Arizona Public Service Company

September 14, 1984
ANPP-30520-TDS/TRB

U. S. Nuclear Regulatory Commission
Region V
Creekside Oaks Office Park
1450 Maria Lane - Suite 210
Walnut Creek, CA 94596-5368

Attention: Mr. T. W. Bishop, Director
Division of Resident
Reactor Projects and Engineering Programs

Subject: Final Report - DER 83-49
A 50.55(e) Reportable Condition Relating to Broken Impeller Blades and Diffuser Bolts Broken/Loose In The Reactor Coolant Pumps.
File: 84-019-026; D.4.33.2

Reference: A) Telephone Conversation between P. Narbut and R. Tucker on July 15, 1983
B) ANPP-Telephone conversation between T. Young and R. Tucker on July 18, 1983 (Interim Report)
C) ANPP-ANPP-27593, dated August 19, 1983 (Interim Report)
D) ANPP-28734, dated January 27, 1984 (DER 83-50 Interim Report, Revision 1)
E) ANPP-28733, dated January 27, 1984 (Interim Report, Revision 1)
F) ANPP-28313, dated November 29, 1983 (Time Extension)
G) ANPP-29713, dated June 11, 1984 (Time Extension)
H) Telephone conversation between P. Narbut and T. Bradish on August 14, 1984)
I) ANPP-30188, dated August 13, 1984 (Time Extension)

Dear Sir:

Attached is our final written report of the deficiency referenced above, which has been determined to be Not Reportable under the requirements of 10CFR50.55(e).

Very truly yours,

EEVanBrunt/TRB

E. E. Van Brunt, Jr.
APS Vice President
Nuclear Production
ANPP Project Director

EEVB/TRB/nj
Attachment
cc: See Page Two

1/1

EE-27

CE Doc. No. CEN-271(V)-P
- Revision 1-P -
Proprietary Copies

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* Non-Proprietary Copy Attached

FINAL REPORT - DER 83-49
DEFICIENCY EVALUATION 50.55(e)
ARIZONA PUBLIC SERVICE COMPANY (APS)
PVNGS UNITS 1, 2, 3

I. Description of Deficiency

After pre-core hot functional testing (HFT) in July 1983, the Unit 1 RCP (tag 1MRCEP01A) was disassembled to repair a previously identified linear indication in the pump casing circumferential weld. An inspection of the pump internals revealed four broken and two loose diffuser-to-casing retaining cap screws. Also, ten of the diffuser-to-suction pipe cap screws were found to be loose and the impeller shaft keyway bolt was broken, (Ref. NCR 2657). There was also slight cavitation damage on the leading edge of seven diffuser vanes.

As a result of the above, the other three Unit 1 RCPs (tags 1MRCEP01B, C, D) were disassembled and inspected. In addition to discovering loose and/or broken diffuser and suction pipe cap screws, damage was noted as follows (Ref. NCRs SM-2658, 2659, and 2660):

- The pump casing internal surface above the impeller had sustained peening damage from the loose diffuser cap screws.
- The pump casing-to-diffuser fit indicated surface fretting damage had occurred due to relative motion between the parts.
- Pieces were missing from the leading edge of one impeller vane on RCP 1B and two vanes on RCP 2A.
- There were broken and/or loose impeller key retaining screws shaft protection sleeve key retaining rings, and carbon journal bearing key retaining screws.
- The shaft seals showed wear on the stationary seal ring holders and heavy deposits of O-ring lubricant was noted throughout the seal assemblies. Also, bolts in the seal cartridges were loose.
- Leakage was observed between the carbon bearing sleeve and the seal housing, indicating seal ring failure.

The PVNGS type R01 Reactor Coolant Pumps are supplied by Combustion Engineering (C-E), designed by Klein Schanzlin & Becker (KSB) of West Germany, and were manufactured and performance-tested by CE-KSB in Newington, New Hampshire.

Evaluation

CE-KSB has manufactured and tested a total of 24 duplicate type R01 RCPs at their Newington facility for use in System 80 plants. The Palo Verde 1B pump, the first of this group tested, was run approximately 600 hours in the test loop. All the other pumps were tested approximately fifty hours each. The damage described in section I above was incurred during 700 to 1100 hours of operation per pump during the HFT. There are no RCPs of this design in any operating plant. The pumps at Palo Verde Unit 1 are the first of this particular design to be operated in other than a test loop, therefore, any design or material deficiencies would be evidenced after the HFT at Palo Verde.

