FINDINGS, CORRECTIVE ACTIONS AND GENERIC IMPLICATIONS REPORT

Title. Toledo Edison - Main Steam Header Pressure

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REV	DATE	REASON FOR REVISION	WRITTEN BY	APPROVED BY
0	8/27/85	Initial Issue	N. Moisidis L. Huston	L. Grime
1	8/30/85	Incorporate Sections VI, VII and VIII and Revised Plan Additional Actions C and E	N. Moisidis L. Huston	L. Grime
2	9/6/85	Additional Findings & Trouble-shooting Results Incorporated	N. Moisidis L. Huston	D. Mominee
3	10/3/85	Additional Findings & Trouble-shooting Results Incorporated	N. Moisidis L. Huston	L. Grime

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I. ISSUE/CONCERN

Following the plant trip on June 9, 1985, there were several periods during which steam header pressure dropped below the expected control pressure of either the atmospheric vent valves (AVVs) or the main steam safety valves (MSSVs). At one point the pressure decreased by approximately 150 psi on Steam Generator one (SG-1) header. Such a large pressure swing is unexpected. More important, if pressure swings were the result of equipment malfunctions that could cause depressurization of the steam generators, they could cause a trip of the main feedwater pumps (MFPs) followed by a loss of steam generator inventory and potentially loss of the ability to drive the steam-driven auxiliary feedwater pumps (AFPs).

An examination of the plant instrument pressure plots for both steam headers following the June 9th event revealed five instances when pressure decreased in an unexpected fashion. These are described below:

A. Issue No. 1:

During the period between 1:41:11 and 1:41:25, pressure in the header from SG-1 dropped from 942.4 psig to 924.5 psig while pressure in the header from Steam Generator two (SG-2) dropped from 1001.0 psig to 973.2 psig.

B. Issue No. 2:

During the period between 1:50:13 and 1:51:55, pressure in the header from SG-1 dropped from 934.7 psig to 749.6 psig.

C. Issue No. 3:

During the period between 1:36:09 and 1:38:54, pressure in the header from SG-2 dropped from 994.6 psig to 960.3 psig.

D. Issue No. 4:

During the period between 1:48:44 and 1:49:27, pressure in the header from SG-2 dropped from 980.0 psig to 927.5 psig.

E. Issue No. 5:

The steam pressure trends in SG-1 between 1:48:33 and 1:50:13 and in SG-2 between 1:46:43 and 1:48:44 are considered abnormal.

F. Other Concerns:

Examination of the pressure plots for both steam headers also revealed several instances in which the MSSVs did not operate as expected. In some cases, the indicated pressure at which

the valves opened was as much as 3.7% below the expected set
pressure. Specifications for new valves call for a 1% tolerance
on set pressure. In other cases, the steam pressure data
indicate that blowdown following valve opening was possibly as
little as 1.5% of the opening pressure. The expected blowdown
is 3%. Finally, there were some rapid pressure oscillations in
SG-2 header subsequent to MSSV closure. In all instances,
the MSSVs performed their required function in that they
limited steam pressure to below 105% of system design pressure,
and in all cases the MSSVs were reclosed. In no case were these 3
anomalies a cause of uncontrolled steam generator depressuriza-
tion. Therefore, they were not potential threats to the
operation of the main or auxiliary feedwater pumps. These
unexpected trends are being investigated, and their significance
to long-term operation will be assessed.

It was also noted that AVV-2 only came partially open at about
1:39 when the pressure in SG-2 header increased to the AVV
pressure control setpoint. Temperature data from the AVV
exhaust indicate the AVV did open but not fully as would be
expected since the header pressure ultimately increased to 3
approximately 1015 psig and caused the MSSVs to open. AVV-2
did operate properly under automatic control later during the
recovery from the reactor trip.

II. BASIC PRINCIPLE OF OPERATION

The basic purpose of the main steam system is to direct the steam produced by the once through steam generators to the turbine through the main steam piping. Steam produced in the steam generators removes heat from the reactor coolant system.

The main steam lines can be isolated (except for steam inlets to the auxiliary feedwater pump turbines) by closing the main steam isolation valves (MSIVs).

Following a turbine trip and closure of the MSIVs, eighteen spring loaded safety valves (nine per steam generator) will relieve steam to the atmosphere if steam pressure exceeds their setpoints. These valves are passive in that no automatic control functions nor operator actions are required for the valves to release steam and prevent overpressurization of the main steam system. The first bank of MSSVs is set to open at 1050 psig. Additional safety valve banks are set to open at pressures up to 1100 psig. The pressure relief capacity is such that the energy generated at the reactor high-power-level trip setting can be dissipated through this system.

The steam bypass system automatically controls the steam supplied to the condenser during startup while the turbine is being brought into service. It also provides the capability of automatically dumping 3
steam to the condenser during minor steam transients at any power level. Control signals for automatic operation of the bypass system

are provided by the Integrated Control System (ICS). The system may
also be controlled by the operator and used to manually dump steam 3
at any load level. The steam bypass system includes the turbine
bypass valves and one AVV on each steam generator header.

Following a turbine trip or MSIV closure, header pressure control is maintained by modulation of either the AVVs if the MSIVs are closed or the turbine bypass valves if the MSIVs are open. The AVVs relieve to the atmosphere and the turbine bypass valves relieve to the condenser.

