ACTION PLAN # 1A and 1B

TITLE: AUXILIARY FEED PUMPS OVERSPEED TRIPS

REV	DATE	REASON FOR REVISION	BY	CHAIRMAN TASK FORCE
0	6/20/85	Initial Issue	Dan 6/20/85 Waleczynski	B. Berger / JHS 6/20

TITLE: AUXILIARY FEED PUMPS OVERSPEED TRIPS

REPORT BY: Dan Wilczynski, Chuck Rupp

Plan No.: 1A and 1B

DATE PREPARED: 6/20/85

This report has been prepared in accordance with the "Guidelines to Follow When Troubleshooting or Performing Investigative Actions into the Root Causes Surrounding the June 9, 1985, Reactor Trip," Rev. 2. These guidelines were developed in response to Confirmatory Action Letter 85-05.

I. INTRODUCTION

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 safeties 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 1-1 (SG 1-1). This SFRCS actuation attempted to initiate auxiliary feedwater flow by opening the steam supply valve, MS 106, from SG 1-1 to auxiliary feedwater pump turbine (AFPT) #1. Two seconds later (1:41:08) the reactor operator inadvertently initiated an SFRCS low pressure trip on both channels. 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 SFRCS trip initiated the following, as designed:

1. Sent a close signal to MS 106 (partially open) and MS 107 (not open).

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

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

Approximately 25 seconds after initial AFPT roll, both AFPTs had tripped on overspeed (4500 RPM).

This report documents the review of data from previous unit trips, the 6/9 trip, and from AFPT testing to determine possible causes of the overspeed trips. Based on this review, this report presents hypothesized causes of the observed overspeed.

II. SUMMARY OF DATA

In order to determine possible causes for the overspeed, the following data was collected/and analyzed:

A. Past Trips and Surveillance/Testing Data

1. March 2, 1984 Trip:

   SG 1 and 2 Pressure, Temperature, and Level
   AFP 1 and 2 Speed, Discharge Pressure, and Flow
   Alarm printer data from trip

2. January 15, 1985 Trip:

   SG 1 and 2 Pressure, Temperature, and Level
   AFP 1 and 2 Speed, Discharge Pressure, and Flow
   Alarm printer data from trip

3. March 21, 1985 Trip:

   SG 1 and 2 Pressure, Temperature, and Level
   AFP 1 and 2 Speed, Discharge Pressure, and Flow
   Alarm printer data from trip

4. June 2, 1985 Trip:

   AFP 1 and 2 Speed

5. June 9, 1985 Trip:

   SG 1 and 2 Pressure, Temperature, and Level
   AFP 1 and 2 Speed, Discharge Pressure, and Flow
   Alarm printer data from trip

6. April 12, 1985 Testing:

   AFP #2 Speed

7. June 9, 1985 Testing (Post Trip):

   AFP 1 and 2 Speed

B. Modifications

During the 1984 refueling outage, the #2 AFPT governor was changed out from a Woodward PG-PL governor to a Woodward PGG governor. The new governor was supplied with 7# buffer springs and a 30 second speed setting bushing. Prior to startup, the 7# buffer springs were changed to 26# buffer springs by a Woodward Governor representative. Changeout was made to provide more stability and match the existing PG-PL governor.

C. Maintenance History

The maintenance work done excluding oil replacement since the 1984 refueling outage for AFPT 1-1 is as follows:

1. Replacing of governor control motor (6-2-85), MWO# 1-85-1876-03.

2. Adjustment of governor slip clutch (6-2-85), MWO# 1-85-1878-00.

3. Replace low speed stop roll pin (6-2-85), MWO# 1-85-1878-01.

The maintenance work done excluding oil replacement since the 1984 refueling outage for AFPT 1-2 is as follows:

1. Changeout of speed setting bushing (4-12-85), MWO# 2-83-0136-11.

A review of these maintenance records does not reveal any evidence that could support the overspeed trips of 6/9/85.

III. CHANGE ANALYSIS

The differences associated with the 6/9 trip compared to previous trips and actuations are listed below (conditions listed below existed only on 6/9/85 trip).

1. Both auxiliary feedwater containment isolation valves (AF 599 and 608) were closed when overspeed occurred. Pump flow was limited to the min-recirc flow. (It is noted that the AFPTs previously (prior to 2/84) started against AF 360 and AF 388 closed: At AFPT 2800 RPM these valves would open.)

