# AEOD TECHNICAL REVIEW REPORT[1/]

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| UNIT: | Davis-Besse Unit 1 | TR REPORT NO.: | AEOD/T603 |
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SUBJECT: INADVERTENT PUMP SUCTION TRANSFER AND POTENTIAL AUXILIARY FEEDWATER PUMP CAVITATION AT DAVIS-BESSE

EVENT DATE/LER NO.: January 15, 1985; LER NO. 50-346/85-002-00


SUMMARY

On January 15, 1985, the Davis-Besse reactor was critical and zero power physics testing was in progress. An anticipatory reactor trip occurred following a steam and feedwater rupture control system (SFRCS) trip. Thirty seconds after the SFRCS actuation, the auxiliary feedwater pump (AFWP) #1 suction spuriously transferred from the condensate storage tank (CST) to the service water system (SWS). The AFWPs are designed to take suction from either of the CSTs or the SWS. They are normally lined up to the CST and the SWS is used as a back-up. However, the service water is essentially untreated and using this source as a supply of water to the steam generators should be kept to a minimum to avoid adverse effects on the secondary water chemistry. In their analysis of this event, the licensee staff considered the possibility of minor cavitation of AFWP #1. There were no indications in the control room of an AFWP malfunction and no pump operating parameters were measured; thus there was no conclusive evidence that pump cavitation had occurred. However, the licensee has identified methods to eliminate potential cavitation problems to ensure pump protection.

To prevent spurious auto-transfer of pump suction from the CST to the SWS and potential AFWP cavitation, the licensee is reviewing two modifications. The first modification requires installing time-delay switch in the AFWP suction - transfer circuitry. This feature would minimize pump suction transfer on momentary low pressure. The second modification requires opening the CST supply valve breaker. This design change also minimizes AFWP cavitation should an inadvertent pump suction transfer occur followed by an inadvertent isolation of the SWS. The AFWPs will not cavitate as they will have adequate supply of water as long as the CSTs are available. The second design modification has the drawback of defeating the design isolation function of the feedwater valves. In case of a seismic event, this modified design feature may enable the service water to drain through a potential break in the non-seismic piping upstream of the feedwater valves. However, since the probability of a seismic event at Davis-Besse site is small, the combined probability of this event occurring concurrent with a seismic event is even smaller.


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[1/] This report supports ongoing AEOD and NRC activities and does not represent the position or requirements of the responsible NRC program office.

## 1.0 DISCUSSION

Our study was initiated due to a statement in the referenced LER that it is acceptable, under some circumstances, for the AFWP to cavitate for short periods of time. This LER does not mention the length of time and the circumstances under which the pump cavitation would be acceptable. Our examination of this event was conducted to determine the safety implications of this occurrence. Our approach was to: (1) examine the extent of cavitation; (2) determine if the pump cavitation (if any) and auto-transfer to the SWS were related; and (3) evaluate the rationale used by the licensee as to the circumstances under which cavitation could be acceptable.

During the course of this study, it was determined that AFWP cavitation could not be positively established during this event. Therefore, no link between pump cavitation and inadvertent switchover of pump suction to the SWS could be established. After the total loss of feedwater event on June 9, 1985, we continued our review of potential inadvertent transfer of both pumps to the SWS and subsequent operator error of SWS isolation that could result in a safety significant situation.

### 1.1 Event Description

On January 15, 1985, the Davis-Besse reactor was critical and zero power physics testing was in progress. The integrated control system (ICS) was not properly controlling the steam generator #1 level at the desired setpoint of 35". While the instrumentation and control (I&C) personnel were investigating the ICS, the operators placed the main feedwater controls in manual to prevent the ongoing investigation from affecting the steam generator levels. The low steam generator level annunciator (30") had been previously received and the operators failed to monitor the steam generator level, which continued to drop. The level in steam generator #1 further decreased until it reached the SFRCS trip set point ($\sim$ 27"). The SFRCS trip occurred causing an anticipatory reactor trip.

The following sequence of events occurred:

- About 30 seconds after SFRCS actuation, the AFWP #1 suction transferred from the CST to the SWS. The automatic switchover probably occurred because of a momentary low suction pressure, although this cannot be confirmed.

- Approximately four minutes after the trip, the control room operator noticed that the AFWS was being supplied by the SWS and closed the service water supply.

- Since the low suction pressure switch had already isolated the CST, the operator's isolation of the SWS inadvertently isolated all water supply to AFWP #1.

