2-131E

Georgia Power

POWER GENERATION DEPARTMENT

VOGTLE ELECTRIC GENERATING PLANT

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1 of 2

TRAINING STUDENT HANDOUT

TITLE:	CASE STUDY FOR THE LOSS OF RHR COOLING AT DIABLO CANYON	NUMBER:	LO-HO-60990-C-001
PROGRAM:	LICENSED OPERATOR	REVISION:	0
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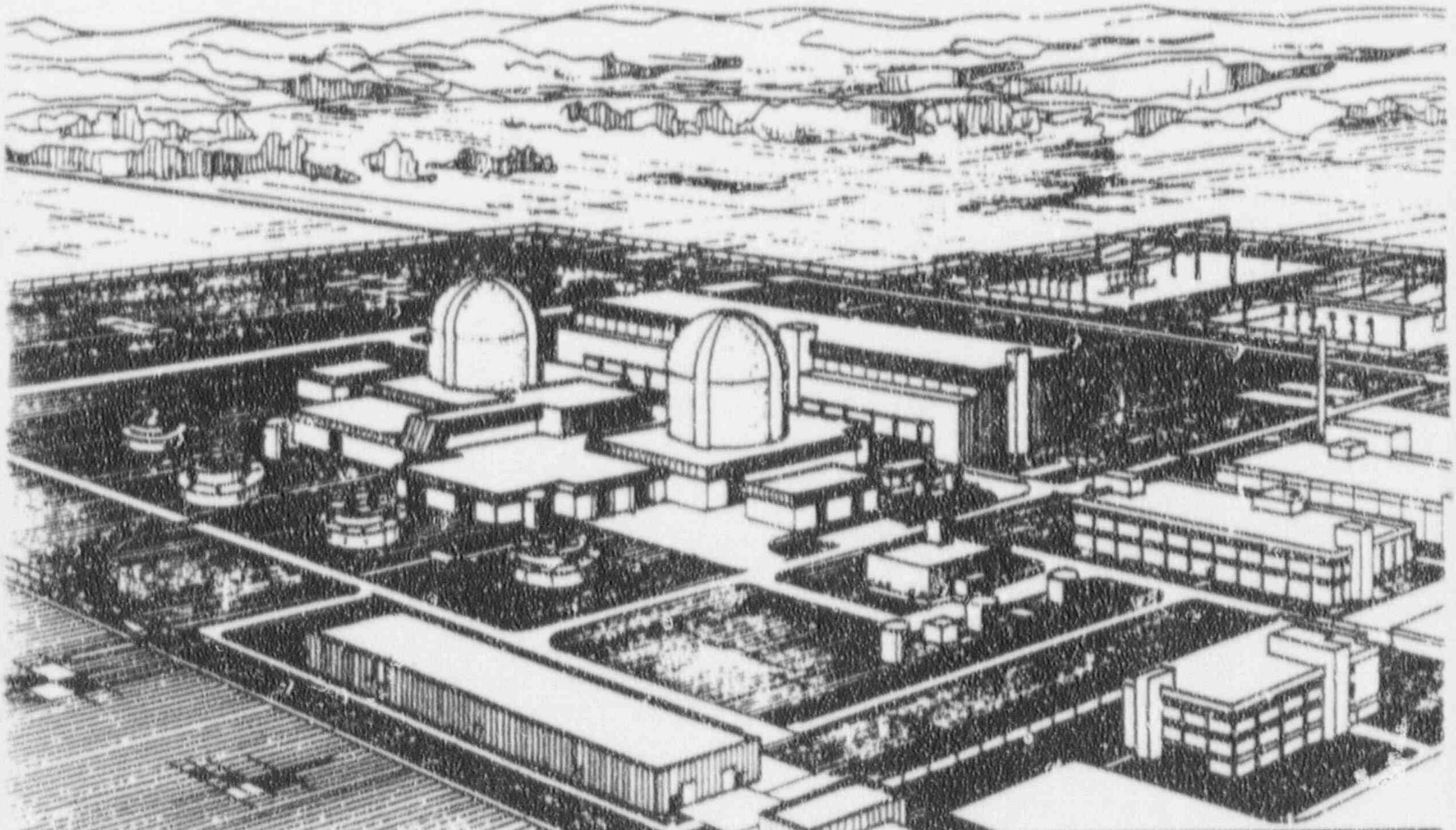
REFERENCES:			



STUDENT ____________________ DATE ____________________

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I. PURPOSE STATEMENT:

This case study is designed to provide understanding of the events leading up to, during, and the corrective actions associated with the loss of RHR cooling at Diablo Canyon. Included in the case study are the actions taken at Plant Vogtle to reduce the possibility of a similar event occurring.

