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SUBJECT: LEAKING PULSATION DAMPENER LEADS TO LOSS OF CHARGING SYSTEM

The report describes three events of a loss of charging pump suction at Palo Verde due to the failure of the gas-filled pulsation dampener or the suction stabilizer on a positive displacement charging pump. The charging system at Palo Verde is not safety-related and subsequent investigation indicated that the only safety-related system that could be affected by a similar failure of the pulsation dampener is at San Onofre 2 and 3. Accordingly, it is suggested that NRR be informed of this finding by a separate memorandum. Failures of the suction stabilizer, as occurred in one of the events at Palo Verde, have previously been identified and documented by other studies and no new recommendations or suggestions are appropriate at this time.

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AEOD TECHNICAL REVIEW REPORT*

UNITS: Palo Verde Units 1 & 2
DOCKET NOS.: 528 and 529
LICENSEE: Arizona Public Service

TR REPORT NO. AEOD/T
DATE:
EVALUATOR/CONTACT: T. C. Cintula

SUBJECT: LEAKING PULSATION DAMPENER LEADS TO LOSS OF CHARGING SYSTEM

EVENT DATES: February 18, July 12, and July 18, 1986

SUMMARY

Three events of a loss of charging pump suction at Palo Verde are described. The positive displacement pumps lost suction when their gas-filled pulsation dampener or gas-filled suction-stabilizer leaked. In two events, the failed pulsation dampener led to all three positive displacement pumps becoming gas bound through their common suction header. The positive displacement pumps at Palo Verde are not safety-related. Subsequent investigation concluded that a postulated similar failure of the pulsation dampener would not affect the safety-related charging pumps at Westinghouse plants, but could impair the safety-related charging pumps at San Onofre 2 and 3 (the only Combustion Engineering plants with a safety-related charging system). NRR has been alerted of this finding by separate memorandum. Similar failures of the suction stabilizers have been investigated and documented by previous reports and no additional recommendations were identified by this study.

DISCUSSION

In three events at the Palo Verde Nuclear Generating Station the charging pumps became filled with gas and failed to operate. The source of gas was traced to a failure of a bladder in either the pulsation dampener (also referred to as a pulsation damper) or the suction stabilizer. The details of each event follow.

1. Palo Verde Unit 1 on February 18, 1986

The unit was at 100% power during a routine dilution of the reactor coolant system (RCS). All three positive displacement charging pumps (PDPs A, B, and E) were running and PDPs A and E were being used for a dilution evolution. The B PDP was being operated for a post-maintenance packing run-in, prior to being placed into normal operation. Their common pump suction header was being supplied by the makeup water section of the chemical and volume control system (CVCS).

At the start of the RCS dilution, the VCT isolated as designed when its outlet check valve (CH-V118) seated from the higher pressure of the makeup water section. When the RCS dilution was completed, and the makeup water source was secured, it should have resulted in the VCT automatically supplying charging pump suction through the reopening of the VCT outlet check valve (see Figure 1). However, the licensed operators immediately noted a decrease in charging pump flow. At this time, the charging pump header flowmeter indicated 17 gpm for a condition that should have provided a header flow of approximately 132 gpm

*This document supports ongoing AEOD and NRC activities and does not represent the position or requirements of the responsible NRC program office.

