10 CFR 50.73

APS

A subsidiary of Pinnacle West Capital Corporation

Palo Verde Nuclear Generating Station

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102-05498-CE/SAB/JAP/REB
May 22, 2006

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Dear Sirs:

Subject: Palo Verde Nuclear Generating Station (PVNGS)
Unit 1
Docket No. STN 50-528
License No. NPF 41
Licensee Event Report 2005-009-00

Attached please find Licensee Event Report (LER) 50-528/2005-009-00 prepared and submitted pursuant to 10 CFR 50.73. The LER reports a technical specification violation for reactor coolant system loops being inoperable.

In accordance with 10 CFR 50.73(d), copies of this LER are being forwarded to the NRC Regional Office, NRC Region IV and the PVNGS Senior Resident Inspector. If you have questions regarding this submittal, please contact James A. Proctor, Section Leader, Regulatory Affairs, at (623) 393-5730.

Arizona Public Service Company makes no commitments in this letter.

Sincerely,

CE/SAB/JAP/REB/gt

Attachment

cc:	B. S. Mallett	NRC Region IV Regional Administrator
	M. B. Fields	NRC NRR Project Manager - (send electronic and paper)
	G. G. Warnick	NRC Senior Resident Inspector for PVNGS

IE22

NRC FORM 366 (6-2004) | U.S. NUCLEAR REGULATORY COMMISSION

LICENSEE EVENT REPORT (LER)

(See reverse for required number of digits/characters for each block)

1. FACILITY NAME	2. DOCKET NUMBER	3. PAGE
Palo Verde Nuclear Generating Station Unit 1	05000528	1 OF 11

4. TITLE
Technical Specification Violation For Operation Without Both Reactor Coolant System Loops Operable

5. EVENT DATE			6. LER NUMBER			7. REPORT DATE			8. OTHER FACILITIES INVOLVED	
MONTH	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REV NO.	MONTH	DAY	YEAR	FACILITY NAME: None	DOCKET NUMBER: 05000
12	21	2005	2005	- 009 -	00	05	22	2006	FACILITY NAME: None	DOCKET NUMBER: 05000

9. OPERATING MODE: 3

10. POWER LEVEL: 000

11. THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR§: *(Check all that apply)*

☐ 20.2201(b)	☐ 20.2203(a)(3)(i)	☐ 50.73(a)(2)(i)(C)	☐ 50.73(a)(2)(vii)
☐ 20.2201(d)	☐ 20.2203(a)(3)(ii)	☐ 50.73(a)(2)(ii)(A)	☐ 50.73(a)(2)(viii)(A)
☐ 20.2203(a)(1)	☐ 20.2203(a)(4)	☐ 50.73(a)(2)(ii)(B)	☐ 50.73(a)(2)(viii)(B)
☐ 20.2203(a)(2)(i)	☐ 50.36(c)(1)(i)(A)	☐ 50.73(a)(2)(iii)	☐ 50.73(a)(2)(ix)(A)
☐ 20.2203(a)(2)(ii)	☐ 50.36(c)(1)(ii)(A)	☐ 50.73(a)(2)(iv)(A)	☐ 50.73(a)(2)(x)
☐ 20.2203(a)(2)(iii)	☐ 50.36(c)(2)	☐ 50.73(a)(2)(v)(A)	☐ 73.71(a)(4)
☐ 20.2203(a)(2)(iv)	☐ 50.46(a)(3)(ii)	☐ 50.73(a)(2)(v)(B)	☐ 73.71(a)(5)
☐ 20.2203(a)(2)(v)	☐ 50.73(a)(2)(i)(A)	☐ 50.73(a)(2)(v)(C)	☐ OTHER
☐ 20.2203(a)(2)(vi)	☒ 50.73(a)(2)(i)(B)	☐ 50.73(a)(2)(v)(D)	Specify in Abstract below or in NRC Form 366A

12. LICENSEE CONTACT FOR THIS LER

FACILITY NAME	TELEPHONE NUMBER (Include Area Code)
James A. Proctor, Section Leader, Regulatory Affairs - Compliance	623 393 5730

13. COMPLETE ONE LINE FOR EACH COMPONENT FAILURE DESCRIBED IN THIS REPORT

CAUSE	SYSTEM	COMPONENT	MANU-FACTURER	REPORTABLE TO EPIX	CAUSE	SYSTEM	COMPONENT	MANU-FACTURER	REPORTABLE TO EPIX

14. SUPPLEMENTAL REPORT EXPECTED		15. EXPECTED SUBMISSION DATE	MONTH	DAY	YEAR
☐ YES *(If yes, complete 15. EXPECTED SUBMISSION DATE)*	☒ NO				

