



UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

December 9, 1986

Docket Nos. 50-275
50-323

LICENSEE: Pacific Gas and Electric Company
FACILITY: Diablo Canyon Nuclear Power Plant, Unit 1 and Unit 2
SUBJECT: MEETING SUMMARY - NATURAL CIRCULATION/BORON MIXING/
COOL DOWN TESTS

NRC staff and its consultants from Brookhaven National Laboratory (BNL) met with Pacific Gas and Electric Company (PG&E) and Westinghouse (W) on November 21, 1986 to discuss the BNL evaluation of the natural circulation, boron mixing and cool down test which had been performed in March 1985 at Diablo Canyon Unit 1. The PG&E final test report had been submitted to the staff on March 25, 1986 (DCL-86-078). The NRC meeting notice and a list of attendees are attached as Enclosures 1 and 2, respectively. The staff stated that BNL had prepared for NRC staff review a draft report on its evaluation of the test. The final report will be included in the staff evaluation. J. Jo (BNL) presented a summary of the BNL evaluation and conclusions using the viewgraphs attached as Enclosure 3. BNL reached the following conclusions:

- 1) The test demonstrated that adequate natural circulation was established and the plant was capable of removing the decay heat by natural circulation using only safety-grade equipment.
- 2) Adequate boron mixing could be achieved by natural circulation in the main flow path of the RCS using only safety-grade equipment.
- 3) The effect of relatively unborated water entering the RCS from the upper head and pressurizer appears to be minimal as long as depressurization is conducted carefully to limit the size of possible void formation.
- 4) The pressure would rise and reach the PORV actuation pressure without letdown during the boron mixing period.
- 5) The test demonstrated that the main RCS can be cooled down to the RHR system initiation temperature while maintaining adequate subcooling during the natural circulation using only safety-grade equipment.
- 6) The test demonstrated that the upper head could be cooled without void formation when the CRDM fans were in operation.

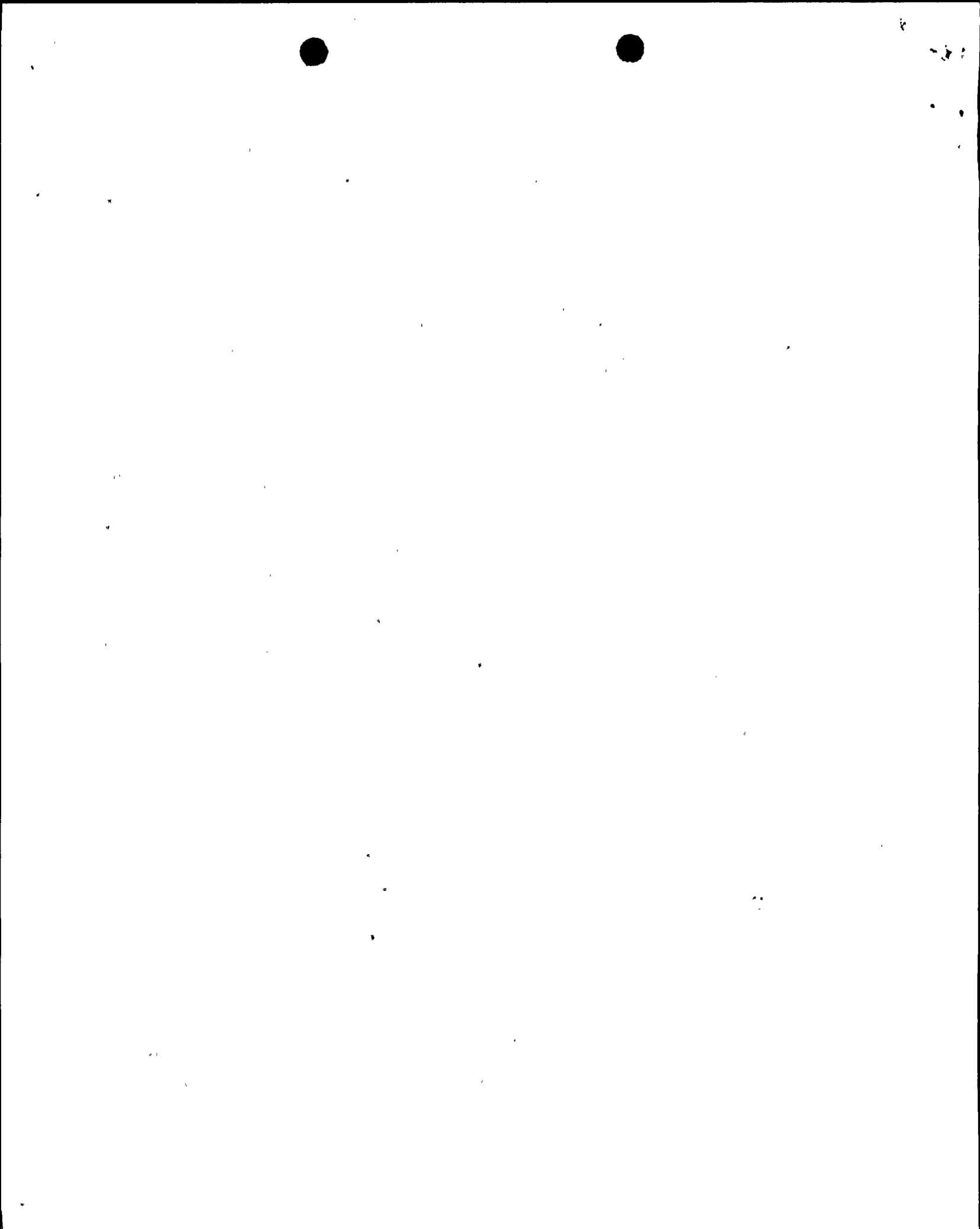
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- 7) The test results indicate that the upper head cooldown rate without the CRDM fans is about 6°F per hour. This is higher than the conservative BNL calculation (accounting only for conduction heat loss) which estimated a minimum rate of 3°F per hour.
- 8) The RCS pressure should be maintained above 1200 psia by means of either the pressurizer heaters (if available) or charging during the cooldown period to avoid the void formation in the upper head when the CRDM fans were not in operation.
- 9) Sufficient supply of safety grade cooling water was available to support the proposed plant cooldown method even if the CRDM fans were not available for the Diablo Canyon Plant but the worst case requirements (360,000 gallons) may not be available at all plants.
- 10) Only one motor-driven AFW pump was needed to supply the necessary cooling water throughout the transient.
- 11) Sufficient ASD valve capacity was available to support the cooldown even when the cooldown rate was 50°F per hour.
- 12) The availability of the pressurizer heaters and letdown system, while not essential, would affect the operational procedures in a major way. The strategy to reduce the upper head cooling time by intentionally forming a void may be difficult to perform without pressurizer heaters. Some plants appear to have the capability to control voiding by charging and venting through reactor vessel head vents.
- 13) The RCS pressure would increase and stay high, and the PORV may be actuated periodically if the letdown system was not available, due to the boron injection and the continuous injection of RCP seal flow. The operation of the auxiliary pressurizer spray normally requires letdown to be in operation to prevent the possible thermal stress on the charging nozzles.
- 14) Additional information is needed from Westinghouse on the details of its estimation for the upper head cooling time without the CRDM fans. (The BNL analysis and the test data indicated that the cooling period should be substantially longer than the 8 hours estimated by Westinghouse).

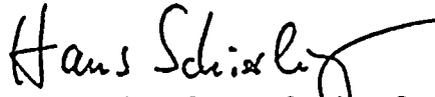
The staff stated that these were BNL conclusions which the staff had not yet evaluated as of the time of the meeting. The major subjects of discussion were the cooldown and mixing of the water in the upper head. The factors of significance include the direction of flow through the upper head, the potential for stratified flow in the lower layers of the upper head leaving a relatively undisturbed volume in the upper layers, the heat conduction along the CRDMs to the outside which act as cooling fins, the effect of upper head internal structures on



mixing, the heat loss from the upper head with and without the CRDM cooling fans operating, and the effect of the Westinghouse "T-hot" and "T-cold" plant upperhead designs.

Westinghouse stated that good mixing cooldown should be assumed for all Westinghouse plants. To evaluate the cooling effect of the CRDM fans (assumed not to be available during natural circulation cooldown) the fans were turned off at 18.5 hours after initiation of the test. The temperature of the upper head, as measured with a thermocouple mounted on the upper head, increased for approximately one hour and then decreased steadily for about one half hour after which the fans were turned on again. Westinghouse calculated an upper head cooldown rate of about 6°F per hour while BNL, using conservative assumptions, estimates a cooldown rate of 3°F per hour.

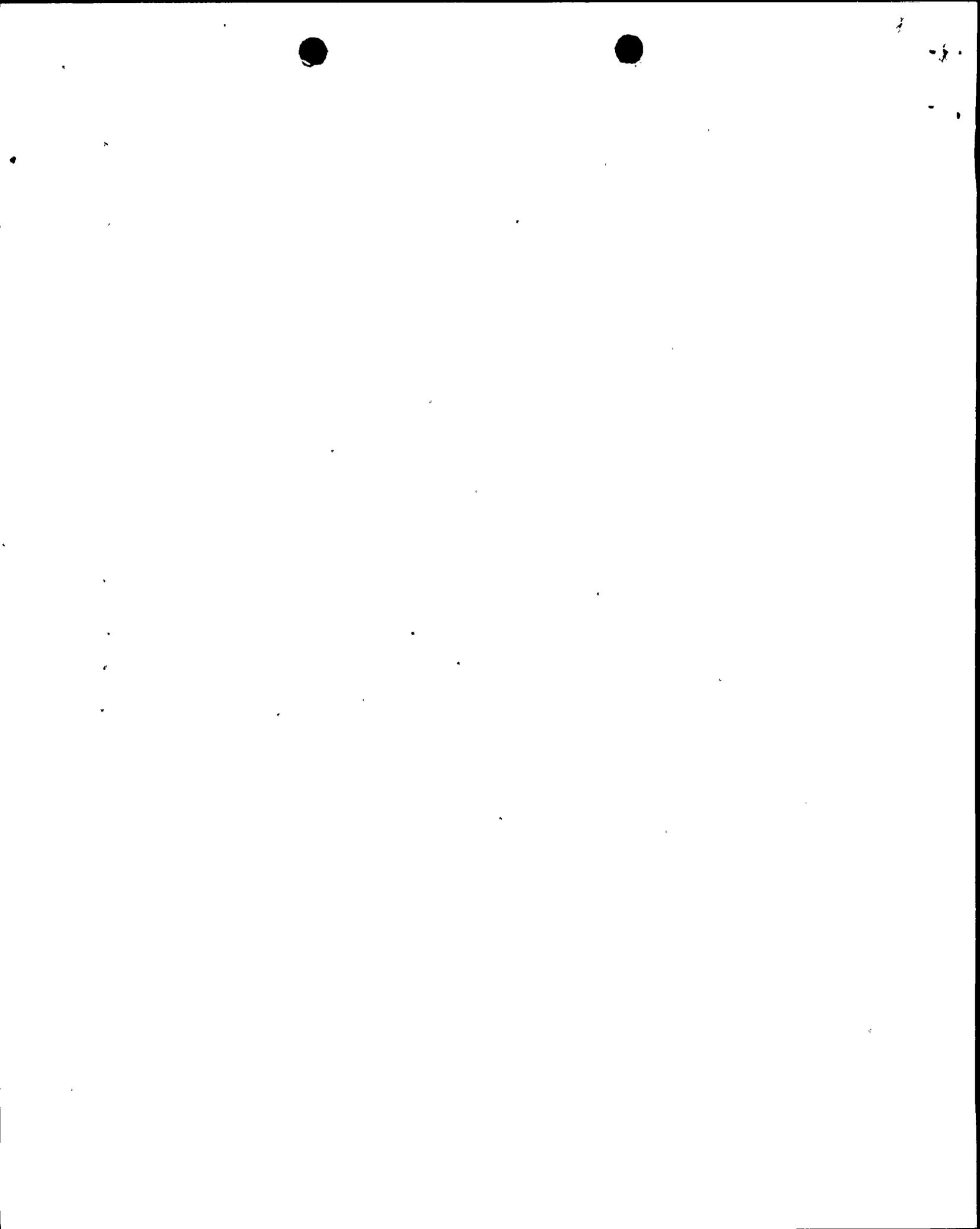
The staff stated that, based on the information discussed by Westinghouse during the meeting, no additional information appeared to be necessary to complete the evaluation of the test for the Diablo Canyon Plant. BNL will prepare a final report for the NRC staff which will be the basis for the staff's Diablo Canyon Safety Evaluation. Regarding the applicability of the Diablo Canyon test to other Westinghouse plants, staff requested BNL to identify by early December specific additional information needed for the evaluation, which will then be issued by the staff to PG&E and Westinghouse for response. The staff/BNL will review the information and conclude on the applicability of the Diablo Canyon test to other Westinghouse Plants.



Hans Schierling, Senior Project Manager
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Enclosures:
As stated

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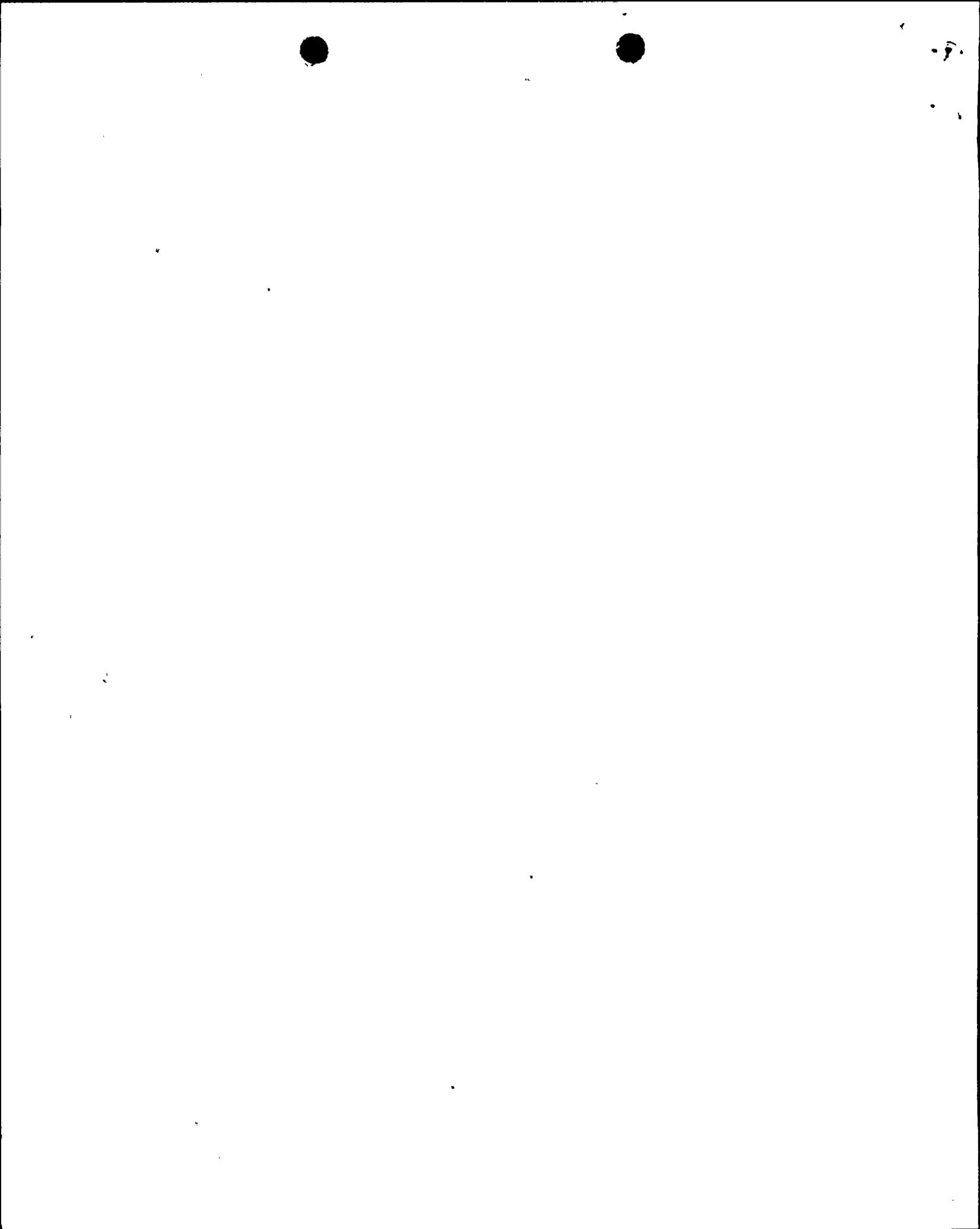
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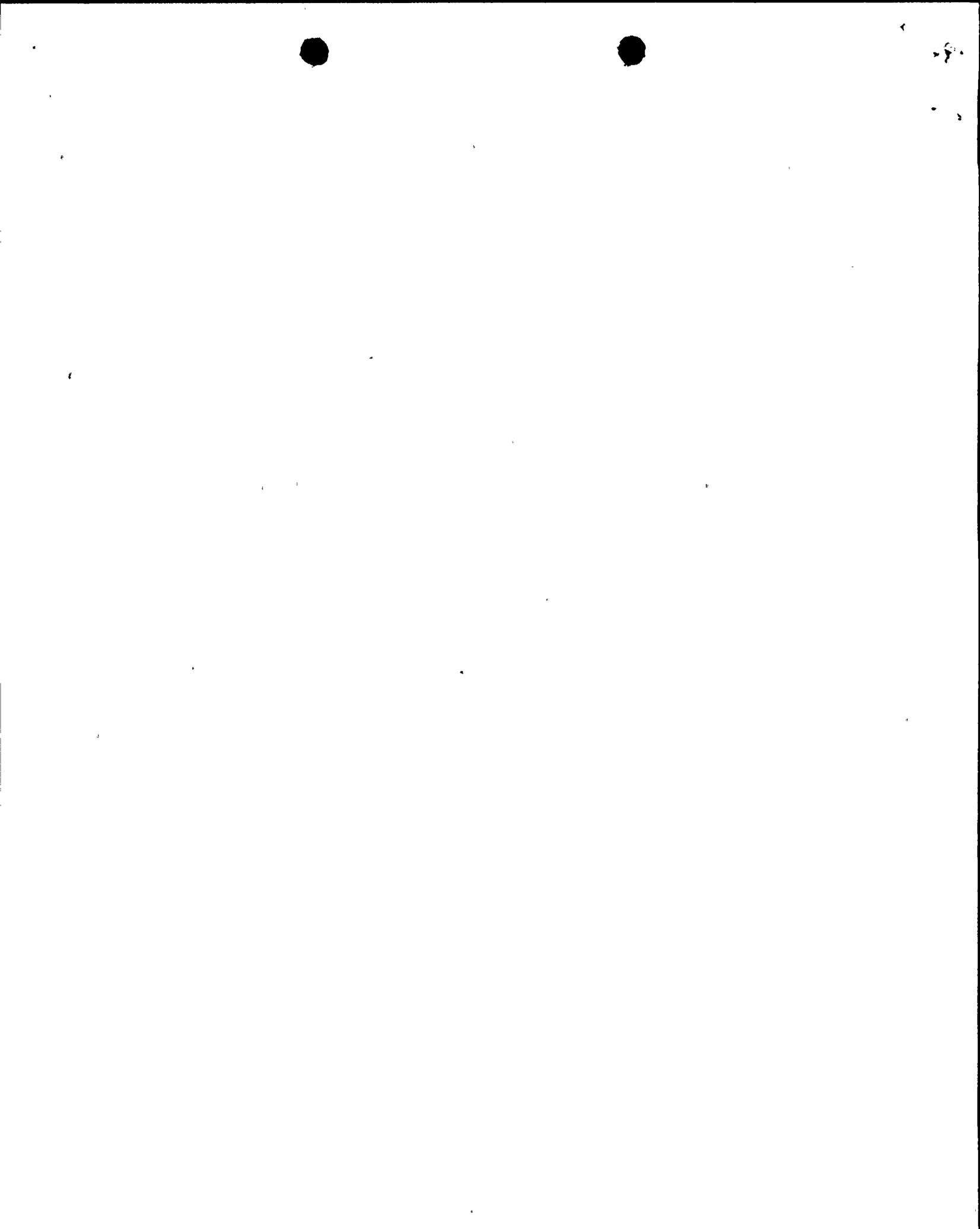
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November 13, 1986

Docket No. 50-275

MEMORANDUM FOR: Steven A. Varga, Director
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 Division of PWR Licensing-A

FROM: Hans Schierling, Senior Project Manager
 Project Directorate #3
 Division of PWR Licensing-A

SUBJECT: FORTHCOMING MEETING WITH PACIFIC GAS AND
 ELECTRIC COMPANY

DATE & TIME: November 21, 1986
 8:30 a.m. - 2:30 p.m.

LOCATION: 7920 Norfolk Ave.
 NRC Offices, Room P-110
 Bethesda, Maryland

PURPOSE: Discussion of Natural Circulation, Boron Mixing, and
 Cooldown Test with PG&E and Westinghouse.