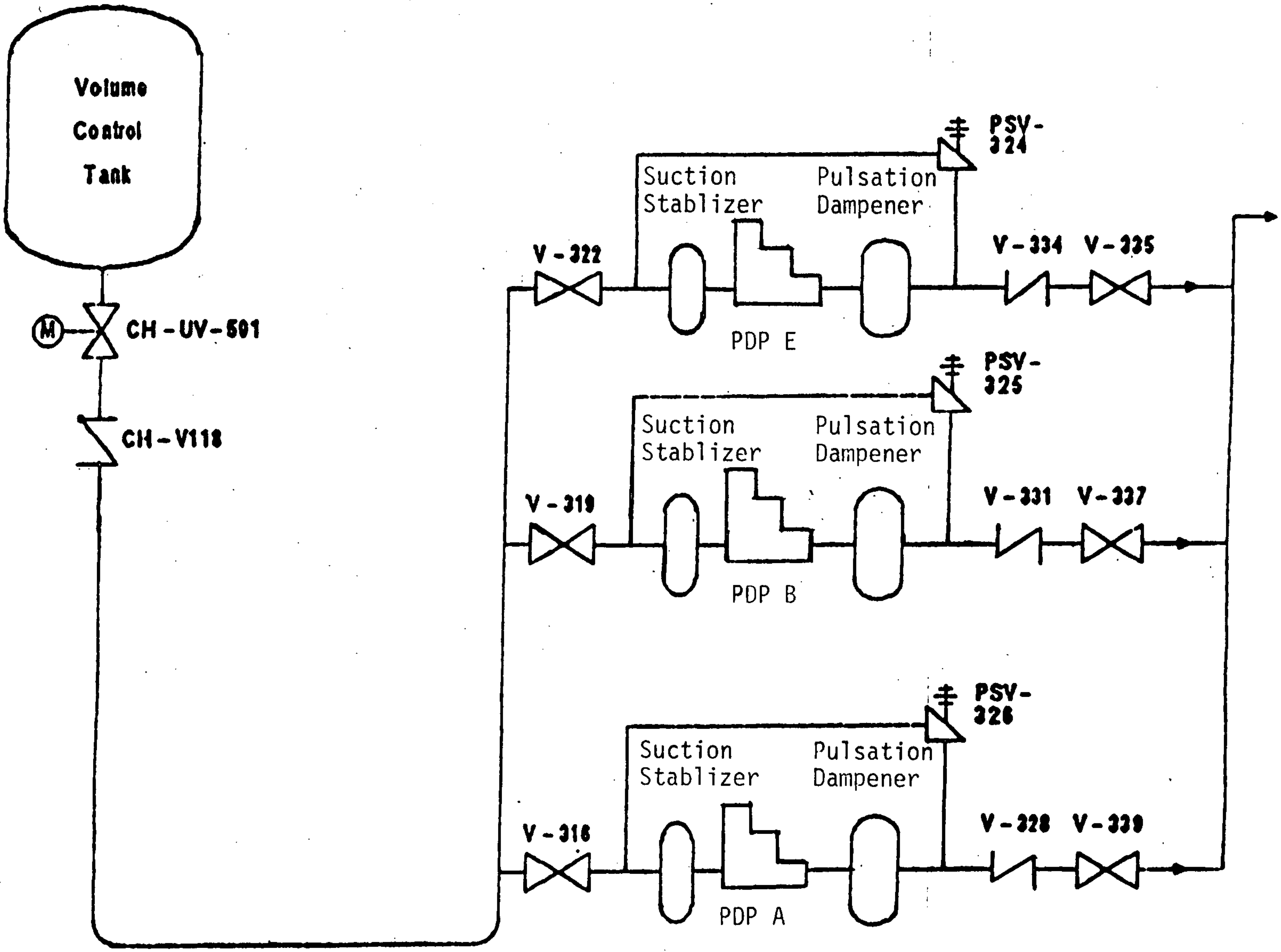

Figure 1. Charging Pumps at Palo Verde Units 1 and 2.

(i.e., three PDPs operating, each with a 44 gpm capacity). Several lineup configurations were tried, but a normal flow rate could not be achieved. During the valve lineup alterations, the VCT outlet check valve was checked and verified to be fully open. However, after the valve was mechanically agitated, one charging pump seemed to begin operating correctly. The E charging pump was then vented and it too began to operate as designed. The necessity of venting this pump for it to operate raised a suspicion that gas had collected against the VCT closed outlet check valve and filled the charging pump suction header.

During the troubleshooting of the charging system of the CVCS, a check of records showed that the pulsation dampener of the B charging pump had been repeatedly charged with nitrogen gas over the last several shifts. Subsequent investigation discovered that the pulsation dampener bladder had been leaking.

The licensee concluded that the attempts to pressurize the leaking pulsation dampener over several shifts had resulted in nitrogen gas being introduced into the B pump discharge piping. Subsequent operation of the B pump with a gas-water mixture is believed to have resulted in pressure spikes large enough to lift the relief valve (PSV-325) on the discharge of the pump. This valve relieves directly to the B charging pump suction header. Thus, nitrogen gas was introduced into the B charging pump suction header and collected in the high points of the charging system (i.e., the VCT or the VCT discharge check valve when this valve was in the closed position). The nitrogen gas collected on the discharge side of the check valve during the RCS dilution, and prevented the subsequent reopening of the check valve after the dilution was completed. Mechanical agitation of the check valve allowed the check valve to open and in doing so, restored flow from the VCT. It should be noted that although the licensee believed that the positive displacement charging pumps were capable of pumping a gas-water mixture, there were no indications of gas accumulation in the high points of the RCS.