- The automatic low-low suction pressure trip closed the steam isolation valve which shut down the AFWP #1 turbine.

AFWP #2 operated properly throughout the event and the levels in steam generator #2 were maintained above the low level setpoint. Both AFWPs are manufactured by the same vendor. However, they do not have identical controls.

## 1.2 Safety Significance

### Pump Cavitation

Pump cavitation has a potential for damaging the AFWPs. The extent of pump cavitation, if any, could not be established in this event as there were no measurements of pump operating parameters. Furthermore, there were no indications in the control room or observable pump damage to suggest AFWP malfunction. Since the pump cavitation could not be positively established, its link to the inadvertent transfer of the AFWP suction from the CST to the SWS cannot be positively determined. Should there be minor cavitation, the pump vendor has assured the licensee of enough conservatism in the pump design to permit pump operation for short times under cavitating conditions without causing significant damage.

### Inadvertent Transfer of the AFWP Suction to the SWS

Since the reactor was not at power and it had been shut down for nearly four months for refueling, there was little decay heat to be removed and the steam generator #1 level was adequate until normal feedwater level was restored (within 12 minutes of the SFRCS trip). Had the reactor been at power, a significant transient could have occurred if the second AFWP had also inadvertently switched over from the CST to the SWS and the operators had subsequently isolated the service water.

The auto-transfer of AFWP #1 to the SWS has an adverse effect on the secondary water chemistry but it does not present a near-term safety concern. The auto-transfer of AFWP to the SWS prior to the depletion of CST inventory is a concern only if the SWS is inadvertently isolated to both AFWPs and then switchover to the CST is not possible. The licensee has proposed design modifications to prevent recurrence of the spurious AFWP suction switchover and subsequent operator error of SWS isolation.

## 1.3 Other Inadvertent AFWP Suction Transfers at Davis-Besse

At Davis-Besse, there have been previous occurrences of spurious switchover of AFWP suction from the CST to the SWS. These events were not reported in LERs. Since 1981, there have been at least three other events involving spurious transfers of AFWP #1 suction to the SWS and at least one involving that of AFWP #2 (Ref. 1). No occurrence involving simultaneous transfer of both pump suctions from the CST to the SWS could be recalled by the licensee's staff. However, since both pumps have a history of previous inadvertent transfer(s), a spurious simultaneous transfer of both pumps could occur.

On June 9, 1985 a total loss of feedwater event occurred at Davis-Besse (Ref 2). Late in the event, after the AFWPs were restored to operation, AFWP #1 suction inadvertently transferred from the CST to the SWS.

## 1.4 Investigation by the Licensee

### Pump Cavitation

Pump cavitation could not be positively established during the January 15 event as there were no measurements of pump operating parameters and there was no indication in the control room to suggest an AFWP malfunction.

Based on the information obtained from the members of the licensee's technical staff, the following points are noted:

1. The licensee's review of the reactor trip data raised some questions about the possibility that there might have been minor cavitation of the AFWP #1. However, there was no positive indication of pump cavitation. The suspected cavitation of AFWP #1 was thought to be only momentary. There was no direct assessment of pump cavitation. Making a crude assumption that the pump discharge pressure is the same as the steam generator #1 pressure, a review of the pump design curves by the licensee indicated the operating point to be "on the edge" of the pump design curves -- thus "susceptible" to cavitation. However, the pump discharge pressure has to be greater than the steam generator pressure. Since the fundamental assumption made by the licensee is invalid, the position of the "operating point" on the design pump curves derived in this manner is unrealistic. Furthermore, there were no direct measurements of pump flow, pump discharge pressure, and/or pump current to conclusively establish that AFWP cavitation had indeed occurred. In addition, the control room operators had no indication of the impaired performance of AFWP #1. Thus, pump cavitation was not evident.

2. The licensee has examined the effect of minor cavitation on pump performance and its impact on the life of the pump. This aspect has been discussed with the pump manufacturer. The licensee was assured that there is at least 20% conservatism in the net positive suction head (NPSH) estimates of these pumps and only extended operation under cavitating conditions may damage these rugged pumps. In order to prevent potential damage to the pumps, the licensee is evaluating various means of eliminating pump cavitation.

Inadvertent AFWP Suction Transfer to the SWS

As described in Reference 1, following the June 9, 1985 event, the licensee has performed a study to investigate the cause of this and the past inadvertent transfers of the AFWP suction from the CST to the SWS. That study concluded that drop in the suction pressure due to the conical strainer S257 (downstream of the CST) may be responsible for the inadvertent AFWP suction transfer.

