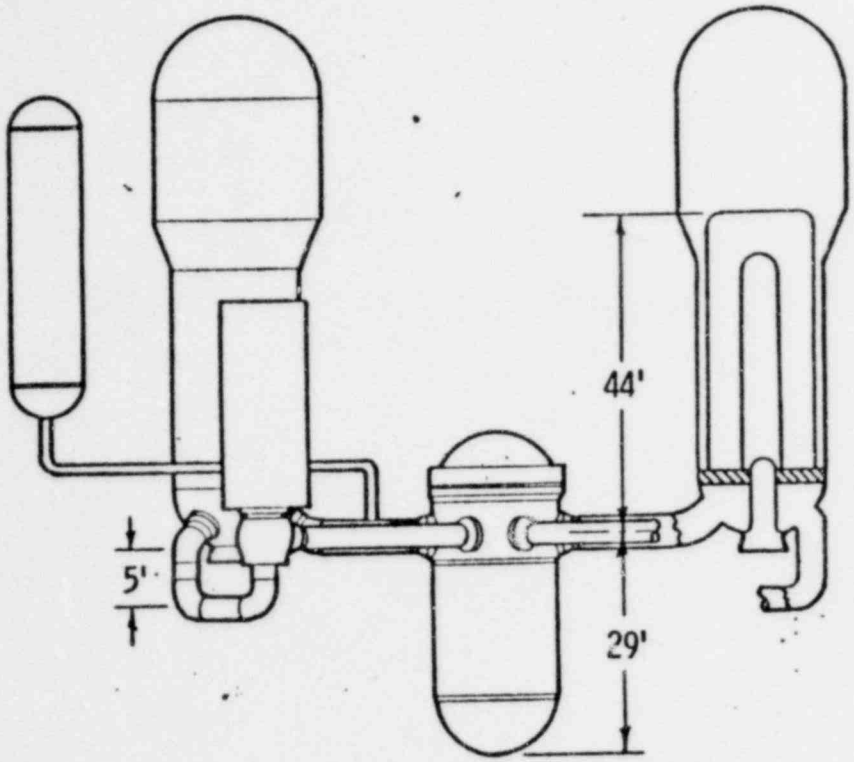
AGENDA FOR
ACRS PRESENTATION
MAY 10, 1979

I.	INTRODUCTION	- A. E. SCHERER
II.	DESIGN FEATURES OF C-E NSSS	- W. E. BURCHILL
III.	C-E NSSS RESPONSE	
	A. NATURAL CIRCULATION	- R. S. DALEAS
	B. SMALL BREAK LOCA	- J. LONGO
	C. LOSS OF FEEDWATER FLOW AND PORV MALFUNCTION	- C. KLING
IV.	C-E PLANT EXPERIENCE	- W. R. CORCORAN
	OBSERVATIONS ON I&E BULLETINS AND ACRS RECOMMENDATIONS	
V.	CONCLUSIONS	- F. M. STERN

