Number:	Symptom/Title:	Revision No./Date
FR-H.1	RESPONSE TO LOSS OF SECONDARY HEAT SINK	HP - Basic 1 Sept., 1982

STEP	ACTION/EXPECTED RESPONSE	RESPONSE NOT OBTAINED

Caution

- *If RCS pressure and temperature start to increase due to loss of secondary heat sink while doing steps 1 through 11, go immediately to step 13.*
- *A faulted or ruptured steam generator should remain isolated throughout further restoration actions.*

STEP	ACTION/EXPECTED RESPONSE	RESPONSE NOT OBTAINED
1	**Check If Secondary Heat Sink Is Required:**	
	a. RCS pressure - GREATER THAN ANY INTACT STEAM GENERATOR PRESSURE	a. IF less than all intact steam generator pressures, THEN go to E-1, LOSS OF REACTOR COOLANT, STEP 1.
2	**Establish AFW Flow To intact Steam Generators:**	
	a. Align AFW valves for proper emergency alignment (1)	a. Locally align valves, if possible.
	b. Start AFW pumps: • Motor-driven pumps • Turbine-driven pump	b. Locally start pumps, if possible.
	c. Check CST level - GREATER THAN (2) %	c. IF CST level low, THEN switch to alternate AFW water supply.
3	**Check AFW Flow To Intact Steam Generators:**	
	a. Total AFW flow to intact steam generators - GREATER THAN (3) GPM	a. IF less than (3) gpm, THEN go to step 4.
	b. IF greater than (3) gpm, THEN return to guideline in effect	

(1) Enter plant specific list.

(2) Enter plant specific low level setpoint.

(3) Enter plant specific flow equal to at least one motor-driven AFW pump at design pressure.

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STEP	ACTION/EXPECTED RESPONSE	RESPONSE NOT OBTAINED
4	**Check Feedwater Isolation:** a. [Enter plant specific means] IF feedwater isolation is actuated, THEN reset SI and feedwater isolation	
5	**Establish Main Feedwater Flow To Intact Steam Generators:** a. [Enter plant specific means]	IF main feedwater cannot be established, THEN go to step 7.
6	**Check Intact Steam Generator Levels:** a. Narrow range level in at least one intact steam generator – GREATER THAN (1) % b. IF greater than (1) %, THEN return to guideline in effect	a. IF less than (1) %, THEN go to step 7.
7	**Check Condensate System – AVAILABLE**	IF NOT available, THEN go to step 12.
8	**Rapidly Depressurize At Least One Intact Steam Generator(s) To (2) PSIG.**	
9	**Check Feedwater Isolation:** a. [Enter plant specific means] IF feedwater isolation is actuated, THEN reset SI and feedwater isolation	
10	**Establish Condensate Flow To At Least One Depressurized Intact Steam Generator(s):** a. [Enter plant specific means]	IF condensate flow cannot be established, THEN go to step 12.

(1) Enter plant specific value showing level just in narrow range including allowances for normal channel accuracy, post-accident transmitter errors and reference leg process errors.

(2) Enter plant specific pressure below shutoff head of condensate pumps.

STEP	ACTION/EXPECTED RESPONSE	RESPONSE NOT OBTAINED
11	**Check Intact Steam Generator Levels:**	
	a. Narrow range level in at least one depressurized intact steam generator - GREATER THAN (1) %	a. IF less than (1) %, THEN go to step 12.
	b. IF greater than (1) %, THEN return to guideline in effect	
12	**Check For Loss Of Secondary Heat Sink:**	
	a. RCS temperature: 1) Wide range temperatures - INCREASING -OR- 2) Core exit TCs - INCREASING	a. IF stable or decreasing, THEN return to step 1.
	b. RCS pressure - INCREASING	b. IF stable or decreasing, THEN return to step 1.

Caution *Steps 13 through 17 must be performed quickly in order to establish RCS heat removal by RCS bleed and feed.*

STEP	ACTION/EXPECTED RESPONSE	RESPONSE NOT OBTAINED
13	**Verify SI Initiated.**	IF NOT initiated, THEN: a. Manually initiate SI. b. Verify SI automatic actuations while continuing in this guideline. • Implement steps 5 through 15 of E-0, REACTOR TRIP OR SAFETY INJECTION.

(1) Enter plant specific value showing level just in narrow range including allowances for normal channel accuracy, post-accident transmitter errors and reference leg process errors.

STEP	ACTION/EXPECTED RESPONSE	RESPONSE NOT OBTAINED
14	**Check RCS Feed Path:**	
	a. Check charging/SI valve alignment - PROPER EMERGENCY ALIGNMENT	a. Manually open or close valves, as appropriate.
	b. Check charging/SI pump running - AT LEAST ONE BREAKER INDICATOR LIGHT LIT	b. Manually start pumps. IF at least one charging/SI pumps cannot be started, THEN DO NOT ESTABLISH RCS BLEED PATH. Continue attempts to start charging/SI pumps.

Caution *DO NOT proceed to step 15 until RCS feed path is established.*

STEP	ACTION/EXPECTED RESPONSE	RESPONSE NOT OBTAINED
15	**Establish RCS Bleed Path:**	
	a. Verify power available to pressurizer PORV block valves	a. Restore power to block valves.
	b. Verify pressurizer block valves - OPEN	b. Open block valves.
	c. Open all pressurizer PORVs	
16	**Check RCS Bleed Path:**	
	a. Pressurizer PORVs - AT LEAST TWO OPEN	a. IF two pressurizer PORVs NOT open, THEN: 1) Start one RCP (preferably in an intact loop). 2) Open steam generator PORV for at least one intact steam generator(s). 3) Depressurize intact steam generator(s) to atmospheric pressure. 4) Align low pressure water source to depressurized intact steam generator(s). 5) Go to step 18.

STEP	ACTION/EXPECTED RESPONSE	RESPONSE NOT OBTAINED
	Caution *Seal injection flow should be maintained to all RCPs.*	
17	**Maintain RCS Heat Removal:**	
	a. Maintain SI flow	
	b. Maintain AT LEAST TWO pressurizer PORVs open	
	c. Stop all RCPs	
	Caution *If RWST level reaches (1), align SI system for cold leg recirculation per ES-1.3, TRANSFER TO COLD LEG RECIRCULATION FOLLOWING LOSS OF REACTOR COOLANT.*	
18	**Prepare For Switchover To Cold Leg Recirculation While Continuing In This Guideline:**	
	a. Implement steps 13 through 17 of E-1, LOSS OF REACTOR COOLANT	
19	**Continue Attempts To Establish Secondary Heat Sink:** • AFW flow • Main feedwater flow • Condensate flow • Other low pressure flow	
20	**Check RCS Temperatures:**	
	a. Core exit TCs - DECREASING	a. IF NOT decreasing, THEN return to step 19.
	b. Wide range temperatures - DECREASING	b. IF NOT decreasing, THEN return to step 19.

(1) Enter plant specific value corresponding to RWST switchover alarm in plant specific units.

STEP	ACTION/EXPECTED RESPONSE	RESPONSE NOT OBTAINED
21	**Check For Adequate Secondary Heat Sink:**	
	a. Narrow range level in at least one intact steam generator - GREATER THAN (1) %	a. IF less than (1) %, THEN return to step 19.
	b. RCS subcooling based on core exit TCs - GREATER THAN (2) °F	b. IF less than (2) °F, THEN return to step 19.
22	**Isolate RCS Bleed Path:**	
	a. Monitor and record core exit TC baseline temperatures	
	b. Close all pressurizer PORVs	
	c. Compare core exit TC temperature increase to baseline - INCREASE LESS THAN 15°F	c. IF increase greater than 15°F, THEN reopen all pressurizer PORVs and return to step 19.

NOTE *It may be necessary to modify subsequent diagnostic and recovery guidance to account for plant conditions resulting from actions performed in this guideline.*

STEP	ACTION/EXPECTED RESPONSE	RESPONSE NOT OBTAINED
23	**Check If SI Can Be Terminated:**	
	a. RCS pressure - INCREASES BY AT LEAST 200 PSIG	a. DO NOT TERMINATE SI. Go to E-0, REACTOR TRIP OR SAFETY INJECTION, STEP 29.
	b. Pressurizer level - GREATER THAN 50%	b. DO NOT TERMINATE SI. Go to E-0, REACTOR TRIP OR SAFETY INJECTION, STEP 29.
	c. RCS subcooling - GREATER THAN (2) °F	c. DO NOT TERMINATE SI. Go to E-0, REACTOR TRIP OR SAFETY INJECTION, STEP 29.

(1) Enter plant specific value showing level just in narrow range including allowances for normal channel accuracy, post-accident transmitter errors and reference leg process errors.

(2) Enter sum of temperature and pressure measurement system errors translated into temperature using saturation tables.

STEP	ACTION/EXPECTED RESPONSE	RESPONSE NOT OBTAINED
24	**Terminate SI:** a. Go to ES-2.1, SI TERMINATION FOLLOWING LOSS OF SECONDARY COOLANT	

—END—

BACKGROUND INFORMATION FOR
WESTINGHOUSE
EMERGENCY RESPONSE GUIDELINES

FR-H.1
RESPONSE TO LOSS OF
SECONDARY HEAT SINK

REVISION: HP-BASIC
SEPTEMBER 1, 1982

FR-H.1

RESPONSE TO LOSS OF

SECONDARY HEAT SINK

CONTENTS

1.0 INTRODUCTION

Guideline FR-H.1, Response to Loss of Secondary Heat Sink, is a Function Restoration Guideline within the Emergency Response Guideline (ERG) set. It is one of five guidelines that address challenges to the Heat Sink critical safety function. Guideline FR-H.1 provides guidance to address an extreme priority (i.e. red) challenge to secondary heat sink that results from the potential loss of secondary inventory in all steam generators. Less severe challenges to the Heat Sink critical safety function that result from secondary inventory concerns on individual steam generators are discussed in the background information documents for guidelines FR-H.3, Response to Steam Generator High Level, and FR-H.4, Response to Steam Generator Low Level.

The objective of guideline FR-H.1 is to maintain reactor coolant system (RCS) heat removal through maintaining secondary heat removal capability or through establishing RCS bleed and feed heat removal if secondary heat removal capability cannot be maintained. Guideline FR-H.1 is structured to be entered at the first indication that secondary heat removal capability is in jeopardy. This permits maximum time for operator action to restore feedwater flow to one or all steam generators before secondary inventory is depleted and heat removal capability is lost. Once secondary heat removal capability is lost, RCS bleed and feed must be established to minimize core uncovery and prevent inadequate core cooling.

The first sign that secondary heat transfer capability is in jeopardy is that auxiliary feedwater (AFW) flow is not available to any steam generator. Following a reactor trip or safety injection (SI) actuation, main feedwater isolation is automatically actuated. Auxiliary feedwater flow to the steam generators must be automatically or manually actuated in order to maintain adequate secondary inventory for secondary heat removal capability. Consequently, the loss of AFW flow is utilized to

detect the loss of secondary heat sink challenge to the Heat Sink critical safety function. When this extreme priority challenge is detected, the operator is directed to immediately implement guideline FR-H.1.

Entry into guideline FR-H.1 may occur from several sources within the ERG set. Following a reactor trip without automatic SI actuation, guideline FR-H.1 may be entered from step 2 of Guideline ES-0.1, Reactor Trip Recovery. Following a reactor trip with automatic SI actuation, guideline FR-H.1 may be entered from Step 15 of Guideline E-0, Reactor Trip or Safety Injection. In both cases, the subject steps direct the operator to guideline FR-H.1 if AFW flow cannot be verified. Other possible entry sources are the Heat Sink critical safety function status tree and the foldout page of various optimal recovery guidelines. These sources ensure continuous monitoring of the plant safety state and direct the operator to guideline FR-H.1 if AFW flow is lost as a result of equipment failures subsequent to the initiating event.

Guideline FR-H.1 may be exited at several locations depending on the status of secondary heat sink and whether RCS bleed and feed heat removal is initiated. In general, the operator is directed to the optimal recovery guideline in effect if secondary heat sink is restored before RCS bleed and feed heat removal is initiated. If RCS bleed and feed heat removal is initiated, the operator is directed to Step 29 of guideline E-0 or Step 1 of guideline ES-2.1, SI Termination following Loss of Secondary Coolant, following restoration of secondary heat sink and termination of RCS bleed and feed heat removal. The transitions and interactions of guideline FR-H.1 are described in detail in Section 3.0

2.0 DESCRIPTION OF EVENT

A loss of secondary heat sink transient can result from a loss of all feedwater initiating event (i.e. loss of all main feedwater with AFW flow unavailable) or can occur in combination with other plant emergency events (i.e. reactor trip or SI condition with AFW flow unavailable).

The loss of heat sink transient is characterized by depletion of secondary inventory and degradation of secondary heat transfer capability. As secondary heat transfer capability degrades, core decay heat will increase RCS temperature and pressure until the pressurizer power operated relief valves (PORVs), if available, or pressurizer safety valves open to relieve the increasing RCS pressure. At this point a small loss of reactor coolant will exist. If operator action is not taken, the pressurizer PORVs or safety valves will cycle open and closed at their setpoint pressure removing RCS mass inventory and a limited amount of core decay heat until sufficient mass is removed to uncover the core. If the loss of secondary heat sink transient results from loss of main feedwater with AFW flow unavailable or from a reactor trip with AFW flow unavailable, the transient will not result in automatic SI actuation.

The loss of secondary heat sink transient resulting from the loss of all feedwater initiating event is the basis for the generic analyses that have been performed to evaluate the RCS bleed and feed recovery technique. To establish a reference for a description of the RCS bleed and feed recovery technique, a description of the loss of all feedwater transient without operator action is included herein. This transient description is followed by a description of RCS bleed and feed recovery.

2.1 Loss of All Feedwater

The loss of all feedwater transient begins with loss of all main feedwater. The steam generator water levels rapidly decrease since steam is still flowing to the turbine without being replaced. The secondary

pressure and secondary fluid temperature increase rapidly since the cooling effect of the subcooled feedwater has been lost. The reduction in primary to secondary heat transfer caused by the reduction in primary to secondary temperature difference causes the RCS pressure and temperatured to increase. The RCS fluid is forced to absorb some of the full core power since the degrading secondary conditions reduce the heat transfer capability in the steam generators. The resultant temperature increase will swell the RCS fluid causing a surge into the pressurizer raising its level. This initial pressurization and heatup are terminated when the reactor and turbine trip on the coincident signals from feed flow-steam flow mismatch and low steam generator water level. This early, short-lived phase is characterized as a power pressurization since the reactor core remains at full power for about 16 seconds after main feedwater is lost.

After the trip, the RCS pressure and hot leg temperature immediately drop. The pressurizer surge line mass flow rate reverses and mass flows out of the pressurizer reducing the level as the RCS fluid cools and shrinks. Although not as rapidly as before trip, the steam generator levels continue to fall as steam continues to be generated and relieved either by the steam dump system or through the steam generator safety valves. Makeup by the AFW pumps is assumed to be unavailable.

The initial RCS depressurization after reactor trip gives way to a quasi-steady state period characterized by core decay heat energy removal through the steam generators. As mass is depleted through the steam dumps or the steam generator safety valves, the steam generators will slowly dry out. During this period the RCS pressure and temperature will be relatively constant as the steam generator level decreases slowly and begins uncovering the tubes. There will still be sufficient secondary heat removal capability even with a portion of the tubes uncovered to maintain relatively stable RCS conditions.

