Arizona Nuclear Power Project
P.O. BOX 52034 • PHOENIX, ARIZONA 85072-2034

October 9, 1986
ANPP-38589-JGH/DJW/DRL-92.11

U. S. Nuclear Regulatory Commission
Region V
1450 Maria Lane - Suite 210
Walnut Creek, California 94596-5368



Attention: Mr. D. F. Kirsch, Acting Director
Division of Reactor Safety and Projects
Palo Verde Nuclear Generating Station (PVNGS)
Units 1, 2, 3
Docket Nos. 50-528, 529, 530

Subject: **Final Report - DER 86-23**
A 50.55(e) and 10CFR21 Condition Relating to the Failed ASTM A540 Grade B24 Class 1 Nut
File: 86-006-216; D.4.33.2

Reference: (A) Telephone Conversation Between A. Hon and D. R. Larkin on July 25, 1986 (Initial Notification - DER 86-23)
(B) ANPP-37839, dated August 22, 1986 (Interim Report - DER 86-23)

Dear Sir:

Attached, is our final written report of the deficiency under 10CFR50.55(e) referenced above. The 10CFR21 evaluation is also included.

Very truly yours,

J. G. Haynes
Vice President
Nuclear Production

JGH/DRL:kp

Attachments

cc: See Page 2



1/1

IE-27

cc: J. M. Taylor
Office of Inspection and Enforcement
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

A. C. Gehr (4141)
R. P. Zimmerman (6295)

Records Center
Institute of Nuclear Power Operations
1100 Circle 75 Parkway - Suite 1500
Atlanta, Georgia 30339

FINAL REPORT - DER 86-23
DEFICIENCY EVALUATION 50.55(e)
ARIZONA NUCLEAR POWER PROJECT (ANPP)
PVNGS UNITS 1, 2, 3

## I. Description of Deficiency

### Discovery of Problem

On the afternoon of July 11, 1986, a workman discovered that an approximately 1 inch wide, wedge shaped piece had fallen out of a nut anchoring the Unit 3 number one (1) steam generator pedestal. The failure of the nut resulted in one of the twelve anchors being unable to supply its required 1500 kip residual preload.

### Background

The steam generator lower support is composed of two 12 inch thick forgings which resist lateral loads, four vertical support pads to resist downward compressive loads and eight 6 inch diameter anchor bolts to resist uplift forces. The larger of the two forgings of the steam generator lower support is designated as forging "A"; the smaller as forging "B". Forging "A" serves as a key to resist the translational forces transmitted by the steam generator sliding base when the steam generator is subjected to pipe break and seismic loads. Details of the steam generator lower support are shown in Figure 1.

The Palo Verde Project purchased the studs and nuts from Marathon Steel Company, Phoenix, Arizona. Marathon Steel Company in turn used several subtier suppliers as sources for the studs and nuts. A review of the Certified Material Test Reports (CMTR) revealed that Joseph Dyson and Sons, Inc. of Painesville, Ohio, supplied the failed Unit 3 nut.

Bechtel Drawing 13-ZCS-605, Revision 11, "Containment Internals, Steam Generator Lower Supports, Sections and Details," specified high strength anchor bolts, heavy hexagon nuts and washers meeting ASTM Specification A540, Grade B23, Class 1 (E-4340-H). A documentation search conducted at the jobsite showed the failed nut to be ASTM A540, Grade B24, Class 1, however, it also meets all of the strength and hardness requirements of Grade B23, Class 1.

## EVALUATION

### Metallurgical Evaluation

In order to determine the nature and cause of cracking, the fractured nut was subjected to metallographic examination, chemical analysis, mechanical tests, and heat treatment tests. In addition, the corrosion products and other substances on the thread surfaces and nut base were subjected to emission spectrographic analysis, infrared analyses, x-ray powder diffraction, and energy dispersive x-ray analysis (EDX). The metallurgical evaluation concluded:

1. The 5-1/2 inch nut in the number one (1) steam generator lower support in Palo Verde Unit 3 failed due to stress corrosion cracking (SCC).

2. The steel met the material specification requirements stated in 13-CM-125. The high hardness (43.6 HRC) of the nut, chloride-containing water incursion, and high hoop stress near the base of the nut is the primary cause of SCC. It is estimated that the hoop stress was 100 Ksi.

3. The source of high chloride (up to 8 percent in corrosion products) has not been identified. Moisture condensation and rain water, however, may be excluded from consideration as a possible source. Well water may be considered a possible source of high chloride and it was used in curing concrete.