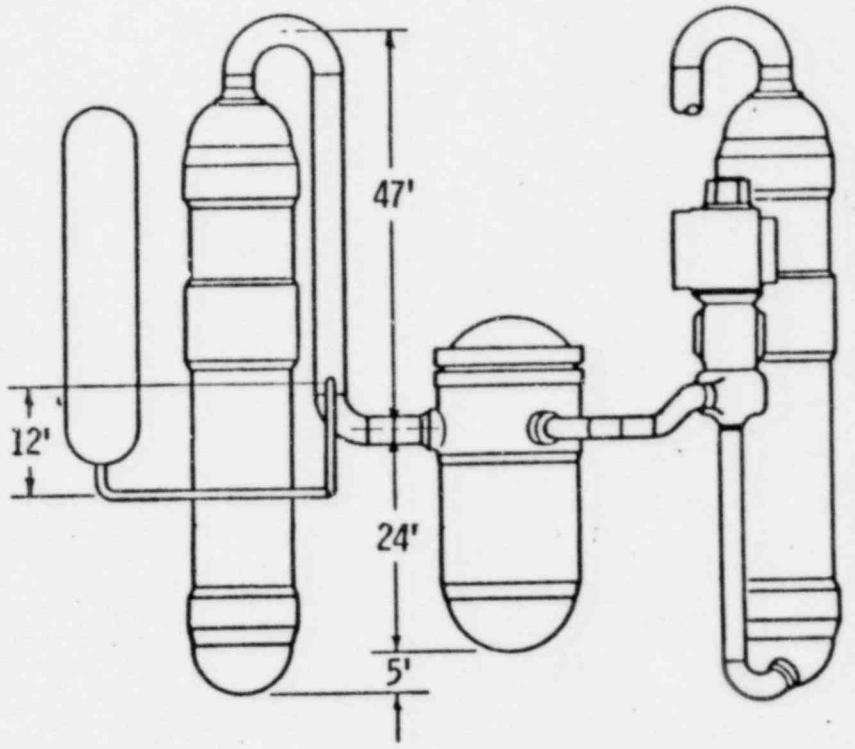
CE-210

E SHERER
5/10/79
CE

NSSS GENERAL ARRANGEMENT

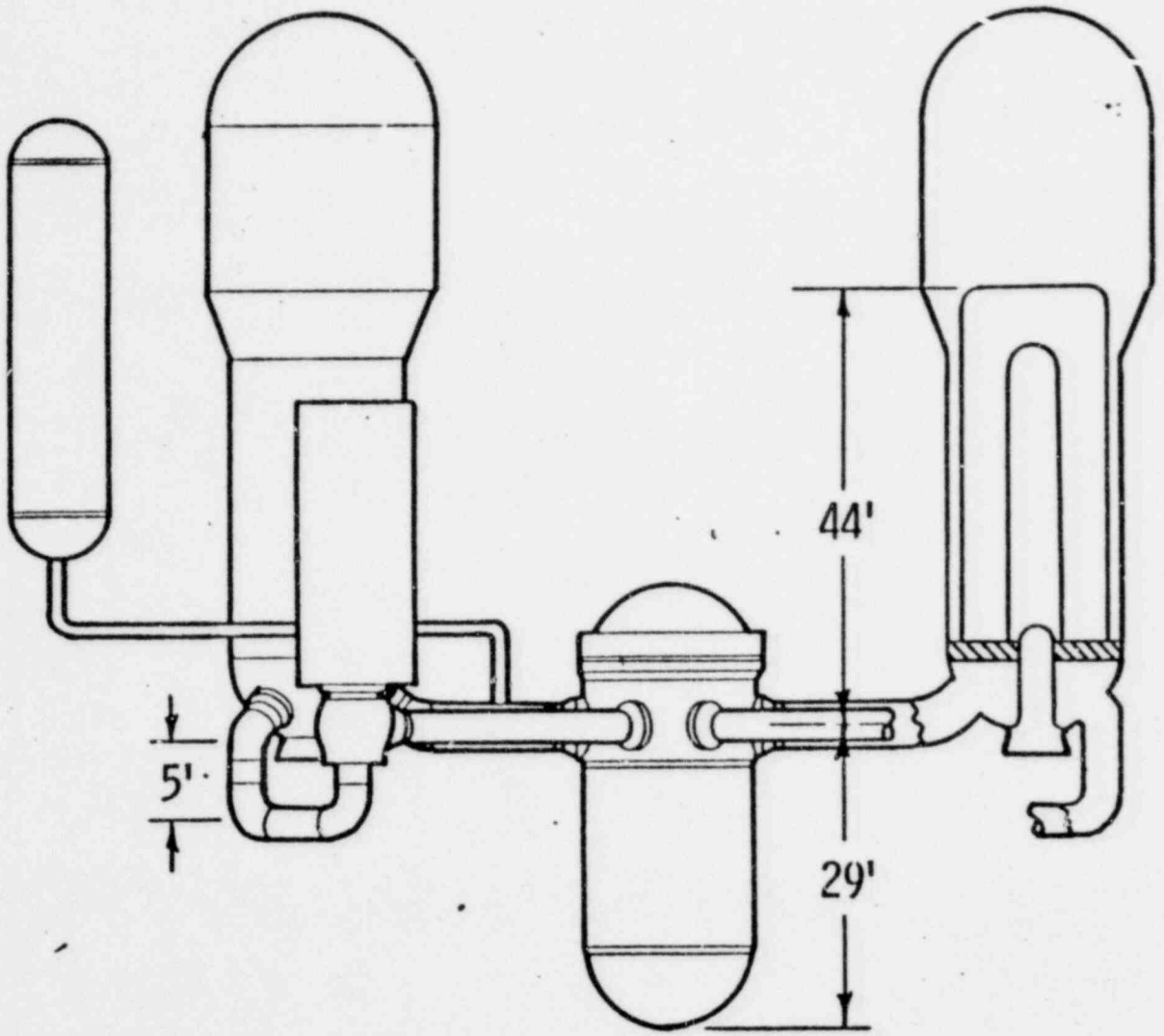


TYPICAL C-E



TMI-2

NSSS GENERAL ARRANGEMENT



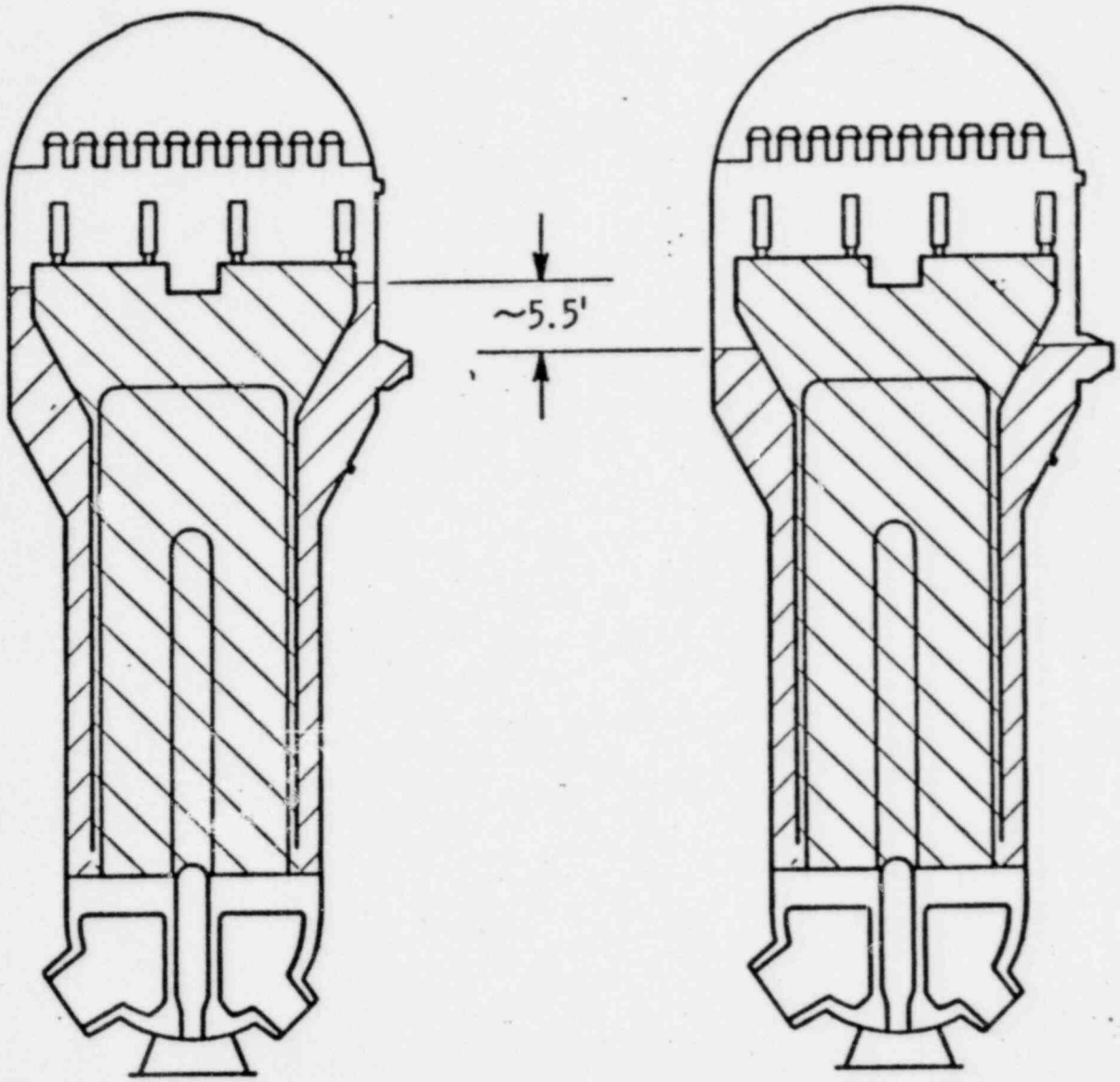
IMPACT OF NSSS LAYOUT

NSSS ELEVATION LAYOUT OF MAJOR COMPONENTS

ENHANCES RCS NATURAL CIRCULATION CAPABILITY

ALLOWS ONLY 20 - 25% OF RCS INVENTORY TO COVER REACTOR CORE

STEAM GENERATOR DESIGN

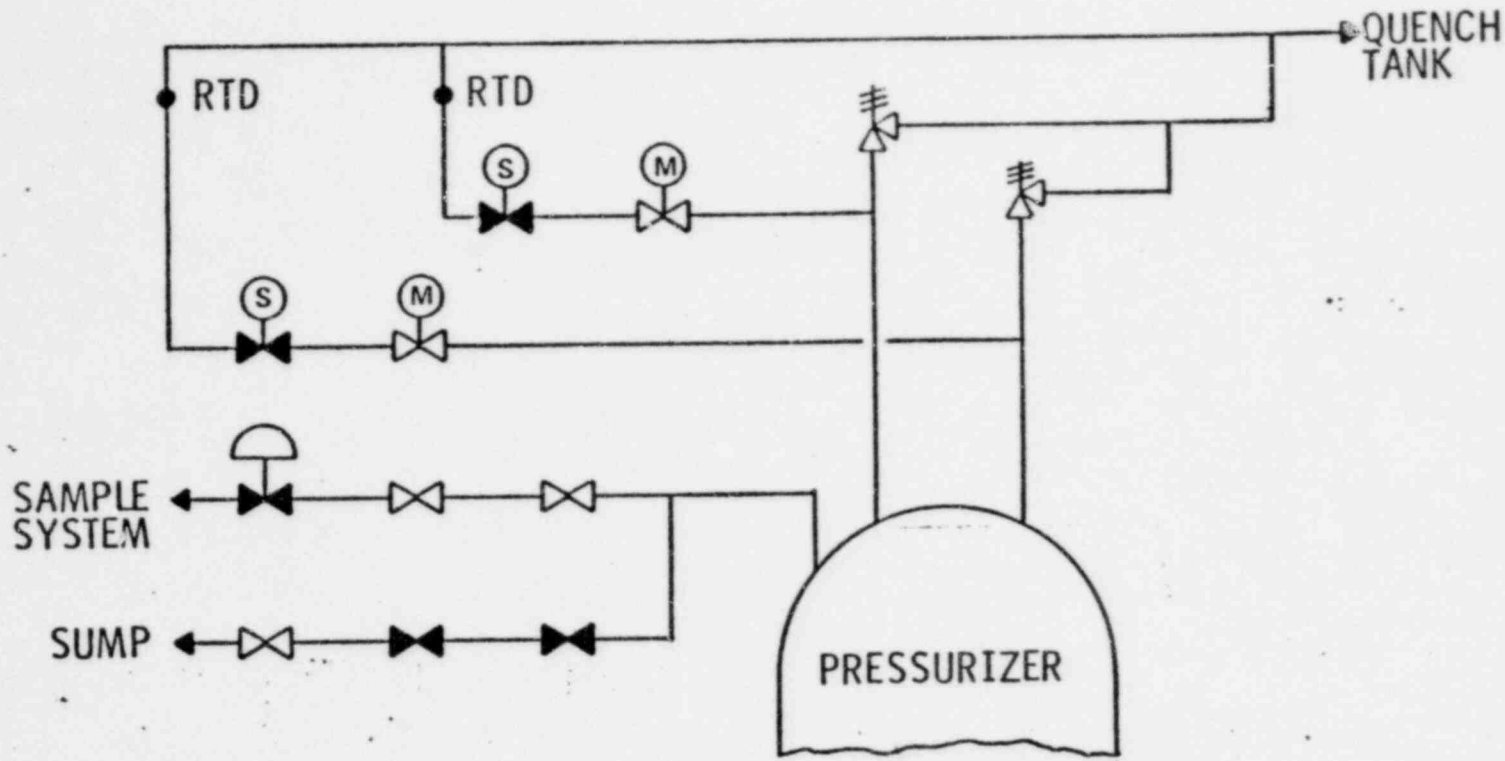


IMPACT OF STEAM GENERATOR DESIGN

SECONDARY WATER INVENTORY AND REACTOR TRIP ON LOW SECONDARY WATER LEVEL

NORMALLY PRECLUDE OPENING PRESSURIZER RELIEF/SAFETY VALVES FOLLOWING LOSS OF FEEDWATER

ALLOW SUFFICIENT TIME FOR ESTABLISHING AUXILIARY OR EMERGENCY FEEDWATER



PRESSURIZER POWER OPERATED RELIEF
VALVES CONFIGURATION

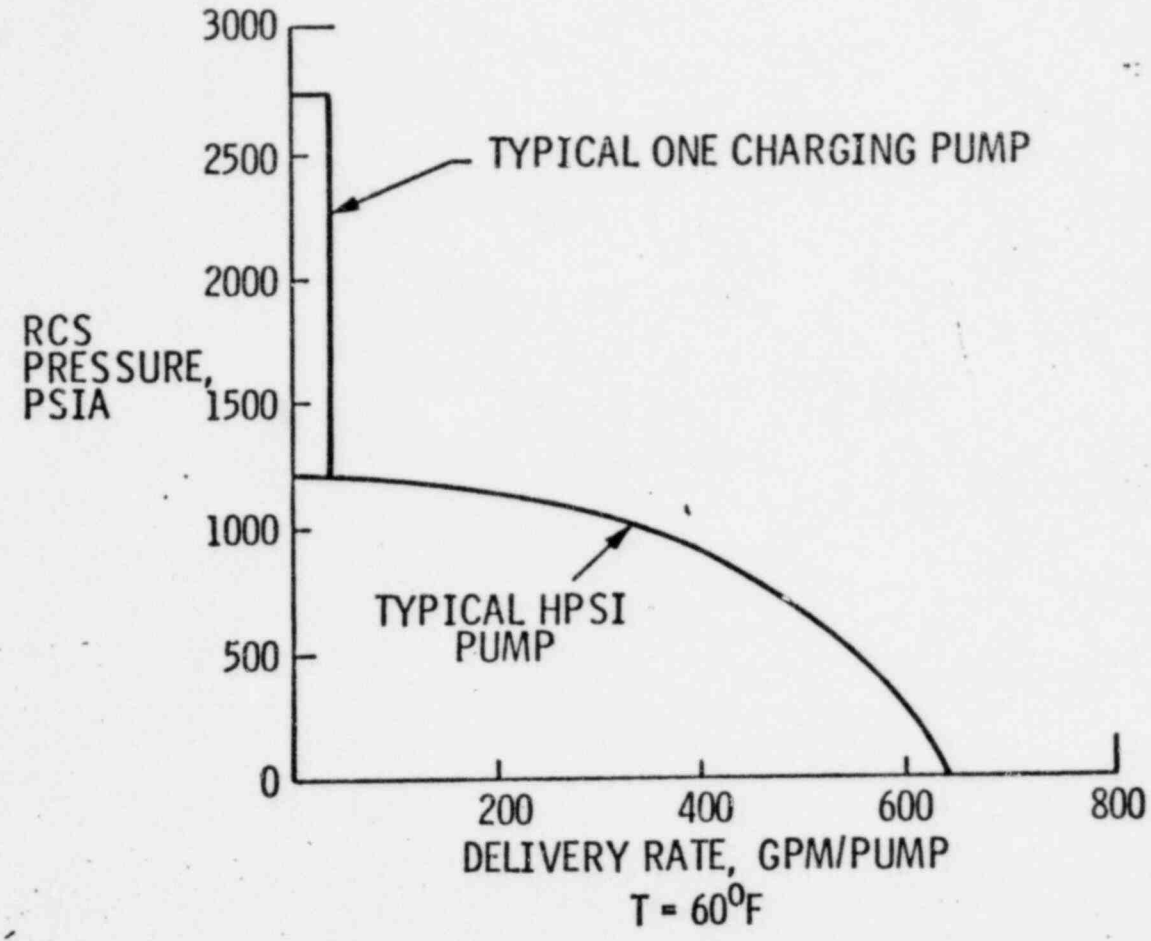
IMPACT OF PRESSURIZER POWER OPERATED RELIEF VALVE CONFIGURATION DESIGN

DUAL POWER OPERATED RELIEF VALVES AND RTDs IN THE VALVE DISCHARGE LINES

ALLOW CONTROLLED PRESSURE RELIEF WITH ONE VALVE BLOCKED OUT

ALLOW COMPARISON OF VALVES' DISCHARGE LINES TEMPERATURES

HIGH PRESSURE COOLANT INJECTION SYSTEM
PUMP DELIVERY CHARACTERISTICS



IMPACT OF HPSI PUMP DELIVERY CHARACTERISTICS

HPSI SHUTOFF HEAD IS BELOW THE
NORMAL REACTOR OPERATING PRESSURE

WHICH ALLOWS HPSI TO BE LEFT INJECTING
AS LONG AS NECESSARY WITHOUT OPENING
PRESSURIZER RELIEF OR SAFETY VALVES

CONTROL SYSTEMS' DESIGN PHILOSOPHY

MINIMIZE CHALLENGES TO THE REACTOR PROTECTION SYSTEM (RPS) DUE TO CONTROL SYSTEMS' FAILURES

AVOID INHIBITING RPS REACTION TO TRANSIENTS WHICH REQUIRE REACTOR PROTECTION

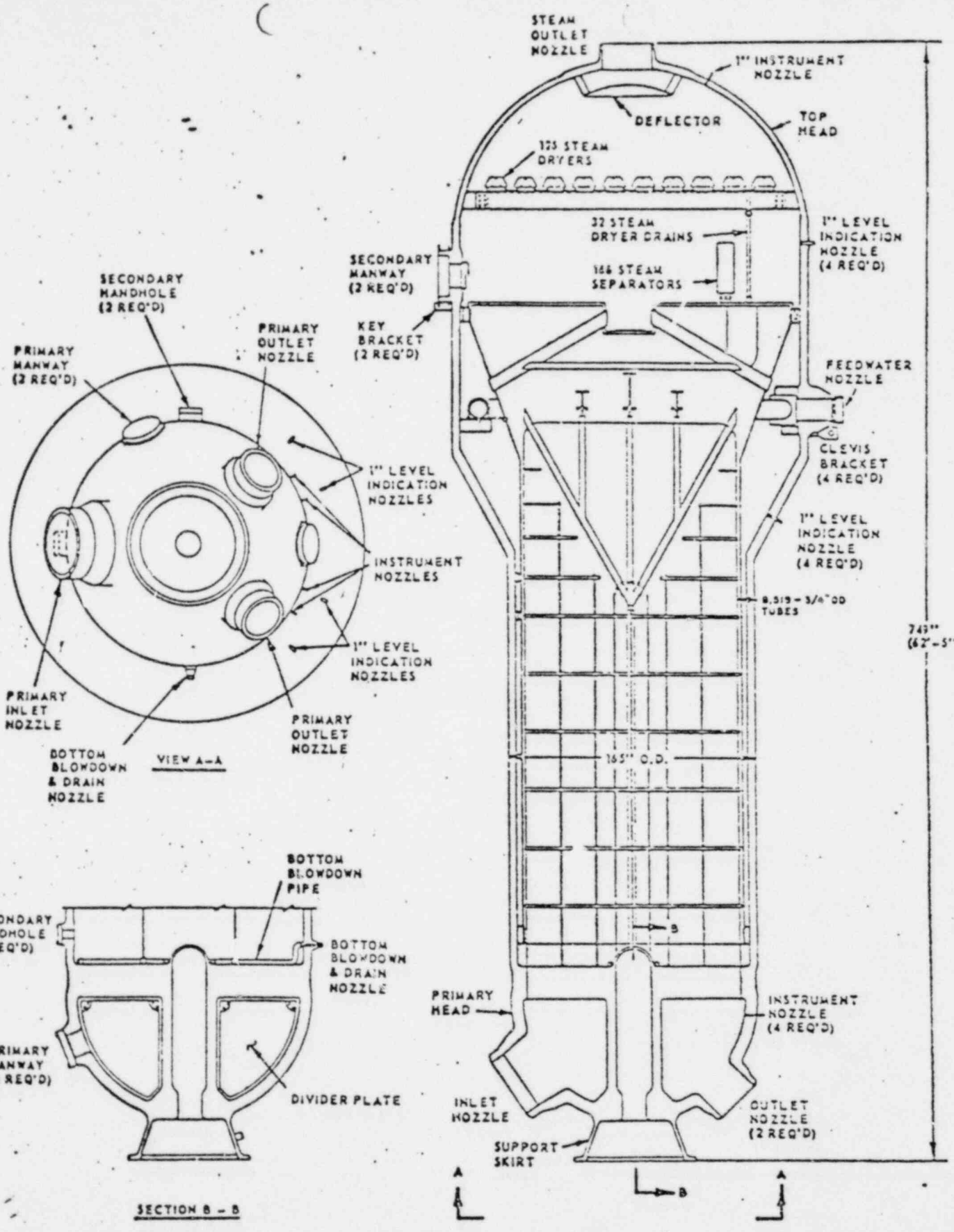
(NOTE: PRESSURIZER LEVEL IS USED ONLY IN CONTROL SYSTEM, NOT IN ANY SAFETY SYSTEM ACTUATION.)

NATURAL CIRCULATION

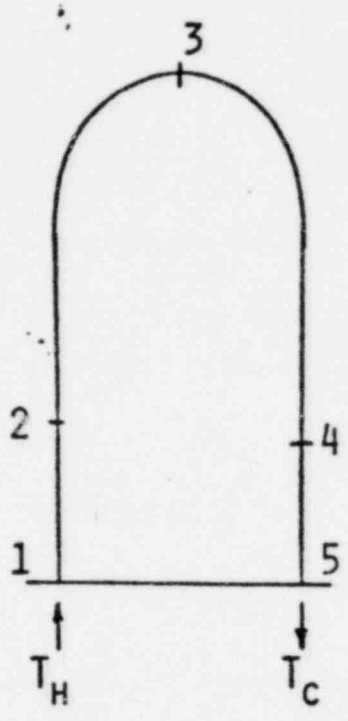
DESIGN FEATURES

FIELD TESTS - POWER ASCENSION TEST PROGRAM

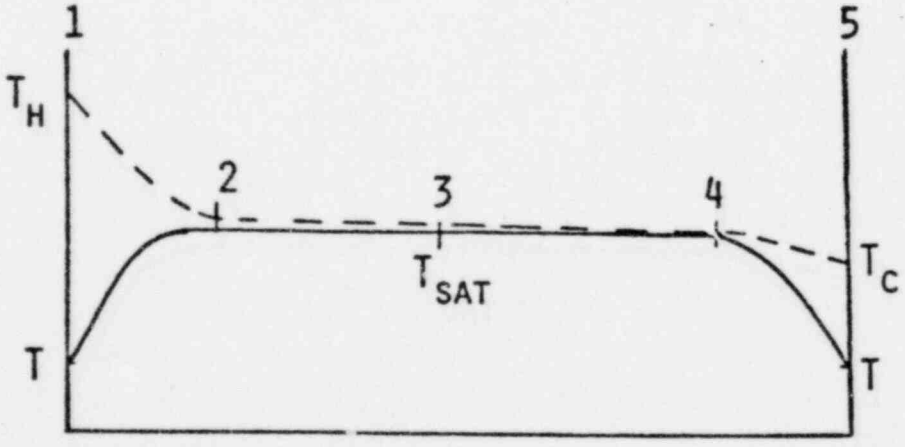
FIELD EVENTS INVOLVING NATURAL CIRCULATION



