LICENSEE EVENT REPORT (LER)

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TITLE (4) Inappropriate Material In Electrical Penetration Assembly Module Seals Cause Leakage and Potential Loss of Electrical Continuity

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)
05	10	91	91	- 0 1 1 -	0 2	12	22	93	N/A	0 5 0 0 0
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OPERATING MODE (9): 6

POWER LEVEL (10): 0

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

[ ] 20.402(b)	[ ] 20.405c	[ ] 50.73(a)(2)(iv)	[ ] 73.71(b)
[ ] 20.405(a)(1)(i)	[ ] 50.36(c)(1)	[X] 50.73(a)(2)(v)	[ ] 73.71(c)
[ ] 20.405(a)(1)(ii)	[ ] 50.36(c)(2)	[ ] 50.73(a)(2)(vii)	[X] OTHER (Specify in Abstract below and in Text, NRC Form 366A)
[ ] 20.405(a)(1)(iii)	[X] 50.73(a)(2)(i)	[ ] 50.73(a)(2)(viii)A	Part 21
[ ] 20.405(a)(1)(iv)	[X] 50.73(a)(2)(ii)	[ ] 50.73(a)(2)(viii)B	
[ ] 20.405(a)(1)(v)	[ ] 50.73(a)(2)(iii)	[ ] 50.73(a)(2)(x)	

LICENSEE CONTACT FOR THIS LER (12)

NAME	TELEPHONE NUMBER AREA CODE	
M. H. Megehee, Compliance Engineer	503	556-7334

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
X	B D	P E N	A 3 8 0	N					

SUPPLEMENTAL REPORT EXPECTED (14)		EXPECTED SUBMISSION DATE (15)	MONTH	DAY	YEAR
[ ] YES (if yes, complete EXPECTED SUBMISSION DATE)	[X] NO				

ABSTRACT (16)

During local leak rate testing on March 30, 1991, excessive leakage was identified in one Containment Building electrical penetration assembly (EPA) due to a failed seal. Although the leakage quantified on April 6, 1991 was not sufficient to cause Overall Containment Integrated Leakage to exceed acceptable values, it was subsequently decided on May 10, 1991, that the condition of the Containment EPA seals may have caused the plant to be in an unanalyzed condition. The seals were made of a material that was inappropriate for the application, and therefore possible degradation of the seals made it indeterminate whether the seals would perform their design function of ensuring containment integrity. This issue was reported pursuant to 10 CFR 21 on June 24, 1991.

The purpose of the EPAs was to provide for electrical continuity of the contained conductors, while maintaining containment integrity. Nitrogen is applied between the inner and outer seals to ensure continuity by preventing moisture intrusion. Following a postulated loss of coolant accident, degradation of the seals combined with a poor design would allow moisture intrusion potentially resulting in degradation of electrical continuity. The seals have been replaced with seals of a more durable material. This supplement is being submitted to indicate additional applicable reporting criteria and to provide additional details on the design and safety functions of the EPAs.

INTRODUCTION

On March 30, 1991, leakage in excess of acceptance criteria was identified in one Containment [NH] Building electrical penetration [BD-PEN] during the performance of local leak rate testing. Although the leakage was not sufficient to cause Containment leakage to exceed the allowable integrated leak rate, it was decided on May 10, 1991, that the condition of the Containment Building electrical penetration assembly seals may have caused the plant to be in an unanalyzed condition. Accordingly, Revision 0 of this Licensee Event Report was submitted per the requirements of 10 CFR 50.73(a)(2)(ii). Revision 1 of this LER provided additional information concerning the root cause and potential safety consequences of the seals.

It was recognized recently that some aspects of the Electrical Penetration Assembly design, information concerning seal replacement activities, and previous similar events were not fully discussed in the previous revisions of this LER. It was also decided that additional reporting criteria may be applicable. This supplement is being submitted to indicate the additional reporting criteria and to provide additional details on the design and safety functions of the Electrical Penetration Assembly seals.

BACKGROUND

The Trojan Nuclear Plant has been permanently shutdown. At the time of permanent closure, Trojan had 33 Bunker Ramo-Amphenol type Electrical Penetration Assemblies (EPAs) and 8 Conax type EPAs currently installed. The seal assemblies were manufactured by the Amphenol SAMS Division of Bunker Ramo. The discussions in this LER apply to the Amphenol type EPAs.

The primary function of the Electrical Penetration Assemblies was to provide continuity of electric circuits through the containment building wall while maintaining containment integrity. This was accomplished by casting copper conductors in a glass reinforced epoxy module. The module was held in the header plate cavity by a retaining shoulder on one face of the plate and a stainless steel retaining ring which threaded into the opposite face.