The root cause of the capscrew and impeller vane failures is fatigue, i.e., cyclic loading exceeded the material fatigue strength. In the case of both the diffuser-to-casing and diffuser-to-suction pipe capscrews, it was determined that loss of pre-load preceded the fatigue failures. The loss of pre-load was due to a combination of cyclic loading, a relatively low capscrew working pre-load (approximately 45% of yield), and ambiguous and multiple load paths.

The proximity of the impeller outer diameter (OD) to the leading edge of the diffuser vanes (ID), in this case 11mm (2.3% of impeller radius), contributed to the magnitude of the dynamic forces which caused the fatigue failures and to the cavitation damage of some diffuser vanes. Fatiguing hydraulic pressure fluctuations are generated at the rate of 78,000 impulses per minute (6 impeller vanes x 11 diffuser vanes x 1180 rpm). The close gap between the impeller and diffuser vanes increases the pulse intensity and the potential for fatigue failures. Operation at runout (single-pump) which is approximately 142% of design flow, produces the highest pulse intensities and therefore the highest stresses in the working parts.

KSB conducted model tests to evaluate the affects of increased impeller-to-diffuser clearance to preclude diffuser vane leading edge cavitation damage and reduce the magnitude of dymanic forces, both at design and runout flows. The hydraulic model employed for this test program was the same as used during the original development of this particular RCP. This testing was also used to verify that the original design requirements for head-capacity, horsepower, and NPSHR would

not be compromised by this modification. From these tests, it was determined that increasing the radial gap from 11mm to 28.5mm (6.0% of impeller radius) by cutting back and re-profiling the leading edges of the diffuser vanes would produce the desired results of reduction in the magnitude of the dynamic forces and elimination of cavitation damage. These model tests also verified that head reduction at the design capacity due to the increased gap could be efficiently recovered by backfiling the impeller vanes and that the resultant change in runout performance would be acceptable.

Analyses of material properties of both capscrews and impellers by CE-KSB verified that the materials conformed to specifications were not deficient, and that failures were due to fatigue.

A detailed survey of the three broken impeller vanes and nineteen intact vanes (the two remaining vanes were used for metallurgical examinations) revealed that the broken vanes were thinner than the intact vanes in the critical area at the leading edge to upper shroud junction. Both finite element stress analysis and strain gage tests were correlated to the known fatigue failure stress in the failed vanes, including variables such as casting imperfections and stress concentrations. Using these values, the analysis of an intact vane with greater thickness and greater fillet radius than the failed vanes results in peak stresses well below the fatigue failure stress. This design analysis by CE-KSB concludes that all the impellers now installed have a safety factor of at least 1.5 over the impellers originally used in the Unit 1 RCPs. (For impeller modifications, see section III, paragraph 2). The increased impeller to diffuser gap further reduces loads, therefor , the current safety margin is now approximately 1.75 compared to the thickest vane which previously failed.

II. Analysis of Safety Implications

C-E investigated various failure mechanisms of the RCPs and consequential damage to the system including locked rotor, degraded pump costdown and core flow blockage. In all cases it was determined that the internal failures would not constitute a safety hazard. The safety requirement of the RCPs is to maintain the Reactor Coolant System (RCS) pressure boundary integrity. C-E has determined that if the conditions had remained uncorrected, the integrity of the RCS pressure boundary would not be compromised.

Based on the preservation of the reactor coolant pressure boundary integrity and the fact that fragments of RCP internals will not damage the reactor, have adverse affect on heat transfer to fuel elements, or interfere with control rod movement, the project evaluates the RCP deficiencies as not reportable under the requirements of 10CFR50.55(e) and 10CFR Part 21; since, if these conditions were to remain uncorrected, they would not represent a significant safety hazard.

III. Corrective Action

A comprehensive program was completed by C-E, CE-KSB, and KSB confirm the root cause of the deficiencies and define and implement specific modifications. Additionally, programs were established to verify the modifications by analysis, model testing, prototype testing, and full-scale field testing. These programs and their results are contained in Reference (1).

C-E's corrective action program and disposition of the referenced NCRs are summarized as follows:

1) The diffuser-to-casing fit (#1) and the suction pipe-to-diffuser fits (#2) were redesigned to eliminate ambiguous load paths and to minimize the number of multiple load paths, i.e., elimination of tapered fits, use of shorter ring segments at fit #1, and addition of a support ring and four reinforcing level pins at fit #2. Additionally, the number of capscrews was increased (from 16 to 29 for fit #1 and from 16 to 24 for fit #2) and the design torques increased to provide working stresses of 85% of yield. Also, the fit #1 capscrews were increased in length by 54% to make them less susceptible to loss of preload due to thermal and cyclic loading affects and the length of the threaded inserts (helicoils) in the diffuser was increased to guarantee complete thread engagement. A re-analysis was conducted to verify that the capscrew preloads will exceed operating loads under all variations of operating conditions.

