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[1] This report is provided in Appendix C.1.3
[2] This report is provided in Appendix C.1.2

FINDINGS, CORRECTIVE ACTIONS, AND GENERIC IMPLICATIONS REPORT

TITLE: Overspeed Trips of the Auxiliary Feed Pump Turbines on 6/9/85 at Toledo Edison's Davis-Besse Nuclear Power Station

REPORT BY: Dan Wilczynski
Chuck Rupp

PLAN NO. 1A & 1B/1C

REV	DATE	REASON FOR REVISION	WRITTEN BY	APPROVED BY
0	8/31/85	Initial Issue	Wilczynski Rupp	L. A. Grime
1	9/09/85	General Correction	Wilczynski Rupp	L. A. Grime (signature)
2	9/16/85	General Corrections	Wilczynski Rupp	L. A. Grime (signature)

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I. INTRODUCTION

A. Purpose

This report documents the troubleshooting and investigative actions performed to identify the root cause of the overspeed trips of the Auxiliary Feed Pump Turbines (AFPTs) at Davis-Besse on 6/9/85. Also presented in this report are the proposed corrective actions to eliminate the cause of the overspeed trips and a summary of the proposed confirmatory testing to ensure proper system operation.

Mode 3 testing which attempts to recreate the overspeed conditions is no longer considered to be necessary or advisable. This conclusion is based on several factors:

1) Induction of water can be defined as root cause. Discussions with the vendor and the experience at other plants utilizing Terry Turbines provide confidence in the root cause identification. Several other plants have experienced similar problems with AFPT overspeed and have implemented corrective actions to eliminate water induction.

2) Possible equipment damage. Prior to 6/9/85, Toledo Edison discovered damage to pipe supports on the steam inlet lines to the AFPTs which was attributed to the water slugs created by steam condensation in the lines. Recreation of the 6/9/85 overspeed has the potential of damaging components, piping, and/or supports. Also, overspeed of the AFPTs could result in equipment damage or personal injury if the overspeed protection were to fail.

3) The uncertainty of event recreation. Analysis by Toledo Edison personnel and consultant engineers has concluded that the dynamic situation that resulted in AFPT overspeed is sensitive to many different variables. Exact duplication of the 6/9/85 event will not be possible. Therefore, the probability that AFPT overspeed could be achieved during Mode 3 testing is not certain.

B. Event Description

On Sunday, June 9, 1985, normal feedwater flow to the steam generators was interrupted. The reactor was automatically shutdown and reactor heat was removed via steaming through the main steam safety valves and the atmospheric vent valves. The water level in the steam generators was decreasing and at 1:41:03 a Steam and Feedwater Rupture Control System (SFRCS) full trip was initiated on Channel 1 due to a low water level in Steam Generator #1 (SG #1). This SFRCS actuation attempted to initiate auxiliary feedwater flow by opening the steam supply valve, MS 106, from SG #1 to auxiliary feedwater pump turbine (AFPT) #1 (See Figure 1). Five seconds after the initial SFRCS actuation (1:41:08) the reactor operator inadvertently initiated

an SFRCS low pressure trip on both channels and both steam generators. This low pressure trip of SFRCS is intended to respond to a steam line break or other equipment failure resulting in depressurizing a steam generator. The manual low pressure SFRCS trip initiated the following, as designed:

1. Sent a close signal to MS 106 (which had an open signal at the time) and MS 107 (which was closed at the time).

2. Sent a close signal to AF 608 and AF 599, containment isolation valves on auxiliary feedwater path to steam generator #1 and #2, respectively.

3. Sent an open signal to MS 106A (steam supply for AFPT #1 from steam generator #2) and MS 107A (steam supply for AFPT #2 from steam generator #1) in an attempt to operate both AFPTs on opposite SGs.

4. Sent an open signal to auxiliary feed pump discharge valves AF 3869 and AF 3871.

5. Sent a close signal to auxiliary feed pump discharge valves AF 3870 and AF 3872.

Each AFPT tripped on overspeed (4500 RPM) approximately 25 seconds after initial roll.

II. BASIC OPERATION OF OPERATION

The Auxiliary Feedwater System (AFWS) is required to provide feedwater flow to the steam generators (SGs) upon loss of the main feedwater pumps or upon loss of all normal or reserve electric power to remove decay heat and/or promote natural circulation.

The AFW system consists of two separate pumps and turbine drivers. The turbines receive main steam from either steam generator, depending on the emergency actuation signal supplied by SFRCS. The normal steam supply paths are; SG #1 supplying steam to AFPT #1 through MS 106 and SG #2 supplying steam to AFPT #2 through MS 107. In the case of a low pressure condition in a steam generator, the system is realigned to isolate the bad generator and the good generator will supply steam to either AFPT through the cross connect valves (MS 106A and MS 107A).

The AFPTs at Davis-Besse are Terry Steam Turbines. The #1 AFPT was equipped with a Woodward model PG-PL governor and the #2 AFPT was equipped with a Woodward model PGG governor.

III. SUMMARY OF TROUBLESHOOTING AND INVESTIGATIVE ACTIONS

A. Change Analysis

In order to determine the reasons for the 6/9/85 overspeed trips a change analysis was performed to compare the operation of the

AFPTs on 6/9/85 to past quick starts of the system. The change analysis reviewed five previous plant trips (3/2/84, 1/15/85, 3/21/85, 4/12/85, 6/2/85) as well as several surveillance tests (STs) to attempt to identify a distinguishing factor between 6/9/85 and other system operations.

The one difference that was found was that the 6/9/85 plant trip was the first time that the AFPTs were run solely on the cross connect steam supply lines. Also, 6/9/85 was the only actual overspeed trip of the AFPTs at Davis-Besse.

During the change analysis phase, maintenance and modification records were checked to determine whether there was any work performed prior to 6/9/85 that could have caused an overspeed to occur. This review did not reveal any evidence that could support the overspeed trips.

B. Data Search

1. Investigation of Other Utility Experience with Overspeed Trips

Problems with overspeed trips of Terry Turbines is not unique to Davis-Besse. Nuclear Power Experience (NPE) includes descriptions of turbine overspeed incidents at three plants which have been attributed to condensation in the steam supply lines to the turbines. The major features of these incidents as documented by NPE are discussed in this section.

In addition to the incidents which were directly attributed to condensation, there are other instances of actual turbine overspeed (as contrasted to spurious overspeed trips). These are generally attributed to governor valve malfunctions or improper adjustment. In most cases, these incidents appear to have been the result of specific malfunctions of the governor such as clogged or dirty oil, miscalibration, corrosion, or faulty electronics. It cannot be established whether condensate or condensation during startup may have also had some effect on these other incidents.

Plant #1

In June of 1977, the turbine drive auxiliary feed pump (EPF-2) tripped on overspeed upon initial start in a surveillance test. A new governor was installed; however, the problem persisted. The cause of the problem was then attributed to condensation in the steam line. Modifications were made to the drain system to increase its capacity. Subsequent multiple starts from cold conditions showed that the problem had apparently been corrected. However, on July 17, 1977, the main feed pumps tripped and upon auto start of the auxiliary feed pump EFP-2, that pump tripped

on overspeed. The turbine was reset and the immediate restart was successful. Subsequent first start overspeed trips were experienced on July 22, 23, 25, and August 1. The cause was determined to be condensation buildup in the steam inlet lines. In addition to the previous modifications of the drain system, a bypass valve was installed to prevent condensate buildup. Satisfactory operation of the turbine was demonstrated.

Plant #2

In July of 1979, the turbine for auxiliary feed pump 2P7A tripped when it was started automatically by an Engineered Safeguards Features Actuation System (ESFAS) signal. It is stated that the overspeed trip was due to water in the steam supply line. Water was blown from the line and the turbine was successfully started three times. In September of 1979, the turbine for auxiliary feed pump 2P7A was manually started and the turbine tripped on overspeed. The turbine was then restarted three times to verify its operability. The apparent cause was stated as water in the steam supply header. Additional drains were installed. These additional drains were evidently not completely successful since in April, 1980, the turbine for feed pump 2P7A again tripped when it was started in response to an ESFAS actuation. The turbine was successfully restarted on three successive starts after the overspeed.

However, on October 11, 1981, steam driven emergency feedwater pump 2P7A tripped on overspeed following a manual start during a unit trip recovery. This overspeed trip was attributed to condensation in the steam lines which resulted from insulation not being reinstalled and a steam trap remaining isolated after a maintenance activity. The insulation was replaced and the trap was placed back in service. Also, the trap bypasses were opened to ensure that condensation would not occur in the lines. Pump 2P7A was tested, found operable, and returned to service.

Plant #3

On August 25, 1982, it was found that the drive turbine for auxiliary feed pump 2P-140 was tripping on overspeed during starting. It is stated that the tripping was caused by condensate in the steam supply header and throttle valve. Some drains were modified to improve their effectiveness.

Although the investigations by other plants into similar problems with overspeed of Terry Turbines upon startup have not been definitive as to the mechanism by which water causes the turbine to overspeed, they appear to strongly indicate that condensate in the steam lines is detrimental to turbine operation. Their approaches to corrective action have been to reduce the amount of condensate and in

some cases to keep the lines hot by bypasses or repeated starting of the pumps.

2. Vendor Experience

Discussion between MPR Associates and Terry Steam Turbine (the turbine supplier) have revealed that water induction to the turbine can indeed cause an overspeed condition. The relationship to overspeed is based on Terry Turbine's knowledge of turbine design as well as some testing performed in 1969. The testing involved injecting quantities of water into the turbine to verify the turbine's ability to withstand the water. One of the observations during testing was that turbine speed increased after the water had cleared the governor valve. Although no testing data is available, the information below describes the testing based on discussions with Terry Turbine personnel involved with the test.

The initial set of tests involved operating the turbine on steam, injecting cold water into the pipe upstream of the turbine, and observing the turbine response. The amount of water was varied between 50 and 600 gallons. During the transient, turbine speed and governor valve position were measured. The turbine behavior is described below:

> As the slug came through, the turbine speed began to fall. The turbine control, or governor, began to develop an error signal due to the speed decrease and attempted to further open the governor valve. However, apparently because of the effect of water flowing through the valve, the valve was not able to respond to the control signal. Terry refers to this as "waterlock" of the valve. Speed continued to fall until the slug was cleared, at which point steam was applied to the turbine and the valve could respond. Since an error signal was present, the valve opened causing a rapid acceleration of the turbine. Terry said that the turbine speed would increase quickly and overshoot before settling back to the demanded speed. The overspeed trip in these tests was set higher than normal, so they observed no overspeed tripping of the turbine. But they did see large overshoots in speed as the water slug cleared.

The final set of tests involved quick starting the turbine with 600 gallons of water initially in the inlet lines. A valve was opened to admit high pressure steam behind the water slug to force the slug through the turbine. It is not known whether the governor valve started fully open or was opened simultaneously with the steam supply valve. Turbine response is described below:

The turbine accelerated as the water was forced through the machine. The governor gained control of the acceleration. When the water was expelled and steam was applied to the turbine, there was an increase in turbine speed but the governor was able to maintain control.

The Terry Turbine Company representative has said that the governor valve used in the testing was not the same design used at Davis-Besse. The valve in the tests is thought to have been more susceptible to being affected by hydraulic forces due to water flow. However, the Davis-Besse governor valve cannot be guaranteed not to lock up due to water flow because it was designed to run with steam.

Terry Turbine has also stated that water could also cause a turbine overspeed by flashing through the turbine nozzles and thereby, due to the increased mass flow, impart more energy to the turbine wheel and potentially cause an overspeed.

3. Toledo Edison Experience

To further support the root cause of water causing the overspeed trips, a review of past AFPT quick starts was performed. This review involved analyzing the plots of turbine speed versus time during the starting transient. The review clearly showed a difference in stability of the turbines (especially AFP #1) when run on cold supply lines versus hot supply lines. When the turbines are started with cold steam supply lines, the turbine speed is very erratic during acceleration to rated speed. However, when the turbines are started with hot steam supply lines, the speed graphs are very smooth with a constant acceleration to rated speed. (See Figures 2 and 3 for typical AFPT speed graphs of cold versus hot lines.)

The erratic turbine speed is attributed to the formation of water slugs when the steam is introduced into the cold supply lines.

C. Field Actions

Two "hands on" investigations were performed to eliminate other possible causes. The first was performed on 6/9/85 at approximately 1:00 p.m. (about 10 hours after the unit was stable). The AFPTs were "quick-started" on the normal steam supply paths via MS 106 and MS 107. The pump discharge path during this testing was through the min-recirc line only, just as it was during the overspeed trips of 6/9/85. The piping was still hot at this time and both AFPTs started without any erratic control. The governors functioned properly and accelerated both units to rated speed within 40 seconds as designed. This testing indicates

that it wasn't a governor problem that caused the overspeed trips earlier on 6/9/85.

The second investigation was a visual inspection of both governors by a Woodward Governor Representative to verify that the governors were in proper order. The inspections were performed under Maintenance Work Orders (MWOs) 1-85-2131-00 and 1-85-2132-00. The visual inspection identified that both governors contained no deficiencies that would impair proper operation.

D. Analysis

To better define the possibility of condensate in the steam supply causing the overspeed trips, analyses were performed to determine the amount of water available due to steam condensing in the cold steam supply piping and to simulate the transient formation and transport of condensation in these lines.

1. Amount of Water Available

Initial calculations were performed by MPR Associates Inc. to determine the mass of water condensed as a result of heating the AFPT steam piping from 70°F to 535°F. These calculations were intended to give "ball park" numbers and therefore the assumptions were made that the entire pipe heats up from room temperature (70°F) to the nominal SG temperature (535°F) and that all the heat given up by the condensing steam goes to heating the pipe. The results are shown in Table 1, values are pounds of water generated. The actual values will be less due to the real parameters involved, (i.e., the effect of piping insulation, the effect of flow on heat transfer, the time required to heat the pipe, etc.).

Steam From	AFPT #1	AFPT #2
MS 106	790	---
MS 106A	1490	---
MS 107	---	260
MS 107A	---	900

TABLE 1

These results show that large quantities of water can be generated in the steam supply lines. Also the cross connect lines are capable of generating more water than the normal supply paths. This is due to the increased length of cold horizontal piping when the system is run on the cross connect lines.

When comparing the amount of water generated from MS 106 to AFPT #1 to the amount of water generated from MS 107A to AFPT #2 it is not evident why AFPT #1 has never tripped on overspeed when run on MS 106. However, the isometric

drawing of these two routings shows that the MS 107A line is comprised of long horizontal runs and a vertical rise which tends to more easily cause a slug formation when compared to the MS 106 piping which is comprised of a series of shorter horizontal runs and vertical drops. This tendency against slug formation is postulated to be the reason why AFPT #1 had never oversped in the past. It also points to the complexity of the phenomenon.

2. Transient Flow Analysis

A transient flow analysis was performed by MPR Associates Inc. to simulate the effects of the 6/9/85 transient. The computer model used solves the mass, momentum, and energy conservation for the piping system including the effects of the heat transfer to the pipe wall.

The results of the transient flow analysis indicate that a significant amount of water is formed in the steam supply piping to the AFPTs as a result of the sequence of events which occurred on 6/9/85. Within 30 seconds after the initial opening of valve MS 106, the analysis indicates that the pipe immediately upstream of AFPT #1 is completely filled with water. Also, the pipe directly upstream of AFPT #2 is calculated to be about half full of water at the same time. This is shown in Figures 4 and 5.

This transient analysis substantiates the fact that large amounts of water can be generated when steam is initiated into the long cold piping. In addition, it shows that the condensate can be expected to reach the turbines in approximately the time frame required to support the observed overspeed trips of the AFPTs (25-30 seconds).

IV. RESULTS/CONCLUSIONS OF FINDINGS

A. Direct and Root Cause

The direct and root cause is judged to be Hypothesis A of the original troubleshooting report (Reference #4).

Hypothesis A:

Water slugs in steam piping to the turbine due to residual condensation or rapid condensation of steam while heating long, cold steam supply path to AFPTs caused the overspeed trips.

B. Disproved Hypotheses

As part of the original troubleshooting report, four (4) other possible causes for the AFPT overspeeds were developed. Of those four, two were eliminated in the original report based on

data collected during the 6/9/85 plant trip and previous AFPT initiations. Those two were:

Hypothesis C:

Sudden decrease in pump load due to a sudden flow reduction when pump discharge flow is abruptly stopped at the closed valves AF 599 and AF 608.

