10 CFR 50.73

BOSTON EDISON

Pilgrim Nuclear Power Station
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George W. Davis
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November 27, 1991
BECo Ltr. 91-996

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

Docket No. 50-293
License No. DPR-35

Dear Sir:

The enclosed Licensee Event Report (LER) 91-023-00, "Loose Drywell Head Bolts Discovered During An Integrated Leak Rate Test", is submitted in accordance with 10 CFR Part 50.73.

Please do not hesitate to contact me if there are any questions regarding this report.

G W Davis
G. W. Davis

DWE/bal

Enclosure: LER 91-023-00

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NRC FORM 366 (6-89)

U.S. NUCLEAR REGULATORY COMMISSION

APPROVED OMB NO. 3150-0104
EXPIRES: 4/30/92

ESTIMATED BURDEN PER RESPONSE TO COMPLY WITH THIS INFORMATION COLLECTION REQUEST: 50.0 HRS. FORWARD COMMENTS REGARDING BURDEN ESTIMATE TO THE RECORDS AND REPORTS MANAGEMENT BRANCH (P-530), U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, DC 20555, AND TO THE PAPERWORK REDUCTION PROJECT (3150-0104), OFFICE OF MANAGEMENT AND BUDGET, WASHINGTON, DC 20503

LICENSEE EVENT REPORT (LER)

FACILITY NAME (1)	DOCKET NUMBER (2)	PAGE (3)
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TITLE (4)
Loose Drywell Head Bolts Discovered During An Integrated Leak Rate Test

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)
									N/A	0 5 0 0 0
0 7	2 8	9 1	9 1	0 2 3	0 0	1 1	2 7	9 1	N/A	0 5 0 0 0

OPERATING MODE (9): N

POWER LEVEL (10): 0 0 0

THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: (Check one or more of the following) (11)

20.402(b)	20.405(c)	50.73(a)(2)(iv)	73.71(b)
20.405(a)(1)(i)	50.36(c)(1)	X 50.73(a)(2)(v) C	73.71(c)
20.405(a)(1)(ii)	50.36(c)(2)	50.73(a)(2)(vii)	OTHER (Specify in Abstract below and in Text, NRC Form 366A)
20.405(a)(1)(iii)	50.73(a)(2)(i)	50.73(a)(2)(viii)(A)	
20.405(a)(1)(iv)	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)
Douglas W. Ellis - Senior Compliance Engineer	5 0 8 7 4 7 - 8 1 6 0

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
E	B D	V S L	C 1 3 0	Y					

SUPPLEMENTAL REPORT EXPECTED (14)

		EXPECTED SUBMISSION DATE (15)	MONTH	DAY	YEAR
YES (If yes, complete EXPECTED SUBMISSION DATE)	X NO				

ABSTRACT (Limit to 1400 spaces, i.e., approximately fifteen single-space typewritten lines) (16)

On July 28, 1991 at approximately 2300 hours, 11 of 76 Drywell head bolts were discovered to be loose during a required 10 CFR 50 Appendix J integrated leak rate test (ILRT). The test was being performed at full pressure (45 psig), near the end of a refueling outage, and after a satisfactory local leak rate test (also at 45 psig) of the Drywell head gaskets. The cause of the loose Drywell head bolts was the failure of some of the spherical type washer sets that are part of the Drywell head flange connection. The primary cause of the failed washers was the use of washers made of case hardened AISI 8620 material instead of hardened and tempered AISI 4140 material. The exact source of the washers made of the AISI 8620 material had not been determined when this report was submitted. Factors possibly contributing to the failure of some of the washers were the inverted installation of some of the washers, corrosion, and crack propagation over time. Corrective action taken included the replacement of all Drywell head bolt washers. The new washers are made of AISI 4140 material hardened and tempered to the specified hardness. A subsequent ILRT was completed with satisfactory results on August 6, 1991. Corrective actions planned include revising the procedure used to install the Drywell head to include specific detail regarding how the Drywell head washer sets are to be installed. The Drywell was manufactured by the Chicago Bridge & Iron Company. The discovery occurred while shut down with the reactor mode selector switch in the REFUEL position. The Reactor Vessel (RV) head vent valves were open and the RV water temperature was 82 degrees Fahrenheit. This report is submitted in accordance with 10 CFR 50.73(a)(2)(v)(C). The loose Drywell head bolts were determined to be reportable on October 29, 1991. The loose bolts posed no threat to the public health and safety.