STEAM GENERATOR



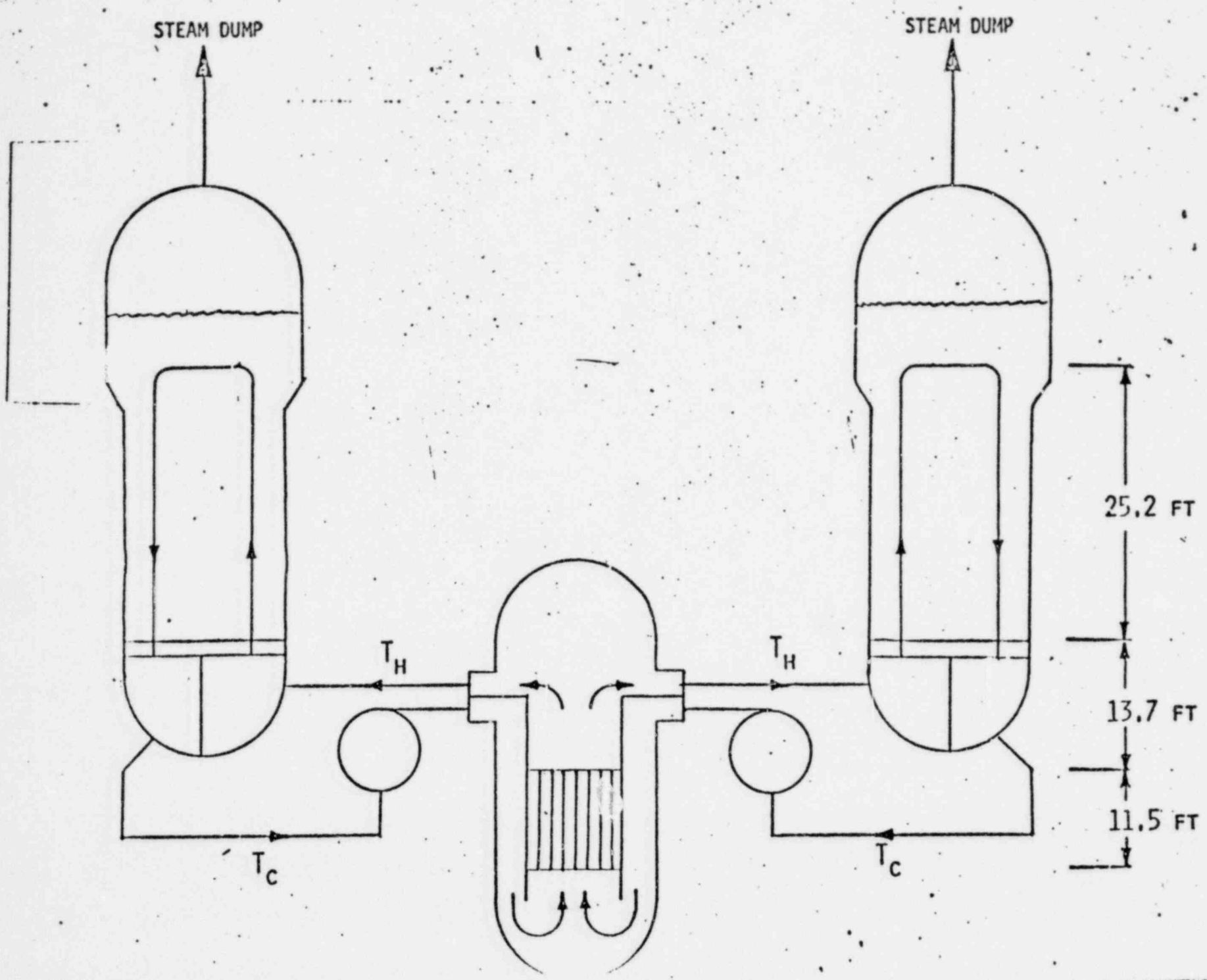
REACTOR COOLANT SYSTEM TEMPERATURES



TUBE LENGTH

— — — PRIMARY TEMPERATURE

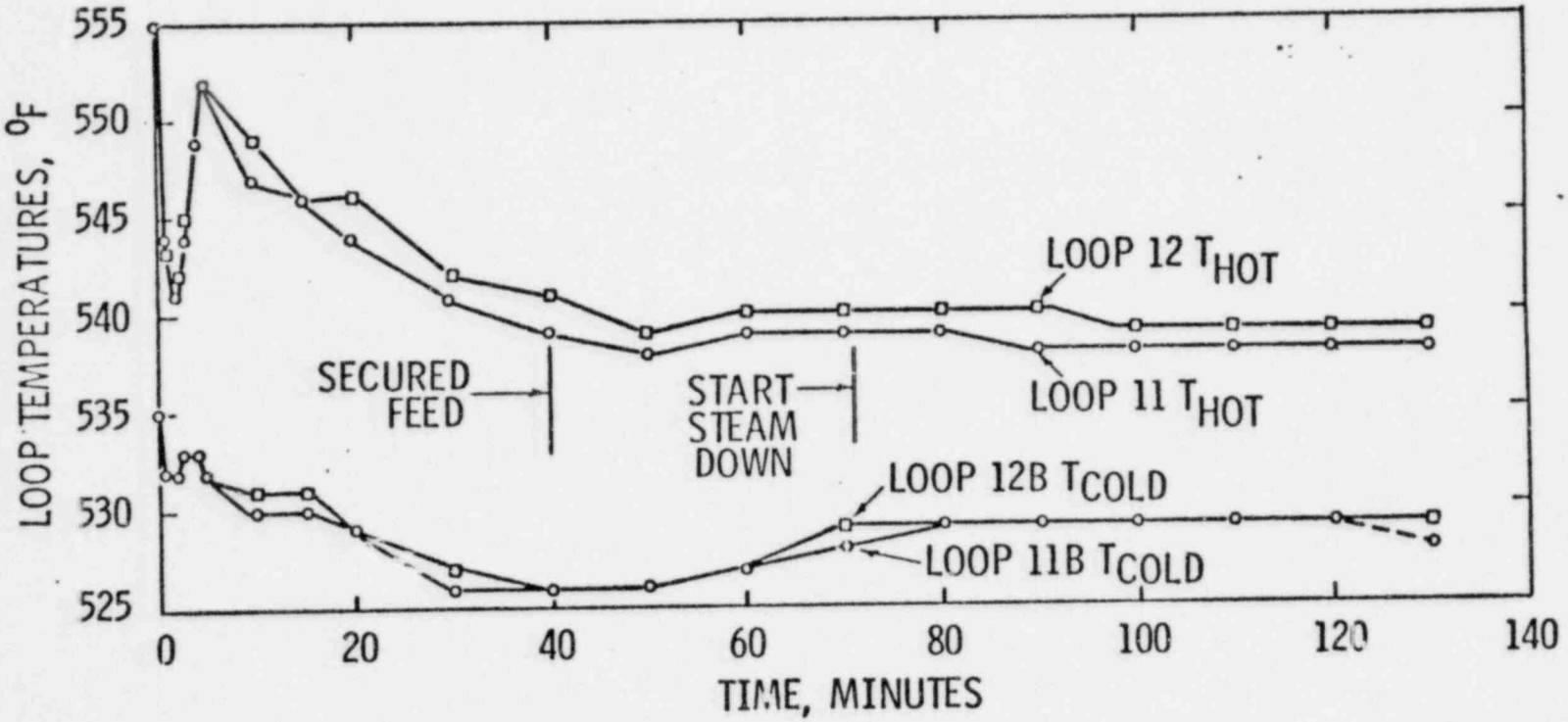
——— SECONDARY TEMPERATURE


STEAM DUMP
STEAM DUMP
T_H
T_H
T_C
T_C
25.2 FT
13.7 FT
11.5 FT

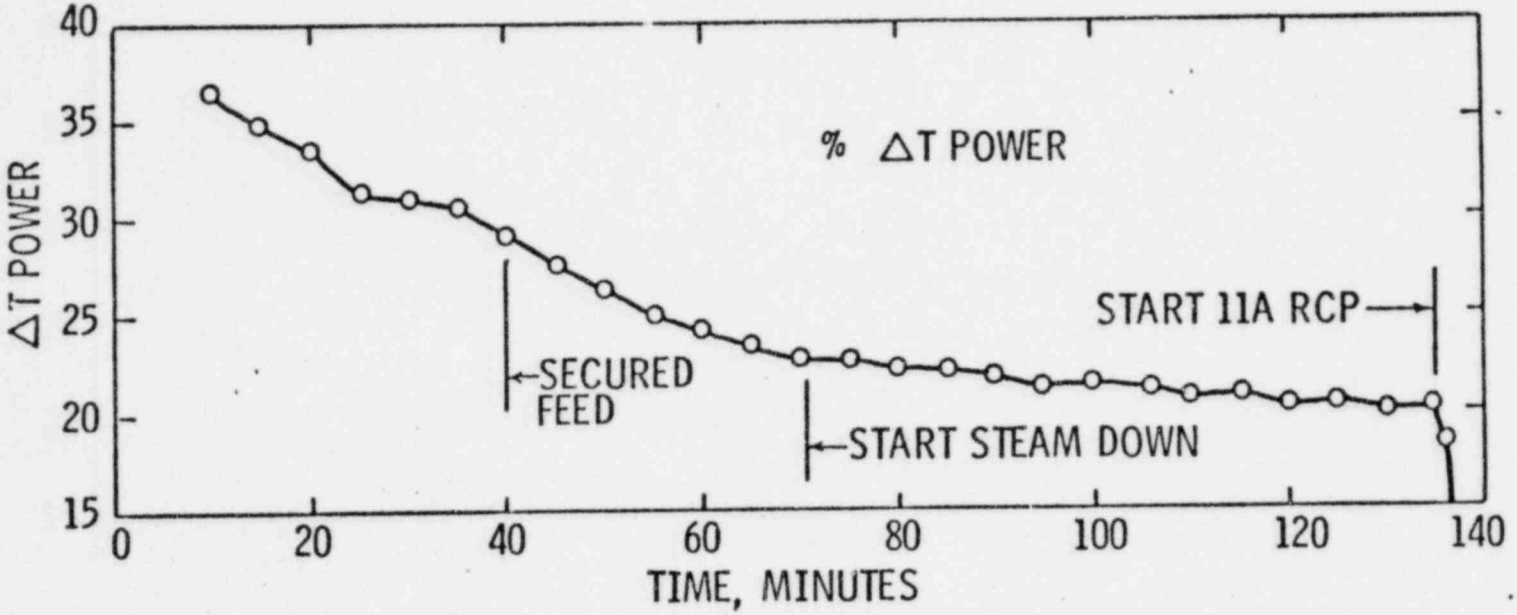
FLOW COASTDOWN AND NATURAL CIRCULATION
POWER ASCENSION TEST

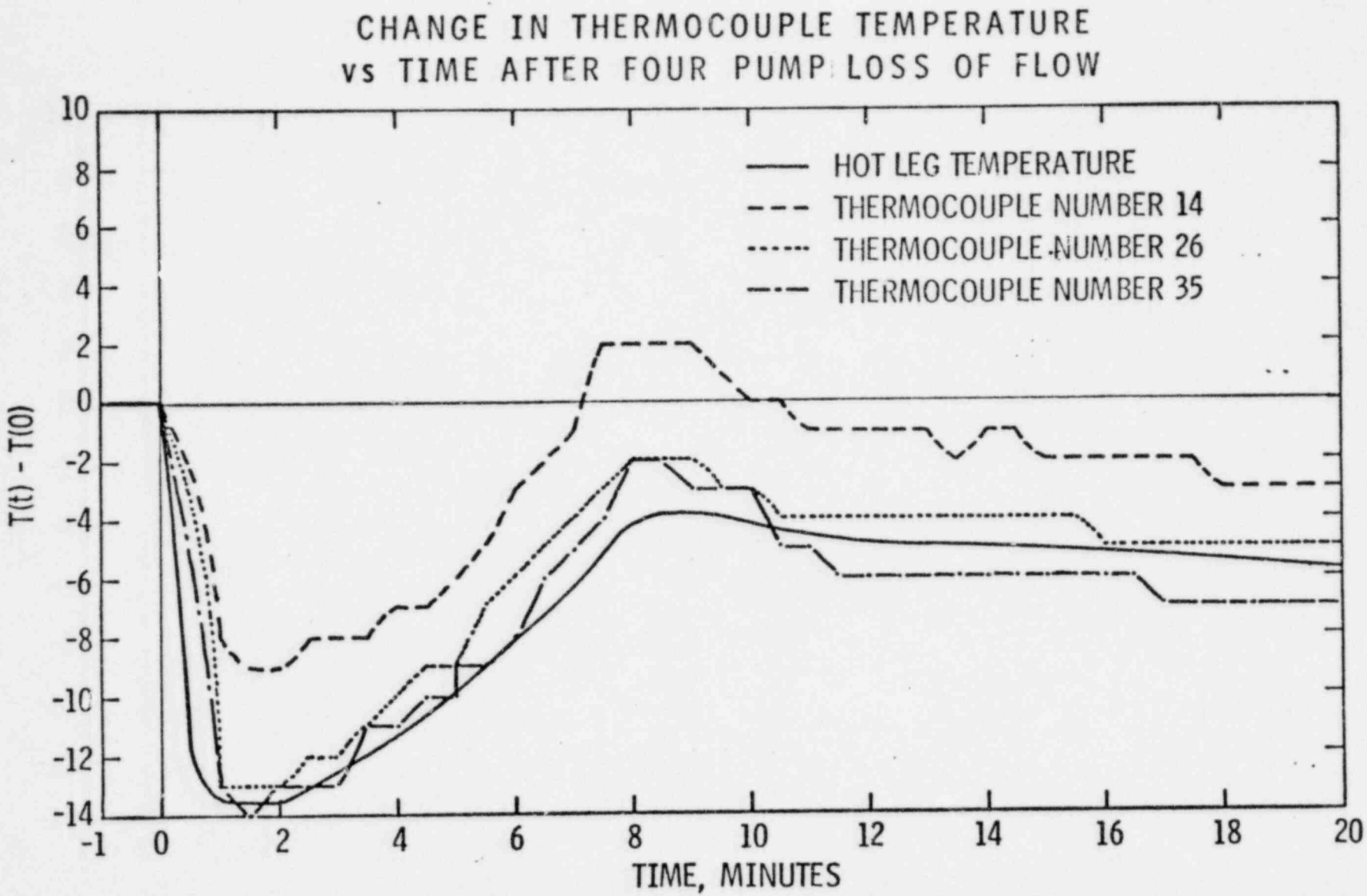
INITIAL CONDITIONS:	40% POWER
	NSSS CONTROLS IN AUTOMATIC MODE
SEQUENCE OF EVENTS:	TRIP RCPs MANUALLY
	RPS TRIPS REACTOR AND TURBINE
	OPERATOR SLOWLY RESTORES SG WATER LEVELS USING AUXILIARY FEEDWATER
	OPERATOR TERMINATES AUXILIARY FEEDWATER AND SGs "STEAM DOWN" FOR 1-2 HOURS
EVALUATION:	CORE DECAY HEAT IS DERIVED FROM MEASURED SG WATER LEVEL CHANGES AND CORRESPONDING INVENTORY DEPLETION
	RCS FLOW IS DERIVED FROM MEASURED T_H, T_C AND DERIVED CORE DECAY HEAT
RESULTS:	CORE DECAY HEAT 0.53%
	RCS FLOW 2.2%

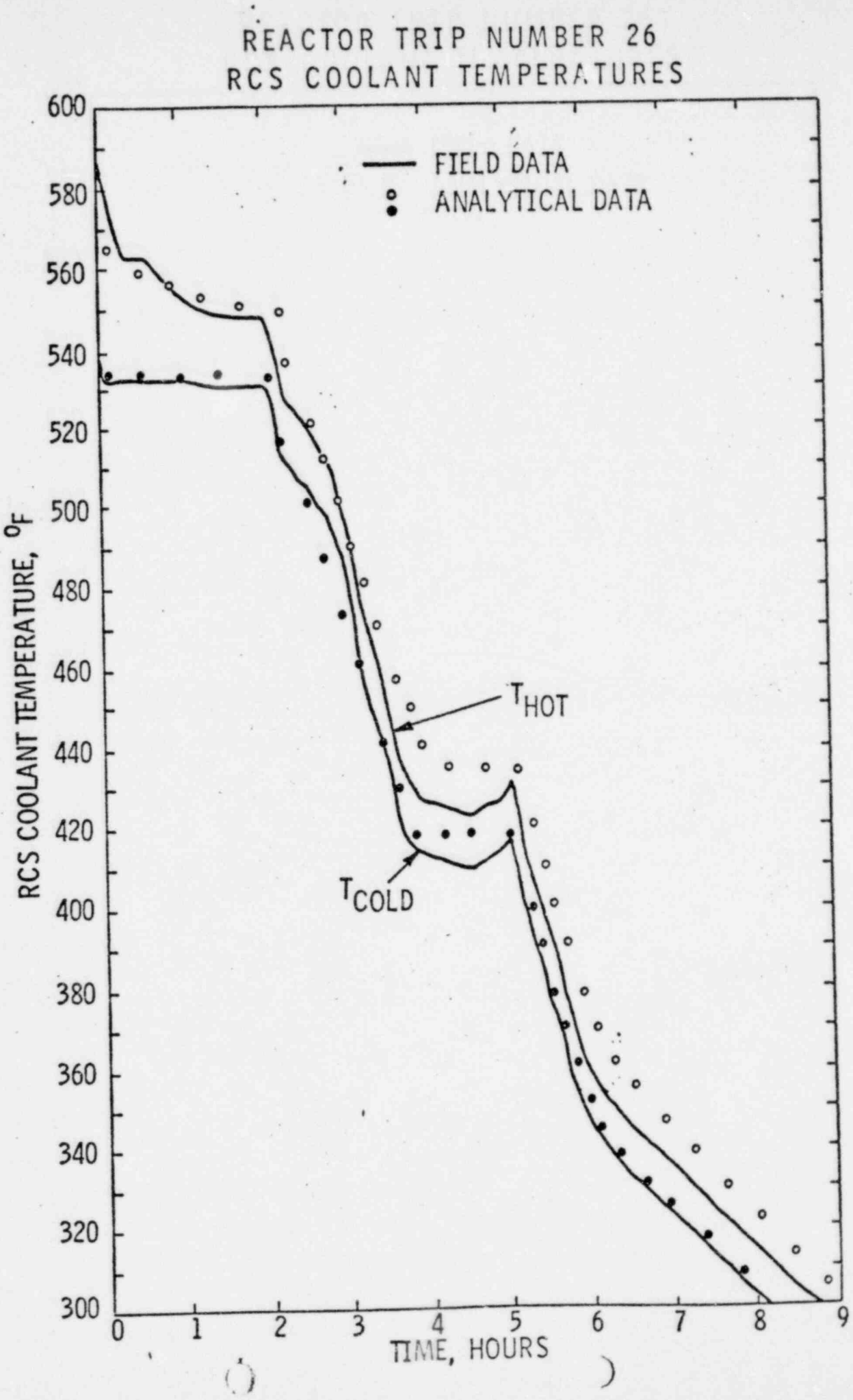
RCS LOOP TEMPERATURES



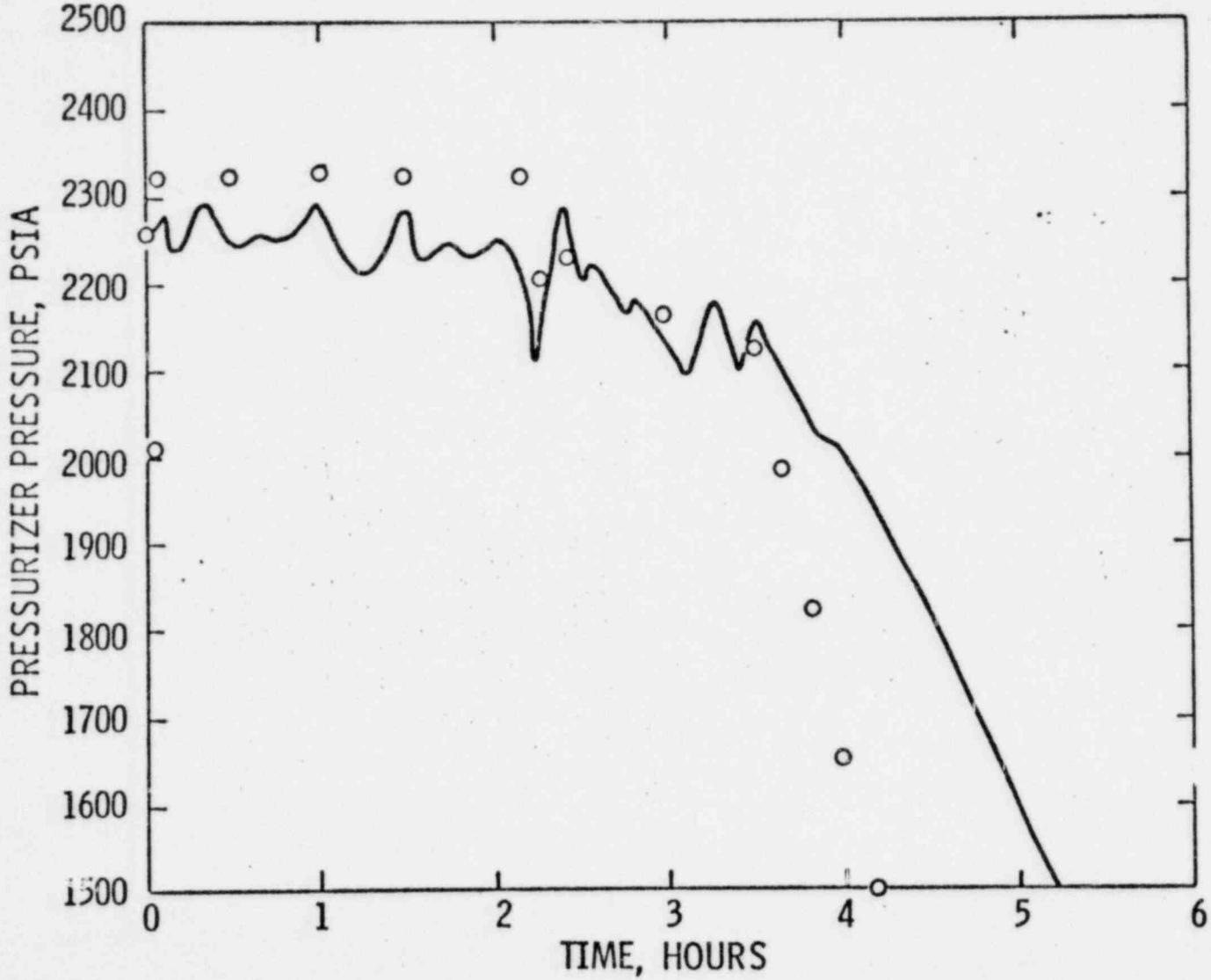
NATURAL CIRCULATION TEST
APRIL 1, 1975 EPT APPENDIX PPD



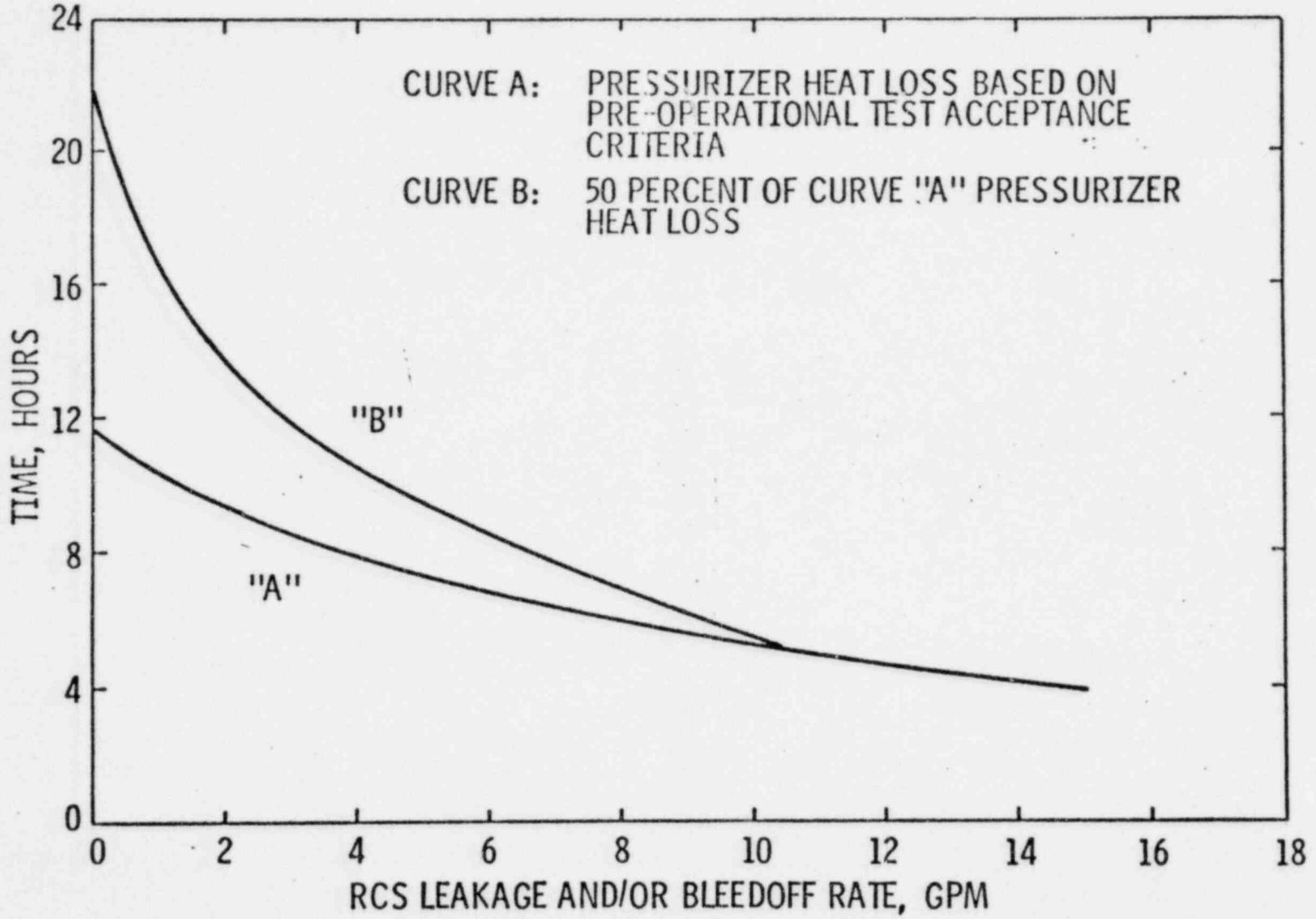

CHANGE IN THERMOCOUPLE TEMPERATURE
vs TIME AFTER FOUR PUMP LOSS OF FLOW
HOT LEG TEMPERATURE
THERMOCOUPLE NUMBER 14
THERMOCOUPLE NUMBER 26
THERMOCOUPLE NUMBER 35
T(t) - T(0)
TIME, MINUTES
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-1
0
2
4
6
8
10
12
14
16
18
20


REACTOR TRIP NUMBER 26
RCS COOLANT TEMPERATURES
FIELD DATA
ANALYTICAL DATA
T_{HOT}
T_{COLD}
RCS COOLANT TEMPERATURE, °F
TIME, HOURS
600
580
560
540
520
500
480
460
440
420
400
380
360
340
320
300
0
1
2
3
4
5
6
7
8
9

REACTOR TRIP NUMBER 26
PRESSURIZER PRESSURE



PRESSURIZER COOLDOWN TO HOT LEG SATURATION TEMPERATURE



SUMMARY

1. NATURAL CIRCULATION IS VERIFIED IN EVERY C-E PLANT.
2. NATURAL CIRCULATION COOLDOWN CAPABILITY OF C-E PLANT HAS BEEN VERIFIED.
3. SEVERAL INDICATIONS OF ADEQUATE NATURAL CIRCULATION ARE AVAILABLE IN THE PLANT.

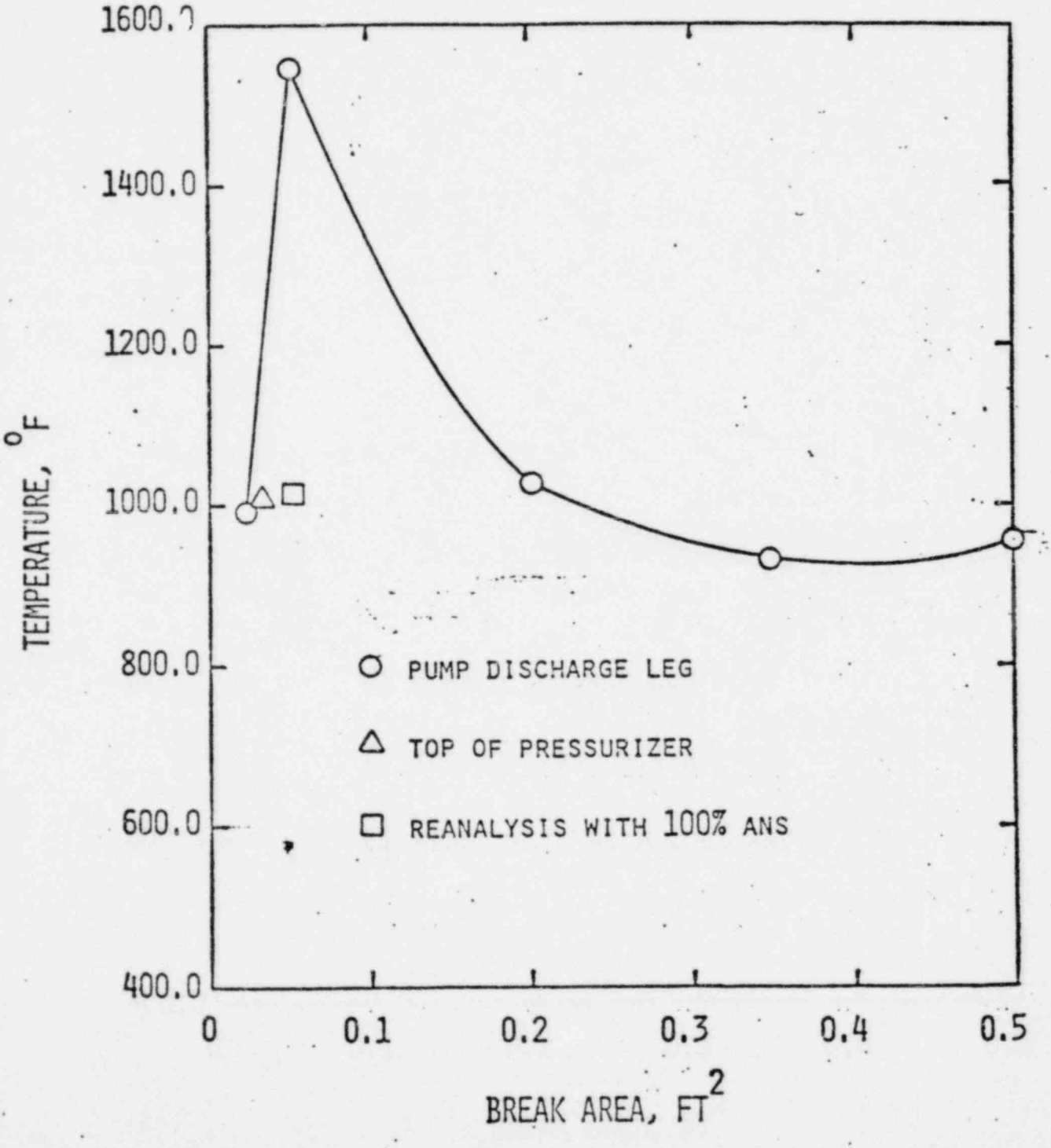
   A. SUBCOOLING INDICATED BY PRESSURIZER PRESSURE AND T_H CONDITIONS.

