TU ELECTRIC

COMANCHE PEAK STEAM ELECTRIC STATION

UNIT 2 ENGINEERING

BWIP CHECK VALVE 2AF-0083
FAILURE INVESTIGATION

PTR-32, Revision 0

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Prepared by John B. Rowlett — 8/6/92 Date

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Design Engineering, Unit 1 — 8/7/92 Date

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UNIT 2 ENGINEERING BWIP CHECK VALVE 2AF-0083 FAILURE INVESTIGATION

I. BACKGROUND AND PURPOSE

This engineering report provides a summary of the investigation into the cause of the failure of valve 2AF-0083.

On July 3, 1992, Borg Warner International Products (BWIP) check valve 2AF-0083 failed a backflow test being performed in accordance with Unit 2 preoperational test procedure 2PT-[illegible]1. The valve was subsequently radiographed, disassembled, and found to have a broken disk-stud assembly. The break was located on the stud just above the disk to stud [illegible] (Reference B).

The valve is located in the motor driven auxiliary feedwater pump (MDAFWP) 2-0[illegible] discharge line to steam generator (SG) number 2 and is relied upon to prevent backflow from the feedwater system when the associated MDAFWP is not running. Seven (7) other valves perform similar functions in the auxiliary feedwater system.

II. IMMEDIATE ACTIONS TAKEN

A. A review was performed of the operational history of the eight (8) BWIP check valves. The review indicates valves 2AF-0075/83/93/101 associated with the MDAFWPs had been in service. All four (4) valves were disassembled and visually examined. Valves 2AF-0075/93/101 had wear patterns on their backstops. Valve 2AF-0083 had a major indentation on its backstop which was mapped by QC prior to reassembly of the valve (Reference Q).

B. Because Unit 1 has performed maximum expected differential tests (MEDP) tests and subsequent backflow checks, and no other stud failures were identified, Unit 1 valves were considered operable. In addition, a preliminary review determined that a modification (or backstop) had been added to the Unit 2 valves. This modification appeared to increase stresses in the Unit 2 valves.

C. Since the cause of the failure was unknown at the time of occurrence, Unit 2 was administratively limited to a flow rate of 300 gpm through each of these valves. This flow rate corresponds to the maximum expected flow rate during normal operation. The valves were reworked and the systems placed in service to support HFT (Reference N).

D. A review of startup testing revealed that there was a flow of approximately 670 gpm through 2AF-0083 on 5/25-/92 and only 580 gpm when performing the runout flow and MEDP tests on 7/2/92 (Reference P). This data indicated the valve had failed in the time period between these tests.

III. INVESTIGATION

In order to determine the cause of the failure of valve 2AF-0083, metallurgical examinations, transient analyses, system and valve design reviews, and an operating history review were performed. In addition, a review was performed for generic implications.

A. **Metallurgical Examination** (Reference A). The report stated:

> The chemical composition, physical properties, metallurgical structure, and appearance of the fracture surface were evaluated to determine the failure mechanism of the stud. The fracture occurred due to stress overload at the convergence of the stud heat-affected zone, a thread root, and the fillet weld toe extending from the disk. The part was subjected to a high energy, complex load with components of axial tension and bending. At the terminus of the fracture, the stud had significant cold work in the microsegregated microstructure. Due to the high rate of loading, little evidence of ductile stretching or necking was visible to the unaided eye....

NOTE: Reference A is currently under final review.

B. **Transient Analyses/Investigation**

Design basis transients have been calculated (Reference R) for pump start and a pump stop for a water solid condition The force in the piping segment containing the check valves is very small with an order of magni-

tude of about 20 lbf for pump start and 572 lbf for pump stop. These forces are not capable of causing the failure which occurred.

A non-design basis transient which results in a slug fluid velocity of 29.48 ft/sec and a force of approximately 15,000 lbf was determined using the Jaukowski equation, assuming a partially drained system (Attachment 3).

A walkdown of the system was performed as described in Reference E. No damage to supports or evidence of large pipe movements was found. The check valves are located just upstream of anchors, and the forces transmitted would have been vertical into the valve bonnet. Therefore, due to the general stiffness of the piping configuration it was unlikely to have found any support damage or indications of large pipe movements.