When approximately 70 percent of the tubes are uncovered, the primary to secondary heat transfer will degrade enough that the RCS will begin a gradual heatup. The rate will slowly increase as the steam generators approach dry out. Fluid swell due to the heatup will be reflected in an increasing pressurizer surge line mass flow and the RCS pressure is expected to increase to the pressurizer PORV pressure setpoint at this time. [It should be noted that computer models used for this transient calculate a decrease in RCS pressure during this period. This is due to the model assumption of an equilibrium pressurizer model. During each time step the model computes the mass flow into or out of the pressurizer. With an equilibrium model assumption, the steam and liquid masses are determined by homogenizing the mass and energy over the entire pressurizer volume. The subcooled fluid surging into the pressurizer will tend to lower the pressurizer temperature and pressure since the mass averaged internal energy will be reduced. The internal energy of the pressurizer volume is used to determine the saturation pressure and since it is decreasing pressure will also be calculated to decrease. Thus, the equilibrium pressurizer model tends to indicate a reduction in RCS pressure as the RCS heats up and subcooled mass surges into the saturated pressurizer volume. Realistically, the pressurizer is a highly non-equilibrium fluid volume and when the subcooled fluid surges into the pressurizer it is expected to compress the steam space with only a limited amount of steam condensation. Therefore, the RCS pressure would be expected to increase steadily to the pressurizer PORV setpoint pressure as a reflection of the RCS heatup.]

Once the steam generators dry out, the secondary will no longer be capable of RCS heat removal and the core decay heat will virtually all go into raising the RCS fluid temperature through sensible heat absorption. The pressurizer PORVs will cycle open and closed to relieve enough mass to maintain RCS pressure at their setpoints.

If operator action is not taken, the system will continue in this mode until saturation temperature is reached in the core. The core decay heat will no longer be removed as sensible heat, and will instead be removed from the fuel rods as latent heat through steam void production in the core. Steam will continue to be generated and eventually a significant and prolonged core uncovery will occur. An automatic SI actuation will not occur, but even if manually actuated will not be very effective at this high RCS pressure condition.

Even the minimum capacity pressurizer PORVs are calculated to be large enough to compensate for the increasing specific volume of the RCS fluid while it is still subcooled. Therefore, the RCS pressure is not expected to rise to the safety valve setpoint since the intermittent pressurizer PORV discharge will exceed the fluid swell. Once the RCS nears saturation and boiling begins, the pressurizer PORVs may not be large enough to compensate for the greater specific volume increases and the RCS pressure may start to rise towards the pressurizer safety valve setpoint pressure. If this happens, the pressurizer PORVs will be effectively maintained continuously open.

In summary, the loss of secondary heat sink transient without operator action will lead to a loss of reactor coolant through the pressurizer PORVs without automatic SI actuation. Core uncovery will result at an RCS pressure equal to the pressurizer PORV setpoint or greater and SI capability, even if manually actuated, will be severely limited.

2.2 RCS Bleed and Feed Recovery

Following the loss of secondary heat sink, operator action to establish RCS bleed and feed heat removal can prevent or minimize core uncovery. To establish RCS bleed and feed heat removal, the operator must initiate high-pressure SI flow to feed subcooled fluid to the RCS and open all pressurizer PORVs to bleed hot reactor coolant out of the RCS.

The effectiveness of RCS bleed and feed heat removal depends on four basic considerations. These are (1) the time at which RCS bleed and feed is initiated following degradation of secondary heat transfer capability, (2) the core decay heat at the time of RCS bleed and feed initiation, (3) the capacity of the pressurizer PORVs (i.e. number and size of valves), and (4) the capacity of the high-pressure SI system (i.e. number and size of high pressure SI pumps). The first three considerations govern the RCS depressurization, repressurization and pressure stabilization during RCS bleed and feed heat removal. The fourth consideration governs the amount of SI flow delivered to the RCS at existing RCS pressures. RCS bleed and feed effectiveness is maximized by a combination of these considerations that maximize initial RCS depressurization, minimize subsequent RCS repressurization and pressure stabilization point, and maximize SI flow to the RCS at existing RCS pressures.

Generic analyses have been performed to evaluate these considerations in support of the RCS bleed and feed recovery technique. A summary description of the plant transient and a description of the generic transient analyses follow.

Transient Description

RCS bleed and feed heat removal is initiated as soon as possible after RCS pressure and temperature start to increase due to loss of secondary heat removal capability. Maximum SI flow is initiated and all pressurizer PORVs are opened when the core fluid temperature is still subcooled. This will result in rapid RCS depressurization as the pressurizer steam bubble and saturated liquid are quickly vented and a large subcooled liquid flow is established through the pressurizer PORVs. The core fluid temperature when the pressurizer PORVs are opened will govern the degree of depressurization since the RCS pressure will decrease until saturation is reached at the hotest point in the system.

After saturation pressure is reached in the core the RCS will begin to heat up as the energy addition and volume swell due to core decay heat generation exceeds the energy and volume removal capability of the pressurizer PORVs. The flow of subcooled liquid through the pressurizer PORVs will not remove enough volume to make up for the system swell so that RCS pressure will continue to rise until a balance between pressurizer PORV volume flow and system swell is reached. At that point, the pressure will stabilize until either a change to steam flow out the pressurizer PORVs increases the volume removal rate or the core uncovers reducing the core steam generation rate. This RCS repressurization and pressure stabilization point will depend on the core decay heat level, the pressurizer PORV capacity and the SI system capacity. All pressurizer PORVs should be held open to minimize this RCS repressurization and pressure stabilization point.

During the pressure stabilization period, all pressurizer PORVs should be maintained open and all high pressure SI pumps should continue to run to maximize RCS feed flow. Even with SI feed flow maximized, RCS net inventory will continue to decrease resulting in an eventual emptying of the reactor vessel upper head and a drain down to the hot leg elevation. At that time, steam will begin to be vented out through the hot leg to the pressurizer. When the quality of the bleed flow increases to a large fraction of steam, the RCS pressure will begin to decrease rapidly. This pressure decrease will permit an important increase in SI flow to prevent or minimize core uncovery. As core decay heat generation continues to decrease with time, the energy removal capability of the pressurizer PORVs will start to exceed the energy addition due to core decay heat. This will be accompanied by increasing net inventory in the RCS.

Transient Analyses

Generic analyses have been performed to evaluate the time at which RCS bleed and feed must be initiated to prevent sustained core uncovery. These analyses have been performed for the range of pressurizer PORV

capacities and core power levels existing in Westinghouse plants. A convenient way to categorize the relationship of pressurizer PORV capacity to core power level is the pressurizer PORV flow to rated core power ratio. These analyses indicate that plants with charging/SI pumps can delay the time at which RCS bleed and feed is initiated until secondary heat removal capability starts to degrade. Once this degradation is detected, RCS bleed and feed should be initiated as soon as possible to maximize its effectiveness. The time available to initiate RCS bleed and feed to prevent a sustained core uncovery depends on the pressurizer PORV flow to core power ratio. The larger this ratio the more time available to initiate RCS bleed and feed to prevent sustained core uncovery.

Detailed analyses and descriptions of RCS bleed and feed heat removal are provided in WCAP-9600 (Report on Small Break Accidents for Westinghouse NSSS Systems), WCAP-9744 (Loss of Feedwater Induced Loss of Coolant Accident Report) and WCAP-9914 (PORV Sensitivity Study for LOCW-LOCA Analyses). WCAP-9914 utilizes an improved model to predict required pressurizer PORV opening times to prevent sustained core uncovery following a loss of all feedwater event for a range of pressurizer PORV flow to core power ratios. This WCAP should be utilized to determine plant-specific pressurizer PORV opening requirements.

Three cases from WCAP-9914 are included at the end of this section to illustrate plant response to RCS bleed and feed heat removal. Cases 1 and 2 show plant response to opening the pressurizer PORVs (flow to core power ratio of 157.77 (lb/hr)/MWt) at 1700 seconds and 2100 seconds, respectively. Case 3 shows plant response to opening pressurizer PORVs (flow to core power ratio of 79.55 (lb/hr)/MWt) at 1700 seconds. All cases show that core uncovery is minimized and eventually recovered through RCS bleed and feed operation. Cases 1 and 2 can be compared to observe the effect of the RCS bleed and feed initiation time on plant

parameters. Cases 1 and 3 can be compared to observe the effect of pressurizer PORV capacity on plant parameters. The following plant parameters are included for each case.

a. RCS Hot Leg Fluid Temperature
b. RCS Cold Leg Fluid Temperature
c. RCS Pressure
d. Pressurizer Mixture Level
e. Core Mixture Level
f. Steam Generator Pressure
g. Steam Generator Mixture Level

The generic analyses are based on a 4-loop, 3411 MWt plant and assume minimum safeguards flow (i.e. one charging/SI pump and one high head SI pump) with no spilling lines and subcooled SI temperature of 100°F. Although not evaluated in the generic analyses, increased SI flow capacity through the operation of all high pressure SI pumps (i.e. two charging/SI pumps and two high-head SI pumps) will increase RCS bleed and feed effectiveness by providing increased SI flow at existing RCS pressures. Safety injection system flow capacity is important for two basic reasons. First, cold SI water has available heat capacity to absorb some quantity of heat in reaching the average RCS temperature. This initial subcooling helps to reduce the repressurization rate and the point of pressure stabilization. Second, SI water replaces the mass lost out through the open pressurizer PORVs and helps prevent or decrease the severity of any core uncovery.