   B. T_H (AND ΔT POWER) "TURNS-OVER" WITHIN 5-10 MINUTES OF SECURING RCPs.

   C. CORE EXIT THERMOCOUPLES TRACK T_H.

   D. $T_H - T_C$ INDICATION LESS THAN FULL POWER VALUE ALSO ΔT POWER INDICATION IS LESS THAN 100%.

   E. T_C CONTROLLABLE BY SECONDARY HEAT SINK.

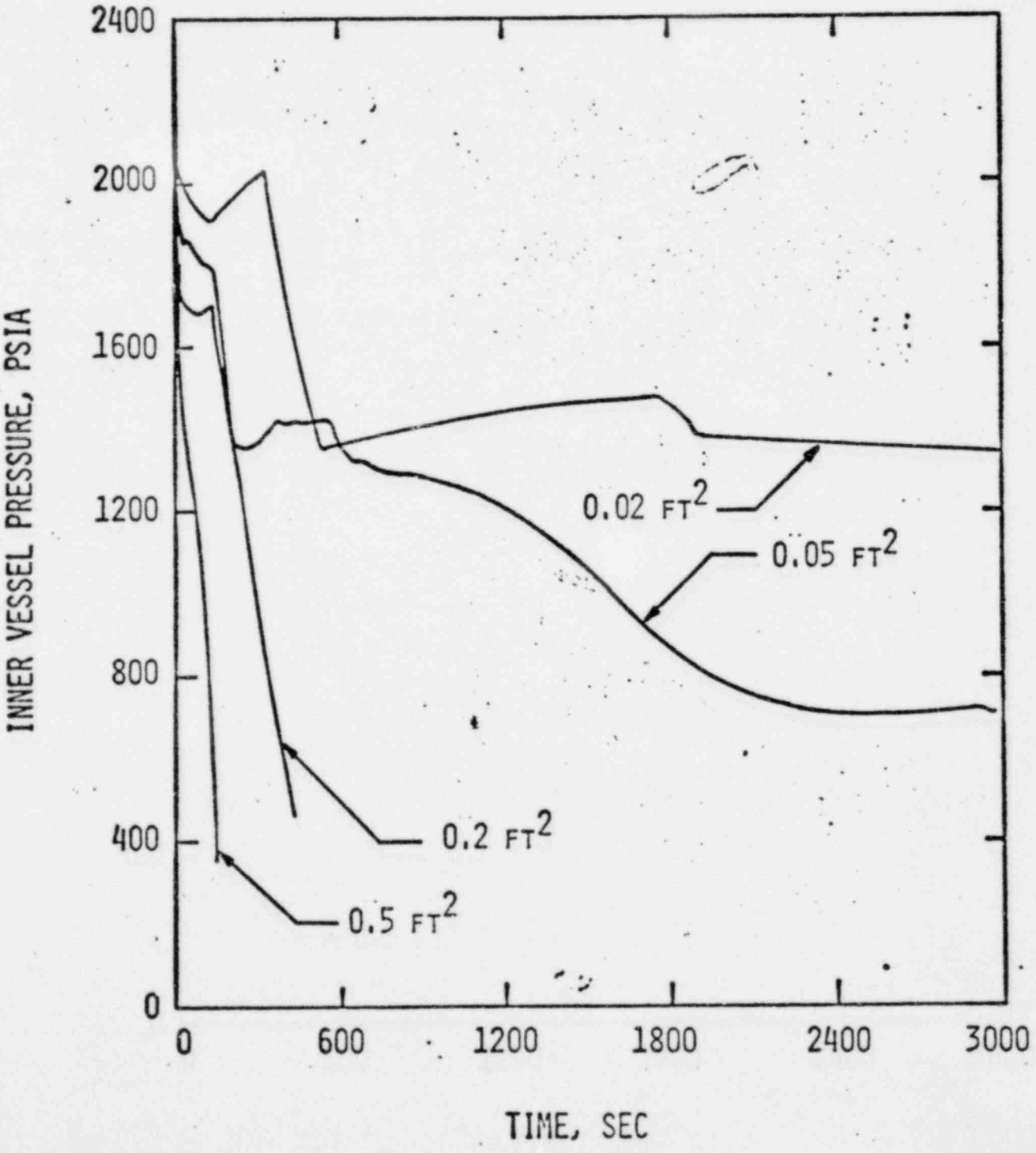


C-E SYSTEM 80

MAXIMUM HOT SPOT CLAD TEMPERATURE
vs BREAK SIZE

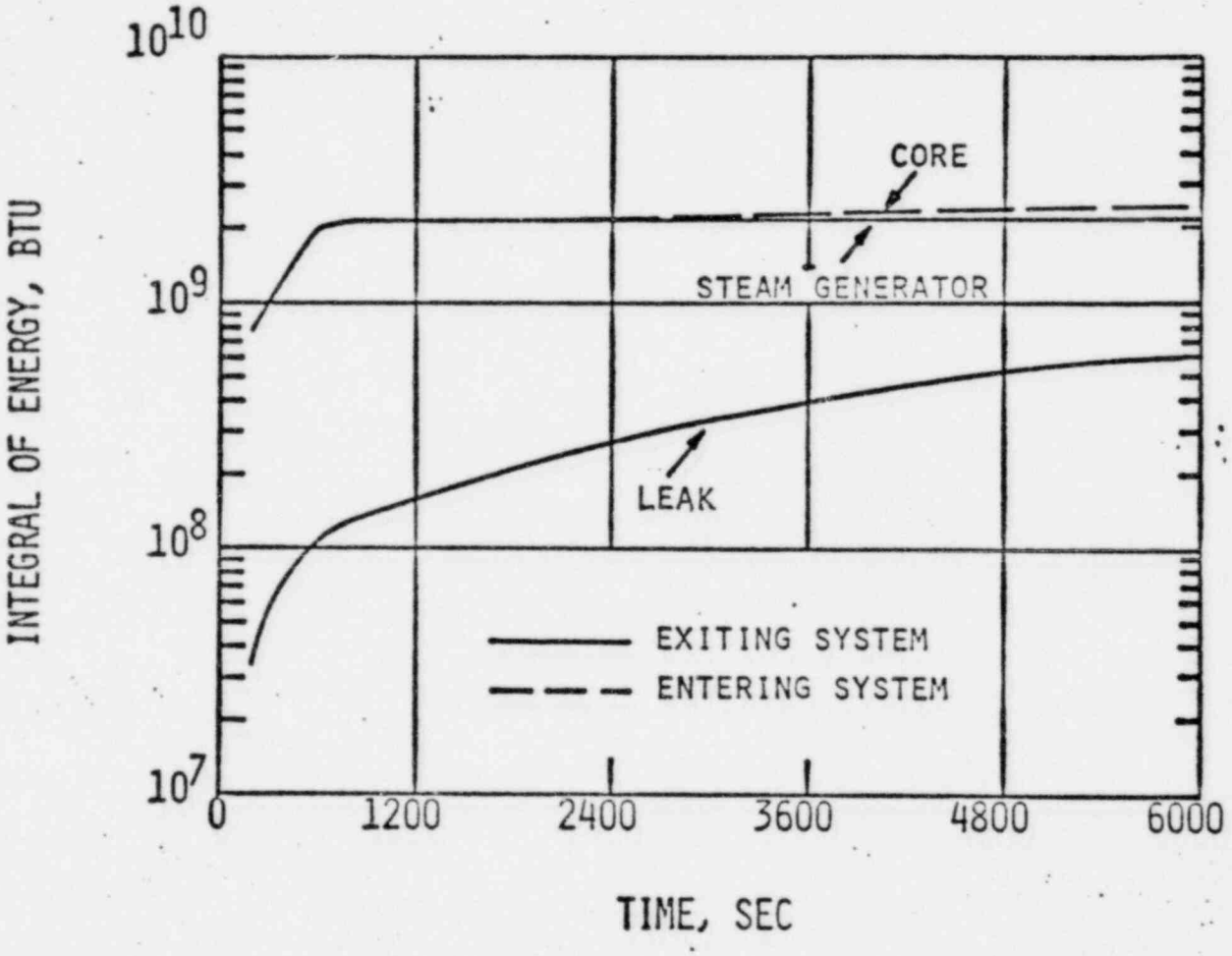
Figure 6.3.3.3-7

SYSTEM 80


2400
2000
1600
1200
800
400
0
INNER VESSEL PRESSURE, PSIA
0.02 FT2
0.05 FT2
0.2 FT2
0.5 FT2
0
600
1200
1800
2400
3000
TIME, SEC

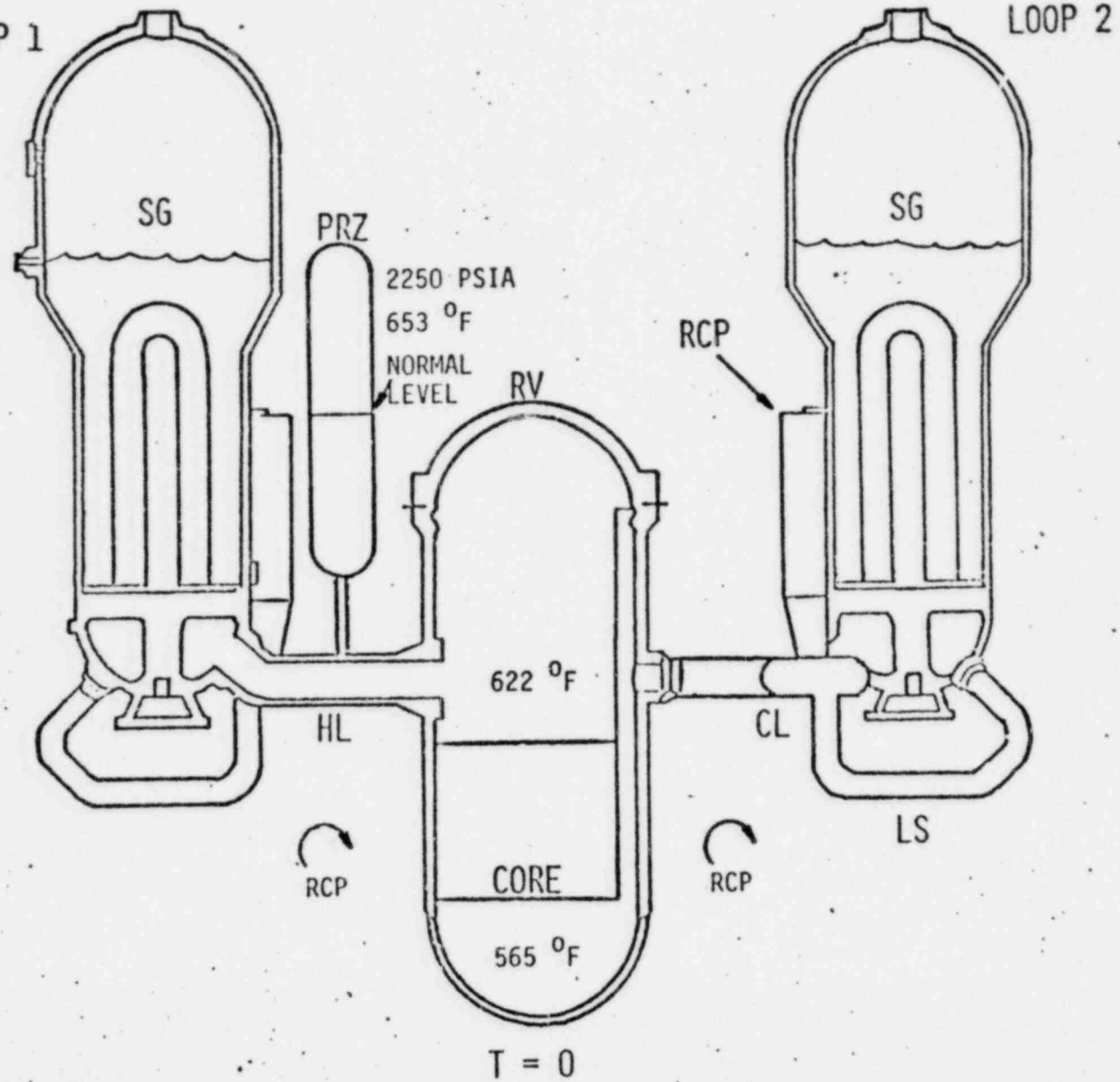
SYSTEM 80

1OPSV - ENERGY BALANCE, RCS
.03 FT^2 HL



SYSTEM 80
0.02 FT^2 DISCHARGE LEG BREAK

- BREAK OCCURS AT FULL POWER CONDITIONS



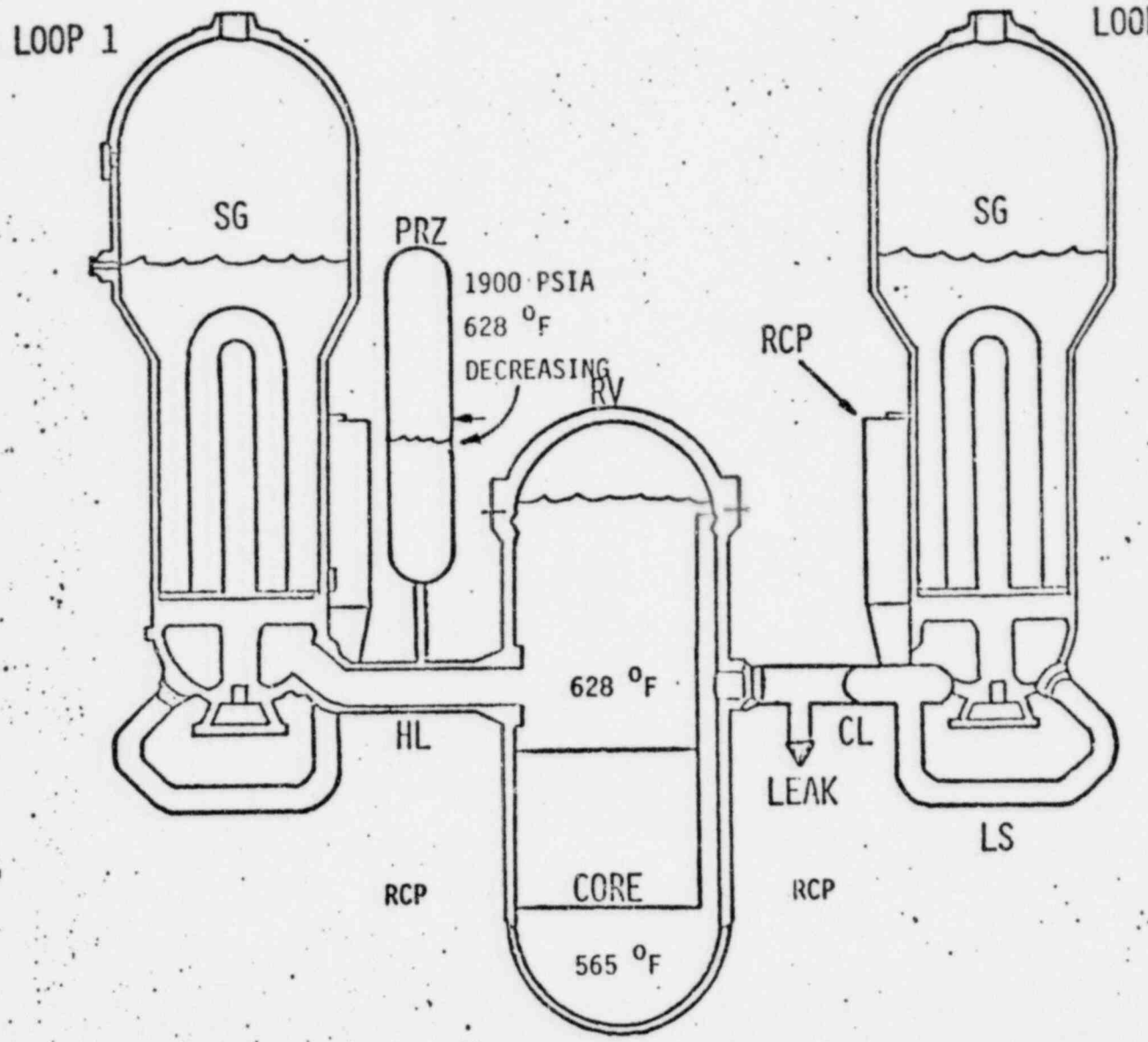
T = 0

SUBCOOLED FORCED CONVECTION

SYSTEM 80

0.02 FT^2 DISCHARGE LEG BREAK

- RV UPPER PLENUM SATURATES :