II. LIST OF OBJECTIVES:

1. Describe briefly the initial conditions for operating with the RCS at mid-loop.
2. List the instrumentation used to monitor RCS level when operating at mid-loop.
3. List the instrumentation used to monitor RCS temperature when operating at mid-loop.
4. Discuss the events that led to the loss of RHR cooling at Diablo Canyon.
5. Describe the actions that the operators took to mitigate the loss of RHR cooling.
6. Describe the possible consequences that could result from a loss of RHR cooling.
7. Describe actions taken to reduce the probability of a similar event from occurring at Plant Vogtle.

LESSON OBJECTIVES

(REPLACE THIS PAGE WITH THE LATEST REVISION OF THE LESSON OBJECTIVES)

CASE STUDY OF THE DIABLO CANYON LOSS OF RHR EVENT DURING MID-LOOP OPERATION

I. INTRODUCTION

This case study material covers a loss of residual heat removal during mid-loop operation and the phenomena influencing that behavior at PG&E's Diablo Canyon Unit #2. An event description that covers major operator actions and plant response related to the event are included. In addition, some instructor aids are provided to assist the instructor.

It should also be noted that other plants have experienced a loss of RHR and this is not the only case of this event that has occurred. According to Generic Letter 87-12, 37 additional events have occurred that are attributed to inadequate RCS water level.

This is significant in that core damage or a release to the environment could have occurred.

II. SUMMARY

PG&E's Diablo Canyon Unit #2, a four-loop Westinghouse 1119 MWe PWR, achieved a capacity factor > 80% during its first fuel cycle.

At 2123, on 4/10/87, operating in Mode 5, 7 days after shutdown for its first refueling outage, loss of both RHR trains occurred for a period approximately 1.5 hours. The loss of RHR cooling was complicated by removal of the containment equipment hatch (release path to the environment), RCS hot leg mid-loop level operation, and steam generator manway removal in progress during the event.

During the period that heat removal was lost, the reactor coolant heated from 87°F to boiling, steam was vented from the RV head, water spilled from the partially unsealed SG manways into the containment due to pressurization of the RCS, and containment radiogas activity was observed to increase.

If allowed to continue, the loss of RHR cooling could have led to core damage and an environmental release of radioactivity.

III. DETAILED EVENT DESCRIPTION

Initial Conditions

The plant had been shut down, approximately one week, for its initial refueling outage.

The containment building equipment hatch was removed.

The personnel airlock was open.

Containment purge was in progress.

Removal of steam generator manways to gain access to the SG channel head areas was in progress.

Core exit thermocouples were decoupled in preparation for RV head removal.

Local leak rate testing of containment penetrations was in progress.

The RHR pump 2-1 was operating through both RHR heat exchangers, both trains were cross-connected.

The other train of RHR was operable as well as all instrumentation associated with the RHR system.

The RCS was drained down to the mid-loop level to support entry into the steam generator head areas for planned steam generator work.

RV level was being monitored by a temporarily installed reactor vessel refueling level indication system consisting of a tygon tube manometer inside containment and 2 electrical systems (in wide and narrow range).

The normal RVLIS was out of service due to work on the post accident monitoring system.

The RV was vented to the pressurizer by a temporary vent rig.

The SI pumps circuit breaker were racked out.

RV level was being maintained by sending excess water to the RWST or by makeup from the RWST.

A centrifugal charging pump was available for immediate service.