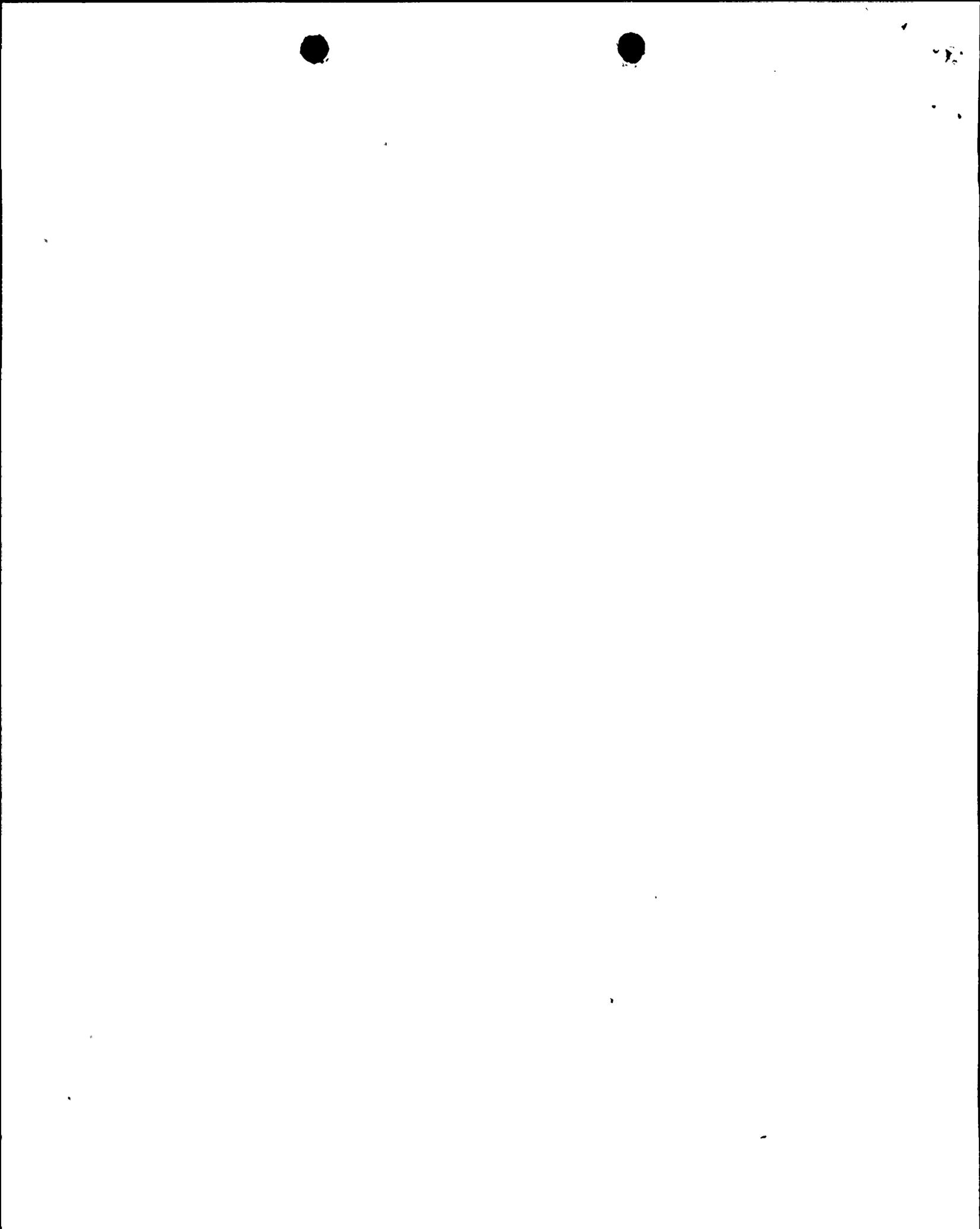
PARTICIPANTS:	<u>NRC</u>	<u>PG&E</u>
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	C. Berlinger	S. Diab
	B. Mann	K. Perkins (BNL)
	J. Wilson	J. Joe (BNL)
	R. Lobel	B. Lew
	T. Marsh	M. Norem et al.
	C. Liang	A. Cheung (W)
		R. Sermon (W)


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 Project Directorate #3
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PD#3
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 11/13/86



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NRC/PG&E MEETING

November 21, 1986

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R. Lobel
J. Watt
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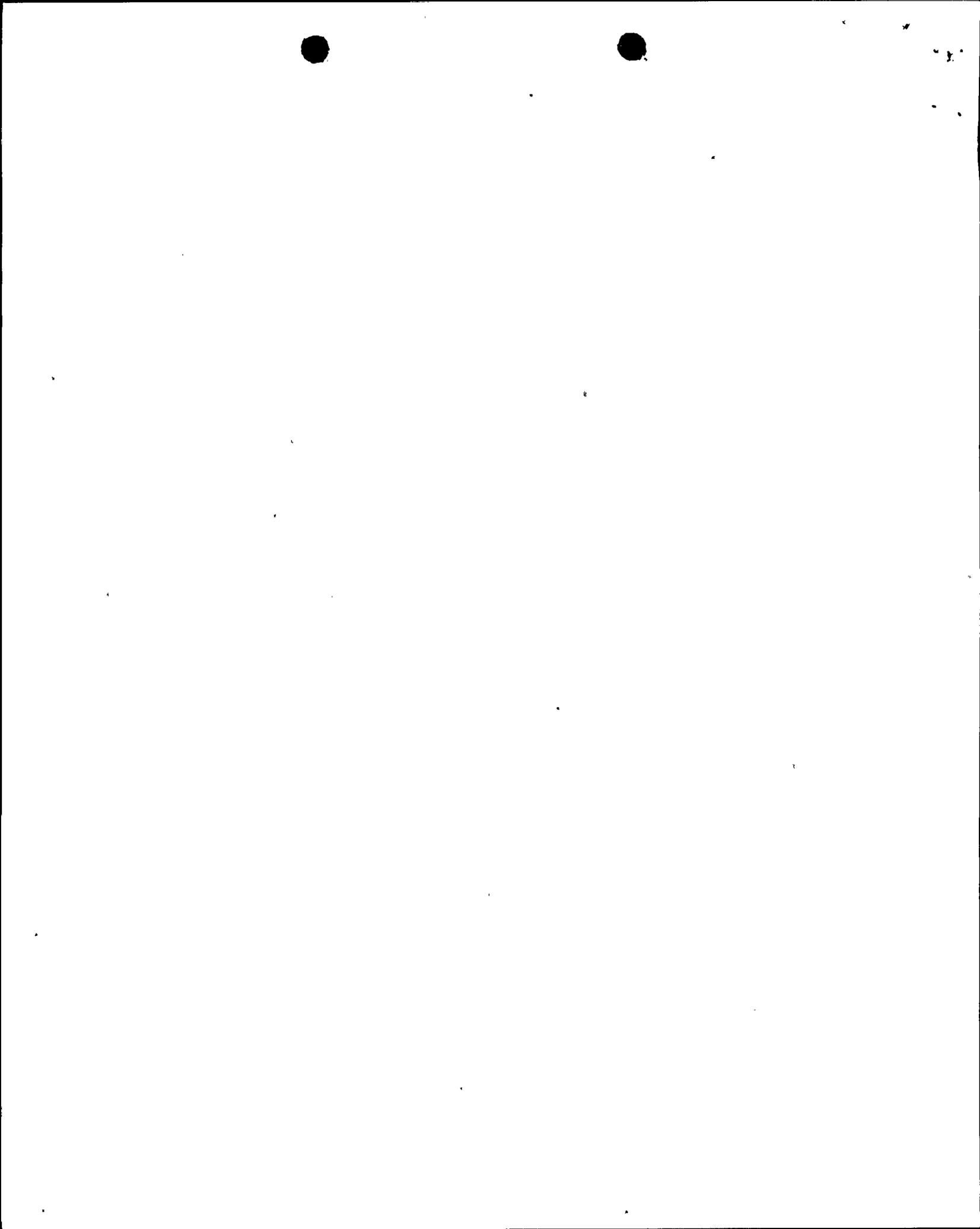
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REVIEW OF
NATURAL CIRCULATION, BORON MIXING AND
COOLDOWN TEST AT DIABLO CANYON

J.H. JO, N. CAVLINA AND K.R. PERKINS

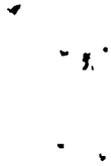
CONTAINMENT & SYSTEMS INTEGRATION GROUP

DEPARTMENT OF NUCLEAR ENERGY



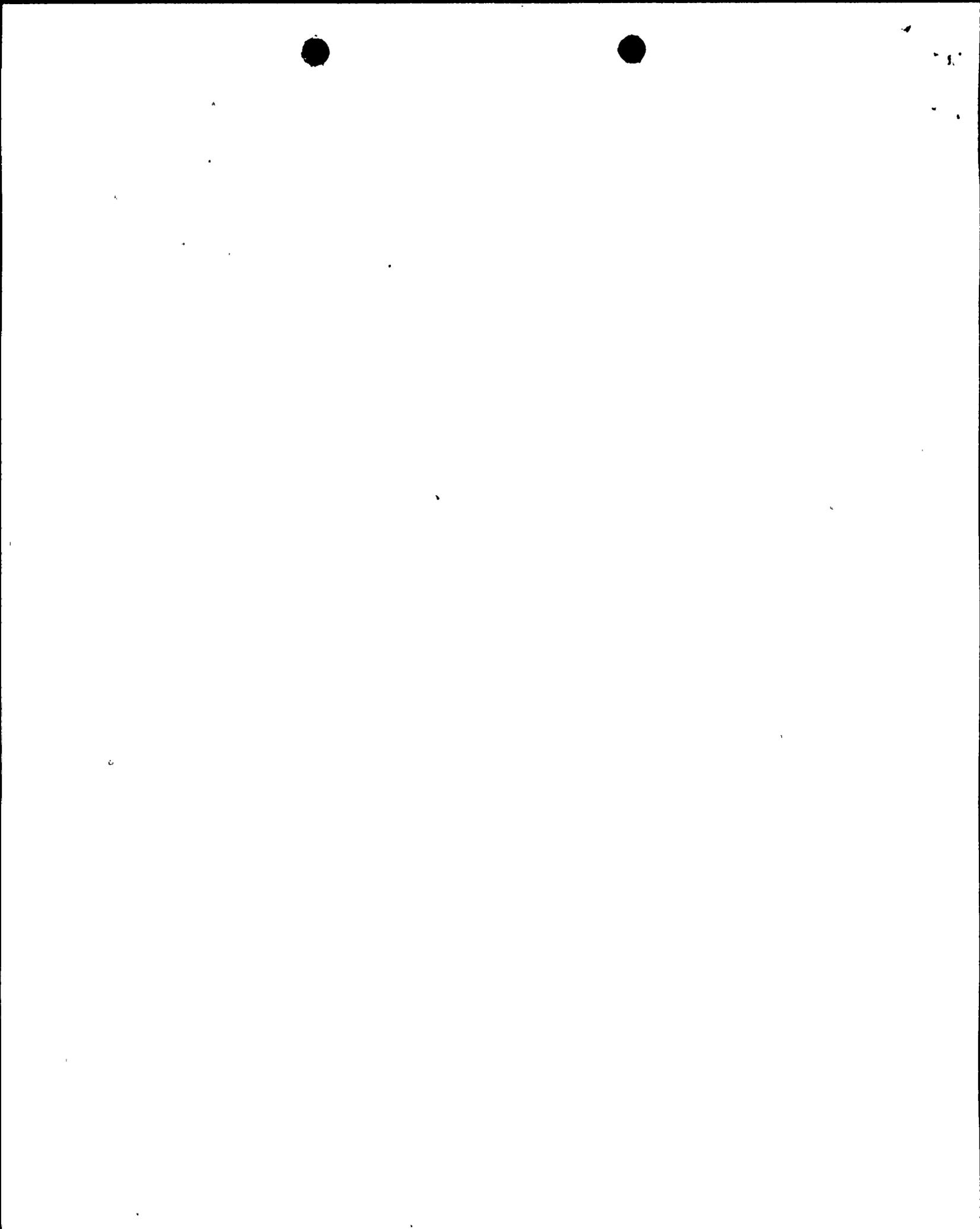
OBJECTIVE

TO ASSIST THE NRC STAF IN EVALUATING DATA AND SUPPORTING ANALYSES OBTAINED FROM THE NATURAL CIRCULATION, BORON MIXING AND COOLDOWN TEST PERFORMED AT DIABLO CANYON UNIT 1 IN COMPLIANCE WITH THE BTP RSB 5-1 REQUIREMENT FOR A CLASS 2 PLANT.



TIMING OF EVENTS FOR THE TEST

<u>TIME</u>	<u>CLOCK TIME</u>	<u>EVENT</u>
0:00	21:30	PLANT TRIP
2:58	00:28	RCP TRIP
3:22	00:52	BORON INJECTION INITIATED
3:28	00:58	PORV OPEN
3:43	01:13	BORON INJECTION TERMINATED
7:20	04:50	COOLDOWN INITIATED (20°F/HR)
16:26	13:56	DEPRESSURIZATION INITIATED (8 PSI/HR)
20:35	18:05	RHR SYSTEM INIATIATED
21:01	18:31	CRDM FANS SECURED
22:45	20:15	CRDM FANS RE-ENERGIZED
25:15	22:45	END OF TEST



SIMULATION OF THE TEST

- RELAP5/MOD1
- MINIMUM NUMBER OF NODING; ALL FOUR LOOPS
COMBINED INTO A SINGLE LOOP
- MODELING INCLUDES:
 - VESSEL
 - STEAM GENERATORS
 - PRESSURIZER
 - UPPER HEAD BYPASS FLOW
 - RCP SEAL INJECTION
 - HEAT STRUCTURES (FUEL, PIPING, U-TUBE, ETC.)
 - PRESSURIZER HEAT LOSS
 - RELIEF VALVES
 - AFW
 - ASD VALVES
- SEVERAL SENSITIVITY CALCULATIONS PERFORMED
 - 20°F/HR COOLDOWN { WITH RCP SEAL INJECTION
WITHOUT RCP SEAL INJECTION
 - 50°F/HR COOLDOWN



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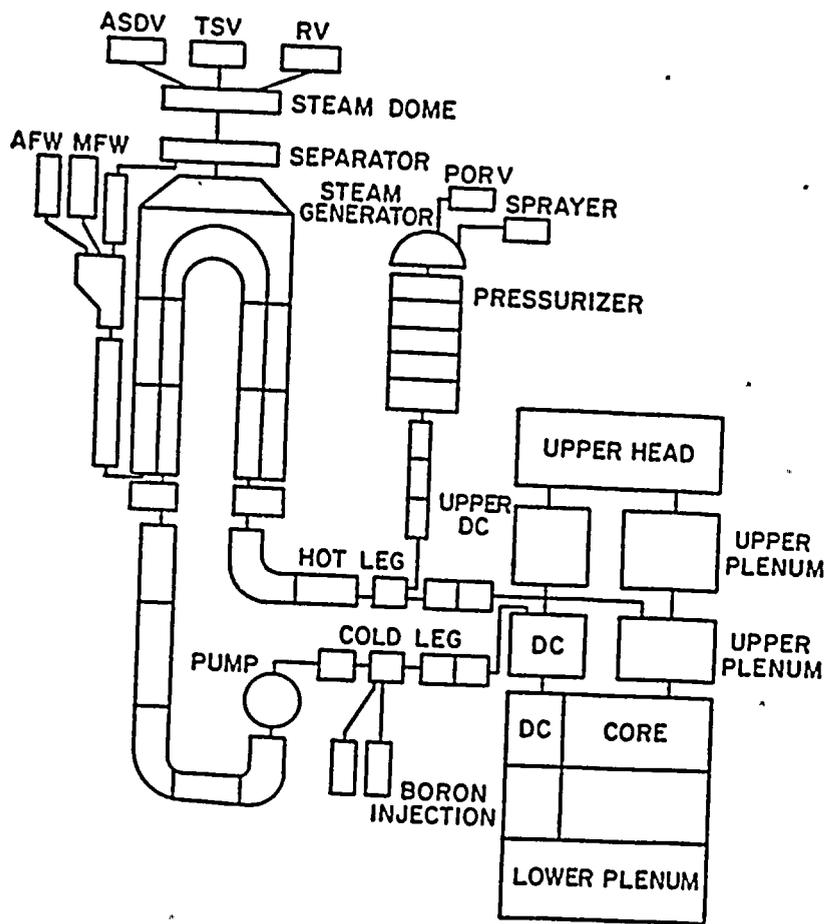


Figure 3.1. Noding diagram.

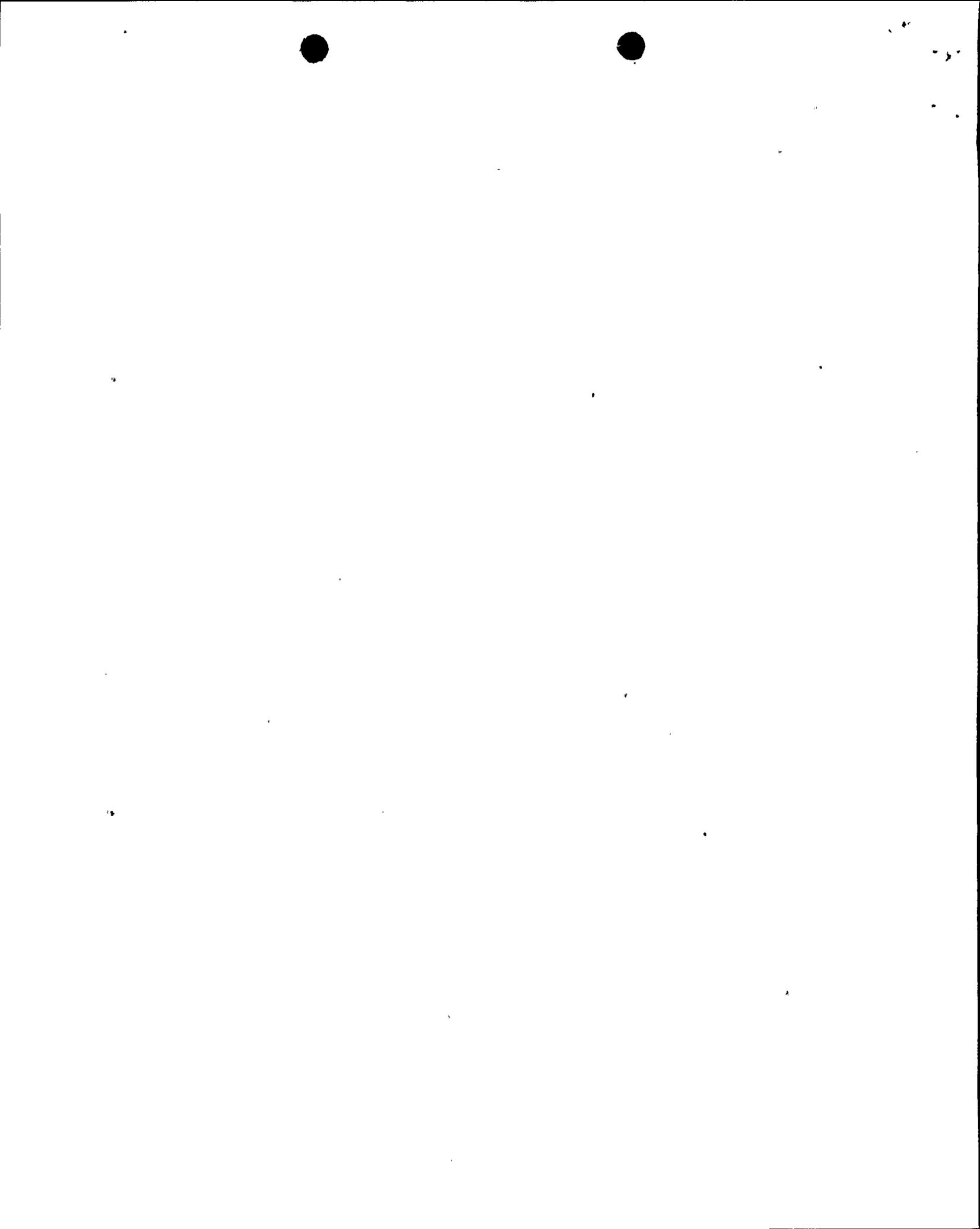
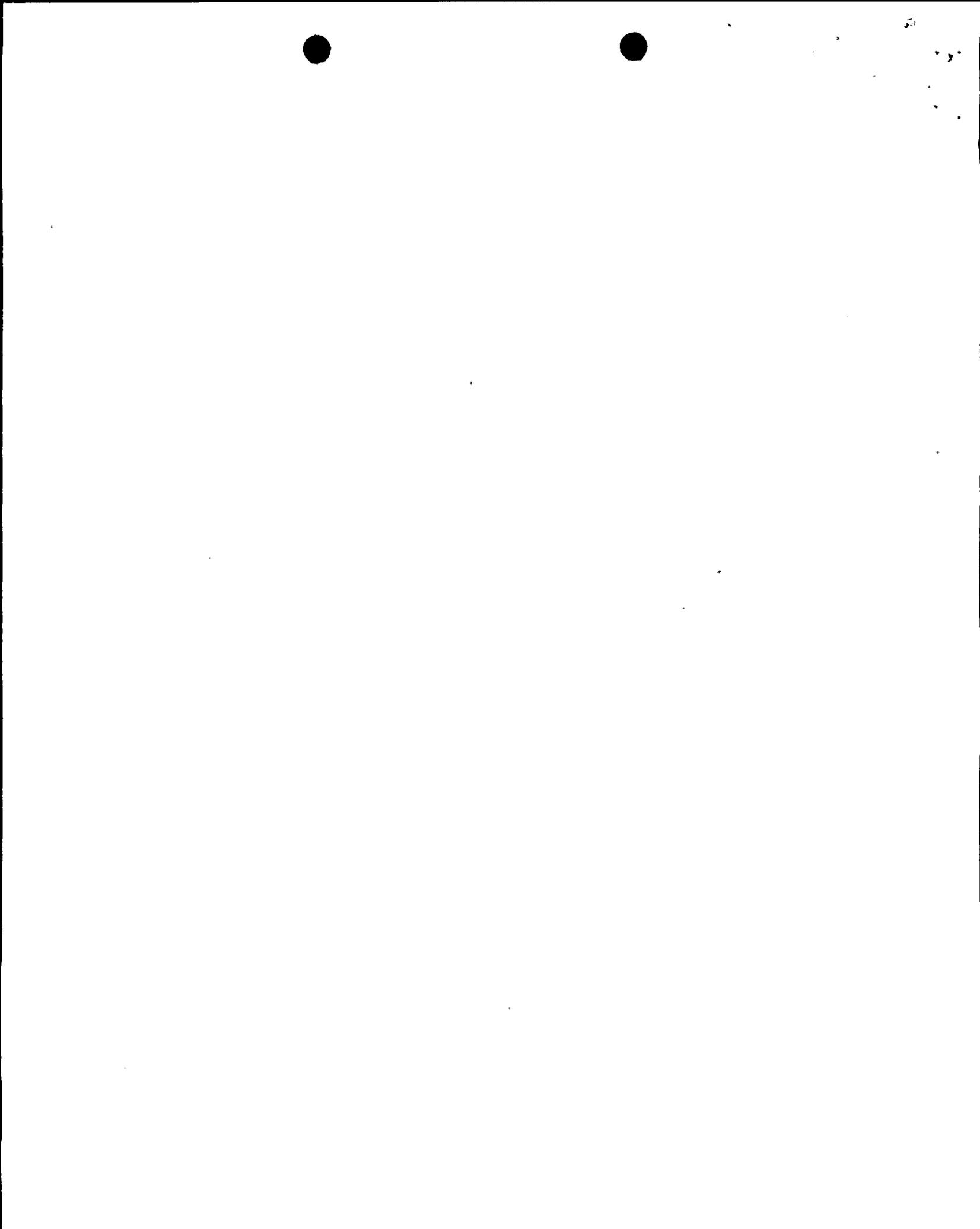
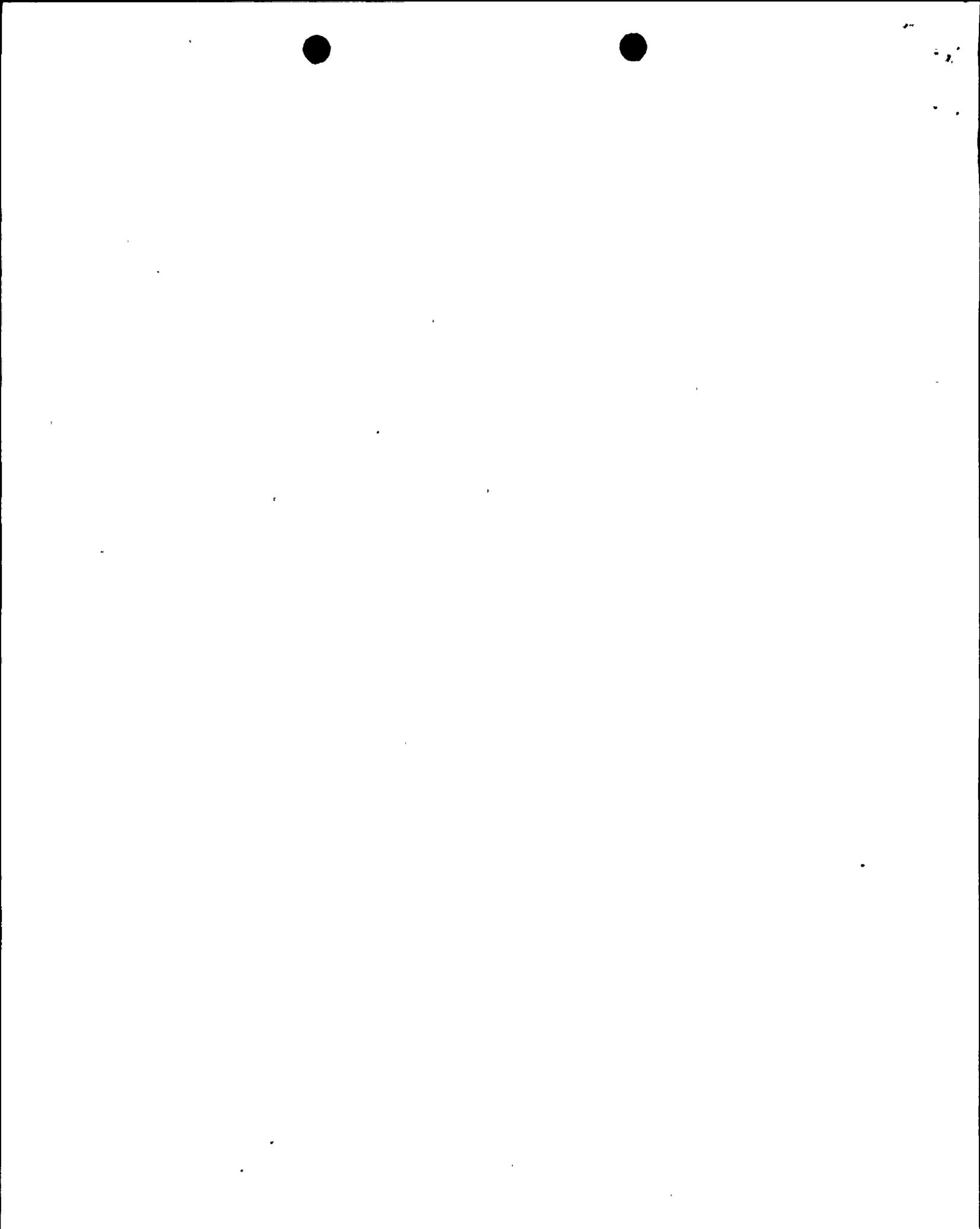