ABSTRACT *(Limit to 1400 spaces, i.e., approximately 15 single-spaced typewritten lines)*

On March 18, 2006 vibration testing was being performed in Unit 1 to obtain data to correct an issue with vibration of the shutdown cooling train A suction line. The test data unexpectedly indicated that stopping one reactor coolant pump (RCP) in loop 2 with all four RCPs operating resulted in vibration levels at the shutdown cooling suction valve, 1JSIAUV0651, which exceeded the design vibration limit.

The apparent cause of the vibration is a latent design deficiency which allowed the shutdown cooling suction line to form an acoustic resonator that produced the high vibration. Corrective action includes relocating valve SI 651 to alter the fundamental frequency of the acoustic resonator.

There have been no previous similar reports made by Palo Verde Nuclear Generating Station in the last three years.

17. NARRATIVE *(If more space is required, use additional copies of NRC Form 366A)*

Note: All times in this report are approximate and Mountain Standard Time unless otherwise noted.

1. REPORTING REQUIREMENT(S):

This LER (50-528/2005-009-00) is being submitted pursuant to 10 CFR 50.73(a)(2)(i)(B), to report an event where technical specifications LCO 3.4.4, Reactor Coolant System (RCS) Loops-Modes 1 and 2 and LCO 3.4.5, RCS Loops-Mode 3 were not met and the required actions were not complied with. Specifically, during periods of operation with all four reactor coolant pumps (RCP)(EIIS: AB) in service, from December 20, 2005 to March 18, 2006 the RCS did not comply with General Design Criterion 15. During this time period there was not sufficient design margin to ensure that design conditions of the RCS would not be exceeded if a Loop 2 RCP should trip or experience a sheared shaft event with all four RCPs initially in operation.

In addition, violations of LCO 3.0.4, entry into a mode or specified condition with an LCO not met, occurred four times when Mode 2 and Mode 1 entries were made with all four RCPs in operation. These occurred on December 21, 2005 (Mode 2 entry), December 22, 2005 (Mode 1 entry), and January 20, 2006 (Modes 2 and 1 entry following a unit shutdown).

2. DESCRIPTION OF STRUCTURE(S), SYSTEM(S) AND COMPONENT(S):

The primary function of the RCS is to remove heat generated in the nuclear fuel due to the fission process and to transfer the heat, via the steam generators (SG)(EIIS: AB), to the secondary plant. The RCS configuration for heat transport uses two RCS loops. Each RCS loop contains a SG and two RCPs. Flow exits the reactor vessel (EIIS: AB) and is transported to the steam generators through respective hot-legs. Flow is discharged from the steam generators and is circulated back to the reactor vessel through the respective RCPs and associated cold-legs. RCP flow rate has been sized

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to provide the required core heat removal with appropriate margin to Departure from Nucleate Boiling (DNB) during power operation and for anticipated transients originating from power operation.

During shutdown conditions, the reactor coolant is cooled by one of two independent trains of Shutdown Cooling (SDC)(EIIS: BP). Suction is taken on the RCS through a nozzle at the bottom of each of the respective RCS hot-legs. The train 'A' SDC system is isolated from the RCS during power operation by closing the reactor coolant pressure boundary (RCPB) valves (EIIS: ISV) 1JSIAUV0651 (referred to as SI 651) and 1JSIAUV0653. Similarly, the train 'B' SDC system is isolated from the RCS by closing the associated train 'B' RCPB valves 1JSIBUV0652 and 1JSIBUV0654. The SDC suction line RCPB valves are Borg Warner high pressure stainless steel gate valves equipped with Limitorque type SMB-3 (651 and 652) or SMB-1 (653 and 654) valve actuators. The valves are normally operated remotely by handswitch from the control room when either of the respective trains of SDC are placed into or removed from service.

3. INITIAL PLANT CONDITIONS:

At the time of discovery (when the decision was made that a license amendment would be required for four RCP operation), March 23, 2006, Unit 1 was in Mode 3, Hot Standby, at normal operating temperature and pressure. Both RCPs in RCS loop 2 (2A and 2B) were in operation and one RCP in RCS loop 1 (1A) was in operation.