Several corrective actions were implemented as a result of this event. The leaking bladder was replaced and the charging pumps were subsequently verified to operate normally. The bladder was believed to have leaked due to normal end-of-life age related degradation of the component. The bladders have a shelf life of three years. A preventative maintenance program was initiated to verify the condition of each pulsation dampener bladder monthly to provide early detection/replacement of a leaking bladder. The Unit 1 and 2 VCT outlet check valves were disassembled and no discrepancies were found.

2. Palo Verde Unit 1 on July 12, 1986

The unit was operating at 100% power when a reactor trip occurred. Several anomalies occurred after the reactor trip, including an actuation of the engineered safety features (ESF). However, the following discussion will be limited to charging pump problems.

Prior to the reactor trip, the charging system had been operating at approximately 35 psig suction pressure from the VCT. Charging pump suction pressure began to decrease with the ESF valve realignment from the VCT to the refueling water tank (RWT). The isolating valve for the VCT closed as designed, but the RWT outlet valve did not automatically open. With both sources of suction isolated, the charging pumps lost suction pressure and tripped.

Subsequently, the operators were able to line up the charging pumps suction to the RWT. The three charging pumps were restarted, however, charging pump E was not providing charging flow and was secured. The pump was vented (a small amount of gas and water was obtained prior to a solid water stream) and after a prestart check the pump was successfully run.

A post-trip investigation revealed that the bladder in the E pump suction stabilizer had ruptured and in doing so, added gas to the charging pump suction. The A and B pump bladders were checked and found to be intact. The time that the E pump bladder ruptured could not be determined. It was postulated that the most probable cause for the premature rupture of the bladder of the suction stabilizer was not venting the suction stabilizers when the CVCS was filled.

3. Palo Verde Unit 2 on July 18, 1986

The unit was in hot standby while a routine dilution was in progress using charging pumps A and E. Charging pump B had been taken out of service for replacement of its suction stablizer bladder. The charging pump common suction header was being supplied through the RWT gravity feed header. Charging pump A was then taken out of service at 1056 MT to allow for precharging of the discharge pulsation dampener. At approximately 1137, control room operators noted that charging pump E had no indication on discharge flow. As a result, the three charging pumps were declared inoperable.

An investigation determined that charging pump A discharge pulsation dampener bladder (Greer Hydraulics Inc., Part No. 720507) had ruptured. When the bladder ruptured, nitrogen gas leaked to the suction side of charging pump A through relief valve PSV-326 on the discharge line.

The licensee presumed with only charging pump E running, there was not sufficient flow in the suction header to impede gas movement from the pulsation dampener of charging pump A to charging pump E. When enough gas had migrated through the common suction header to charging pump E, the pump E became gas bound.

The root cause of the gas binding of charging pump E was the rupture of the charging pump A discharge pulsation dampener bladder. The bladder is believed to have ruptured due to normal inservice wear. The manufacturer's recommended replacement interval (based on shelf life) is three years. As a conservative measure, the dampener bladders will now be replaced during each refueling outage.

The immediate corrective action was to replace the charging pump A discharge pulsation dampener bladder. To prevent recurrence, the preventive maintenance procedures for Units 1 and 2 have been revised, to include the following steps:

(a) The suction valve of the pump being charged will be closed prior to the precharge of the pulsation dampeners and suction stabilizers. This will prevent gas from migrating into the suction of the other pumps should a bladder failure occur during the precharge.

(b) After completion of each precharge, the pressure in the discharge piping will be reduced below the bladder precharge pressure to ensure the bladder has not failed.

4. Purpose of Pulsation Dampeners and Suction Stabilizers

High pressure PDPs can produce substantial pressure pulses in both their suction and discharge lines from the reciprocating movement of the pistons in the pump. The frequency of the pressure pulses are directly proportional to the number of pistons (usually four) and the speed (variable) of the pump. As a consequence, a number of licensees have reported cracks and leaks in the PDP pipes and casings which were directly attributed to the high pressure pulse characteristics of these pumps.