TABLE 3.1 THE STEADY STATE CONDITIONS

PARAMETERS	PLANT	RELAP5/MOD1
POWER, MW	3338	3338
PRESSURE, PSIA	2252.8	2252.8
HOT LEG TEMP., °F	608.8	612.1
COLD LEG TEMP., °F	544.4	548.0
COOLANT FLOW, LB/SEC	36918	36678
BYPASS FLOW, LB/SEC	77.3	79.6
ΔP PUMP, PSIA	84.0	84.6
PRESSURIZER LEVEL, %	60.0	61.7
STEAM PRESSURE, PSIA	805.0	805.0
STEAM TEMPERATURE, °F	519.0	518.9
STEAM FLOW, LB/SEC	4039	4035.8
SG WATER VOLUME, FT ³	7930	7068.0
BORON CONCENTRATION, PPM	890	890



- 1) THE TEST DEMONSTRATED THAT ADEQUATE NATURAL CIRCULATION WAS ESTABLISHED AND THE PLANT WAS CAPABLE OF REMOVING THE DECAY HEAT BY THE NATURAL CIRCULATION USING ONLY SAFETY-GRADE EQUIPMENT.



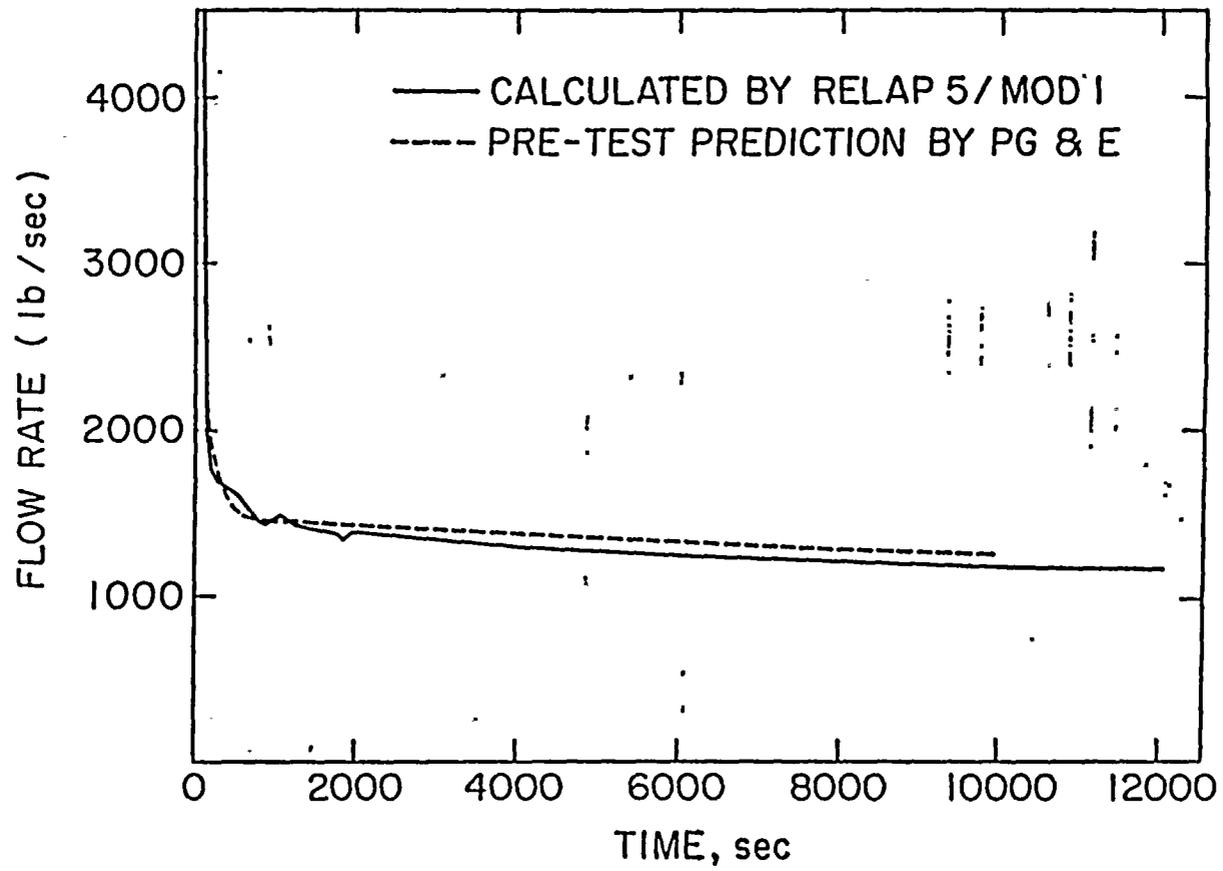
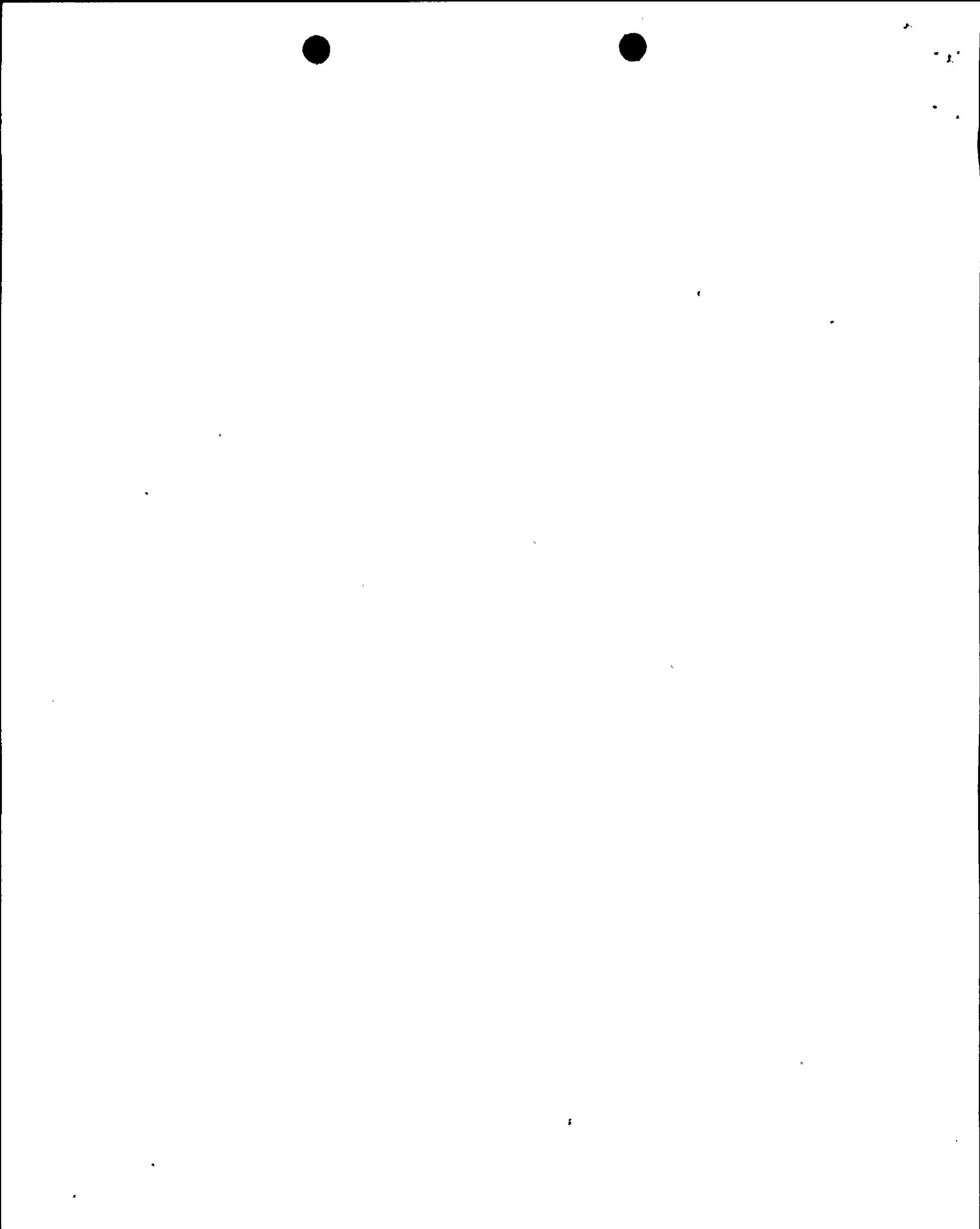


Figure 3.2 RCS flow.



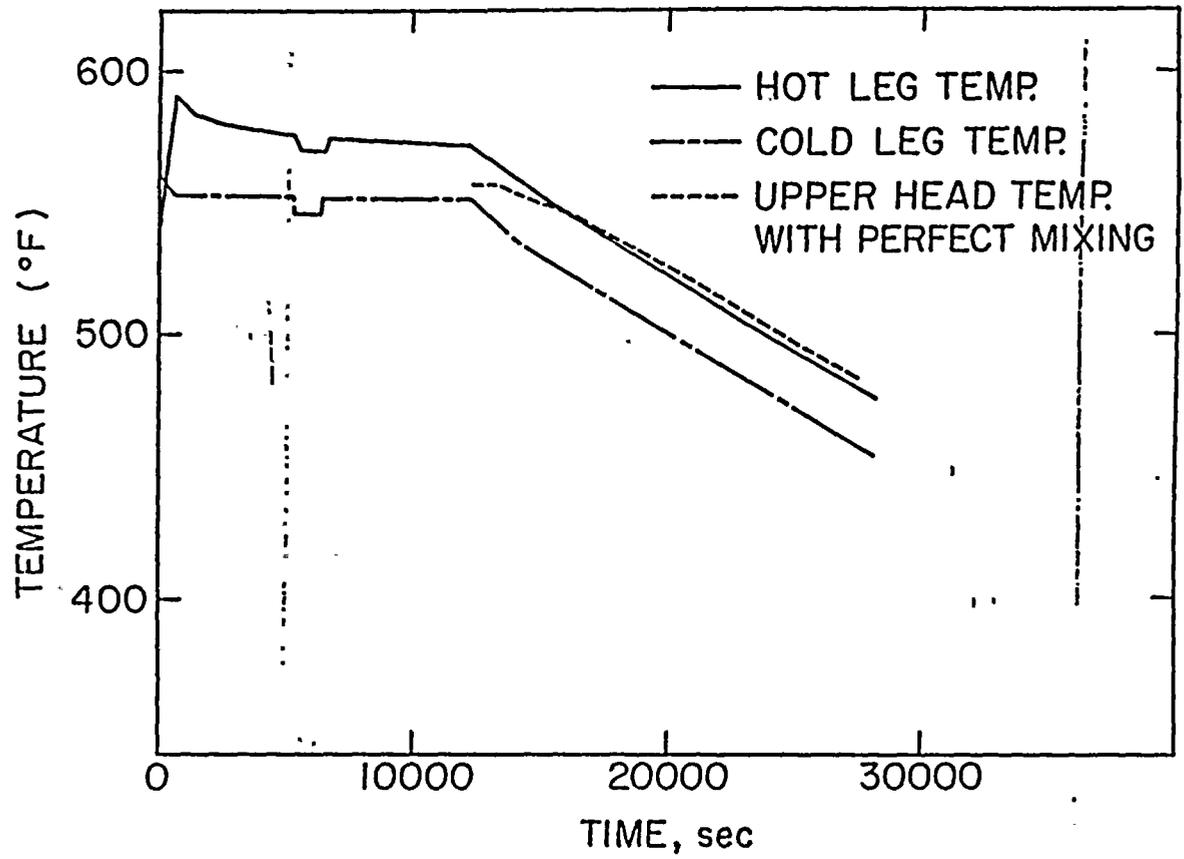
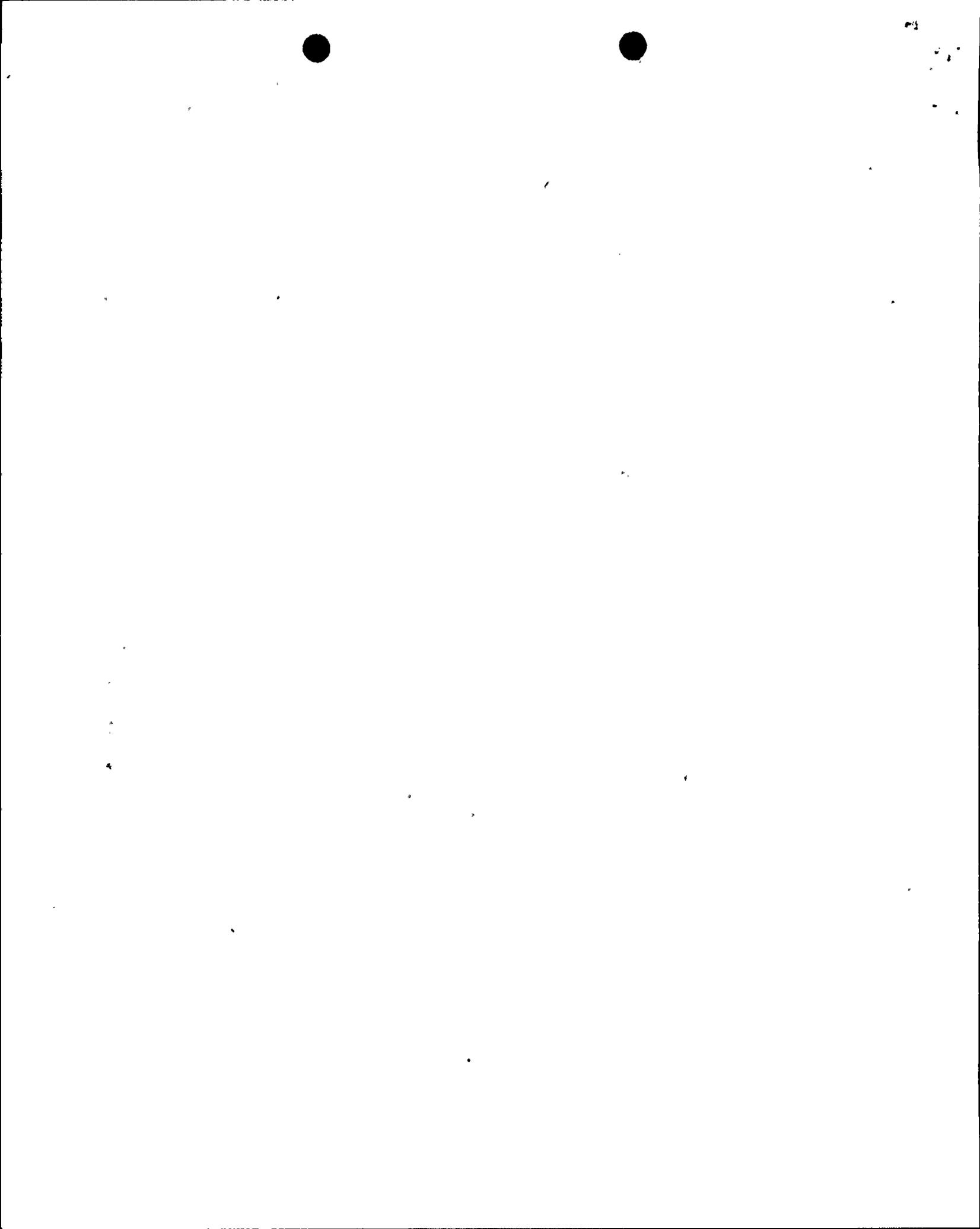


Figure 3.4 The calculated RCS temperature (20°F/hr cooldown).