4. EVENT DESCRIPTION:

Higher than normal vibration levels were first observed on Unit 1, train 'A' SDC line in cycle 9 (U1C9) which began in November 1999. Vibration levels measured at the reference location 'V1H' (located on valve SI 651 actuator yoke clamp) during full power operation remained below the administrative limit of 2.0 inches per second (ips) through

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the end of U1C12 (October, 2005). The administrative limit of 2.0 ips provides margin for measurement uncertainty to ensure that the design limit of 2.25 ips is not exceeded. The design limit is based on limiting the vibration acceleration at the SDC train 'A' isolation valve SI 651 actuator at or below 1.25g for continuous operation.

Following Unit 1 Refueling 12 (U1 R12 October – December 2005), in which the Unit 1 steam generators were replaced, during power ascension for Unit 1 Cycle 13 (U1C13 December, 2005), the vibration amplitude at V1H increased significantly relative to the previous cycles. Power ascension was terminated at approximately 32% rated thermal power (RTP) at which point the vibration amplitude reached the administrative limit of 2.0 ips. Unit 1 operated at approximately 32% RTP until the plant was shutdown in January, 2006. Vibration amplitude again increased following restart of the unit which subsequently limited power to approximately 25% RTP. Unit 1 has since been shut down and defueled in preparation for installation of a modification to eliminate the vibration condition.

On March 18, 2006, Unit 1 was shutdown in order to collect data to support evaluation of the vibration condition on the train 'A' SDC suction line. With the unit in Mode 3 (Hot Standby) at normal operating pressure and temperature (NOP/NOT) with all four RCPs operating, the data collection program provided instruction to shut down RCP 2A in order to assess the impact of increased Loop 1 hot-leg flow rate on train 'A' SDC line vibration at VH1. The RCS Loop 1 hot-leg flow rate increased when RCP 2A was secured (increase not measured but estimated by calculation). The flow increase was due to increased hydraulic losses in the RCS Loop 2 side resulting from reverse flow in the cold leg of the secured RCS Loop 2 RCP. Immediately after RCP 2A was secured, the train 'A' SDC suction line vibration at VH1 increased from approximately 1.3 ips to an observed average amplitude of approximately 2.8 ips, with an instantaneous maximum observed amplitude of 3.05 ips. These vibration levels occurred for

approximately one minute. Unit 1 operators, in accordance with approved procedures, restarted RCP 2A after which the vibration amplitude dropped to approximately 1.3 ips.

In order to prevent a recurrence of this scenario, an RCS loop 1 RCP (RCP 1B) was secured. Securing either Loop 1 RCP ensures that, in the event of a concurrent failure of either of the Loop 2 RCPs, the Loop 1 hot-leg flow rates will be less than nominal flow rates at NOP/NOT, thereby precluding the vibration excursion recorded during testing. Simultaneous operation of both Loop 1 RCPs (RCP 1A and 1B) has been administratively restricted until corrective action is taken to reduce the vibration.

On March 23, 2006, licensee personnel concluded that, in order to complete the vibration testing program in Unit 1 in support of the root cause evaluation for the vibration, a license amendment was required to allow the use of manual operator action as a compensatory measure to prevent exceeding the train A SDC system line vibration limit if a Loop 2 RCP should trip or experience a sheared shaft during four-RCP operation.

On March 31, 2006 Arizona Public Service (APS) requested a PVNGS Unit 1 facility operating license amendment under exigent circumstances to change the Updated Final Safety Analysis Report (UFSAR), Section 3.1.11, "Criterion 15 – Reactor Coolant System Design." The UFSAR change would allow the use of an operator action as a compensatory measure to prevent exceeding the train A SDC system vibration operability limit if a loop 2 RCP should trip or have a sheared shaft during four-RCP operation. This compensatory measure could only be used during a one-time 12 hour period to complete the SDC system vibration root cause data collection in Mode 3. The Nuclear Regulatory Commission issued the amendment on April 6, 2006.

5. ASSESSMENT OF SAFETY CONSEQUENCES:

The assessment is addressed in two parts. First, the actual consequences are addressed then the potential safety consequences are addressed.

ACTUAL SAFETY CONSEQUENCES

From December 20, 2005 to March 18, 2006 there were two occurrences of operation with both Loop 1 RCPs (1A and 1B) in operation and only one Loop 2 RCP (2A or 2B) operating. Neither of these occurrences (discussed below) resulted in a degraded condition.