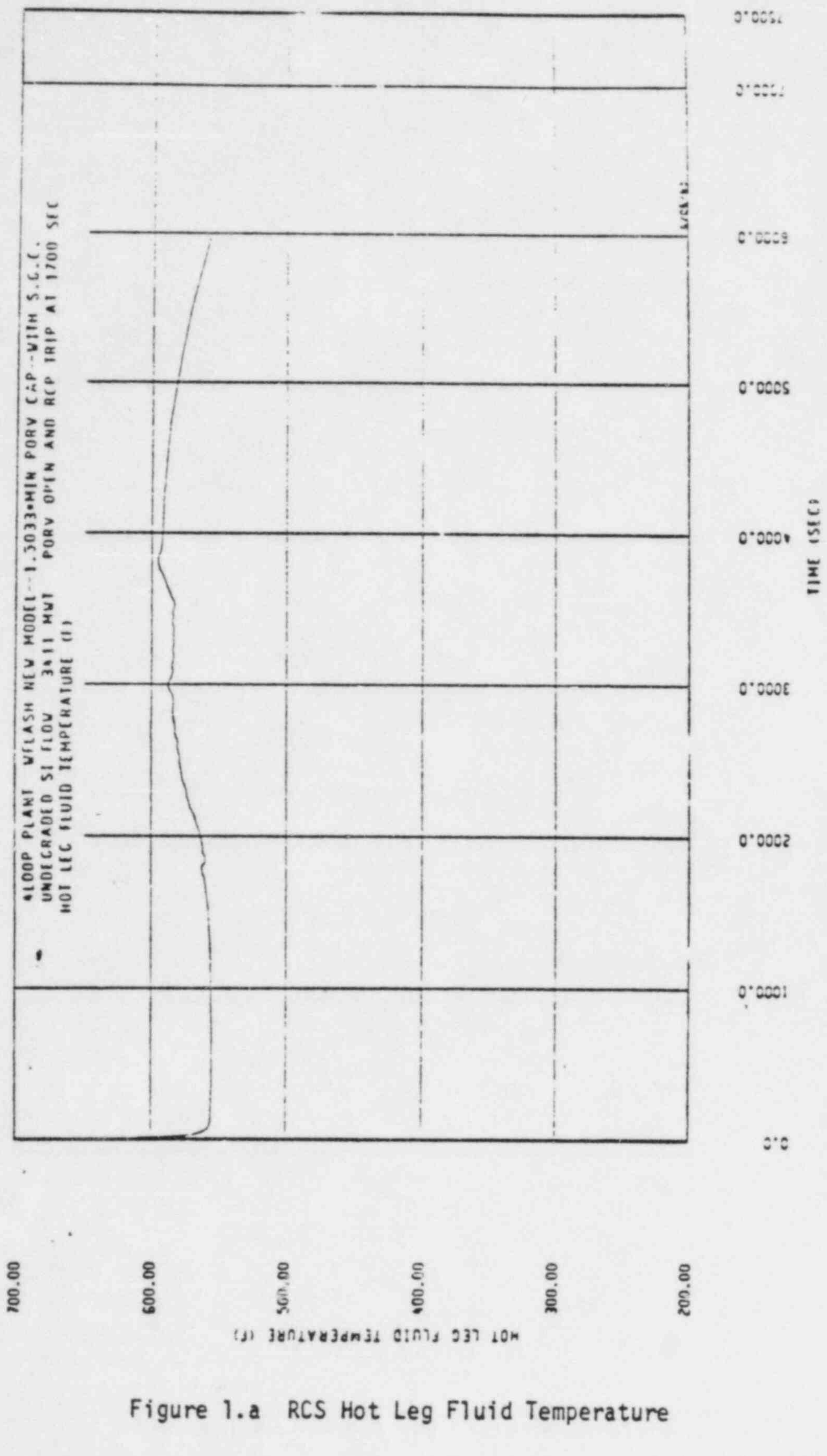


Figure 1.a RCS Hot Leg Fluid Temperature

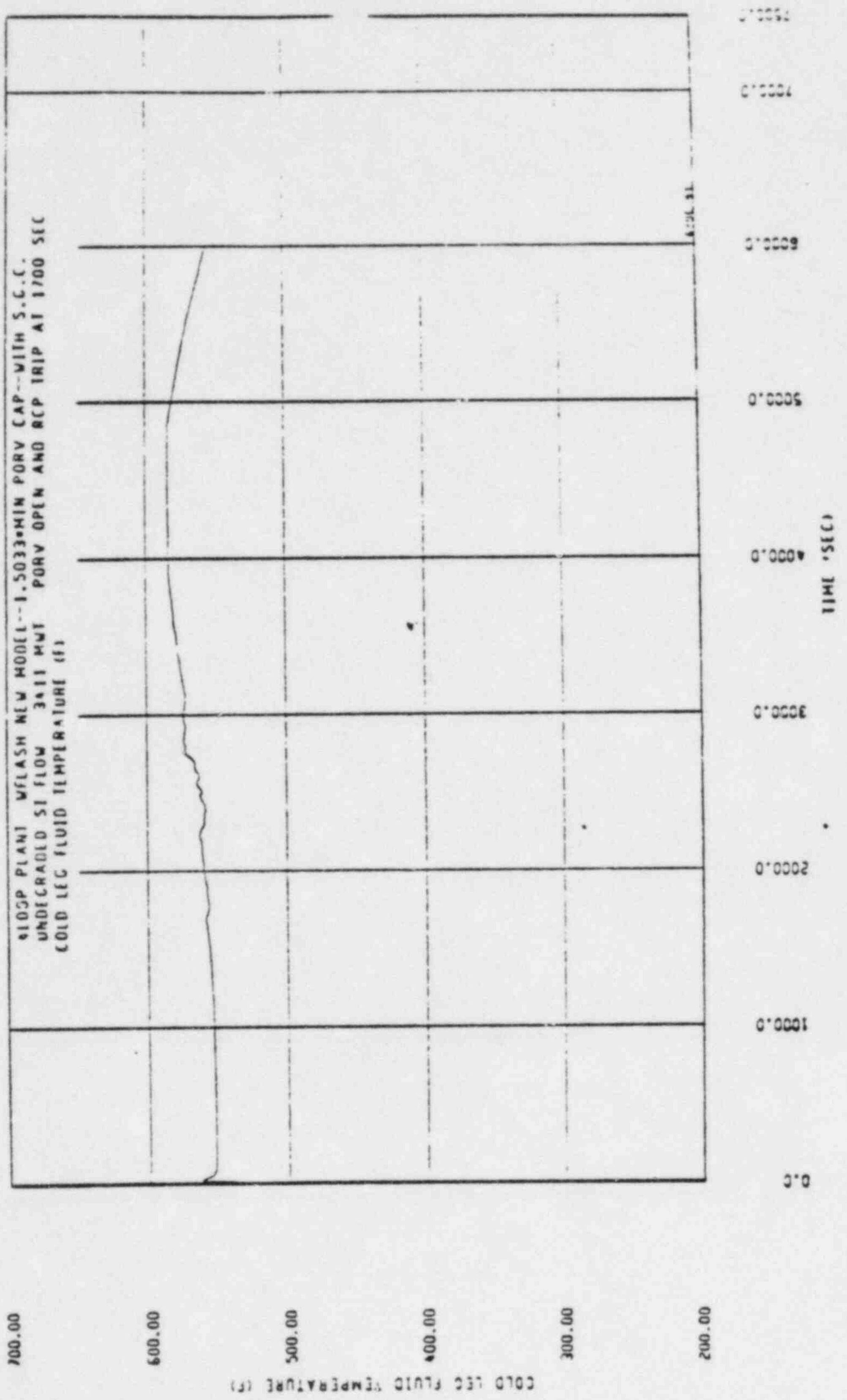


Figure 1.b RCS Cold Ley Fluid Temperature

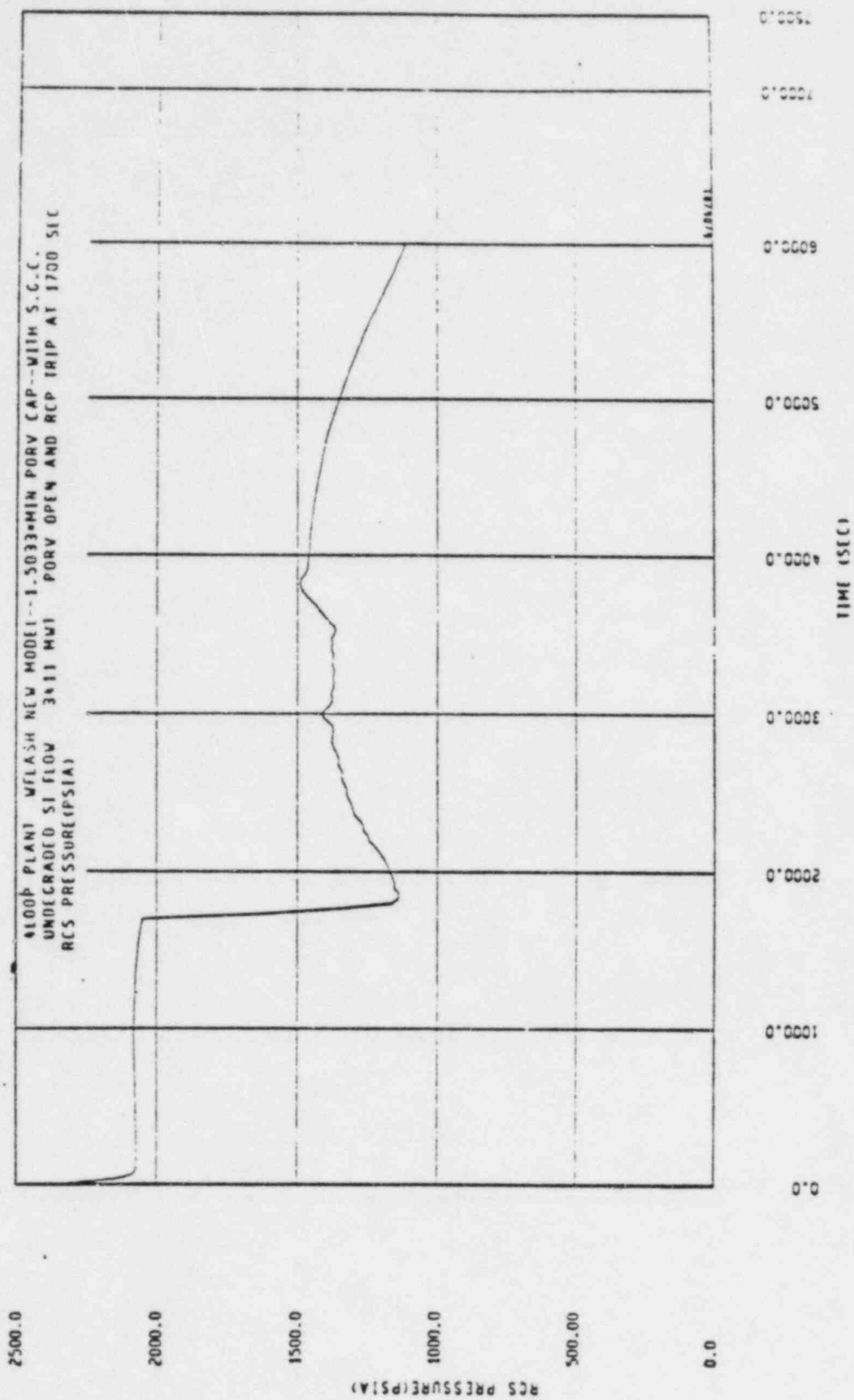


Figure 1.c RCS Pressure

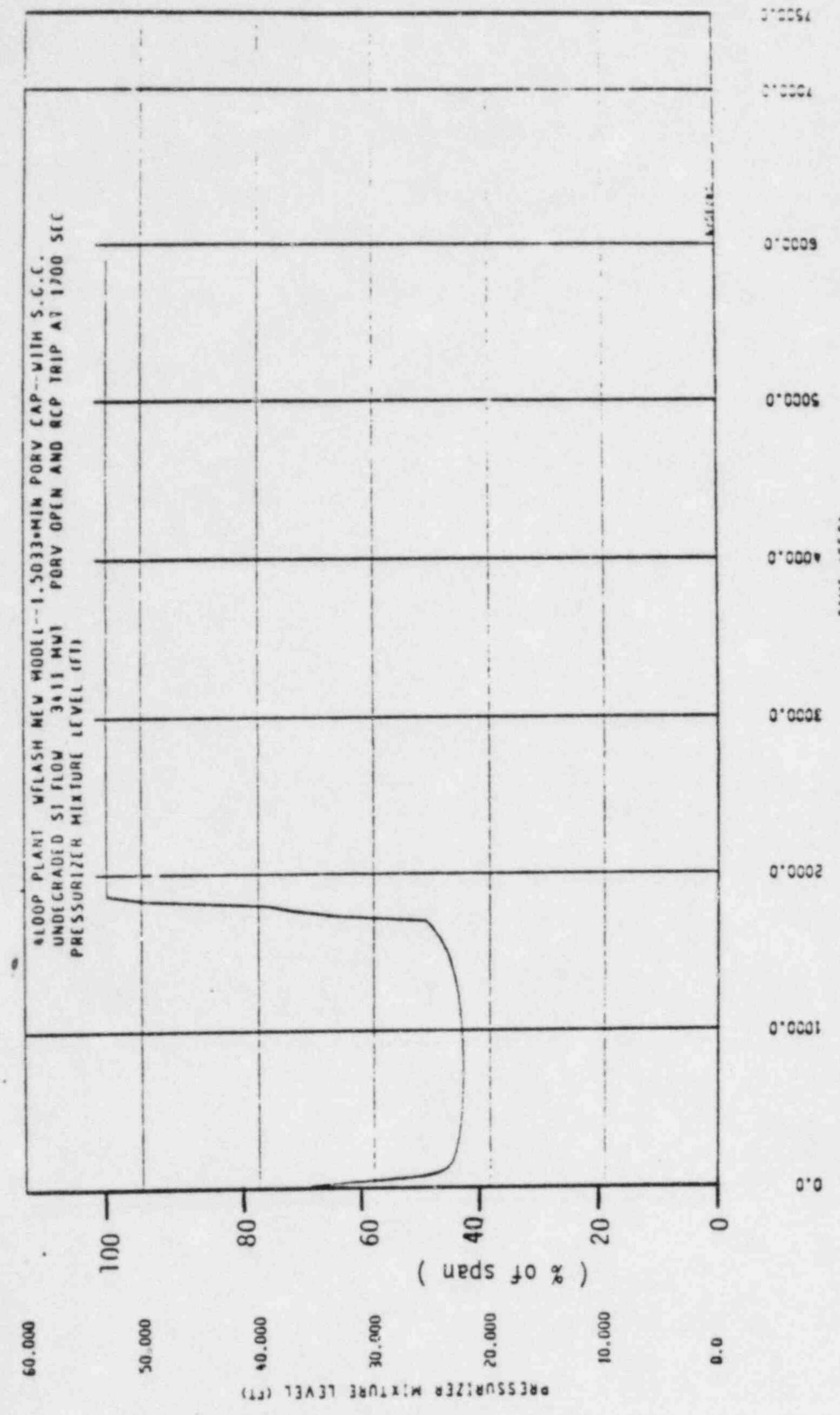


Figure 1.d Pressurizer Mixture Level

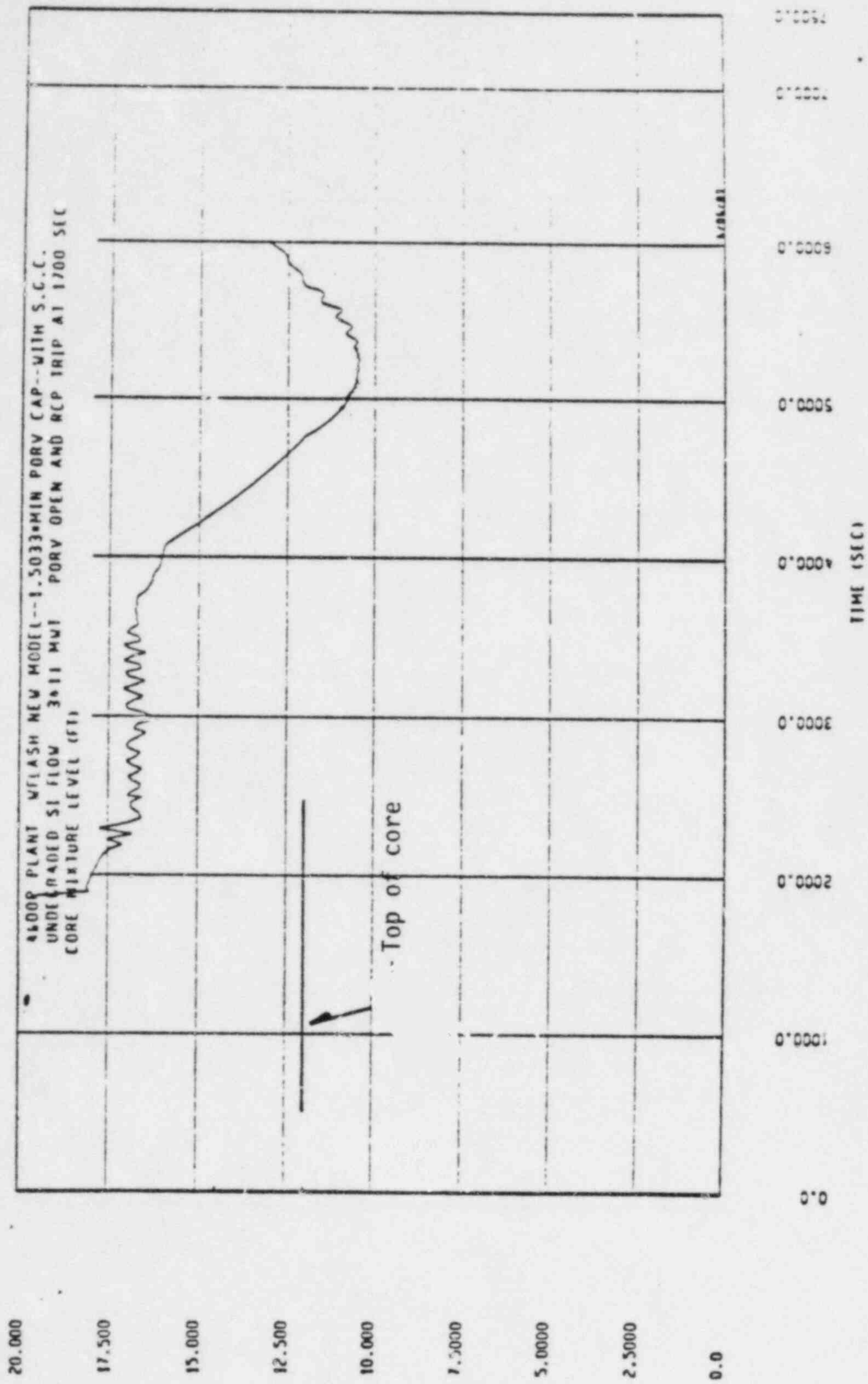


Figure 1.e Core Mixture Level

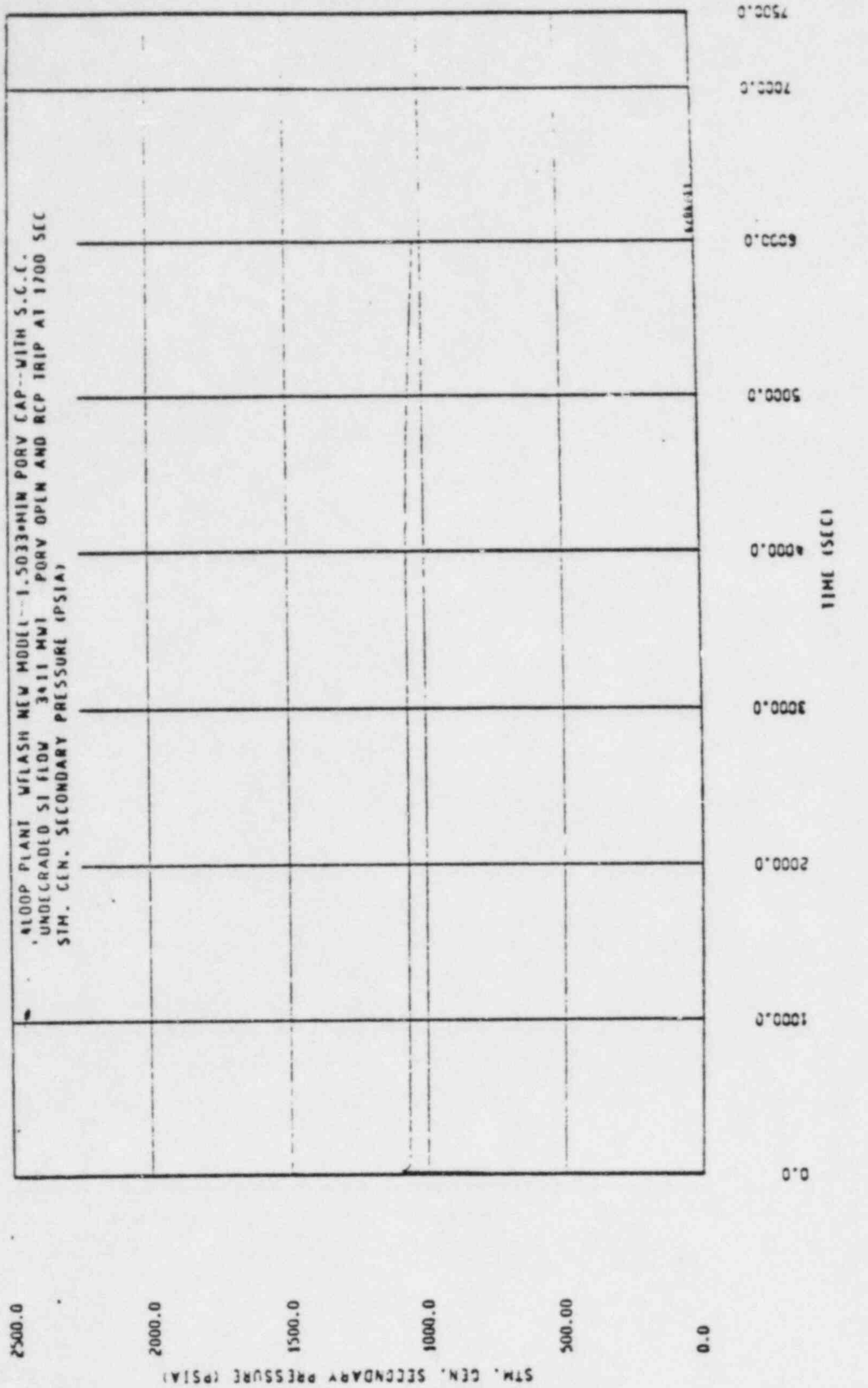


Figure 1.f Steam Generator Pressure

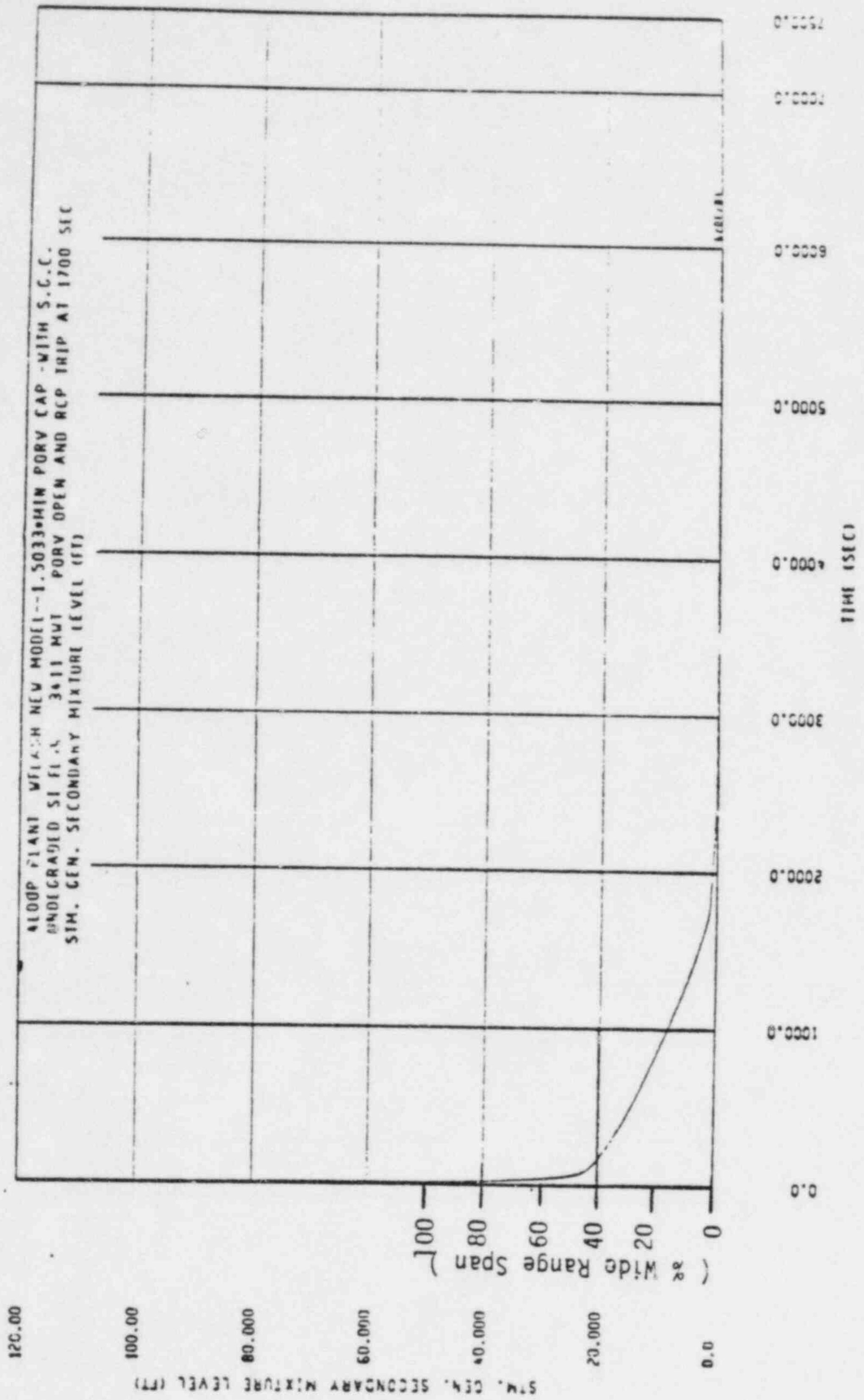


Figure 1.g Steam Generator Mixture Level

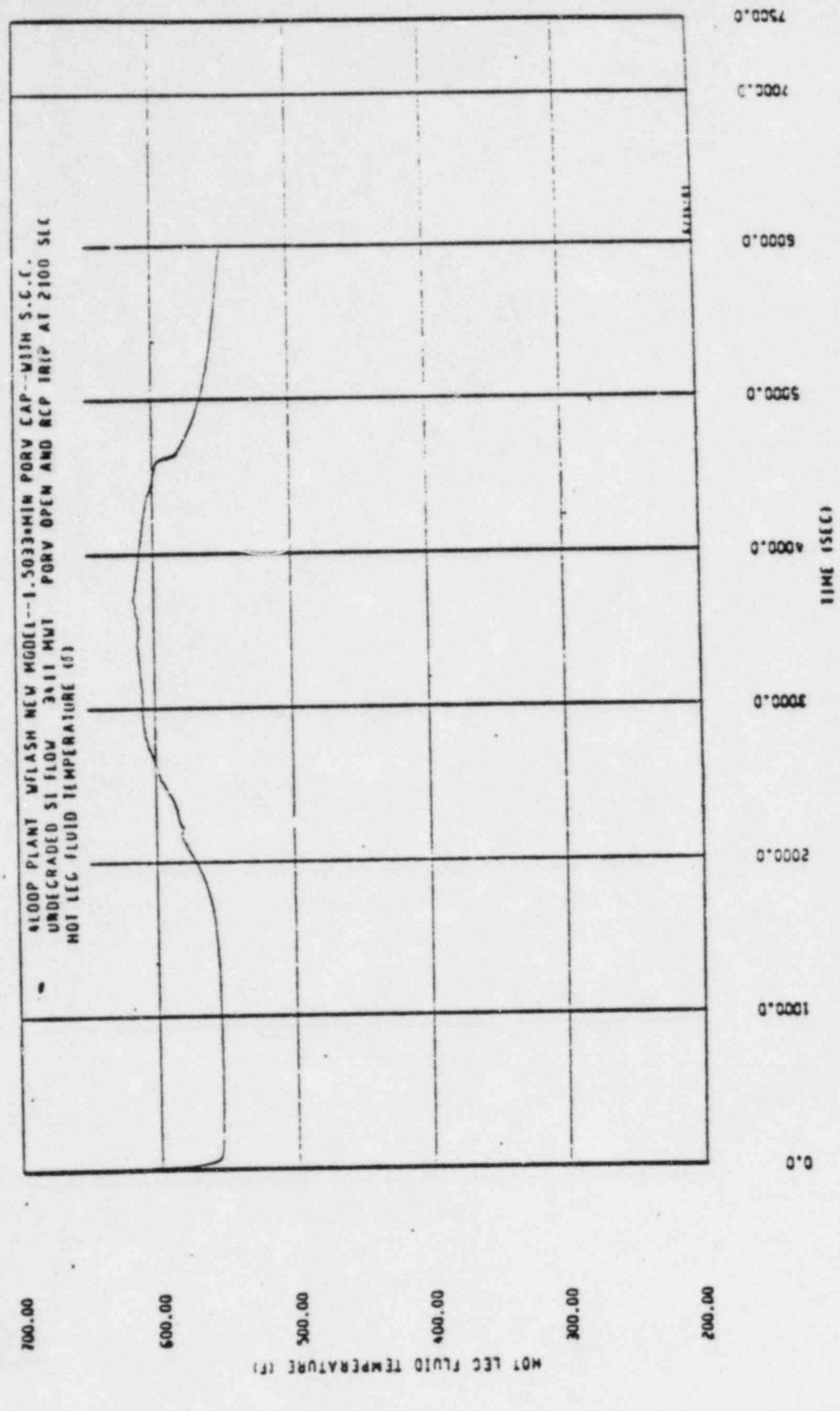


Figure 2.a RCS Hot Leg Fluid Temperature

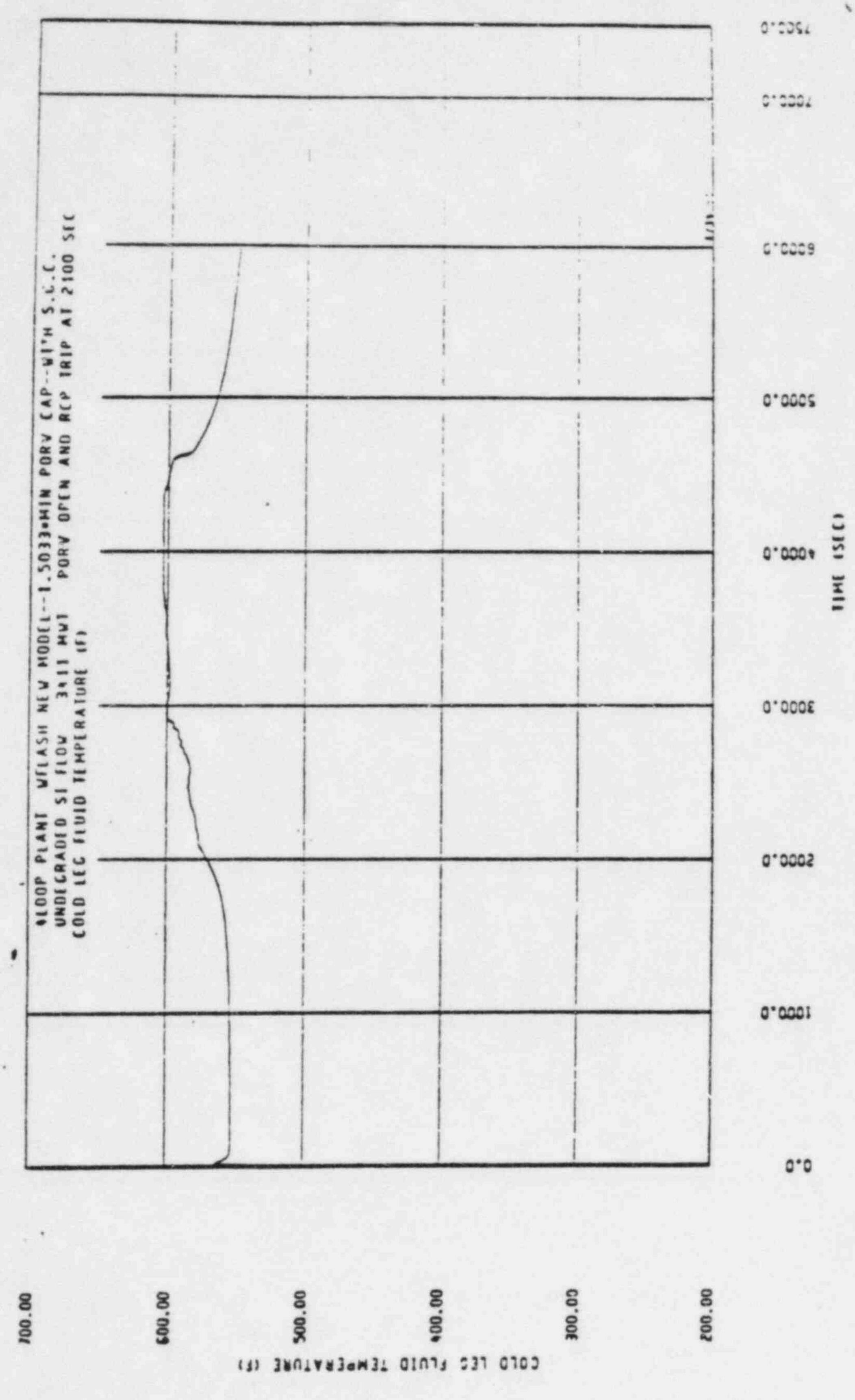


Figure 2.b RCS Cold Leg Fluid Temperature

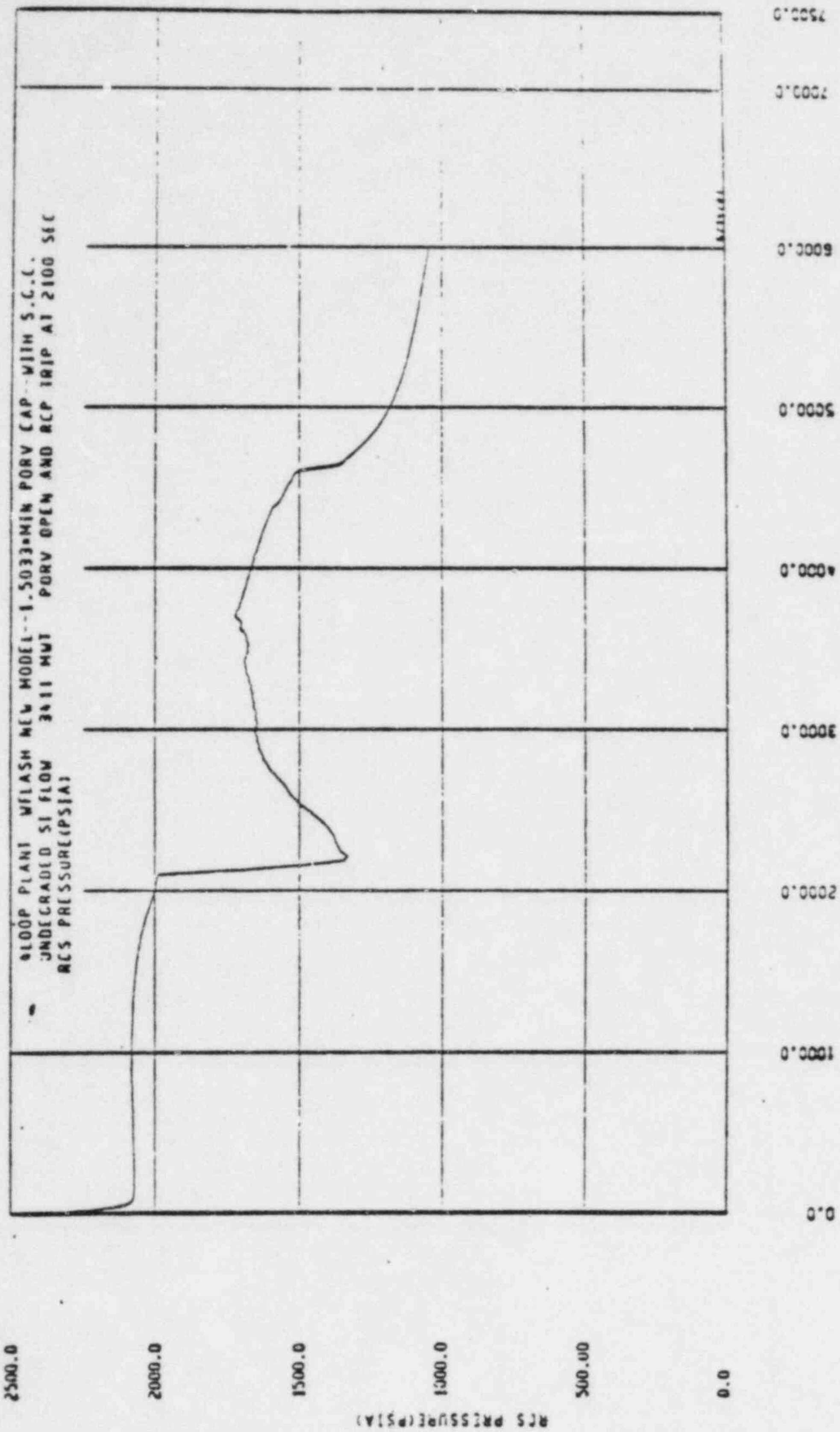


Figure 2.c RCS Pressure

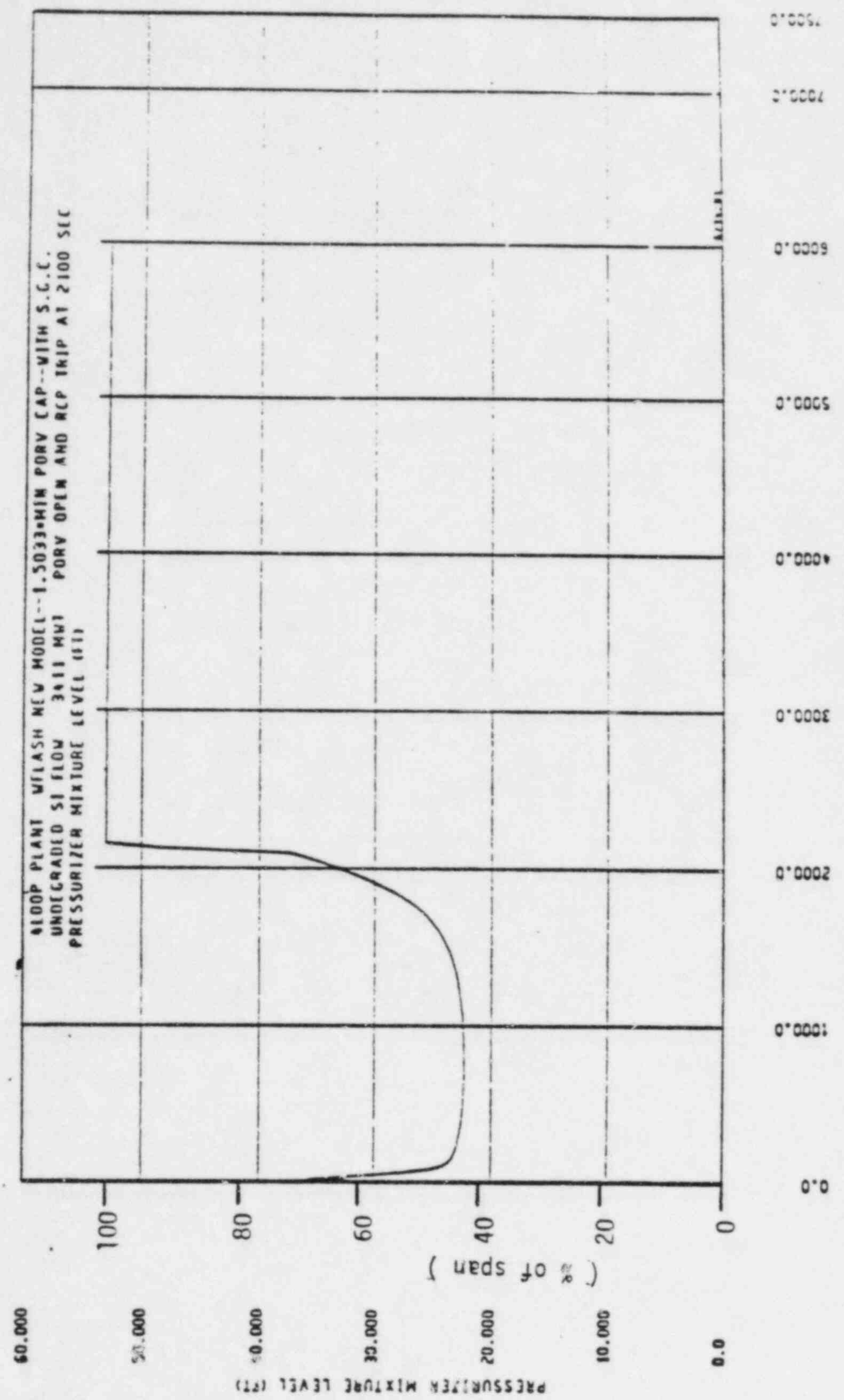


Figure 2.d Pressurizer Mixture Level

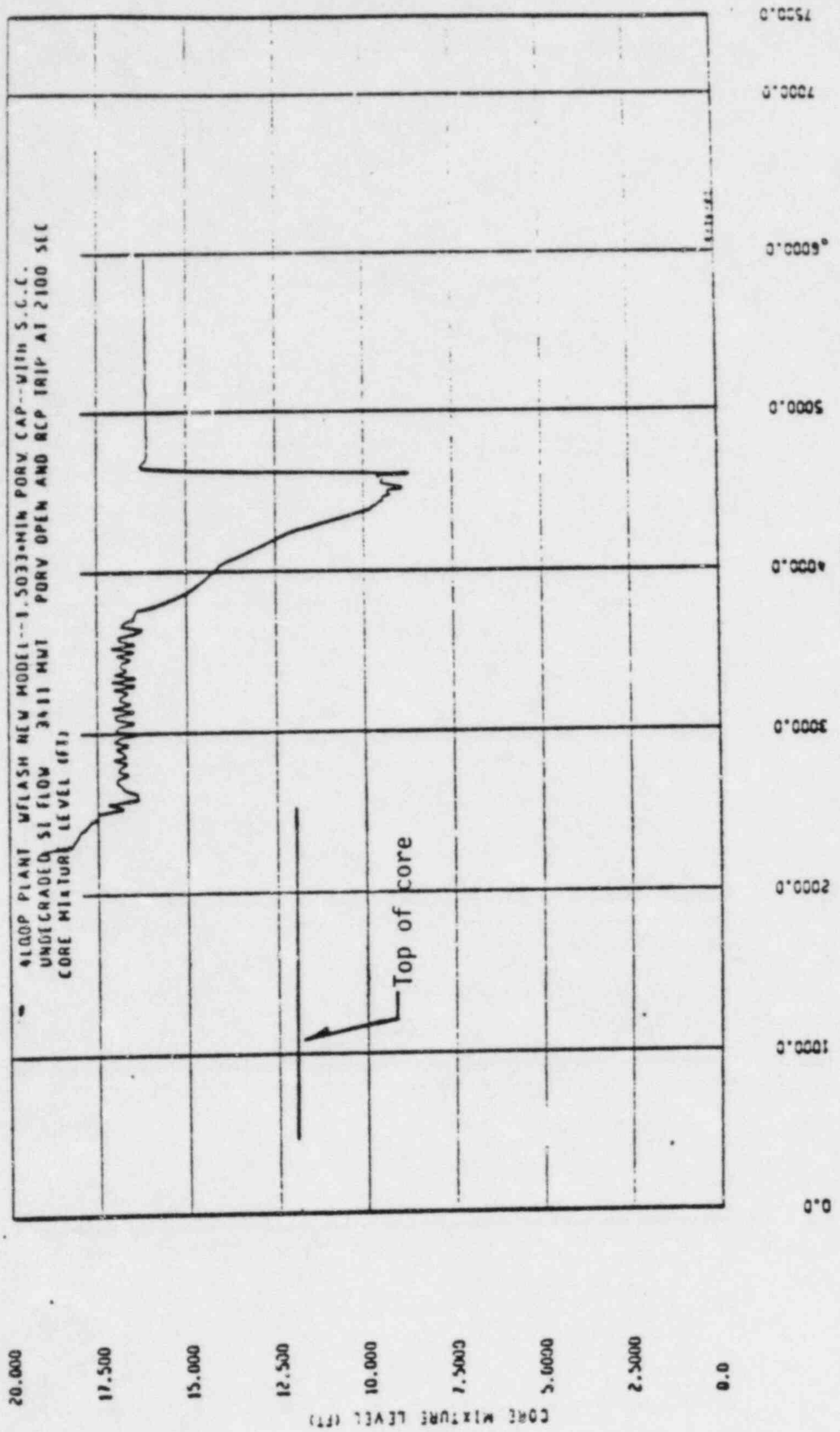


Figure 2.e Core Mixture Level

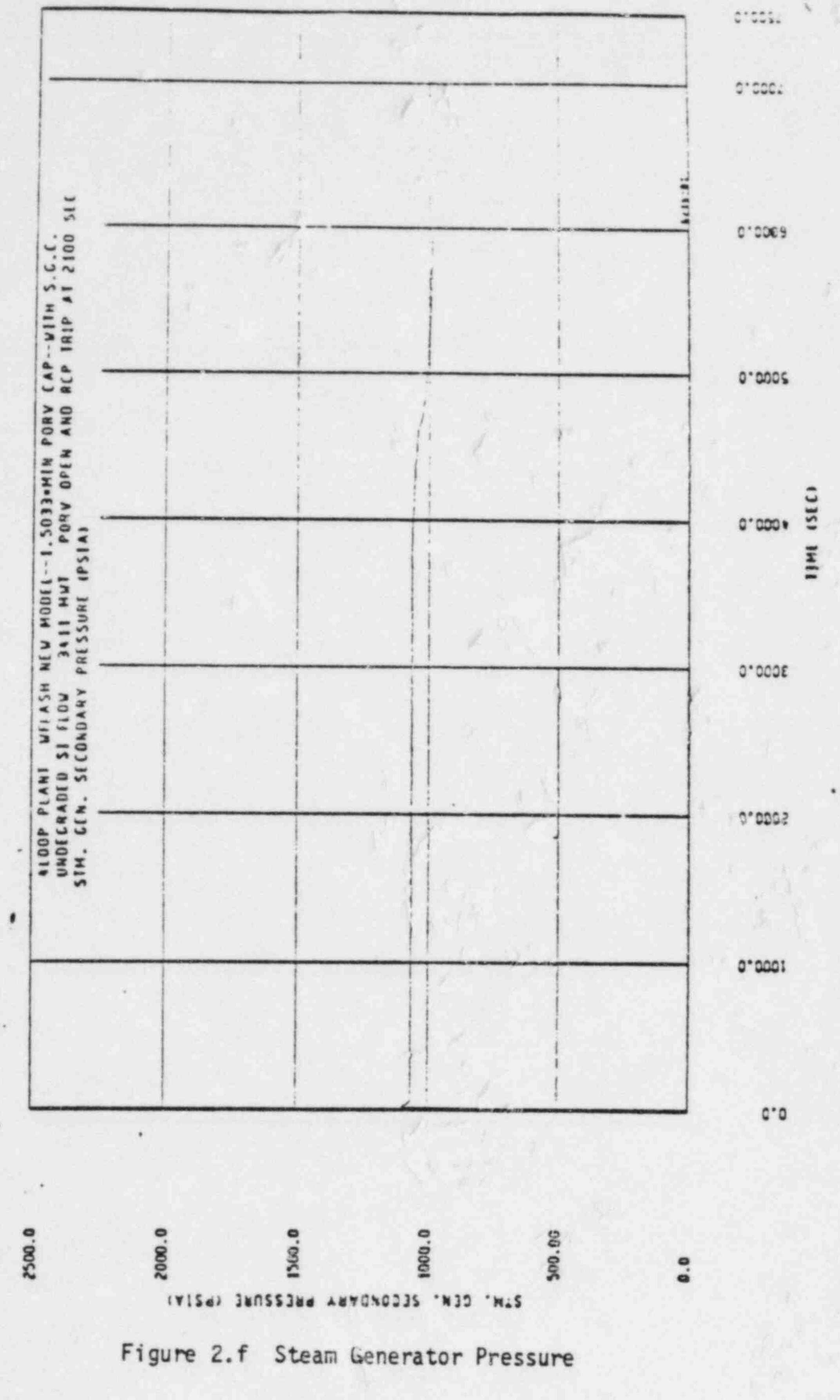


Figure 2.f Steam Generator Pressure

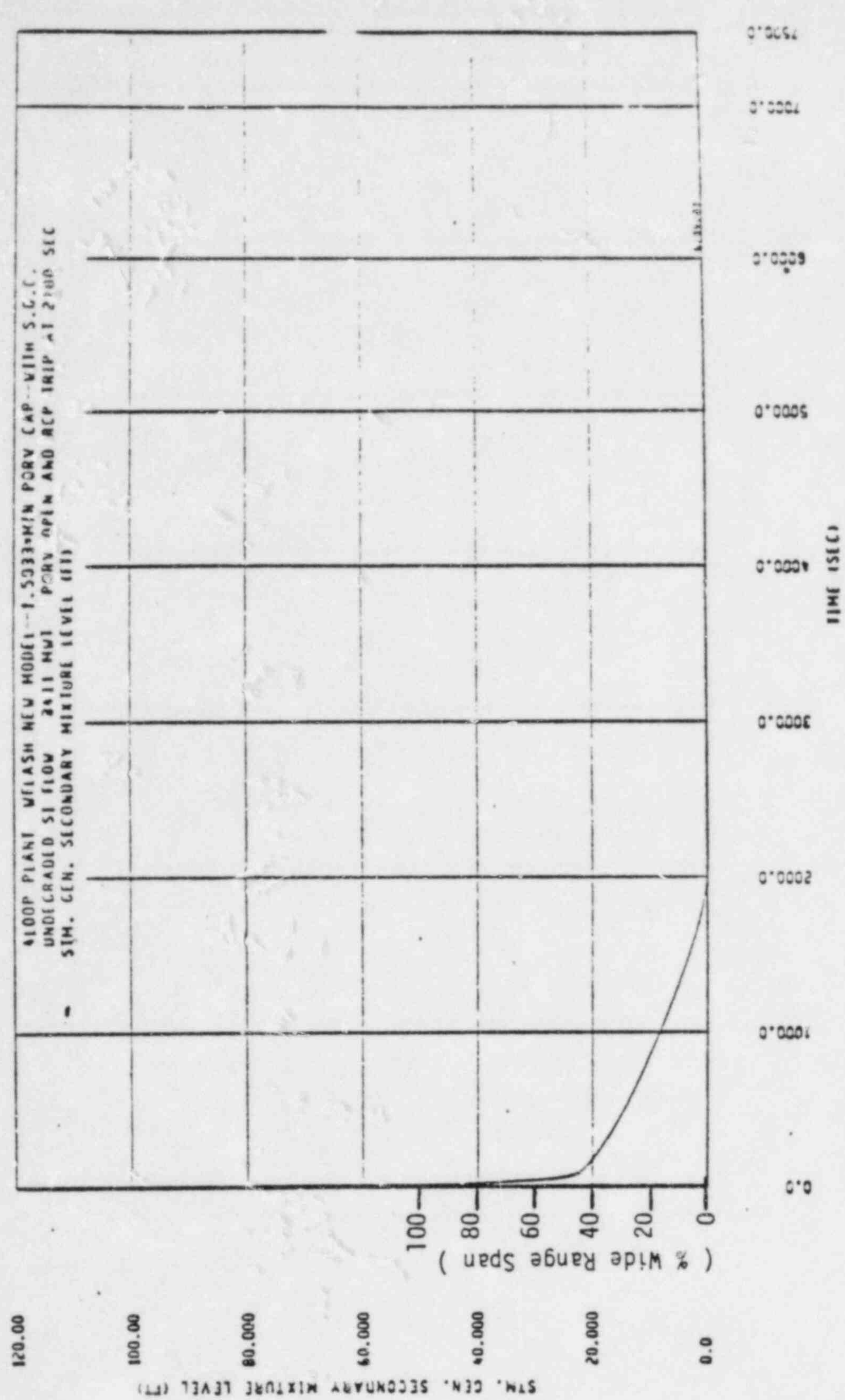