The ICS is a combination of electric and electronically-operated devices designed to produce process variable outputs in accordance with desired or set point conditions. The system includes the following major components:

- Measuring element and signal conversion means
- Hand-Automatic selector stations
- Action unit controllers
- Power operators
- Valve or drive positioning systems

The system uses a standard signal range of -10 to +10 volts DC
throughout. All measuring elements and signal conversion means are
local. The Hand-Automatic selector stations are on the operator's
control board. Power operators are mounted at the valves or dampers 3
being controlled. Signal converters which convert the -10 to

+10 volt signal range to the pneumatic signal required by the power operators are mounted near the power operators. The controllers, signal manipulation devices, and alarm monitors are in the control cabinets.

The Hand-Automatic transfer station and its associated circuitry allow the operator to transfer either from "automatic to hand" or from "hand to automatic" at any time simply by depressing the correct pushbutton on the selector station. No balancing of the selector station is required. However, when transferring to auto-
matic control, it is necessary for the operator to insure that the
automatic signal is at the correct level since the automatic system 3
will, as soon as the transfer is made, begin to correct the position of the final control element as directed by the automatic signal.

The controllers are of a modular design and are identified as action units capable of producing one of the following control actions:
differentiation, integration, proportioning, summing, subtraction, 3
etc. Each action unit is a plug-in device which can be easily removed from the cabinet.

The electro-pneumatic converter is a force-balance device in which the electric signal moves a pressure sensitive vane by means of an electric coil. The resulting change in pressure is fed back through a booster relay to reposition the vane and change the output pres-
sure signal of the electro-pneumatic converter. The pressure signal 3
is then transmitted to a conventional pneumatic operator.

The ranging and biasing components provide, in addition to gain adjustment, changes to the ±10 volts DC signal range.

The AVVs are equipped with Fisher-type electro-pneumatic transducers 3
which receive a milliampere DC current electrical signal and transmit a proportional pneumatic output pressure to the AVV. An increase in the DC milliampere signal to the transducer coils increases the
output pressure to the AVV. 3

The AVVs also have positioners equipped with an input capsule that serves as a force-balance member to match the valve stem position to the control signal. An increase in the control pressure produces an increase in air pressure to the top of the actuator and a decrease
in pressure at the bottom of the actuator. This difference in 3
pressure will move the piston downward stretching a range spring until the spring tension balances the force resulting from the control pressure signal.

III. SUMMARY OF TROUBLESHOOTING AND INVESTIGATION

This section provides a summary of the troubleshooting and investigation of the large pressure swings experienced on both steam headers following the June 9, 1985 reactor trip.

Action Plan No. 16 provides some of the maintenance, surveillance,
and testing history of the AVVs and MSSVs prior to the June 9, 1985 3

trip. Also included in this report are the hypotheses determined to be the probable causes of the large pressure swings of both steam headers during the June 9, 1985 trip.

A. <u>Field Actions Performed</u>

Of the eight steps listed in Action Plan No. 16 report, the following have been performed:

1. <u>Step Number 1</u>: An inspection of the AVVs, turbine bypass valves, and ICS equipment associated with the steam bypass 3
system revealed no visual evidence of unusual or abnormal equipment conditions.

2. <u>Step Number 4</u>: Maintenance Work Orders 1-85-2190-00, 1-85-2344-00 and 1-85-2345-00 provided string checks of the Integrated Control System (ICS) modules which provide automatic control of the AVVs.

The testing was done in a manner that closely simulates the actual conditions under which the AVVs operate. For the specified input 3
voltages to ICS Modules 4-3-8 (AVV-1) and 4-3-9 (AVV-2), all measured voltages through the AVV control strings were as expected.

An operational check of the HS-SP12A and HS-SP12B hand/auto 3
stations was performed by energizing and de-energizing the component modules and verifying the voltage difference across the pins. The results of this check indicated that the stations were functioning properly.

Bench testing was performed on each module in the AVV ICS
channel. All modules, except Module 4-3-4 sum-plus-integral, 3
were found to function properly. Module 4-3-4 was found to give anomalous readings and had an improper gain. This module was sent to Bailey Controls for further troubleshooting (see item 4 below). The remaining modules were reinstalled in the ICS.

Operability and calibration checks of the steam header pressure transmitters were performed in accordance with the instructions for Surveillance Test 5036.03 (Section 6.1 only) for steam generator outlet pressure instrument strings SP12A1 and SP12B1. The output from the current buffers and voltage buffers were found to exceed the required tolerances by ±30 mv and ±20 mv respectively. However, the actuation pressures from both the pressure indicators and the computer printout were within the tolerances for both instrument strings.

3. Step Number 6: Maintenance Work Order #1-85-2693-00 provided for testing of eight of the eighteen MSSVs at Wyle Laboratories. The eight valves selected for testing were the four valves set to actuate at 1050 psig and the four valves set to actuate at 1070 psig. These valves were picked because they are subjected to the most demanding operational duty, i.e. their lower setpoint pressures cause them to be opened more often and to remain open longer than the valves with higher set pressures. Therefore, these valves were expected to provide conservative indication of any valve degradation that had occurred. All eight valves were subjected to full steam flow testing, and the following items were monitored: 3

   a. Actual valve setpoint

   b. Steam blowdown

   c. Steam leakage before actuation and after reseating.

   Each valve was actuated at least three times with no more than 10 minutes between each actuation.