Many licensees have installed pulsation dampeners on the discharge lines and suction stabilizers on the suction lines to mitigate system pressure variations from the PDP. The pulsation dampeners and suction stabilizers are generally similar to those in place at Palo Verde (i.e., bladder-type nitrogen-filled accumulators). Thus, the problem of failed pulsation dampeners could be generic to plants using high-pressure positive displacement charging pumps.

5. Safety Considerations of a Loss of Charging Pumps

A. Combustion Engineering (CE) Plants

Combustion Engineering plants are generally similar to Palo Verde in CVCS design and usually have PDPs in the charging system. These pumps inject concentrated boric acid into the RCS on an emergency core cooling system (ECCS) actuation signal. However, the CE plant safety analysis does not take credit (except for San Onofre 2 and 3) for the contribution of the charging system during a postulated accident. Therefore, with the exception of San Onofre 2 and 3, the charging system is not safety-related at CE plants.

At San Onofre 2 and 3, the safety-related charging system appears similar to the nonsafety system at Palo Verde. Each of the three PDPs has a gas-filled suction stabilizer and pulsation dampener with an internal rubber bladder. Also, the relief valve for the PDP discharges into the common charging pump suction header. Thus, it would appear that a failure, similar to those that occurred at Palo Verde, could also affect the safety-related charging system at San Onofre 2 and 3. However, discussions with an inspector indicated that:

1) There is no history of problems with the pulsation dampeners and suction stabilizers at San Onofre, and

2) The piping configuration features a significant physical separation for each pump and therefore, a large volume of gas would be required for common mode failure of all pumps to occur due to gas binding.

B. Westinghouse (W) Plants

Some W designs also have a PDP in their charging system. The other two pumps are centrifugal charging pumps (CCPs), and all pumps have a common suction header (see Figure 2). In this design, the PDP is not safety-related and the two CCPs are the motive force for the high head safety injection system to provide protection for steamline breaks or for small RCS breaks where the pressure remains above the shutoff head of the intermediate head pumps for an extended time period. Therefore, at W plants the two CCPs are safety-related.

It is conceivable that a failure similar to those described at Palo Verde could cause gas binding of the safety-related centrifugal charging pumps through their common suction header by a bladder failure of either the pulsation dampener of the suction stabilizer of the nonsafety-related PDP.

On February 12, 1982 such an event did occur at a W design plant. While operating at 50% power, McGuire Unit 1 experienced a loss of all three charging pumps and thus, the total loss (for a period of 38 minutes) of the safety function of these pumps. A malfunction of the suction stabilizer water level instrument led to a continuous supply of hydrogen gas to the PDP suction stabilizer. The hydrogen gas subsequently entered the common suction header of the charging pumps. In this event scenario, a single failure in the nonsafety-related portion of the system resulted in a loss of the safety function of the system. This event was communicated to all licensees by IE Information Notice No. 82-19. Subsequently, concerns regarding the desirability of technical specification requirements for plant shutdown, which may be undesirable or unsafe without the system which became inoperable, led to Generic Issue 59.

As the failure of the PDP suction stabilizer at W plants is thoroughly documented, the remaining concern is whether failure of the pulsation dampener on the discharge of the PDP could similarly affect the CCPs. In a survey of five W plants of this design, the inspector at each plant responded that:

(a) The PDP is never used for normal charging.

(b) The PDP relief valve does not discharge into the charging pump suction header; it discharges into the VCT.

Thus, it would appear that failure of the pulsation dampener of the PDP could not lead to gas binding of the safety-related centrifugal charging pumps at a W plant.

FINDINGS AND CONCLUSIONS

Almost all plants with PDPs have installed pulsation dampeners and suction stabilizers to mitigate pressure pulses from these pumps. These modulating devices have proven effective in reducing cracks and leaks in the charging system. Failures of either bladder are infrequent occurrences, and thus, the three events at Palo Verde are considered to be a plant-specific problem.