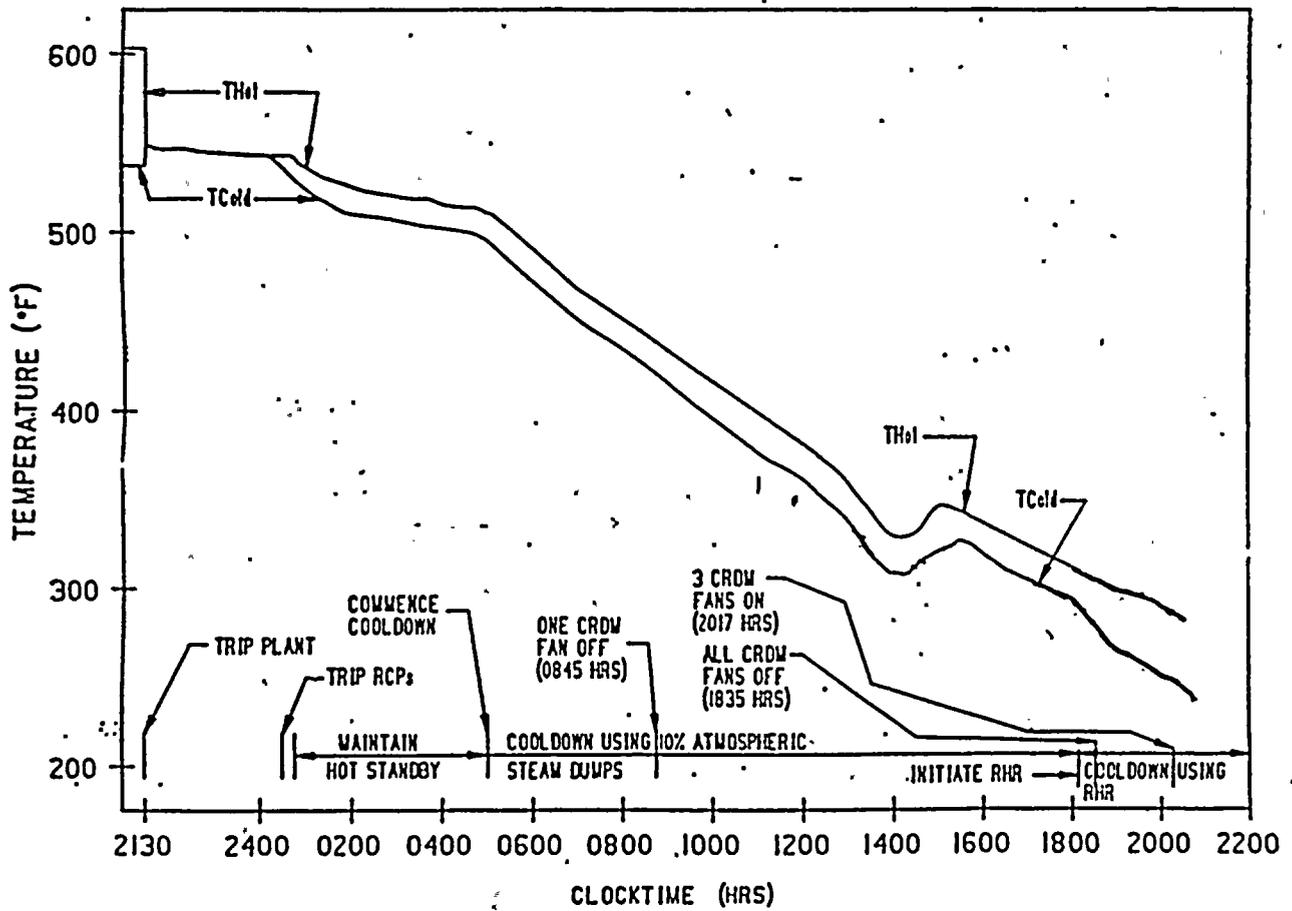


Figure 3.6 RCS temperature for the test.



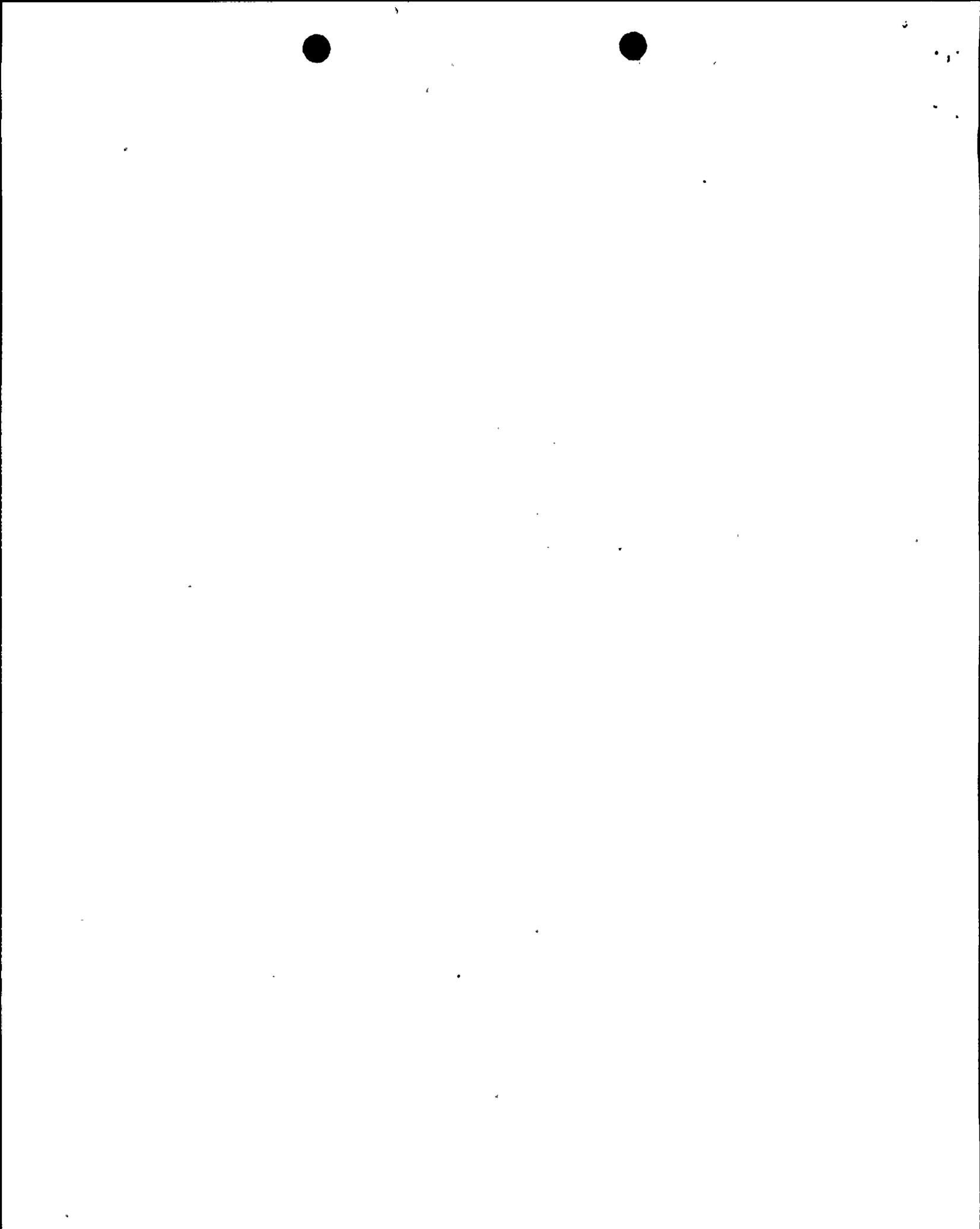
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- 2) ADEQUATE BORON MIXING COULD BE ACHIEVED BY THE
NATURAL CIRCULATION IN THE MAIN FLOW PATH OF THE
RCS USING ONLY SAFETY-GRADE EQUIPMENT.



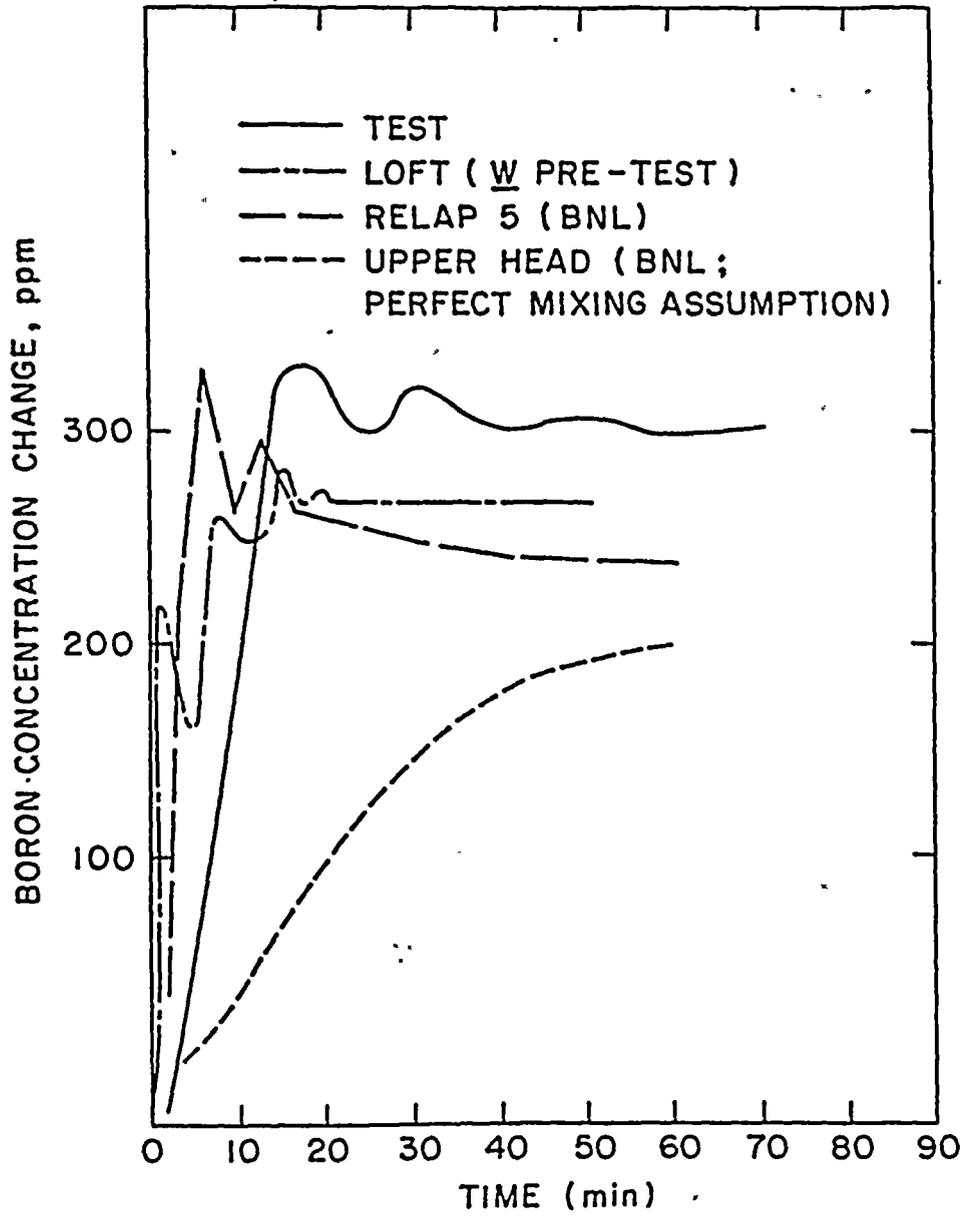
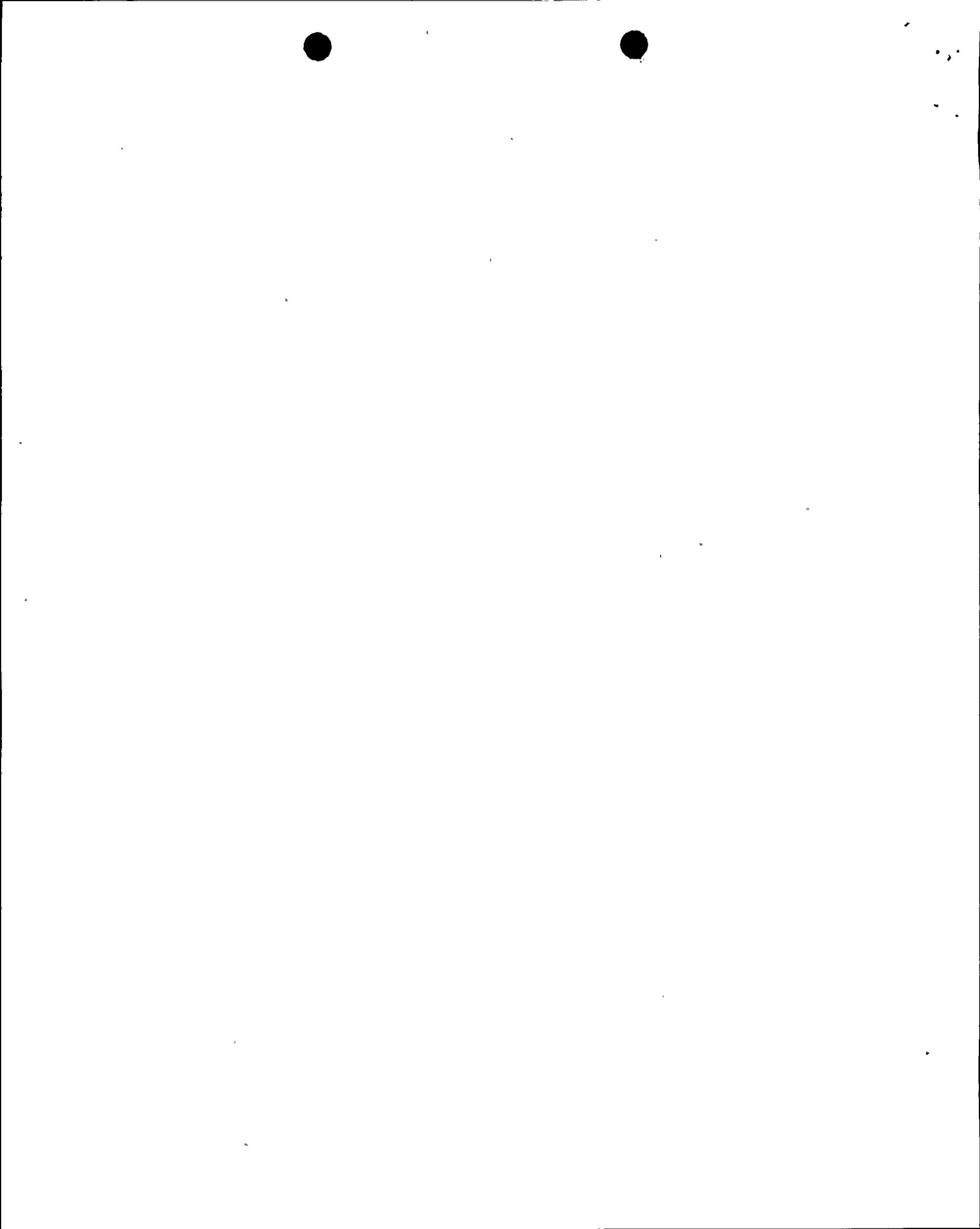
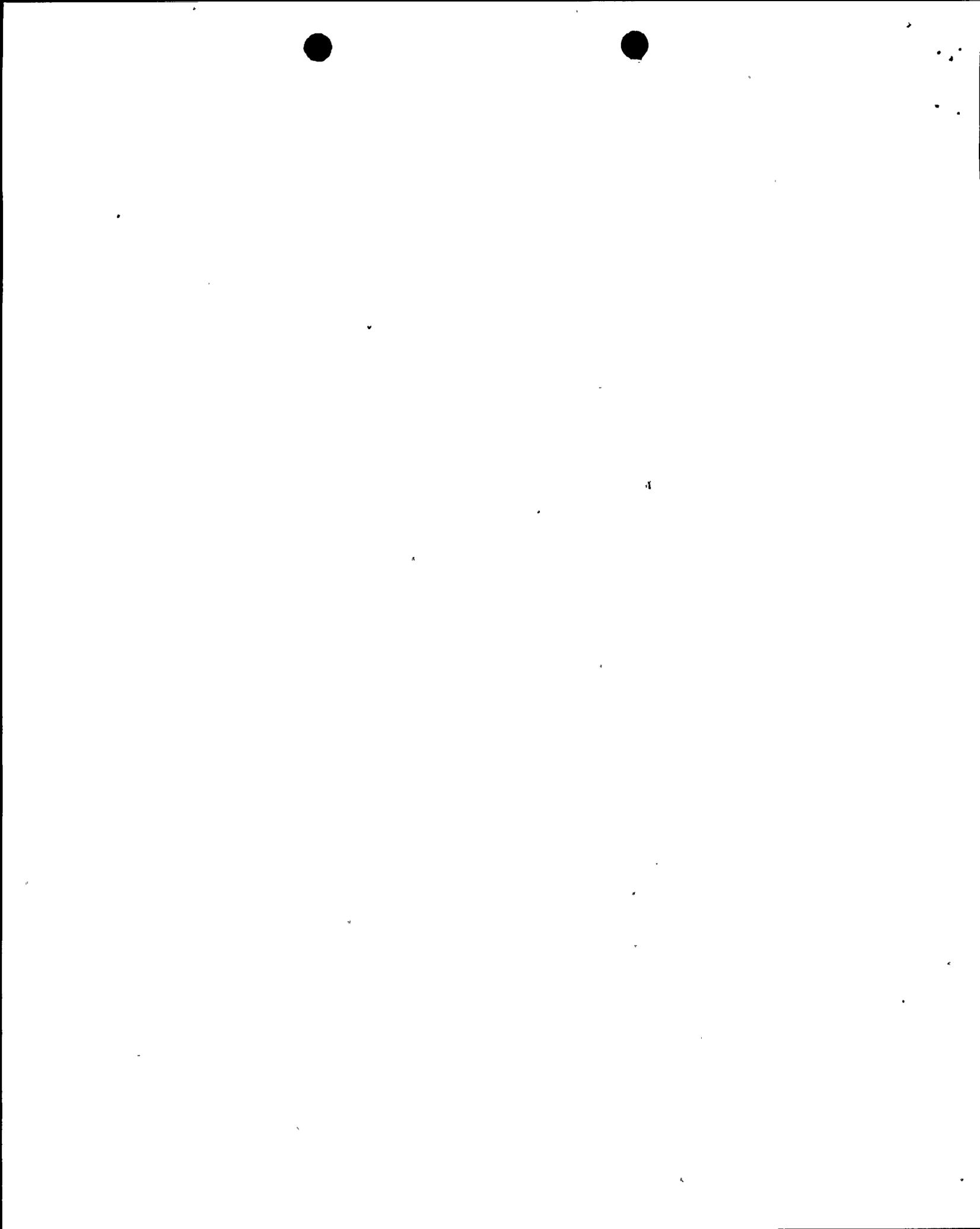


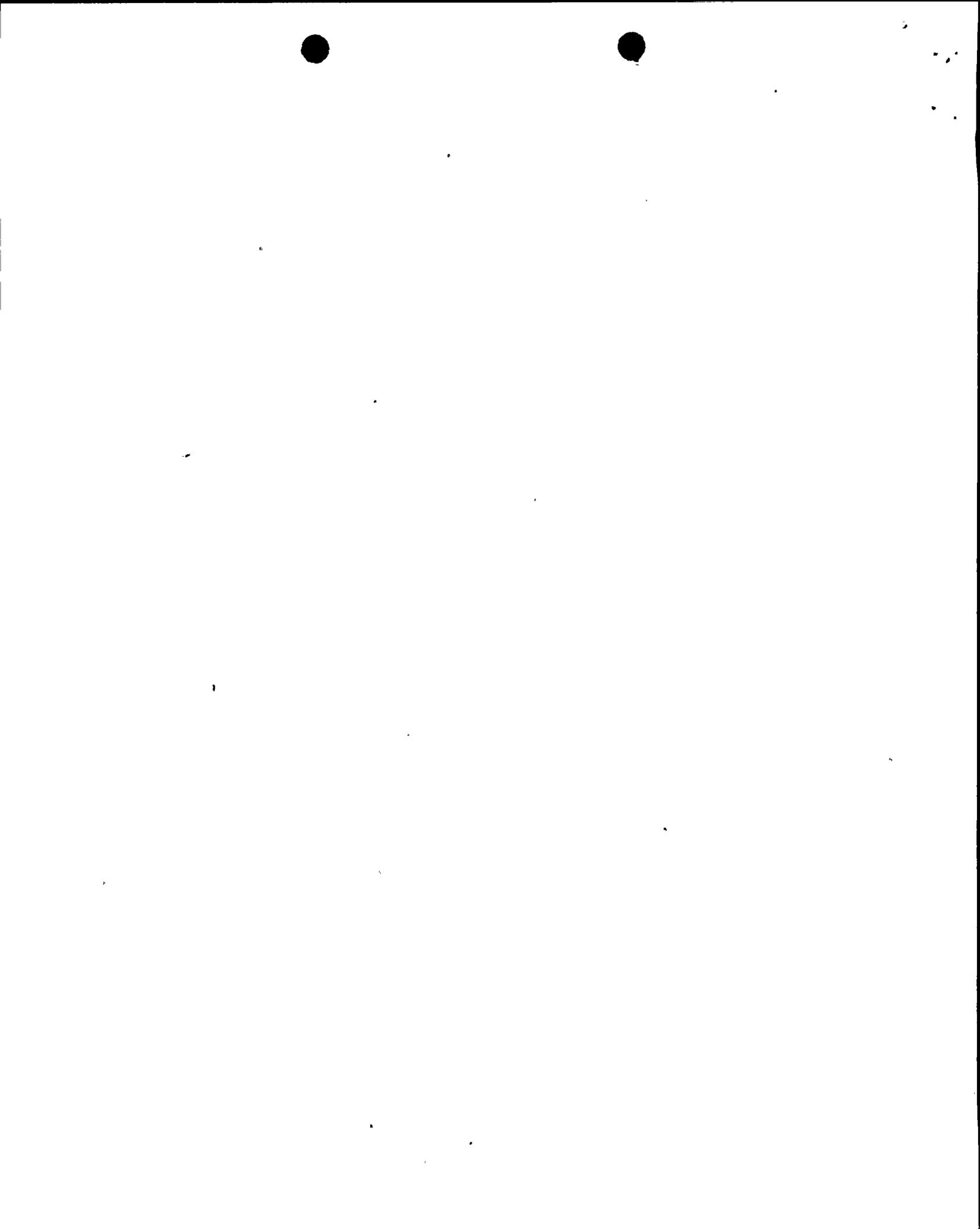
Figure 3.9 Boron concentration.



- 3) THE EFFECT OF RELATIVELY UNBORATED WATER ENTERING THE RCS FROM THE UPPER HEAD AND PRESSURIZER APPEARS TO BE MINIMAL AS LONG AS DEPRESSURIZATION IS CONDUCTED CAREFULLY TO LIMIT THE SIZE OF POSSIBLE VOID FORMATION.



- 4) THE PRESSURE WOULD RISE AND REACH THE PORV ACTUATION PRESSURE WITHOUT LETDOWN DURING THE BORON MIXING PERIOD.