4. No material flaws such as forging defects or quench cracks were found.

Field Investigation of 5-1/2 Inch Diameter Nuts

As an initial step of the problem resolution, all accessible 5-1/2 inch diameter nuts on forging "A" of both the Number 1 (Tag No. 3 MRCE E01A) and Number 2 (Tag No. 3 MRCE E01B) steam generators of Unit 3 were visually examined. The fractured nut on the Number 1 steam generator lower support was the only nut found to be cracked.

In addition to the visual examination, all accessible nuts were subjected to hardness tests and ultrasonic examination. Excluding the fractured nut, 18 of a total of 23 remaining Unit 3 5-1/2 inch diameter nuts were accessible for hardness testing and ultrasonic examination. Hardness tests using an Equotip Hardness Tester, determined the hardness of the 18 remaining accessible nuts ranged from 37.6 to 42.4 HRC. Thus, the fractured nut has the highest hardness of all nuts tested. In addition, ultrasonic examination of the 18 accessible 5-1/2 inch diameter nuts did not detect any cracking.

Documentation Review

A documentation review was conducted to identify the location of other ASTM A540 material procured by Bechtel. Of specific interest were certified material test reports for bolts, studs and nuts that indicated material hardnesses equal to or greater than 41 HRC. The 41 HRC hardness is significant since, steels with hardnesses greater than 41 HRC are regarded as having less resistance to SCC than softer materials.

The review identified the following Unit 3 installations as potentially having material with hardnesses equal or greater than 41 HRC:

1) 2-1/2 inch diameter heavy hex nuts for the steam generator upper support (Custom Bolt, heat trace No. 5C).

2) 6 inch diameter steam generator lower support anchor bolts (Daido Steel, heat trace Nos. 08 and 11).

3) 3-3/4 inch diameter heavy hex nuts for the steam generator lower support (forging B) Jos. Dyson & Sons, heat trace No. C74D).

4) 2 inch diameter pressurizer anchor bolts (Daido Steel, heat trace No. 26).

Field Investigation of Material Identified by the Document Review

Visual examination of Unit 3 nuts and anchor bolts identified with the above listed heat trace codes did not reveal any additional fractured nuts or anchor bolts. Visual examination did reveal that none of the 3-3/4 inch diameter heavy hex nuts for the steam generator lower support were from the same heat trace code as the cracked nut.

Hardness testing using the Equotip hardness tester was performed on 11 out of 160 (11 out of 11 from heat 5C) 2-1/2 inch diameter nuts for the Unit 3 steam generator upper support and 16 out of 16 2 inch diameter pressurizer anchor bolts. In addition, hardness tests were performed on the 16 out of 16 3-3/4 inch diameter nuts for the Unit 3 steam generator lower support. The 6 inch diameter steam generator lower support tie down anchor bolts in Unit 3 were not accessibly for hardness testing. The results of the hardness testing concluded that the fractured nut had the highest hardness of all nuts or studs tested. None of the additional nuts or studs tested exceeded an average of 41.5 HRC.

Hardness testing did reveal another problem with material supplied by Custom Bolt Manufacturing Company. Hardness testing resulted in identifying six 2-1/2 inch diameter heavy hex nuts for the Unit 3 steam generator upper support having hardness below the values specified in ASTM A540 Grade B23 Class 1. The acceptable minimum hardness value for this material is 321 Brinnell. The hardnesses for the six nuts ranged from 200 to 220 Brinnell. Subsequent chemical analysis using the Texas Nuclear Alloy Analyzer identified the six nuts as being made of carbon steel. DER 86-26 has been initiated to address the investigation and evaluation of the "soft" nuts.

In addition to the details given above, ultrasonic examination of all (16 total) Unit 3 6 inch diameter steam generator lower support tie down anchor bolts, all (16 total) Unit 3 2 inch diameter pressurizer anchor bolts and 11 out of 160 (11 out of 11 from heat 5C) Unit 3 2-1/2 inch diameter heavy hex nuts for the steam generator upper support was performed. The ultrasonic examination did not detect any cracking. It was determined that no 3-3/4 inch high hardness (greater than 41 HRC, based on CMTR review) accessible heavy hex nuts were installed in Unit 3, therefore no ultrasonic examination was performed.

Engineering Calculation

Engineering Calculation (Calc. No. 13-CC-ZC-140, Rev. 1) was performed considering the recent modification to General Design Criteria (GDC) 4 of Appendix A, 10CFR50, effective May 12, 1986. By utilizing the leak-before-break technology, the original calculated loads are reduced by approximately 80 percent. This reduction in original design loads results in only 4 studs and nuts (one in each quadrant) being required for forging "A".

