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AUTH.NAME AUTHOR AFFILIATION
CONWAY,W.N. Arizona Public Service Co. (formerly Arizona Nuclear Power
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SUBJECT: Application for amends to Licenses NPF-41,NPF-51 & NPF-74, implementing augmented vibration monitoring program for reactor coolant pumps.

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102-02617-WFC/TRB/JRP
August 23, 1993

WILLIAM F. CONWAY
EXECUTIVE VICE PRESIDENT
NUCLEAR

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Mail Station P1-37
Washington, DC 20555

Dear Sirs:

Subject: **Palo Verde Nuclear Generating Station (PVNGS)**
Units 1, 2, and 3
Docket Nos. STN 50-528/529/530
Proposed Amendment to Operating License
File: 93-056-026; 93-005-419.05

Arizona Public Service Company (APS), is requesting an amendment to the Operating License for PVNGS Units 1, 2, and 3. The proposed amendment would remove the License Condition from Units 1 and 3, and the Confirmatory Order Modifying the License for Unit 2. The License Condition and Confirmatory Order required APS to implement an augmented vibration monitoring program for each of the four reactor coolant pumps in Units 1, 2, and 3.

Provided in the enclosure to this letter are the following:

A. Description of the Proposed Amendment Request
B. Purpose of the License Condition and Confirmatory Order
C. Need for the Operating License Amendment
D. Safety Analysis of the Proposed Operating License Amendment
E. No Significant Hazards Consideration Determination
F. Environmental Impact Consideration Determination

Pursuant to 10 CFR 50.91(b)(1), a copy of this request has been forwarded to the Arizona Radiation Regulatory Agency.

A001

Should you have any questions, please contact Thomas R. Bradish at (602) 393-5421.

Sincerely,

WFC/TRB/JRP/bcf

Enclosure

cc: B. H. Faulkenberry
J. A. Sloan
C. M. Trammell
A. V. Godwin

STATE OF ARIZONA)
) ss.
COUNTY OF MARICOPA)

I, W. F. Conway, represent that I am Executive Vice President - Nuclear, that the foregoing document has been signed by me on behalf of Arizona Public Service Company with full authority to do so, that I have read such document and know its contents, and that to the best of my knowledge and belief, the statements made therein are true and correct.

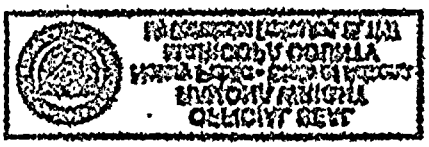
W. F. Conway

Sworn To Before Me This 23 Day Of August, 1993.

Ramona Wright
Notary Public

My Commission Expires

OFFICIAL SEAL
RAMONA WRIGHT
Notary Public - State of Arizona
MARICOPA COUNTY
My Commission Expires Aug. 15, 1997



ENCLOSURE

PROPOSED AMENDMENT TO OPERATING LICENSE

A. DESCRIPTION OF THE PROPOSED AMENDMENT REQUEST

The amendment request would remove License Condition 2.C(13) from the Unit 1 Operating License and License Condition 3 of Attachment 1 to the Unit 3 Operating License. The amendment request would also remove the Confirmatory Order Modifying the Operating License for Unit 2.

The License Condition and Confirmatory Order required Arizona Public Service Company (APS) to implement an augmented vibration monitoring program for each of the four reactor coolant pumps (RCPs) in Units 1, 2, and 3.

B. PURPOSE OF THE LICENSE CONDITION AND CONFIRMATORY ORDER

By letter dated October 8, 1987, APS informed the NRC that European RCPs similar to the PVNGS RCPs in design and manufacture had exhibited shaft cracking. As a result, APS planned to inspect the RCP shafts in Unit 1 during the first refueling outage (October - December, 1987). In subsequent correspondence, APS provided results of the RCP inspections for Units 1 and 2 to the NRC (Unit 3 results were not available at the time of the report). APS also noted that the original RCP shafts would be replaced with new modified shafts during each Unit's first refueling outage.

In response to the October 8, 1987 letter and presentations made by APS during the October 24 and November 4, 1987 meetings held in the NRC offices, the NRC issued a Confirmatory Order Modifying the Unit 2 Operating License. In part, the NRC noted that, "no shaft failures have been experienced at Palo Verde. However, since the root cause of the current cracking phenomenon had not been identified and corrected, the NRC Staff was concerned that the European data, as well as the information obtained from Palo Verde Unit 1, indicated an increased probability of a reactor coolant pump shaft failure, as well as a potential failure mode which could involve the failure of more than one reactor coolant pump shaft. Although the existing reactor protection system would shut the reactor down upon a pump shaft failure, the significantly increased probability of a shaft failure at this time had raised immediate concerns relative to the public health and safety."