An auxiliary feedwater system elevation diagram was developed (Attachment 1). This diagram shows that the system has a potential to drain down to the elevation of water (853'-4" to 834'-3") in the condensate storage tank (CST) which is between 8" to 19'-9" below the check valve which corresponds to between 29 linear ft to 70 linear ft. This drain down could occur when the associated steam generator is not receiving flow through the preheater nozzle, the steam generator is at atmospheric pressure, and in addition if the check valve has any leakage. The check valve in question had not been backflow tested prior to the failure.

C. **Stress Analysis**

A dynamic stress analysis was performed (Reference D) of the valve with and without a backstop. The analysis evaluated the mechanisms which could cause the failure of the disk-stud and estimated the lower bound of the force required to break the stud under a one-time event to be between 9.6 to 10.9 kips. A disk velocity of 30 ft/sec was used, which corresponds to the upper bound fluid transient analysis velocity of 29.48 Ft/sec. The corresponding reaction forces predicted on the bonnet backstop are consistent with a static test performed at BWIP which resulted in an indentation of 24 mils for a load of 8 kips. The greater energy involved in a dynamic collision would probably cause a greater indentation. The actual measured indentation was 64 mils (Reference Q).

D. **System Operation**

The auxiliary feedwater is normally operated to maintain level in the steam generators during startup and shutdown operations (modes 2 and 3) until the feedwater system is placed in operation. The system is also used to fill and maintain level in the steam generators. The system is operated in accordance with SOP-304-B (Reference M). The system is initially filled and vented up to the isolation valves. The flow control valves and isolation valves are then fully opened and the piping monitored for temperature to determine if the check valves are leaking. This check would not be meaningful with the steam generator at atmospheric/ambient conditions.

E. **System Design Review** (Reference J)

The auxiliary feedwater system is designed to provide the following flow rates through the subject check valves:

1.	Loss of feedwater	215 gpm minimum
2.	Feedwater line break	265 gpm minimum to non-faulted generator 700 gpm maximum to faulted generator for MDAFWPs 680 gpm maximum for TDAFWP
3.	Hot standby	235 gpm minimum
4.	Plant startup	300 gpm minimum
5.	Normal plant startup and shutdown	40 to 275 gpm

The subject check valves are not relied upon to prevent backflow in the event of a feedwater line break to the faulted steam generator. The flow control valves on the MDAFWP trains differ from the TDAFWP flow control valves in that they are provided with an automated feature which drives them to a full open position on an auto MDAFP initiation signal. The flow control valves are normally open when the system has been filled and vented and the pumps are not in operation. The motor operated isolation/block valves are normally open and fail as is.

F. **BWIP Check Valve Design Review** (Reference I)

There are 25 pressure seal bonnet BWIP check valves in Unit 2 which were modified. Bolted bonnet check valves were not modified and therefore were excluded from the review. There are eight (8) 4" diameter valves in the auxiliary feedwater system which have been modified by adding counter weights, backstops, and a height adjustment spacer. The corresponding eight (8) valves in Unit 1 have added counter weights. No height adjustment spacer or backstop was added. This allows the Unit 1 valves to swing further out of the flow stream and significantly reduces tensil stress on the stud during transients similar to the event discussed in this report. The other seventeen (17) valves in Unit 2 have backstops and height adjustment spacers, but since they do not have counter weights the disk-studs were generally shortened to allow the disk swing angle to be near to those in Unit 1 which do not have backstops (Reference 1).

G. **Operating History Review**

Flow was provided thirteen (13) times to steam generator Number 2 prior to discovery of the failed valve. There were periods of up to six (6) to ten (10) days between pump operations, including one inadvertent auto start on 7/1/92 (Reference K).

The first two operations of this valve, on May 25, 1992, were at increasing flow rates up to maximum flow (670 gpm from MDAFWP 01 and 650 gpm from MDAFWP 2-02 to SG #2) to determine if test line restriction orifice was the cause of pump vibration.

The third operation of the valve, on May 26, 1992, was to fill SG #2. No flow rate was recorded.

The fourth operatio [illegible] the valve, on June 2, 1992, no reason or flow rate was provided.

The fifth operation of the valve, on June 11, 1992, MDAFWP 2-01 was run on minimum flow and to fill SG #2. No flow rate to SG #2 was provided.

The sixth operation of the valve, on June 12, 1992, was to verify the test line restriction orifice modification was acceptable. MDAFWP 2-01 was run on minimum flow and through the test line, not to the steam generator.

ator.