2. Both AFPTs were running solely on the cross connect steam supply valves (MS 106A and 107A).

3. AFP #1 was started on steam from MS 106 but then was switched to steam from MS 106A.

IV. HYPOTHESIZED CAUSES OF OVERSPEED

From the above data and from discussions with the turbine vendor, Terry Turbine (Ken Wheeler); MPR Assoc. Inc. (Phil Hildebrandt, Bob Fink, and Tim Clarke); the following list of possible causes of overspeed was developed.

A. Loss of pump suction source, resulting in no pump load.

This is not considered a viable hypothesis, since the control room alarm printer shows no evidence of low pump suction pressure prior to the overspeed. Also, the 1 psig pressure switch on the pump suctions did not close the steam supply valves.

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

This hypothesis, although viable, is judged unlikely to have caused an overspeed trip by itself. The brake horsepower at min-recirc is approximately half of the design point, or 350 HP. Although this change in load is judged to not be capable of causing an overspeed, it tends to increase the chance of overspeed when combined with other phenomena. Also the discharge piping is assured to be full at all times thereby causing the pumps to operate at min-recirc conditions until the discharge valves are open.

C. Governor problems, including governor valve and linkage--
(1) AFPT 1-1 has the previously used Woodward PG-PL governor which has experienced speed control oscillation problems,
(2) AFPT 1-2 has the new Woodward type PGG governor design which was installed during the 1984 refueling outage which has not indicated any oscillation problems.

Neither governor apparently could respond to the cause of the turbine overspeed. However, it is not considered that failure or malfunction of the governors was the cause based on the following:

1. The speed graphs for the trip indicate that the governors were controlling speed as designed during the initial turbine acceleration.

2. Post trip testing shows proper operation of both governors.

3. The governor on AFP #1 is a PG-PL model with external Bodine motor for remote speed setting, while the AFPT #2 has a new PGG model with an internal motor for remote speed setting. It is considered unlikely that both of these governors would fail at the same time in a manner capable of causing an overspeed trip on the turbines.

   Since we have limited experience with the PGG governor (installed during 1984 refueling outage), we plan to further investigate whether this governor is susceptible to overspeed.

D. AFPT 1-1 rolling on steam from MS 106 prior to receiving steam flow from crossover.

This mechanism may be a contributor to the overspeed trip on AFPT 1-1, however, it is not considered likely. Discussions with Terry Turbine as well as Dawn Cook (Florida Power, CRIII) indicate that if the turbine is rolling, and steam flow is stopped and restarted, the turbine may overspeed. This is caused by the speed setting bushing (the internal piece that

controls the acceleration to rated speed) being ineffective due to the prior rotation of the turbine which has increased the governor oil pressure to its operating pressure. Since the governor oil pressure is established and controlling, loss or reduction in steam flow results in the governor valve opening in an attempt to increase steam flow. When full steam pressure and flow is re-established, the governor valve is open further than necessary and cannot close quickly enough, resulting in an overspeed condition.

This sequence may have occurred for AFPT 1-1 as a result of initial roll of the turbine on steam from MS 106 followed by closure of MS 106 coincident with opening of MS 106A. However, examination of the trip event sequence suggests that steam flow would not have been interrupted during switchover from MS 106 to MS 106A as the steam source.

Additionally, if a common cause exists for overspeed of both AFPTs, this hypothesized mechanism would not be applicable to AFPT 1-2.

E. 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.

This hypothesis is judged to be a viable description of the cause of the observed AFPT overspeed trips.

The piping between the steam isolation valves (MS 106, 106A, 107, 107A) and the AFPTs is at a temperature less than about 250°F. When the isolation valves are opened, steam at about 500 to 550°F is introduced. These steam lines range in length from 125 to 650 lineal feet.

Steam will be condensed in these lines during initial steam introduction and line heating. This condensate is expected to form water slugs, particularly in the long, approximately horizontal crossover lines downstream of MS 106A or MS 107A.

Damage to pipe hanger supports on these lines has been experienced previously, apparently due to transient operational loads. Steam flow loads would not be expected to result in hanger damage. Water slug formation or water hammer may produce these loads.

The turbine design for the AFPTs is a single stage configured similar to a bucket type "water wheel". This design is considered susceptible to increased speed excursions when water slugs are introduced. Analyses are currently being performed to confirm this hypothesis.