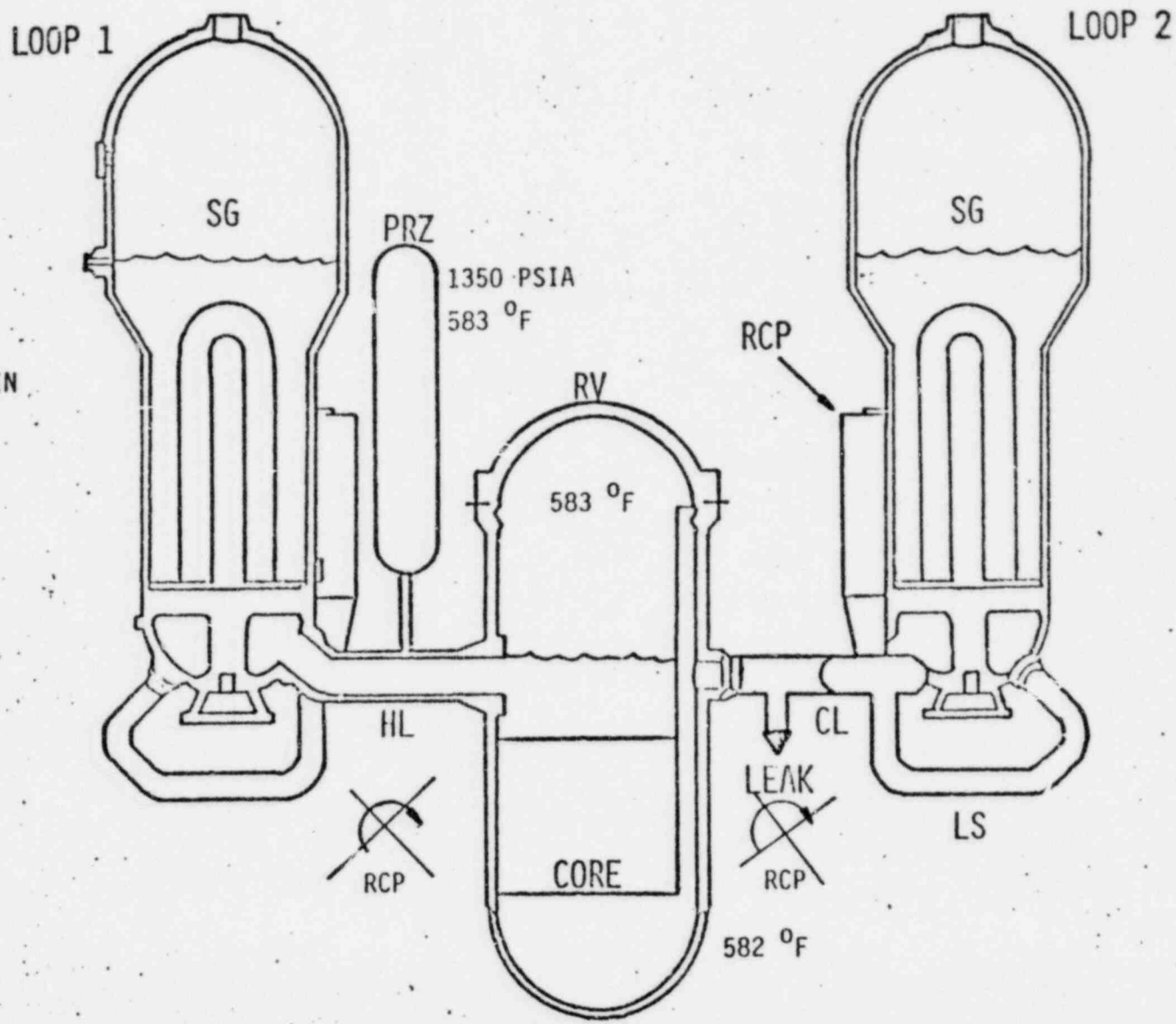
T = 100 SECS

FORCED CONVECTION

SYSTEM 80

0.02 FT^2 DISCHARGE LEG BREAK

- PRZ EMPTY
- SIAS, TRIP HAPPENED
- RCP OFF/COASTDOWN
- SG TUBES START TO DRAIN
- SG SECONDARY ISOLATED



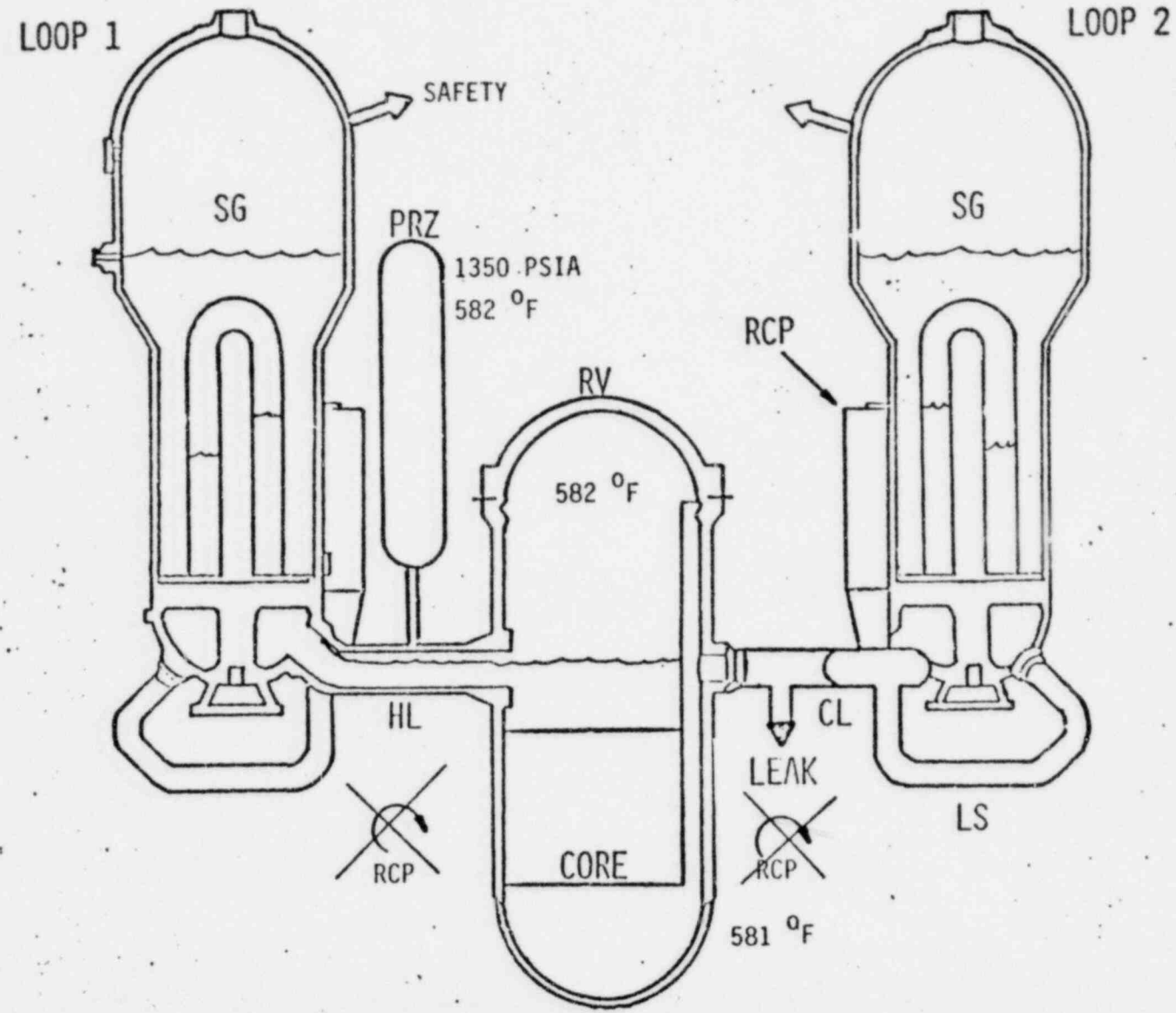
T = 500 SECS

TRANSITION FROM FORCED CONVECTION TO POOL BOILING

SYSTEM 80

0.02 FT^2 DISCHARGE LEG BREAK

- SG SECONDARY RELIEF VALVES OPENED
- SG TUBES DRAINING
- STEAM BUBBLES UP FROM RV TO SG'S
- RCP COASTDOWN TO <5% SPEED



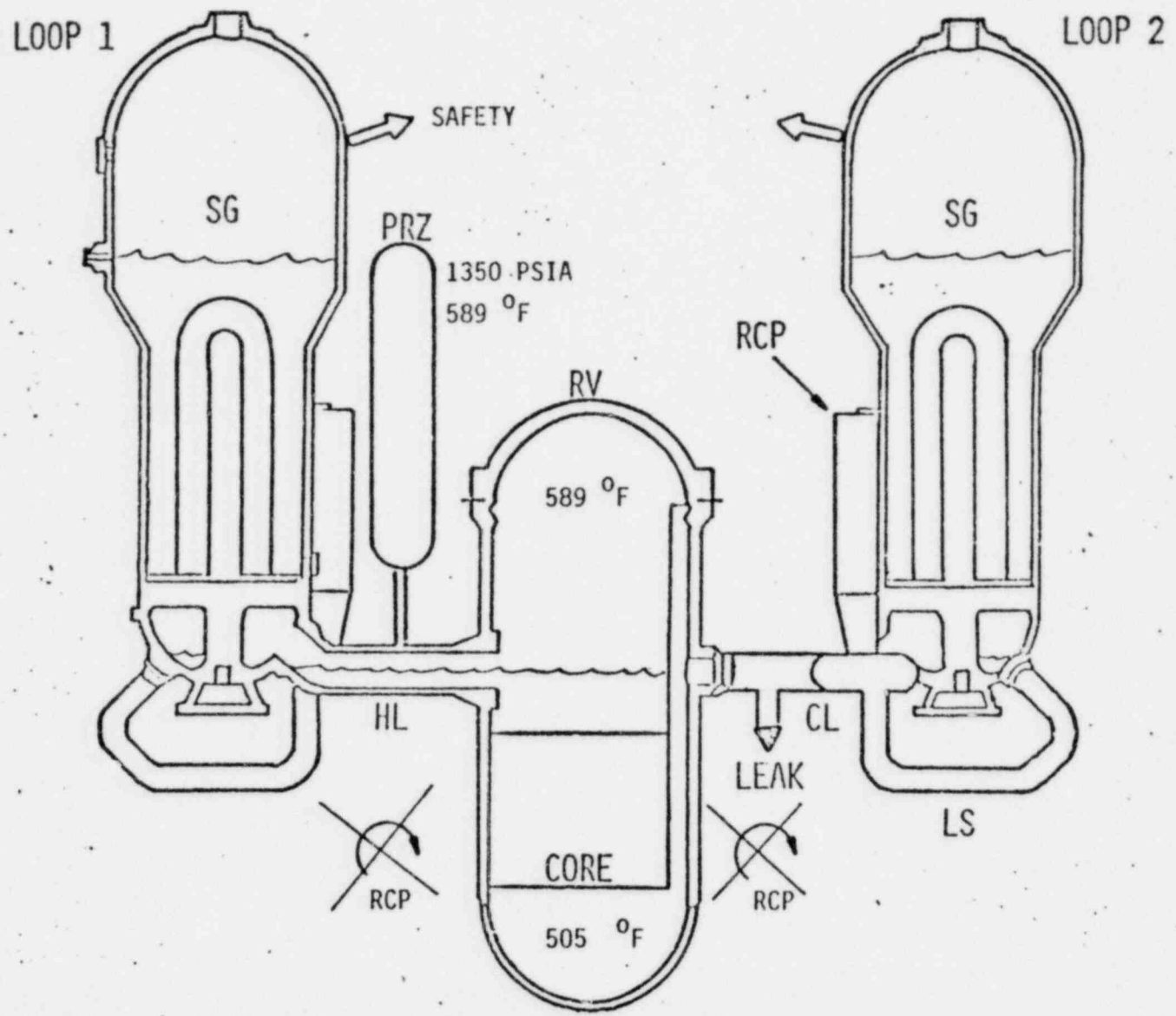
T = 600 SECS

TRANSITION FROM FORCED CONVECTION TO POOL BOILING

SYSTEM 80

0.02 FT^2 DISCHARGE LEG BREAK

- SG TUBES EMPTY
- CORE FLOW ALMOST ZERO



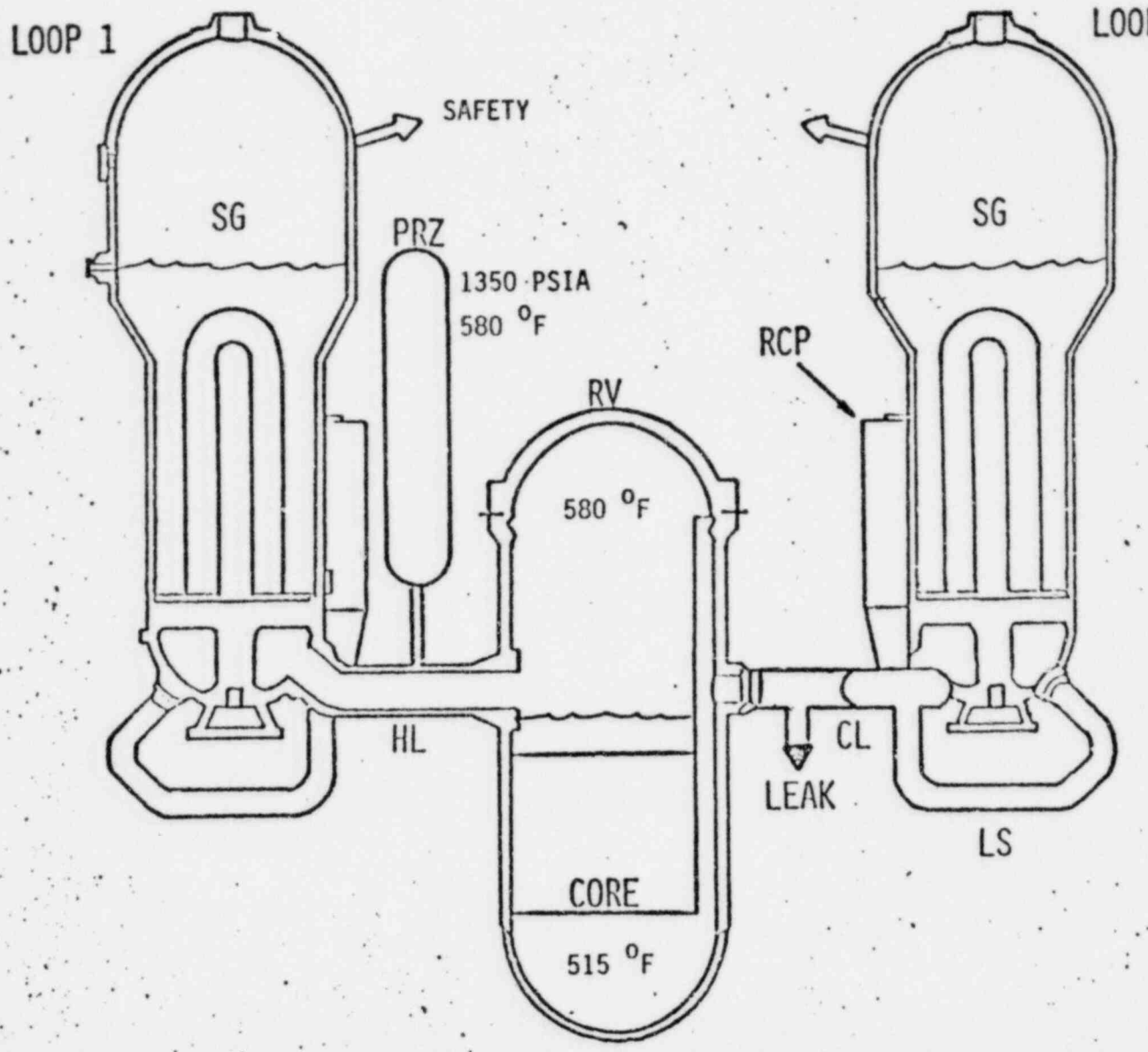
T = 1200 SECS

POOL BOILING CORE, CONDENSATION IN SG'S

SYSTEM 80

0.02 FT^2 DISCHARGE LEG BREAK

- HOT LEGS EMPTY
- COLD LEGS EMPTY
- LOOP SEALS EMPTY



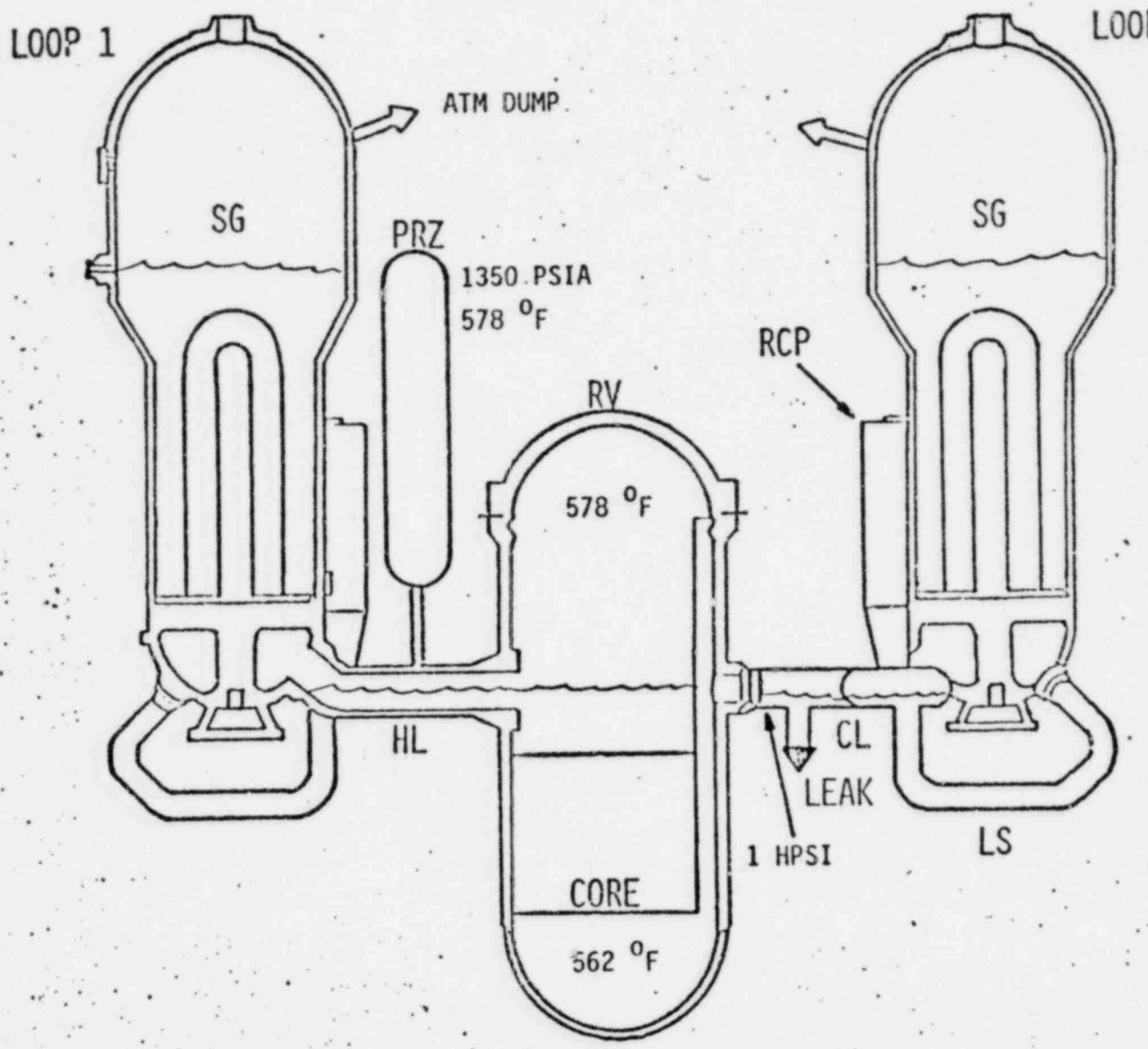
T = 1800 SECS

POOL BOILING CORE, CONDENSATION IN SG'S

SYSTEM 80

0.02 FT^2 DISCHARGE LEG BREAK

- START PROCEDURE TO ESTABLISH LONG TERM COOLING



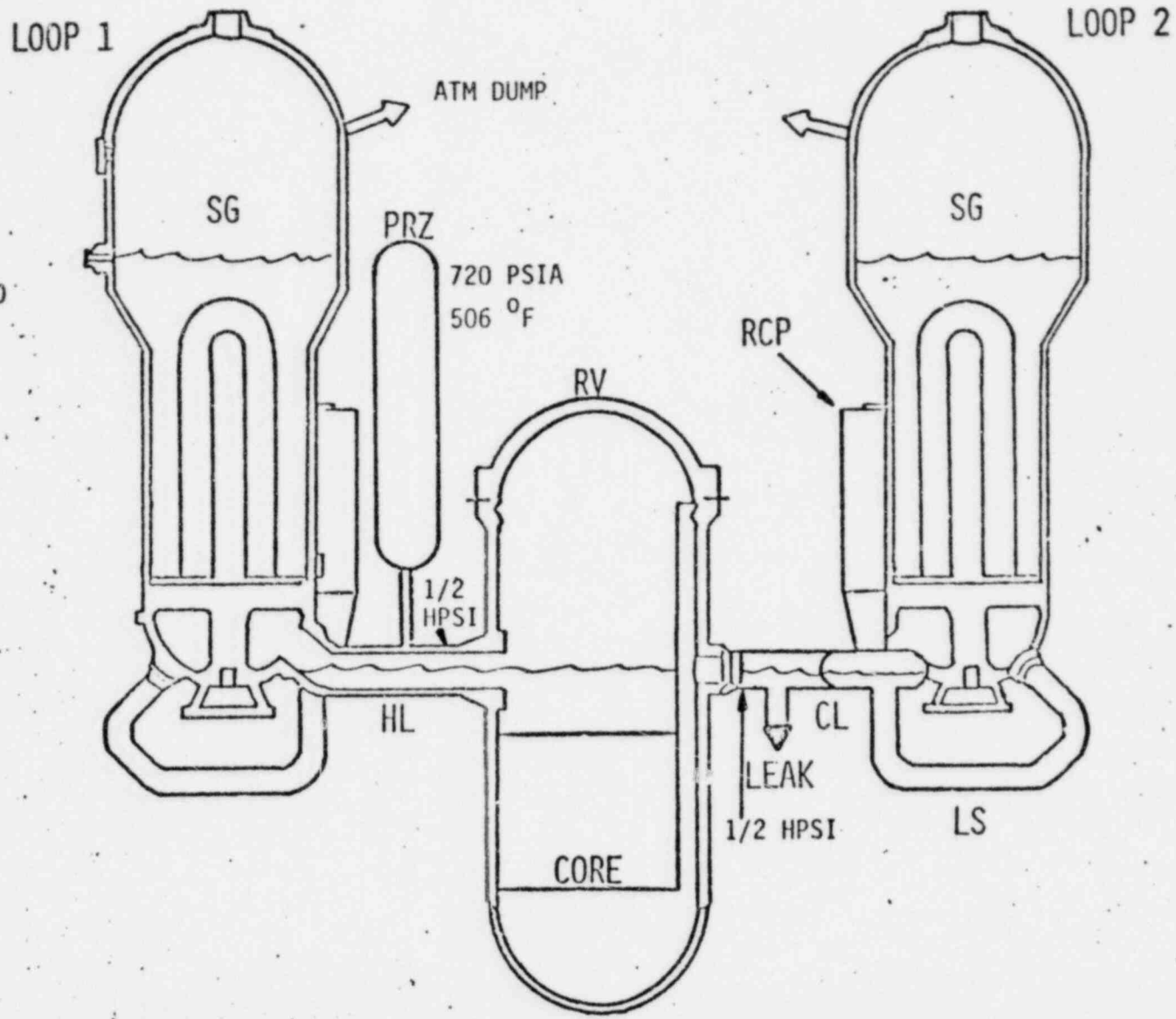
T = 1 HOUR

SG COOLDOWN INITIATED

SYSTEM 80

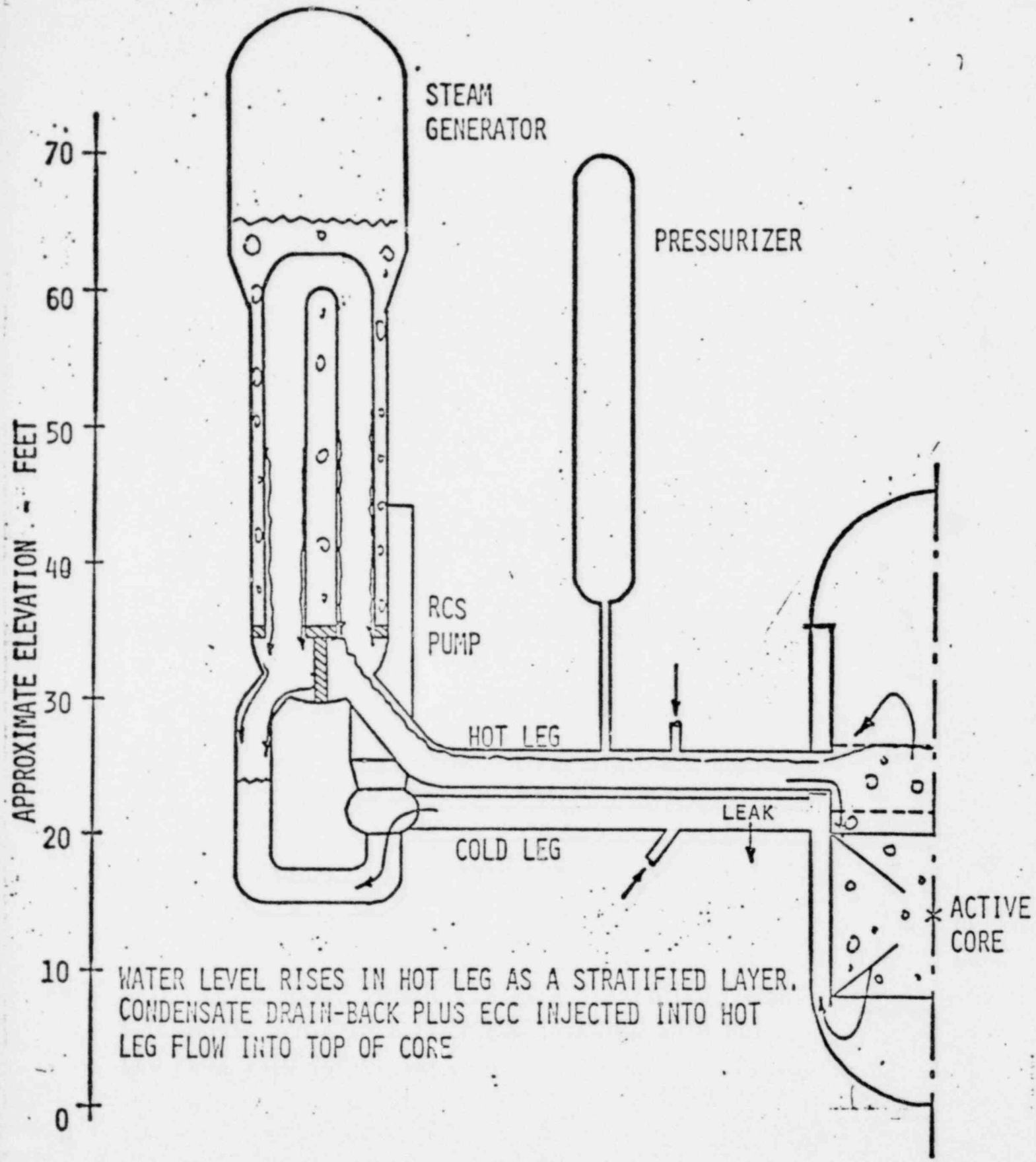
0.02 FT^2 DISCHARGE LEG BREAK

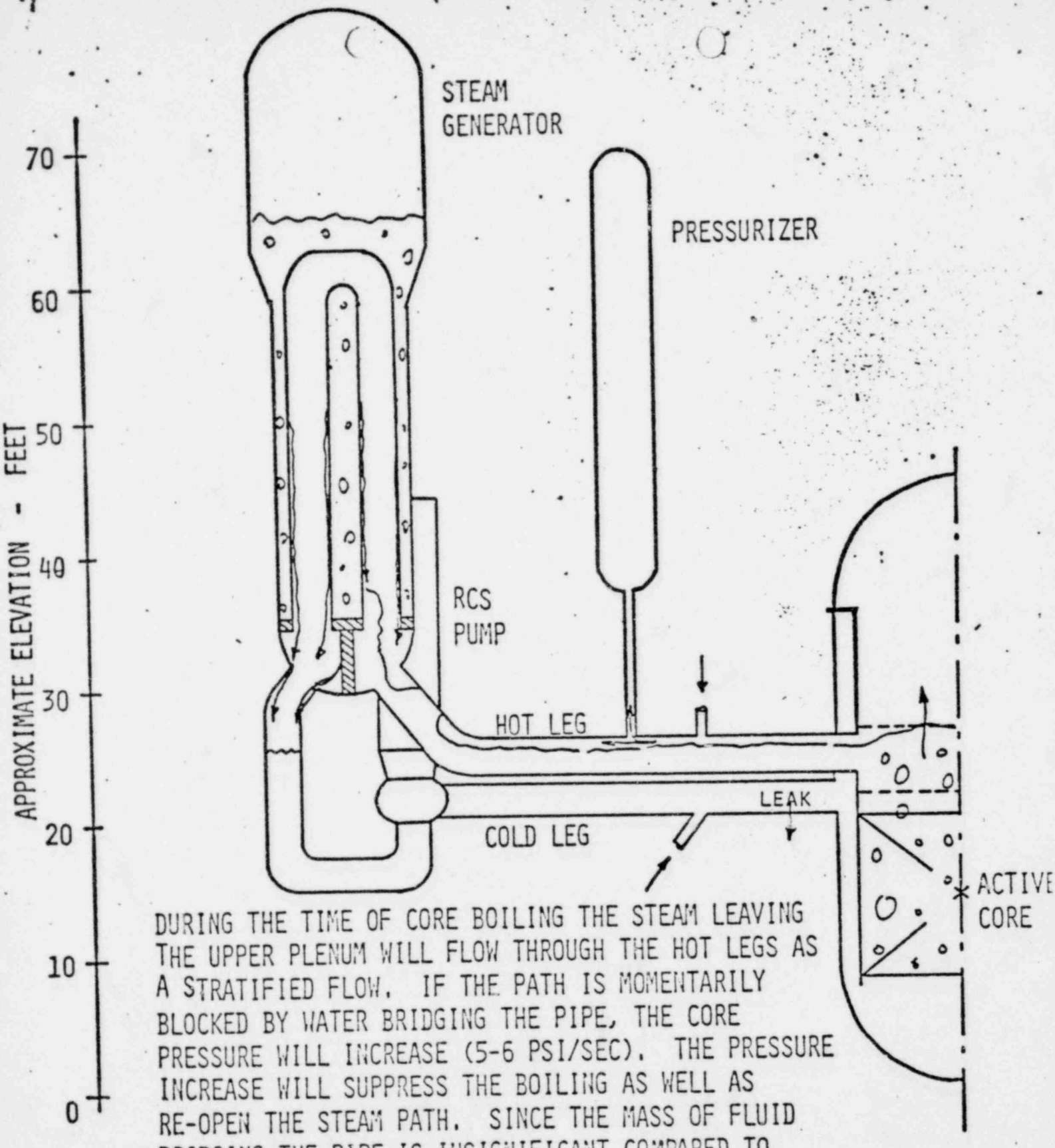
- HPSI > LEAKFLOW