   In order to successfully pass the above testing, each valve was required to meet the following conditions:

   a. The average actuation pressure for the three test lifts had to be within ±3% of the average actuation setpoint measured during the two surveillance test lifts performed at the last plant outage;

b. Valves whose average actuation pressure was not within ±1% of their nominal setpoint but were within the ±3% tolerance indicated above had to be adjustable to within ±1% as confirmed by two additional, consecutive test lifts;

c. Valve blowdown had to be no less than 2% and no 3
greater than 7% of the valve actuation pressure;

d. Valves whose blowdown was less than 3% or greater than 4% of the valve actuation pressure had to be adjustable to within this blowdown range as confirmed by two additional consecutive test lifts;

e. Valves could not exhibit any visual or audible evidence of leakage.

Valves failing any of the above conditions were disassembled, inspected for damage, and repaired.

Seven of the eight valves failed one or more of the specified test criteria. A variety of problems were found including worn/deformed guides, eroded valve seats, disc rock, gross valve leakage, and one bent valve stem. All seven valves are being repaired and reassembled.

4. Step Number 8: As mentioned above, during the ICS module string test, Module 4-3-4 (Bailey Catalog Number 6624151A1C) was found to give anomalous readings and to have an improper gain and was sent to Bailey Controls Company for testing. The testing included checks of the following:

   a. Physical appearance
   b. Power supplies
   c. Calibration and adjustment
   d. Heat test

   The schematic of the Bailey module is illustrated in Figure 1.

   The verification was performed in accordance with Bailey Product Instructions Section E92-60-2.

   The findings were:

   - The S3, S4, and S5 switches were corroded and very difficult to operate.

   - Resistances of 1.5-2.0 ohms were found across the closed contacts of switches S3, S4 and S5. Contact resistance of 0.0 ohms was expected.

- Bias voltage was found to be at the saturation level of the amplifier (output = +15.1 V as compared to an expected value of +10.0 volts).

Module 4-3-4 was returned to Davis-Besse. Additional testing
was conducted to determine the effects of the problems noted 3
above on AVV operation. The results indicated that Module 4-3-4
was not a cause of anomalous operation of AVV-2 following the
trip on June 9th.

B. Analysis Performed

1. A review of the Data Acquisition Display System (DADS) and
Sequence of Events Monitor (SEM) computer printouts 3
provided the following information:

    a. Alarm printouts from the limit switches on the AVVs indicated that following the June 9th trip the AVVs were open at the times shown in the following table:

	AVV-1		AVV-2		
Time	Position (Z961)	Pressure (P932)	Position (Z969)	Pressure (P936)	
1:35:37	Open	1072.8			
1:40:18	Closed	970.0			
1:40:23	Open	989.3			
1:41:04	Closed	912.8			
1:46:29	Open	1033.3			
1:48:01	Closed	945.3			
1:50:13	Open	934.7			
1:53:58			Open	976.4	
1:58:28	Closed	916.6			
1:59:35			Closed	892.0	
2:03:06			Open	970.5	
2:03:15	Open	972.0			
2:03:23	Closed	966.7	Closed	973.5	3
2:03:31	Open	978.2	Open	981.4	

b. The limit switch data in the above table indicate that AVV-2 did not open prior to 1:53:58; however, data from the AVV exhaust stack temperature monitors for the period immediately following the June 9 plant trip clearly indicate that AVV-2 was also open from approximately 1:48:20 to approximately 1:49:20 (data points were recorded only every 30 seconds).

It can therefore be concluded that either the SEM limit switches intended to detect operation of AVV-2 or the computer logging of the operation of these switches did not operate properly. This will be investigated.

c. The exhaust temperature data also indicate that AVV-2 was being controlled in a partially open position by

the ICS from approximately 1:39 until approximately 1:46. This is indicated by a slowly rising exhaust stack temperature on AVV-2 during this time period.

d. A review of the computer data indicated that AFP 3
turbine trip throttle valves were open as indicated below:

Time	AFP-1	AFP-2
1:46:27	Open	Closed
1:52:15	Open	Open
1:58:33	Closed	Open
1:58:56	Open	Open

Information from operators on shift on June 9th and the computer alarm logs indicate that all four AFP turbine steam admission valves (MS-106, MS-106A, MS-107, and MS-107A) were open throughout the time shown above. Therefore, steam to drive the AFP turbines was being taken from both steam generators after 1:46:27.

NOTE: The opening times for the AFP turbine trip
throttle valves are inferred from an indica- 3
cation of AFP speed; therefore, they may not be an exact measure of valve opening time. The closing time is based on indications from the "valve full open" limit switches on the valves. Also, during periods when the valves were open, they were being controlled locally by the equipment operators.

2. The following data were extracted from the review of the sequence of events:

At 1:41:11 the Steam and Feedwater Rupture Control System (SFRCS) Steam Generator No. 1 (SG-1) low level trip caused the Auxiliary Feedwater Pump (AFP) No. 1 to be aligned to draw steam from and provide feed to SG-1. Four seconds later the incorrect actuation of the SFRCS on low steam pressure isolated both Steam Generators preventing the auxiliary feed flow from reaching either Steam Generator. The immediate effect of steam flow to the AFPTs is a slight drop in header pressure. This was actually observed between 1:41:11 and 1:41:25 in both steam headers.