Figure 2.g Steam Generator Mixture Level

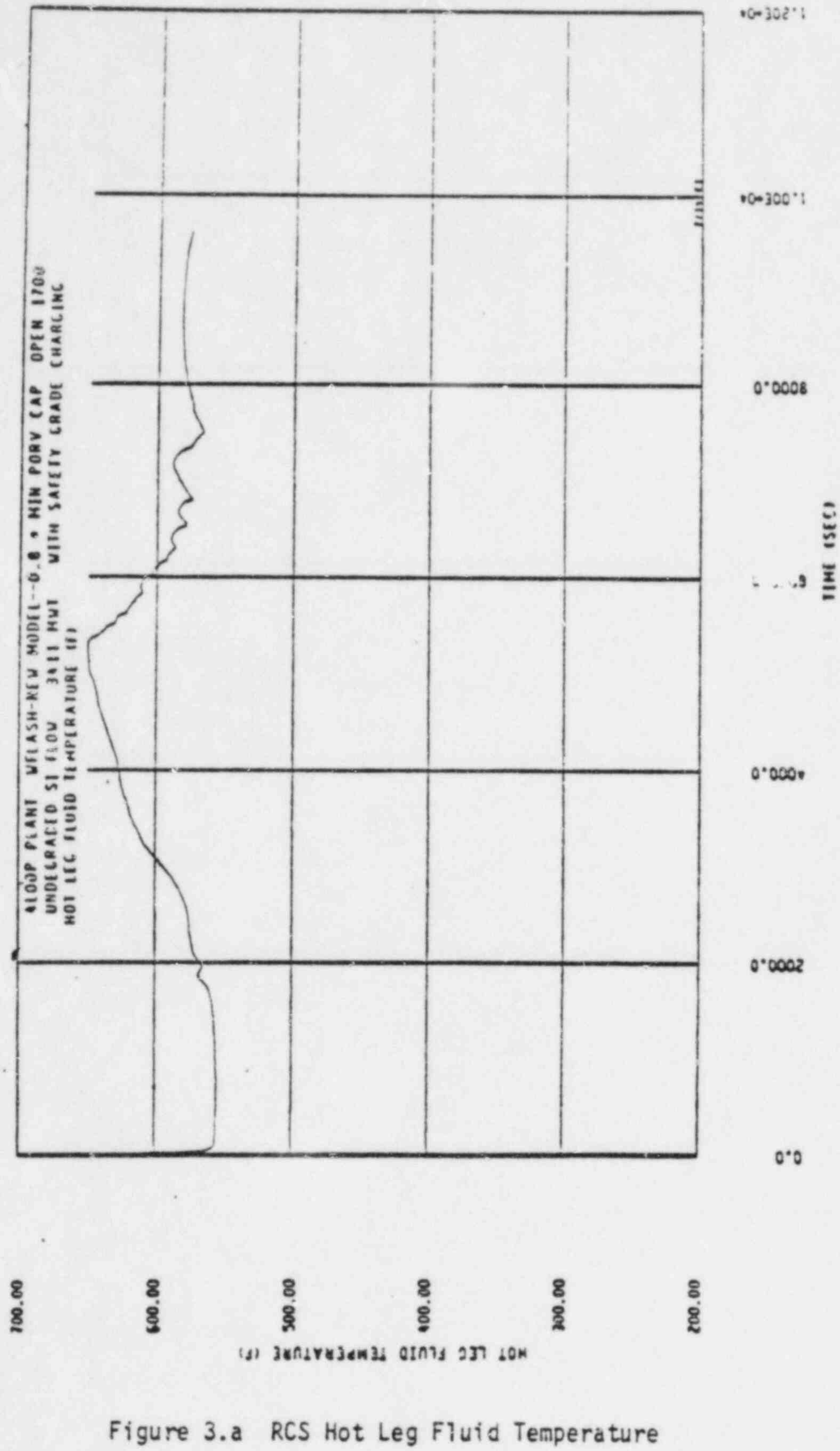


Figure 3.a RCS Hot Leg Fluid Temperature

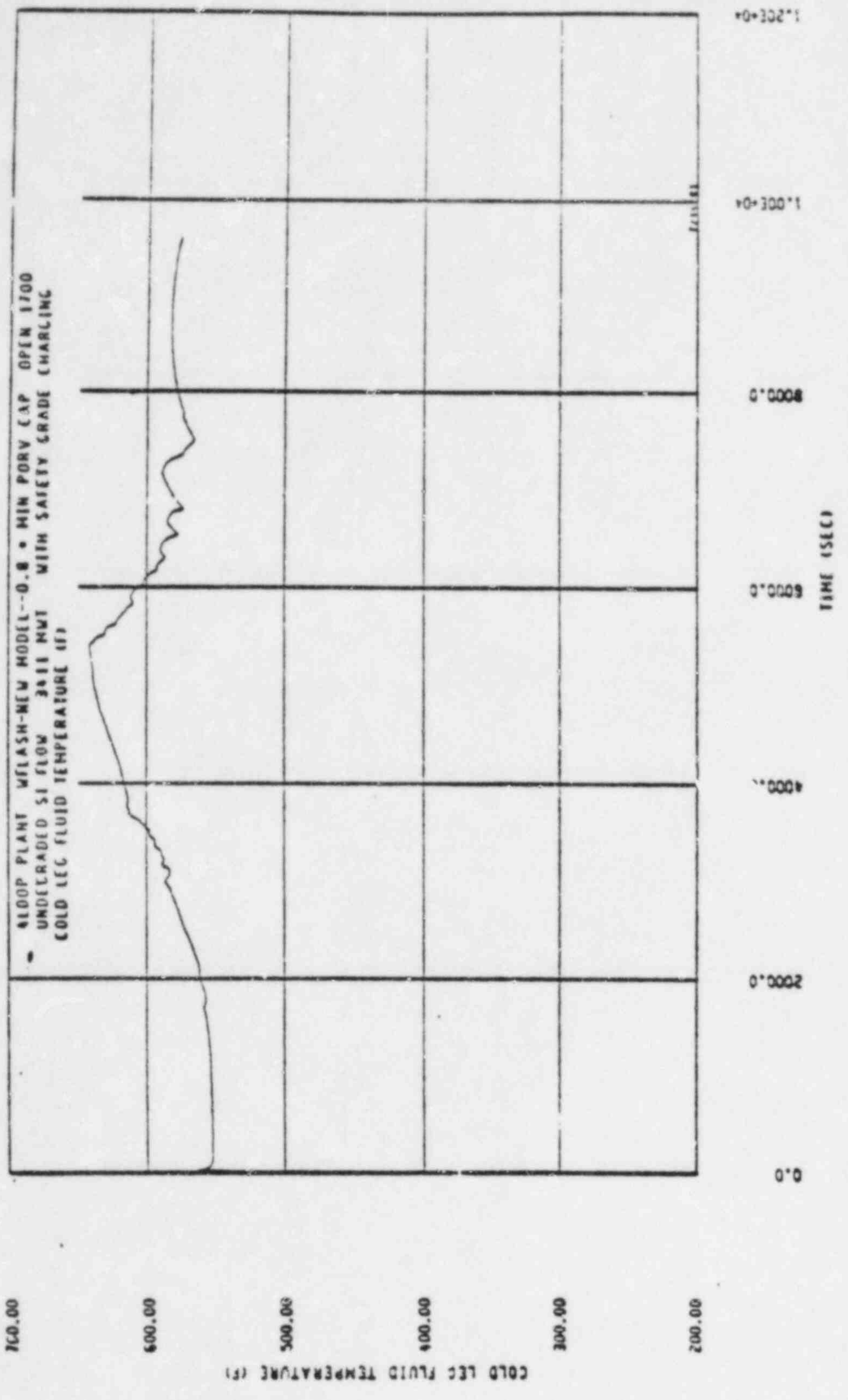


Figure 3.b RCS Cold Leg Fluid Temperature

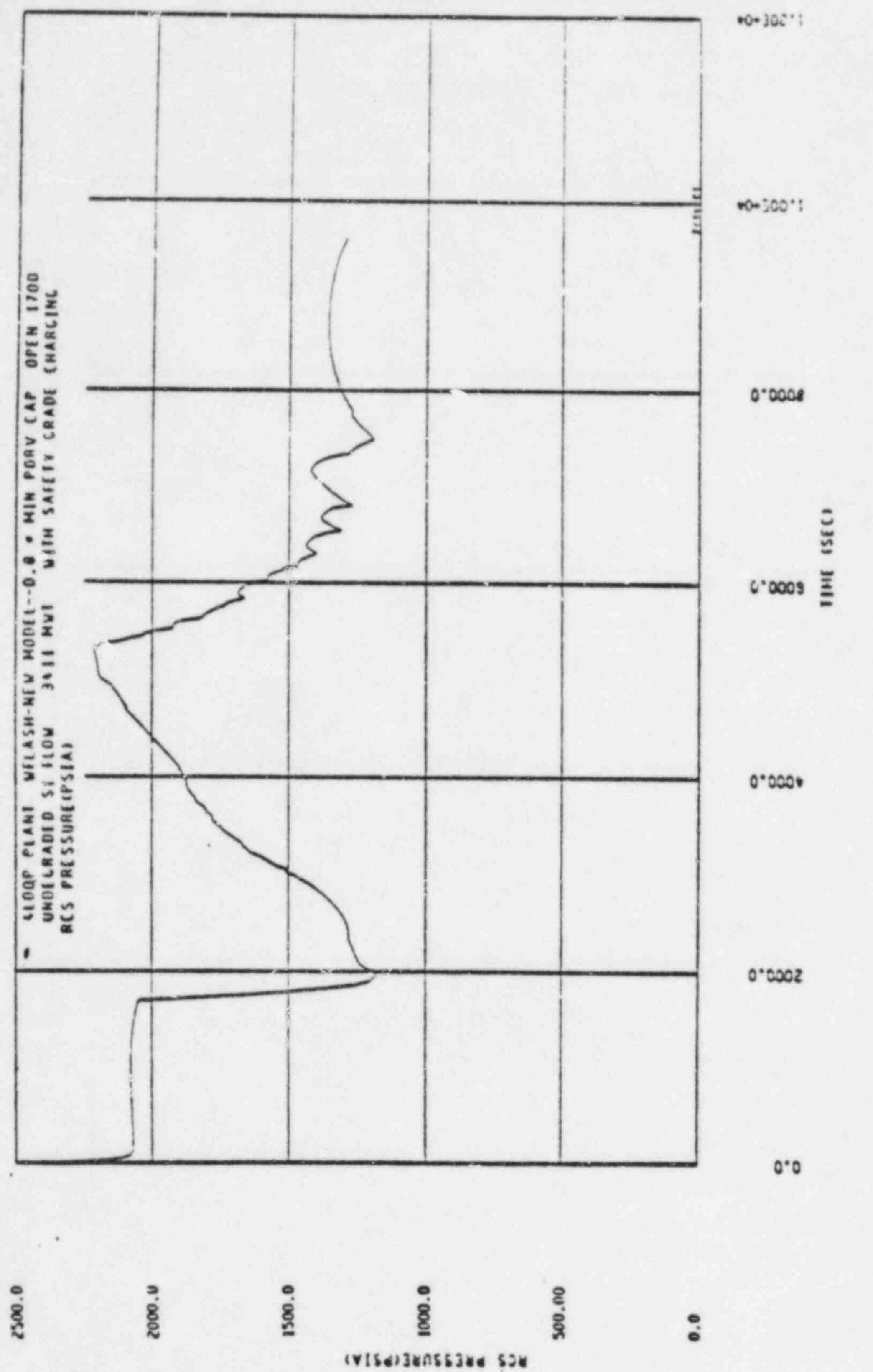


Figure 3.c RCS Pressure

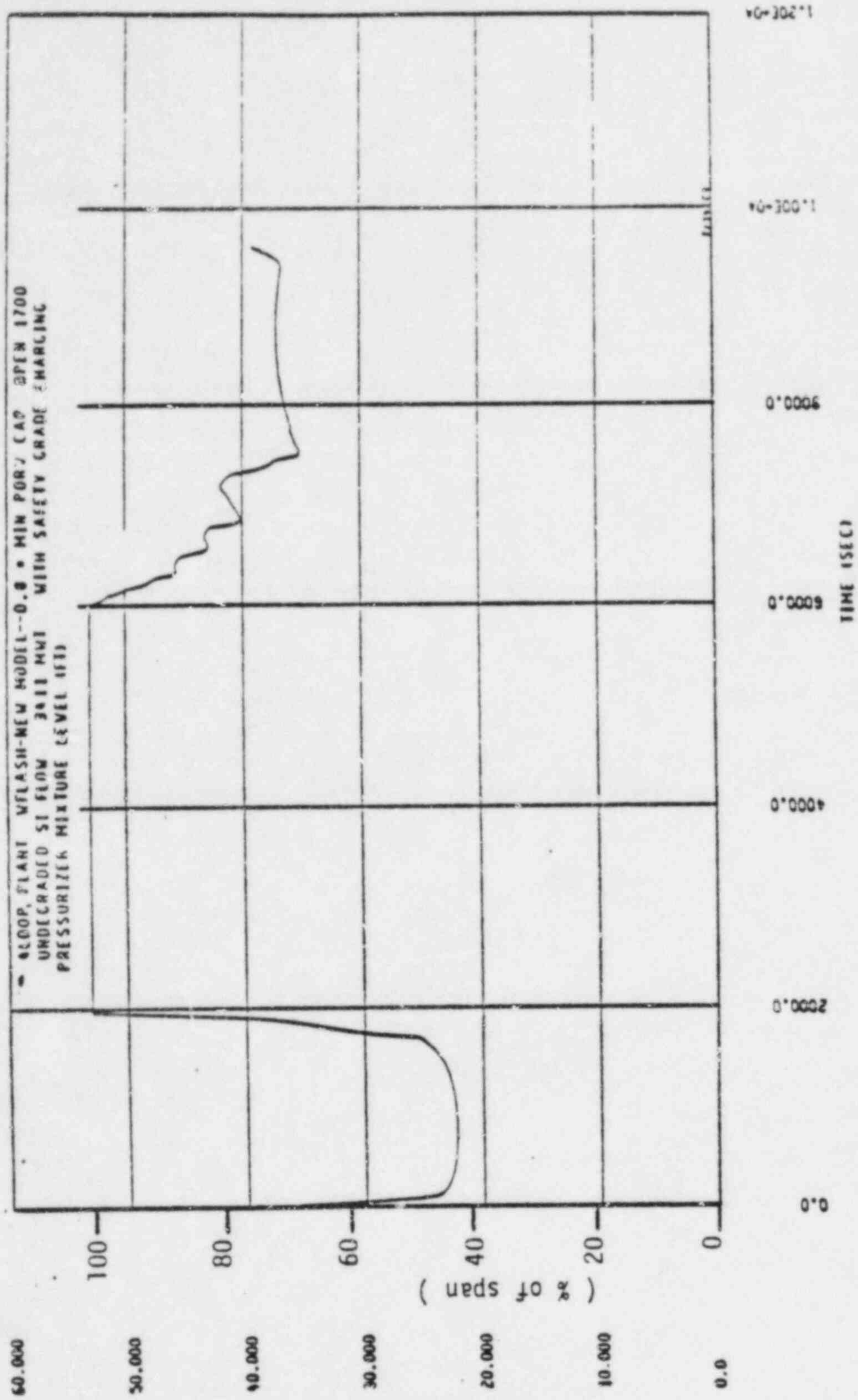


Figure 3.d Pressurizer Mixture Level

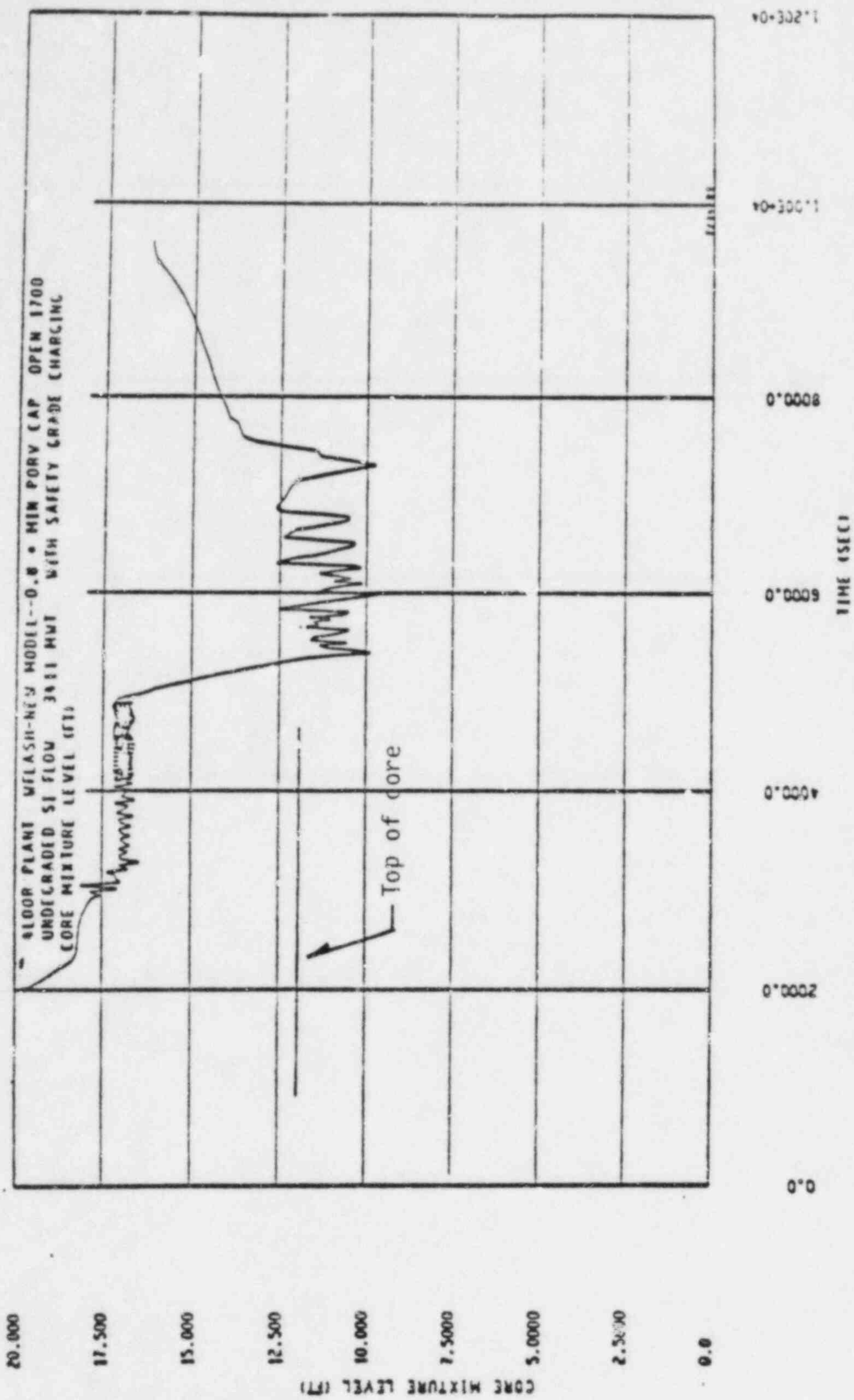


Figure 3.e Core Mixture Level

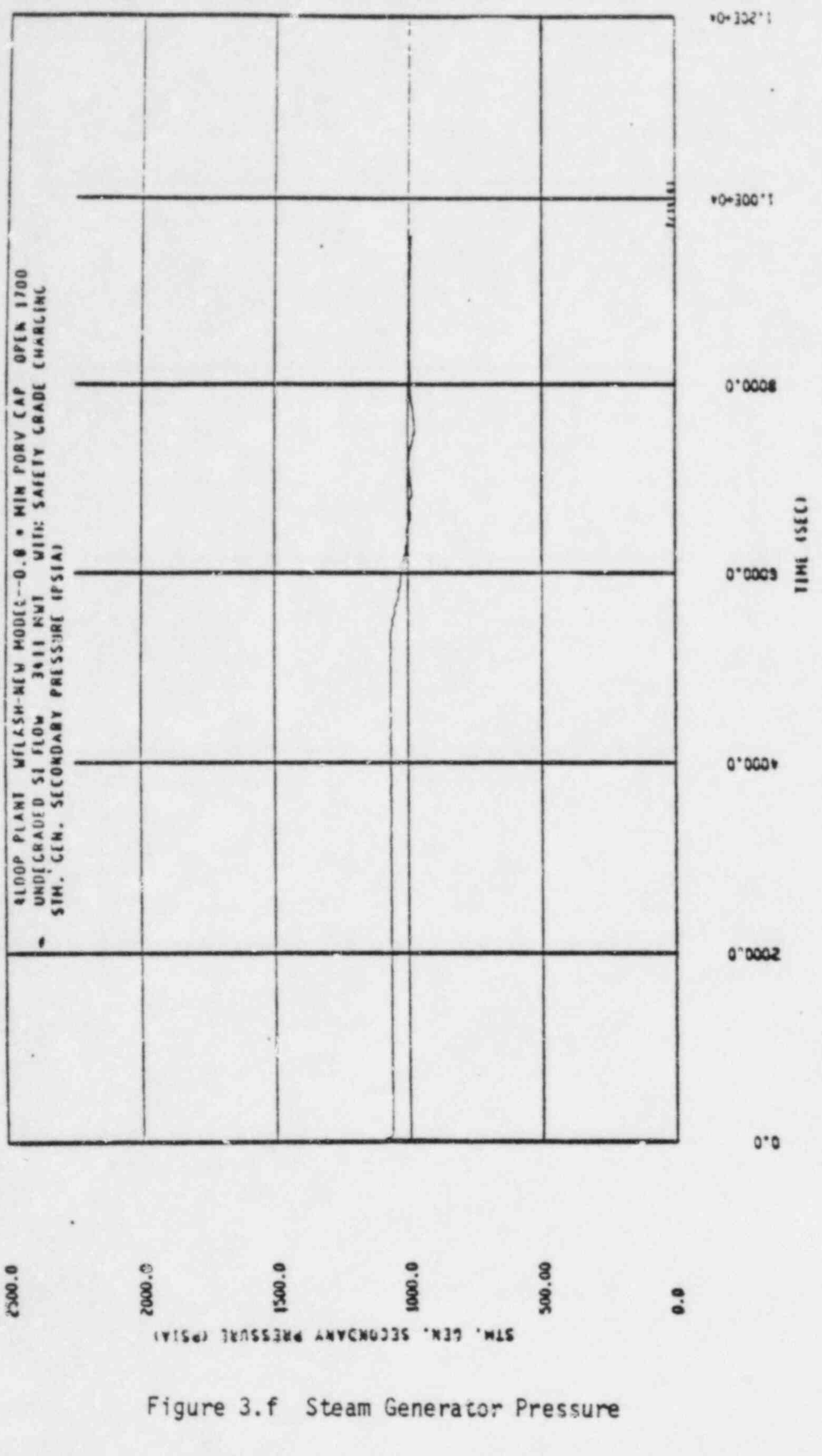


Figure 3.f Steam Generator Pressure

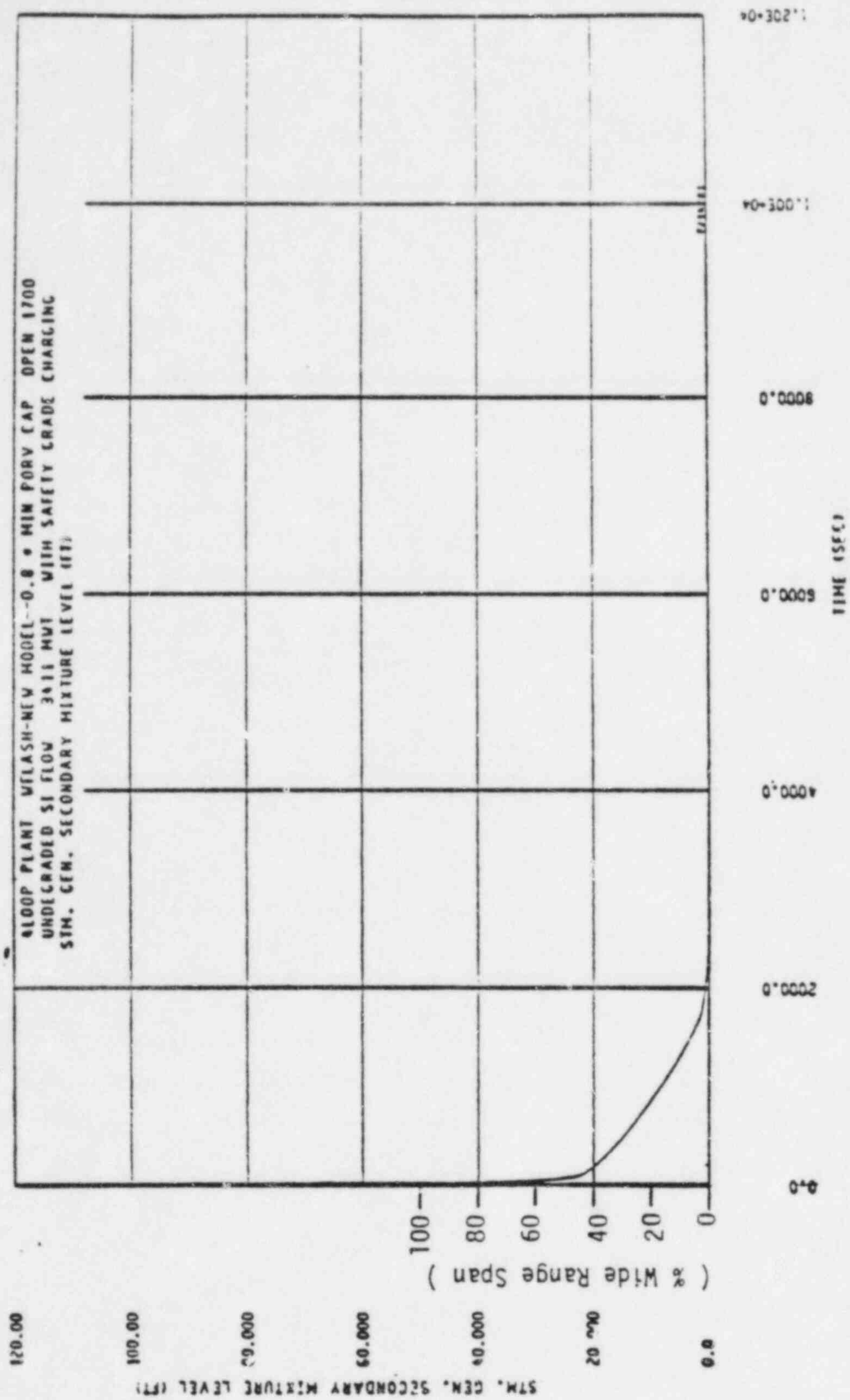


Figure 3.g Steam Generator Mixture Level

3.0 DESCRIPTION OF RECOVERY TECHNIQUE

Following detection of the loss of all AFW flow, the operator is directed to immediately implement guideline FR-H.1. Guideline entry may come from step 15 of guideline E-0, step 2 of guideline ES-0.1, the Heat Sink status tree or the foldout page of various optimal recovery guidelines.

Prior to initiating secondary heat sink restoration actions, the operator first checks RCS and steam generator pressures to confirm that secondary heat sink is required. If secondary