- INITIATE HOT SIDE/COLD SIDE HPSIP INJECTION



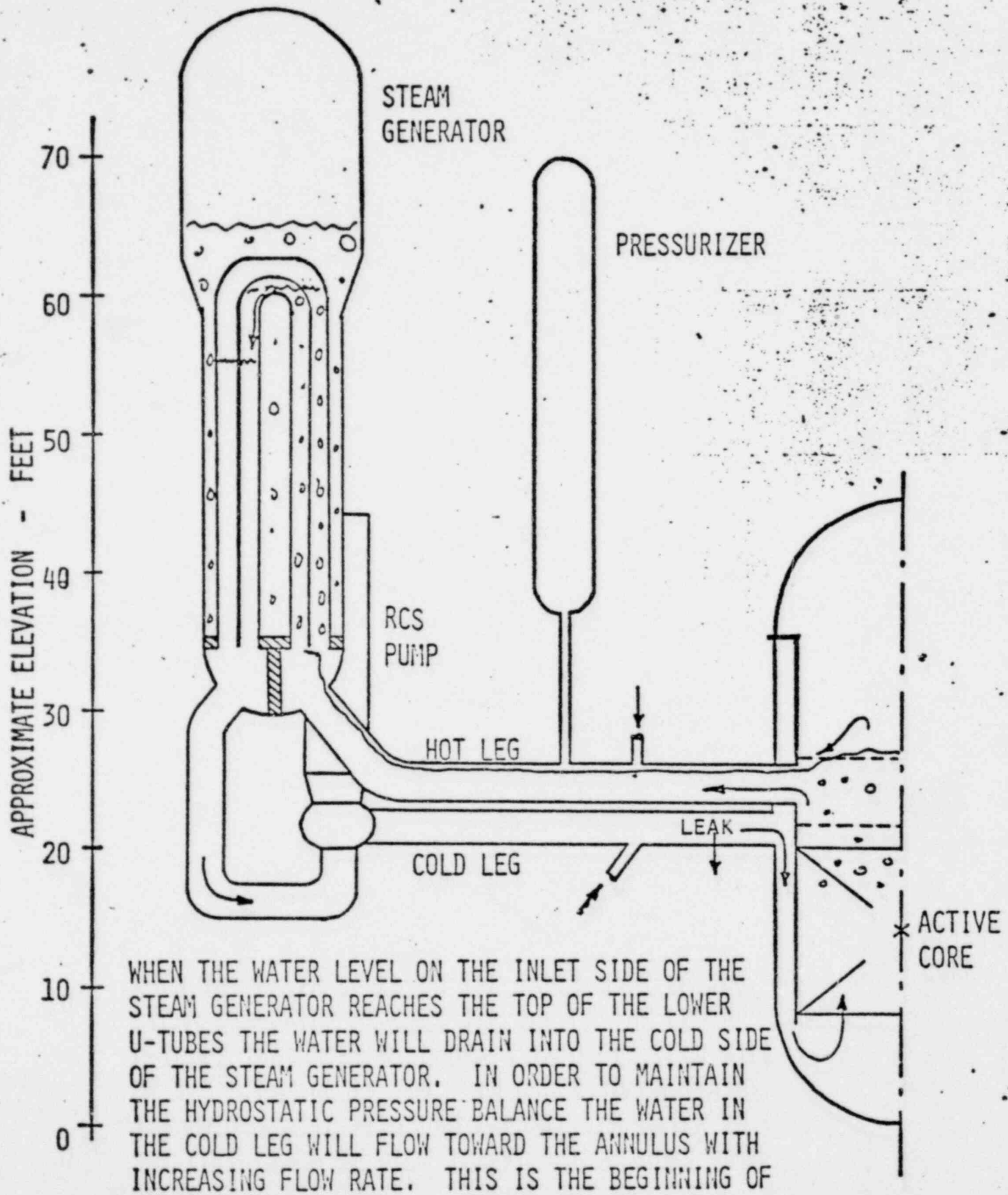
T = 2 HOURS

INITIATE HOT/COLD SIDE INJECTION

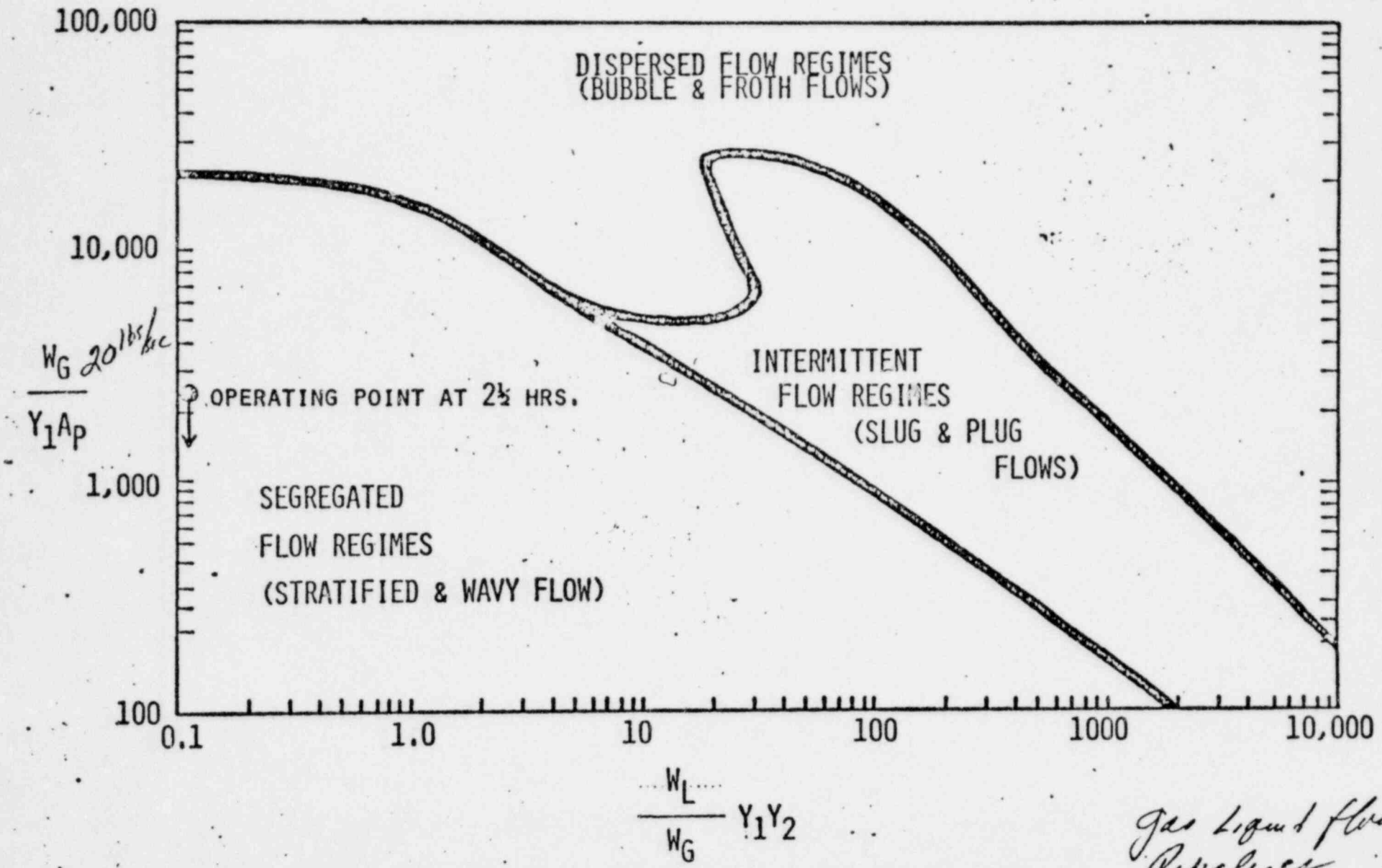

STEAM GENERATOR
PRESSURIZER
RCS PUMP
HOT LEG
LEAK
COLD LEG
ACTIVE CORE
APPROXIMATE ELEVATION - FEET
70
60
50
40
30
20
10
0
WATER LEVEL RISES IN HOT LEG AS A STRATIFIED LAYER. CONDENSATE DRAIN-BACK PLUS ECC INJECTED INTO HOT LEG FLOW INTO TOP OF CORE



DURING THE TIME OF CORE BOILING THE STEAM LEAVING THE UPPER PLENUM WILL FLOW THROUGH THE HOT LEGS AS A STRATIFIED FLOW. IF THE PATH IS MOMENTARILY BLOCKED BY WATER BRIDGING THE PIPE, THE CORE PRESSURE WILL INCREASE (5-6 PSI/SEC). THE PRESSURE INCREASE WILL SUPPRESS THE BOILING AS WELL AS RE-OPEN THE STEAM PATH. SINCE THE MASS OF FLUID BRIDGING THE PIPE IS INSIGNIFICANT COMPARED TO THE MASS OF FLUID FILLING THE REACTOR VESSEL AND COLD LEGS, THE LEVEL OF WATER IN THE CORE WILL NOT CHANGE SIGNIFICANTLY DURING THESE PRESSURE FLUCTUATIONS.



WHEN THE WATER LEVEL ON THE INLET SIDE OF THE STEAM GENERATOR REACHES THE TOP OF THE LOWER U-TUBES THE WATER WILL DRAIN INTO THE COLD SIDE OF THE STEAM GENERATOR. IN ORDER TO MAINTAIN THE HYDROSTATIC PRESSURE BALANCE THE WATER IN THE COLD LEG WILL FLOW TOWARD THE ANNULUS WITH INCREASING FLOW RATE. THIS IS THE BEGINNING OF NATURAL CIRCULATION.