The seventh operation of the valve, on June 21, 1992, MDAFWP 2-02 was run on minimum flow and to feed SG #2. No flow rate was recorded.

The eighth operation of the valve, on June 21, 1992, was a backflow test on the minimum flow check valves. MDAFWP 2-01 was run on minimum flow, not to the steam generator.

The ninth and tenth operations of the valve, on July 1, 1992, was to fill and vent.

The eleventh operation of the valve, also on July 1, 1992, was an inadvertent auto start of MDAFWP 2-01, which is recorded in Reference K. The flow control valve would have been in a full open position after the fill and vent. It is also possible for drain down to the CST level to have occurred. This appears to have been the most probable system configuration to develop the transient which damaged the valve.

The twelfth and thirteenth operations of the valve, on July 2, 1992, the MDAFWPs 2-01 and 2-02 were again operated to fill, vent, and perform runout and MEDP testing in accordance with 2CP-PT-37-01.

IV. CONCLUSIONS

A. Cause

Based on the evidence available to date, the failure of 2AF-0083 was most likely due to a system fluid transient which was the result of starting MDAFWP 2-01 into a partially drained system with the flow control and isolation valves fully open. This conclusion is based on the following:

1. A potential for a partial system drain down in conjunction with atmospheric pressure in the steam generators. The potential for a similar occurrence in the operating Unit is low due to the administrative controls and physical barriers described in Attachment 2.

2. Evidence of a rapid failure from the metallurgical examination. The failure was not due to incorrect and/or defective material/components.

3. The stress analysis is consistent with the transient analysis and metallurgical examination.

B. **Contributing Factors**

1. The backstop installed in the Unit 2 valves allows a higher stress to be developed in the Unit 2 disk-stud than if the backstop were not installed. There is at least approximately 40% more stress in Unit 2 (due to the backstop) for the same transient.

2. An orifice is installed upstream of each of the check valves to limit flow through the line in the event of a feedwater line break. For normal operating bases the orifice has little effect on the flow. It is difficult to quantify the effect of the orifice at high flow and low backpressure conditions, and it may have contributed in a significant way to turbulence.

3. The disk-stud is a 5/8" diameter all thread rod with a 0.507" root diameter. This provides both a stress riser and a "notch effect" where the failure occurred.

V. **CORRECTIVE ACTIONS**

A. The eight (8) Unit 2 check valves 2AF-0075/78/83/86/93-/98/101/105 will have their backstops removed to make them less susceptible to failure prior to proceeding with high flow/low steam generator pressure testing.

B. SOP 304A and B, "Auxiliary Feedwater System," will be revised in accordance with Attachment 2.

C. BWIP will be requested to provide replacement disk-stem assemblies with a shank instead of an all-thread stud for the eight (8) valves in each unit. The new disk-stud assemblies will be installed as replacements for the disk-studs are required.

D. The valves will be acoustically monitored during these conditions to determine what effect the orifice has on the valves following HFT.

VI. REFERENCES

A. Failure Analysis of BWIP Swing Check Valve 2AF-0083 disk-stud, VL-10295

B. TUE-92-5719

C. CPSES-9224904 dated July 29, 1992, subject: Unit 2 Valve Modifications.

D. Calculation 0218-SQ-0096

E. CPSES-9222(7 dated July 15, 1992, subject: Auxiliary Feedwater Pipe Support Walkdown Subsequent to Transient Event.

F. Technical Evaluation TE-92-001445

G. TU Electric office memorandum U2OP-92252 dated July 27, 1992, subject: Run Times of MDAFWPs

H. DCA-94663, Rev. 3

I. CPSES-9225677 Interoffice memorandum JO/WO: 01531.02 dated July 22, 1992, subject: Auxiliary Feedwater Check Valve Modification History.