Hypothesis E:

Loss of pump suction source resulting in no pump load.

A third hypothesis was disproved by the 6/9/85 testing and the governor inspections performed by a Woodward representative. It was Hypothesis D of the original troubleshooting report.

Hypothesis D:

Governor problems had caused the overspeed trips.

The final hypothesis was Hypothesis B.

Hypothesis B:

AFPT #1 rolling on steam from MS 106 prior to receiving steam flow from crossover (Double Start).

This is highly unlikely to have occurred based on an examination of the sequence-of-events log which suggests that steam flow would not have been interrupted. This judgement is based on the timing of the cycling of valves MS 106 and MS 106A. This hypothesis also does not explain the overspeed trip of AFPT #2 because it was run on steam from MS 107A only.

V. TECHNICAL JUSTIFICATION OF FINDINGS

The basis for the direct and root cause determination is:

1. Other utilities have experienced overspeed trips of similar turbines due to water in the steam supply.

2. Toledo Edison experience shows that when the steam supply lines are hot (i.e., small amounts of water generated), the AFPTs accelerate to rated speed without any erratic behavior.

3. Terry Turbine has stated that water in the steam supply can lead to an overspeed condition.

4. Analysis has shown that the existing piping configuration will generate significant amounts of water due to condensation and that this water will reach the turbine during the initial starting transient.

Presently the method by which water causes an overspeed is not precisely known. It could be any combination of the following:

1. Governor valve becomes "water-locked" and is open too far when water clears, therefore allowing too much steam to flow into the turbine which leads to an overspeed.

2. Water entering the turbine flashes through the turbine nozzles thereby releasing more energy than required and the turbine accelerates to the overspeed setpoint.

3. Water entering the turbine slows the turbine down. The governor tries to maintain turbine speed by opening the governor valve further. When the water clears, the valve is open too far to be able to control turbine speed below the overspeed setpoint.

Even though the method is uncertain, it is apparent that the water is the cause of the overspeed trips of the AFPTs that occurred at Davis-Besse on 6/9/85.

VI. SPECIFIC CORRECTIVE ACTIONS |2

A. Required Corrective Action

To eliminate the water which is judged to have caused the overspeed trips, Toledo Edison has decided to reconfigure the steam supply system to the AFPTs. The new configuration would provide the ability to sustain the steam piping in a hot and pressurized condition whenever the AFPTs are required to be operable. By keeping the piping hot, the amount of water delivered to the turbines during a start would be reduced to a negligible quantity. The system change is highlighted below:

- Valves MS 729 and MS 730 (turbine inlet isolation valves located approximately ten (10) feet from the turbines) will be replaced with pneumatically operated control valves.

- Valve opening time will be adjustable to allow control of steam flow during initial stages of turbine starting. This flexibility will alleviate the possibility of overspeeding the turbine when opening a supply valve near the turbine as has been experienced at several other power plants.

- Valves MS 106, 106A, 107, and 107A will be normally open to pressurize the supply lines up to the new control valves. These valves will retain their close signals to act as containment and steam generator (SG) isolation valves.

- Steam trap capacity of the supply lines will be reviewed for adequacy. New traps will be added as required.

- Steam supply lines to the AFPTs will be analyzed as high energy lines. Support, whip restraint, impingment barrier, and environmental qualification modifications will be performed as required.

- The new control valves will be opened on an SFRCS actuation signal.

- In addition to the piping changes, the existing Woodward model PG-PL governor on AFPT #1 will be changed to a Woodward model PGG governor to increase governor reliability. This change-out was originally planned for the 1986 refueling outage.

These modifications or other alternatives to keep the piping hot and pressurized will be performed prior to restart of the Davis-Besse unit. After the modifications are performed, Toledo Edison will perform a series of tests to confirm that the new system configuration will operate as designed.

B. Planned Additional Actions

The new auxiliary feed pump steam supply system modifications will be tested after implementation is complete. The testing will consist of the following:

1. Several quick starts of both AFPTs to verify that the units accelerate to rated speed without any erratic behavior. This testing will also verify that the turbines reach rated speed in less than 40 seconds as required by Davis-Besse Technical Specifications. During these quick starts the following data will be collected:

   - Pipe movement will be measured to verify that piping and hanger loads are within design limits.

   - Governor valve position will be monitored to verify proper governor operation.

   - Turbine speed versus time will be recorded to verify a smooth acceleration ramp.

2. AFPT stability will be checked. This will be done by momentarily increasing turbine speed by using the overspeed test device. Turbine speed will be plotted to verify that the governor resumes control after the instability input is removed.

3. All steam traps on the steam supply piping will be checked for operability and adequate removal capacity during the steady state condition (i.e., lines pressurized with turbine stopped). This testing will ensure that condensation will not accumulate in the piping during the long periods when the AFPTs are idle.

4. Testing will be performed to verify the hypothesis of Action Plan 1C. (Hypothesis - Trip throttle valves being only partially open limited steam flow and thus limited RPM. This was perceived as not being able to control AFPT speed from the control room.)

All of these modifications and testing will combine to assure Toledo Edison that the Auxiliary Feed Water System is functional to perform its intended safety function at any time as required.

VII. GENERIC IMPLICATIONS |2

The design of the Davis-Besse Plant utilizes only two quick start steam driven turbines (AFPT #1 and #2) to supply motive power to equipment. Therefore, there are no generic implications beyond the two AFPTs.

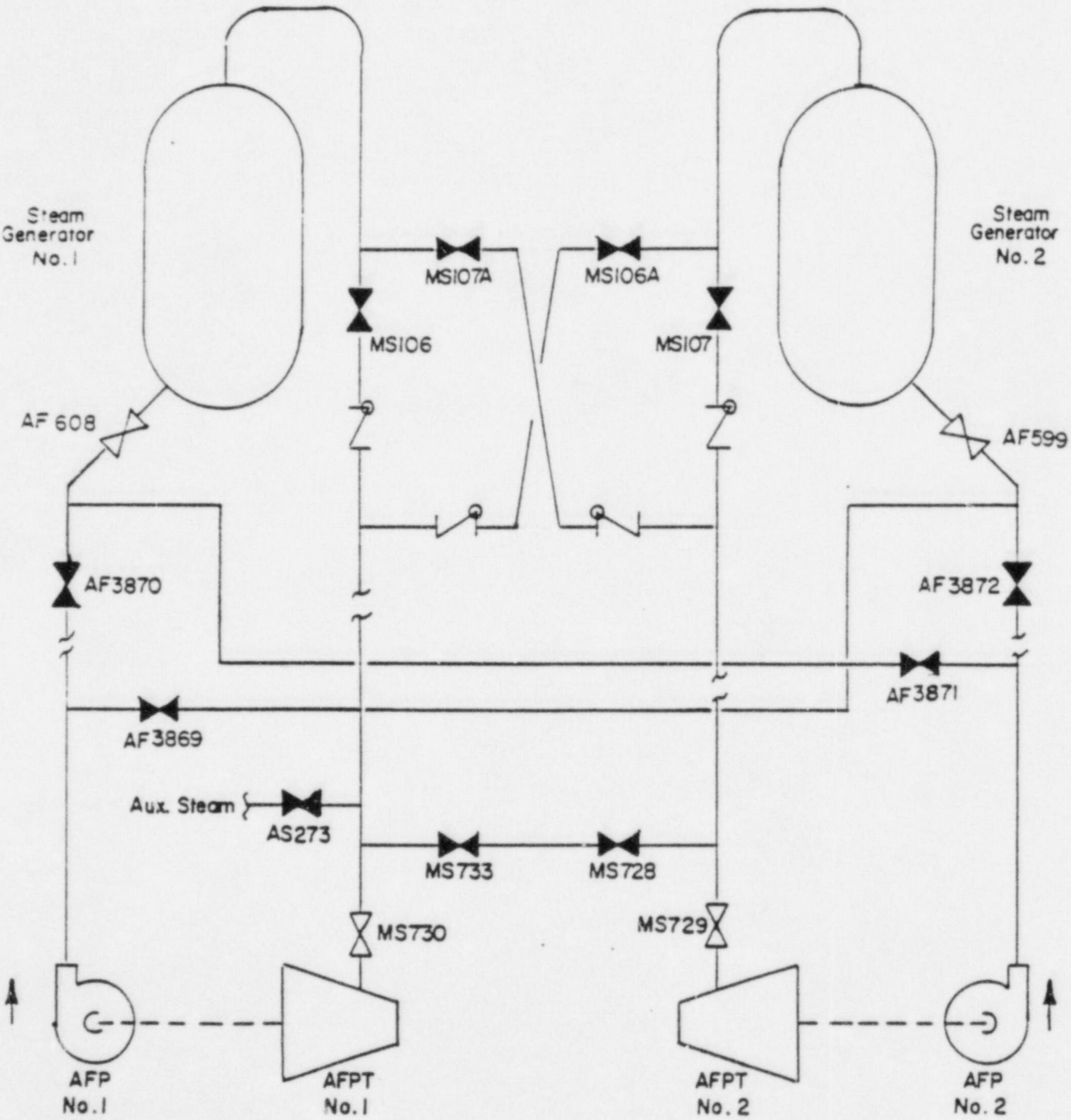
VIII. REFERENCES |2

1. Telephone conversation documentation between MPR and Terry Steam Turbine Company, (7/2/85).

2. Steam condensation calculations by MPR, (4/5/85).

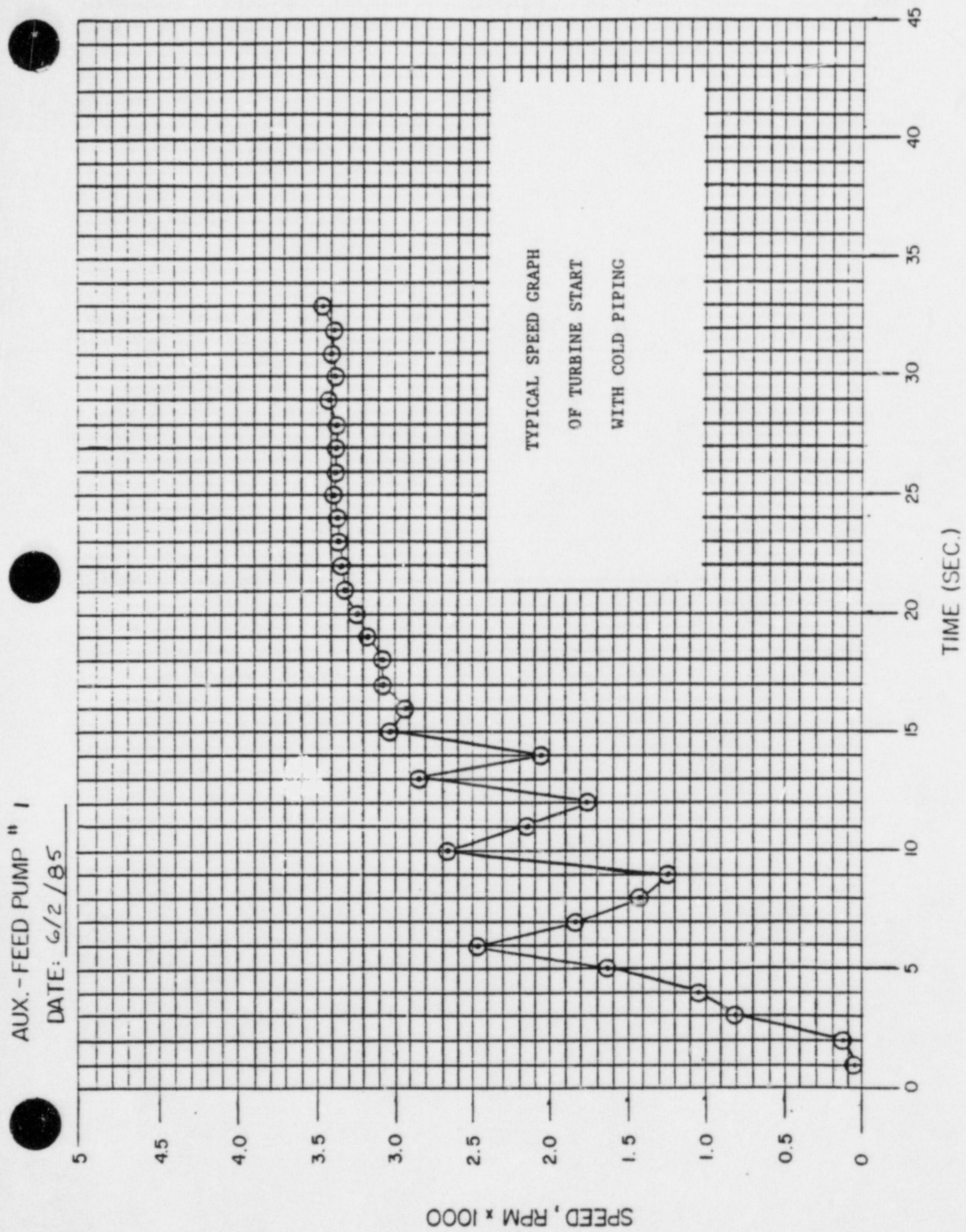
3. Draft transient flow analysis by MPR.

4. Action Plan 1A & 1B Investigation & Troubleshooting Report, Rev. 1 (6/25/85).



SCHEMATIC REPRESENTATION OF
AUXILIARY FEED PUMP TURBINE STEAM PIPING SYSTEM

Figure 1



AUX.-FEED PUMP # 1
DATE: 6/2/85
TYPICAL SPEED GRAPH
OF TURBINE START
WITH COLD PIPING
SPEED, RPM x 1000
5
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
TIME (SEC.)
0
5
10
15
20
25
30
35
40
45