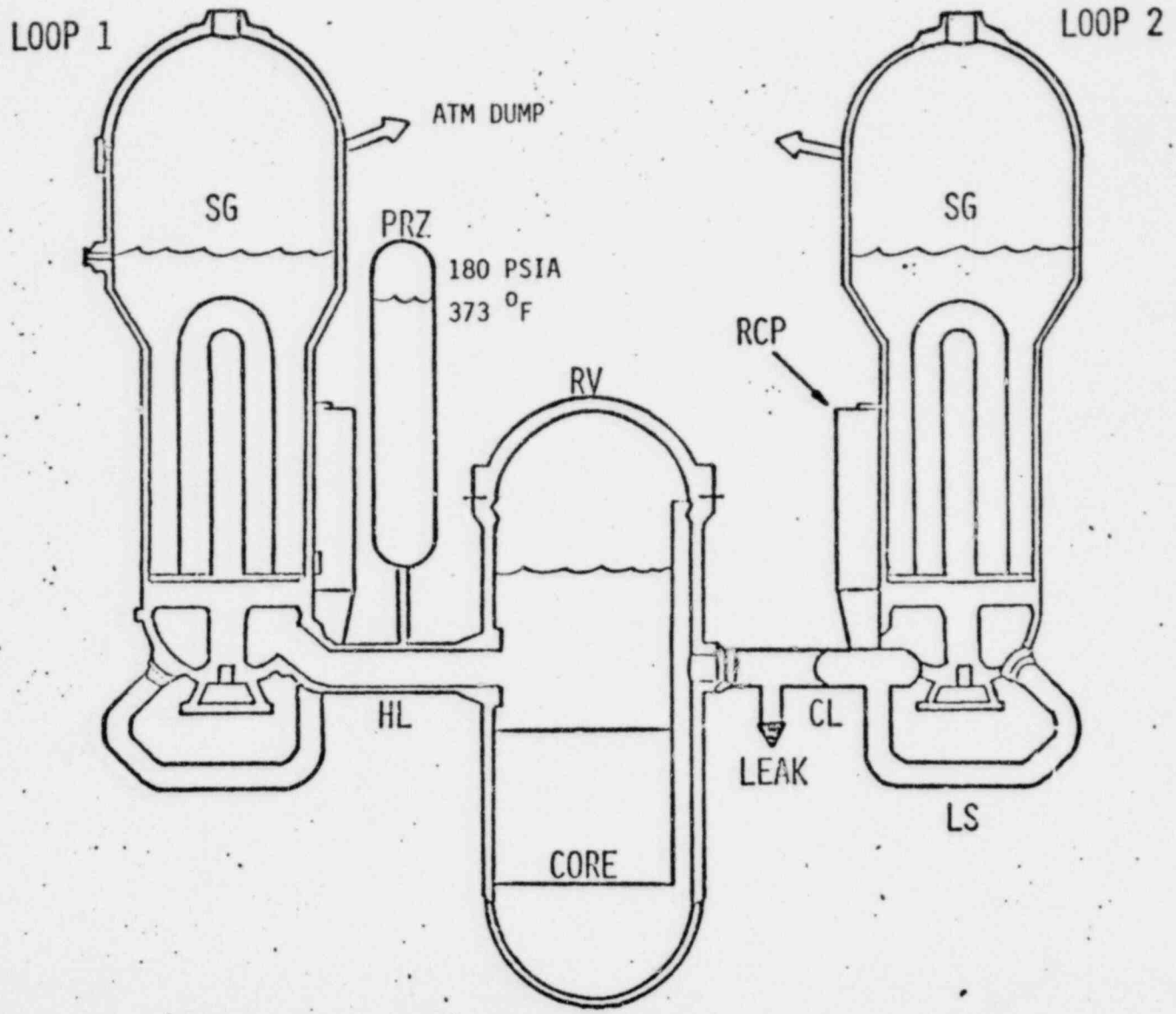


FLOW REGIME MAP. OPERATING POINT IN HOT LEG DURING REFILL PHASE OF A SMALL BREAK LOCA.

Gas Liquid flow in Pipelines
A. E. Dukler
May 1969

SYSTEM 80

0.02 FT^2 DISCHARGE LEG BREAK



T = 4.0 HOURS

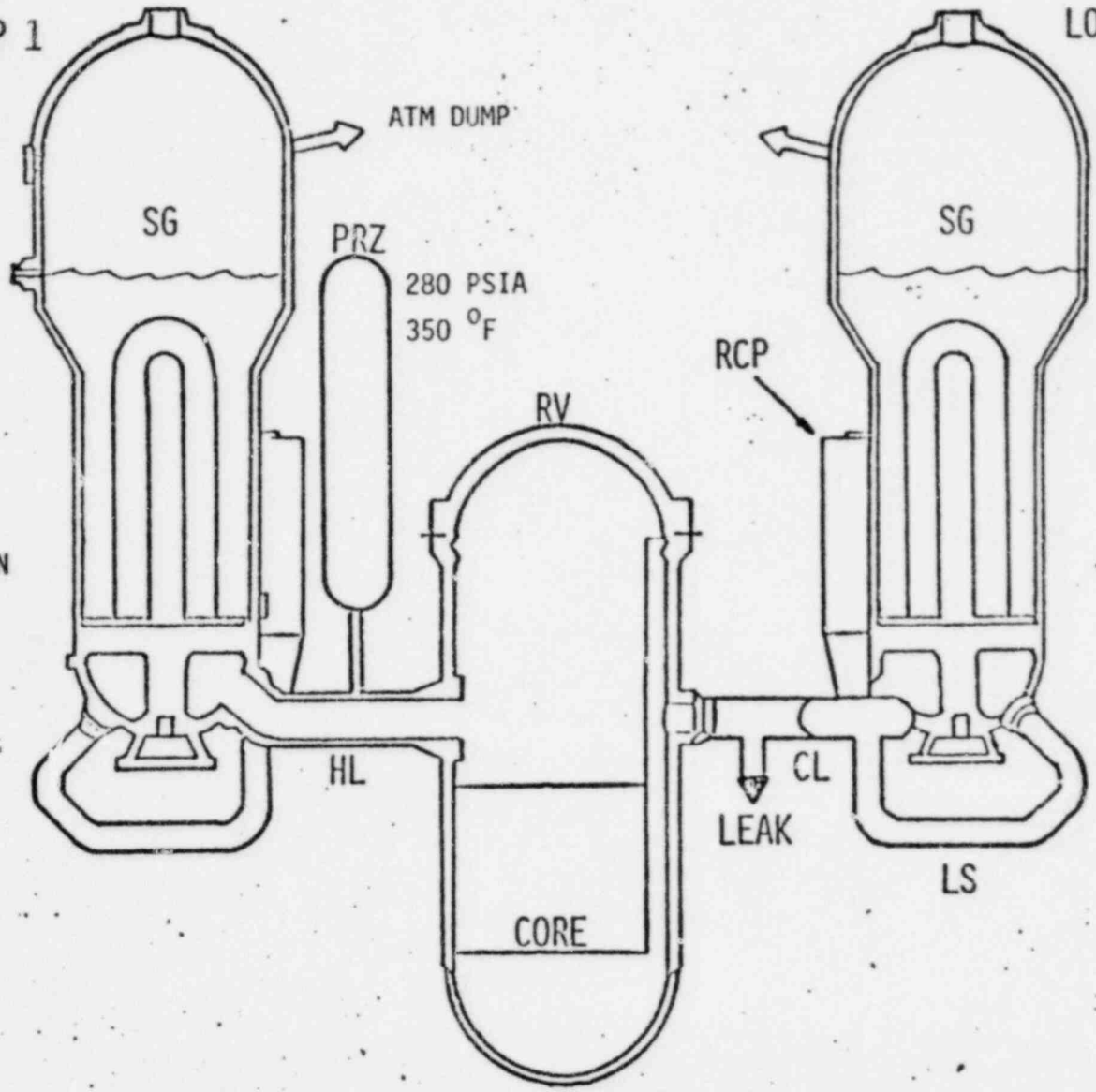
RCS REFILLING

SYSTEM 80

0.02 FT^2 DISCHARGE LEG BREAK

- SUBCOOLED
- SOLID SYSTEM
- HPSI = LEAKFLOW

START NATURAL CIRCULATION



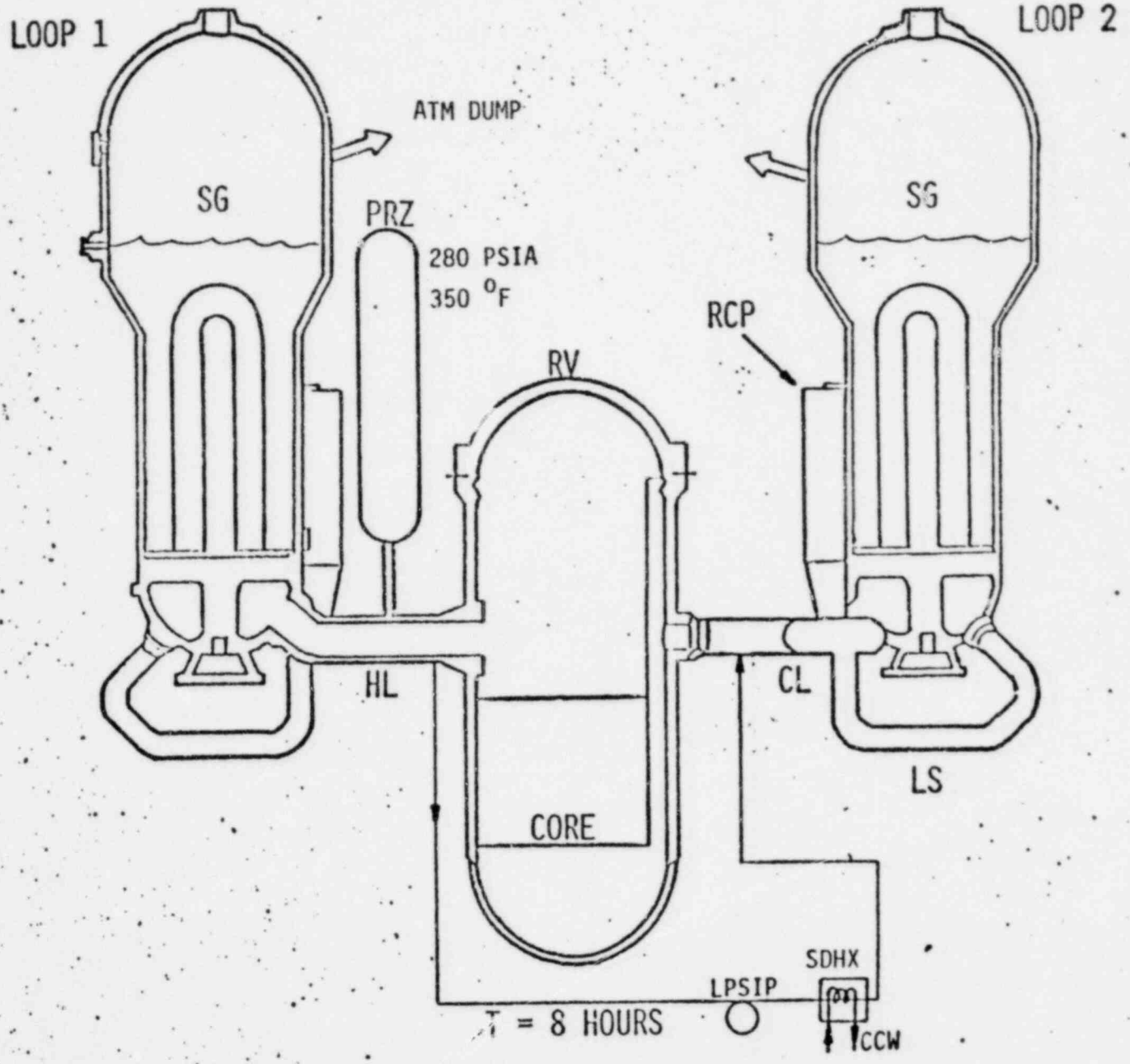
T = 4.3 HOURS

RCS REFILLED

SYSTEM 80

0.02 FT^2 DISCHARGE LEG BREAK

- RCS IN NATURAL CIRCULATION
- PREPARE TO STARTUP SDCS



INITIATE SHUTDOWN COOLING SYSTEMS

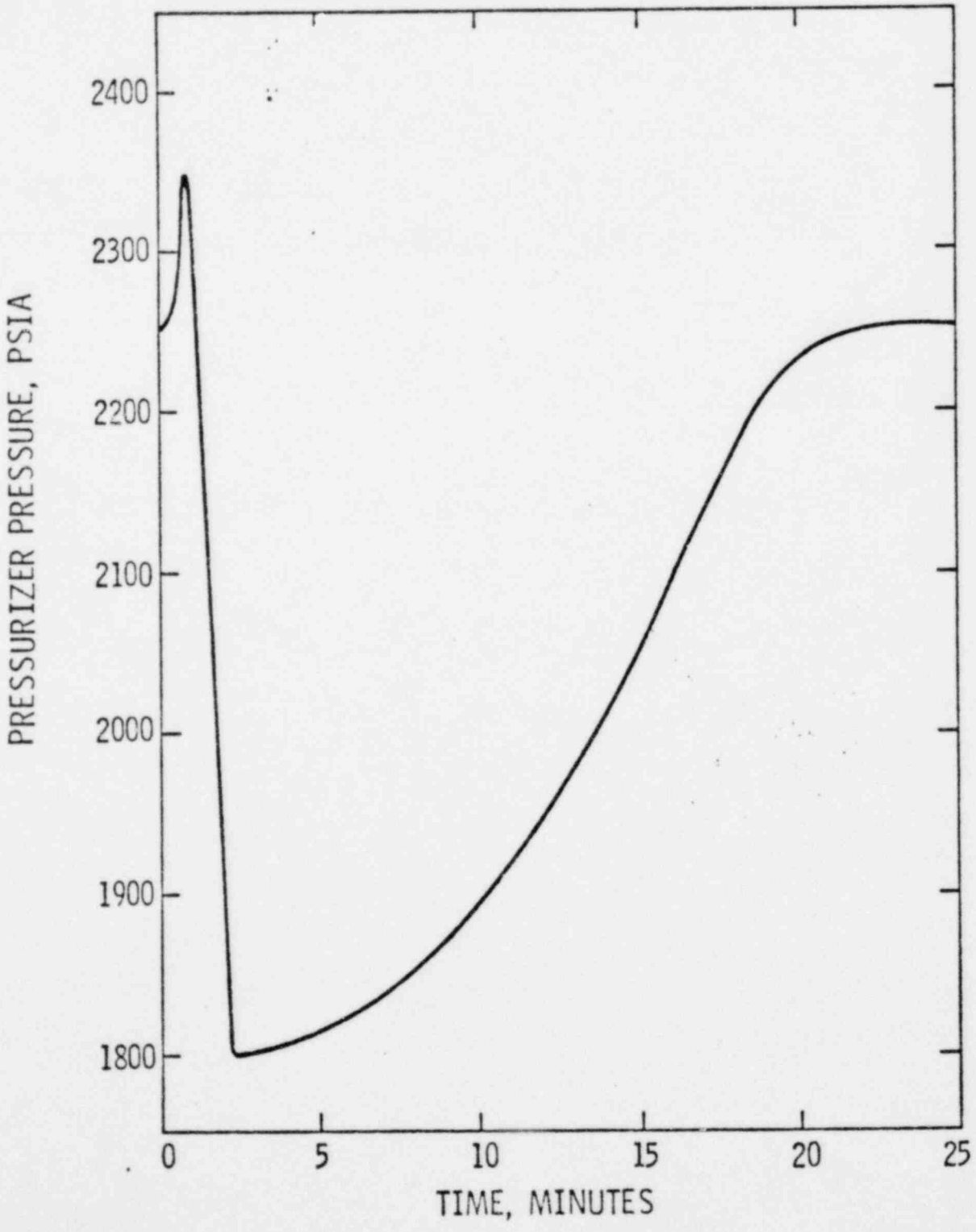
- TYPICAL COMPLETE LOSS OF FEEDWATER SEQUENCE FOR A C-E OPERATING PLANT

- TYPICAL STUCK PRESSURIZER RELIEF VALVE SEQUENCE FOR A C-E OPERATING PLANT

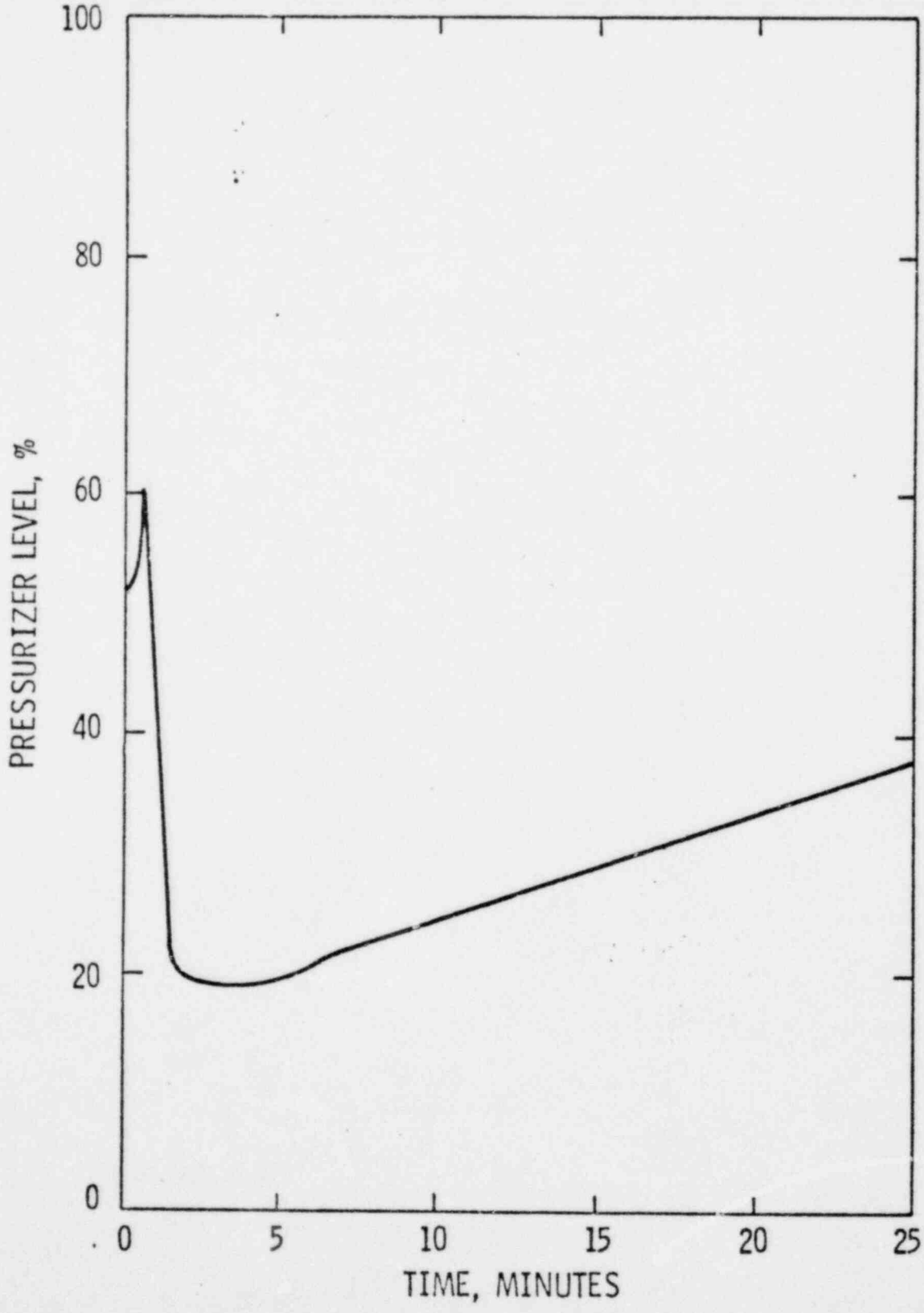
TYPICAL COMPLETE LOSS OF FEEDWATER SEQUENCE FOR A C-E OPERATING PLANT

TIME (SEC)	EVENT
0	TERMINATION OF MAIN FEEDWATER FLOW RESULTING IN DECREASING STEAM GENERATOR WATER LEVEL
20	PRE-TRIP ALARM ON LOW STEAM GENERATOR WATER LEVEL
25	REACTOR TRIP ON LOW STEAM GENERATOR WATER LEVEL
30	PEAK PRESSURIZER PRESSURE < PORV SETPOINT (2400 PSIA) (PORV DOES NOT OPEN)
30+	STEAM DUMP, BYPASS, AND PRESSURIZER CONTROL SYSTEMS REGULATE TO HOT STANDBY CONDITIONS
120	MINIMUM PRESSURIZER PRESSURE ~1800 PSIA (NO SIAS)
780 - 900	FROM THE CONTROL ROOM THE OPERATOR MANUALLY STARTS AUXILIARY FEEDWATER PUMPS AND OPENS VALVES TO THE STEAM GENERATORS BEFORE RCS PRESSURE RISES TO PORV SETPOINT (2400 PSIA)