J. DDB-ME-206, Revision 6, Auxiliary Feedwater System

K. ONE Form 92-629

L. Interoffice correspondence from Jim Sabin of S & W to Glenn Milley of S & W, subject: CP2-Pump Start Empty Column.

M. SOP-304A, Rev. 9, Auxiliary Feedwater System

N. CPSES-9221931 dated July 9, 1992, subject: Justification for hot functional testing.

O. Flow Diagram M2-206 Auxiliary Feedwater System

P. 2CP-PT-37-02

Q. SWP-20057

R. Calculation 1561600-F020, Rev. 1, "Water Hammer Analysis for Auxiliary Feedwater"

VII. ATTACHMENTS

1. Elevation Sketch of Auxiliary Feedwater System

2. Interoffice Memorandum, Jim Brau to John Roberts, dated August 4, 1992

3. Interoffice Correspondence from Jim Sabin to Glen Milley, dated July 24, 1992

ATTACHMENT 1
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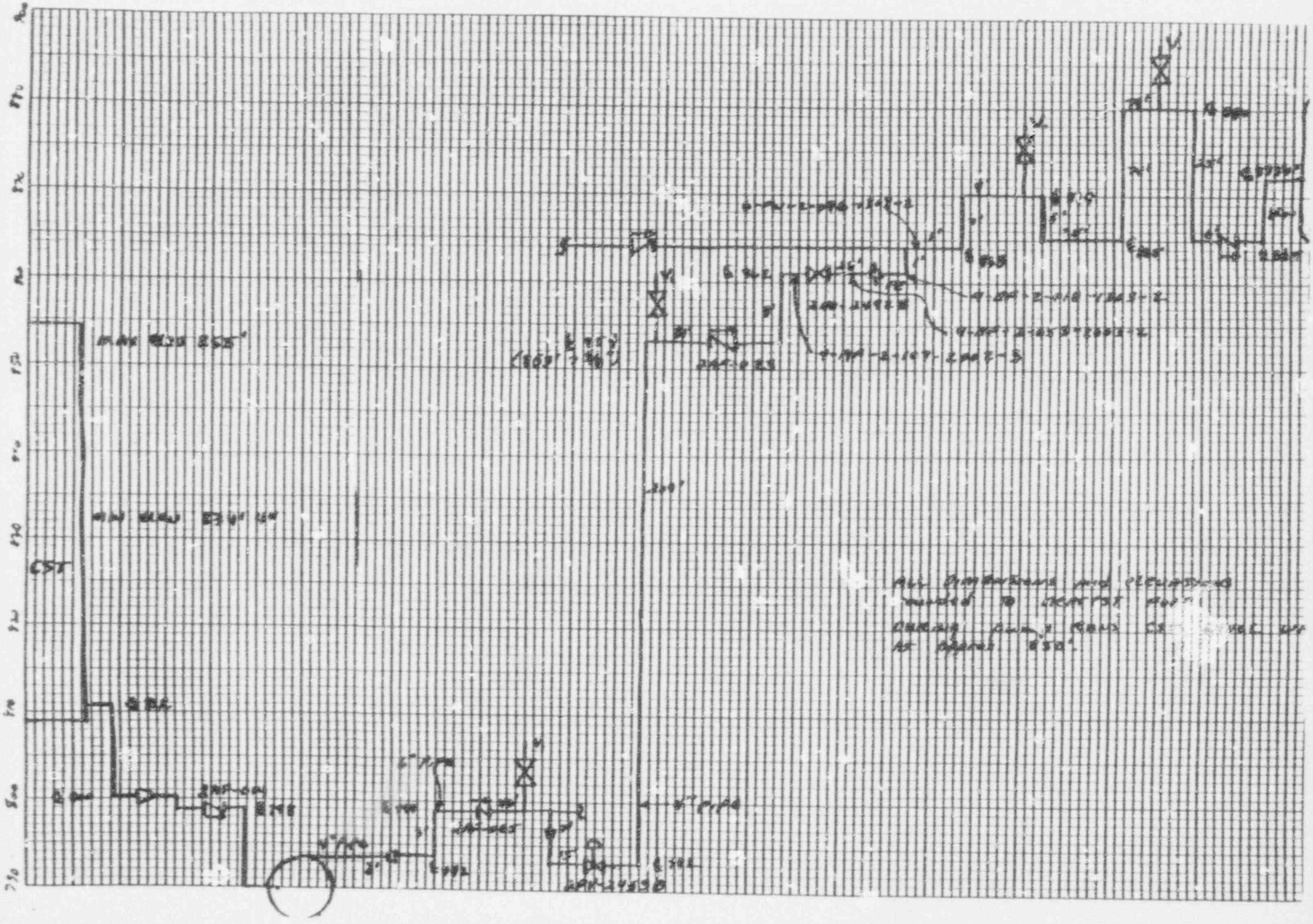

TU ELECTRIC

OFFICE MEMORANDUM

To: John Roberts

August 4, 1992

Subject: Damage to Unit 2 Auxiliary Feedwater Check Valve

This letter is in response to your discussion with my staff on August 4, 1992. The discussion addressed damage to check valve 2AF-0083 due to an inadvertent start of the Motor Driven Auxiliary Feedwater Pump. Questions were raised if adequate steps exist in SOP-304B, Auxiliary Feedwater Pump, to prevent this reoccurrence.