The swing shift was maintaining the RCS level at or near the centerline of the hot leg, and below the level at which water could enter the channel area of the steam generators. Level was being controlled by balancing the makeup and letdown flows (by flow from the VCT via the normal charging path through an idle centrifugal charging pump).

Event Initiation

At approximately 2043, a plant operator opened a valve on an "isolated" portion of a reactor coolant pump seal water return line to the VCT to perform a local leak rate test. The control room was not informed of the start of the test. The portion of the system had been tagged out with a clearance and the valves necessary to isolate the penetration for the test were independently verified to be closed. After opening the valve, the engineer left the area.

Unknown to the Involved personnel, one of the valves positioned in the closed position was improperly seated (note: this valve is reach rod operated and is difficult to position). When the plant engineer opened this valve, RCS flow from the drain line to the RCDT began. This leakage from the RCS was immediately seen as a decrease in VCT level by the control room operators and caused RCDT level to increase as reported by the auxiliary building operator.

The operator compensated for the decrease in VCT level by increasing letdown flow from the RCS. Indicated vessel level began to decrease on the temporary RVLIS. The operators attempt to restore VCT level by increasing letdown flow resulted in a slow decrease in RV level.

At 2054 the ABO reported that RCDT level had increased, and shortly thereafter the RCDT pump automatically started and stopped 3 times to pump down the RCDT to control the high level.

The operators isolated charging and letdown flow paths to stop the leak. The resulting loss of flow into the VCT, and the flow out the leak test drain caused VCT level to decrease rapidly, but indications in the control room showed the level decrease in RV level had stopped. The auxiliary building operator reported the leak into the RCDT was approximately 30 gpm.

Loss of RHR Cooling

2125: The control room operators noticed that the amperage on the #2 RHR pump began to fluctuate. This pump was shut down and the #1 pump was started. This pump also showed fluctuating amps and was shut down. Operators were dispatched to vent the pumps and seal coolers on both RHR pumps.

At this point RHR cooling capability was lost and the operators had no method of monitoring incore temperatures. Vortexing or cavitation were suspected as the cause of the pump motor current fluctuations.

Since the apparent vortexing or cavitation were unexpected, the validity of the temporary RV level indication in the control room was suspected. An operator was dispatched to check local RV tygon tube indication inside the containment.

The status of the steam generator manway removal was requested by the shift foreman. This was done to ensure that no personnel were inside, or in the vicinity of the steam generator manways of channel heads, before the RHR valves were opened to allow gravity flow from the RWST to fill the RCS.

2138: The outlet valve on the VCT was closed to stop VCT inventory loss. This isolated the VCT from the RCDT and the decrease in VCT level stopped. The RV level continued to decrease.

2200: The plant engineer opened the vent valves associated with the penetration being drained. After opening the valves he left to find a HP technician to assist in the leak rate test.

2203: The RHR pumps were reported vented.

2210: RV indicated level begins to increase. RCS heating up.

2221: The #1 pump was started. Pump amps were fluctuating and the pump was stopped.

2227: The shift foreman declared a Significant Event. RHR flow had been lost for greater than an hour. About this same time the plant engineer discovered a large amount of water which he believed was associated with his draining evolution. The engineer notified HP personnel of the spill and closed the vent valves.

2230: Containment activity levels were observed to be increasing. Air samples were initiated to determine the source. HP personnel began evacuation of personnel on the elevation of the elevated radiation readings inside containment.

Restoration of RHR Cooling

2241: Operators believed steam was being generated in the RV due to the increasing trend on the temporary RVLIS. Also, the control room was notified that the steam generator manways had not been removed although some of the bolts had been detensioned. Valves were opened to allow gravity flow of water from the RWST to the RCS, the indicated RV level leveled off and began decreasing due to the cooling effect of the RWST water entering the RCS. Charging and letdown were established.

2250: Th leak path was isolated and reported to the control room by personnel inside containment.

2254: RHR pump #2 was started and RHR cooling flow was established.

Shortly after the pump start, the pump discharge temperature rose to approximately 220°F. Within 5 minutes the temperature had dropped to less than 200°F.