On March 18, 2006, Unit 1 was in Mode 3 at NOP/NOT to collect data for the root cause evaluation and to validate a proposed modification to reduce the SDC line vibration. With four RCPs operating, RCP 2A was stopped at which time the vibration amplitude on the SDC suction line increased from approximately 1.3 ips to an observed average amplitude of approximately 2.8 ips, with an instantaneous maximum observed amplitude of 3.05 ips. These vibration levels occurred for approximately one minute. RCP 2A was subsequently restarted and the vibration amplitude dropped to approximately 1.3 ips.

Subsequent engineering inspections of the RCS and SDC piping from the hot leg to the containment penetration and the valve actuator limit switch compartment components for SI 651 did not identify any degraded conditions. Engineering personnel also evaluated the piping stresses and vibration levels for the RCS/SDC piping and valve actuator for SI 651 and concluded the components were not degraded as a result of the high vibration.

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A review of plant start-up data was performed to determine if the plant had been previously exposed to the higher vibration levels on the SDC suction line. This review identified that on December 19, 2005 from 13:03 until 14:11, RCPs 1A, 1B, and 2A were in operation with valve SI 651 closed. During this time interval hot-leg temperature was approximately 300 degrees F. As a result of the large fluid density differences between 300 degrees F and NOP/NOT (565 F), Loop 1 RCS hot-leg flow rate on December 19, 2005 was less than that which resulted during testing on March 18, 2006 when RCP 2A was stopped. Vibration levels during the December start-up were not recorded. However, given that the flow velocity in the Loop 1 hot leg would be lower at lower RCS temperatures, the vibration levels would not have been as high as those recorded during the performance of data collection activities of March 18, 2006 noted above. In addition, the vibration levels of March 18, 2006 were visually and audibly identified by personnel in the containment building. However, during the Unit 1 plant start-up on December 19, 2005, numerous individuals were present in containment and no identification of high vibration was reported.

PVNGS Calculation 01-MC-SI-509 was completed and the results determined that vibration induced piping stress and the resulting fatigue remain within acceptable levels for long term operation (infinite cycles) with vibration levels of approximately 3.0 ips. In addition, the SI 651 valve actuator was evaluated by engineering personnel relative to the actual measured vibration duration and amplitude. This evaluation determined that the short duration high vibration measured during the March 18, 2006 test was acceptable. This evaluation also concluded that the actuator would have remained operable at a vibration level of 5.27 ips for 10 minutes including peak vibration as high as 6.0 ips for three minutes.

Therefore, there was no actual safety consequence as a result of the condition.

POTENTIAL SAFETY CONSEQUENCES

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Unit 1 operated with all four RCPs in operation from December 20, 2005 to March 18, 2006. Had one Loop 2 RCP (2A or 2B) tripped (or experienced a sheared shaft) the vibration levels for the RCS piping and SDC valve SI 651 may have exceed the design limits.

As noted above, engineering evaluation of the associated piping stresses at amplitudes above the design limit of 2.25 ips concluded that the piping and components could endure an infinite number of cycles at vibration levels of up to approximately 3.0 ips. Instantaneous vibration measurements during the March 18, 2006 testing program with RCP 2A secured ranged from approximately 2.5 ips to 3.05 ips. A reasonable estimated average during this event is 2.8 ips based on the instantaneous values indicated by the vibration technician at SI 651. However, the uncertainty associated with the instantaneous vibration measurements taken during the test is larger than that associated with the typical process sampling and spectral analysis algorithm used to collect the average vibration amplitude at V1H. A true time averaged vibration amplitude can not be precisely determined. Therefore, it is conservatively postulated that sustained vibration amplitudes equal to or slightly greater than 3.0 ips may have been possible from December, 2005 through March, 2006 in the event that either RCP 2A or 2B failed during the time period in question.

Until the March 18 data collection activity identified the potential for higher vibration resulting from the loss of either Loop 2 RCPs, operations procedures did not provide guidance to trip one of the Loop 1 RCPs to reduce the vibration to within acceptable limits. Therefore, had a Loop 2 RCP tripped or experienced a sheared shaft event, the time at elevated vibration levels could have been protracted. However, the Engineering pipe stress and fatigue analysis has shown that the RCS piping and associated components and supports could withstand vibration levels of 5.0 ips for approximately 31 minutes and 6.0 ips for 12 minutes. Consequently, vibration levels at or slightly

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above 3.0 ips would have provided operators time (i.e. hours) to identify the condition and take corrective action. As a result, the integrity of the RCPB would not have been jeopardized. It should be noted that the loss of any RCP, including a sheared shaft event, results in an automatic reactor trip placing the unit in Mode 3.