3. Calculations have been performed to explain the trend of the pressure transient from time 1:50:13 (AVV-1 open) to 1:58:28 (AVV-1 close). The calculations indicate that the pressure profile for SG-1 header can be obtained by consider-
ing that an AVV remained open (as indicated by the data in 3
Section III B.1) while the steam generator was partially refilled by the Start Up Feedwater Pump (SUFP) (flow for approximately 3.5 minutes at a capacity of approximately 150 gpm).

The secondary system operator stated in his interview with 3
the NRC that he reclosed AVV-1 when the steam generator pressure was dropping rather rapidly and unexpectedly

during the time when SUFP flow was initially being added to SG-1. However, the SEM computer data indicate that the valve remained open until 1:58:28. This implies that the operator reduced the AVV-1 flow but did not completely close the valve. This action combined with the added flow from the SUFP would cause the repressurization of SG-1. After the SUFP flow stopped, the pressure in SG-1 started to decrease again until AVV-1 was completely closed at 1.58:28.

4. The temperature downstream of the MSIV in steam line two was found to be consistently higher than the temperature downstream of the MSIV in steam line one. A comparison of temperature and pressure data in steam line two indicates that the steam in this line was superheated from approximately 1:45 a.m. until approximately 6:00 a.m. when the MSIV bypass valve was reopened and the steam line repres- 3
surized. Therefore it can be concluded that there was some leakage through either the MSIV or the MSIV bypass valve from SG-2.

   The magnitude of MSIV leakage is difficult to assess accurately. However, several actions were taken to determine 3
if the leakage was significant. First, a nitrogen leak test of the valve was conducted according to Davis-Besse System Procedure SP-1106.08. The test indicated that valve leakage is within specifications with the valve in its current cold condition. Second, Davis-Besse piping drawings

were reviewed to determine if there are pathways for large amounts of steam to be removed from steam line number two downstream of the MSIV. Only a 3/8" sample line and a supply line to the low pressure gland steam header were found. The supply line to the gland steam header contains a pressure reducing control valve which limits flow to the low pressure header. The sample line is normally isolated during operation.

Finally, since opening of the MSIV bypass valves at approximately 6:00 a.m. resulted in a rapid repressurization of the steam lines, a conservative calculation of the flow through the valve was performed to determine an upper limit on
leakage through the MSIV or bypass line. The calculation 3
indicated that the maximum flow through the bypass line is approximately 2.5 lb./sec. Leakage through the MSIV or the bypass valve was necessarily much smaller because the steam line did not repressurize prior to opening of the bypass line.

5. The operation of the MSSVs is dependent on the piping system natural frequency of vibration during a transient event. Following the plant trip on June 9, 1985, the steam headers can be expected to have experienced combined acoustic and frictional pressure fluctuations caused by the fast traveling waves. Preliminary evaluation indicates

that the fluid transient loads and the structural system response and support reactions on the steam headers may cause poor reseating of the MSSVs, valve opening pressures lower than valve set pressures and lower steam blowdown
than expected. A review of the steam header design for 3
both steam generators shows the following:

a. While the configuration of the steam headers is almost identical, the pipe support configuration between the two anchors enclosing the MSSVs and the MSIV is different. The header from SG-1 was provided with a lateral snubber (SR-47) as a result of an incorrect stress intensification factor that had been used in the seismic piping analysis for that header. The header from SG-2 has lower seismic loading and does not have this lateral snubber.

b. The Davis-Besse MSSV header design incorporates a non-symmetrical arrangement of valve exhausts. In addition, there are no supports provided to withstand thrust loading on the exhaust elbow. The combined effects of this design with the valve reaction forces during operation may contribute to valve fluttering.

It should be noted that the team investigating operator actions following the June 9th trip have indicated that safety valve chattering has been noted as a problem by the

operators. Preliminary indications are that, in order to assure proper reseating of the MSSVs, operators have developed the practice of manually reducing header pressure subsequent to trips by using the AVVs.

6. Nalco Chemical Co. performed an analysis of the corrosion found on the switches of ICS Module 4-3-4. The corrosion was found to consist primarily of magnesium, aluminum, silicon, sulfur and chlorine; however, no conclusion could be reached as to the source or cause of the corrosion.

   Examination of other ICS equipment uncovered additional
   corroded elements in circuits not related to the AVVs. The 3
   investigations also indicated that only modules containing bias circuits, integrators and/or switches seem to be susceptible to the corrosion phenomenon.

7. Energy balance calculations were performed on each steam generator at several points during the period between 1:36:09 and 1:38:54. During this period, the pressure in SG-1 was being controlled by AVV-1, but the pressure in SG-2 was decreasing. Also, the feedwater flow being supplied to SG-2 through the startup feed control valve was generally 20% - 50% greater than the flow being supplied to SG-1. The energy balance considered decay heat, reactor coolant pump power, and the energy required to heat incoming feedwater. The calculations indicate that the larger feedwater

flow to SG-2 presented a significant additional heat load to that unit. Also, since level in both generators was constant during this period, all feedwater entering the steam generator is assumed to have exited either through the AVVs or MSSVs (or compensated for shrinkage of fluid in SG-2 as its temperature dropped). 3

C. Significance of Findings

1. Issue No. 1:

The findings relative to the drop in steam pressure in SG-1 & 2 headers at 1:41:11 indicate that this pressure drop was the result of steam flow out of SG-1 and SG-2 to the AFPs following the SFRCS actuation. The pressure drop lasted for only fourteen seconds and is thought to represent the time required to pressurize the AFP steam supply line. A detailed thermal-hydraulic analysis indicates that the pressure drop in the AFPT steam supply lines should be 3 expected to last approximately 15 to 16 seconds when both admission lines are opened.