Figure 2

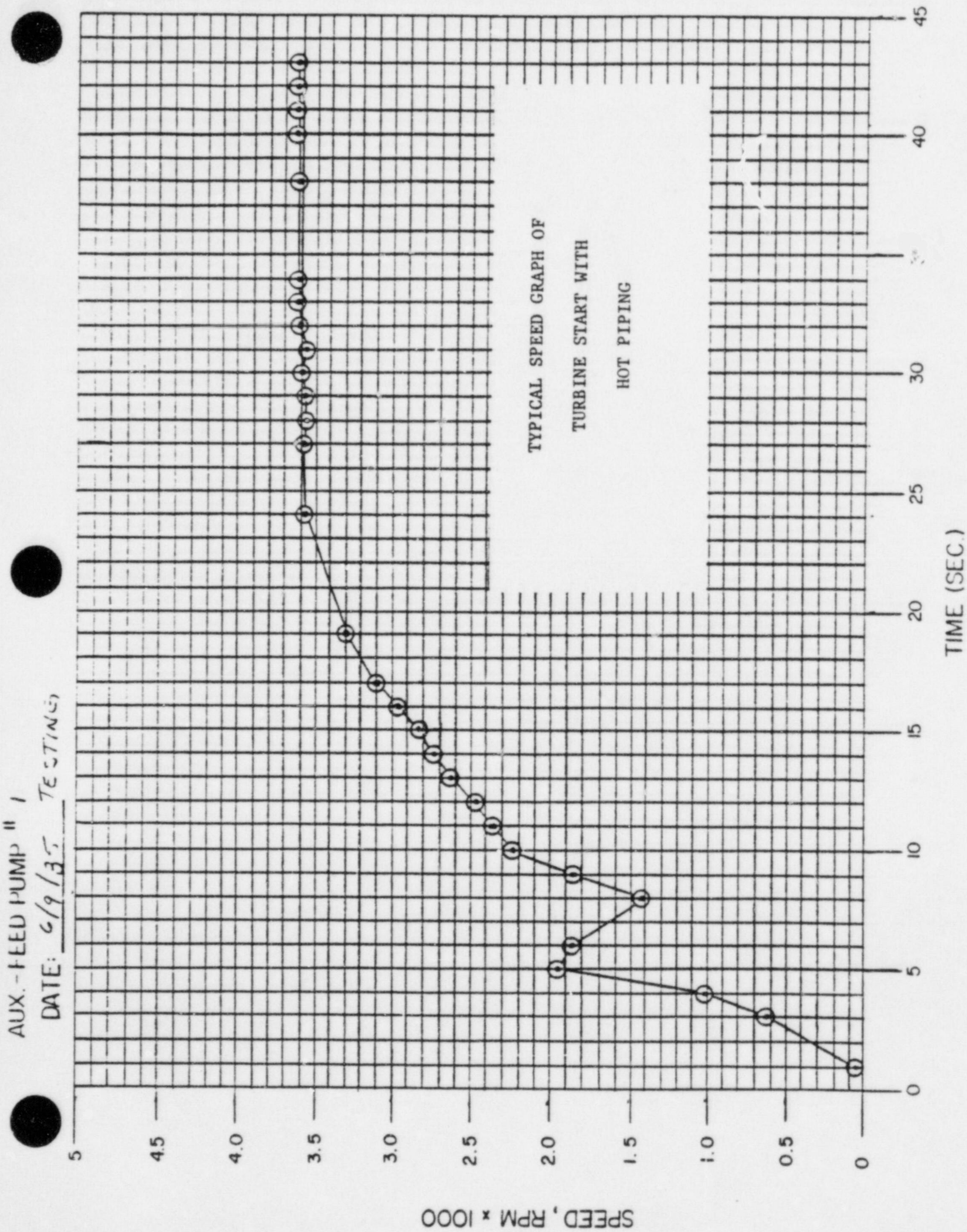
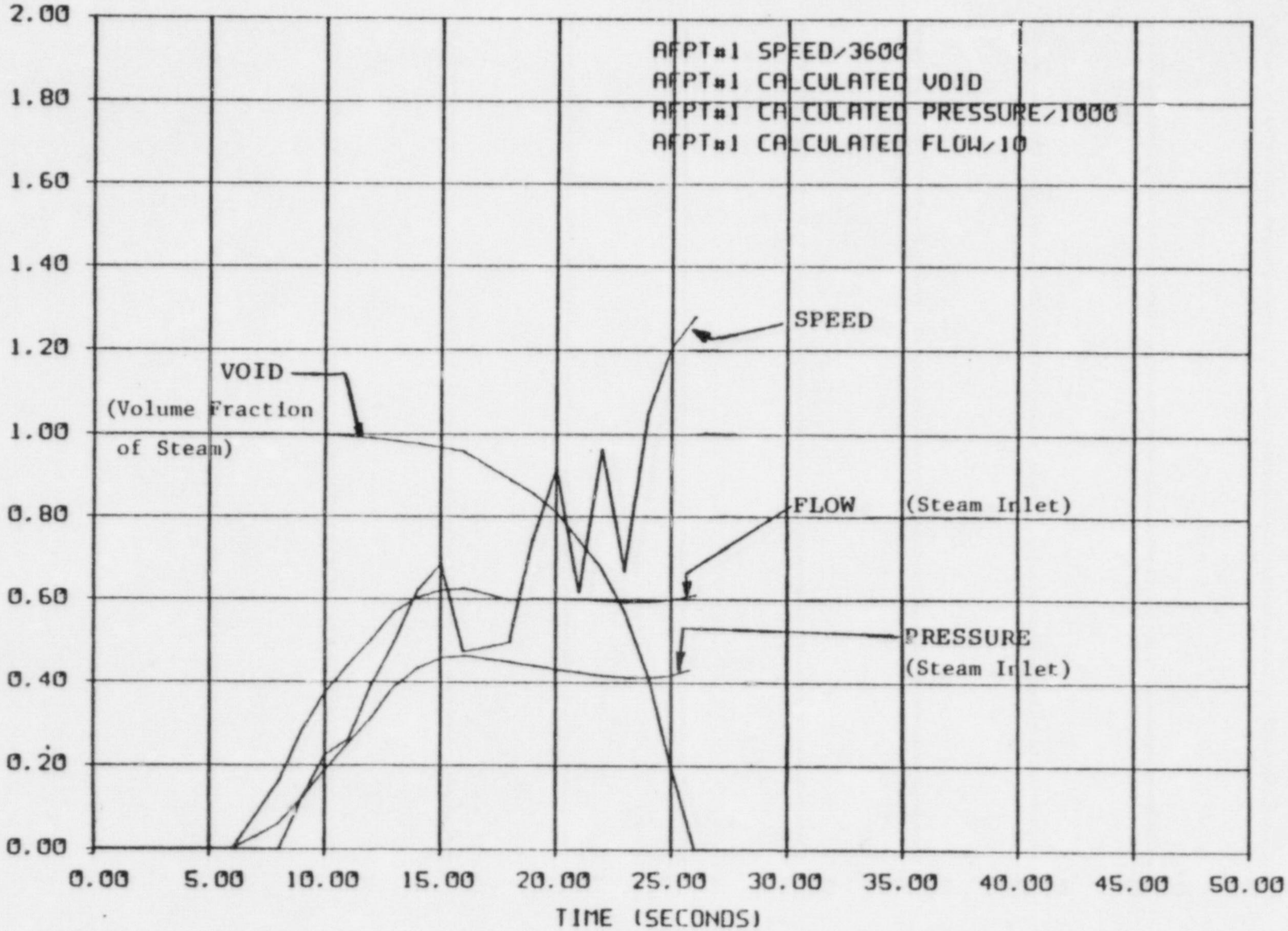

AUX.-FEED PUMP # 1
DATE:
TESTING
TYPICAL SPEED GRAPH OF
TURBINE START WITH
HOT PIPING
SPEED, RPM x 1000
5
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
TIME (SEC.)
0
5
10
15
20
25
30
40
45

Figure 3

COMPUTER MODEL OF AFPT #1 PARAMETERS ON 6/9/85

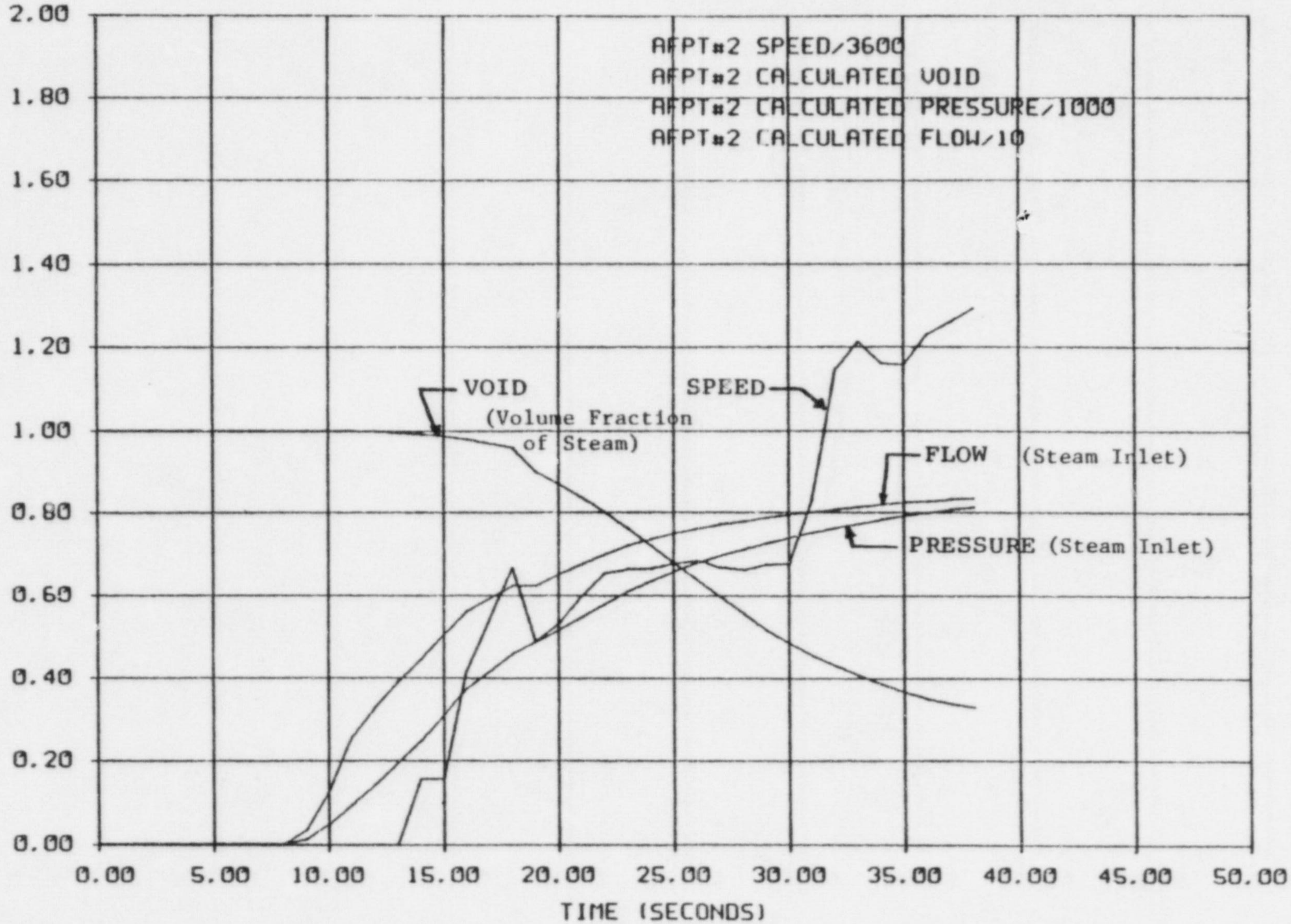


DATE: 08-20-1985 FILE: DBCOM

JUNE 9 TRANSIENT - BOTH TURBINE DRIVEN PUMPS TRIPPED

Figure 4

COMPUTER MODEL OF AFPT [illegible]ARAMETERS ON 6/9/85



DATE: 08-20-1985 FILE: DBCOM

JUNE 9 TRANSIENT - BOTH TURBINE DRIVEN PUMPS TRIPPED

Figure 5

FINDINGS, CORRECTIVE ACTIONS AND GENERIC IMPLICATIONS REPORT

TITLE: Toledo Edison - Source Range Nuclear Instrumentation NI-1, Channel 2

REPORT BY: M. Borysiak (TED)
P. Alleman (B&W)

PLAN NO.: 15A

REV	DATE	REASON FOR REVISION	BY	CHAIRMAN TASK FORCE
0	8/23/85	Initial Issue	M. Borysiak P. Alleman	L. Grime
1	8/30/85	Title Change	M. Borysiak P. Alleman	[signature]
2	9/16/85	Added Data	M. Borysiak P. Alleman	[signature]

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|2

I. ISSUE/CONCERN

Both NI Source Range Channels were inoperable during he Reactor Trip on June 9, 1985. This had no significant impact on plant operability but was an added distraction to the operators.

On June 4, 1985, source range out of core detector NI-1 was declared inoperable due to it reading an elevated count rate $\simeq$ 1.5 decades above NI-2 with the detector high voltage cut off. A reading of 10^{-1} is normal for this condition. Spiking was also associated with the elevated count rate. NI-1 was still inoperable during the trip on June 9, 1985. After the trip when high voltage was applied to NI-2, it failed to respond and remained inoperable for approximately 1 hour. Technical specifications require that at least one source range channel be operable or shutdown margin be verified by the operator.

Even though there was no significant impact during or following the transient on June 9, the inoperability of both NI-1 and NI-2 did create an undesirable added distraction to the operators in having to verify the shutdown margin requirements per Action Statement 6 of T.S. 3.3.1.1. From this standpoint, it is highly desirable to locate and correct the problem with NI-1.

II. BASIC PRINCIPLE OF OPERATION

The Source Range instrumentation consists of two redundant count rate instrument strings designated NI-1 and NI-2 which measure neutron flux.

The subject of this report is NI-1, Source Range Instrument String 2
as shown in Figure 1. NI-1 is located in Nuclear Instrumentation/ Reactor Protection System Channel 2.

The Source Range Signals originate in high sensitivity BF_3 proportional counters located in thimble wells in the reactor vessel cavity.

The proportional counters are connected to preamplifiers located in the reactor building. The preamplifiers are used to shape and amplify the low-level pulses from the proportional counter. The signal output of the preamplifier is sent to the count rate amplifier module (CRAM) located in the Nuclear Instrumentation/Reactor Protection System Cabinets.

The CRAM which contains a discriminator and log count rate amplifier further shapes and amplifies the signal pulses. The discriminator discards background and gamma pulses. A log count rate amplifier converts the neutron pulses to a signal suitable for displaying the log count rate level both locally and remotely to the operator. The display range is from 10^{-1} to 10^{6} counts per second.

The Rate of Change module has differentiator amplifiers which calculate the rate of change of the log count rate for display locally and remotely to the operator. An interlock is provided for control rod withdraw hold and alarm on high startup rate.

III. SUMMARY OF TROUBLESHOOTING AND INVESTIGATION

Nuclear Education and Training Services, Inc. (NETS) from Ohio State University was requested to review action plans and Troubleshooting as an independent input. The NETS input is included in this report as Attachment 1. 2

A. Field Actions Performed

Maintenance Work Orders - 1-85-2092-00 and 01, 1-85-2192-00 and 01

Action Plan Step 1A and 1C - The object of this step is to measure the CRAM pulse input, CRAM pulse amplifier output and CRAM output. These were observed at normal and elevated count rates. The source used for these tests was reactor residual neutron flux. It was determined by performing cable and connection inspections that the high count rate problem was upstream from the CRAM. After this, only the CRAM pulse input was monitored. Oscilloscope pictures were taken indicating both normal and elevated count rates. See action plan Step 1D for the results evaluation.

Action Plan Step 1B - The object of this step was to repeat readings of 1A above with the reactor at power (Mode 1) and the high voltage off. This step cannot be completed when the reactor is shutdown.

Action Plan Step 1D - By a slight movement of the Amphenol connector between the MI cable and Triax cable at the detector well, the elevated count rate could be made to come and go away. This was repeated three times and establishes the assembly of the detector, MI Cable or Triax cable interface as a possible cause of the elevated count rate.

The existing detector with attached Triax cable and Amphenol connector has been removed and sent to the vendor for determination of root cause. The vendors analysis indicates that the detector has no problems and that a cause of elevated count
rate appears to be in the Amphenol connector. Westinghouse
Test and Evaluation Report number NC TR 85-19 has been pro- 2
vided to Toledo Edison Co.

A new detector with integral MI cable and Amphenol connector has been installed in NI-1. An elevated count rate with spiking conditions has been observed since replacement of the detector and connector.

Action Plan Step 2A - Time Domain Reflectometer (TDR) traces were taken using a Tektronix Model 1502 Time Domain Reflectometer. The time domain reflectometer measures impedance vs. cable length by sending a high frequency signal down the cable and monitoring reflections coming back.

The cables checked are as follows:

1. RPS Cabinets to the Preamp

   a. Signal Cable

   b. High Voltage Cable

   c. Low Voltage Cable

2. Preamp to Detector

   a. Signal/High Voltage Cable

The results of the TDR tests are:

1. The low voltage cable from the RPS cabinets to the preamp shows very small impedance changes from the penetration to the preamp. The small impedance changes are judged not to be a cause of the elevated count rate.

2. The high voltage cable from the RPS cabinets to the preamp shows very small impedance changes from the penetration to the preamp. The small impedance changes are judged not to be a cause of the elevated count rate.

Action Plan 2B - The concern is that NI-1 cable length is terminated in a ¼, ½ or full wave length to be susceptible to resonating at a frequency of 45 to 60HZ. The elevated count rate normally fell in the 45 to 60 counts per second range and is the basis for selecting the resonating frequency range of 45 to 60HZ. The calculation of resonant frequency of the cables need not be performed due to determination of the root cause 2
as explained by Significant Problem #8.

Action Plan Step 2C - An inspection of conduit and cables looking for improper assembly of connectors, NI cables located close to high power cables and other things that could contribute to the elevated count rate problem has been completed except for two connectors per cable internal to the penetration as outlined by Section VIB Additional Planned Actions Item 8. 2
As part of the troubleshooting procedures some repairs were made with approval of the Region 3 NRC representatives. The problems listed below were detected during this inspection and other troubleshooting procedures:

Significant Problems

1. RPS Cabinet (Cabinet 1) (5755F) has a loose connection to the station ground bus. Tightening of this connection 2 has been completed.

2. The center pin on the preamp detector cable connector was pushed in approximately ¼" and was off center. This connector has been replaced using installation instructions written in the Maintenance Work Order. Figure 2 shows a typical connector assembly.

3. Operation of Reactor Protection System (RPS), Safety Features Actuation System (SFAS), and Steam Feedwater Rupture Control System (SFRCS) cabinet door switches 2 (which provide annunciator indication of open doors) frequently cause high level spikes visible by use of an oscilloscope at the input to the CRAM. No alarms have resulted. Spiking is aggravated by the elevated count rate problem and is not a problem when the elevated count rate is not present. The monitoring recorder temporarily connected to the output of the CRAM does not respond to these spikes.