heat sink is not required, the operator is transitioned to guideline E-1, Loss of Reactor Coolant. If secondary heat sink is required, the operator attempts to establish flow to the secondary side of the steam generators utilizing the AFW system, the main feedwater system or the condensate system, in that order of priority. While attempting to establish flow to the secondary side of the steam generators, the operator monitors RCS pressure and temperature for increasing indications. If operator actions to restore flow to the steam generator are effective (i.e. minimum AFW flow is established or steam generator narrow range level is restored) before secondary heat sink is lost (i.e. RCS pressure and temperature start to increase), the operator is transitioned to the optimal recovery guideline in effect. If secondary heat sink is lost before operator actions are successful, the operator proceeds to initiate RCS bleed and feed heat removal.

RCS bleed and feed heat removal is initiated as soon as possible after RCS pressure and temperature start to increase due to degradation of secondary heat removal capability. Maximum SI system flow is initiated and all pressurizer PORVs are opened to bleed hot reactor coolant out of the RCS while the SI pumps feed subcooled fluid into the RCS. The operator checks that adequate RCS bleed flow is established (i.e. at least two pressurizer PORVs are open) and maintains RCS bleed and feed heat removal to prevent or minimize core uncovery. If adequate RCS bleed flow is not established, core uncovery will occur. To delay core uncovery, the operator starts one reactor coolant pump (RCP) to enhance RCS

mixing and attempts to depressurize at least one intact steam generator to atmospheric pressure and establish flow to the depressurized steam generator from any low pressure makeup source. Secondary heat sink must be restored by any possible means to prevent core uncovery if adequate RCS bleed and feed is not established.

Following successful RCS bleed and feed initiation, sustained core uncovery is prevented. The operator should prepare for switchover to recirculation while continuing attempts to restore secondary heat sink. If secondary heat sink cannot be restored, the operator should switchover to cold leg recirculation following depletion of refueling water storage tank (RWST) inventory. If secondary heat sink can be restored, recirculation operations can be avoided.

If operator actions to restore flow to the secondary side of the steam generators are successful and secondary heat sink is restored, the operator isolates the RCS bleed path and evaluates SI termination criteria. If the termination criteria are satisfied, the operator is transitioned to step 1 of guideline ES-2.1 to terminate SI and complete plant recovery. If the termination criteria are not satisfied, the operator is transitioned to step 29 of guideline E-0 to rediagnose the plant condition and complete plant recovery.

4.0 DESCRIPTION OF GUIDELINE STEPS, NOTES AND CAUTIONS

This section describes the logic and bases for individual guideline steps, notes and cautions. A logic diagram is included as Figure 4. The guideline step numbers are included on the logic diagram adjacent to the corresponding logic block(s).