Drawing Discrepancy

Bechtel Drawing 13-C-ZCS-605, Revision 11, "Containment Internals, Steam Generator Lower Supports, Sections and Details," specifies high strength anchor bolts, heavy hexagon nuts and washers meeting ASTM Specification

A540, Grade B23, Class 1 (E-4340-H). The review of the CMTR's at the jobsite showed the failed nut to be ASTM A540, Grade B24, Class 1, which also meets all of the strength and hardness requirements of Grade B23, Class 1.

A review of Supplier Deviation Disposition Requests (SDDR) against Specification 13-CM-125 identified SDDR No. 17, dated July 21, 1977. This SDDR requested approval for Marathon Steel to supply ASTM A540, Grade B23 material in lieu of ASTM A540 Grade B24. Thus ASTM A540, Grade B24 material was originally required by the specification. The SDDR was approved and Drawing 13-C-ZCS-605 revised to specify ASTM A540, Grade B23 material, but the engineer did not specify an option to use the Grade B24 material. However, ASTM A540, Grade B24 is an acceptable alternative to the Grade B23 material for this application.

Potential For Future Failures

SCC is a time-dependent phenomenon which occurs after an incubation period. Once the crack has started, it follows the crack propagation rate predicted by the fracture mechanics theory. Both the incubation period and the rate of crack propagation are dependant upon strength (or hardness) of the material, stress level, and the environment.

Assuming that the studs and nuts were exposed to an "aggressive environment" soon after tensioning a sufficiently long period of time has elapsed for SCC to occur. Therefore, the lack of any visual indications of distress on, or around, the remaining nuts along with the results of ultrasonic examination of the nuts indicate that no further failure is likely to occur. Not only are the remaining nuts lower in hardness than the one nut that failed, but it is also unlikely that these nuts will be exposed to environments more aggressive than previously exposed to.

Units 1 and 2 Operation

A walkdown and visual observation by ANPP was completed for all accessible Units 1 and 2 steam generator lower support 5-1/2-inch diameter nuts. No signs of distress or cracking were identified.

Although the previously listed conditions did lead to failure of one 5-1/2-inch diameter nut in Unit 3, the failure is considered to be an isolated case. Thus the operability of Units 1 and 2 is not adversely affected. The results of the engineering evaluation leading to this conclusion are summarized as follows:

1. The heat trace code of the failed nut was D74L. The documentation review concluded that none of the D74L nuts were used in Unit 1, only six (6) nuts were used in Unit 2 and the remaining nuts of this heat were used in Unit 3.

2. All Certified Material Test Reports (CMTR) for the 5-1/2-inch diameter lower steam generator nuts were reviewed to identify heats of material having a hardness of 41 HRC or greater. Only the CMTR for the D74L heat trace code material reported a hardness of 41 HRC or greater.

3. The failed nut had the highest hardness of those Equotip hardness tested. Ultrasonic examination of the remaining accessible D74L nuts in Unit 3 showed no evidence of SCC.

4. All Certified Material Test Reports for ASTM A540 material purchased by Bechtel under specification 13-CM-125 were reviewed to identify heats of material reporting a hardness of 41 HRC or greater. Using accessible bolts in Unit 3 as a sample, ultrasonic examination, hardness testing and/or visual examination of material identified by the CMTR review was performed in Unit 3 and did not provide any additional evidence of SCC.

5. Visual examination by ANPP of the Unit 1 and Unit 2 steam generator lower supports did not reveal any cracking.

6. SCC is a time dependent phenomena. A sufficiently long period of time has elapsed for SCC to occur. Therefore, a visual examination looking for signs of distress and cracking would be sufficient to detect SCC.

7. Nuts embedded in concrete are not of concern because of the alkaline environment they are subjected to. Analysis of corrosion products determined that the failed nut had been subjected to an acidic environment (PH 2.5).

8. A calculation considering a recent revision to the General Design Criteria resulted in only four (4) studs and nuts of 12 (one in each quadrant) being required to anchor forging "A".

Transportability

SCC is a time-dependent phenomenon. SCC occurs after an incubation period. Once the crack has started, it follows the crack propagation rate predicted by the fracture mechanics theory. Both the incubation period and the rate of crack propagation are dependent upon strength (or hardness) of the material, stress level, and the environment.

The studs and nuts of the steam generator lower support are assumed to have been exposed to an "aggressive environment" soon after tensioning and prior to painting. Review of the stud tensioning dates has determined that a sufficiently long period of time has elapsed for stress corrosion cracking to occur. Therefore, the lack of any signs of distress on or aroung the remaining nuts and the results of ultrasonic examination of the nuts indicate that no further failure is likely to occur. Not only are the remaining nuts lower in hardness than the one nut that failed, but it is also unlikely that these nuts will be exposed to environments more aggressive than they have already been exposed to.