4. No grounding wire is connected to the outside box which contains the preamp.

5. RPS Channel 2, Cabinet 2 has a loose connection where the Cabinet 1 safety ground bus wire is connected to the safety ground bus by a single bolt. Tightening of this 2
connection has been completed.

6. Every Amphenol connector inspected was tarnished and many contained metal flakes from the connector assembly.

7. Between August 24 and August 26 NI-1 failed due to elevated count rate. This was after the new detector and interfacing connector had been installed. Subsequent to this it was determined that connectors installed on the preamp over top of paint was not providing an adequate ground connection. It was determined by test that re- 2
sistance values, sensitive to forces on the connector, from infinity to less than one ohm existed between 1) the Triax cable inner shield and the preamp inner box and 2) the Triax cable outer shield and the preamp outer box. Both items 1 and 2 above should be low resistance (<1 ohm) connections. This condition was corrected by removing the paint from the preamp boxes at the locations where the connectors are attached.

8. Operation of some motor operated SFAS isolation valves have been identified as causing some spiking at the output of the Rate of Change Amplifier Module (ROCAM). Observation of spiking vs. valve operation is continuing and is being logged by the reactor operators. This observation will continue until a month of power operation is accomplished.

Observations

1. The power supply high voltage output connection has a crushed "O" ring.

2. The preamp had no "O" rings on any of the cable connectors.

3. The detector cable bushing on the preamp outer box has a very small clearance of ~ 1/32 inch from the detector cable connector. The concern is that these points may short causing a potential ground loop. These points are electrically insulated from each other. Additional spacing was provided by installing a gasket on the mounting for the detector cable bushing. 2

4. The TDR trace for the low voltage cable shows very small impedance changes from the penetration to the preamp. The small impedance changes are judged not to be a cause of the elevated count rate problem.

5. The detector center line location versus midplane of reactor core for both NI-1 and NI-2 was investigated. By comparison of the exposed MI cable in the thimble connection boxes it looked like one detector was not located properly on the core midplane. This investigation has been completed and both detectors were located properly.

6. The detector and high voltage cable connectors at the preamp appears to be nickel (shiny) plated versus silver plated. Silver plated connectors are specified by the vendor.

7. The TDR trace for the high voltage cable show very small impedance changes from the penetration to the preamp. The small impedance changes are judged not to be a cause of the elevated count rate.

8. In some cases fiber (shipping) washers have been left on the bulkhead connectors installed at the Preamp and RPS Cabinets. This fiber washer prevents the connector from being tightened in place properly. The result would be that the connector body would turn during tightening of the connector. The fiber washers were inadvertently left in place during initial construction. All bulkhead 2 connectors have been checked and fiber washers removed where they existed.

9. The Blue Ribbon Connector on the source range high
voltage power supply in the RPS cabinet is chipped 2
and cracked.

10. The Masonite spacers used to block the area around the
detector signal cable in the detector thimble plug were
approximately 5 inches long. They should have extended 2
the full length of the detector thimble plug. When the
new detector was installed the correct length spacers were
used.

Action Plan Step 3 - This test is to remove modules in RPS Channel 2 to determine if noise is being introduced from sources external to NI-1.

This test was to determine the source of a high frequency noise signal with an amplitude of approximately 100 millivolts and is a separate action from the elevated count rate problem. The input to the CRAM was the monitoring point in all cases. The source range test module and rate of change module were removed and reinserted individually with no change in the monitored noise level. The high voltage, low voltage cables and signal cable were removed at the RPS cabinets individually with no change in the monitored noise level.

The CRAM was removed and bench tested. No input noise was present during this test and the module tested OK.

NOTE: The noise present on NI-1 source range signal even though within specifications was higher than that observed for NI-2. It was felt that if the source of this noise could be determined in conjunction with other troubleshooting being performed that overall system operation could be improved. This noise is present with and without the elevated count rate present and does not contribute to the count rate problem.

Action Plan Step 4 - The results of Step 3 testing did not indicate that removal of individual boards within modules would be necessary. |2

Action Plan Step 5 - The object of this test was to perform extensive tests on control relays within the NI-1 instrument string modules. None of the previous results indicated relays were a problem therefore this test need not be performed. |2

Action Plan Step 6 - The object of this test was to investigate all RPS Channel 2 power supplies for sources of noise. The DC buses within the RPS cabinets were tested for sources of the noise. The plus 15 volt bus in both RPS Channel one and two contained a ripple frequency of 7300 Hz with a 10 millivolt amplitude with the detector high voltage power supply turned on. This noise signal disappeared with the detector high voltage power supply turned off. The 10 millivolt amplitude of

this signal is within specification and is not significant to the elevated Count Rate Problem.

To isolate system power supplies as a possible cause of the 2
elevated count rate problem the source range high voltage and the 15 VDC cables to the preamp were disconnected one at a time at the back of the RPS cabinets. An external power supply was connected to provide power to the preamp. The elevated count rate was still present in each case when the external power supplies were providing power to the preamp. This test eliminates the system power supplies as the cause of the elevated count rate problem.

Action Plan Step 7 - This test objective was to determine if the CRAM was going into oscillation. With the signal cable disconnected at the preamp the count rate was $< 10^{-1}$; however, when a resistive/capacitive network (to simulate the detector) was connected to the signal cable the count rate saturated at $> 10^6$ counts. It was concluded that the resistive/capacitive network was inadequate to complete this test. A new detector was then used to complete this test. See Action Plan Step 11.

Action Plan Step 8 - A spectrum analyzer was used to compare the CRAM input of both NI-1 and NI-2. A DC component and also a 60 Hz component was present. The frequency spectra obtained for NI-1 and NI-2 were identical.

Action Plan Step 9 - The Object was to increase discriminator settings with elevated count rate to determine if the noise could be discriminated from the signal. The discriminator setting was increased in steps to a dial setting of 5. It was concluded that the signal to noise ratio was such that the noise could not be discriminated from the signal when the elevated count rate was present. The existing discriminator setting of 0.7 for NI-1 currently exceeds the existing setting of 0.56 for the NI-2 instrument string.

Action Plan Step 10 - The object was to transfer modules
between NI-1 and NI-2 to determine if the associated problem in
each channel follows. The CRAMS and the detector high voltage |2
power supply modules were interchanged between NI-1 and NI-2.
Noise level and count rate remained unchanged in each respective channel when the modules were interchanged.

The preamp in NI-1 was replaced by a new preamp with no ob-
served changes in the associated problems. The preamp removed
from NI-1 was bench tested successfully in accordance with the
vendor manual preinstallation acceptance test procedure. No |2
other interchanging of modules is planned.

Action Plan Step 11 - The object is to connect a spare detector at the preamp location and evaluate NI-1 noise level. A new detector was connected at the NI-1 preamp location with no elevated count rates being observed after monitoring for four

days. The output of the CRAM was recorded. Completion of Action Plan Step 11 satisfies the requirements of Action Plan Step 7 in that no oscillations or elevated count rates were observed during the four day monitoring period.

Action Plan Step 12 - The object is to remove NI-1 modules while observing CRAM input for elevated count rate and also perform bench test of NI-1 modules. The source range test module and rate of change module were individually removed with no change in count rate level observed at the input to the CRAM module. The CRAM module was removed and a bench test was performed successfully in accordance with vendors manual preinstallation acceptance test procedure. No anomalies were noted during these tests.

Action Plan Step 13 - The object of this test was to interchange the high voltage cable and signal cable between the RPS and the preamp to determine cable effects on the elevated count
rate. This test was performed with elevated count rate present 2
and the elevated count rate remained after interchanging the signal and high voltage cable.

Action Plan Step 14 - The object of this step is to:

1. Remove the NI-1 Source Range detector, interfacing connec- 2
tor and a short section of the triax cable to be returned to the vendor for evaluation.

2. Install a new detector in the thimble well.

3. Install a new connector on the triax cable at the thimble well and at the preamp.

4. Place channel back in operation and continue monitoring for elevated count rate and spiking.

This action item was completed and an elevated count rate problem occurred as described by Significant Problem Number 7 under Action Plan Step 2c.

Action Plan Step 15 - The object of this step is to inspect, clean and/or replace connectors as required. Each connector cleaned or replaced is to be documented and monitored for elevated count rate and spiking.

This step has been completed except as described by additional planned Action Item 6.

2

Action Plan Step 16 - The object of this step is to correct loose Station ground connections in cabinets C5755E&F and monitor for elevated count rate and spiking.

This action plan step was completed with no change in the elevated count rate problem.

B. Significance of Findings

The significant findings are:

1. Movement of the Amphenol connector between the MI cable and Triax cable at the detector well would cause the elevated count rate to occur.

2. Improper installation of Triax cable connectors and the poor state of maintenance of connectors in the NI-1 instrument string contributed to the elevated count rate 2
problem.

3. High resistance connections existing between Triax cable shields and preamp inner and outer boxes contributed to the elevated count rate problem. This condition was caused by failure to remove paint or use star washers properly by the manufacturer when installing connectors in the inner and outer preamp boxes.

IV. RESULTS/CONCLUSIONS OF FINDINGS

A. Direct Causes

1. A direct cause of elevated count rate on NI-1 was deter- 2
mined by Westinghouse to be improper installation of the Triax cable jack which mates with the detector cable

connector. This Triax cable jack was X-rayed by the Exam Company which verified the Westinghouse conclusion. 2

2. Another direct cause of the elevated count rate on NI-1 was determined to be high resistance connections existing between Triax cable shields and preamp inner and outer boxes. This condition was caused by the failure to remove paint or use star washers properly when connectors were installed by the manufacturer on the inner and outer preamp boxes.

3. Some spiking alarms are clearly related to the annunciator associated with RPS cabinet door switches when an elevated count rate is present.

Troubleshooting efforts are continuing to further identify the sources of NI-1 startup rate spiking.

B. Root Cause

1. Inadequate grounding of the connectors where attached to the preamp housings caused by failure to remove paint or 2 improper use of star washers by the manufacturer was a cause of elevated count rate.

2. Improper installation of the Amphenol connector at the interface between the detector MI cable and the triax cable at the detector thimble well. This was concluded by the vendor evaluation as a cause of elevated count rate. 2

3. Other contributing factors to the elevated count rate was degraded condition of other triax connectors.

V. TECHNICAL JUSTIFICATION OF FINDING

Moving the MI cable at the detector well of the source range instrument string identified that an elevated count rate problem could be induced in the detector MI cable or the MI cable to Triax cable interface connector.

The preamp and modules were interchanged between NI-1 and NI-2 and bench tested in accordance with vendor procedures and no abnormalities were found; however, by further testing it was determined that resistance values, sensitive to forces on the connector, from infinity to less than one ohm existed between 1) The Triax cable inner shield and the Preamp inner box and 2) The Triax cable 2
outer shield and the preamp outer box. It was determined that when the high resistance conditions were present an elevated count rate existed. Monitoring has been in progress for 15 days after removing the paint from the preamp at the connector locations with no elevated count rate problems occurring.

The power supplies were evaluated for sources of the problem. No abnormalities were found.

The assembly of the detector, MI cable, and MI cable to Triax connector has been evaluated by Westinghouse.

The Westinghouse conclusion was that:

1. The detector was in good operating condition.

2

2. The center pin of the triaxial jack that was mated to the detector cable connector was positioned incorrectly. This conclusion was verified by X-ray of the connector after return to the Toledo Edison Company.

VI. <u>SPECIFIC CORRECTIVE ACTION</u>

A. Required Corrective Action

1. The NI-1 detector has been replaced. Inspection, cleaning, and replacing (as necessary)[1] shielded cable connectors from the detector to the RPS cabinets is in progress. All connectors for the NI-1 string from the

---

1 "As necessary" means replacing those connectors that cannot be cleaned properly, the tarnish removed or shows other signs of not being a quality connection.

detector to the RPS cabinets have been inspected/cleaned/
replaced except two per cable which are inaccessible at 2
the penetration. The connectors at the penetration are
operating satisfactory are not a cause of the elevated
count rate problem but will be replaced as an additional
planned action prior to startup after the next refueling
outage to assure that all connectors in the NI-1 instrument
string are installed to the latest procedures. This
work is being done with approval of the Region 3 NRC
representatives. The connectors are being replaced using
installation instructions written in the Maintenance Work
Orders. Selected personnel have been instructed in the
proper installation procedures by the system vendor
representative.

2. Recorder monitoring of the CRAM output is in progress for
assurance that the elevated count rate problem has been
corrected. Monitoring will continue until a month of 2
power operation is accomplished.

B. Additional Planned Actions:

1. Revise or prepare new procedure for installing triaxial
cable connectors. Current procedure is MP 1410.24. Due 2
to the generic corrective actions as outlined in Section VIII,
this item will be completed prior to the start of the
next refueling outage.

2. Provide cable connector installation training for station personnel. This item to be completed prior to further cable connections. Work is planned to commence during next refueling outage and training must be completed prior to this. 2

3. Add grounding wire to the outside box which contains the preamp. An engineering evaluation will be completed this fuel cycle to determine if this ground wire is required. The ground wire will be installed during the next refueling outage if required. 2

4. Review and revise (as required) procedure number MP 1504.04 for adequacy in determining if the seal plate rubber gasket, for the connector box at the top of the detector thimble, requires replacement. The existing procedure provides for applying RTV sealant to the seating surfaces ensuring a watertight seal. Gasket replacement concerns will be addressed prior to next refueling outage. 2

5. Replace Blue Ribbon Connector for the source range high voltage power supply. The chipped/cracked Blue Ribbon Connector would not effect system operation and could be replaced any time, however it will be replaced prior to this startup. 2

6. Replace Source Range NI-1 Amphenol penetrations with new Conax penetrations. This action is necessary in that the existing penetrations contain Triax connectors that require penetration removal to inspect or replace the connectors. The new Conax penetrations will eliminate one connector per cable and the connectors will be accessible after penetration installation. The replacement of the penetration modules will be completed at the next refueling outage. 2

7. Revise procedure number IC 2002.02 so that it adequately addresses all areas of NI detector removal and installation. No further detector removal/installation is planned. This item to be completed prior to next refueling outage. 2

8. Revise procedure number IC 2002.04 to address current requirements for source range discriminator and high voltage settings. This item will be completed as part of the annual procedure review or prior to next refueling outage, whichever comes first. 2

9. Revise procedure number MP 1410.24 to address current requirements for installation and removal of Raychem heat shrinkable tubing. This item will be completed as part of the annual procedure review or prior to the next refueling outage, whichever comes first. 2

10. Continue observation of spiking vs. SFAS isolation valve operation and look for/correlate with any other equipment actuations that cause spikes at the output of the ROCAM 2
and perform tests to determine source of spiking. This observation will continue until a month of power operation is accomplished.

11. Prepare an interim administrative procedure for operating with SFAS isolation valve spiking present and any other equipment actuations that cause spiking pending (if possible) location and elimination of the source of the 2
spiking. The SFAS isolation valves would not normally be operated during plant startup or shutdown therefore this would not present a problem to operation during startup or shutdown.

VII. GENERIC IMPLICATION

1. Triax shielded cable connectors on the other NI Systems may 2
have conditions similar to those found on the source range instrumentation.