In order to provide a means of monitoring the integrity of the assembly, porting was provided between module mounting holes. The mid-plane of each module contained a gas permeable membrane which provided a gas path from the outside diameter of the module to each of the feed-through conductors. In the glass-reinforced epoxy module, conductors were routed bare (insulation removed) surrounded by the epoxy and the gas permeable membrane.

The gas permeable membrane and bare wire feature in the area between the seals were necessary to ensure that radioactive materials in a post accident environment could not esc[ape] containment by traveling along the conductors - i.e., these features prevented postulated leakage along the conductors.

Sealing of the assembly was achieved by c-shaped seals facing each other at either end of the module. Prior to 1991, the seals were made of polyurethane. The outer seal was part of the Containment boundary and faced inward (such that Containment Building pressure would tend to seat the seal). The inner seal faced outward and functioned to allow pressurizing the space between the seals for testing and to maintain a nitrogen environment between the seals.

During plant operation, nitrogen pressure was provided in the area between the seals to prevent moisture intrusion. Additionally, the nitrogen pressure may have helped to keep the seals engaged. A dry environment helped to guard against shorting of power conductors or current leakage in instrument conductors. As discussed in Licensee Event Report 50-344/88-003, for a period of time in 1988 the nitrogen supply to the containment electrical penetrations was isolated. This was done due to concerns that a single failure of the nitrogen supply system could overpressurize the seals. While the nitrogen system was isolated, plant operators were instructed to check nitrogen pressure approximately once per shift and to pressurize each header to approximately 30 psig. It was subsequently determined that the seals would not be subject to overpressurization in the event of a nitrogen pressure regulator failure, and this Licensee Event Report was withdrawn on December 23, 1988.

DESCRIPTION OF EVENT

On March 30, 1991, the Plant was in Mode 5 (Cold Shutdown). During the performance of a local leak rate test (LLRT), it was determined that one of the high-voltage modules in the Containment Building Electrical Penetration Assembly NZ02 had excessive leakage. This module houses conductors supplying 12.47 kV ac electrical power to the "A" Reactor Coolant Pump (RCP) motor.

The NZ02 module leak rate exceeded the maximum range of 60,000 cubic centimeters per minute (ccm) of the test equipment being used to measure the leakage. Adjusting the maximum scale reading to standard conditions, the leak rate was greater than 66,600 $\pm$110 standard cubic centimeters per minute (sccm).

On April 6, 1991, another LLRT was performed on EPA NZ02 using higher range measuring instruments. The leak rate was determined to be approximately 100,000 sccm during this test.

Trojan Technical Specification 3.6.1.2.b, Containment Leakage, requires the combined leak rate of all penetrations and valves subject to Type B and C local leak rate tests to be less than or equal to 0.60 La (La = 0.10 percent by weight of the Containment Building air per 24 hours at pressure, Pa = 60 pounds per square inch - gauge (psig)). For the Trojan Containment Building the Type B and C leak rate limit equates to approximately 120,000 sccm.

At the time NZ02 was tested on March 30, 1991, and on April 6, 1991, measured leakage from other Containment Building Type B and C penetrations totaled approximately 46,000 sccm. Following the initial test of EPA NZ02 on March 30, 1991, it was concluded that the combined leakage rate from EPA NZ02 and other Type B and C penetrations could have exceeded the leak rate allowed by Technical Specification 3.6.1.2.b. The results of the April 6, 1991, test confirmed that the combined leakage from EPA NZ02 and other Type B and C penetrations was in excess of the Technical Specification 3.6.1.2.b limits.

In 1991, Portland General Electric (PGE) evaluated the effects of the EPA NZ02 leakage on the containment overall integrated leak rate. Trojan Technical Specification 3.6.1.2.a, "Containment Leakage", requires that the overall integrated leak rate of the Containment Building be less than or equal to 0.10 percent by weight of the Containment air per 24 hours at 60 psig. This equates to approximately 200,000 sccm. In 1990, the overall integrated leak rate was determined to be approximately 13,000 sccm. Adding the 1990 integrated leak rate to the combined Type B and C leak rates (46,000 sccm) and multiplying by 1.33 to account for possible degradation and instrument error, gives a total leakage of approximately 80,000 sccm. Adding this conservative leak rate to the measured EPA NZ02 leak rate of 100,000 sccm gives a total leak rate of 180,000 sccm. This leak rate is less than the Technical Specification 3.6.1.2.a limit. Therefore, it was concluded in 1991 that the Technical Specification limit for the overall integrated leak rate of the Containment Building was not exceeded due to the leakage from EPA NZ02.