2. Issue No. 2:

The findings relative to the drop in header pressure from SG-1 during the period between 1:50:13 and 1:51:55 indicate that this pressure drop was the result of:

a. Prolonged manual control of AVV-1 by the reactor operator;

b. To a small degree to the steam flow being provided to the AFP turbines subsequent to 1:46:27.

The repressurization beginning at 1:51:55 was due to water being added to SG-1 by the SUFP, as well as a manual reduction of AVV flow by the operator. After SUFP flow was stopped, pressure in SG-1 header once again began to decrease because the AVV was still open. The decrease in header pressure ended at 1:58:28 when the AVV was closed.

3. Issue No. 3:

The energy balance calculations indicate that several factors produced the decreasing pressure in SG-2 between 1:36:09 and 1:38:54. Higher than necessary feedwater flow
being supplied through the startup feed control valve 3
acted to cool the generator. The energy necessary to heat up and convert this water to steam was greater than the energy being added to the steam generator from the primary system. Since level remained constant during this period and since AVV-2 was not opened by the ICS, the flow being added to SG-2 is assumed to have escaped through MSSVs that did not reseat properly following their initial actuation at the time of the plant trip. As a result of both of these factors, the pressure in SG-2 header decreased.

The decreasing pressure trend continued until feedwater flow was significantly reduced at approximately 1:39, greatly reducing the heat removal from the generator and causing pressure to rise and reopen the MSSVs.

Steam leakage through either the MSIV or the MSIV bypass valve from SG-2 would contribute to the pressure drop during the period between 1:36:09 and 1:38:54 as well as during other time periods. However, this effect was determined to be small both because there are no significant steam leakage paths downstream of MSIV-2 and because the pressure in the steam line dropped and stayed below 600 psig for several hours after the plant trip. Additionally, performance testing indicates that valve leakage is currently 3
within specifications, and prior to this test the valve had not been operated since it was closed on June 9.

The magnitude of MSIV leakage can also be bounded by considering the bypass valves around the MSIVs. The bypass valves around both MSIVs were opened several hours after the June 9 trip in order to heat the steam lines and operate the turbine bypass valves. The rapid increase in steam line pressure when these valves were opened provides a basis for assessing the leakage through MSIV-2 or its bypass valve. The bypass valves are 1" valves and are installed in 3/4" lines around each MSIV. Therefore, the flow through

these lines is small. However, the steam pressure data
from June 9th indicate that pressure downstream of the
MSIVs increased at rates of 15-20 psi/min. when the valves
were opened. Since pressure in the steam lines had remained
below 600 psig for several hours prior to opening of the
bypass valves, it can be concluded that leakage through
either MSIV-2 or its bypass was very much smaller than flow
through the 3/4" bypass lines when the bypass valves were
opened. This is additional verification that MSIV leakage 3
had a negligible effect on the SG-2 header pressure between
1:36:09 and 1:38:54.

Finally, operators on shift during the June 9th event indicated that MSSVs did not reseat properly after the trip and that they used the AVVs to lower steam generator pressure in order to properly reseat these MSSVs. Pressure data from the SG-1 header support this fact. The decreasing pressure in SG-1 beginning about 1:38:20 is interpreted to be the result of a manual reduction of the AVV pressure control setpoint by the operator in an attempt to reseat MSSVs.

4. <u>Issue No. 4</u>:

Temperature data taken from the exhaust stack of AVV-2 clearly show that AVV-2 was opened during the period between approximately 1:48:20 and 1:49:20 even though indications of valve operation from the SEM limit switches

cannot be found in the computer alarm log. This fact is also consistent with statements from the operators that they were manually controlling the AVVs during this period of the recovery following the June 9th trip. Operation of the AVV would cause a rapid decrease in SG-2 header pressure during this period. 3

5. Issue No. 5:

The opening times of both the AVVs and the AFPT trip throttle valves indicate that the pressure trends in SG-1 header between 1:48:33 and 1:50:13 and in SG-2 header between 1:46:43 and 1:48:44 were a result of steam flow being provided to the AFP turbines. The trip throttle valve to AFP-1 was opened at 1:46:27 and steam from both steam generators was supplied to AFPT-1. At this time AVV-1 was also open and pressure in SG-1 header was decreasing. At 1:48:01 the AVV was closed; however, AFP-1 continued to run and take steam from both SGs. The combined effects of steam flow to the AFP turbine and the decreasing water inventory in SG-1 caused the observed pressure trend in SG-1. Similar effects occurred in SG-2 header. The only difference is that AVV-2 was not open 3 when AFP-1 was started, and therefore, the effects of the steam flow on SG-2 pressure can be observed very shortly after AFP-1 was started ($\cong$ 16 sec.).

IV. RESULTS/CONCLUSION OF FINDINGS

A. Direct Causes

1. Issue No. 1:

The drop in steam header pressure on both steam generators
between 1:41:11 and 1:41:25 was the direct result of steam
being supplied from both steam generators to the AFP 3
turbines following SFRCS actuation. The drop in pressure
and subsequent recovery are attributed to the transient
pressurization of the AFP turbine steam lines.