2. Inadequate grounding of preamp connectors may effect other 2
plants using the same model number preamp.

VIII. GENERIC CORRECTIVE ACTIONS[2]

1. Inspect, clean and replace (as necessary)[1] shielded cable connectors on NI Intermediate Range Instrument strings.

2. Inspect, clean and replace (as necessary)[1] shielded cable connectors on NI Power Range Instrument strings.

3. Inform B&W resident engineer of the grounding problem associated with connector installation on the source range preamp. This information should be distributed to other plants which use the same model preamp. 2

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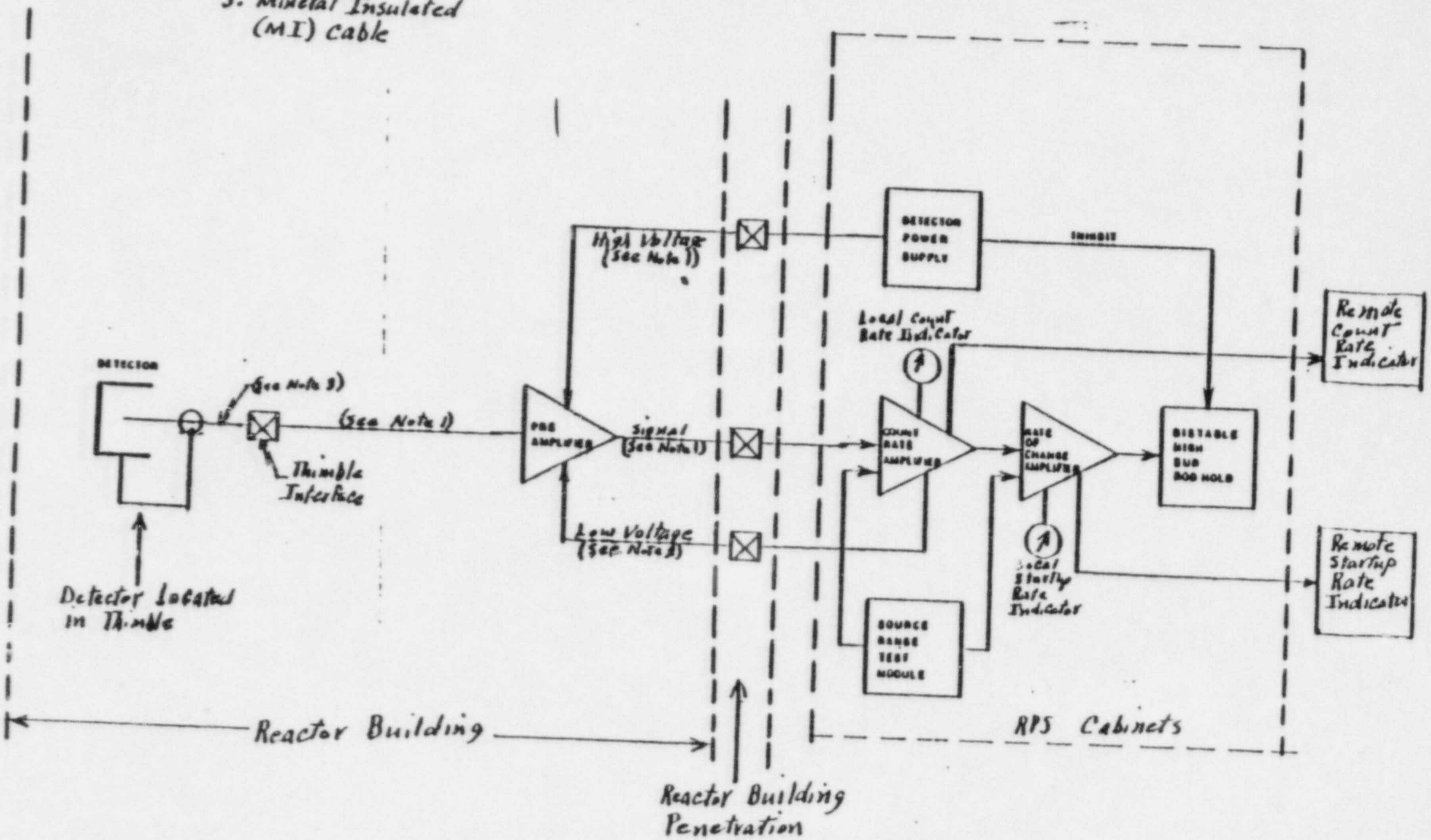
[1]"As necessary" means replacing those connectors that cannot be cleaned properly, the tarnish removed or shows other signs of not being a quality connection.

[2]More time is required to get an adequate supply of replacement connectors. No known problems exist in the Intermediate or Power Range Instrument strings which are less susceptible to elevated count rate and noise problems and have performed satisfactorily to date; therefore, this work will be performed at the next outage. 2

Notes: 1. RG/11U Triax cable
2. Twinaxial cable
3. Mineral Insulated (MI) cable

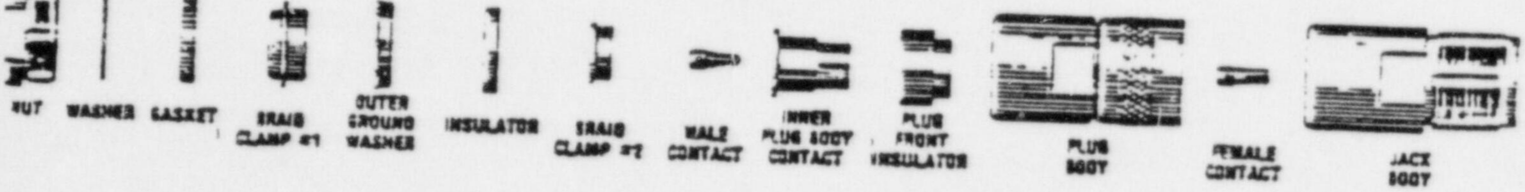


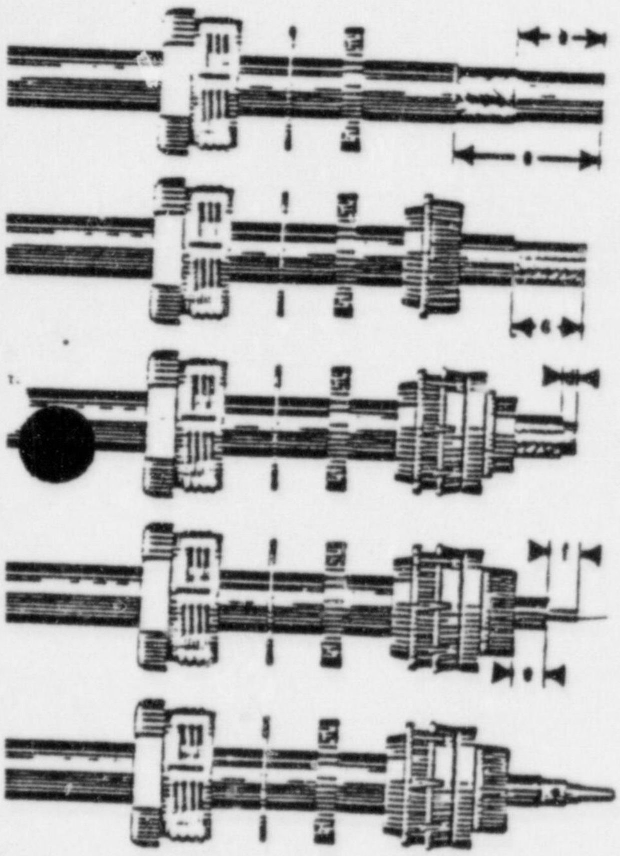
SOURCE RANGE
INSTRUMENT STRING

Fig 1

TRIAX ASSEMBLY INSTRUCTIONS

Fig. 2





Slide nut, washer and gasket over cable. Cut off outside jacket (using razor blade or wire strippers) to dimension a. Make a clean cut, being very careful not to nick braid. Cut first braid to dimension b.

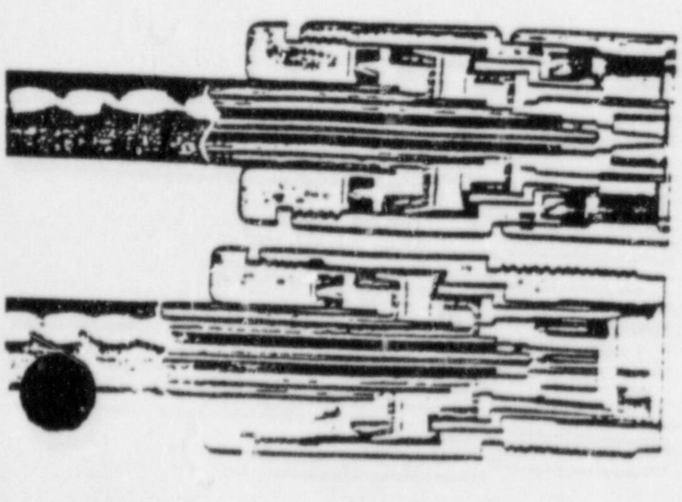
Slide first braid clamp over braid up to jacket of cable. Fold first braid back over clamp, making sure braid is evenly distributed over the surface of the clamp. Trim second jacket to dimension c, again being very careful not to nick braid.

Trim second braid to dimension d. Slide on outer ground washer, insulator and second braid clamp. Fold second braid back over braid clamp, again making sure that braid is evenly distributed over surface of clamp.

Trim cable dielectric to dimension e.

Tin the inside hole of the contact. Tin wire and insert into contact and solder. Remove any excess solder. Be sure cable dielectric is not heated excessively and swollen so as to prevent dielectric from entering body of fitting.

Plug only: Place front insulator and outer contact assembly into back of connector body and push into proper place. Insert cable-contact assembly into body. Screw nut into body with wrench until moderately tight.



Stripping dims. ± 1/64 (0.4) inches (millimeters)

Plugs	58A, 59 Type	8, 11 Type
a	7/8 (22.2)	15/16 (23.8)
b	19/32 (15.1)	19/32 (15.1)
c	9/16 (14.3)	15/32 (11.9)
d	11/32 (8.7)	5/16 (7.9)
e	11/32 (8.7) △	5/16 (7.9)
f	9/64 (3.6)	1/8 (3.2)
Jacks	**58A, 59 Type**	**8 Type**
a	19/32 (15.1)	29/32 (23.0)
b	21/64 (8.3)	19/32 (15.1)
c	19/64 (7.5)	[illegible] (14.5)
d	1/4 (6.4)	5/16 (7.9)
e	1/4 (6.4)*	5/16 (7.9)
f	3/32 (2.4)	1/8 (3.2)

△ for 53100 and 53150 plugs this dimension is .187 (4.5)

*for [illegible] jacks this dimension is [illegible] (3.3)

Attachment 1

nets

NUCLEAR EDUCATION & TRAINING SERVICES, INC.
4500 CROMPTON DRIVE
COLUMBUS, OHIO 43220

August 21, 1985

A85-303 c1

RECEIVED
AUG 27 1985
NUC. FAC. ENG.

To: Mr. Mike Borysiak
The Toledo Edison Company
300 Madison Avenue
Toledo, Ohio 43652

From: Don W. Miller, Ph.D.

Subject: Summary of Meeting at The Davis-Besse Nuclear Power Plant, August 15, 1985, 10:00 AM - 4:00 PM. NI-1 Source Range Nuclear Instrument Channel.

This memo is intended to summarize the activities, and our conclusions and recommendations resulting from the recent meeting to discuss the operational difficulties with the NI-1 Channel.

Meeting Attendees: Steven A. Arndt, Joseph W. Talnagi, Don W. Miller, and Mike Borysiak.

Activities:

(1) Reviewed and discussed color photographs of many of the key elements in the Channel between the BF3 Proportional Counter Neutron Detector (including the detector connections) and the Count Rate Amplifier Module (CRAM). The photographic study was directed primarily to the triaxial cabling and connectors since it is expected that the observed difficulties with NI-1 have their root cause(s) in the signal lines between the detector and the control room. The study included significant attention to the penetrations and their installation.

(2) Reviewed and discussed the measurements and data recorded by the Davis-Besse technical staff during the past two months. These data included strip chart recorder time records, oscilloscope trace pictures, and time domain reflectometry (TDR) information.

(3) Observed strip chart recordings and oscilloscope traces of both NI-1 and NI-2 in operation.

Conclusions and Recommendations:

Two general and qualitative conclusions were made during and following the completion of the above activities. First there are several potential contributors to the operational difficulties of NI-1 Channel. These include a high stress on the cable at the input to the preamplifier, a recessed pin (.25") on the preamp input connector, high noise on the CRAM input signal, noise pulses occuring with cabinet door closing or opening, possible ground loop connection at the preamp input, cable connectors incorrectly installed or maintained, and low signal cable resistances. Second, there may be more than one root cause of the intermittent operation of the NI-1 Channel.

Since there are several possible items, many of which may be interactive, that may be contributing to the difficulty with NI-1, the combinatorial difficulty introduced into trouble shooting represents a significant challenge to the Davis-Besse technical staff. As a consequence, we endorse the Davis-Besse staff decision to proceed on the straight forward, but tedious and time consuming task of replacing the detector, and cleaning and maintaining each cable, connector and penetration in the NI-1 Channel beginning with the detector and ending at the input to the CRAM. Following each maintenance activity, the NI-1 Channel response will be observed and changes recorded. By following the planned procedure there is a reasonable probability that the root cause(s) of the difficulty with the NI-1 Channel will be determined and a high probability the Channel will be repaired.

Although this approach is "brute force", there appears to be no other reasonable solution to the problem. We therefore agree with the approach being taken by the Davis-Besse technical staff. Additionally, we recommend that laboratory evaluation of replaced components be made wherever possible, as is already planned for the detector-cable assembly.

cc: S.A. Arndt
B.K. Hajek
J.W. Talnagi

FINDINGS, CORRECTIVE ACTIONS and GENERIC IMPLICATIONS REPORT

TITLE: Toledo Edison - Source Range Nuclear Instrumentation NI-2 Channel 1

REPORT BY: Jack DeSando (TED)
Paul Alleman (B&W)

PLAN NO.: 15B

REV	DATE	REASON FOR REVISION	WRITTEN BY	APPROVED BY
0	8/26/85	Initial Issue	J. DeSando and P. Alleman	L. Grime
1	8/30/85	Title Change	J. DeSando and P. Alleman	[signature]
2	9/19/85	Added Data	J. Desando and P. Alleman	[signature]

TABLE OF CONTENTS

I. ISSUE/CONCERN

Both NI Source Range Channels were inoperable during the Reactor Trip on June 9, 1985. This had no significant impact on Plant operability but was an added distraction to the operators.

Prior to the reactor trip on June 9, 1985, NI-2 indicated less than 1×10^{-1} counts per second with the detector high voltage cutoff in effect. Source range high voltage is turned off when neutron flux level exceeds 1×10^{-9} amps as detected by both intermediate range channels. A source range indication of less than 1×10^{-1} counts per second is normal for this condition.

During the reactor trip on June 9, 1985, as neutron flux level decreased to less than 1×10^{-9} amps, as detected by both intermediate range channels, and high voltage was applied to the source range detectors, the NI-2 indication remained at less than 1×10^{-1} counts per second. Under these conditions, NI-2 should have registered approximately 10^{5} counts per second. NI-2 remained inoperable for approximately 1 hour after which a normal NI-2 indication was observed on the Control Room Indicator and on the local meter on the Count Rate Amplifier Module (CRAM) located in the Nuclear Instrumentation/Reactor Protection system cabinets. On two previous occasions, once when the RPS cabinet door was opened and once when tapping on the front of the CRAM, the count rate level indication returned to normal.

Even though there was no significant impact during or following the transient on June 9, the inoperability of both NI-1 and NI-2 did create an undesirable added distraction to the operator in having to verify the shutdown margin requirements per action statement six of T.S.3.3.1.1. From this standpoint it is highly desirable to locate and correct the problem with NI-2.

II. BASIC PRINCIPLE OF OPERATION

The source range instrumentation consists of two redundant count rate instrument strings, designated NI-1 and NI-2, which measure neutron flux.

The subject of this report is the NI-2 source range instrument string as shown by Fig. 1. NI-2 is located in the Nuclear Instrumentation/Reactor Protection system channel 1.

The source range signals originate in high sensitivity BF_3 proportional counters located in thimble wells in the reactor vessel cavity.

The proportional counters are connected to preamplifiers located in the reactor building. The preamplifiers are used to shape and amplify the low-level pulses from the proportional counters. The signal output of the preamplifier is sent to the count rate amplifier located in the Nuclear Instrumentation/Reactor Protection system cabinets.

The CRAM which contains a discriminator and Log Count Rate amplifier further shapes and amplifies the signal pulses. The signal pulses are sent to discriminators where background and gamma pulses are discarded. A log count rate amplifier converts the neutron pulses to a signal suitable for displaying the log count rate level both locally and remotely to the operator. The display range is from 10^{-1} to 10^{6} counts per second.

The Rate Of Change Module (ROCM) has differentiator amplifiers which calculate the rate of change of the log count rate for display locally and remotely to the operator. An interlock is provided for control rod withdraw hold and alarm on high startup rate.

III. SUMMARY OF TROUBLESHOOTING AND INVESTIGATION

Maintenance Work Order #1-85-2030-00, 01, 02, 03

Note: As part of the troubleshooting procedures some repairs were made with approval of the Region 3 NRC representatives.

Action Plan Step 1

Pictures were taken of cabinets, wiring, etc. to document existing conditions. Readings were taken at test jacks on all associated modules. The source used for these tests was reactor residual neutron flux. There were no anomalies noted in any of the readings.

During NI-2 inspection and other troubleshooting the following problems were detected.