Another study was conducted by the licensee to verify the design and logic of the circuitry for the automatic transfer of the AFWP suction. This study concluded that:

- The circuitry will provide the automatic transfer of the AFWP suction upon sensing low pressure at both low pressure switches (i.e., PSL 4928A and PSL 4928B for AFWP #1; PSL 4929A and PSL 4929B for AFWP #2).

- No single failure or inadvertent actuation of any single device will cause the automatic transfer of the auxiliary feedwater pump suction. The automatic transfer for each pump requires both low pressure switches to trip.

- Barring the supposition of multiple or common mode failure of the pressure switches, actuation of the automatic transfer of the AFWP #1 suction was likely caused by sensing of low pressure by PSL 4928A and PSL 4928B.

Investigations of AFWP suction automatic transfers from the CST to the SWS have shown that (Ref. 1):

- o The inadvertent AFWP suction transfer at Davis-Besse has occurred four times; three times on train 1 (November 9, 1983; January 15, 1985; and, June 9, 1985) and once on train 2 (July 30, 1981).

- o All inadvertent transfers occurred after the addition of strainer S257 in 1981. This strainer was added to prevent any debris from the condensate storage tanks from plugging the pump suction strainers during a seismic event.

- o Most transfers occurred during or shortly after a large auxiliary feedwater flow or AFWP turbine speed change. The July 1981, November 1983 and January 1985 transfers occurred when the pump was accelerating. The June 1985 transfer occurred almost concurrent with cut off of the steam to the AFWP #1 turbine. Alarm printouts showed that during the June 9 event, the inadvertent transfer took place at 1:58:40 and the AFWP #1 turbine throttle valve left the open position at 1:58:39. Reference 1 states that in this event, the inadvertent transfer of the AFWP #1 suction transfer was as a result of the hydraulic transient in the auxiliary feedwater system which occurred when the turbine trip throttle valve on AFWP #1 turbine spuriously closed, shutting down the pump. Data have shown that the flow from AFWP #1 to the steam generator dropped from about 500 gpm to zero within two seconds of valve closure.

1.5 Corrective Actions by the Licensee

Currently, the following corrective actions are being considered (Ref. 1):

- o To lower the current setpoints for all the four pressure switches. Analysis has shown that the pressure switches may have been responding to the pressure drop associated with strainer S257. Lowering the setpoint would increase the margin between the actuation of the transfer of the AFWP suction and system's hydraulic characteristics.

- o To install a time-delay switch in the circuit for the automatic transfer of the AFWP suction. The time-delay switch would prevent the automatic transfer of the AFWP suction due to short term pressure fluctuations but would provide the transfer upon sensing actual low suction pressure.

- o To provide a coarser mesh in strainer S257. All inadvertent transfers of the AFWPs have occurred after the installation of S257. Analysis has shown that S257 produces a sizeable pressure drop. Making the strainer coarser will reduce the pressure drop on the suction of the AFWPs; thus, making the switches less susceptible to pressure fluctuations.

- o To ensure an adequate water supply to the AFWP when the SWS is inadvertently isolated, subsequent to a spurious transfer from the CST, the licensee is considering a design modification which involves leaving open the breaker for the CST supply valve. This proposed modification is redundant to the time-delay mechanism discussed earlier.

Figure 1 shows a schematic of the supply lines to the AFWPs. In the current design, the feedwater valves FW786 and FW790 close on sensing low suction pressure, and service water valves SW1382 and SW1383 open. If it is an inadvertent transfer to the SWS then the operator would have to manually open the feedwater valves FW786 and FW790, and close the service water valves SW1382 and SW1383. In the proposed modification, the feedwater valves FW786 and FW790 will be left open and de-energized. After receiving a low pump suction pressure signal, the time-delay mechanism in the suction transfer circuitry, after a pre-determined delay (a couple of seconds), will open the service water valves SW1382 and SW1383. In the event of an inadvertent switchover of the pump suction from the CST to the SWS and subsequent isolation of the SWS, the pump will continue to receive suction from the CST. If the CST is available, then in case of an inadvertent pump suction transfer, the operators would only need to isolate the SWS. Thus, with minimal operator intervention, an adequate supply of water to the AFWPs will be ensured.