NRC FORM 366A (6-89)

U.S. NUCLEAR REGULATORY COMMISSION

LICENSEE EVENT REPORT (LER) TEXT CONTINUATION

APPROVED OMB NO. 3150-0104
EXPIRES 4/30/92

FACILITY NAME (1)	DOCKET NUMBER (2)	LER NUMBER (6) YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	PAGE (3)
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TEXT (If more space is required, use additional NRC Form 366A's) (17)

BACKGROUND

The safety objective of the Primary Containment System (PCS) is to provide the capability in conjunction with other safeguard features, to limit the release of fission products in the event of a postulated design basis accident so that offsite doses would not exceed the guideline values set forth in 10 CFR Part 100. The PCS design employs a low leakage pressure suppression containment system which houses the Reactor Vessel, the Reactor Recirculation System loops, and other branch connections of the Reactor Primary System.

The Drywell is a steel pressure vessel with a spherical lower portion and a cylindrical upper portion. The Drywell head, one double door airlock and two bolted equipment hatches provide access to the Drywell. The Drywell head and equipment hatch covers are bolted in place and sealed with gaskets. The Drywell is enclosed in reinforced concrete for shielding purposes. Shielding over the top of the Drywell is provided by removable, segmented, reinforced concrete shield plugs. The Drywell was manufactured by the Chicago Bridge & Iron Company.

The Drywell head is removable to facilitate refueling operations, and is bolted in place. There are two sets of spherical type washers and one nut for each of the 76 Drywell head bolts. Each washer set consists of one plano-concave washer and one plano-convex washer that mate at the concave and convex surfaces. The plano-concave washer portion of a washer set is designed to be installed with the plano (flat) surface against the Drywell head (upper washer sets) or against the Drywell top flange (lower washer sets). Conversely, the plano-convex washer portion of a washer set is designed to be installed with the flat surface against the bolt head or nut.

The Drywell head was relanded on the Drywell head flange on July 22, 1991. The tensioning of the Drywell head bolts was completed on July 25, 1991 at 0015 hours. The Drywell head gaskets were leak rate tested with satisfactory results at 45 psig and the shield blocks were then installed. After pressurizing the Drywell to 45 psig, the four hour stabilization period for the Integrated Leak Rate Test (ILRT) began on July 27, 1991 at 0413 hours.

EVENT DESCRIPTION

On July 28, 1991 at approximately 2300 hours, 11 of 76 Drywell head bolts were discovered to be loose during the ILRT. The discovery occurred after the shield blocks were removed from their installed location above the Drywell head. The shield blocks were removed as part of investigating the reason for the Drywell leakage rate observed on July 27, 1991.

Failure and Malfunction Report 91-348 was written to document the discovery. A critique and root cause analysis were initiated as a result of the discovery of the loose Drywell head bolts. The loose Drywell head bolts were determined to be reportable on October 29, 1991 as a result of assessing the root cause analysis report.

The primary containment leak rate value on July 27, 1991 was approximately 1.2 percent per day. Prior to depressurizing the Drywell, the contribution of the Drywell head flange leakage to the Primary Containment Leak Rate value was determined to be approximately 0.74 percent per day. The determination was made by eliminating leakage from the Drywell head flange and comparing the subsequent leak rate to the leak rate value of 1.2 percent per day. The leakage from the Drywell head flange was eliminated by pressurizing the volume between the Drywell head inner and outer gaskets to the Drywell pressure (45 psig).

The discovery occurred while shutdown, near the completion of a refueling outage, with the reactor mode selector switch in the REFUEL position. The Reactor Vessel (RV) head was installed with the RV head bolts tensioned. The RV head vent valves were open, and the RV water temperature was 82 degrees Fahrenheit.

Nuclear Network entries were made on August 6, 1991 (OE 4743) and September 6, 1991 (IS 1042/SEN 83) regarding the Drywell head washers.