V. CONCLUSION

We conclude that the most probable hypothesis of those examined is introduction of water slugs into the AFPTs causing overspeed. Although other factors may have contributed to the overspeed, the major contributor is judged to be condensation.

This conclusion is based on the fact that both turbines ran on the crossover lines (MS 106A and MS 107A) which introduce an additional 250 to 350 feet of cold piping compared to operation via the normal steam supply path. Discussions with Terry Turbine (Turbine supplier) have revealed that water induction to the turbine can result in an overspeed condition due to the fact that the water will flash through the turbine nozzles. It is noted that pipe support damage to these steam lines has been encountered previously (e.g., February through April, 1985) due to transient operational loads. The magnitude of the loads required to sustain this damage suggests the presence of water slugs or water hammer (e.g., steam trapped between water slugs). Investigations of the pipe support problem were being performed prior to the 6/9/85 trip.

Testing and analyses are currently being planned/performed to further confirm this hypothesis.

DVW:CER:lrh

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DATE PREPARED	PREPARED BY
6/19/85	Rupp/ Wilczynski

TITLE

AUXILIARY FEEDPUMP TURBINE 1-1 OVERSPEED TRIP

SPECIFIC OBJECTIVE

Verify hypothesis to support root cause determination.

STEP NUMBER	ACTION STEPS	PRIME RESPONSIBILITY	ASSIGNED TO	START DATE	TARGET DATE	DATE COMPLETED
	All steps of this Action Plan are to be performed in accordance					
	with the latest revision of "Guidelines to Follow When Trouble-					
	shooting or Performing Investigative Actions into the Root					
	Causes Surrounding the June 9, 1985 Reactor Trip".					
1	Develop approved procedure for turbine disassembly and	Wilczynski	Thompson			
	reassembly.					
2	Remove casing on Auxiliary Feedwater Pump Turbine (AFPT) 1-1.	Wilczynski	Thompson			
	All work is to be performed under the guidance of a Terry					
	Turbine representative.					
3	Document as-found/baseline conditions of turbine. Identify	Wilczynski	Rupp			
	and document any discrepancies found between turbine design					
	and as-found conditions.					
4	Prepare Maintenance Work Order (MWO) for repair/replacement	Wilczynski	Thompson			
	of components as required/determined by vendor representative					
	and engineering. Update baseline conditions as necessary.					
5	Reassemble turbine.	Wilczynski	Thompson			

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TITLE

AUXILIARY FEEDPUMP TURBINE 1-1 OVERSPEED TRIP

DATE PREPARED	PREPARED BY
6/19/85	Rupp/ Wilczynski

SPECIFIC OBJECTIVE

Verify hypothesis to support root cause determination

STEP NUMBER	ACTION STEPS	PRIME RESPONSIBILITY	ASSIGNED TO	START DATE	TARGET DATE	DATE COMPLETED
6	Remove governor cover on AFPT 1-1 and document as-found/ baseline conditions of governor. All work is to be done by Woodward Governor representative.	Wilczynski	Thompson			
7	Prepare MWO for repair/replacement of components as required/ determined by vendor representative and engineering. Update baseline conditions as necessary.	Wilczynski	Thompson			
8	Reassemble AFPT 1-1 governor.	Wilczynski	Thompson			
9	Develop test procedure or modify (T-mod) existing procedure to simulate the conditions of the 6/9/85 overspeed trip on AFPT 1-1 using MS106A (crossover line). The test will include a "back-up" system for tripping turbines manually and instrumentation to monitor the thermo-hydraulic conditions in the supply piping.	Wilczynski	Missig			
10	Run test procedure for AFPT 1-1 (MS106A) after entering Mode 3.	Wilczynski	Missig			

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TITLE
AUXILIARY FEEDPUMP TURBINE 1-1 OVERSPEED TRIP

SPECIFIC OBJECTIVE

Verify hypothesis to support root cause determination.