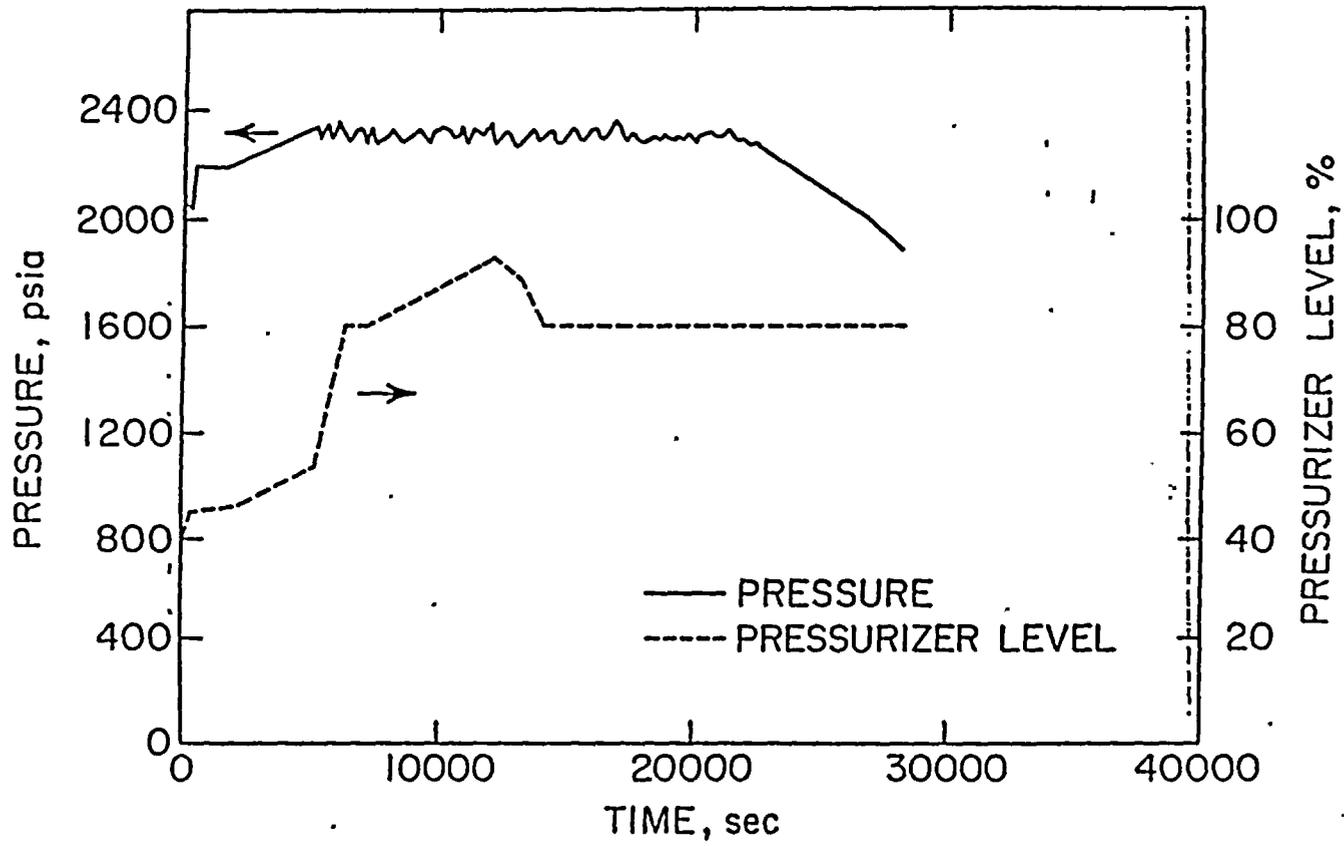
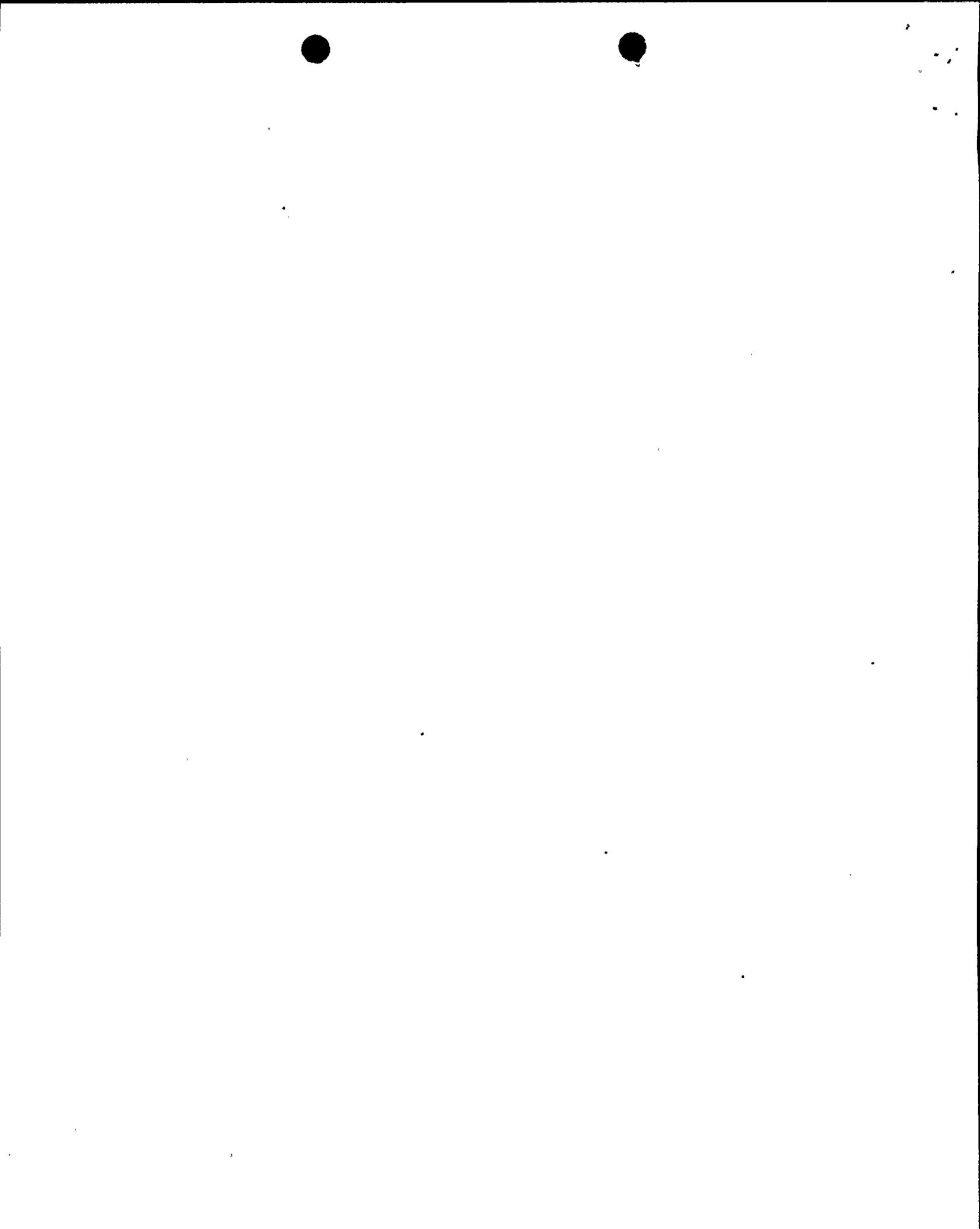


Figure 3.5 RCS pressure and pressurizer level (20°F/hr cooldown).



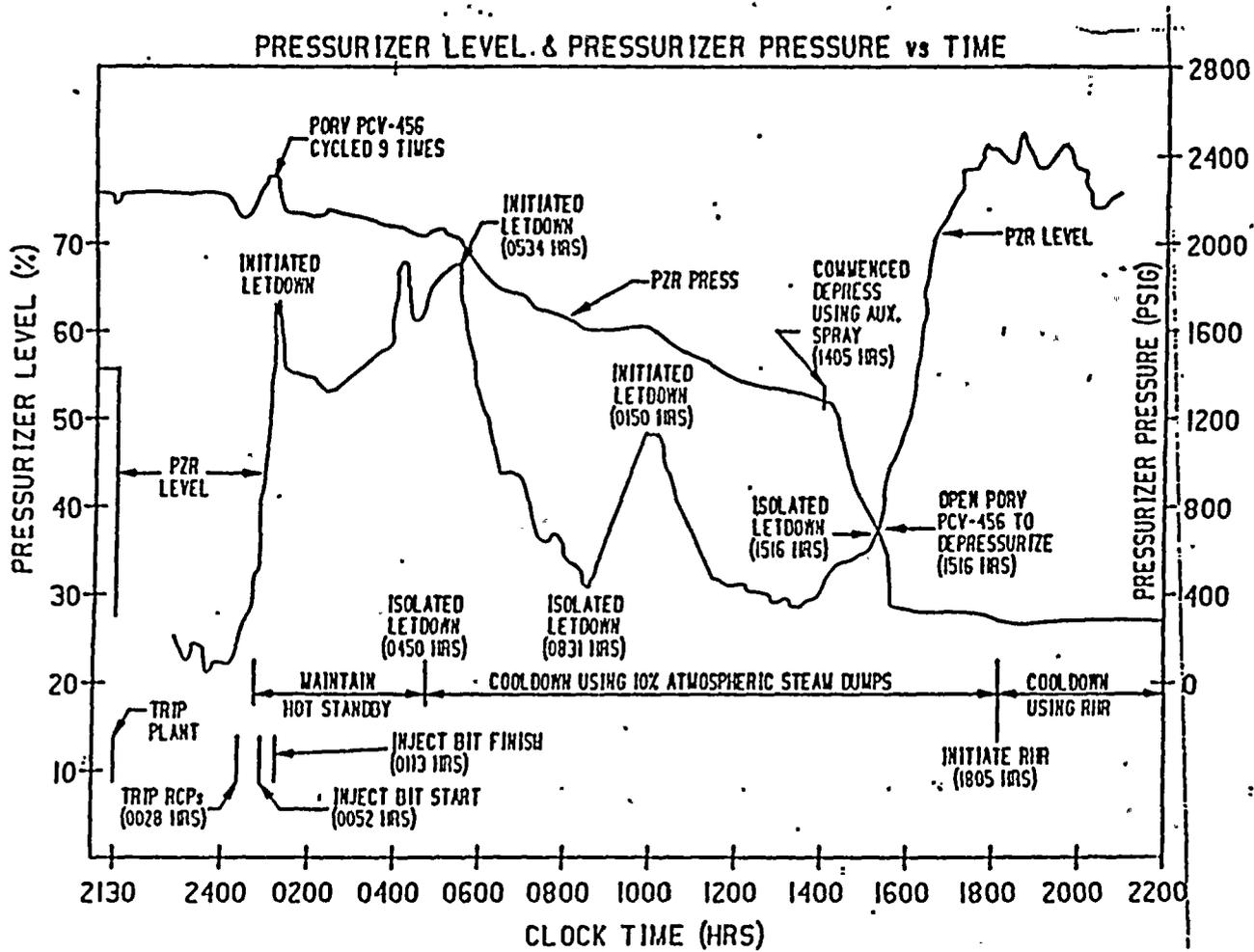
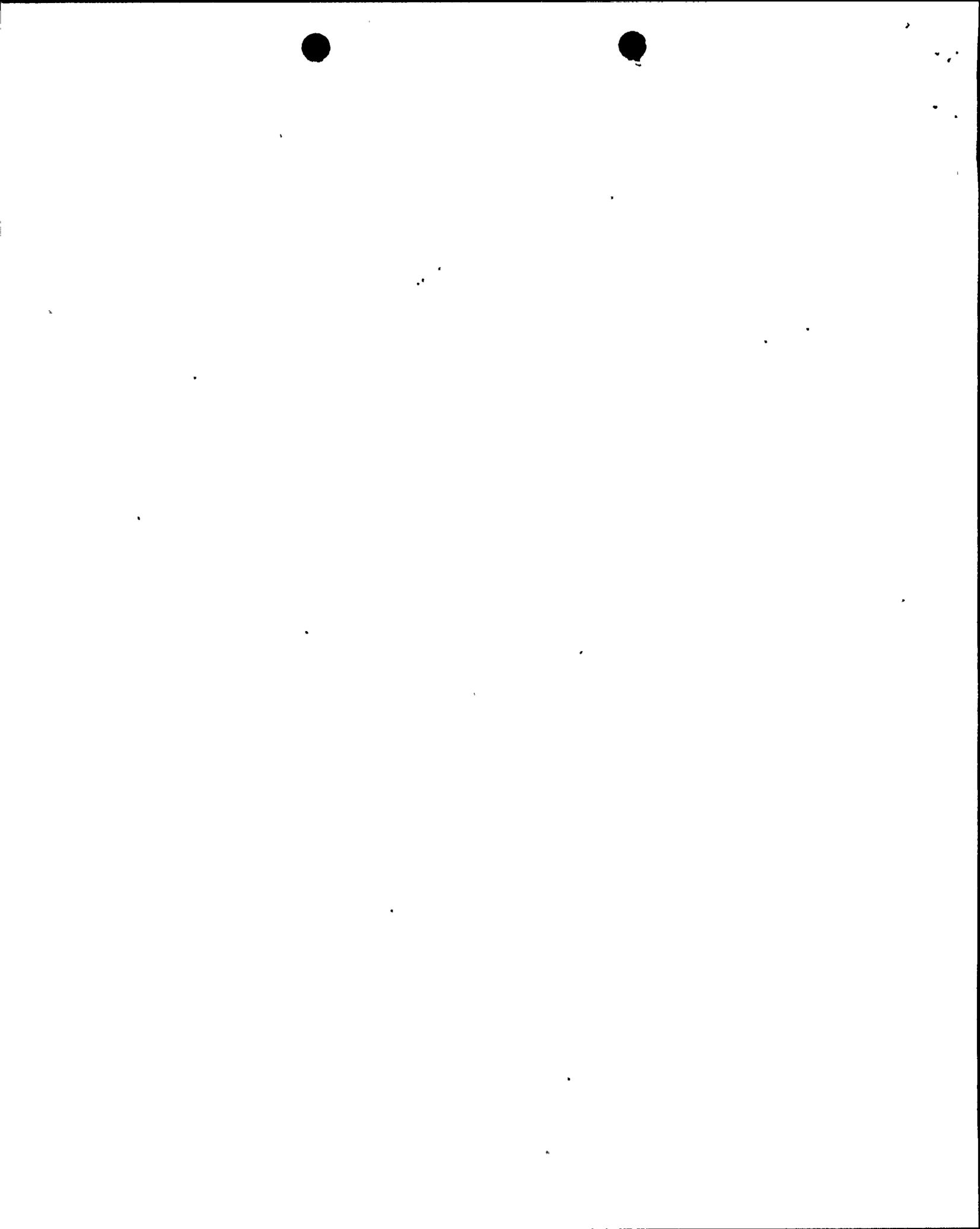
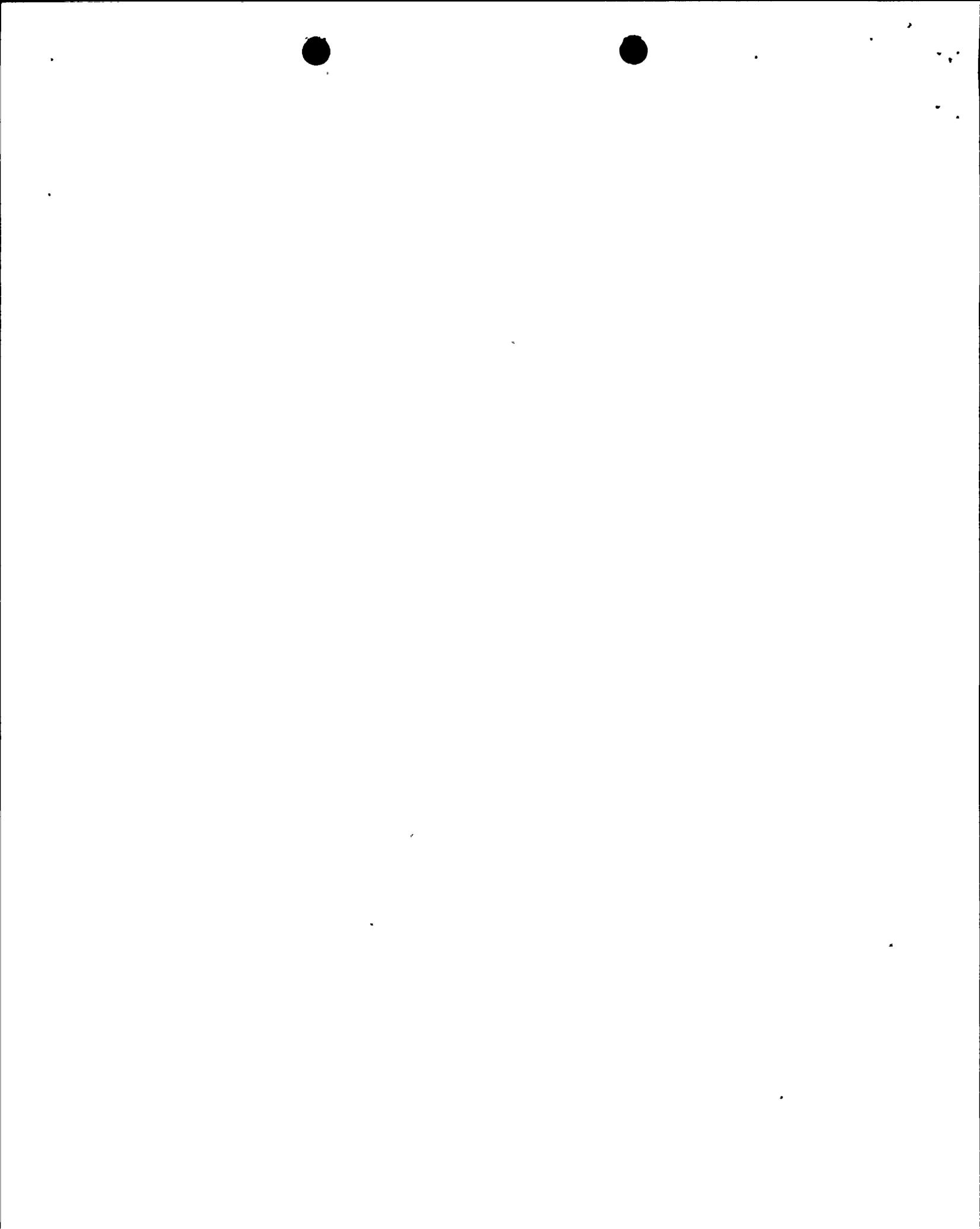


Figure 3.7 Test pressure and pressurizer level.



5) THE TEST DEMONSTRATED THAT IT COULD COOL THE MAIN
RCS TO THE RHR SYSTEM INITIATION TEMPERATURE WHILE
MAINTAINING ADEQUATE SUBCOOLING DURING THE NATURAL
CIRCULATION USING ONLY SAFETY-GRADE EQUIPMENT.



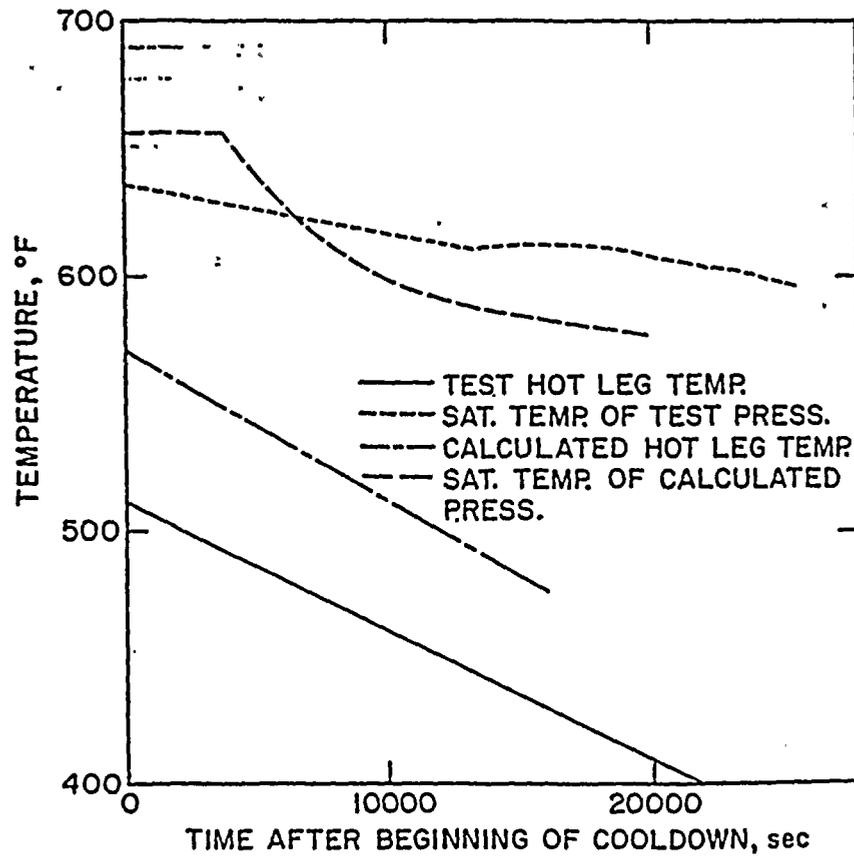


Figure 3.11 Hot leg and saturation temperature of test and calculation (20°F/hr cooldown).