   A total of 351 hours of testing was conducted in the CE-KSB test loop to generate baseline data on an unmodified pump and comparable data after modifications. Accelerometer and strain gage data indicated that the original loss of preload could be duplicated within 100 hours of runout operation. After modification, data verified that there was no change of capscrew strain after 150 hours of operation at runout.

2) The Atlas (foundry source) impellers for the Unit 1 & 2 RCPs were replaced by Schmidt and Clemens (S&C, foundry source) impellers which were available from other (cancelled) System 80 plants. The S&C impellers have thicker vanes with a flatter profile than the Atlas impellers near the leading edge where the failures occurred. At sections further away from the leading edge, there are less differences in vane thickness between the Atlas and S&C impellers. The Unit 3 impellers were replaced with Atlas impellers where the vane leading edges were re-profiled so the leading edge thicknesses are equal to or greater than the replacement S&C impellers installed in the Unit 1 & 2 RCPs.

   All impellers were backfiled (to compensate for head loss due to cutting back the diffuser vanes) and rebalanced. One S&C and one modified Atlas impeller were retested with their diffusers in the CE-KSB test loop in Newington to verify the hydraulic performance of the modified parts.

3) Examination of the broken impeller key retaining screws indicated that the sockets in the heads were formed too deep. This resulted in insufficient wall thickness in the head to shank area. These screws were redesigned with a larger head to accommodate the socket. These screws will be installed with retaining sleeves and staked in place.

   The shaft protection sleeve and carbon journal bearing key retaining screws are smaller screws and their looseness was attributed to vibration. The method of torquing these screws and staking them was revised.

4) The bearing sleeve to seal housing seal ring was replaced with a flexitallic type gasket. The size of the bolts in the joint was increased to insure that the gasket is properly seated.

5) Regarding the shaft seal deficiencies, instructions will be issued by C-E on the proper use of "O" ring lubrication. Precautions will also be taken to insure that the seal cartridge bolts are properly torqued.

   The Unit 1 seal cartridges have been designated as test sets and have been installed in the Unit 2 RCPs for use during hot functional tests (HFT). They will subsequently be used for Unit 3 HFT. Unit 2 seal cartridges have been installed in the Unit 1 RCPs, reference NCR dispositions.

6) Special demonstration tests during July/August 1984 for the four modified Unit 1 RCPs, with subsequent disassembly of the 2B pump for a detailed inspection, have reconfirmed the adequacy of the corrective actions. The test sequence included the same conditions as those which resulted in the original damage and totaled 737 hours of running time on the 2B RCP (Reference 2).

   The post-test inspection confirmed all diffuser and suction pipe cap screws were properly secured. Also, there was no evidence of cavitation wear on either the diffuser or impeller vanes. Liquid penetrant inspection of the impeller vanes showed no unacceptable indications.

7) The required corrective actions for Unit 1 were implemented prior to the above-mentioned demonstration test via the following Design Change Packages (DCPs).

   1SM-RC-107 1SM-RC-109 1SM-RC-113

   Additionally, these same changes will be implemented in the Units 2 and 3 RCPs prior to their fuel load via DCPs as follows:

2SM-RC-107	3CM-RC-107
2SM-RC-109	3CM-RC-109
2SM-RC-113	3CM-RC-113

   These DCPs provide the corrective action disposition of NCRs SM-1657, -2658, -2659, and -2660.

IV. References

1. Letter V-CE-30867, August 30, 1984
   C-E Final Report (proprietary) on Palo Verde Nuclear Generating Station Reactor Coolant Pumps, CEN-271(V)-P, August 1984.

2. Letter V-CE-21757, August 14, 1984.

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Windsor, Connecticut 06095

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NS DOC CENTER

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POWER SYSTEMS

August 30, 1984
V-CE-30867

Mr. E. E. Van Brunt, Jr.
Arizona Nuclear Power Project
P. O. Box 21666 - Sta. 3003
Phoenix, Arizona 85036

Subject: 10 CFR 50.55(e) Report on the Palo Verde Reactor Coolant Pumps

Dear Mr. Van Brunt:

Enclosed for your submittal to the Nuclear Regulatory Commission is the 10 CFR 50.55(e) report on the Palo Verde Reactor Coolant Pumps along with the proprietary affidavit. Copies 1 through 25 of the proprietary repport are intended for submittal to the NRC. Copies 26 through 43 are provided for APS use. In addition, thirty-five copies of the non-proprietary version are also enclosed. This report is a final report and is considered complete.