As described above, Engineering also evaluated the impact of high vibration on the valve actuator for SI 651. This evaluation concluded that the actuator could have withstood vibration levels of 5.27 ips for 10 minutes including peak vibration as high as 6.0 ips for three minutes at a frequency range of 24 to 25 Hz and been able to function. Even if the integrity of the SI 651 actuator would have been challenged leading to electrical failure of the actuator, the valve would have been able to be opened manually at the hand-wheel.

A review of vibration data collected during cycles U1C9 through U1C12 was also completed to determine if this same condition would have resulted in vibration levels in excess of the design limit. In U1C12 and before, the vibration amplitude at full power operation was less than 2.0 ips. In the event that a Loop 2 RCP motor failed or a sheared shaft occurred, the unit would have tripped. Within a very short period of time, the RCS temperature would be reduced to approximately 565 degrees F (Mode 3). The density change associated with this change in RCS temperature results in an approximate 9% reduction in the Loop 1 hot-leg volumetric flow rate. During normal shut-down this results in a reduction in vibration amplitude to less than 0.3 ips. The combined effect of the loss of a Loop 2 RCP and the fluid density change is a net reduction in Loop 1 flow rate. Consequently, it can be concluded that long duration vibration levels would have been no greater than those measured during full power operation with adequate margin relative to the stress and fatigue limits on the RCS piping and associated components.

There were no other systems or components that were inoperable during this condition that contributed to the condition. The condition would not have prevented the fulfillment of any safety function and did not result in a safety system functional failure as defined by 10CFR50.73(a)(2)(v).

6. CAUSE OF THE EVENT:

The investigation into the cause of the high vibration is ongoing. Evidence collected during the investigation indicates that the direct cause of the condition is flow induced vibration caused by coupling between an excitation source and the fundamental acoustic mode of the isolated SDC suction line. The excitation source is the pressure disturbance produced by RCS flow past the nozzle joining the SDC suction line to the RCS hot leg. The SDC suction line is open to the RCS hot leg and effectively forms a deep "organ pipe" resonator bounded by the normally closed SDC isolation valve (SI 651) located more than 54 feet from the nozzle.

The root cause of the condition is believed to be a latent design deficiency in that the configuration of the train A SDC suction line creates a resonator with a fundamental frequency close to the pressure disturbance frequency caused by RCS flow past the SDC nozzle. The deficiency became self revealing when the RCS hot leg flow profile changed sufficiently to allow coupling between the pressure disturbance produced by RCS flow past the SDC nozzle and SDC suction line. The amplification of the pressure is dependent on the flow velocity in the region of the RCS hot leg nearest the SDC suction line nozzle. In this situation, subtle changes in the hot leg flow profile are sufficient to intensify coupling between the source and resonator with a resultant "lock in" of flow induced vibration. Flow conditions in Units 2 and 3 are different and, hence, the vibration amplitude is different. The vibration levels in Units 2 and 3 are an order of magnitude lower with levels in the 0.2 to 0.3 ips range at full power. However, the

existence of this predominant vibration frequency in Units 2 and 3 suggests that the latent design defect also exists in the train 'A' SDC suction line in these two units.

The train B SDC suction lines in all three units are unaffected because the associated suction isolation valve is located closer to the hot leg effecting a higher fundamental acoustic frequency.

If substantial information is identified in the completed investigation report that significantly changes the description, consequences, or cause of the condition as described in this LER, then an LER supplement will be submitted.

7. CORRECTIVE ACTIONS:

A modification of the Unit 1 Train A SDC suction line piping and relocation of valve SI 651 is in progress to change the fundamental frequency of the acoustic resonator formed by the SDC suction line. Design validation testing and vibration monitoring during restart and for the balance of U1C13 will evaluate the effectiveness of this modification. This modification will be completed prior to Unit 1 returning to operation.

Actions for Units 2 and 3 are under evaluation.

If the completed investigation report has substantial changes in the corrective actions for the condition, then an LER supplement will be submitted.

8. PREVIOUS SIMILAR EVENTS:

There has been no similar event reported to the NRC by APS in the last three years.