2256: Fluctuating amperage was noted on the running RHR pump. The RWST to RHR pump suction valve was opened to increase makeup to the reactor vessel. Pump amps stabilized and RV level increased rapidly, approximately 5 in/min.

2258: Personnel inside the containment reported steam venting from a ruptured tygon tube on the reactor head vent. Containment evacuation was ordered. RCS was beginning to press[illegible] due to the air in the system.

2313: The leak from the head vent [illegible]. Leakage from the steam generator manways was also reporte[illegible]

From this point on the operators restored the plant to a normal lineup.

IV. INSTRUCTORS AIDS

A. Fundamental Causes and Discussion Topics

1. The operators did not fully understand the behavior associated with the temporary RV level indication system.

2. Vessel level indications are provided by:

a. Tygon hose connected on RCS loop 1 intermediate leg and vented to the pressurizer

b. RVLIS (out of service during the Diablo Canyon event)

c. Temporary system using a differential pressure transmitter feeding a signal to a recalibrated and relabeled accumulator level indicator in the control room.

3. Levels are influenced by:

a. The reference leg for the temporary level instrument and the tygon tube are connected to the intermediate leg of RCS loop 1. The level read by these can be approximately 2 inches higher than actual level at the RHR pump suction connection due to RHR system flow. The operator should be aware of this difference.

b. RHR return water entering the RCS piping causes a slightly higher elevation difference on the cold leg side of the RCP. Water enters the top of the piping and is directed downward. When the loops are full the water enters the pipe and no splashing effect is encountered.

c. Air entrainment in the system displaces water and can be up to 5% to 10% of the system volume in the RHR pump suction piping. This is affected by the flow rate through the system. When the system is shut down the water and the air separate and RV level decreases lower than it was with the pump running.

d. Capillary effects on the tygon tubing can cause a higher indicated level than actual and prevents fast response to changes in level.

e. Level as read on the tygon tubing should be clearly marked.

f. Movements of the tygon tubing affect indicated level. Tygon tubing should be mounted to prevent movement.

g. Tygon-tube should be free of entrained air and have a constant slope. Air in the tubing can give a false high level reading. Ensure the tygon tube is vented.

h. Temperature differences between the RCS and the level instruments can affect indicated verses actual level.

4. Operators need to be familiar with the location of the RV level instruments.

5. The leak was caused by an improperly seated valve and was complicated by:

a. Operators were not familiar with how to determine valve position on valves with reach rod operators. Plant Vogtle has had this problem also.

b. An engineer opened the valve that initiated the event. The engineer should have had an operator perform the valve positioning.

c. The valve that was not fully seated was difficult to position due to the design of the reach rod assembly.

d. Control room operators were not aware that local leak rate testing was in prgress. Operators need to be aware of all work in progress at all times that affect the integriy of the RCS.

e. Operators did not know the status of the SG manway removal. This affects RCS integrity.

f. During the transient the opertors were uncertain of plant valve lineups.

g. Outage activities were not coordinated.

h. Operators should have a feel for what instruments are telling them and some of the limitations associated with instruments.

i. The equipment hatch was off. The RCS now has direct vent path to atmosphere. Consideration should be given taht the SG manways were to be removed. The length of time operation at mid-loop was to be long and 2 fission product boundaries were ineffective during this time.

j. The only temperaturrre indicacion available ws the RHR loop temperature. Opeators were unaware of the reactor heatup rate. They expected a 1 °/minute; actual heatup was 2.4 °/minute. Heatup rate of the RCS was underestimated.

k. Procedures were deficient.

l. Shift briefing did not mention leak rate tests that had been approved but not started.

m. Personnel did not inform the control room prior to starting a test.

n. The RHR pump erratic current was observed and tripped by an operator that was not a member of the shift crew.

o. Communications were poor.

 1) The RO should handle communications and relay them back to the shift supervisor. This was not done and a lack of clear information into the control room was a distraction.

 2) Operators did not pass along information experiences that occurred prior to the event and problems that were encountered were not documented in the control room logs.

p. The event was classified as a NOUE instead of an ALERT. The shift foreman classified the event because he determined that RHR was not inoperable. Gravity feed from the RWST would have been ineffective if the RCS pressure reached approximately 25 psig.