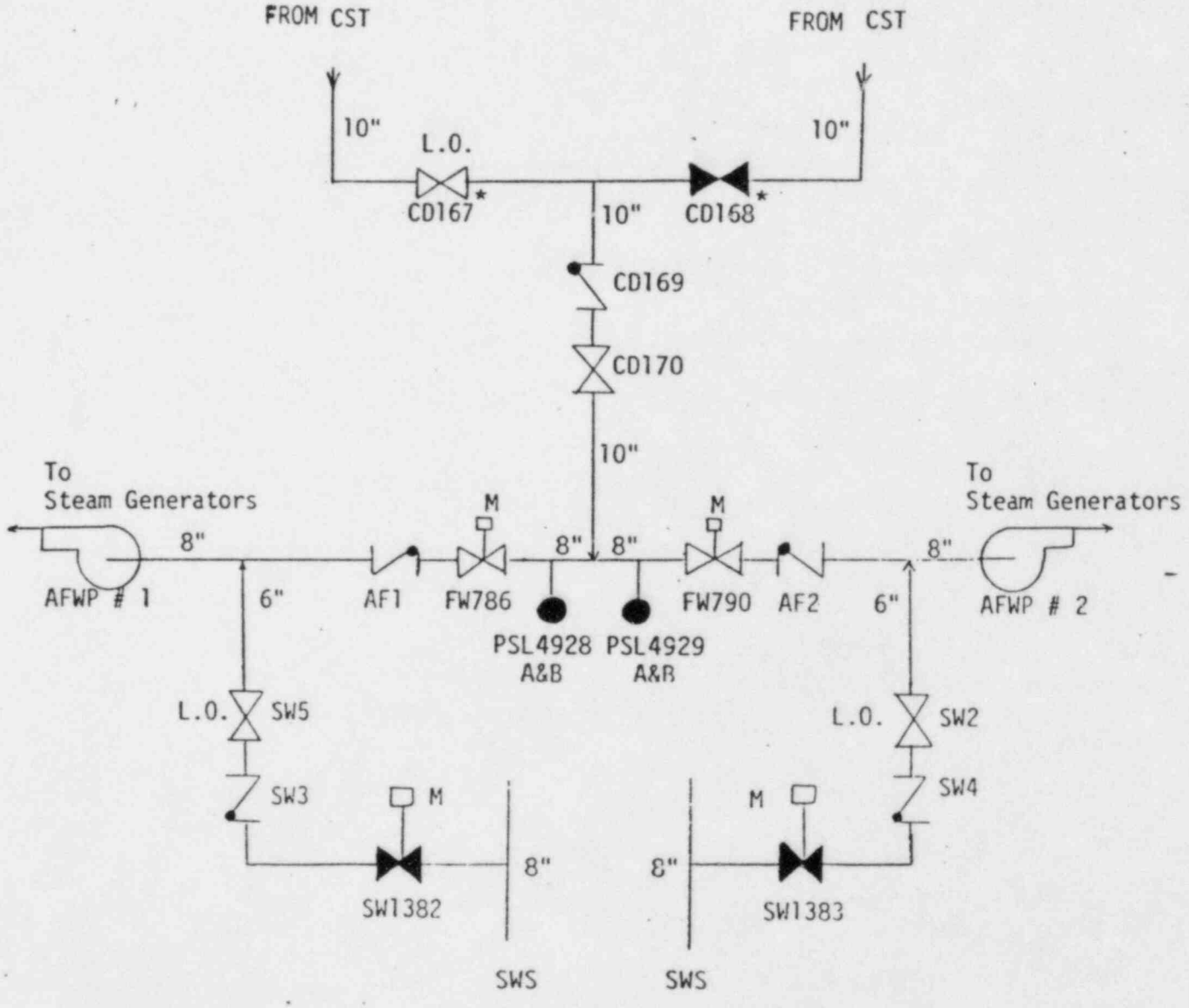
In the event the CST inventory is depleted, the switchover to the SWS will take place as it does now. The check valves AF1 and AF2, downstream of the feedwater valves FW786 and FW790, respectively, will prevent backflow to the CST as designed. Since the SWS pressure is, typically, 90 psig, the AFWPs will take suction from the SWS rather than draw on the lower pressure segment of the supply line from the CST. The check valves will isolate this portion of the system. We note that both pairs of valves - FW786 & FW790 and SW1382 & SW1383 -receive the low pressure signal at the same time. Furthermore, we have examined the stroke times of the feedwater valves and the service water valves from the last in-service test and note that the service water valves open fully before the feedwater valves close. This proposed modification of leaving the feedwater valves open and de-energized is intended to minimize any potential AFWP cavitation problem. We note that there are two pressure sensors for each AFWP and following single failure of the associated pressure sensor, a potential pump cavitation problem due to the AFWP drawing on empty CST does not exist. In case of a seismic event, leaving the feedwater valves open and de-energized has a disadvantage of draining the service water through a potential break in the piping upstream of the feedwater valves because this portion of the auxiliary feedwater piping is not seismically qualified, thus defeating the design isolation function of the feedwater valves. However, the probability of a seismic event occurring at the Davis-Besse site is small. Therefore, the combined probability of an event similar to the one being discussed occurring concurrent with a seismic event is even smaller.