An evaluation was performed on SOP-304B for all modes of operation. The results of the evaluation are as follows:

Modes 1, 2, and 3

In Mode 1, 2 and 3, OPT-206B is performed to ensure system operability. The Motor Driven and Turbine Driven Auxiliary Feedwater Pump flow control valves are required to be fully open per Technical Specifications. In Mode 3, the fuses for the Main Feedwater Pump trip signal are removed which reduce the possibility of an inadvertent pump start. A manual start of the Auxiliary Feedwater Pumps with the control valves open would be a violation of procedure. In addition, the piping downstream of the check valves would be pressurized due to Auxiliary and Main Feedwater System operation. This would reduce the difference in pressure across the check valve which would in turn reduce the forces applied to the valve. Any back leakage of the check valves would be sensed by upstream temperature monitors.

Recommendation:

A change to SOP-304B for Modes 1, 2, and 3 is not required.

Mode 4

In Mode 4 the Motor Driven and Turbine Driven Auxiliary Feedwater Pumps flow control valves are fully open. The fuses for the Main Feedwater Pumps are removed in Mode 3 which reduces the possibility of an inadvertent pump start. A manual start of the Auxiliary Feedwater Pumps with the flow control valves open would be in violation of the procedure.

Recommendation:

A change to SOP-304B is not required. Changing the SOP to close the flow control valves in Mode 4 would misalign the Auxiliary Feedwater System prior to the transition to Mode 3. The fuses for the Main Feedwater Pumps are removed which reduces the possibility of an inadvertent pump start. In addition, the suggested change would increase the potential for system misalignment at a time when multiple activities are in progress during the Mode change.

Modes 5 and 6

In Modes 5 and 6, the Motor Driven and Turbine Driven Auxiliary Feedwater Pumps flow control valves are fully open. The SSPS is placed in Mode 5/6 which removes all automatic start signals from inadvertently starting the Auxiliary Feedwater Pumps. Due to a void that would exist upstream and downstream of the check valves, a manual start of the Auxiliary Feedwater Pump could result in check valve damage.

Recommendation:

Change SOP-304B to close the flow control valves in the Shutdown and Standby operations while in Modes 5 and 6. This would prevent an inadvertent pump start from possibly damaging the check valves.

If you have any questions or comments contact myself or Kit Wilson at extension 5443.

Jim Brau Oll
Supervisor, Operations Support

INTEROFFICE CORRESPONDENCE

TO:	LOC:	SUBJECT / REFERENCE / I.O. NO.
Glen Willey	245/9	CP2 - Pump Start Empty Column
FROM: Jim Sabin	LOC: 245/9	

MESSAGE:

As you requested, this IOC will document the data previously provided to you on the telephone regarding column rejoining following the AF motor driven pump start. Water hammer pressure waves created by void collapse can be determined by the Joukowsky equation $\Delta P = \rho a \Delta V$ and the impact force caused by over-pressurization after a void collapse is calculated by $F = \Delta P A$.

Where:

a = pressure wave speed (≈ 3715. fps)
ρ = density of the liquid (1.94 slugs/ft³)
ΔV = Velocity of the liquid just prior to impact (ft/sec).
(From the manufactures pump performance curve, the runout flow rate is ≈ 950 gpm = $0.408(950/3.526^2)$ = 29.48 ft/sec - for a 4" Sch 120 line)

$\Delta P = \{(1.94)(3715)(29.48)\}/144 = 1474.$ psi

$F = 1474(\pi(3.626^2)/4) = 15{,}220.$ lbs

July 24, 1992
DATE

James W. Sabin
SIGNATURE

7329
TELEPHONE

REPLY:

DATE

SIGNATURE

TELEPHONE