At the time the EPA NZ02 leakage was identified, the plant was in Mode 5, Cold Shutdown. In this mode of operation, Technical Specification 3.6.1.2 is not applicable and containment integrity is not required. Prior to the test, indications of leakage on NZ02 were not observed (i.e., no Maintenance Requests for maintenance on NZ02 were known to exist). Personnel reported to the Plant Review Board that the penetration showed no signs of leakage until it was pressurized with the 60 psig nitrogen from the LLRT test cart.

Based on this information, the Trojan Technical Specification 3.6.1.2.a limit for overall integrated leakage rate was not exceeded due to the leakage on EPA NZ02. However, the Trojan Technical Specification 3.6.1.2.b limit for combined leakage from Type B and C

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tests was exceeded.

An engineering evaluation was conducted to evaluate the potential for degradation of the other seals of this type. Failed seals were returned to the seal vendor, Parker Packing, for analysis. On May 9, 1991, preliminary discussions with Parker Packing indicated that the seal material, polyurethane, was susceptible to hydrolysis. The rate of degradation of the material may accelerate in the presence of moisture, acids, and high temperatures. Based on this information, it was indeterminate whether the aged seals would perform their design functions under Design Basis Accident (DBA) conditions.

On May 10, 1991, it was decided that this situation was reportable pursuant to 10 CFR 50.73 (a)(2)(ii), as an event or condition that resulted in the power plant being in an unanalyzed condition. At this time, the unit was in Mode 6, Refueling, following the reloading of fuel in the reactor vessel.

The situation of having a local leak rate test failure was reported via the Emergency Notification System on April 1, 1991. The notification was updated on April 19, 1991, when it was determined that the cause of the event was that a module outer seal had "compression set", allowing leakage past the seal during the test. Following completion of the engineering evaluation, the notification was again updated on May 10, 1991. In the second update, the following information was presented:

(1) the lubricants used to install the seals may cause premature degradation,

(2) that the manufacturer indicated that the service life of the seals may be less than earlier recognized, and

(3) that the manufacturer indicated that the seals may degrade if subjected to Design Basis Accident (DBA) moisture/temperature conditions.

On June 24, 1991, PGE submitted a report in accordance with 10 CFR 21. This report was submitted due to the fact that the capability of the EPA seals to perform their design function of providing the Containment pressure boundary was indeterminate.

During recent (1993) review of the degraded EPA seal issues, the 1991 engineering evaluation was reviewed. The conclusions, as to the suitability for service of the polyurethane, remain applicable.

During the recent review of these issues, it was determined that the leakage identified in module NZ02 constituted a condition prohibited by the Trojan Technical Specifications because it is assumed that the module could have experienced leakage in excess of allowable values had it been exposed to the post-accident Containment pressure of 60 psig. Consequently, this event is being reported in accordance with 10 CFR 50.73 (a)(2)(i).

Additionally, it was decided that this event may also be reportable per 10 CFR 50.73 (a)(2)(v), as a single cause or condition that alone could have prevented the fulfillment of the safety function of structures or systems that are needed to shutdown the reactor and maintain safe shutdown, remove residual heat, control the release of radioactive materials, and/or mitigate the consequences of an accident. Since the nitrogen pressure between the seals (nominally 30 psig) was less than the peak containment pressure following a design basis Loss of Coolant Accident (nominally 60 psig), there was the potential for moisture intrusion past the inner seal particularly with the aged seals. This moisture could cause shorting of the circuits within the EPA module preventing the fulfillment of necessary safety functions.

ROOT CAUSE AND CONTRIBUTING FACTORS

An independent authority on failure analysis was requested to perform a root cause analysis. This analysis was completed on September 24, 1991, and concluded that the cause of seal leakage was inadequate seal material. The polyurethane seal material was deemed inappropriate because of its tendency to acquire compression set over time, its susceptibility to moisture related degradation, and its incompatibility with the lubricants present in the header assembly. Additionally, the manufacturer's handbook gives only a two to five year rating for polyester urethane. The original Electrical Penetration Assembly Seal design, procurement and installation activities took place primarily in the 1970's, during plant construction. The Design Verification Test Report(s) provided by the manufacturer in 1972 supported use of the polyurethane seal material. Because of the length of time that has transpired since the construction of the plant, the root cause of the inappropriate material selection has not been determined.

In 1984, in conjunction with PGE's electrical equipment environmental qualification program, surveillance (e.g., trending) was decided upon as a means to determine seal degradation. PGE committed to the Nuclear Regulatory Commission to review periodic test data and to establish criteria to identify degradation of pressure boundary components.