2. Issue No. 2:

The direct causes of the large pressure swing between 1:50:13 and 1:58:28 are:

a. Prolonged relief through AVV-1 due to operator action;

b. To a lesser degree the effects of steam being provided to the AFP turbine;

c. To the water supplied to the SG-1 by the SUFP which caused the repressurization starting at 1:51:55.

d. Action by the operator at about 1:51:30 to reduce AVV-1 flow.

3. <u>Issue No. 3</u>:

The direct cause of decreasing pressure in SG-2 between
1:36:09 and 1:38:54 was the combined effect of cooling
of the generator by feedwater being supplied through the
startup feedwater control valve and leakage through the 3
MSSVs. The amount of feedwater supplied through the startup
control valve following a plant trip is controlled by the
rapid feedwater runback (RFR) signal from the ICS.

4. <u>Issue No. 4</u>:

The pressure drop in SG-2 header between 1:48:44 and 1:49:27 was due to operation of AVV-2. Temperatures in the exhaust stack confirm this. However, computer logs from the limit switches that indicate AVV-2 position did not show the valve to be opened during this time. Therefore, further investigation of the ICS and limit switch indications will be performed to determine the cause of this discrepancy.

5. Issue No. 5:

The unexpected pressure response of SG-1 header between 1:48:33 and 1:50:13 and SG-2 header between 1:46:43 and 1:48:44 are due to steam flow being provided to the AFP turbines. 3

6. Other Concerns:

The set pressure variations and steam blowdown variations of the MSSVs were the result of mechanical degredation of the MSSVs. Mechanical problems found when the MSSVs were inspected included worn/deformed guides, valve seat erosion, disc rock, and, in one case, a bent valve stem.

The rapid pressure oscillations associated with the MSSVs may also be a result of some of the mechanical problems discovered; however, the structural evaluation performed on 3 the headers indicate that these oscillations could be the result of MSSV flutter. This is being investigated.

The partial actuation of AVV-2 at approximately 1:39 when the pressure in SG-2 header first increased to the MSSV actuation pressure is expected to be the result of either sluggish operation or incorrect adjustment of amplifiers in the ICS. These questions are being addressed through additional testing of the ICS.

B. Root Causes

The root causes for issues number 1, 2, 4 and 5 are the same as
the direct causes indicated above. The pressure trends in the
headers are the expected thermal-hydraulic responses for the 3
steam generator conditions, equipment operation, and operator
actions that occurred during the indicated times.

A root cause of issue number 3, in addition to degradation of
the MSSVs, is the RFR control settings for the startup feed con- 3
trol valve supplying SG-2. The control system is supplying more
feedwater to this generator following a trip than is needed.

C. Disapproved Hypotheses

Action Plan No. 16 dismissed the hypothesis that pressure drops
in the steam headers were due to steam flow past the MSIVs
(Hypothesis No. 4). At present there are data which indicate
that there is MSIV leakage. However, investigations that have 3
been performed indicate this leakage is insignificant.

D. New Hypotheses

Some of the unexpected pressure trends in the steam headers
following the June 9th trip were the result of steam flow 3
to the AFP turbines.

V. Planned Additional Actions

The following additional actions are planned in order to complete the direct/root cause determinations.

A. Issue No. 1:

No further actions are planned.

B. Issue No. 2:

No further actions are planned.

C. Issue No. 3:

No further actions are planned.

D. Issues No. 4:

Proper functioning of the alarm points Z961 and Z969 that
provide position status of AVV's will be ensured. Other 3
limit switches which may affect AVV operation will be
determined. To ascertain proper operation of this equip-
ment, investigation and troubleshooting will be performed,
including disassembly if required (see Step No. 3 from
Action Plan No. 16 report).

E. Issue No. 5:

No further actions are planned.

F. Other Concerns:

1. Toledo Edison will disassemble, inspect, repair as
necessary, and adjust the remaining 10 MSSVs. This will
be done in the presence of representatives from the valve
vendor and will include visual inspections, dimensional 3
checks, and adjustment. Any necessary repairs will
include correction or replacement of deteriorated parts.
All valves will then be sent to Wyle Laboratories for
testing to confirm proper operation before the valves are
reinstalled in the plant.

2. Proper settings of setpoint pressures of all MSSVs will be confirmed by performing Surveillance Test Procedure ST 5070.01 during the next plant startup.

3. A review of the fluid transient loads following a turbine 3
trip event and the structural system response and support
reactions will be performed. The effects of piping feed-
back forces on main steam safety valve operability during
valve actuation will be assessed. For this review, both
thermal-hydraulics and steam line piping analyses will be 3
used and additional materials such as piping modeling,

assumptions made, and fluid transient and structural dynamics computer analyses will be reviewed. This review may 3
also identify causes for MSIV leakage from SG-2 header.

4. A review of the operability data of spring-loaded self- 3
actuating MSSVs used for overpressure protection in other nuclear plants will be conducted. The review will focus on:

   a. set pressure tolerance
   b. blowdown
   c. leakage

5. Additional checks of the ICS modules which provide automatic control of the AVVs will be performed to
determine the cause of poor AVV control on SG-2 header at 3
approximately 1:39 following the June 9th trip. This will include testing while the AVV is operated.

6. If the actions noted above indicate a need for additional information, a program for monitoring and analyzing operating conditions which could contribute to degradation of the ICS and MSSVs will be developed (See Step No. 7 from Action Plan No. 16 report).

