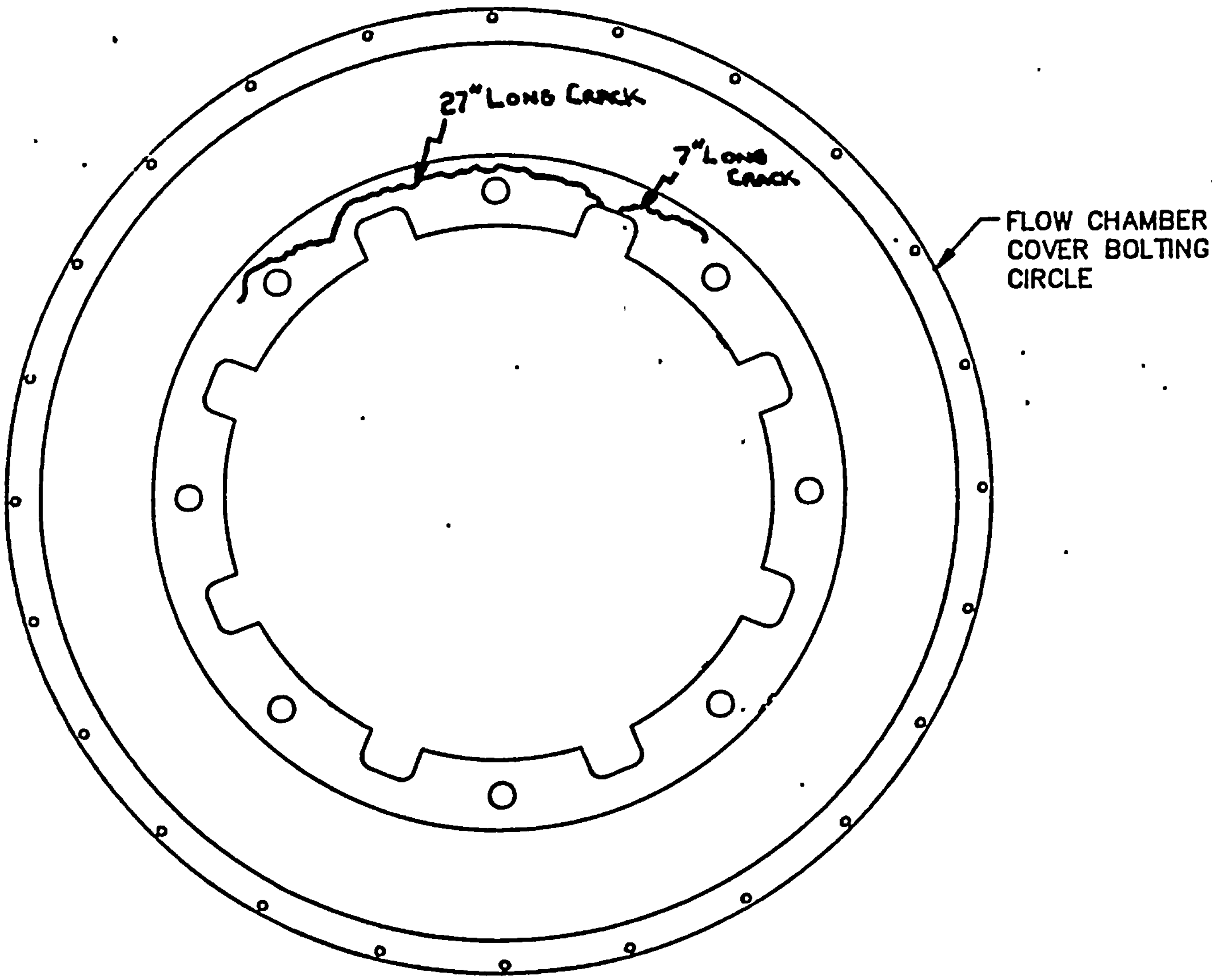
TEXT (If more space is required, use additional NRC Form 366A's) (17)

FIGURE 2

LEVELING WASHER CRACK DETAILS



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Pacific Gas and Electric Company

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415/972-7000
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James D. Shiffer
Vice President
Nuclear Power Generation

December 22, 1988

PG&E Letter No. DCL-88-311

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 Unit 1 and 2
Licensee Event Report 1-88-015-01 (Voluntary)
Reactor Coolant Pump Motor Oil Reservoir Assemblies Degradation Attributed To Metal Fatigue

Gentlemen:

PG&E is submitting a revision to the enclosed voluntary Licensee Event Report regarding the degradation of the reactor coolant pump motor oil reservoir assemblies due to metal fatigue. This report documents completion of PG&E's evaluation and corrective actions and is being submitted for information purposes only, as described in item 19 of Supplement Number 1 to NUREG-1022.

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

Kindly acknowledge receipt of this material on the enclosed copy of this letter and return it in the enclosed addressed envelope.

Sincerely,

J. D. Shiffer

cc: J. B. Martin
M. M. Mendonca
P. P. Narbut
B. Norton
H. Rood
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Enclosure

DC1-88-MM-N056

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