CAUSE

The cause of the loose Drywell head bolts was the failure of some of the washers that were installed on the Drywell head bolts at the nut end (lower washer sets). The primary cause of the Drywell head washers that failed was the use of washers made of a material (AISI 8620) other than that specified in the design (AISI 4140). Factors possibly contributing to the failure of some of the washers were the inverted installation of some of the washers, corrosion, and crack propagation over time.

The exact source of the failed washers made of AISI 8620 material could not be determined during the root cause investigation. Additional searches were conducted of pertinent construction records in both records vaults and in the information retrieval system (SEEK). The searches focused on specifications, reports/replies, orders, permits, authorizations, and memoranda by the architect-engineer (Bechtel Corporation), vendor (Chicago Bridge & Iron Company), and Boston Edison Company. These searches revealed all of the Drywell head washers were replaced during original construction (c. 1971). However, the searches did not reveal the exact source of the replacement washers and washer material certification. A representative of the Chicago Bridge & Iron Company (CB&I) was contacted to establish the source of the replacement washers and washer material through a search of CB&I records. This search had not been completed when this report was submitted. This report will be updated if the CB&I search of their records identifies the exact source of the AISI 8620 washers and washer material.

The upper and lower washer sets of each Drywell head bolt were inspected. The inspection of the upper washer sets revealed all of those washer sets were installed correctly. The inspection of the lower washer sets revealed 41 of these washer sets were installed correctly. However, the other 35 lower washer sets were installed inverted, i.e. with the plano-concave portion of the washer sets installed with the flat surface against the nut instead of against the Drywell top flange.

The upper and lower washer sets consisted of a mixture of washers made from hardened and tempered AISI 4140 material and AISI 8620 case hardened material. A file hardness check of the cracked or broken washers that could be found showed all of the cracked or broken washers were made of AISI 8620 case hardened material. Of the 22 cracked or broken plano-concave washers, 16 were part of the washer sets that were installed inverted. Of these 16 inverted washer sets, 11 washers were found broken. This higher than random relationship indicates incorrect washer set installation was a contributing factor in the failure of some of the Drywell head washers.

A metallurgical examination of two broken pieces from part of one washer identified the washer material as AISI 8620 which was case hardened. The cracked washer had a hardened case, Rockwell hardness Rc=62, which is very brittle. This type of material is not as ductile as a lower hardness AISI 4140 material nor does it have the elongation properties.

A two-dimensional axisymmetric finite element analysis of the washer/bolt configuration was performed. The analysis postulated washer orientation coupled with bolt misalignment. The analysis indicated a properly installed washer of either AISI 4140 or 8620 material would be able to withstand a bolt misalignment due to Drywell head/flange alignment of up to two (2) degrees without over-stressing the AISI 8620 or 4140 washer material. An inverted washer set would be acceptable only if there was minimal misalignment. A bolt misalignment of over 0.3 degrees could cause enough stress to potentially fail the plano-concave washer made of either material, assuming the washer was inverted and had an existing flaw. The case hardened AISI 8620 can also fracture under very low static stress if a corrosive medium is present. Rust was present on the washers when they were removed. Also, the metallurgical exam showed the AISI 8620 washer material had a heavy concentration of non-metallic inclusions in the axial direction. These inclusions are a result of poor steel making practice and provided flaw initiation sites in the washers. Also, the AISI 8620 washer material had a very pronounced axial grain orientation.

The orientation of the inclusions indicated the washer was machined from bar stock whose axis was parallel to the axis of the washer. This results in lower tensile properties in the circumferential direction. Washers made from the case hardened AISI 8620 material were more susceptible to failure due to the absence of ductility in the hard case and the substantial inclusion level. The calculated stress intensities for a 0.3 degree misalignment and an inverted washer set would be sufficient to cause existing cracks to propagate to failure. A 0.3 degree misalignment is not easily discernable during installation. Crack initiation could have occurred over time due to corrosion or because of undetected minor manufacturing flaws.

Stress levels in inverted washers become very high if a bolt misalignment of more than 0.3 degree exists. At that point, sliding and/or prying of the washers may occur. This could cause failure in an inverted washer. Sixteen of 35 inverted plano-concave washers were found to be either cracked or broken, but only six (6) of 41 properly oriented plano-concave washers were found to be cracked or broken. Of the six (6) properly oriented cracked or broken plano-concave washers, four (4) were next to or between inverted washers. It is not possible to determine whether the properly installed washers which did fail would have failed if all washers were installed correctly.