II. Analysis of Safety Implications

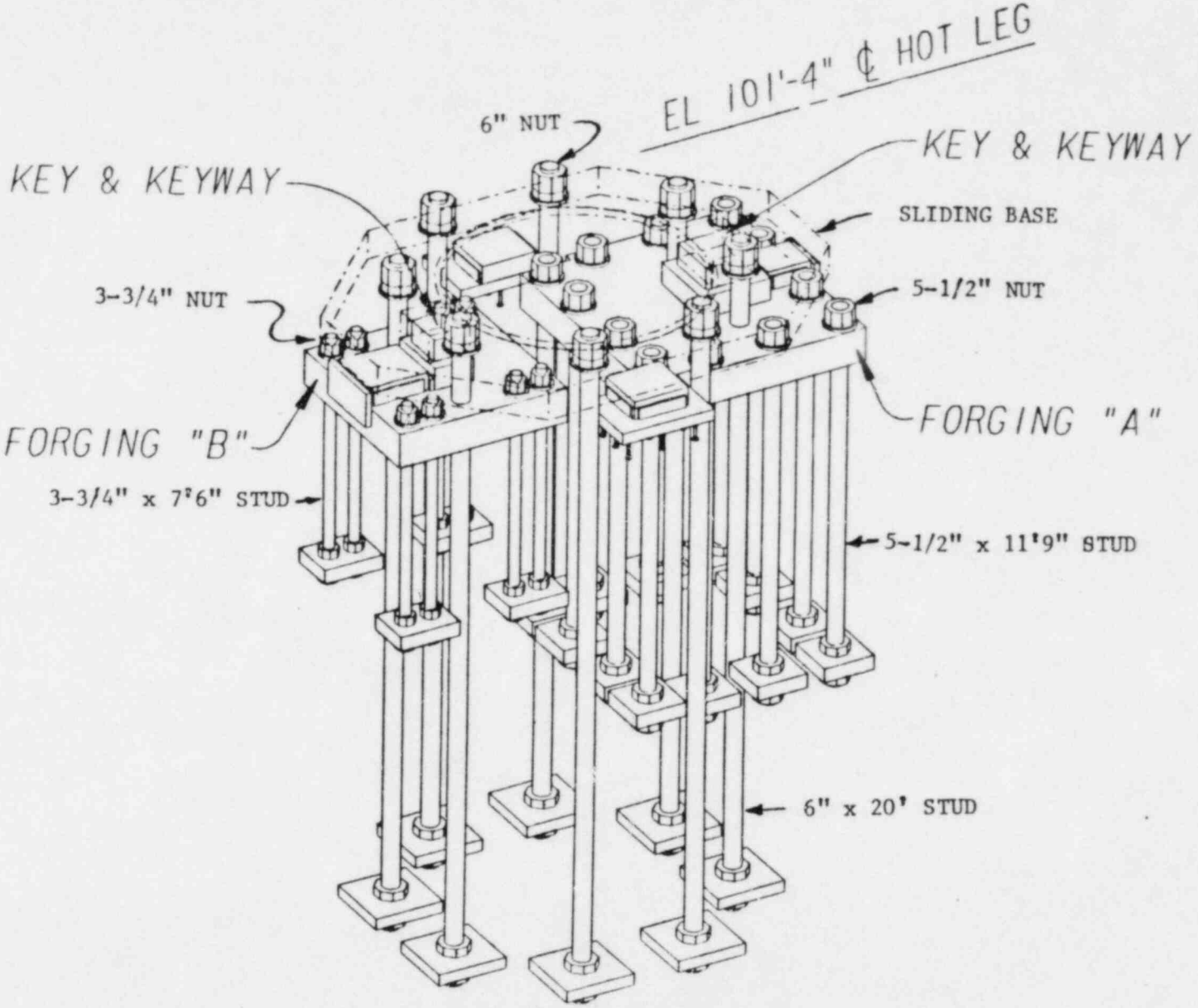
Based on the above, this condition has been determined to be not reportable under the requirements of 10CFR50.55(e) and 10CFR21 since, if left uncorrected, the condition would not represent a safety significant hazard.

III. Corrective Action

The following corrective action will be taken:

1. A Specification Change Notice will be issued for Specification 13-CM-125 to limit both the hardness and the minimum tempering temperature for all future purchases of ASTM A540 material. The maximum hardness will be limited to 41 HRC. The minimum tempering temperature shall be 1000°F.

2. A DCN will be issued for Drawing 13-C-ZCS-605 specifying an option to use either ASTM A540, Grade B23, Class 1 or ASTM A540, Grade B24, Class 1 material with limited hardness for the 5-1/2 inch diameter nuts.




STEAM GENERATOR SLIDING BASE EMBEDS

FIGURE 1