The Confirmatory Order Modifying the Unit 2 Operating License required APS to implement an augmented vibration monitoring program for each of the four reactor coolant pumps that included the following elements:

1. Every four hours, monitor and record the vibration data on each of the four reactor coolant pumps.

2. On a daily basis, perform an evaluation of the pump vibration data obtained in 1 above, by using an appropriately qualified engineering individual.

3. When any one vibration monitor on the reactor coolant pumps indicates a vibration level of 8 mils or greater, the NRC shall be notified within four hours via the Emergency Notification System. In addition, when the vibration on any pump exceeds 8 mils due to a shaft crack or unknown cause, within four hours the affected pump shall have its orbit and spectra continuously monitored and evaluated by an appropriately qualified individual.

4. When any one vibration monitor on the reactor coolant pumps indicates a vibration level of 10 mils or greater, within one hour, initiate action to place the unit in at least HOT STANDBY within the next six hours, and at least COLD SHUTDOWN within the following 30 hours. In addition, the affected pump shall be secured after entering HOT STANDBY.

5. On a daily basis, a spectrum analysis shall be performed on the reactor coolant pump shaft vibration data and shall be evaluated for trends by using an individual qualified in that technique. The evaluation shall consist of comparing the running speed (1 x RPM) and twice running speed (2 x RPM) spectral components to limits computed from the baseline vibration. The limits shall be based on the lowest of: (a) 1.6 times the baseline value, (b) the mean plus three standard deviations, (c) 2 mils for the 2 x RPM components, or (d) 6 mils for the 1 x RPM component. When the amplitude exceeds any limits, further analysis shall be performed. This analysis shall consist of an inspection of the amplitude versus time plots for a steadily increasing trend, and a review of other plant data which might explain the change in amplitude. If it is confirmed that the trend is not caused by plant or pump conditions unrelated to a shaft crack, the trend shall be extrapolated manually and/or by computer to predict the time at which the vibration is expected to reach 10 mils. If the projected time for reaching 10 mils is one week or less, within one hour, initiate action to place the unit in at least HOT STANDBY within the next six hours, and at least COLD SHUTDOWN within the following 30 hours. In addition, the affected pump shall be secured after entering HOT STANDBY.

The NRC also noted in the Confirmatory Order to Modify the Unit 2 Operating License that APS had committed to further augment the RCP monitoring program by including a special analysis of the data and to install modified shafts with the chrome plating removed during the next refueling outage scheduled to start in February 1988.

As a final note, the NRC stated that, "The Regional Administrator, Region V, may relax or rescind, in writing, any of the above conditions upon a showing by the licensees of good cause."

The Unit 3 License Condition was incorporated into the full power license issued on November 25, 1987, and the Unit 1 License Condition was incorporated into the license by Amendment 32, dated May 10, 1988.

C. NEED FOR THE OPERATING LICENSE AMENDMENT

To comply with the requirements of the Confirmatory Order and License Condition, APS dedicated several individuals to monitor and record the vibration data on each of the four RCPs, every four hours. Also, a qualified engineering individual was assigned to perform an evaluation of the RCP vibration data on a daily basis. Since November 19, 1987, APS has dedicated thousands of man hours monitoring and recording RCP vibration data and performing a daily spectrum analysis, which is a manpower intensive task.

APS has since installed an RCP orbital monitoring system to monitor and record the data. The component chosen was a Bently-Nevada "Dynamic Data Manager" which was installed in each unit. This system monitors the critical vibration-related parameters, such as overall vibration, synchronous 1xRPM and 2xRPM amplitude, and phase angle for deviation from a vector acceptance region. APS will continue to monitor RCP vibration data through the use of the installed system.

The requirement to shutdown a unit on a low amplitude vibration trend which cannot be identified as an indication of a cracked shaft puts the unit at risk of being shutdown for reasons other than a cracked shaft. Also, because low amplitude symptoms of shaft cracks are similar to other non-significant pump conditions, the unit is at risk of being shutdown for an unnecessary reason.

D. SAFETY ANALYSIS OF THE OPERATING LICENSE AMENDMENT

General Discussion

The PVNGS RCPs are supplied by CE-KSB. The design of the pumps and shafts are provided under license agreement with Klein, Schanzlin & Becker (KSB) AG of Germany. The RCPs are vertical shaft, single stage, diffuser-type centrifugal pumps utilizing a single suction and radial discharge. The shaft assembly consists of a lower shaft rigidly coupled to an upper drive shaft. The shaft assembly is supported by a water lubricated hydrodynamic journal bearing.

The original pump shafts that experienced cracking were manufactured to German DIN Standard 1.4313 (nearest US equivalent is ASTM A-182 Grade F6NM), a martensitic steel. The shafts were chrome plated (0.15 mm) over the entire length to facilitate assembly/disassembly of the impeller from the shaft. It has been found from laboratory tests that the presence of chrome plating significantly reduced the fatigue strength of the shaft material.