5. Pressurization of the RCR could cause additional leakage paths.

 a. Air in the RCS caused an unexpected pressurization of the RCS

  1) A water/steam filled system would allow condensation to occur in the SG tubes and no pressurization.

 b. Air in the system also inhibits heat transfer from the fuel to the coolant.

6. At Diablo Canyon mid-loop operation was to continue for an indefinite period of time.

 a. Work activities that have the potential for draining the RCS should not be done when operating at mid-loop.

V. DRAWINGS

TABLE 1
PERMANENT PLANT INSTRUMENTATION AVAILABLE
DURING MID-LOOP OPERATION

	TRAIN A	TRAIN B	DESCRIPTION	LOCATION	RANGE
1	PI-0601	PI-0602	RHR pump suction pressure	Local	0- 800 psig
2	PI-1061A		RHR pump discharge pressure	Local	0-1000 psig
3		PI-10613	RHR pump discharge pressure	Local	0- 800 psig
4	FIS-0610	FIS-0611	RHR pump discharge flow	Local	0-1500 gpm
5	PI-403	PI-405	RCS wide range pressure	QMCB	0-3000 psig
6	PI-408	PI-418	Reactor vessel pressure	QMCB	0-3000 psig
7	PI-438	PI-428	Reactor vessel pressure	QMCB	0-3000 psig
8	PI-0614	PI-0615	RHR pump discharge pressure	QMCB	0- 900 psig
9	FI-618A	FI-619A	RHR to RCS cold leg flow	QMCB	0-5000 gpm
10	FIC-618A	FIC-619A	M/A station for RHR heat exchanger bypass valve	QMCB	0- 100 %
11	HIC-606A	HIC-607A	M/A station for RHR heat exchanger outlet valve	QMCB	0- 100 %
12	TR-0612	TR-0613	Pen recorder for RHR heat exchanger inlet & outlet temperatures	QMCB	0- 400 degF
13	FI-618B	FI-619B	same as 5	PSDA,PSDB	0-5000 gpm
14	FIC-618B	FIC-619B	same as 6	PSDA,PSDB	0- 100 %
15	HIC-606B	HIC-607B	same as 7	PSDA,PSDB	0- 100 %
16	TI-604B	TI-605B	RHR heat exchanger outlet temperature	PSDA,PSDB	50-400 degF
17	LT-1311	LT-1321	Reactor vessel level	QMCB	0- 120 %
18	(various)	(various)	Core Exit Thermocouples 25 per train - 50 total	ERF computer	0-2300 degF
19	LI-0462		Pressurizer level (cold)	QMCB	0- 100%
20	PI-0469		PRT pressure	QMCB	0- 100 psig

TABLE 2
PLANT ELEVATIONS ASSOCIATED WITH RCS LEVELS

281'	MINIMUM RWST LEVEL
223'	RWST OUTLET NOZZLE LEVEL
221'	TOP OF STEAM GENERATOR U-TUBES
196'	PRESSURIZER SURGE LINE NOZZLE LEVEL
194'	RV Flange
193'	TOP OF RCP SEAL PACKAGE
190'	BOTTOM OF RCP SEAL PACKAGE
188'	NORMAL RCS LEVEL (1/2 LOOP FULL)
187'	CENTERLINE OF RCP DISCHARGE PIPING
184'	PRT INLET PIPING
124'	CENTERLINE RHR PUMP DISCHARGE PIPING

POTENTIAL DISTURBANCES TO THE DRAIN-DOWN PROCESS

System	Potential Cause
1. Automatic closure of RHR suction valves from RCS hot legs	Instrument failure, error during maintenance or testing
2. Automatic opening of Pressurizer PORV's from COPS	Instrument failure, error during maintenance or testing
3. Automatic initiation of Emergency Core Cooling System	Instrument failure, error during maintenance or testing
4. Automatic initiation of Auxiliary Feedwater System	Error during maintenance or testing
5. Automatic energization of Pressurizer heaters	Error during maintenance or testing
6. Closure or opening of letdown pressure control valve	Instrument failure, loss of instrument air, error during maintenance or testing
7. Closure or opening of RHR heat exchanger outlet valves	Control failure, loss of instrument air, error during maintenance or testing
8. Closure or opening of RHR heat exchanger bypass valves	Instrument failure, loss of instrument air, error during maintenance or testing
9. Change in charging flow	Instrument failure, loss of instrument air, error during maintenance or testing