In an internal 1991 Performance Monitoring and Events Assessment surveillance, the absence of a trending program to monitor leakage trends was identified as a missed opportunity for potentially identifying seal degradation. This trending program commitment was not properly implemented. Although nitrogen header pressure was informally monitored via shift routines, acceptance criteria were not established. Therefore, the shift routines were insufficient to detect aging degradation of pressure boundary materials. Similarly, the procedure for performing Local Leak Rate Testing did not contain acceptance criteria for individual EPA seal leakage and was not effective in predicting seal degradation and aging. It is believed that if an effective trending program had been implemented, problems with sealing effectiveness and aging could have been identified, allowing earlier correction of the problem.

The internal surveillance identified an additional missed opportunity for identifying the issue. In 1989, an outside supplier of engineering services performed a calculation which established a seal life of 18 years, and recommended replacement of seals every 15 years. However, the calculation did not address all pertinent parameters. For example, the calculation did not address hydrolysis damage as a mechanism for failure or whether the seal life should be based on manufacture date or installation date. Because of inadequate review of this matter, PGE did not take these problems into account. If the calculation had been reviewed according to PGE's procedures, correction of the deficiencies in the calculation may have reduced the projected seal life and replacement schedules. Approximately two years later, this calculation was used by PGE as a basis for revising the EPA maintenance and surveillance requirements documentation requiring seal replacement every 18 years although the calculation still had not been reviewed according to PGE's procedures. Additionally, the calculation was used as a basis for concluding that the seals were acceptable for continued use.

It has been concluded that the lack of timely resolution of the Electrical Penetration Seal degradation issue was due to a combination of cognitive and procedural errors. The cognitive error consisted of the failure of some engineering and management personnel to recognize the true nature and potential significance of the problems with the seals. The procedural error consisted of a failure to comply with the intent and, in some cases, the programmatic requirements of several procedures which if followed could have led to earlier recognition of the problem. For example, an Event Report procedure had been established for investigating, evaluating, reporting, documenting, and taking corrective actions for in-house events. The root cause and corrective actions for a 1987 EPA seal leakage event were not appropriately determined and acted upon as required by this Event Report procedure.

The upgrade modifications discussed below suggest that the electrical function as well as the containment pressure boundary function of the EPA's was addressed in time for implementation during the 1991 outage.

CORRECTIVE ACTIONS

EPA NZ02 was repaired and restored to service. The component parts which failed were the seals made of polyurethane, originally manufactured by Parker Packing Company.

To assure Containment integrity and electrical continuity, the following corrective actions were completed during the outage which began in 1991:

1. Replacement seals of a more durable material, ethylene propylene rubber (EPR), were installed. In addition, a silicone rubber O-ring was added to the outer face of each module assembly to provide a backup seal for Containment boundary integrity.

2. Representative EPA modules containing the new seals and O-rings were tested to demonstrate environmental qualification of the replacement seal design in accordance with the requirements of IEEE 317-1983, "Standards for Electrical Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations." To qualify the EPA containing safety-related conductors, the header plate required pressurization to 60 pounds per square inch gauge (post accident pressure) with dry nitrogen to maintain circuit integrity for the electrical conductors in the module. Additionally, the EPA's demonstrated acceptable leak tightness required by IEEE-317 without nitrogen pressurization.

3. The nitrogen supply system was upgraded to safety-grade for those Amphenol penetrations containing safety-related conductors.

4. Subsequent to these repairs and modifications, each repaired EPA was successfully Type B tested in accordance with 10 CFR 50, Appendix J, "Primary Reactor Containment Leakage Testing for Water-Cooled Power Reactors".

Trojan Nuclear Plant is permanently defueled. Therefore, the seal functions of maintaining containment integrity and ensuring electrical continuity for that equipment important to safety are no longer required. Accordingly at this time, there is no benefit to be gained by the establishment of a trending program nor review/ revision of the documentation which was based on the vendor calculation.

The majority of the engineering and management personnel who were involved in the EPA seal issues are no longer employed at the Trojan Nuclear Plant. In recent years, programs and processes for problem resolution have been strengthened and management philosophy has stressed the need for verbatim procedure compliance. It is believed that these changes will serve to preclude recurrence of events of the type discussed in this report. PGE continues to review these events to determine whether any further steps are appropriate.

SAFETY IMPLICATIONS AND CONSEQUENCES

Integrated Leak Rate Tests were performed on the Trojan Containment Building in 1979, 1983, 1986, and 1990. During the 1979, 1983, and 1990 tests, overall containment leakage was within allowable limits. The 1986 Integrated Leak Rate Test was unsuccessful due to inability to pressurize a mechanical penetration. No Integrated Leak Rate Test failures caused by leakage of the EPA seals have been identified.