APS has replaced all of the original shafts with either spare modified shafts or newly manufactured shafts.

The replacement shafts in Unit 1 are spare shafts modified to address the cause of the cracking. The modified shafts are of the same design and material as the original shafts except for the following changes:

- The chrome plating has been removed from the shaft in the keyway area except where needed for assembling the impeller on the shaft. The remaining chrome plating areas are in lower stress areas where cracks have not been found at PVNGS. Since installation of the replacement shafts in Unit 1, no cracks have been detected by ultrasonic examination (UT). However, APS has been informed by CE that cracks in areas where the chrome plating has been removed have been found in similar modified shafts in Europe. The cracks were discovered using centerbore UT and verified after removal by MT. A small (i.e., shallow) indication around the top of the (chrome intact) impeller fit region on one RCP shaft at the Grafenreinfeld station was discovered during a 1989 inspection. Small indications in the (chrome intact) impeller fit areas in one shaft and small indications found in chrome intact region next to the keyway on two other RCP shafts at the Mulheim-Karlich station were discovered during a 1989 inspection. A larger crack (no dimension given) was discovered in a chrome-free impeller fit area at the Goesgen station in 1991.

- An extended shaft stop seal is installed and the impeller hub is modified to provide a thermal barrier to the shaft keyway area.

- All chamfers at step changes in the diameter of the shaft are radiused to reduce stress concentration at these areas.

The replacement shafts installed in Units 2 and 3 are newly manufactured shafts of essentially the same design as the Unit 1 replacement shafts with the following additional enhancements:

- The shafts are surface rolled to induce a residual compressive stress on the surface of the shafts to increase the endurance fatigue strength of the shafts.

- The shafts are coated with chromium carbide instead of chrome plating. Chromium carbide coating has been found to have much less impact on the shaft material's fatigue strength than chrome plating.

Since replacement of the original RCP shafts in the three units, no cracks have been detected by UT examination during each of the units past refueling outages. The replacement shafts were provided with a 25mm diameter center bore. The center bore allows the UT probe to inspect nearly the entire length of the shaft, eliminating the problems resulting from long sonic paths, lower sensitivity and resolution, and multiple signals associated with performing UT examinations from the end of the

shafts. Experience in Europe using center bore UT examination techniques indicates that cracks equivalent to 0.1mm deep notch can be reliably detected.

In addition to the original RCP shafts being replaced, APS also installed a new RCP vibration monitoring system to monitor critical vibration-related parameters. The RCP's are continuously monitored by an analog vibration monitoring system with two proximity probes mounted just above the seal housing, and one accelerometer mounted on the motor base plate. The analog monitors have two set points for each channel which sound an alarm and flash an alarm window in the control room.

In addition to the analog alarm, a computer system is installed which, approximately twice per minute, analyzes the vibration from the proximity probes for the amplitude and phase of the 1xRPM and 2xRPM components. These vector components are compared to an acceptance region, and if they are outside the region, the computer sounds the alarm in the control room. The computer also monitors the condition of the analog monitor every three seconds, and provides status reports, alarm logs, and 21 days of trend data for the overall vibration, 1xRPM and 2xRPM amplitude and phase, and gap voltage.

Safety Analysis

The RCP shaft break event with a concurrent loss of offsite power has been previously evaluated in the Updated Final Safety Analysis Report (UFSAR) subsection 15.3.4, and is discussed in Section E of this amendment request.

To evaluate the potential for multiple shaft failures, an analysis was performed on the effect of a single pump shaft failure upon the remaining three pump's shafts. One pump failure causes one of the other three pumps to run out on its hydraulic curve to approximately 1.25 times normal flow. KSB test results show that torque loads and alternating bending loads on the shaft will decrease due to the reduction in head as run out is reached. Therefore, torsional stresses which cause final shaft failure will be reduced under this condition. After the shaft failure, the rate of propagation for the remaining 3 shafts will be reduced due to the reduction in bending stresses. The shafts will not reach the approximately 90% crack size in which torsional loads will produce the final severance, since the unit will be shut down promptly upon failure of the first shaft.

An evaluation was performed to determine the mechanical reaction of an RCP to a severed shaft and the resultant impact on the reactor coolant system (RCS) pressure boundary. The evaluation concluded that a severed shaft would not result in a breach in the RCS pressure boundary at either the pump casting, shaft seals, or RCS piping.

Because of the small design clearances between the impeller lower end shroud and the suction pipe wear surface, the impeller would be restrained and not penetrate the

RCS pressure boundary. Since the impeller would be restrained, the diffuser would remain in place and not experience significant damage. Actual sheared shaft events at Gosgen and Grafenrheinfeld have not resulted in impeller or diffuser damage.