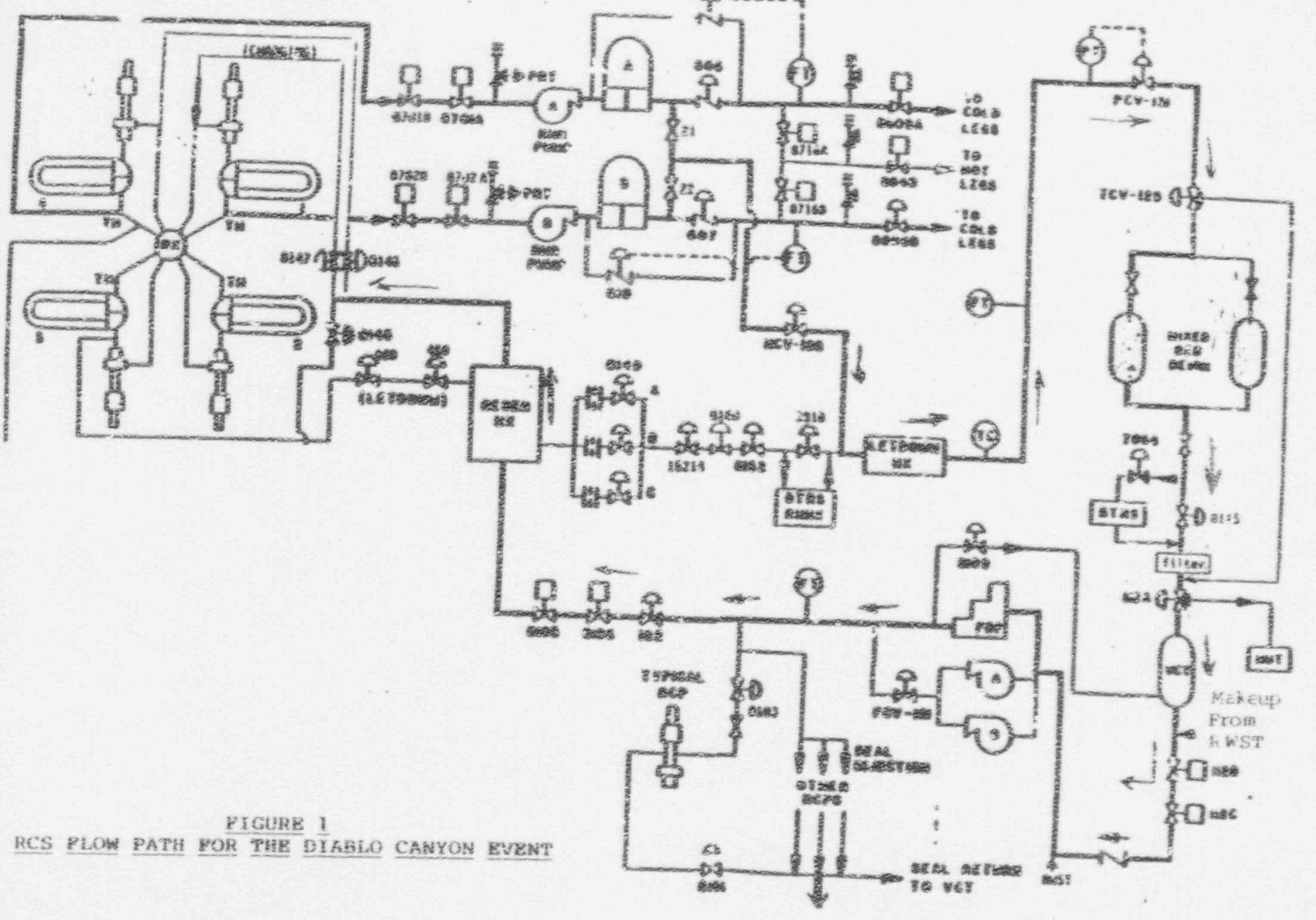