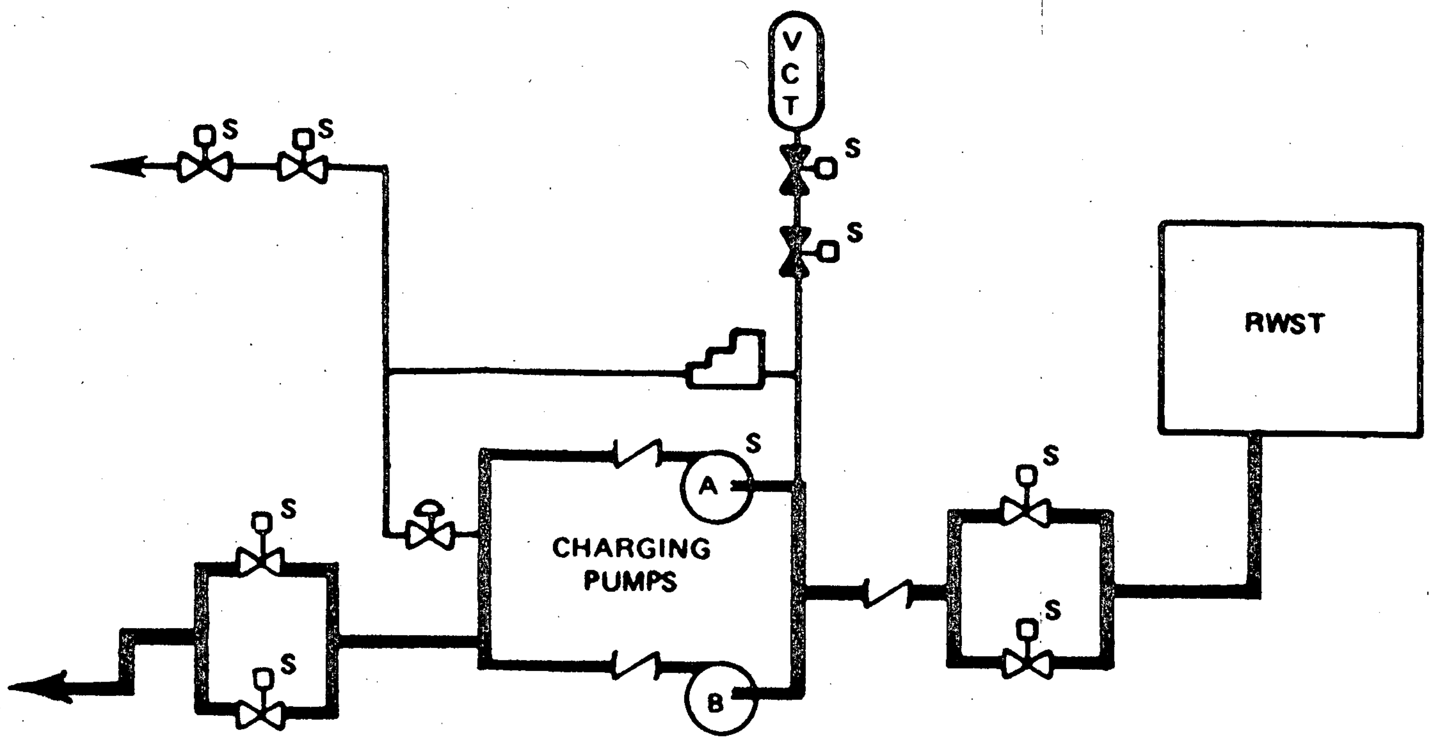

Figure 2. Charging Pump Configuration at Some Westinghouse Plants

There were no safety-related consequences to the simultaneous common-mode loss of all charging pumps at Palo Verde. The consequences of a failure of the suction stabilizer at a plant with a safety-related charging system have been identified by IE IN 82-19 and subsequent concerns with this type of failure are discussed in GI-59. The failure of a pulsation dampener apparently could only affect the safety-related charging system at San Onofre Units 2 and 3 and would not have adverse safety implications at the other CE and W plants that were reviewed.

The events at Palo Verde demonstrated that the charging pumps can be quickly vented and returned to service.

The three events at Palo Verde demonstrated that PDPs are capable of pumping a gas-water mixture. However, in each case, the pumps became gas-bound before injecting a noncondensible into the RCS.

In conclusion, the three closely-spaced events of a loss of all charging pumps at Palo Verde did not have a safety effect on the plant; and is not a widespread potential problem with the safety-related charging pumps at other plants. The frequent failures of the pulsation dampener at Palo Verde are considered an isolated problem.