The area of the shaft where the two failures and the cracking problems have occurred on KSB shafts is below the hydrodynamic journal bearing. Thus, a severed shaft is radially restrained by the thrust bearing, and no damage to the shaft seals would occur. The shaft failure at Gosgen and Grafenrheinfeld facilities resulted in no damage to the seals.

Based on the above evaluation, it is concluded that a single sheared shaft would result in an uncomplicated shutdown with no fuel failure, that multiple shaft failures would not occur, and there would be no break in the RCS pressure boundary.

E. NO SIGNIFICANT HAZARDS CONSIDERATION DETERMINATION

The Commission has provided standards for determining whether a no significant hazards consideration exists as stated in 10 CFR 50.92. A proposed amendment to an operating license for a facility involves a no significant hazards consideration if operation of the facility in accordance with a proposed amendment would not: 1) Involve a significant increase in the probability or consequences of an accident previously evaluated; or 2) Create the possibility of a new or different kind of accident from any accident previously evaluated; or 3) Involve a significant reduction in a margin of safety. A discussion of these standards as they relate to the amendment request follows:

Standard 1 -- Involve a significant increase in the probability or consequences of an accident previously evaluated.

In the unlikely event of an RCP shaft developing a crack and propagating undetected until failure, the results would not involve a significant increase in the probability or consequences of an accident previously evaluated. The RCP shaft break event with a concurrent loss of offsite power has been previously evaluated in UFSAR subsection 15.3.4 with acceptable results. The sequence of events and system operations is similar to that for the RCP rotor seizure event, subsection 15.3.3. The difference is that for the shaft break event, the reactor is tripped on differential pressure across either steam generator, whereas for the pump rotor seizure event, the reactor is tripped by the Core Protection Calculator (CPC) on a low RCP shaft speed condition.

The flow coastdown for a rotor seizure event is faster than the coastdown for a shaft break event. For a shaft break, the rotor is still capable of rotating, thereby offering less resistance to flow during the rapid flow decrease. This results in a less severe coastdown for the shaft break event than for the rotor seizure event. The shaft break

trip time is 1.2 seconds; the rotor seizure trip time is 0.865 seconds. Despite the later trip time, the slower shaft break coastdown results in a higher minimum DNBR and less fuel failure for shaft break than for rotor seizure.

For both rotor seizure and shaft break, three seconds after turbine trip a loss of offsite power (LOP) was assumed. Both rotor seizure and shaft break reach the same three pump asymptotic flow before their respective LOPs and do not result in decreasing DNBR after LOP. The rotor seizure plus LOP minimum transient DNBR (0.808) is lower and fuel failure higher than those for the shaft break plus LOP.

Therefore, the amendment to remove the License Condition from Units 1 and 3, and the Confirmatory Order Modifying the License for Unit 2 would not involve a significant increase in the probability or consequences of an accident previously evaluated.

Standard 2 -- Create the possibility of a new or different kind of accident from any accident previously evaluated.

This amendment request does not involve any changes in equipment and will not alter the manner in which the plant will be operated. For this reason, this amendment will not create the possibility of a new or different kind of accident from any previously evaluated.

Standard 3 -- Involve a significant reduction in a margin of safety.

The margin of safety is not reduced. There are no changes to the equipment or plant operations. The analysis of effects and consequences of a shaft break is similar to that for the RCP rotor seizure event, UFSAR subsection 15.3.3. The shaft break coastdown is slower and the trip is later than those of the rotor seizure event. The shaft break plus LOP event produces a higher minimum DNBR and less radiological release than the rotor seizure plus LOP event.

The radiological consequences due to steam release from the secondary system would be less than the consequences of the rotor seizure event. Thus, the two hour thyroid inhalation dose for the shaft break with LOP is bounded by the rotor seizure event in subsection 15.3.3.3.1, item C. The offsite doses for the rotor seizure event result from steam released through the ADVs. The resultant radiological consequences are a 2-hour site boundary thyroid dose of less than 240 Rem. This is within the 10 CFR 100 limits of 300 Rem.

The conclusion from the shaft break event is that this event would be no more adverse than the rotor seizure event. For both events, the total number of fuel pins calculated in DNB, which are conservatively assumed to fail, is no more than 4.5%. The conclusions of the accident analyses in the UFSAR remain valid and the safety limits continue to be met. Therefore, the amendment request to remove the License

Condition on Units 1 and 3 and the Confirmatory Order Modifying the License for Unit 2 will not involve a significant reduction in a margin of safety.

F. ENVIRONMENTAL IMPACT CONSIDERATION DETERMINATION

APS has determined that the proposed amendment involves no change in the amount or type of any effluent that may be released offsite, and that there is no increase in individual or cumulative occupational radiation exposure. As such, operation of PVNGS Units 1, 2, and 3, in accordance with the proposed amendment, does not involve an environmental impact.