During the Drywell head installation, the bolts were torqued in accordance with procedure 3.M.4-48 (Rev. 13) and excessive preload is not considered to be a factor. Several (eight) bolts were found loose after the initial torquing process and those bolts were retorqued prior to the local leak rate test of the Drywell head gaskets.

CORRECTIVE ACTION

The following corrective actions have been taken:

- All of the upper and lower Drywell head bolt washer sets were replaced with new washers made of AISI 4140 material hardened and tempered to the specified hardness level.

- All of the washer sets were installed correctly, i.e. with the flat surface of the plano-concave washer against the flange and the flat surface of the plano-convex washer against the bolt head or nut.

- The subsequent ILRT was completed satisfactorily on August 6, 1991.

- The Drywell head bolt washer sets that were replaced were segregated for control purposes.

- Drywell head bolt washers stocked as spare or replacement parts have been tested to verify the washers are made of hardened and tempered AISI 4140 (or equivalent) material.

The following preventive actions are planned to preclude recurrence:

- Revise procedure 3.M.4-48 to include steps for a pre-job briefing for each shift crew.

- Revise procedure 3.M.4-48 to include a list of proper hand tools to be used.

- Revise procedure 3.M.4-48 to include a specific procedure step (with signoff) that bolt threads, nut threads, and washers have been lubricated with an approved lubricant prior to bolting. This step is to ensure the sliding surfaces of the washers are free to move during the bolting.

- Revise procedure 3.M.4-48 to include specific detail regarding how the Drywell head upper and lower washer sets are to be installed.

- Revise procedure 3.M.4-48 to include a signoff that the washers have been installed correctly.

- Revise procedure 3.M.4-48 to include two torquing phases for the Drywell head bolts. The first phase compresses the Drywell head gaskets and brings the Drywell head flanges to a metal-to-metal contact. The second phase preloads the bolts to the final torque value using a minimum of two torque passes. The satisfactory completion of the last torque pass ensures that all Drywell head bolts are left at the desired torque value.

- Revise procedure 3.M.4-48 to include a record of measuring and test equipment for the hydraulic pressure gauges and hydraulic torquing units used.

- Revise procedure 3.M.4-48 to reference the drywell head/top flange assembly drawing (C1A-10-4).

- Enhancement of drawing C1A-10-4 relative to the detail of the Drywell head washers.

- Update drawing C1A-10-4 to delete notations regarding tack welds and washer plating.

- Addition of a note to the Chicago Bridge & Iron Company vendor manual (V-0256) page 18 (Rev. 3) regarding Drywell head bolt torque values. Currently, the vendor manual states in part, "...seating of the (Drywell head) gaskets can be obtained by a small fraction of the bolting force available. Additional torque of 800 to 900 ft.-lbs. should be applied after metal to metal contact". Procedure 3.M.4-48 Attachment 3 section 27 (Installation of the Drywell Head) specifies a torque value of 2005 to 2065 ft.-lbs. when torquing the bolts during the final torque pass. The final torque pass is after two torque passes at lower torque values. The note to be added to V-0256 would indicate the torque values were increased to 2005 to 2065 ft.-lbs. in response to NRC Bulletin 78-02.

Other proposed improvements were identified in the root cause analysis report. The improvements are not required to prevent a recurrence of the loose Drywell head bolts or Drywell head washer failure.

The spherical type Drywell head washers are the only washers of this type that are part of the Primary Containment Vessel. The Reactor Pressure Vessel (RPV) head washers are somewhat similar in type to the Drywell head washers in that each RPV head stud has one plano-concave washer and one nut having a convex surface. Review of the Combustion Engineering/RPV vendor manual (V-0392) and General Electric/reactor assembly vendor manual for Pilgrim Station (V-0253) revealed some inconsistencies in that V-0253 (GEK-9662 dated March 1971) section 2-19 incorrectly identifies a set of washers for each stud instead of one washer for each stud. Because V-0253 section 2-19 is referenced in the section of procedure 3.M.4-48 for the installation of the RPV head stud nuts and washers, corrective action program documents (PCAQs 91-213 and 91-214) were written for related improvements to 3.M.4-48 and V-0253. Although procedure 3.M.4-48 references V-0253 section 2-19, the correct nut and washer were installed as designed on each RPV head stud after the RPV head was installed on July 15, 1991.