The licensee plans to submit these design modifications to NRR for review as a part of the proposed measures to improve the reliability of the Davis-Besse auxiliary feedwater system (AFWS).

## 2.0 FINDINGS

1. During the January 15, 1985 event, there were no direct measurements of pump operating parameters to positively conclude pump cavitation. In addition, there were no indications in the control room to suggest AFWP malfunction. Thus, pump cavitation could not be proved or disproved.

Figure-1 Davis-Besse AFW Suction Line-up




*Either CD167 or CD168 is locked OPEN and the other is unlocked CLOSED

(Sketch- Based on Davis Besse USAR, Revision 3/Chapters 9 and 10- From the Licensee)

2. Since 1981, there have been at least four occurrences at Davis-Besse involving spurious suction transfers of AFWPs. In the past, there were at least three separate events involving transfer of AFWP #1 and one involving that of AFWP #2. In the existing design, spurious suction transfer of both AFWPs is not a safety concern, but has an adverse effect on the secondary water chemistry.

3. A review of the operating data by the licensee showed that all previously observed spurious transfers of the AFWP suction to the SWS have occurred after the installation of strainer S257 downstream of the CST. Analyses indicated that the larger than originally specified pressure drop across strainer S257 can result in a lower suction pressure such that the system would respond to momentary pressure fluctuations which would result in inadvertent transfers. In the June 9, 1985 event, the pump suction transfer occurred moments after a spurious closing of the turbine trip throttle valve for the AFWP #1 turbine, shutting down the pump.

4. Several design changes are being considered by the licensee. The design modification involving addition of a time-delay mechanism to the AFWP transfer circuit would be effective in preventing an inadvertent transfer of the AFWP suction to the SWS on a momentary low suction pressure. However, if there is an inadvertent transfer, the other design modification (leaving the CST supply breaker open) would ensure an adequate supply of water to the AFWPs in the event the SWS is inadvertently isolated. This would be accomplished with minimal operator action. In case the CST inventory is depleted, no potential problem of AFWP cavitation due to drawing on an empty CST exists. However, the arrangement of leaving the feedwater valves open and de-energized would negate the isolation function of the valves which was one of the design requirements of these valves. Two other proposed changes include lowering of the setpoints of all the four pressure switches and replacement of the existing mesh in strainer S257 by a coarser one.

5. The licensee plans to submit these proposed modifications for review to NRR in support of improving the reliability of the AFWS at Davis-Besse. As a follow up of the Davis-Besse Task Force efforts following the June 9, 1985 event, the issue of inadvertent switchover is currently being addressed by NRR.

3.0 CONCLUSIONS

1. In this event, the AFWP cavitation could not be positively established.

2. Spurious simultaneous AFWP suction transfer to the SWS is not a safety concern but it would have an adverse effect on the secondary water chemistry. However, an inadvertent isolation of the SWS transfer after a simultaneous transfer of both AFWPs can cause these pumps to cavitate. Under different circumstances (e.g. a trip after extended operation at power), a significant transient may occur.

3. The design modifications proposed by the licensee to install a time-delay mechanism in the AFWP suction transfer circuitry should prevent inadvertent pump suction transfers on momentary low suction pressures.

4. In case the CST inventory is depleted, the proposed modification of leaving the CST supply valve breaker open and deenergized does not present a potential problem of the AFWP cavitation due to drawing on an empty CST. However, in case of a seismic event, this design change has a drawback of draining the service water through a potential break in the non-seismic piping upstream of the feedwater valves. Since the probability of a seismic event at the Davis-Besse site is small, the consequences of this design change are minimal.

REFERENCES

1. Toledo Edison Company, "Davis-Besse Course of Action", Vol. 2 (Appendix C.1.1 - NUREG 1154, Table 5.1 Equipment Deficiencies - Action Plan 26), dated October 1, 1985.

2. Toledo Edison Company Licensee Event Report 50-346/85-013-00, dated July 9, 1985.