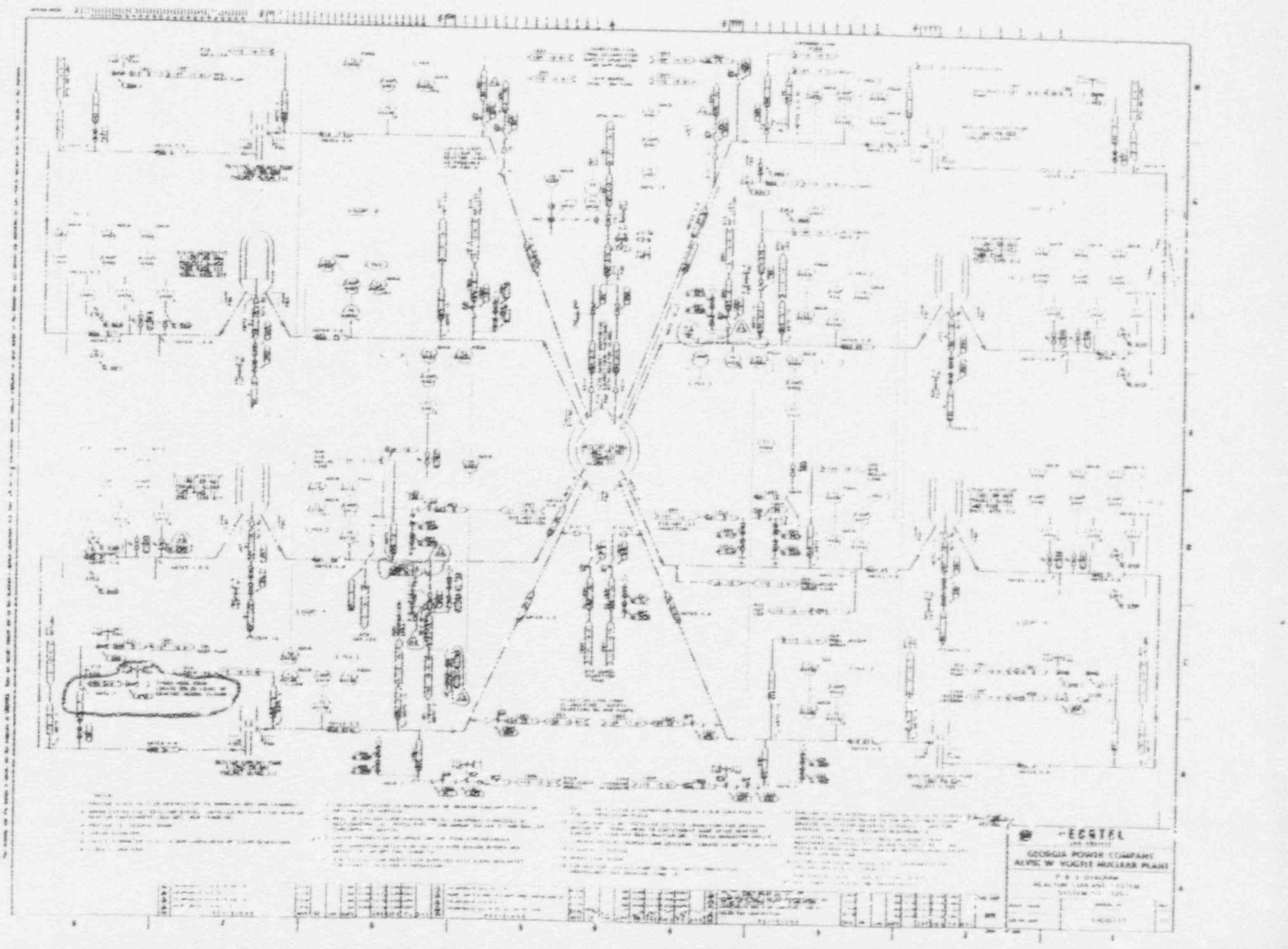