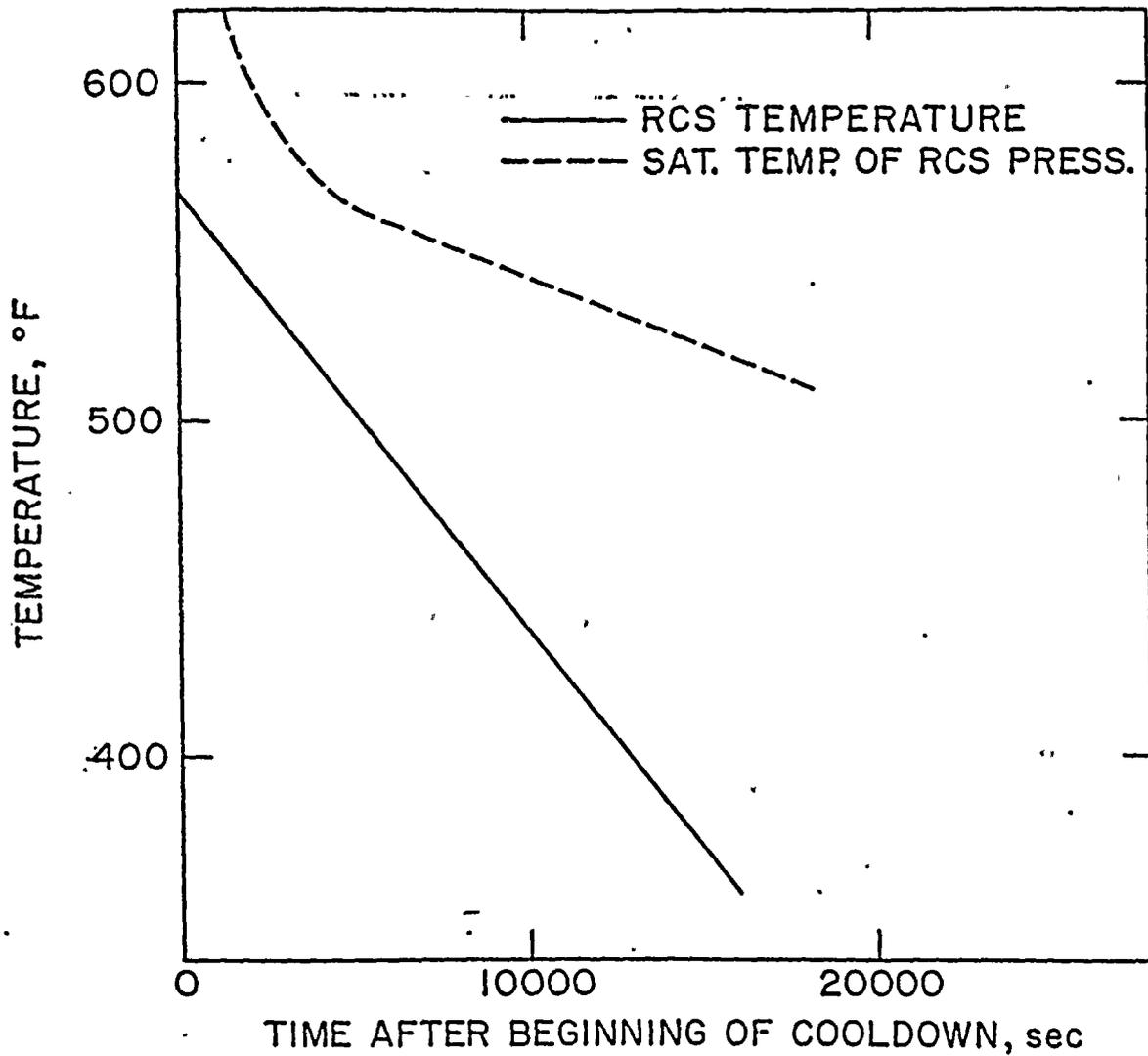
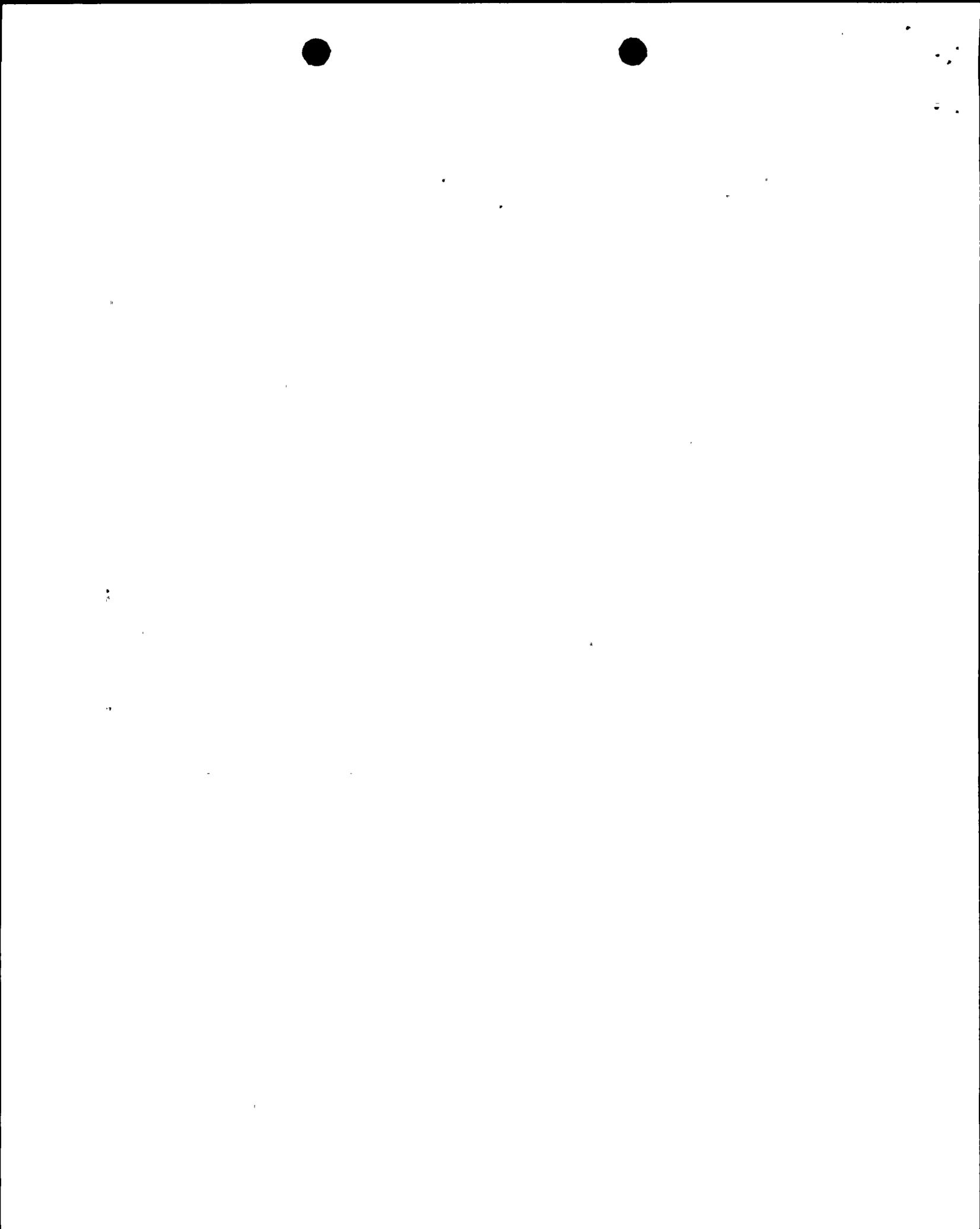
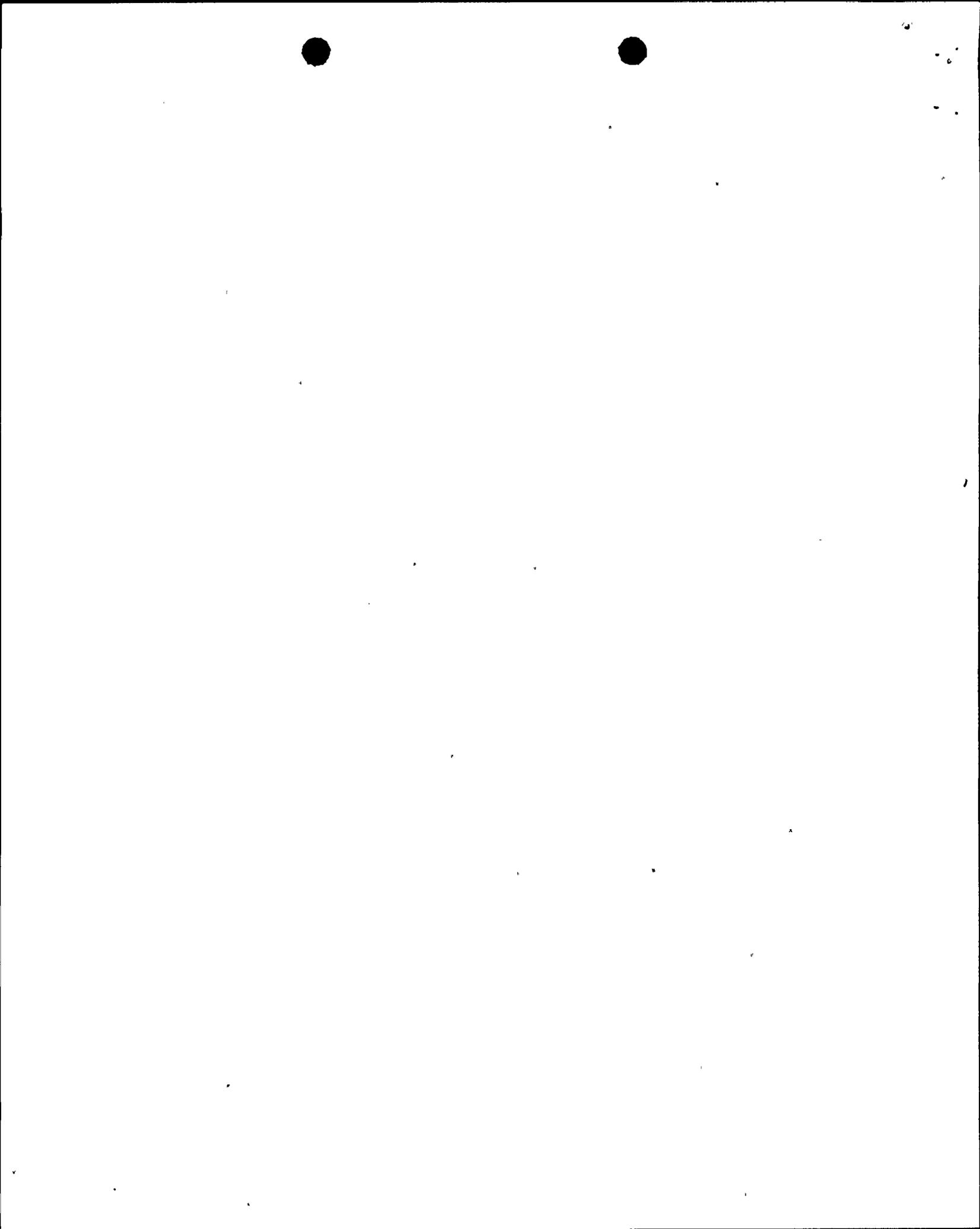


Figure 3.12 RCS temperature and saturation temperature with 50°F/hr cooldown.

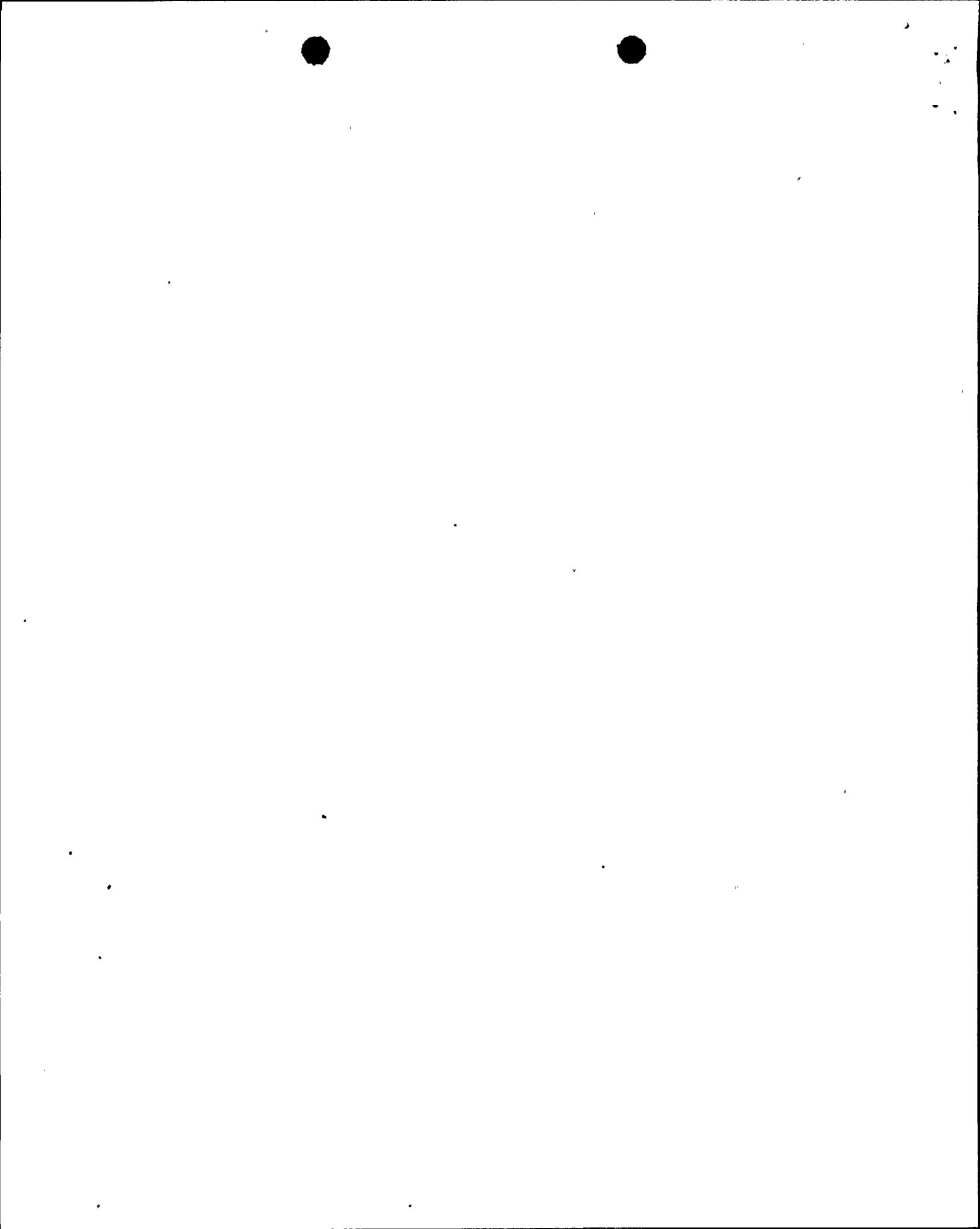


FACTORS INFLUENCING THE COOLING OF THE UPPER HEAD UNDER
NATURAL CIRCULATION CONDITIONS

- A) HEAT REMOVAL FROM THE UPPER HEAD INTO THE CONTAINMENT ENVIRONMENT THROUGH THE CRDM AND THE UPPER HEAD DOME WHEN CRDM FANS OPERATE,
- B) AMOUNT OF BYPASS INTO THE UPPER HEAD,
- C) HEAT CONDUCTION FROM UPPER HEAD TO UPPER PLENUM THROUGH THE GUIDE TUBE STRUCTURES,
- D) HEAT CONDUCTION DOWN TO THE REACTOR VESSEL THROUGH THE UPPER HEAD DOME.



- 6) THE TEST DEMONSTRATED THAT THE UPPER HEAD COULD BE COOLED WITHOUT VOID FORMATION WHEN THE CRDM FANS WERE IN OPERATION.



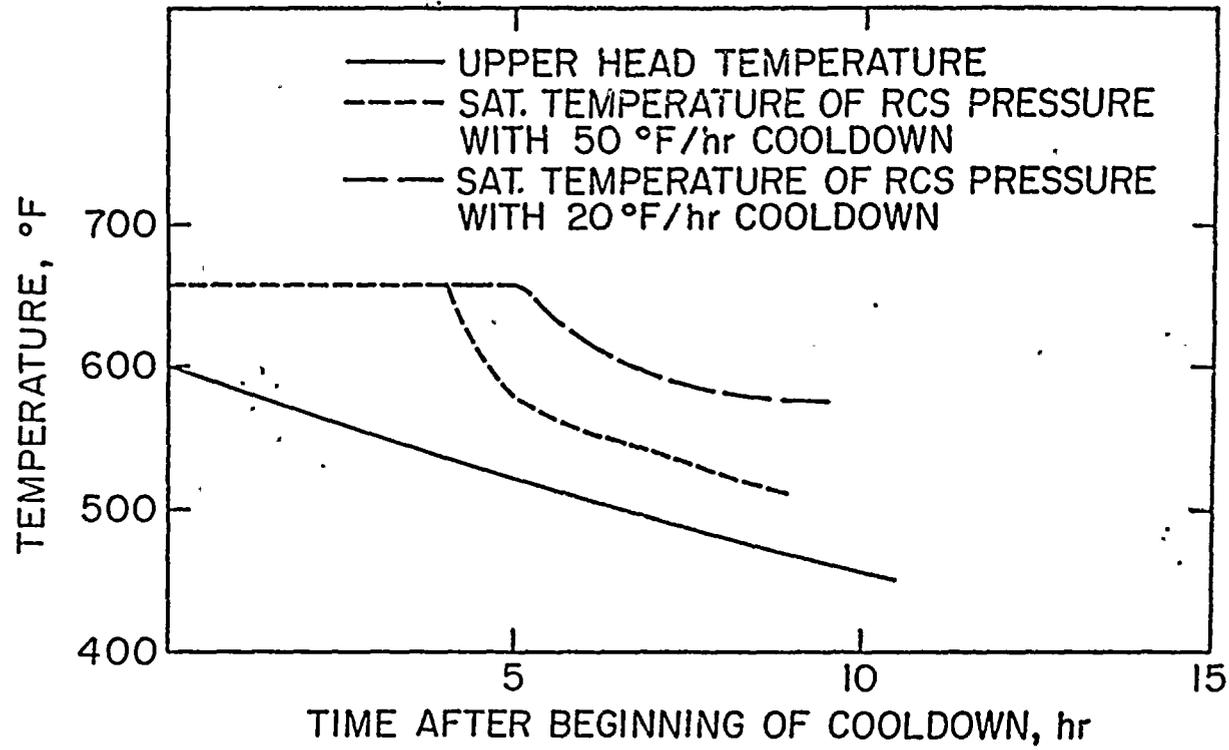
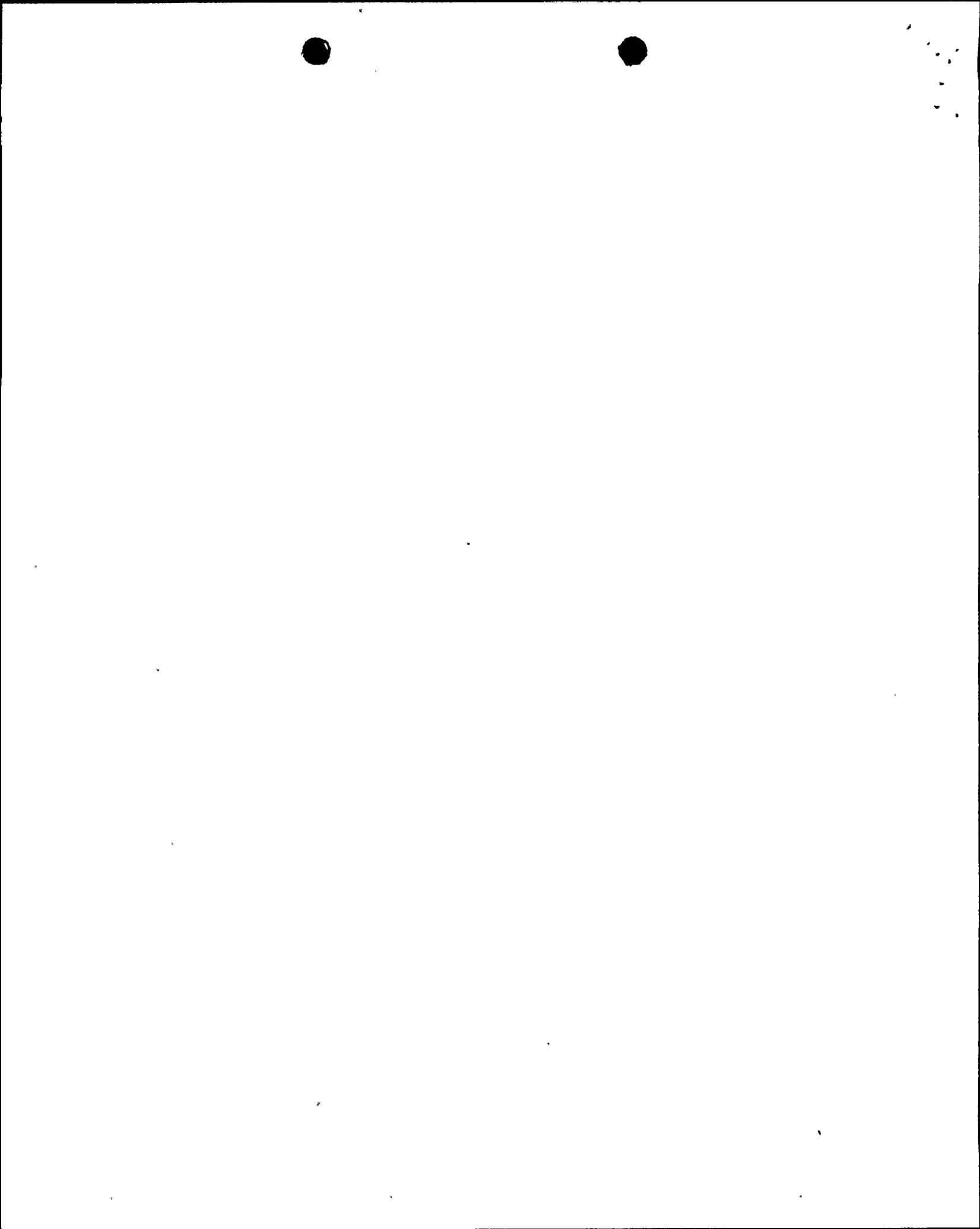


Figure 4.1 Margin of subcooling in the upper head with CRDM fans in operation.