If you have any questions feel free to call.

Very truly yours,

Glenn R. McCoy

C. Ferguson
Project Manager

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CF/TJC:jld
Enclosures
cc: D. B. Amerine w/copy 45
W. G. Bingham w/copy 44
T. R. Bradish
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W. H. Wilson
W. F. Quinn

AFFIDAVIT PURSUANT

TO 10 CFR 2.790

Combustion Engineering, Inc.)
State of Connecticut)
County of Hartford) SS.:

I, A. E. Scherer, depose and say that I am the Director, Nuclear Licensing, of Combustion Engineering, Inc., duly authorized to make this affidavit, and have reviewed or caused to have reviewed the information which is identified as proprietary and referenced in the paragraph immediately below. I am submitting this affidavit in conformance with the provisions of 10 CFR 2.790 of the Commission's regulations and in conjunction with the construction permit of Arizona Public Service Company, for withholding this information.

The information for which proprietary treatment is sought is contained in the following document:

CEN-271(V)-P Rev. 1-P, Final Report on Palo Verde Nuclear Generating Station Unit #1 Reactor Coolant Pumps, August 1984.

This document has been appropriately designated as proprietary.

I have personal knowledge of the criteria and procedures utilized by Combustion Engineering in designating information as a trade secret, privileged or as confidential commercial or financial information.

Pursuant to the provisions of paragraph (b) (4) of Section 2.790 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure, included in the above referenced document, should be withheld.

1. The information sought to be withheld from public disclosure are Reactor Coolant Pump design and experimental test data and analysis from testing, which is owned and has been held in confidence by Combustion Engineering.

2. The information consists of test data or other similar data concerning a process, method or component, the application of which results in a substantial competitive advantage to Combustion Engineering.

3. The information is of a type customarily held in confidence by Combustion Engineering and not customarily disclosed to the public. Combustion Engineering has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The details of the aforementioned system were provided to the Nuclear Regulatory Commission via letter DP-537 from F.M. Stern to Frank Schroeder dated December 2, 1974. This system was applied in determining that the subject document herein are proprietary.

4. The information is being transmitted to the Commission in confidence under the provisions of 10 CFR 2.790 with the understanding that it is to be received in confidence by the Commission.

5. The information, to the best of my knowledge and belief, is not available in public sources, and any disclosure to third parties has been made pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence.

6. Public disclosure of the information is likely to cause substantial harm to the competitive position of Combustion Engineering because:

a. A similar product is manufactured and sold by major pressurized water reactor competitors of Combustion Engineering.

b. Development of this information by C-E required tens of thousands of man-hours of effort and millions of dollars. To the best of my knowledge and belief a competitor would have to undergo similar expense in generating equivalent information.

c. In order to acquire such information, a competitor would also require considerable time and inconvenience related to Reactor Coolant Pump design and detailed test data and analysis.

d. The information required significant effort and expense to obtain the licensing approvals necessary for application of the information. Avoidance of this expense would decrease a competitor's cost in applying the information and marketing the product to which the information is applicable.

e. The information consists of Reactor Coolant Pump design and experimental test data and analysis, the application of which provides a competitive economic advantage. The availability of such information to competitors would enable them to modify their product to better compete with Combustion Engineering, take marketing or other actions to improve their product's position or impair the position of Combustion Engineering's product, and avoid developing similar data and analyses in support of their processes, methods or apparatus.

f. In pricing Combustion Engineering's products and services, significant research, development, engineering, analytical, manufacturing, licensing, quality assurance and other costs and expenses must be included. The ability of Combustion Engineering's competitors to utilize such information

without similar expenditure of resources may enable them to sell at prices reflecting significantly lower costs.

g. Use of the information by competitors in the international marketplace would increase their ability to market nuclear steam supply systems by reducing the costs associated with their technology development. In addition, disclosure would have an adverse economic impact on Combustion Engineering's potential for obtaining or maintaining foreign licensees.

Further the deponent sayeth not.

A. E. Scherer
Director
Nuclear Licensing

Sworn to before me
this 30 day of Aug. 1984

Roger Olsen
~~Notary Public~~
Justice of the Peace