The Trojan Final Safety Analysis Report describes the containment design leak rate to be not more than 0.1 percent by weight in 24 hours at 60 psig. This analysis may not represent the sealing effectiveness of the EPA seals during and following postulated accidents, because containment temperature and pressure remain above normal operating levels for several hours. Elevated containment temperature and pressure could adversely impact seal performance. In evaluating the effects of potentially degraded seal performance on containment integrity, the accident scenario of primary interest is the Loss of Coolant Accident since this accident scenario combines adverse containment environmental conditions with the possibility of a radioactive release. Post-accident containment leakage has not been quantified during the period following a postulated accident. Therefore, the consequences of potential containment leakages due to degraded seal performance is indeterminate.

Elevated containment temperature, humidity, and pressure associated with post-accident conditions could also degrade the electrical penetration continuity function of the assemblies. During and following accident conditions, containment pressure may reach approximately 60 psig. Although a nominal 30 psig nitrogen pressure was normally maintained in the annulus area, this may not have been sufficient to maintain inflation of the inner seal. If the inner seal were to lose its sealing effectiveness, high containment pressure and temperatures could result in moisture in the annulus area which could adversely affect the electrical continuity of the EPAs. This condition could adversely affect the performance of both safety and non-safety related instrumentation and equipment. In the evaluation of the electrical penetration continuity function, accident scenarios which cause adverse containment environmental conditions are of primary importance. The consequences of degraded seal performance on electrical continuity for safety and non-safety related instrumentation and equipment performance has not been quantified. Thus, the consequences of potential degradation of electrical continuity is indeterminate.

PREVIOUS SIMILAR EVENTS

Trojan Licensee Event Report 87-011, "Electrical Penetration Leaked Excessively Due to Degraded Seals", discusses a previous similar event in which one of the modules in EPA NZ07 had excessive seal leakage. The cause of the leakage reported in the LER was compression-set of the seal, due to seal aging. A contributing cause was attributed to a change in penetration temperature following shutdown for refueling. As a corrective action for that event, PGE committed to evaluate the need for a preventative maintenance program to periodically replace the electrical penetration seals. This evaluation was apparently not completed. No preventative maintenance program was formally established. (Replacement of some of the leaking seals during Refueling Outages was begun in 1989.)

There have been several other previous occurrences of EPA module deficiencies documented in plant records. Recent occurrences in the past four years include discovery of leakage in Penetration E-170 on February 3, 1989, during a routine check of nitrogen header pressure. This leakage was not sufficient to cause overall containment leakage to exceed authorized limits. It was determined that the leakage was related to the synergistic effects of age degradation ("compression set") and environment (extremely low ambient air temperature). On Ju[illegible] 27, 1989, a Bank D Control Rod dropped during power escalation[illegible]e cause was determined to be moisture and/or glycerine contam[illegible]n of the gas permeable area between the seals of an EPA module[illegible]Prior to this occurrence, the module had been removed from its assembly for approximately four weeks during the Refueling Outage, without having a nitrogen blanket maintained on the gas permeable area between the seals of the module. It is believed that the module failed because the module had been placed in an atmosphere without a nitrogen blanket, which allowed moisture intrusion, and then the module was placed back in service. It was concluded that since the module was not purged to remove the moisture prior to being placed in service, the module subsequently failed.

There were numerous corrective actions identified as a result of these events. However, not all of the actions were completed in a timely manner. As noted above, PGE continues to review these events to determine whether any further steps are appropriate.

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Nitrogen pressure at the EPA headers was informally monitored. When low nitrogen pressure was identified, a Maintenance Request was generated. A review of Maintenance Requests was performed to identify other instances of EPA performance problems.

Also, in recent history, leakage on EPA module seals was identified during Local Leak Rate Testing. Prior to the decision in 1991 to replace the polyurethane seals, the testing results (penetration leakage), the penetration circuitry, outage schedule, and other considerations were used to determine which module seals were replaced during Refueling Outages. Planned replacement of several module seals was deferred in the 1989 and 1990 Refueling Outages. Prior to the 1989 Refueling Outage, seventeen penetrations were identified as containing one or more leaking modules. During the 1989 Refueling Outage, seals were replaced on modules in eight EPAs. Prior to the 1990 Refueling Outage, thirteen EPAs were identified for review for replacement of their seals. During the 1990 Refueling Outage, seals were replaced in one EPA. By the conclusion of the refueling outage which began in 1991, the Amphenol polyurethane seals were replaced with the new EPR seal design.