SAFETY CONSEQUENCES

The loose Drywell head bolts posed no threat to the public health and safety because the loose bolts were discovered during the ILRT and because primary containment was not required when the ILRT was performed.

The ILRT was performed via procedure 8.7.1.4.2 (Rev. 8), "Primary Containment Integrated Leak Rate Test", to meet Technical Specification 4.7.A.2.a/10 CFR Part 50 Appendix "J". Appendix "J" type 'A' test requirements include preoperational leakage rate tests. These tests are required to be performed three times during each 10 year service period, or at each refueling or approximately 18 months if two consecutive periodic type 'A' tests fail to meet leakage rate test criteria. For Pilgrim Station, the second 10 year service period began in 1982 (June 1982). Beginning in 1982, ILRT/type 'A' tests have been performed during RFO 5 (February 1982 at 23 psig), RFO 6 (December 1984 at 23 psig), RFO 7 (December 1987 at 45 psig), and RFO 8 (July/August 1991 at 45 psig).

Although the loose Drywell head bolts were discovered and corrected as a result of the ILRT, the loose Drywell head bolts could have affected the ability of the PCS to control the release of radioactive material if an ILRT had not been performed and a design basis loss of coolant accident (LOCA) had occurred during subsequent power operation.

The most severe nuclear system effects and the greatest release of radioactive material to primary containment results from a complete circumferential break of one of the recirculation loop pipelines. This accident is described in the Final Safety Analysis Report (FSAR) section 14.5.3 and was established as the design basis LOCA. The radiological consequences of a design basis LOCA are assessed in FSAR section 14.5.3.2 and are part of the bases for Technical Specification 3.7.A/4.7.A for primary containment testing. The design basis LOCA was evaluated at the primary containment maximum allowable accident leak rate of 1.25 percent per day at 45 psig. Thus, the calculated doses are the maximum that would be expected in the unlikely event of a design basis LOCA. The doses include an assumption of no holdup in the Reactor Building/secondary containment, and results in a direct release of fission products from primary containment through the Standby Gas Treatment System (SGTS) filters and Main Stack to the environment. The offsite doses resulting from the design basis LOCA including primary containment conditions at 45 psig with a 1.25 percent per day leak rate, no holdup, fission product release fractions stated in TID 14844, 95 percent SGTS filter efficiency, and Main Stack release would be less than the limits of 10 CFR 100. Therefore, if an ILRT had not been performed and the loose Drywell head bolts had not been discovered and a design basis LOCA had occurred during subsequent power operation and the Drywell leakage rate was the same as the ILRT value on July 27, 1991, then the resulting offsite dose would have been less than 10 CFR 100 limits.

This report is submitted in accordance with 10 CFR 50.73(a)(2)(v)(C) because the loose Drywell head bolts could have affected the ability of the PCS to control the release of radioactive material if an ILRT had not been performed and a design basis LOCA had occurred during subsequent operation.

NRC FORM 366A (6-89)

U.S. NUCLEAR REGULATORY COMMISSION

APPROVED OMB NO. 3150-0104
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TEXT (If more space is required, use additional NRC Form 366A's) (17)

SIMILARITY TO PREVIOUS EVENTS

A review was conducted of Pilgrim Station Licensee Event Reports (LERs). The review focused on LERs involving the primary containment or Appendix J leak rate testing. The review identified LER 50-293/89-008-00 that involved the Drywell personnel access airlock doors and LERs 81-053/03X-1, 83-065/03X-1, 86-011-00, 86-017-01, 90-004-00, and 91-013-00 that involved local leak rate test results since 1981.

ENERGY INDUSTRY IDENTIFICATION SYSTEM (EIIS) CODES

The EIIS codes for this report are as follows:

COMPONENTS	CODES
Vessel (Primary Containment Vessel/Drywell)	VSL
SYSTEMS	
Containment Leakage Control System	BD