VI. Technical Justification of Findings

A. Issue No. 1

Steam flow to the AFPTs is physically similar to operation of a pressure control device such as an AVV or MSSV. Steam exiting the SGs to pressurize the AFPT steam lines and drive the turbines will cause pressure in the SGs to decrease. This is particularly true when the SG water level is low and limits the amount of steam that can be generated via energy extraction from the reactor coolant system. Thermal-hydraulic calculations using detailed computer models indicate that startup of a Davis-Besse AFPT in the configuration that occurred on June 9 should cause a pressure decrease lasting approximately 15-16 seconds. This decrease is followed by a pressure recovery as the AFPT lines pressurize and the AFPT comes up to speed. The actual time seen in the pressure trends on June 9 was approximately 14 seconds. Therefore, it can be concluded that this trend is the transient effect of AFPT startup.

B. Issue No. 2:

The interviews with the operator that were held immediately following the June 9 trip revealed that AVVs were being controlled manually during the period between 1:50:13 and 1:51:55. Moreover, the computer logs indicate that AVV-1 was open from 1:50:13 until 1:58:28. The operator on shift also stated that

he closed AVV-1 when he saw SG-1 pressure dropping very low. While these actions were occurring, the water level in SG-1 was very low indicating a dry or nearly dry unit. Additionally, during this period flow from the SUFP was added to SG-1. Calculations confirm that the water added to a dry or nearly dry steam generator in conjunction with reduction in flow through AVV-1 can account for the repressurization of SG-1 that occurred at approximately 1:51:30. Thus, it may be concluded that the combined effects of AVV operation under manual control and the addition of water to a dry or nearly dry SG explains the large pressure swing in SG-1 header from 1:50:13 until 1:58:28.

C. Issue No. 3

Supplying excessive amounts of feedwater to a steam generator is a well-recognized cause of overcooling and depressurization of steam generators. Feedwater is typically on the order of 100°-150° subcooled when entering the steam generator. Thus, significant energy is required just to raise the temperature of the water to steam generator conditions. Additionally, under the conditions that existed between 1:36:09 and 1:38:54 on June 9th, much of the water was also being converted to steam because of leakage through the MSSVs thereby causing an even greater amount of energy to be extracted from the steam generator. The combined energy extraction of these two effects was greater than the energy being added to SG-2 from the reactor coolant system, and, as a result, pressure in the unit decreased. 3

D. Issue No. 4 3

As noted above, operators were manually controlling the AVVs shortly after the plant trip on June 9. Although limit switch position indication on AVV-2 did not show AVV-2 to be open between 1:48:44 and 1:49:27, the exhaust stack temperature clearly indicates the valve was relieving significant amounts of steam during this time. Additionally, the pressure trend shows characteristics that are essentially identical to other periods of decreasing steam pressure when the AVVs are clearly indicated as being open both by exhaust stack temperature and limit switch position indication. Thus, it may be concluded that this pressure trend was the result of manual operation of AVV-2 by the operators

E. Issue No. 5 3

Information compiled about operation of the AFPTs following the June 9 trip indicates that steam was supplied to the AFPTs from both SGs starting at 1:46:27. Subsequent to this time, the measured water level in each SG indicated that the units were dry or nearly so. Thus, there was limited capability to maintain steam pressure in either unit at any time when steam was being extracted. The trends between 1:48:33 and 1:50:13 in SG-1 header and between 1:46:43 and 1:48:44 in SG-2 header illustrate this effect as a result of steam being supplied to the AFPTs.

The causes of the steam header pressure anomalies observed on June 9th have been established. Further investigation and 3 analysis of MSSV operation and degradation is being done.

VII. Specific Corrective Actions

A. Required Corrective Actions

1. Issue No. 1

No corrective action is necessary. The steam header pressure trends between 1:41:11 and 1:41:25 are normal for the conditions that existed during that time.

2. Issue No. 2

No corrective action is necessary. However, operator practices relative to manual AVV control following plant trips are being reviewed. Operator training will reinforce the proper actions and acceptability of manual pressure control post-trip. This is being done as part of Action Plan 3.

3. Issue No. 3

Prior to plant restart, the AVV controls and RFR control setpoints will be evaluated and, if necessary, adjusted to 3 prevent over feeding of SG-2 following a plant trip.

As described in Sections III.A.3 and V.F.1, MSSVs will be disassembled, inspected, repaired as necessary, and 3
adjusted. All MSSVs will be flow tested to insure proper operation.

4. Issue No. 4

No corrective action is necessary. However, operator practices relative to manual AVV control following plant trips are being reviewed. Operator training will reinforce the proper actions and acceptability of manual pressure control post-trip. This is being done as part of Action Plan 3.

5. Issue No. 5

No corrective action is necessary. The steam header pressure trends between 1:48:33 and 1:50:13 in SG-1 and between 1:46:43 and 1:48:44 in SG-2 are normal for the conditions existing during those times.

6. Other Issues

See VII.A.3 above.

Module 4-3-4 in the ICS string controlling AVV-2 will be 3
replaced.

B. Additional Planned Actions

1. Additional testing of the ICS modules controlling operation of AVV-2 will be performed to determine the cause of improper operation of this valve at approximately 1:39 on June 9th.

2. Preventive maintenance procedures to inspect and, if necessary, replace all components of the AVV control strings that are susceptible to corrosion will be established and implemented prior to the next refueling outage.

3. Other corrective actions to improve MSSV operation, if needed, will be defined after the evaluations described in Section V.E. are completed. 3

VIII. Generic Implications

A. Significance

Contact corrosion, as was found in Module 4-3-4 of the AVV controls, may also effect other control modules.