TYPICAL COMPLETE LOSS OF FEEDWATER
FOR A C-E OPERATING PLANT
PRESSURIZER PRESSURE vs TIME



TYPICAL COMPLETE LOSS OF FEEDWATER
FOR A C-E OPERATING PLANT
PRESSURIZER LEVEL vs TIME



TYPICAL STUCK PRESSURIZER RELIEF VALVE SEQUENCE FOR A C-E OPERATING PLANT

TIME (SEC)	EVENT
0	PORV OPENS RESULTING IN RAPID DEPRESSURIZATION OF RCS
0+	OPERATOR RECEIVES INDICATION AND ALARMS FROM RTD IN PORV PIPING, AS WELL AS, QUENCH TANK TEMPERATURE, PRESSURE, AND LEVEL
0+	PRESSURIZER CONTROL SYSTEMS AND CVCS RESPOND TO DEPRESSURIZATION
5	TM/LP PRE-TRIP ALARM
7	TM/LP TRIP ON LOW THERMAL MARGIN
22	SIAS AT APPROXIMATELY 1600 PSIA AUTOMATICALLY STARTS HPSI PUMPS
30	QUENCH TANK RELIEF VALVE OPENS RELEASING STEAM TO CONTAINMENT
30+	OPERATOR RECEIVES ALARMS AND INDICATION OF INCREASING CONTAINMENT PRESSURE, TEMPERATURE, AND POSSIBLY ACTIVITY
50	FLUID EXPANSION AND SUBSEQUENT FLASHING IN RCS RESULT IN INCREASING PRESSURIZER LEVEL
240	HOT LEG RTDs INDICATE RCS IS APPROACHING SATURATION CONDITIONS

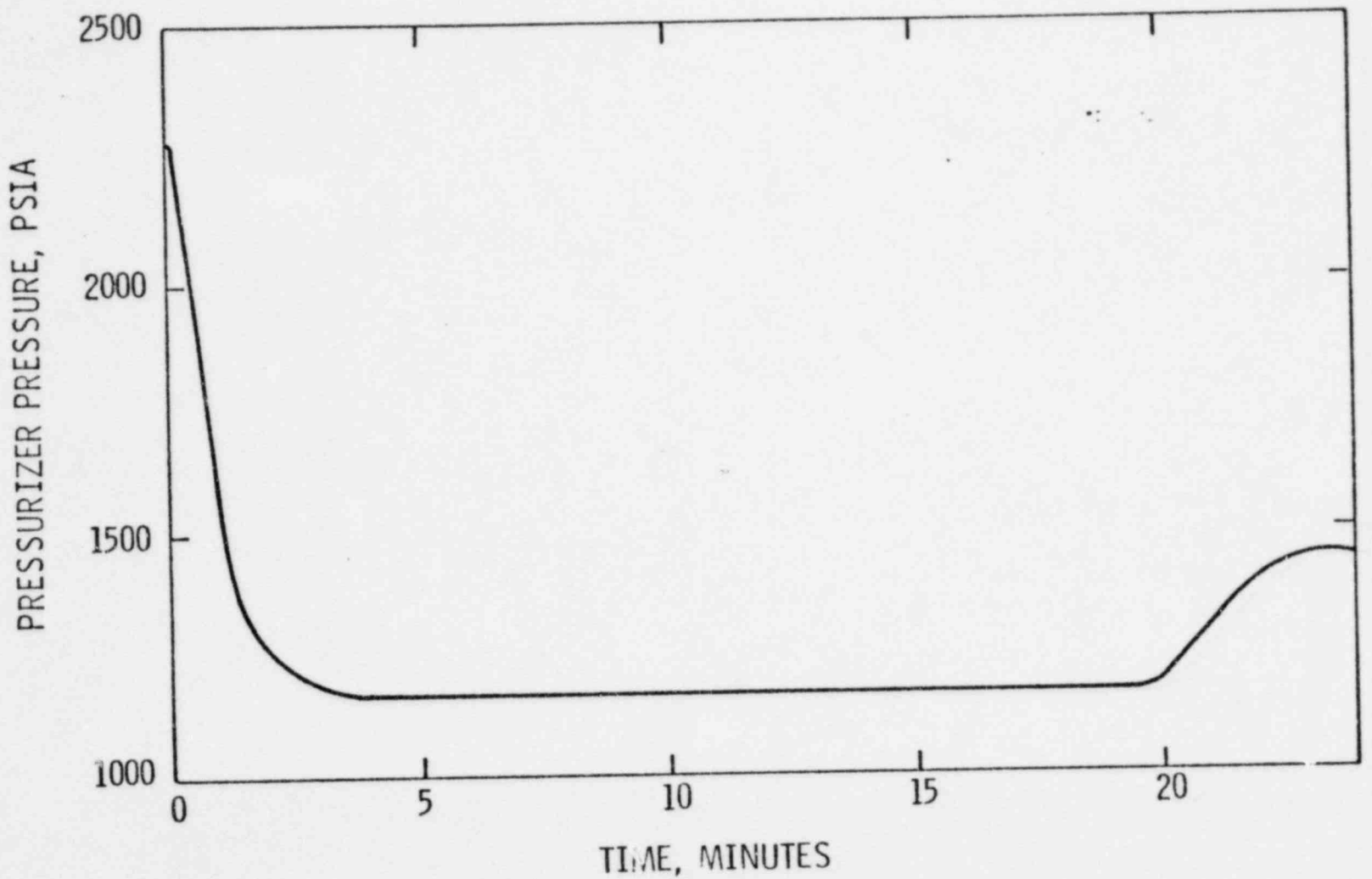
TYPICAL STUCK PRESSURIZER RELIEF VALVE SEQUENCE

FOR A C-E OPERATING PLANT

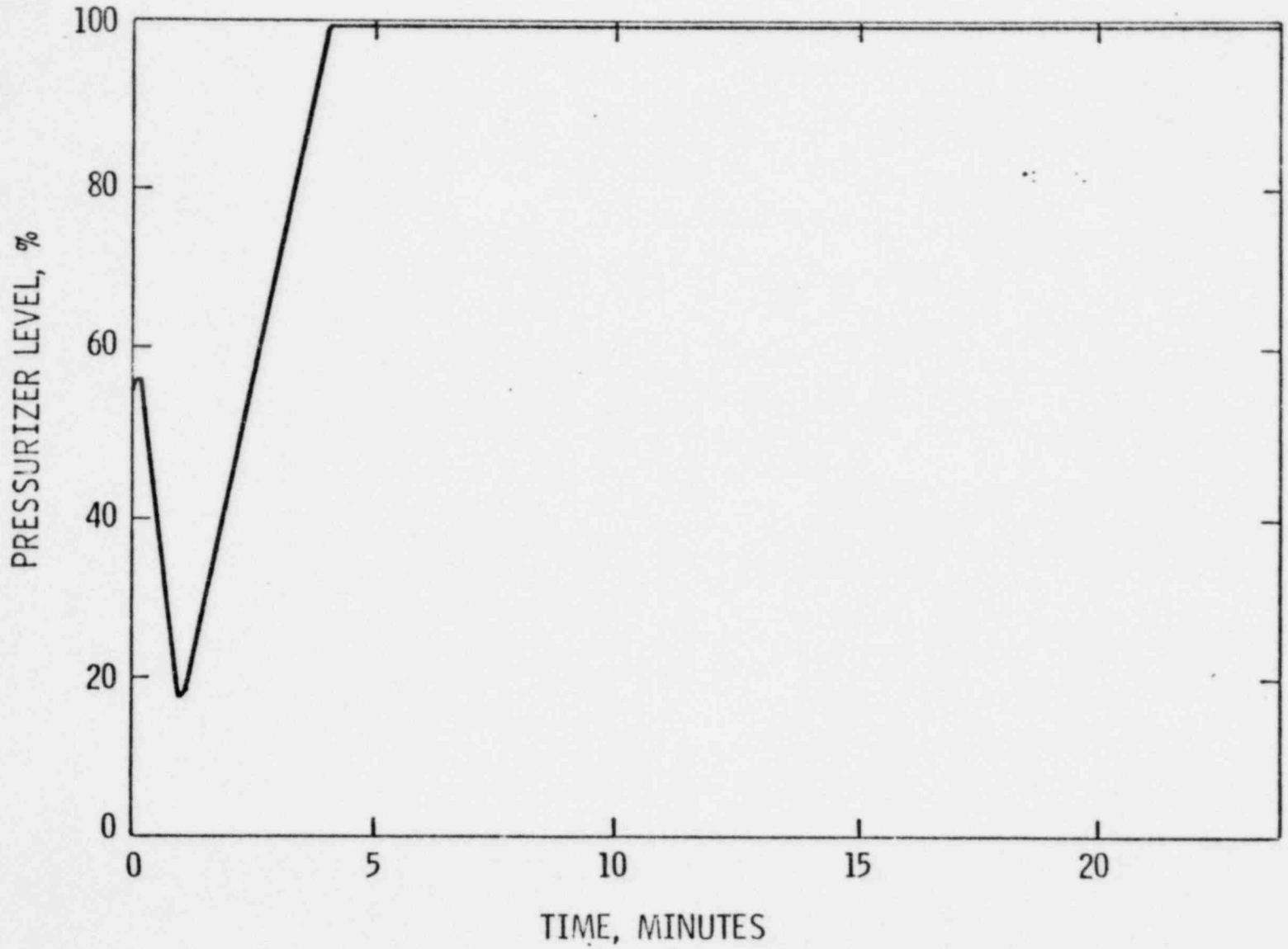
(CONTINUED)

TIME (SEC)	EVENT
260	FILLING OF PRESSURIZER RESULTING IN TWO-PHASE RELIEF THROUGH PORV
300	OPENING QUENCH TANK RUPTURE DISK RESULTING IN FLUID RELEASE TO THE CONTAINMENT
300+	STEAM DUMP AND BYPASS REGULATE RCS TO HOT STANDBY TEMPERATURE
300+	RCS PRESSURE STABILIZES AT ~1100 PSIA WITH HPSI FLOW MATCHING PORV FLOW
600 - 900	AUXILIARY FEEDWATER MANUALLY INITIATED TO STEAM GENERATORS, IF MAIN FEEDWATER WAS LOST
900 - 1800	OPERATOR CLOSES PRESSURIZER BLOCK VALVE TERMINATING UNCONTROLLED RCS FLUID RELEASE
1800+	RCS PRESSURE STABILIZES AT HPSI SHUTOFF HEAD
5400 (1.5 HRS)	PRESSURIZER HEATERS RE-ESTABLISH BUBBLE IN PRESSURIZER

TYPICAL STUCK PRESSURIZER RELIEF VALVE FOR A C-E OPERATING PLANT.
PRESSURIZER PRESSURE vs TIME



TYPICAL STUCK PRESSURIZER RELIEF VALVE FOR A C-E OPERATING PLANT.
PRESSURIZER LEVEL vs TIME



PORV OPERATION

DEMAND VALVE OPENINGS	-	2
FAILURE TO CLOSE	-	0
INADVERTENT ACTUATION	-	2
FAILURE TO CLOSE	-	1

PORV ACTUATION

DEMAND VALVE OPENINGS	OPEN	FAIL TO CLOSE
HIGH PRESSURE TRIP DURING SPURIOUS TURBINE RUNBACK AT POWER -	1	0
HIGH PRESSURE TRIP DURING LOSS OF LOAD - POWER ASCENSION TEST -	1	0
INADVERTENT ACTUATION		
RPS MAINTENANCE - SPURIOUS OPEN SIGNAL - PRE POWER TESTING AT HOT SHUTDOWN -	1	1
PORV MAINTENANCE - SPURIOUS OPEN SIGNAL - COLD SHUTDOWN -	1	0

ECCS OPERATION

DEMAND ECCS OPERATION	- 6
FAILURE TO OPERATE	- 0
INADVERTENT ACTUATION	- 3
FAILURE TO OPERATE	- 0

ECCS OPERATION

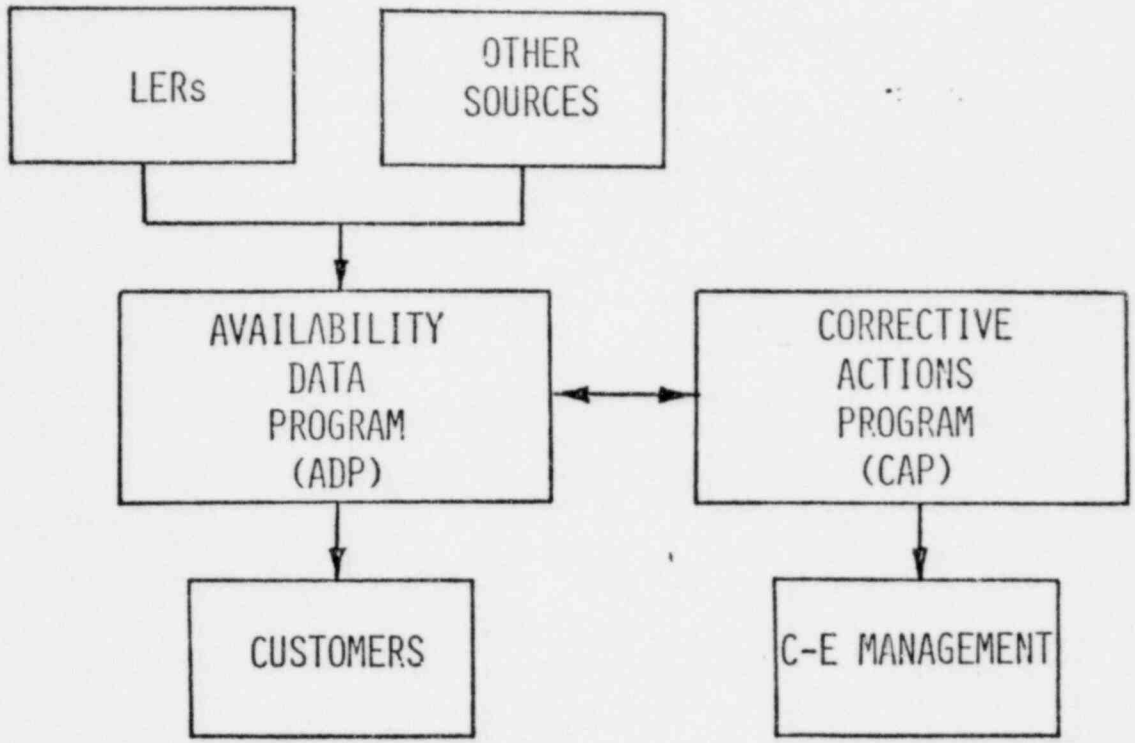
	DEMAND	FAIL TO OPERATE
DEMAND ECCS OPERATION		
PORV OPENING	1	0
POST-TRIP EXCESS FW	3	0
FW BYPASS VALVES STUCK OPEN	1	0
UNBLOCKED SIGNAL DURING COOLDOWN	1	0
INADVERTENT ECCS ACTUATION		
RPS/ESFAS TESTING	3	0

AUXILIARY FEEDWATER OPERATION

	TIMES USED	FAILED TO OPERATE
AS EMERGENCY FEEDWATER		
LOSS OF FEEDWATER	2	0
LOSS OF OFFSITE POWER	9	0
LOSS OF CONDENSER VACUUM	7	0

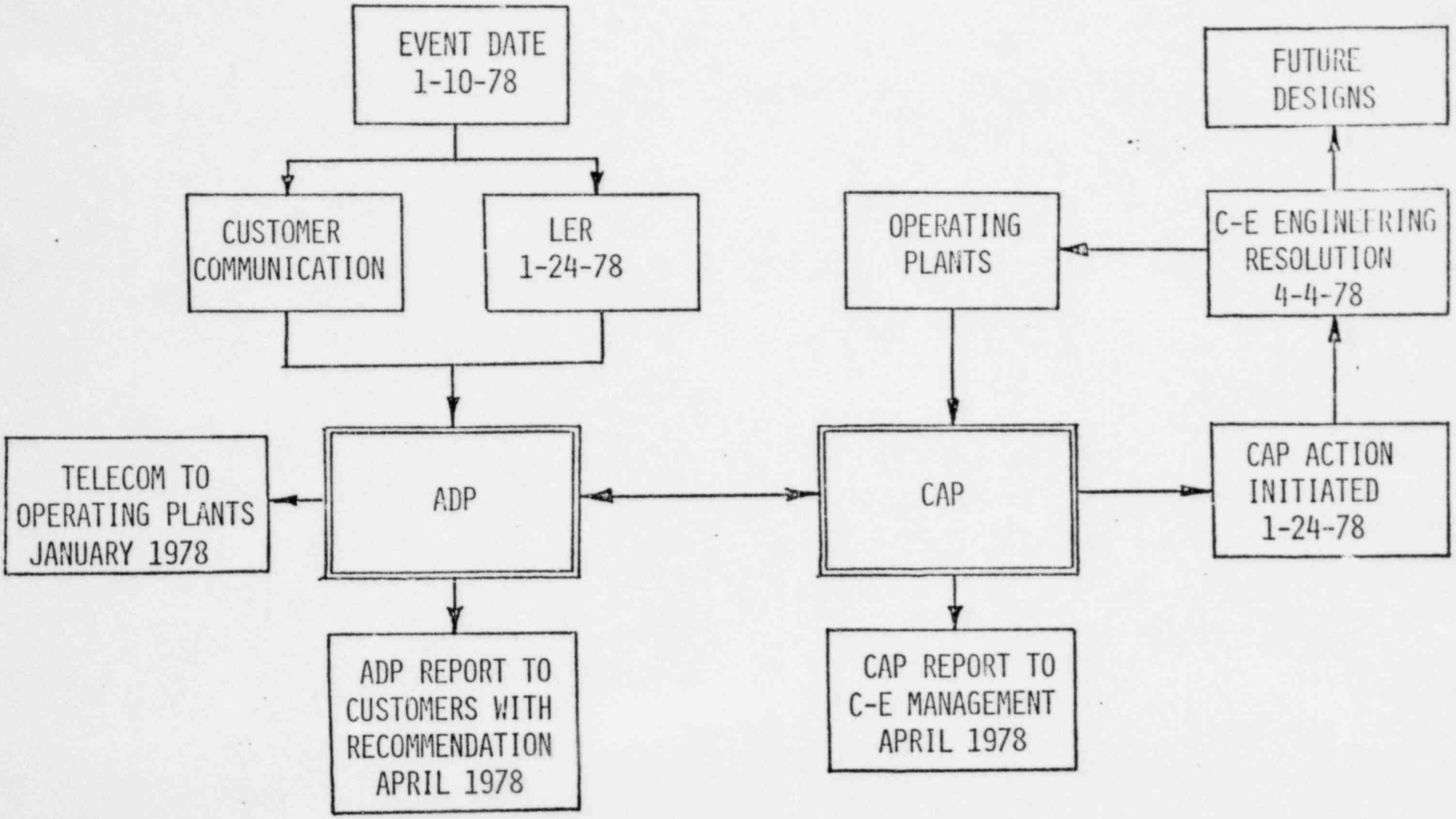
COMBUSTION ENGINEERING

PROCESSING OF OPERATING INFORMATION



EXAMPLE OF LER PROCESSING

CALIBRATION ERROR IN INJECTION TANK LEVEL TRANSMITTER



EXAMPLE OF INFORMATION EXCHANGE

NOBLE GAS DOSE ACCOUNTABILITY DURING REFUELING

COMPLIANCE WITH 10 CFR 20