Significant Problems:

1. It was determined by test that penetration FW 2 P1L1L for NI-2
   signal cable 1LRPSB03C contained a resistance substantially
   higher than the penetration for NI-1 or spare penetration 2
   FW 3 P1L1L when connected into the NI-2 instrument string.
   Operation with FW 2 and FW 3 (spare) penetration interchanged
   indicates that the FW 2 penetration contains an anomaly.

2. The top BNC Coaxial Cable Connector (JC) on the Count Rate Amplifier was not locked in properly. The back of the CRAM has two BNC coaxial cable connectors as interfaces to the CRAM signal input and 15V output to the Preamp. The top BNC coaxial cable connector could not be turned to its fully locked in position. This problem has been corrected. 2

3. The preamp low voltage cable was loose in the connector body. This connector has been replaced. 2

4. The signal cable was loose in the connector body at penetration P1L1I. This connector has been replaced. 2

5. Operation of Reactor Protection System (RPS), Safety Features Actuation System (SFAS) and Steam Feedwater Rupture Control System (SFRCS) cabinet door switches (which provide annunciator indication of open doors) frequently cause high level spikes 2 visible by use of an oscilloscope at the input to the CRAM. No alarms have resulted. The monitoring recorder temporarily connected to the output of the CRAM does not respond to these spikes.

6. The high voltage connector at the preamp is extremely loose (with no "O" ring in place). Witn the knurled connector nut tight, movement was possible between the two halves of the connector. This connector has been replaced. 2

7. No grounding wire is connected to the outside box which contains the preamp.

8. Every Amphenol connector inspected was tarnished and many contained metal flakes from the connector assembly.

9. Operation of some motor operated SFAS isolation valves have been identified as causing some spiking at the output of the Rate of Change Amplifier Module (ROCAM). Observation of 2 spiking vs. valve operation is continuing and is being logged by the reactor operators. This observation will continue until a month of power operation is accomplished.

Observations:

1. The high voltage cable connector on the back of the power supply appears to be nickel (shiny) vs. silver plating. Silver plated connectors are specified by the vendor. This connector has been replaced. 2

2. The high voltage cable connector on the back of the power supply in RPS cabinet #1 is missing the "O" ring. Figure 2 shows a typical connector assembly. This connector has been replaced. 2

3. Time Domain Reflectometer (TDR) traces were taken using a Tektronix Model 1502 Time Domain Reflectometer. The Time Domain Reflectometer measures impedance vs. cable length by sending a high frequency signal down the cable and monitoring reflections coming back.

   When the TDR trace for the signal cable was taken, very small impedance changes through the penetration to the preamp were 2 observed. The small impedance changes are judged not to be the cause of the loss of Count Rate problem.

4. The preamp high voltage cable connector does not have an "O" ring. This connector has been replaced. 2

5. The preamp detector and signal cable connector appears to be nickel (shiny) vs. silver plating. Silver plated connectors are specified by the vendor. These connectors have been 2
replaced.

6. Plastic bushings were not installed in the ends of the 2" conduits that enter into the back of the preamp outer box. The bushings protect cables from abrasion by internal threads on the conduit.

7. The detector cable bushing did not have a gasket where it is attached to the outer preamp box. This problem was corrected
by installing a new preamp. 2

8. The four bolts which mount the detector cable bushing to the outer preamp box did not have lockwashers. This problem was
corrected by installing a new preamp. 2

9. The detector, signal and high voltage connectors mounted on the outer preamp box were loose. The nuts could be turned with
only fingers. This problem was corrected by installing a new 2
preamp. The paint was removed where the connectors attach to the preamp housing due to a grounding problem on NI-1.

10. Rust was observed in the connection box at top of the detector thimble. The seal plate apparently leaked at some time.

11. The TDR trace for the low voltage cable shows very small impedance changes through the penetration to the preamp. The small 2
impedance changes are judged not to be the cause of loss of Count Rate.

12. The printed circuit board mounting for the preamp was loosely mounted off of four slip over metal standoffs. This problem was corrected by installing a new preamp. 2

13. In some cases fiber (shipping) washers have been left on the bulkhead connectors installed at the preamp and RPS cabinets. This fiber washer prevents the connector from being tightened in place properly. The result would be that the connector body would turn during tightening of the connector. The fiber washers were inadvertently left in place during initial construction. All bulkhead connectors have been checked and fiber washers removed where they existed. 2

Action Plan Step 2

To reproduce the count rate failure the NI-2 detector power supply was turned off and on while monitoring readings on the associated modules. This procedure was repeated approximately three times per day over a 14 day period. No failures were observed.

Action Plan Step 3

To reproduce the count rate failure, the associated cabinet doors were opened and closed and the module face plates of the associated modules were tapped lightly while observing the applicable readings on the associated modules. No failures occurred during this procedure.

Action Plan Step 4

The Bench test of the CRAM was not performed so that the problem with the BNC coaxial cable connector would not be destroyed, see significant problem 2. The CRAM was tested while installed and was eliminated as a possible cause of the failure (see Step 6). The CRAM BNC coaxial connector was corrected so that it locks in place properly.

Action Plan Step 5

The detector high voltage power supply was removed, bench tested under load and monitored for 24 hours. No anomalies were found.

Action Plan Step 6

The object of this test was to verify proper operation of relay K1.0 in the CRAM. The CRAM relay K1.0 was monitored for proper operation while switching the test module from "operate" to "test" and back to

"operate". Relay K1.0 contacts connect the test signal or operating signal to ground dependent on whether the "operate mode" or test "mode" has been selected. During this test no anomalies were found.

Action Plan Step 7

A recorder was connected to NI-2 monitoring the CRAM output, the Rate of Change Module output and the detector high voltage divided by one thousand test jack. The intermediate range high voltage cut off bistable was "tripped" and "reset" in an effort to reproduce the loss of count rate problem. This procedure was repeated approximately four times per day for 10 days. One failure occurred which lasted for approximately 4½ minutes.

An additional channel of the recorder was connected directly to the detector power supply high voltage output and monitoring was started with the detector high voltage on continuously.

During continuous monitoring over a period of approximately 20 days, the following three failures occurred:

1. The count rate failed to 10^{-1} for three minutes then returned to normal and then failed for an additional four minutes before returning to normal All other recorded readings were normal.

2. Approximately 24 hours after the failure in 1 above, another count rate failure occurred for less than one minute then returned to normal. All other recorded readings were normal.

3. Approximately 7 days later a new preamp was installed and the recording was continued. Within 24 hours another count rate failure occurred which lasted for 1½ hours. During the failure the low voltage (+15) was measured at the preamp and was found to be within limits. When the high voltage was measured at the preamp the count rate returned to normal. The connectors at the preamp were checked for tightness. When the signal output (to the RPS) connector was rotated, spiking and elevated count rate occurred. The elevated count rate remained for some period of time. No problems were observed with the other preamp connectors.

4. After failure #3 occurred triax cable connectors at the preamp, the detector MI cable/triax cable interface and accessible connectors at the penetration were being inspected/cleaned or
replaced as necessary while maintaining operation of the 2
channel. During this time the channel operated for 12 days without loss of count rate then the following failures occurred: Lost count rate for 8 minutes; 2 hours later lost count rate for 10 minutes; 42 hours later lost count rate for 2 minutes; and 2 hours later lost count rate for 1 minute.

On the basis of resistance tests taken under Action Plan Step 9, Item b (see below), the penetration was indicated as possibly containing an anomaly. Penetration FW 2 P1L1L was interchanged with spare penetration FW 3 P1L1L and the channel placed back in operation. The channel operated in this configuration for 9 days without loss of count rate.

During the time spare penetration FW 3 P1L1L was connected into the NI-2 channel an independent test was run on penetration
FW 2 P1L1L per the following: A 0.5 volt DC source was 2
applied to the FW 2 penetration center conductor, inner shield and outer shield. Each of the three conductors was monitored by a separate channel on a recorder for the loss of the 0.5 VDC signal applied. During the six day duration of this test three separate failures (0.5 VDC was lost) occurred on the center conductor.

The penetrations were then returned to the original configuration (FW 2 connected back into the circuit) and after 21 hours operation the following failures occurred: Lost count rate for 55 minutes; 25 hours later lost count rate for 7 minutes; and 47 hours later lost count rate for 17 minutes.

Action Plan Step 8

(a) The NI-2 preamp was removed and bench tested. The pulse amplitude for the times 10 range was slightly high on bench test. In accordance with the vendor manual pre-installation acceptance

test procedure, the output pulse amplitude limits are -1.9 to -2.1 volts for the times 10 range. The reading for this preamp was -2.2 volts. No other anomalies were noted.

(b) A new preamp (obtained from VEPCO) was installed and monitored for three days. No failures occurred. The NI-1 preamp was removed and installed in the NI-2 channel and monitored for 1½ days. No failures occurred.

(c) The original NI-2 preamp was reinstalled and monitored for two days. No failures occurred. At this time the preamp was removed and taken to the vendor for complete evaluation. 2
Vendor test data has been issued by memo from Bailey Controls Company (Harold Sternberg) to Toledo Edison Company (Jack Kasper) dated 8/22/85. The Bailey Controls Company conclusion is that the preamp operation is satisfactory.

A new preamp (obtained from Consumer's Power Company) was installed and the failure as described by Action Plan Step 7, failure #3 occurred.

Action Plan Step 9

(a) Time Domain Reflectometer (TDR) traces were taken using a Tektronix Model 1502 Time Domain Reflectometer. The Time Domain Reflectometer measures impedance vs. cable length by sending a high frequency signal down the cable and monitoring reflections coming back

The cables checked are as follows:

1. RPS cabinets to the preamp
   a. signal cable
   b. high voltage cable
   c. low voltage cable

2. Preamp to detector
   a. signal/high voltage cable

The TDR test results are:

1. The signal cable from the penetration to the preamp shows very small impedance changes. The small impedance changes are judged not to be a cause of loss of Count Rate.

2. The low voltage cable from penetration to preamp shows very small impedance changes. The small impedance changes are judged not to be a cause of the loss of Count Rate.

(b) Resistance readings on the high voltage and signal cables were taken at the RPS cabinets. The high voltage and signal cables were disconnected at the RPS and the preamp. Appropriate jumpers for the conductors being measured were 2

connected on the cable at the preamp. Resistance readings
were taken from the center conductor through the inner
shield, center conductor through the outer shield and
inner shield through outer shield. Comparative readings
were taken of NI-1, NI-2 with penetration FW2 PILIL
connected and NI-2 with spare penetration FW3 PILIL 2
connected. It was determined that the Center Conductor
resistance for NI-2 with penetration FW2 PILIL connected
was more than double that measured for NI-1 or NI-2 with
spare penetration FW3 PILIL connected in place of pene-
tration FW2 PILIL. Operational tests were also performed,
see Action Plan Step 7, Failure #4 for details.

Action Plan Step 10

Detector checks were taken for both NI-1 and NI-2 at the preamp locations. Readings for NI-1 and NI-2 were similar and did not show any anomalies.

Action Plan Step 11

Inspection, cleaning and replacement (as necessary)[1] of connectors has started. See Section VI A. 1. required corrective action for details.

B. Significance of Findings

The significant findings are:

1. Failure of penetration FW 2 P1L1L |2

2. The poor state of maintenance of the Amphenol Triax Connectors.

IV. RESULTS/CONCLUSIONS OF FINDINGS

A. Direct Cause

1. The direct cause of the loss of count rate was failure of penetration FW 2 P1L1L. |2

2. A secondary cause of loss of count rate was the degraded condition of triax connectors. |2

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1 "as necessary" means replacing those connectors that cannot be cleaned properly, the tarnish removed or shows other signs of not being a quality connection.

B. Root Causes

1. The direct cause of the loss of count rate is the penetration, however within the penetration the root cause cannot be established until the prenetration can be removed and evaluated. 2

2. A secondary root cause of loss of count rate has been established to be the degraded condition of the triax connectors. The degraded condition is center pins out of place due to improper assembly, missing parts and lack of proper cleaning before mating connectors. 2

V. TECHNICAL JUSTIFICATION OF FINDINGS

The cable resistance test data included as part of action plan step 9b and operational test performed on Action Plan Step 7 is justification that the direct causes are the intermittent penetration and degraded condition of triax connectors. 2

On removal of the penetration it will be evaluated for the specific fault.

VI. SPECIFIC CORRECTIVE ACTIONS

Corrective actions are being performed with the approval of the Region 3 NRC representatives. 2

A. Required Corrective Action

1. The penetration has been determined to be intermittent and will be replaced prior to startup after the next refueling outage. In the interim spare penetration FW 3 P1L1L will be used for NI-2.

2. Inspection, cleaning and replacing (as necessary)[2] shielded cable connectors from the detector to the RPS cabinets is in progress. All connectors for the NI-2 string from the detector to the RPS cabinets have been inspected/cleaned or replaced except at the penetration. The connectors are being replaced using installation instructions written in the Maintenance Work Orders. Selected personnel have been instructed in the proper installation procedures by the system vendor representative. 2

B. Additional Planned Actions

1. Revise or prepare new procedures for installing triaxial cable connectors. The current procedure is MP 1410.24. Due to the Generic Corrective Actions as outlined in 2

---

2 "as necessary" means replacing those connectors that cannot be cleaned properly, the tarnish removed or shows other signs of not being a quality connection. 2

Section VIII, this item will be completed prior to the next refueling outage.

2. Provide cable connector installation training for station personnel. This item to be completed prior to further cable connections. Work is planned to commence during the 2
next refueling outage and training must be completed prior to this.

3. Reinstall the 2" plastic bushings in the conduit that enters the back of the Preamp Outer Box. This work will
be accomplished during the next refueling outage. 2

4. Add grounding wire to the outside box which contains the preamp. An engineering evaluation will be completed this
fuel cycle to determine if this ground wire is required. 2
The ground wire will be installed during the next refueling outage if required.

5. Replace the seal plate gasket for the connector box at the top of the detector thimble. This gasket will be replaced
prior to this startup. 2

6. Replace source range NI-2 Amphenol penetrations with new Conax penetrations. This action is necessary in that the
existing penetrations contain triax connectors that 2
require penetration removal to inspect or replace the

connectors. The existing penetration is intermittent and a spare is being used in the interim time period. The new Conax penetrations will eliminate one connector per cable 2
and the connectors will be accessible after penetration installation. The replacement of the penetration modules will be completed at the next refueling outage.

7. Review and revise (as required) procedure number MP 1504.04 for adequacy in determining if the seal plate rubber gasket, for the connector box at the top of the detector 2
thimble requires replacement. The NI-2 rubber gasket will be replaced prior to this startup. The gasket replacement concern will be addressed prior to the next refueling outage.

8. Revise procedure number IC 2002.02 so that it adequately addresses all areas of NI detector removal and installation. No further detector removal/installation is planned. This 2
item will be completed prior to the next refueling outage.

9. Revise procedure number IC 2002.04 to address current requirements for source range discriminator and high voltage settings. This item will be completed as part of 2
the annual procedure review or prior to the next refueling outage, whichever comes first.

10. Revise procedure number MP 1410.24 to address current
requirements for installation and removal of Raychem heat
shrinkable tubing. This item will be completed as part of 2
the annual procedure review or prior to the next refueling
outage, whichever comes first.

11. Continue observation of spiking vs. SFAS isolation valve
operation and look for/corrolate with any other equipment
actuations that cause spikes at the output of the rate of 2
change amplifier module and perform tests to determine
source of spiking. This observation will continue until a
month of power operation is accomplished.

12. Prepare an interim administrative procedure for operating
with SFAS isolation valve spiking present and any other
equipment actuations that cause spiking pending (if 2
possible) location and elimination of the source of the
spiking. The SFAS isolation valves would not normally be
operated during plant startup or shutdown therefore, this
would not present a problem to operation during startup or
shutdown.

13. Recorder monitoring of the NI-2 instrument string will
continue until the start of power operation. 2

VII. GENERIC IMPLICATION

Triax shielded cable connectors on the other NI systems may have conditions similar to those found on the source range instrumentation.