B. Planned Actions

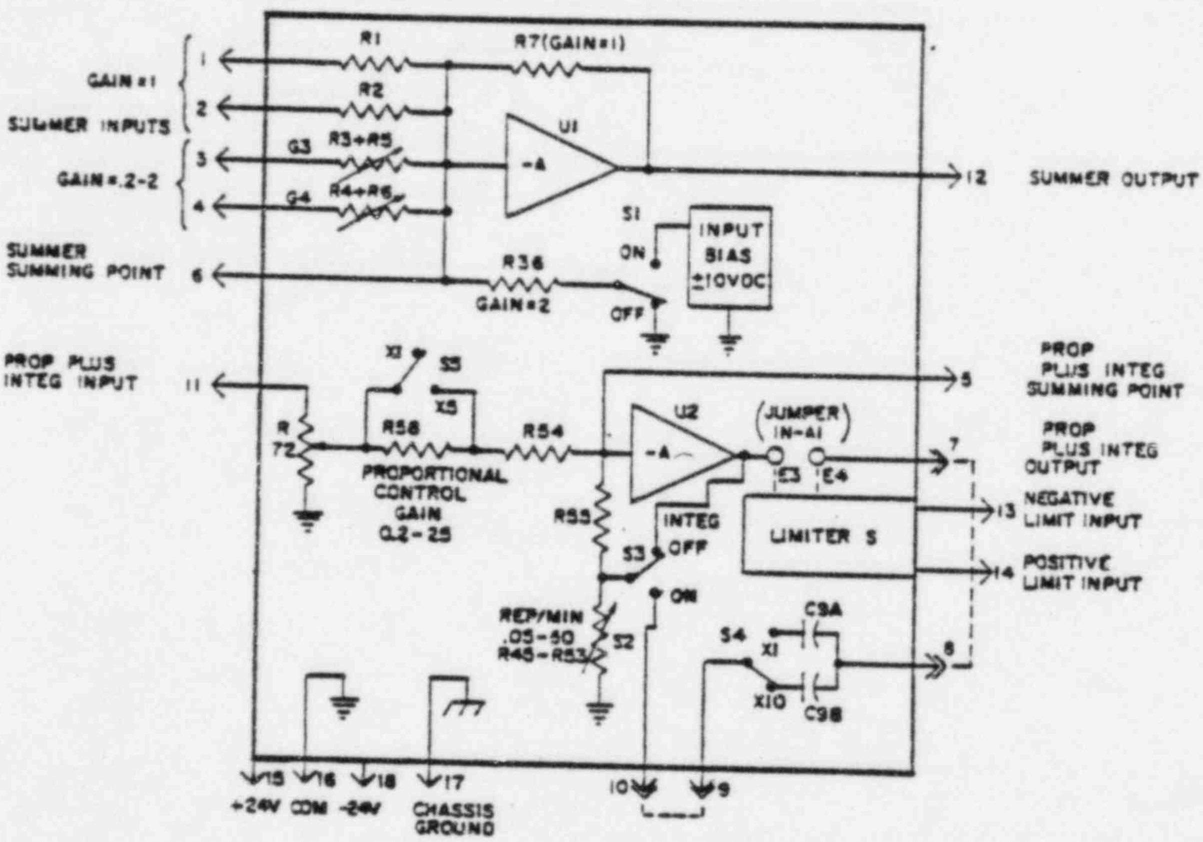
The need to periodically inspect and replace components that are susceptible to corrosion in all ICS control channels will be evaluated to determine if preventive maintenance procedures 3
should be applied to other control equipment besides the AVVs.

bj c/18

Figure 1

MODULE

BAILEY CATALOG NO. 6624151A1C



Simplified Schematic of Module 4-3-4

Locked Valves

Numerous valves throughout Davis-Besse are locked in their desired
position using chains and padlocks. This action was taken to comply with
a TED NUREG 0737 commitment to prevent unauthorized operation which could
render systems unable to perform their emergency function. As demon-
strated by the experience gained during the June 9 event, however, this
need must be balanced against the possibility that valves may have to be
manually repositioned quickly in emergency situations. To assure both
needs are met, availability of locked valve keys will be improved. Each
of the four plant zone operators will be provided with an
emergency-use-only keyring which contains a locked valve key. This
keyring will be turned over to the oncoming operator as part of shift 2
relief. Under normal circumstances, the current administrative controls
will govern the operation of locked valves. In an emergency, plant
operators will have immediate access to locked valve keys for
repositioning locked valves. This corrective action will retain a proven
method of control, developed from Davis Besse and nuclear industry
experience, yet will allow operators to readily reposition valves in an
emergency.

Security Door Access to Vital Areas

Vital areas within Davis-Besse are secured using key card readers controlled by a central security computer. Problems have been experienced with card readers in the past. To prevent these problems

from precluding emergency access, several actions have been evaluated and implemented. The results of these evaluations and details of implementation will be submitted as they are completed in accordance with applicable safeguards procedures.

APPENDIX C.3.3 - SINGLE FAILURE EVALUATIONS OF ENGINEERED SAFEGUARD SYSTEMS 2

Evaluations of the Reactor Protection System (RPS) and Engineered Safety Features Actuation System (ESFAS) are in progress. The results of these evaluations will be included in this Appendix following completion.