STEP NUMBER	ACTION STEPS	PRIME RESPONSIBILITY	ASSIGNED TO	START DATE	TARGET DATE	DATE COMPLETED
11 *	Remove casing on Auxiliary Feedwater Pump Turbine (AFPT) 1-1.	Wilczynski	Thompson			
	All work is to be performed under the guidance of a Terry					
	Turbine representative.					
12 *	Compare turbine as-found conditions to baseline data. Document	Wilczynski	Rupp			
	discrepancies found between baseline and present conditions.					
13 *	Prepare MWO for repair/replacement of components as required/	Wilczynski	Thompson			
	determined by vendor representative and engineering.					
14 *	Reassemble turbine.	Wilczynski	Thompson			
15	Review data to validate hypothesis.	Wilczynski	Wilczynski			
*	These steps will not be performed if the testing does not result					
	in an overspeed.					

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TITLE

AUXILIARY FEEDPUMP TURBINE 1-2 OVERSPEED TRIP

DATE PREPARED	PREPARED BY
6/19/85	Rupp/ Wilczynski

SPECIFIC OBJECTIVE

Verify hypothesis to support root cause determination.

STEP NUMBER	ACTION STEPS	PRIME RESPONSIBILITY	ASSIGNED TO	START DATE	TARGET DATE	DATE COMPLETED
	All steps of this Action Plan are to be performed in accordance with the latest revision of "Guidelines to Follow When Trouble-shooting or Performing Investigative Actions into the Root Causes Surrounding the June 9, 1985 Reactor Trip".					
1	Develop approved procedure for turbine disassembly and reassembly.	Wilczynski	Thompson			
2	Remove casing on Auxiliary Feedwater Pump Turbine (AFPT) 1-2. All work is to be performed under the guidance of a Terry Turbine representative.	Wilczynski	Thompson			
3	Document as-found/baseline conditions of turbine. Identify and document any discrepancies found between turbine design and as-found conditions.	Wilczynski	Rupp			
4	Prepare Maintenance Work Order (MWO) for repair/replacement of components as required/determined by vendor representative and engineering. Update baseline conditions as necessary.	Wilczynski	Thompson			
5	Reassemble turbine.	Wilczynksi	Thompson			

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AUXILIARY FEEDPUMP TURBINE 1-2 OVERSPEED TRIP

DATE PREPARED	PREPARED BY
6/19/85	Rupp/ Wilczynski

SPECIFIC OBJECTIVE

Verify hypothesis to support root cause determination.

STEP NUMBER	ACTION STEPS	PRIME RESPONSIBILITY	ASSIGNED TO	START DATE	TARGET DATE	DATE COMPLETED
6	Determine possible design differences between PG PL governor (existing 1-1 governor) and the new PGG (1-2 governor) that could attribute to less stability in governor controls and possible overspeed.	Wilczynski	Gradomski			
7	Remove governor cover on AFPT 1-2 and document as-found/ baseline conditions of governor. All work is to be done by Woodward Governor representative.	Wilczynski	Thompson			
8	Verify differences found in Step 6 exist in governor.	Wilczynski	Gradomski			
9	Prepare MWO for repair/replacement of components as required/ determined by vendor representative and engineering. Update baseline conditions as necessary.	Wilczynski	Thompson			
10	Reassemble AFPT 1-2 governor	Wilczynski	Thompson			
11	Develop test procedure or modify (T-Mod) existing procedure to simulate the conditions of the 6/9/85 overspeed trip of AFPT 1-2 using MS107A (crossover lines). The test will include a "back-up" system for tripping turbines manually and instrumentation to monitor the thermo-hydraulic conditions	Wilczynski	Missig			

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SPECIFIC OBJECTIVE

Verify hypothesis to support root cause determination.

STEP NUMBER	ACTION STEPS	PRIME RESPONSIBILITY	ASSIGNED TO	START DATE	TARGET DATE	DATE COMPLETED
	in the supply piping.					
12	Run test procedure for AFPT 1-2 (MS107A) after entering Mode 3.	Wilczynski	Missig			
13 *	Remove casing on Auxiliary Feedwater Pump Turbine (AFPT) 1-2. All work is to be performed under the guidance of a Terry Turbine representative.	Wilczynski	Thompson			
14 *	Compare turbine as-found conditions to baseline data. Document discrepancies found between baseline and present conditions.	Wilczynski	Rupp			
15 *	Prepare MWO for repair/replacement of components as required/ determined by vendor representative and engineering.	Wilczynski	Thompson			
16 *	Reassemble turbine.	Wilczynski	Thompson			
17	Review data to validate hypothesis.	Wilczynski	Wilczynski			
*	These steps will not be performed if the testing does not result in an overspeed.					