- 7) THE TEST RESULTS INDICATE THAT THE UPPER HEAD COOLDOWN RATE WITHOUT THE CRDM FANS IS ABOUT 6°F PER HOUR. THIS IS HIGHER THAN THE CONSERVATIVE BNL CALCULATION (ACCOUNTING ONLY FOR CONDUCTION HEAT LOSS) WHICH ESTIMATED A MINIMUM RATE OF 3°F/HOUR.



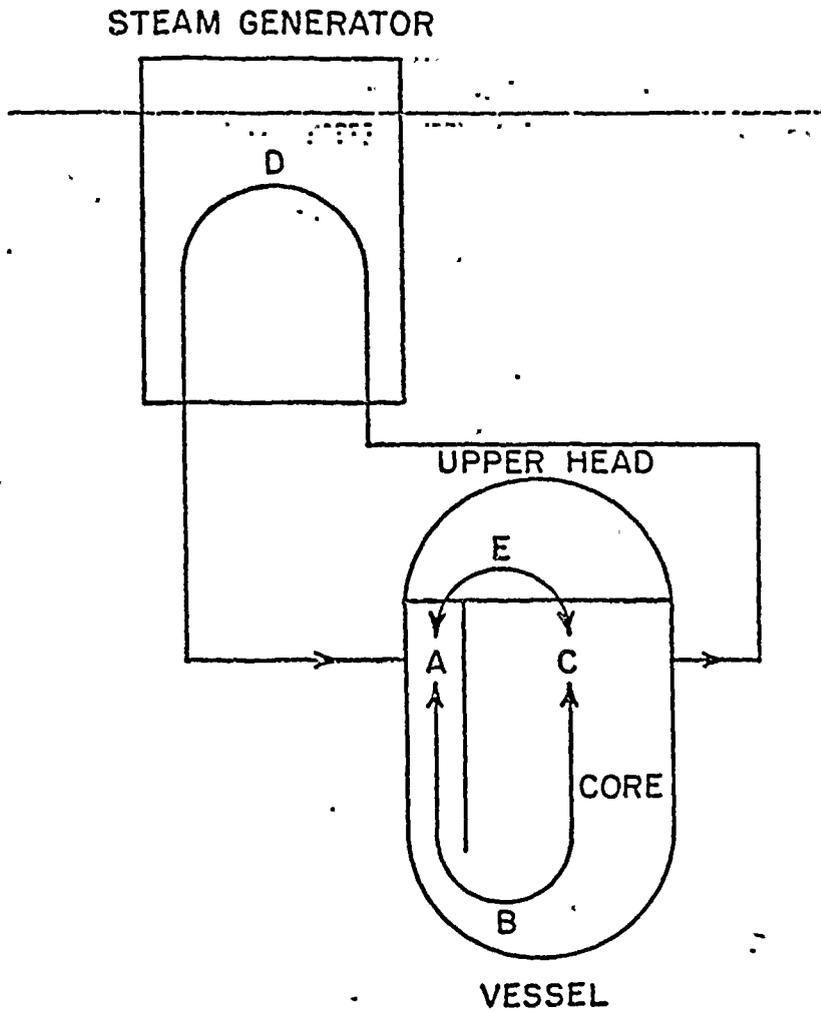
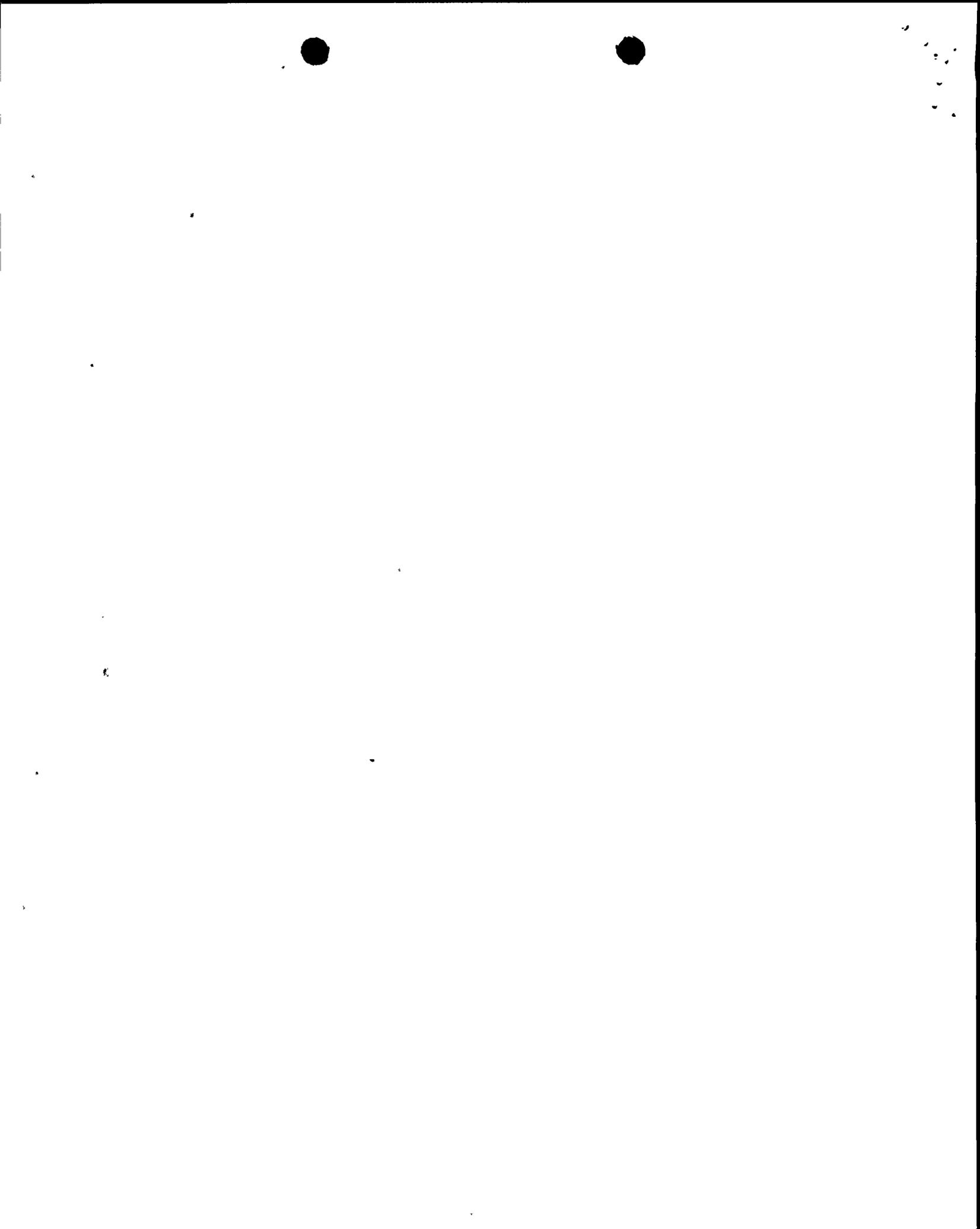
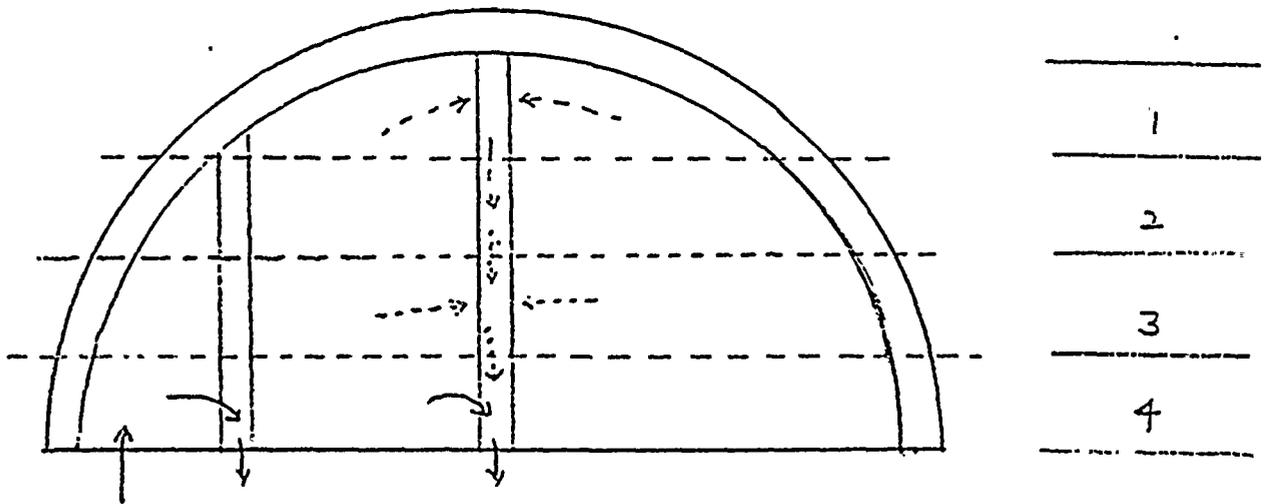
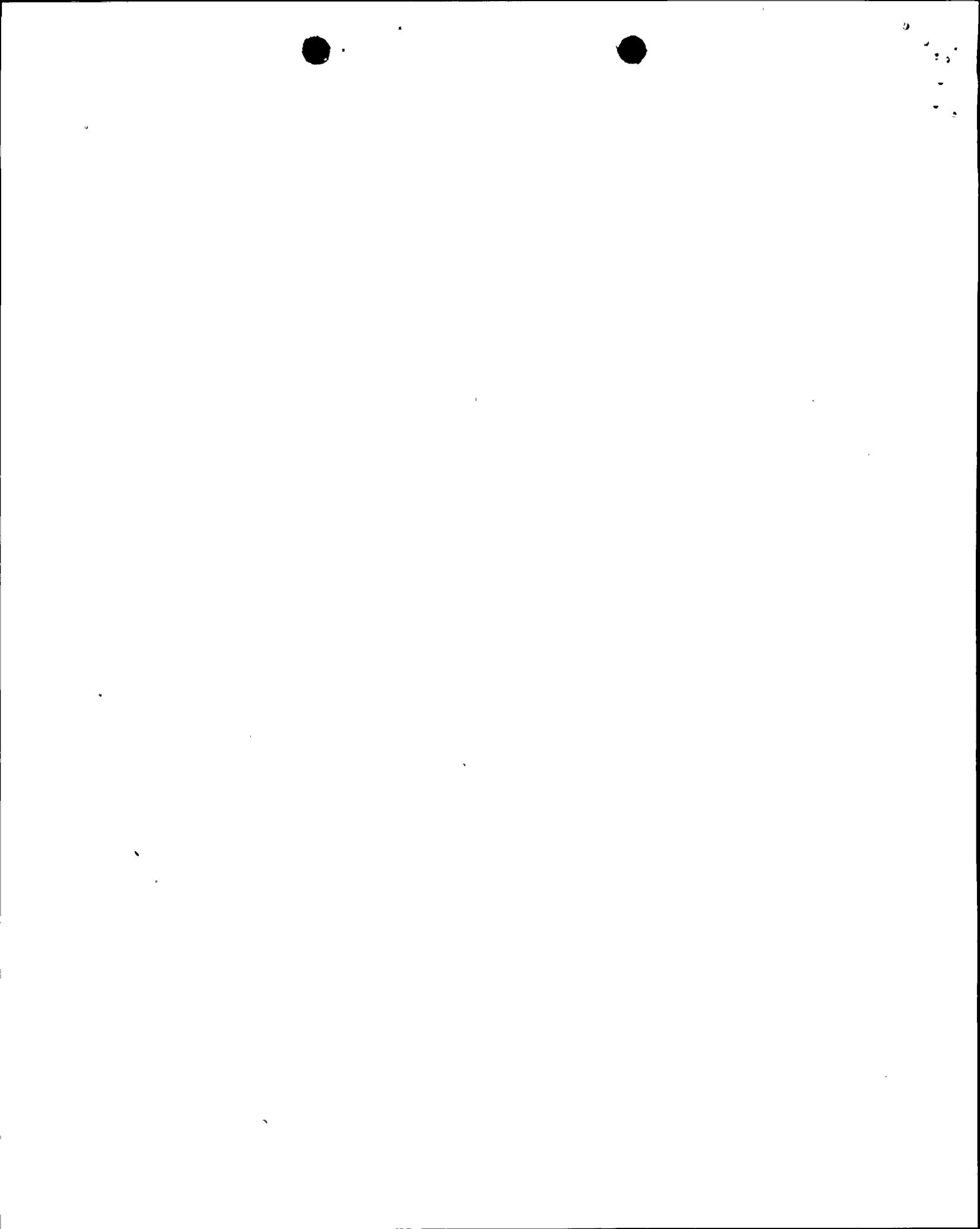


Figure 3.8: Bypass flow.



— FLUID PATH
- - - HEAT COND. PATH





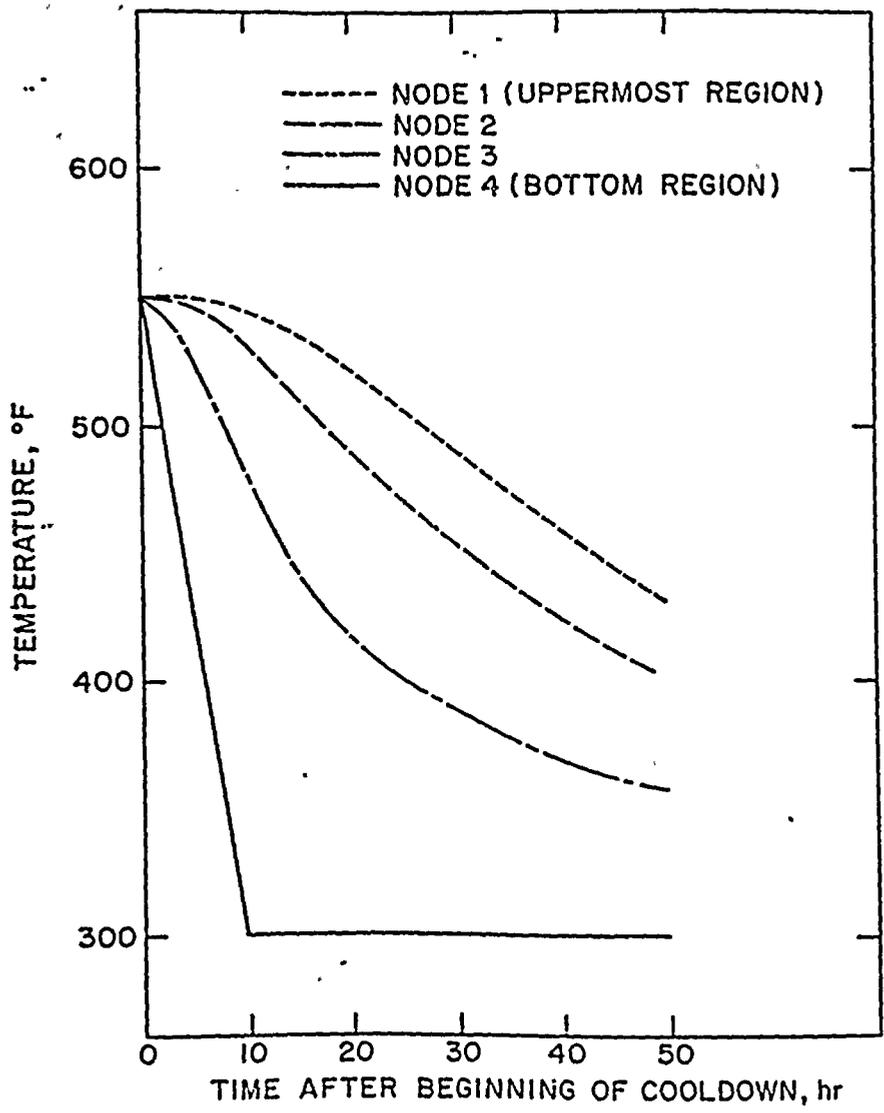
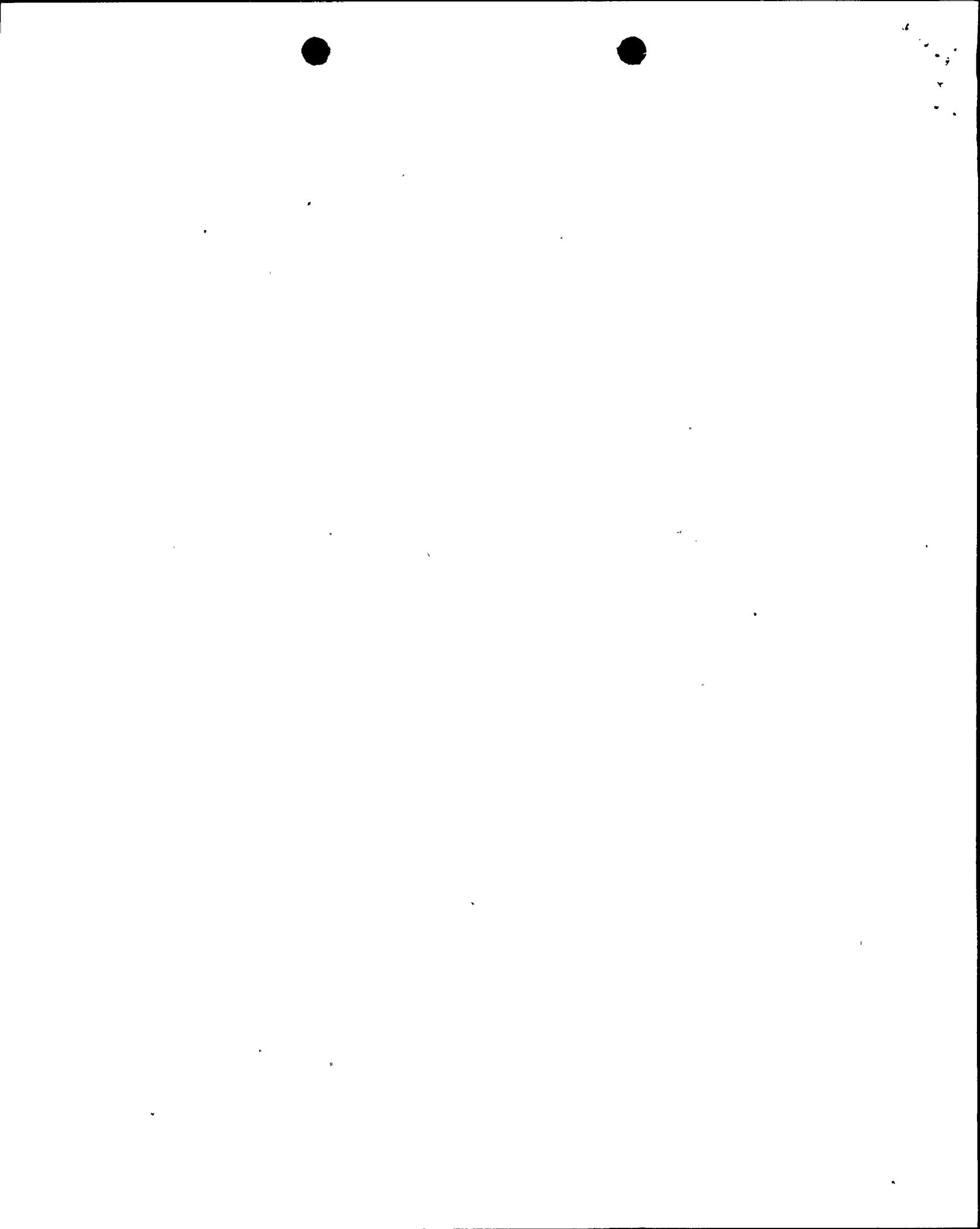


Figure 4.2 Upper head temperature when loss is due to conduction only (25°F/hr cooldown of RCS).



- 8) THE RCS PRESSURE SHOULD BE MAINTAINED ABOVE 1200 PSIA BY MEANS OF EITHER THE PRESSURIZER HEATERS (IF AVAILABLE) OR CHARGING DURING THE COOLDOWN PERIOD TO AVOID THE VOID FORMATION IN THE UPPER HEAD WHEN THE CRDM FANS WERE NOT IN OPERATION.