VIII. GENERIC CORRECTIVE ACTION[3] |2

1. Inspect, clean and replace (as necessary)[4] shielded cable connectors on NI Intermediate Range Instrument Strings. |2

2. Inspect, clean and replace (as necessary)[4] shielded cable connectors on NI Power Range Instrument Strings. |2

bj e/18

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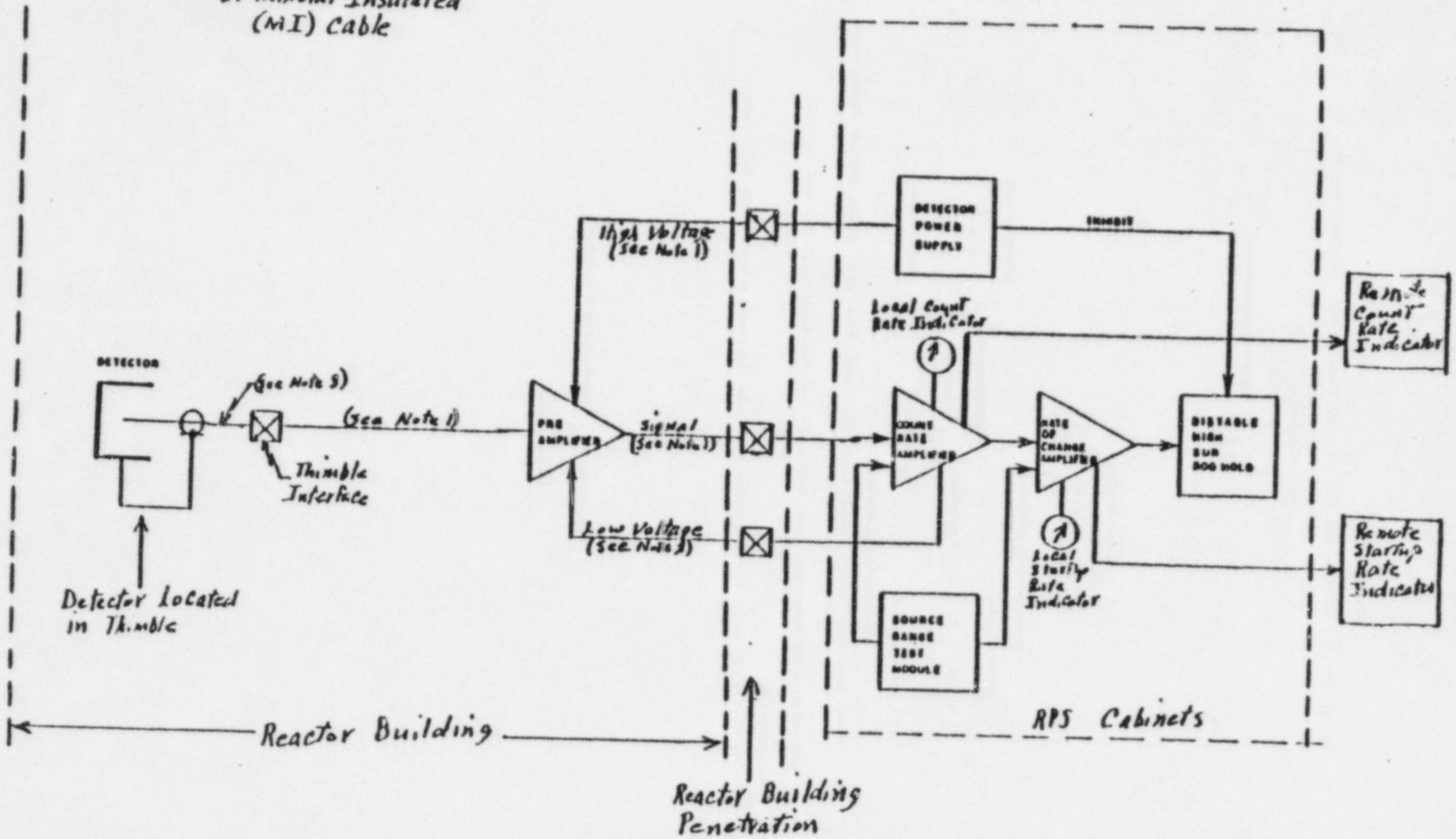
3 More time is required to get an adequate supply of replacement connectors. No known problems exist in the Intermediate or Power Range instrument strings which are less susceptible to elevated count rate and noise problems and have performed satisfactory to date; therefore, this work will be performed at the next refueling outage. 2

4 "As necessary" means replacing those connectors that cannot be cleaned properly, the tarnish removed or shows other signs of not being a quality connection.

Notes: 1. RG/HV Triax cable
2. Twinaxial Cable
3. Mineral Insulated (MI) Cable



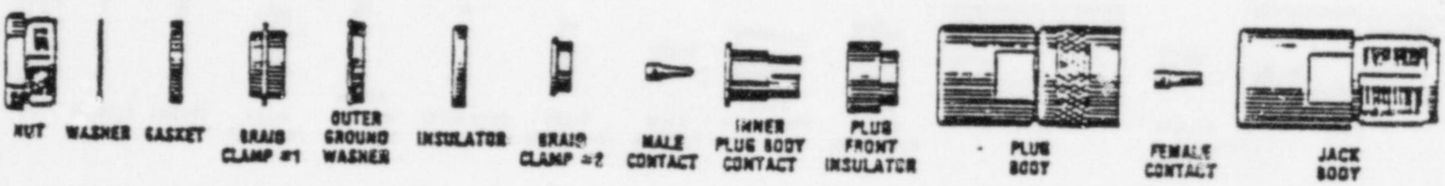
SOURCE RANGE INSTRUMENT STRING

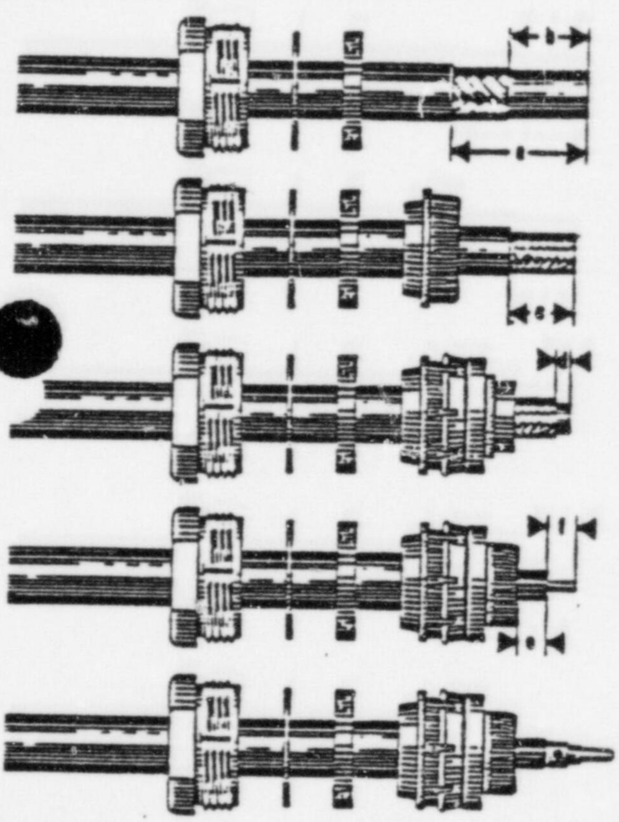
Fig 1

TRIAX

Fig. 2

ASSEMBLY INSTRUCTIONS





Slide nut, washer and gasket over cable. Cut off outside jacket (using razor blade or wire strippers) to dimension a. Make a clean cut, being very careful not to nick braid. Cut first braid to dimension b.

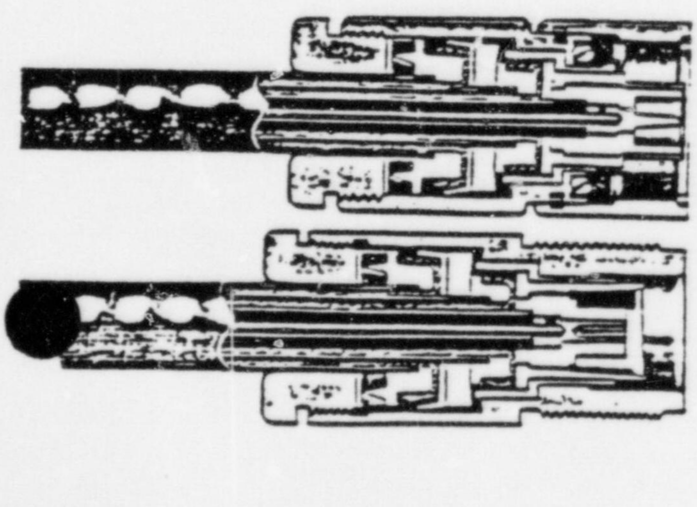
Slide first braid clamp over braid up to jacket of cable. Fold first braid back over clamp, making sure braid is evenly distributed over the surface of the clamp. Trim second jacket to dimension c, again being very careful not to nick braid.

Trim second braid to dimension d. Slide on outer ground washer, insulator and second braid clamp. Fold second braid back over braid clamp, again making sure that braid is evenly distributed over surface of clamp.

Trim cable dielectric to dimension e.

Tin the inside hole of the contact. Tin wire and insert into contact and solder. Remove any excess solder. Be sure cable dielectric is not heated excessively and swollen so as to prevent dielectric from entering body of fitting.

Plug only: Place front insulator and outer contact assembly into back of connector body and push into proper place. Insert cable-contact assembly into body. Screw nut into body with wrench until moderately tight.



Stripping dims. ±1/64(0.4) inches (millimeters)

Plugs	58A, 59 Type	8, 11 Type
a	7/8(22.2)	15/16(23.8)
b	19/32(15.1)	19/32(15.1)
c	9/16(14.3)	15/32(11.9)
d	11/32(8.7)	5/16(7.9)
e	11/32(8.7)△	5/16(7.9)
f	9/64(3.6)	1/8(3.2)
Jacks	**58A, 59 Type**	**8 Type**
a	19/32(15.1)	29/32(23.0)
b	21/64(8.3)	19/32(15.1)
c	19/64(7.5)	9/16(14.5)
d	1/4(6.4)	5/16(7.9)
e	1/4(6.4)■	5/16(7.9)
f	3/32(2.4)	1/8(3.2)

△ for 53100 and 53150 plugs this dimension is .187(4.5)

■ for 34400 and 34375 jacks this dimension is .130(3.3)

FINDINGS, CORRECTIVE ACTIONS AND GENERIC IMPLICATIONS REPORT

TITLE: TOLEDO EDISON - SERVICE WATER TRANSFER

REPORT BY: TIMOTHY CZUBA (TED) PLAN NO. 26
BRUCE HICKMAN (TED)
JAMES TABBERT (TED)

REV	DATE	REASON FOR REVISION	WRITTEN BY	APPROVED BY
0	8/17/85	Initial Issue	Tabbert Czuba B. Hickman	L. Grime
1	8/23/85	Corrective Actions Added	Tabbert Czuba B. Hickman	L. Grime
2	8/29/85	Testing Clarification	Tabbert Czuba B. Hickman	L. Grime
3	9/9/85	Updated Root Cause and Technical Justification	L. Grime	D. Mominee
4	9/17/85	Final Issue	B. Hickman	L. Grime

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I. ISSUES/CONCERN:

During the June 9 transient, an inadvertent automatic transfer of the suction of Auxiliary Feed Pump 1-1 (AFP 1-1) from the condensate storage tanks to the service water system was actuated.

The automatic transfer of auxiliary feed pump suction from the condensate storage tanks to the service water system occurred prior to the actual loss or low water level in the condensate storage tanks. Service water will allow the auxiliary feed water pumps to perform their safety function. Service water is chlorinated lake water which is chemically undesirable for use in the steam generator.

II. BASIC PRINCIPLES OF OPERATION

In the event of loss of the water supply from the condensate storage tanks, an automatic backup is provided from the service water system. Two independent low pressure switches provided on the auxiliary feedwater pump suction line, upon both sensing low pressure, will automatically close the valve from the condensate storage tanks and open the valve from the service water system. Each auxiliary feedwater pump has an independent set of pressure switches, supply valve from the condensate storage tank, and supply valve from the service water system. These components function independently with their respective auxiliary feed pumps. See Figure 1.

III. SUMMARY OF TROUBLESHOOTING AND INVESTIGATION

A. Field Actions Performed

MWO 1-85-2130-00 and 1-85-2133-00 checked the time response, calibration, condition of the switch, and wiring of PSL 4928A, PSL 4928B, PSL 503, PSL 4929A, PSL 4929B, and PSL 507.

PSL 507 was found to actuate at 9.36 PSIG. The setpoint for PSL 507 is 11 PSIG. PSL 507 monitors the auxiliary feed pump 1-2 suction pressure downstream from the strainer S206. PSL 507 provides an alarm indication in the control room, but no control function.

PSL 4928A was found to have a loose terminal connection. It was determined the connection was making contact and had no effect on the operation of PSL 4928A. Review of the circuit diagram shows the loose wire would not affect the actuation of the automatic transfer.

MWO 1-85-2146-00 verified there were no obstructions in strainers S201, S206, or S257. The strainers were disassembled and no obstructions were found.

MWO 1-85-2144-00 verified that upon sensing low pressure at PSL 4928A and PSL 4928B, the suction to auxiliary feedwater pump 1-1 would transfer from the condensate storage tanks to the service

water system. Low pressure was applied to PSL 4928A and PSL 4928B simultaneously and the suction transferred correctly.

B. Analysis Performed

The effects of vibration on PSL 9428A and PSL 4928B were investigated. The evaluation concluded that vibration was not a credible cause of inadvertent actuation of PSL 4928A and PSL 4928B. The conclusion was based on vibration analysis of the supports and switches.

Another analytical study investigated the pressure drop in the pump suction line as a potential cause of the automatic transfer of auxiliary feed pump suction from the condensate storage tanks to the service water system. The study concluded that 4
the conical strainer, S257, (which was added to the system in 1981) may significantly reduce the steady state suction pressure and thus increase the probability of suction pressure dropping below the setpoints of the pressure switches PSL 4928A and PSL 4928B, activating the automatic transfer. It should be noted that the calculations were initially based on a calculated pressure drop for the conical strainer S257. Subsequent testing (see Section C.) showed that at rated flow of 2100 gpm the suction strainer would be estimated to reduce the steady pressure at the pressure switch by 4.6 psi.

A study was conducted to verify the circuitry for the automatic transfer of the auxiliary feedwater pump suction was of correct design and logic configuration. The study concluded:

- The circuitry will provide the automatic transfer of the auxiliary feedwater pump suction upon sensing low pressure at both low pressure switches. (PSL 4928A and PSL 4928B for AFP 1-1. PSL 4929A and PSL 4929B for AFP 1-2).

- No single failure or inadvertent actuation of any single device will cause the automatic transfer of the auxiliary feedwater pump suction. The automatic transfer requires two (2) out of two (2) actuation of the low pressure switches.

- Barring multiple or common mode failures of the pressure 4
switches, actuation of the automatic transfer of the auxiliary feedwater pump 1-1 suction was caused by a low suction pressure which was sensed by PSL 4928A and PSL 4928B.

Investigation of the June 9th and previous documented auxiliary feed pump suction automatic transfers from condensate storage tanks to the service water system has shown:

- The automatic transfer has occurred four (4) times: July 30, 1981; November 9, 1983; January 15, 1985; and June 9, 1985. The earliest transfer was on train 2, the three later transfers all occurred on train 1.

- All transfers occurred after the addition in 1981 of strainer S257.

The three early transfers occurred when the auxiliary feed flow was increasing, i.e., as a pump was accelerating. The transfer 4
on June 9, 1985, however, occurred coincidently with the cut-off of steam to AFPT 1-1. The alarm printout for June 9, 1985, shows the automatic transfer took place at 1:58:40. The same alarm printout shows that the AFPT 1-1 trip throttle valve left the open position at 1:58:39. As explained in the findings report for Action Plan 1D, this corresponded to the spurious trip on the improperly reset trip throttle valve and the rapid cut-off of steam to AFPT 1-1. Data from the June 9, 1985, incident show that the flow from AFP 1-1 to the steam generator dropped from about 500 gpm to zero in less than two seconds at that time.

C. Testing Performed

Test procedure ST 5071.01 (T-mod 9544) (performed on September 6, 1985) determined the steady pressure losses in the line from the auxiliary feed pumps to the condensate storage tank. This was done with AFPT 1-2 operating on auxiliary steam and recirculating through a large recirculation line as well as the normal recirculation path. Based on these data the pressure at the pressure switch location can be calculated for other flow rates and other levels in the condensate storage tank. These results are shown in Figure 2.

Observations of transient pressures during startup of AFPT 1-2 4
were made in August 21, 1982 using test procedure TP 520.48. In this test a pressure transducer was placed in the pump suction and the pressure was recorded as the SFRCS was tripped and auxiliary feed pump 1-2 started. Figure 3 shows the dip in suction pressure which resulted as the pump accelerated. This trace also shows other fluctuations in pressure which are evidently related to flow through the system, but are not the result of acceleration of the turbine.