FIGURE 1
RCS FLOW PATH FOR THE DIABLO CANYON EVENT


GEORGIA POWER COMPANY
ALVIN W VOGTLE NUCLEAR PLANT
P & I DIAGRAM

VII. ATTACHMENT

ATTACHMENT A

PLANT VOGTLE RESPONSE TO GENERIC LETTER 87-12

Some Post-event Technical and Administrative Investigative Actions Taken at Plant Vogtle

The detailed event description performed after the Diablo Canyon loss of RHR cooling resulted in the NRC issuing Generic Letter 87-12, Loss of Residual Heat Removal (RHR) While the Reactor Coolant System (RCS) is Partially Filled, and NUREG 1269, Loss of Residual Heat Removal System. These reports identified factors that either contributed to or caused some aspect of the event.

Additionally, other problems were identified that had the potential to further complicate the event.

Generic Letter 87-12 requested answers to specific questions posed by the NrC on how a similar event occurring at Plant Vogtle is prevented from happening or actions planned to prevent this event. Some of these actions are provided below.

A. Several procedure related deficiencies were identified and corrected.

1. Procedures 12000 - Refueling Recovery, 12006 - Unit Cooldown to Cold Shutdown, and 12007 - Refueling Entry have been revised to require at least 2 incore thermocouples to be maintained operable during periods of mid-loop operation. If the RPV head is removed, the disconnection of these thermocouples will be delayed until the last possible moment and restored at the first opportunity after the head is replaced.

2. Guidelines for monitoring reactor vessel level when draining or filling the RCS have been expanded. More information concerning the parameters to be monitored is also given in Procedures 12000 - Refueling Recovery, 12006 - Unit Cooldown to Cold Shutdown, and 12007 - Refueling Entry.

   a. Continuous monitoring when changing levels when PZR level is < 17%

   b. Periodic level checks are required between the control room indicators and the tygon tube every 4 hours.

   c. A continuous tygon tube watch is required if no control room indicator is available.

   d. A continuous monitoring of the tygon tube level during mid-loop operation is required by 13005 reactor coolant system draining.

3. RHR train operation guidance is given. 1 train in operation with a flow of 3000 gpm in Procedures 12000 - Refueling Recovery, 12006 - Unit Cooldown to Cold Shutdown, 12007 - Refueling Entry, 13011 - Residual Heat Removal System, and 13005 - Reactor Coolant System Draining.

4. During the draining of the steam generator U-tubes, guidance is given for expected RPV level responses in Procedure 13005 - Reactor Coolant System Draining.

5. Minimum level of 188 feet is maintained whenever the RHR is in service per Procedures 12000 - Refueling Recovery, 12006 - Unit Cooldown to Cold Shutdown, 12007 - Refueling Entry, 13005 - Reactor Coolant System Draining.

6. 13005 - Reactor Coolant System Draining instructs the operator that only one drain path shall be used at a time and operators shall be aware o the path being used . Log entries shall be made to keep personnel aware of drain paths.

7. 13005 - Reactor Coolant System Draining instructs the operator that if draining via the RCDT, do not drain from the same loop(s) that are being monitored for level. Thus filling or draining operations should not have an adverse effect on level indication.

8. 13011 - RHR system has the operator disable valves 8804 A/B when placing the RHR system into service. This is able the opening of 8812 A/B from the control room. These valves however are operable from the remote shutdown panels if needed to refill air bound RHR pump suctions on a loss of RHR cooling.

B. Hardware Changes

1. Temporary reactor vessel level indicators are to be installed on the control board using SI accumulator level instruments. Both alarm functions and trending information will be available.

2. An evaluation of the removal of interlocks associated with the RHR loop suction valves is in progress.

VIII. REFERENCES

NUREG 1269 LOSS OF RHR SYSTEM
IEN 87-23 LOSS OF DECAY HEAT REMOVAL DURING LOW REACTOR COOLANT LEVEL OPERATION
GENERIC LETTER 87-12 LOSS OF RHR WHILE THE RCS IS PARTIALLY FILLED