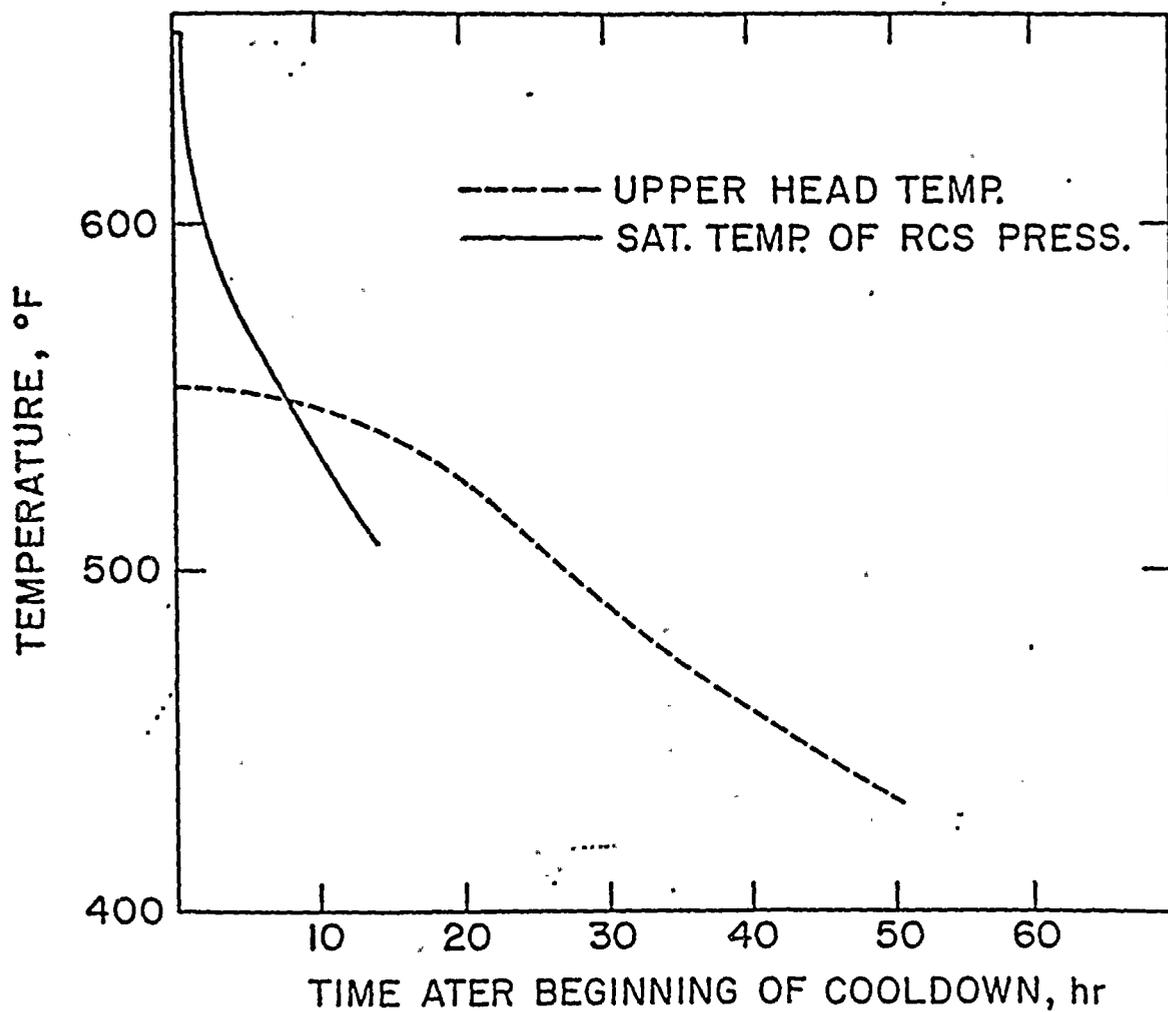


Figure 4.3 Upper head temperature and saturation temperature of RCS pressure with 20°F/hr cooldown.



- 9) SUFFICIENT SUPPLY OF SAFETY GRADE COOLING WATER WAS AVAILABLE TO SUPPORT THE PROPOSED PLANT COOLDOWN METHOD EVEN IF THE CRDM FANS WERE NOT AVAILABLE FOR THE DIABLE CANYON PLANT BUT THE WORST CASE REQUIREMENTS (360,000 GALLONS) MAY NOT BE AVAILABLE AT ALL PLANTS.



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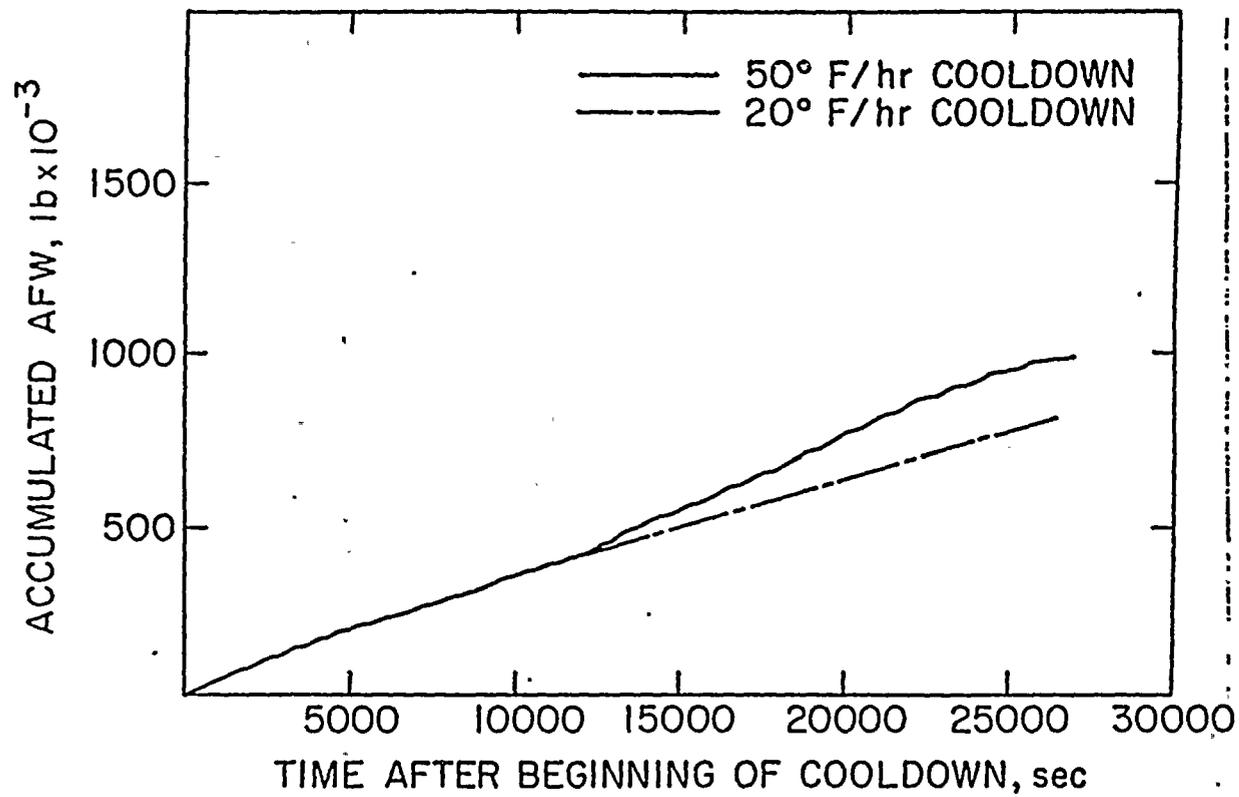
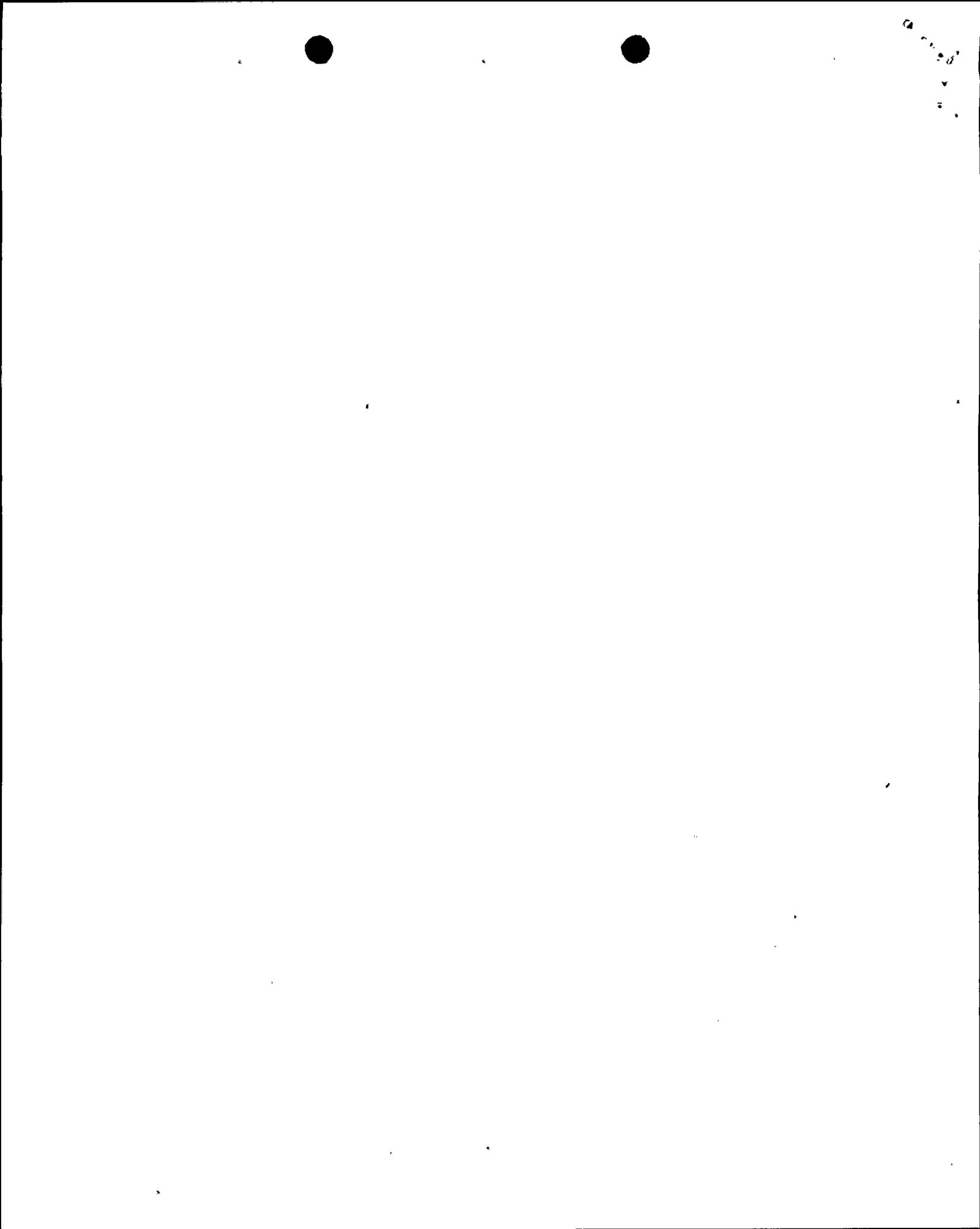


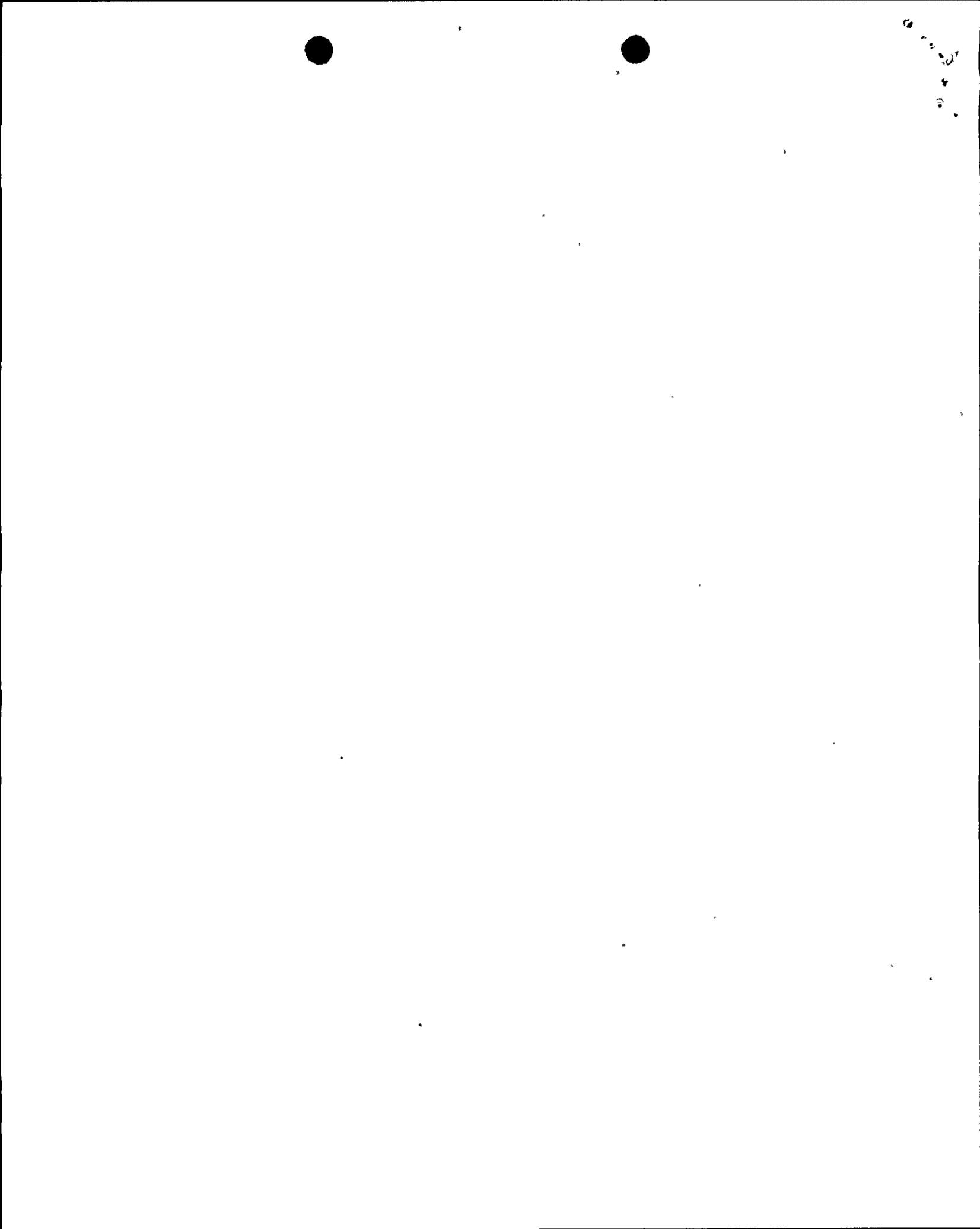
Figure 3.15 Accumulated cooling water.

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- 10) ONLY ONE MOTOR-DRIVEN AFW PUMP WAS SUFFICIENT TO
SUPPLY THE NECESSARY COOLING WATER THROUGHOUT THE
TRANSIENT.



- 11) SUFFICIENT ASD VALVE CAPACITY WAS AVAILABLE TO SUPPORT THE COOLDOWN EVEN WHEN THE COOLDOWN RATE WAS 50°F/HOUR.



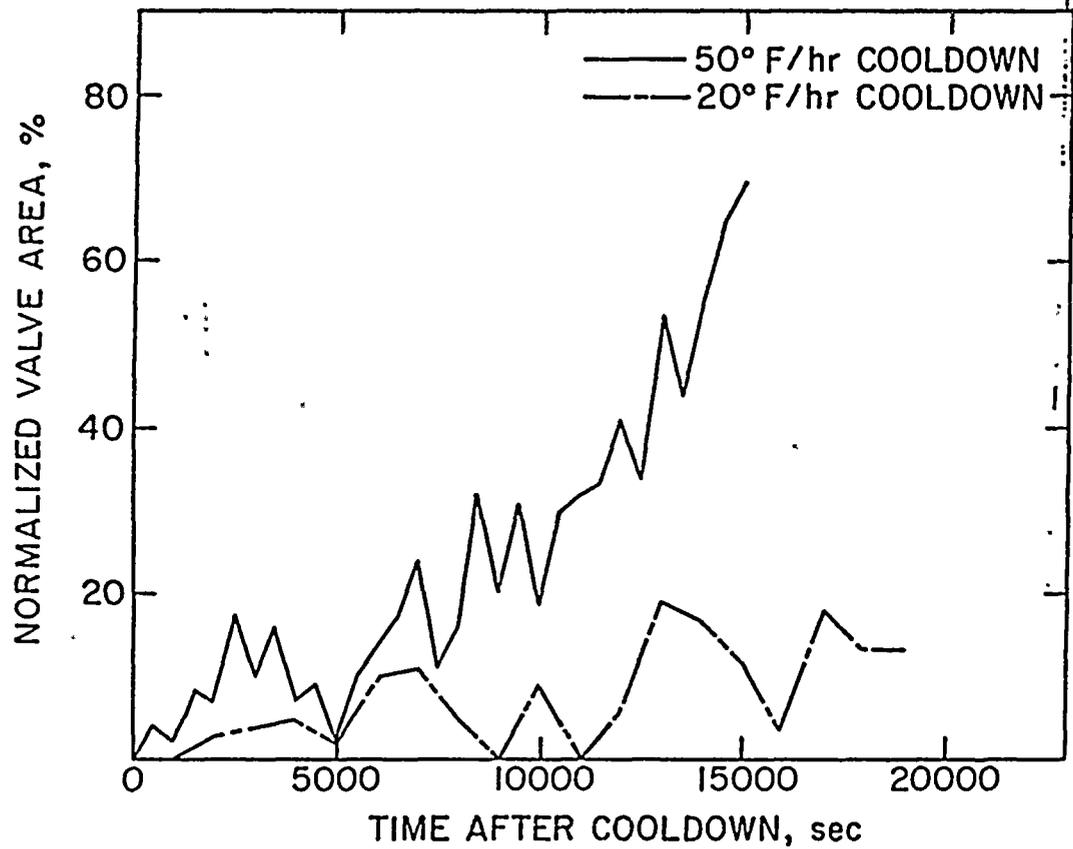
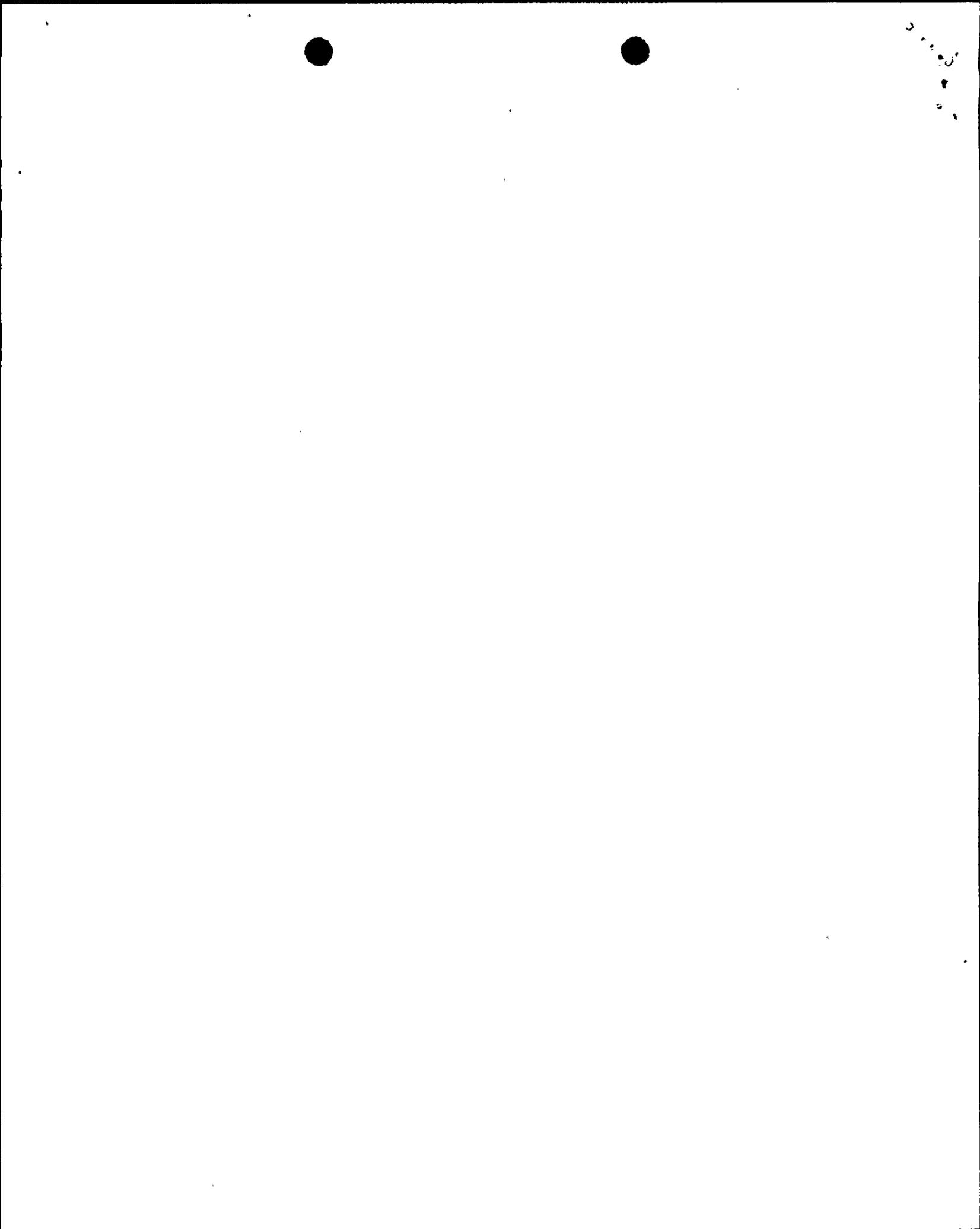


Figure 3.14 Atmospheric steam dump valve opening.



12) THE AVAILABILITY OF THE PRESSURIZER HEATERS AND LETDOWN SYSTEM, WHILE NOT ESSENTIAL, WOULD AFFECT THE OPERATIONAL PROCEDURES IN A MAJOR WAY. THE STRATEGY TO REDUCE THE UPPER HEAD COOLING TIME BY INTENTIONALLY FORMING VOID MAY NOT BE DIFFICULT TO PERFORM WITHOUT PRESSURIZER HEATERS. SOME PLANTS APPEAR TO HAVE THE CAPABILITY TO CONTROL VOIDING BY CHARGING AND VENTING THROUGH REACTOR VESSEL HEAD VENTS.

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- 13) THE RCS PRESSURE WOULD INCREASE AND STAY HIGH,
AND THE PORV MAY BE ACTUATED PERIODICALLY IF THE
LETDOWN SYSTEM WAS NOT AVAILABLE, DUE TO THE
BORON INJECTION AND THE CONTINUOUS INJECTION OF
RCP SEAL FLOW. THE OPERATION OF THE AUXILIARY
PRESSURIZER SPRAYER NORMALLY REQUIRES LETDOWN TO
BE IN OPERATION TO PREVENT THE POSSIBLE THERMAL
STRESS ON THE CHARGING NOZZLES.

14) IT IS RECOMMENDED THAT WESTINGHOUSE PROVIDE THE DETAILS OF ITS ESTIMATION FOR THE UPPER HEAD COOLING TIME WITHOUT THE CRDM FANS. (THE BNL ANALYSIS AND THE TEST DATA INDICATE THAT THE COOLING PERIOD SHOULD BE SUBSTANTIALLY LONGER THAN THE 8 HOURS ESTIMATED BY WESTINGHOUSE).