D. Significance of Findings

Investigations have shown that the automatic transfer of the auxiliary feedwater pump suction was not due to a mechanical or electrical malfunction of PSL 4928A or PSL 4928B. PSL 4928A

and PSL 4928B are mechanically and electrically independent. An automatic transfer of the auxiliary feedwater pump suction caused by a malfunction of PSL 4928A and PSL 4928B would require both to fail at the same time. Therefore, a transfer of the auxiliary feedwater pump suction by a malfunction of PSL 4928A and PSL 4928B is not credible.

Review of historical data shows that three suction transfers had taken place prior to the one on June 9, 1985. However, these transfers were fundamentally different from the transfer which took place on June 9, 1985. The other transfers took place when an auxiliary feed pump was <u>increasing</u> in speed. 4
Consequently, it is concluded that they were a direct result of the suction pressure dip which testing has confirmed occurs when a pump is accelerated. They probably also involved conditions which made this dip deeper than usual, involved other hydraulic pressure fluctuations, or involved lower condensate storage tank levels. The addition of the suction strainer S257 to the system reduced the margin between the dips and the pressure switch setpoint so that instances when the dip could actuate the switches became more probable. Although the dip in suction pressure is necessarily brief (2 to 4 seconds) this is long enough to actuate both switches. (The switches have no intentional delay.) The duration of the suction pressure depression is limited because a high rate of flow acceleration must be terminated or the pump will trip on overspeed.

The automatic suction transfer on June 9, 1985, was different from the earlier transfers; therefore, its direct cause was also different. There will be a significant hydraulic transient in the auxiliary feed system associated with the closure of the trip throttle valve for AFPT 1-1 while AFPT 1-2 is running at essentially full speed. In particular, check valves in both the outlet and inlet will be actuated as the flow is decelerated and potentially reverses. The rapid closing of check valves is capable of generating significant pressure pulses (both positive and negative).

The magnitude and duration of the pressure transients which
occur from check valve closures depends on the particular 4
parameters of the valve and system. The detailed information on the flow changes during the June 9 incident which would be necessary to calculate with confidence the pressure transients is not available. However, it has been repeatedly demonstrated in fluid systems that the waterhammer from check valve closures can easily result in pressure pulses of the magnitude (about 20 psi) which would be needed to reduce the static pressure to the switch setting.

IV. RESULTS/CONCLUSIONS OF FINDINGS

A. Direct and Root Cause

The automatic transfer of auxiliary feedwater pump (AFP) 1-1 on June 9, 1985, was a direct result of the hydraulic transient in the auxiliary feed system which resulted when the turbine trip throttle valve for the turbine for AFP 1-1 spuriously closed shutting down the pump.

The root cause is considered to be a switch and control system
configuration which was capable of responding to rapid hydrau-
lic transients and pressure fluctuations even though the 4
suction transfer was not required, or even desirable, as a
result of those conditions.

V. PLANNED ADDITIONAL ACTIONS

Hypothesis 7 is to be investigated.

VI. SPECIFIC CORRECTIVE ACTION

A. Required Corrective Action

1. Add a time delay to the actuation of the suction transfer to assure that brief drops in suction pressure from hydraulic system transients do not cause the system to actuate.

2. Reduce the suction system pressure drop as much as practical by increasing the suction strainer (S257) mesh size.

B. Additional Planned Action

Proper operation of the switches and the operating margins will be confirmed by monitoring suction pressures (both steady state and dynamic) during auxiliary feed pump testing. This testing will be conducted after the corrective actions have been performed.

VII. GENERIC IMPLICATIONS AND CORRECTIVE ACTIONS

The fluctuations in pressure in the auxiliary feed pump suction system during brief hydraulic transients may affect the operation of other pressure switches in that system. These other pressure switches and associated control systems will be reviewed to add appropriate delays and, if necessary, make changes in setpoints to assure that automatic actions and alarms represent conditions which require such automatic action or operator concern and are not merely the normal consequence of system operation. 4

sm e/17

AUXILIARY FEEDWATER PUMP SUCTION

SCHEMATIC

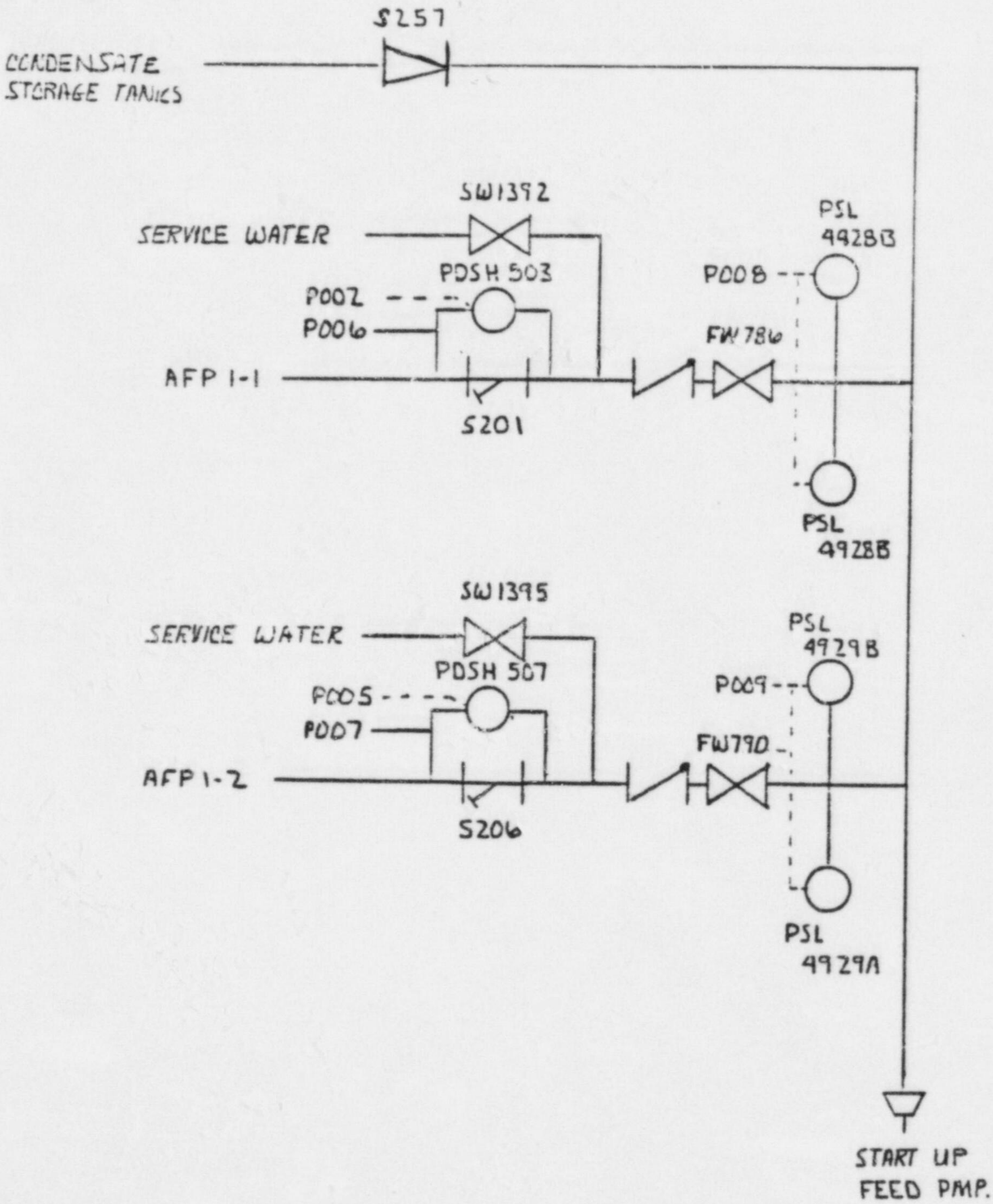
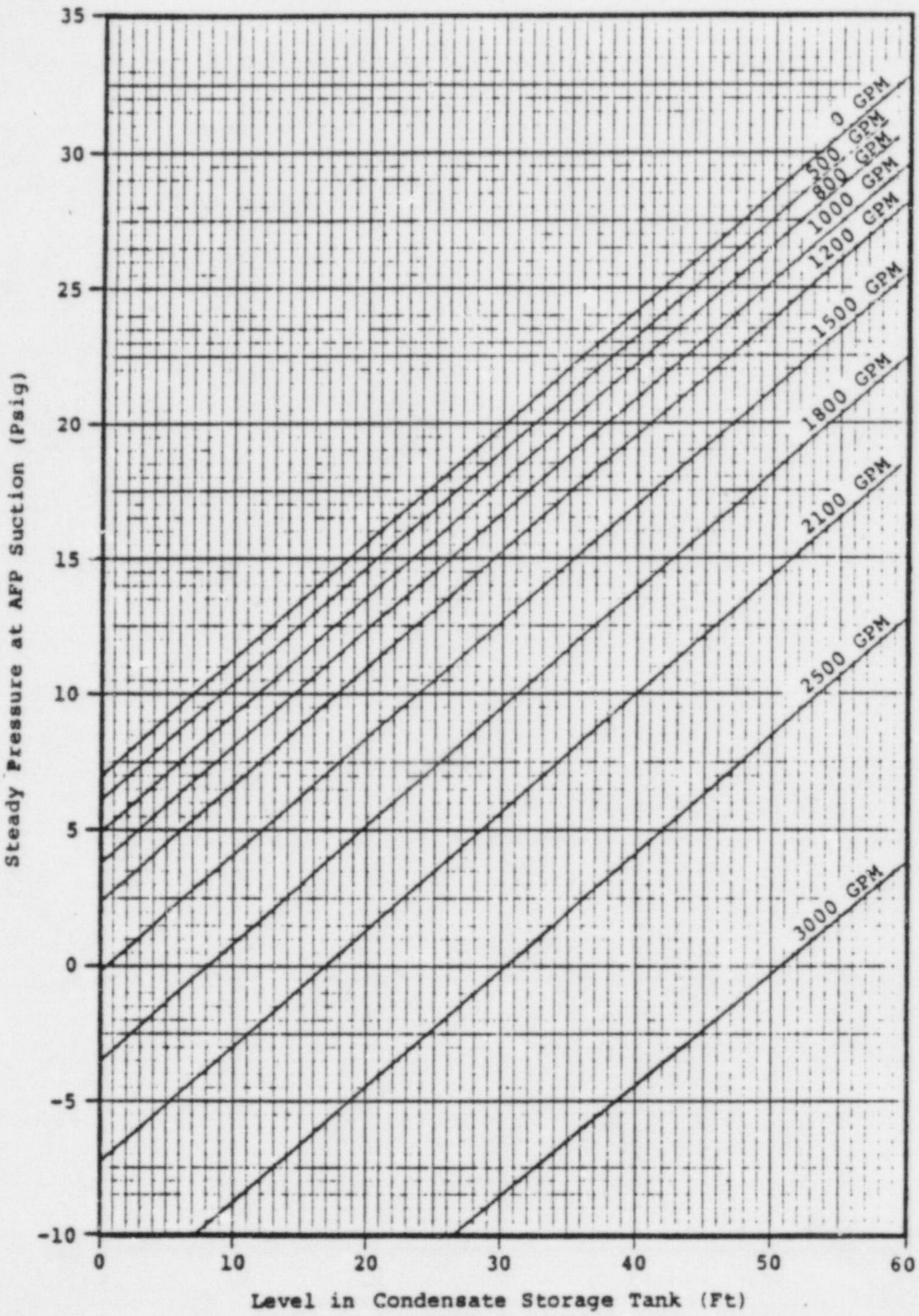
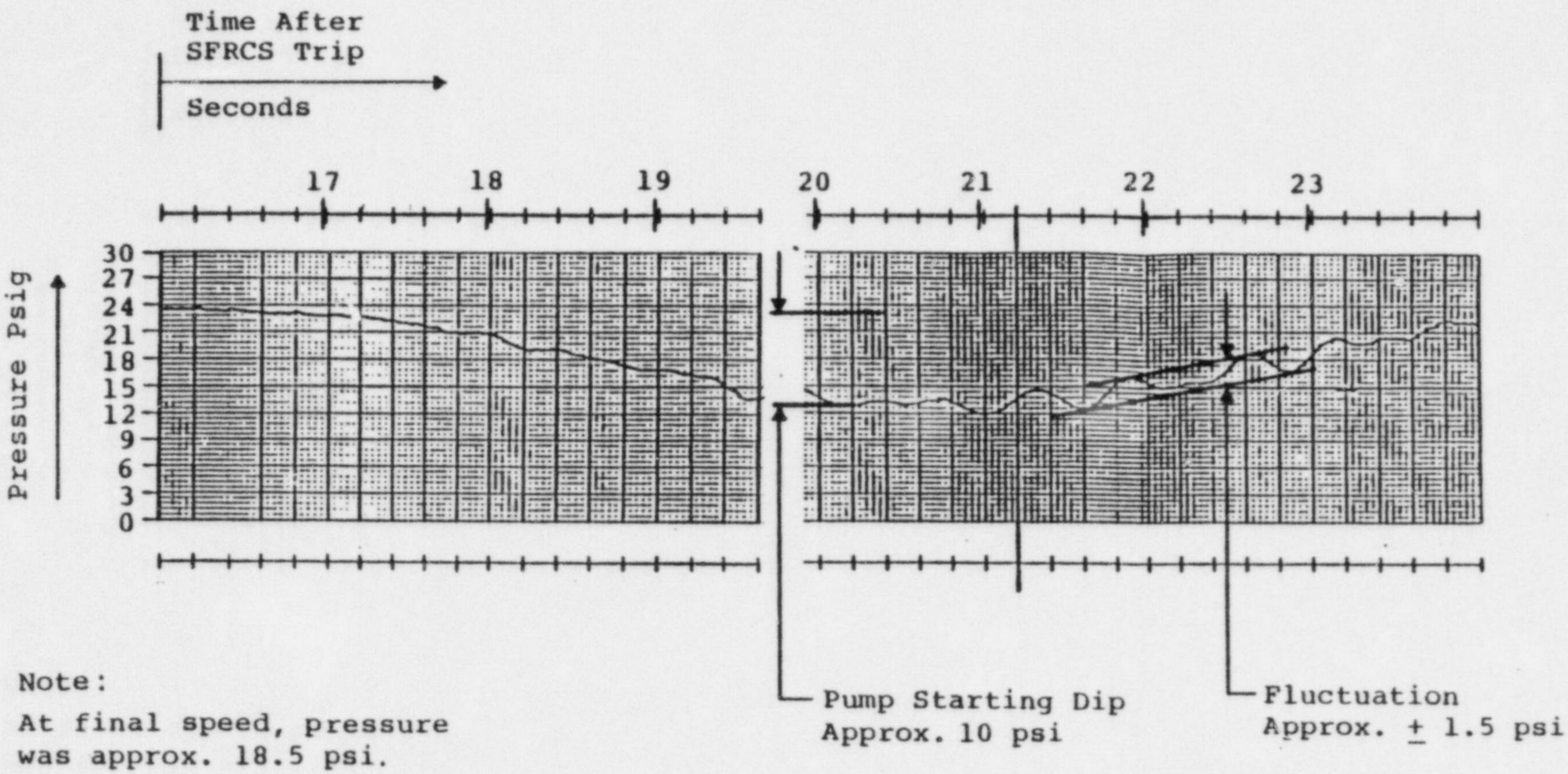


FIGURE 1



AUXILIARY FEED PUMP SUCTION PRESSURE
FIGURE 2



AUXILIARY FEED PUMP SUCTION PRESSURE
AUGUST 21, 1982, TESTING
FIGURE 3

TOLEDO
EDISON

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Docket No. 50-346

License No. NPF-3

Serial No. 1188

October 1, 1985

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
United Stated Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Denton:

The enclosed materials comprise Revision 1 to the Davis-Besse Course of Action submitted to you on September 10, 1985 (Serial No. 1182). A list of effective pages and document control receipt containing instructions for revising this document are included in the revision package. The document control receipt must be returned to Toledo Edison Company to ensure compliance with our document control procedures.

Very truly yours,

J. Williams, Jr.

J. Williams, Jr.
Senior Vice President, Nuclear

JW/VJM/bjs

Enclosures

cc: DB-1 NRC Resident Inspector

A001
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