<u>Caution Before Step 1</u>

Following loss of all AFW flow, the operator should attempt to reestablish flow to the steam generators before secondary heat removal capability is lost due to depletion of steam generator inventory (i.e. dryout) or interruption of reactor coolant natural circulation (i.e. accumulation of voids in the steam generator U-tubes due to boiling in the RCS). The operator should initiate RCS bleed and feed heat removal only if secondary heat removal becomes ineffective. Analyses performed in WCAP-9744 and WCAP-9914 indicate that the operator has approximately 20 to 30 minutes (based on maximum core decay heat generation) to restore flow to the steam generators before secondary heat removal capability is lost. If flow is not restored, the analyses indicate that the operator has several additional minutes to initiate RCS bleed and feed heat removal to prevent or minimize core uncovery. The sooner RCS bleed and feed is initiated after loss of secondary heat removal capability, the more effective it will be in minimizing core uncovery. WCAP-9914 should be utilized for plant-specific information.

Guideline FR-H.1 is structured to permit the operator to continue attempts to restore flow to the steam generators until secondary heat removal becomes ineffective as indicated by increasing RCS pressure and temperature. Steps 1 through 11 direct the operator to attempt to restore flow to the steam generators. Step 12 checks for loss of secondary heat removal capability and directs the operator to return to step 1 if secondary heat removal is still effective or to go to step 13 if secondary heat removal is not effective.

The first caution before step 1 alerts the operator that if RCS pressure and temprature start to increase due to loss of secondary heat removal capability at any time while performing steps 1 through 11, the operator should immediately go to step 13 to implement RCS bleed and feed. This caution addresses the time aspect of permiting the operator as much time as possible before initiating RCS bleed and feed but ensuring as rapid initiation as possible when secondary heat removal capability starts to degrade.

The second caution before step 1 alerts the operator to maintain a faulted or ruptured steam generator isolated throughout restoration actions in guideline FR-H.1. Flow should be restored to the intact steam generators so that an effective secondary heat sink can be maintained. Restoration of flow to a ruptured or faulted steam generator will complicate subsequent plant recovery in that the optimal recovery guidelines direct the operator to isolate any ruptured or faulted steam generator.

Step 1

Before implementing actions to restore flow to the intact steam generators, the operator should check if secondary heat sink is required. For a range of loss of reactor coolant break sizes, the RCS will depressurize below the intact steam generators as the RCS break flow will remove core decay heat. For this range of loss of reactor coolant break sizes, the secondary heat sink is not required and actions to restore secondary heat sink are not appropriate.

If RCS pressure is less than all intact steam generator pressures, step 1 directs the operator to guideline E-1 to address a loss of reactor coolant. The structure of guideline FR-H.1 permits step 1 to address a range of loss of reactor coolant break sizes in that step 1 is performed when the operator enters guideline FR-H.1 and when the operator returns to step 1 from step 12. Break sizes that take longer to depressurize the RCS will be detected during subsequent passes through step 1.

Step 2

The operator should first attempt to restore operation of the AFW system. Restoration actions include manually starting pumps, aligning valves and ensuring an available suction water source. Depending upon the manpower available, the restoration actions should include operations outside the control room.

Plants with dual units that possess the capability to crosstie AFW systems should attempt to establish flow from the non-affected unit.

Step 3

Following actions to restore AFW flow to the intact steam generators, the operator checks total AFW flow to the intact steam generators to determine if adequate flow has been established to maintain secondary heat sink. If total AFW flow to the intact steam generators is equal to or greater than one motor-driven AFW pump at steam generator design pressure, an adequate secondary heat sink exists and the operator is transitioned to the optimal recovery guideline in effect. If flow is less than this value, the operator is directed to step 4 to establish main feedwater flow.

Step 4

Prior to restoring main feedwater flow to the steam generators the operator should check the status of main feedwater isolation. For the reference plant, feedwater isolation will most likely exist, having been actuated by either a reactor trip (P-4 signal) in combination with a low T_{avg} signal or by an SI signal. If feedwater isolation has occurred, the operator should reset the signal in order to permit feedwater isolation and bypass valves to be opened. The reference plant utilizes separate reset features for feedwater isolation depending upon the initiating signals. If feedwater isolation occurred as a result of reactor trip in combination with low T_{avg}, the operator must manually

reset a feedwater isolation retentive memory device in order to open the feedwater isolation and control valves. However, if feedwater isolation occurred as a result of SI actuation, the operator must reset the SI signal and the reactor trip breakers in addition to the feedwater isolation retentive memory device in order to open the feedwater isolation and bypass valves. Since guideline FR-H.1 can be entered following a reactor trip with or without SI actuation, the operator should check which signals initiated feedwater isolation and reset the appropriate signals.

Plants should review their plant-specific logic for feedwater isolation and augment this step with the plant-specific means to check feedwater isolation. It may be difficult for some plants to reset feedwater isolation following SI actuation.

Step 5

The operator should attempt to restore operation of the main feedwater system and establish main feedwater flow to the steam generators. If main feedwater flow is established, the operator is directed to step 6 to evaluate the effectiveness of main feedwater in restoring steam generator levels. If main feedwater is not established, the operator is directed to step 7 to attempt to establish condensate flow to the steam generators.

Plants should augment this step with plant-specific means to establish main feedwater flow.

Step 6

Following actions to establish main feedwater flow to the intact steam generators, the operator checks the intact steam generator narrow range levels to determine if adequate flow has been established to maintain secondary heat sink. If narrow range level (i.e. level just in span including allowances for normal channel accuracy, post-accident transmitter errors and reference leg process errors) has been restored to at

least one intact steam generator, an adequate secondary heat sink exists and the operator is transitioned to the optimal recovery guidelne in effect. If this level does not exist, the operator is directed to step 7 to establish condensate flow to the intact steam generators.

Steam generator narrow range level is utilized in evaluating secondary heat sink since accurate main feedwater flow indication is not available at low flow rates and steam generator wide range level indication may not be accurate under abnormal containment conditions.

Step 7

The operator should check if the condensate system is available to deliver flow to the intact steam generators. If the system is available, the operator is directed to step 8 to establish flow. If the system is not available, the operator is directed to step 12 to check for loss of secondary heat sink.

Plants should augment this step with operator training as to the plant-specific means to check the availability of the condensate system.

Steps 8, 9, and 10

Steps 8, 9 and 10 atte t to establish condensate flow to at least one intact steam generator. The operator should attempt to rapidly depressurize at least one intact steam generator to below the shutoff head of the condensate pumps and establish condensate flow to the depressurized steam generator.

If an SI condition existed prior to step 4, the feedwater isolation signal would have been reset in step 4. The rapid depressurization in step 8 would not actuate feedwater isolation and inhibit operator actions to establish condensate flow to the depressurized intact steam generator. However, if an SI condition did not exist before the rapid

depressurization in step 8, this depressurization may actuate the SI signal (i.e. low steamline pressure or low pressurizer pressure) and feedwater isolation. Step 9 is included to address this possibility and to direct the operator to reset feedwater isolation and continue attempts to restore condensate flow. If an SI condition did not exist before the rapid depressurization, the operator can attempt to block the signals that actuate SI but should not slow the depressurization for this reason.

Plants should augment these steps with operator training as to the plant-specific means to depressurize and establish condensate flow to a steam generator. Any plants that cannot reset feedwater isolation following SI actuation should attempt to block the signals that actuate SI during the rapid depressurization.

Step 11

Following actions to establish condensate flow to the intact steam generators, the operator checks the intact steam generator narrow range levels to determine if adequate flow has been established to maintain secondary heat sink. If narrow range level (i.e. level just in span including allowances for normal channel accuracy, post-accident transmitter errors and reference leg process errors) has been restored to at least one intact steam generator, an adequate secondary heat sink exists and the operaor is transitioned to the optimal recovery guideline in effect. If this level does not exist, the operator is directed to step 12 to check secondary heat sink effectiveness.

Steam generator narrow range level is utilized in evaluating secondary heat sink since accurate condensate flow indication is not available at low flow rates and steam generator wide range level indication may not be accurate under abnormal containment conditions.

Step 12

The operator should continue attempts to establish flow to the steam generators until secondary heat sink starts to degrade, as indicated by increasing RCS pressure and RCS wide range or core exit thermocouple temperatures. If the operator gets to step 12, initial attempts to establish AFW flow, main feedwater flow or condensate flow have been unsuccessful. Step 12 checks RCS pressure and temperatures to determine if secondary heat sink is still effective. If secondary heat removal is not effective, as indicated by increasing RCS pressure and increasing RCS wide range or core exit thermocouple temperatures, the operator continues to step 13 to establish RCS bleed and feed heat removal. If secondary heat removal is still effective, as indicated by stable or decreasing RCS pressure or stable or decreasing RCS wide range or core exit thermocouple temperatures, the operator returns to step 1 to continue attempts to restore flow to the steam generators.

Step 1 through step 12 form a loop in which the operator attempts to restore flow to steam generators until either secondary heat sink is lost (i.e. step 12), secondary heat sink is not required (i.e. step 1) or adequate flow is established to the steam generators to restore secondary heat sink (i.e steps 3, 6, or 11).

Caution before Step 13

Once the operator detects that secondary heat sink is lost, RCS bleed and feed must be established within several minutes to prevent or minimize core uncovery. The caution before step 13 alerts the operator that steps 13 through 17 must be performed quickly in order to establish RCS bleed and feed heat removal.

Step 13

The operator should verify that SI is initiated as the first step in establishing RCS bleed and feed. This will ensure that maximum high pressure SI flow is available to provide RCS feed flow and that the

containment is isolated to confine reactor coolant releases resulting from RCS bleed flow. If SI is not initiated, the operator should manually initiate SI and implement steps 5 through 15 of guideline E-0 to verify SI automatic actuations. The operator should continue to quickly establish RCS bleed and feed while verifying SI automatic actuations.

Step 14

The operator should check that an effective high pressure RCS feed path is established before establishing the RCS bleed path. For the feed path to be effective, the operator should ensure that the charging/SI valves are properly aligned and at least one charging/SI pump is running. The operator should manually aligns valves and start pumps, if necessary, to establish an effective RCS feed path.

Although only one charging/SI pump is required to establish an effective RCS feed path, the operator should attempt to maximize RCS feed flow by operating as many charging/SI pumps and high-head SI pumps as possible. This will maximize RCS bleed and feed heat removal effectiveness. If no charging/SI pump is running, the operator should not open pressurizer PORVs to establish an RCS bleed path since a severe core uncovery will result.

Caution before Step 15

This caution alerts the operator to not establish an RCS bleed path in step 15 unless an effective RCS feed path is established in step 14. A severe core uncovery will result if RCS bleed is established without effective RCS feed.

Step 15

The operator ensures that all pressurizer block valves are open and opens all pressurizer PORVs to establish an RCS bleed path. These valves must be maintained in the open position until secondary heat sink

is restored. The operator should verify that the pressurizer PORVs do not automatically close following release of the control board switches. If the pressurizer PORVs do automatically close due to a spring return to auto switch, the operator should manually maintain the control board switches in the open position.

Once the pressurizer PORVs are open, the RCS will depressurize and the charging/SI pumps will deliver subcooled flow to the RCS. This will provide adequate RCS heat removal until flow can be established to the steam generators to restore secondary heat sink. The operator may observe increasing pressurizer level after the pressurizer PORVs are opened. Eventually the pressurizer may become water solid and water relief will occur through the pressurizer PORVs.

Step 16

After manually opening the pressurizer PORVs, the operator should check that at least two pressurizer PORVs are maintained in the open position. This condition can be checked by observing the valve position indicators on the main control board. If at least two valves are maintained open, sufficient RCS bleed flow exists to permit RCS heat removal. The operator proceeds to step 14.

If at least two pressurizer PORVs are not maintained open, the RCS will not depressurize sufficiently to permit adequate feed of subcooled SI flow to remove core decay heat. If core decay heat exceeds RCS bleed and feed heat removal capability, the RCS will repressurize rapidly further reducing the feed of subcooled SI flow and resulting in a rapid decrease of RCS inventory. Although not sufficient to maintain adequate RCS bleed flow, the operator should maintain a single pressurizer PORV open if possible. To optimally utilize the remaining RCS inventory to delay core uncovery, the operator should start an RCP, if one is not running, to elevate the mixture level in the core. This RCP should be

one in an intact loop, if possible, to maximize any remaining secondary heat removal capability. The operator should then attempt to open a steam generator PORV for at least one intact steam generator(s) and depressurize that steam generator(s) to atmospheric pressure. As the steam generator(s) depressurizes the operator should align a low pressure water source to the depressurized steam generator(s) to restore secondary heat removal.

As the steam generator(s) is being depressurized to atmospheric pressure, RCS inventory depletion will exist out of the single pressurizer PORV or the pressurizer safety valves. The operator should go to step 18 to prepare for switchover to cold leg recirculation.

Plants should augment this step with operator training as to the plant-specific means to depressurize an align a low pressure water source (e.g. fire water or service water) to a steam generator.

Caution Before Step 17

The operator will stop all RCPs in step 17. The caution before step 17 alerts the operator to maintain seal injection flow to all RCPs. Seal injection flow is required to the RCPs even when they are stopped in order to protect the RCP seals.

Step 17

The operator should maintain adequate RCS bleed and feed heat removal established in step 16. All RCPs should be stopped to reduce the core mixture level and maximize the void fraction of the RCS hot leg reactor coolant flow into the pressurizer. This results in maximizing the energy per unit mass being released through the pressurizer PORVs. Stopping all RCPs also eliminates the addition of pump heat to the RCS inventory.

Caution before Step 18

This caution alerts the operator that the SI system must be aligned to cold leg recirculation if RWST level reaches the appropriate setpoint. It precedes Step 18 which directs the operator to prepare for switchover to cold leg recirculation.

Step 18

RCS inventory is being released to containment to remove core decay heat energy. If RCS bleed and feed is established, RCS inventory is being released through the pressurizer PORVs. If RCS bleed and feed is not established, RCS inventory is being released through the pressurizer safety valves. In either case RCS inventory is being discharged to containment and RWST inventory is being depleted at a rate dependent on RCS pressure and SI flow. The operator should implement Steps 13 through 17 of guideline E-1 to prepare for recirculation while continuing attempts to restore secondary heat sink.

Step 19

While maintaining RCS bleed and feed heat removal, the operator should continue attempts to restore secondary heat sink.

Step 20

The operator should monitor RCS wide range temperatures and core exit thermocouple temperatures for an indication that flow has been established to the steam generators. Decreasing temperatures indicate that flow may be reaching the steam generators and starting to remove core decay heat. If temperatures are decreasing the operator should proceed to step 21 to check if the decreasing temperatures result from the restoration of secondary heat sink.

Step 21

Decreasing RCS temperatures indicate the operator should check for an adequate secondary heat sink in preparation for terminating RCS bleed and feed. An adequate secondary heat sink is required to ensure that RCS heat removal can be maintained following RCS bleed and feed termination. Premature termination will result in increasing RCS temperatures and operator action to reopen the pressurizer PORVs to reestablish RCS bleed and feed. An adequate secondary heat sink minimizes the potential for cycling of the pressurizer PORVs.

In order to terminate RCS bleed and feed heat removal, the operator must ensure that narrow range level (i.e. level just in span including allowances for normal channel accuracy, post-accident transmitter errors and reference leg process errors) has been restored to at least one intact steam generator and that RCS subcooling (i.e. the sum of temperature and pressure measurement system errors translated into subcooling) has been restored. These two conditions indicate that the secondary heat sink is adequate to permit termination of RCS bleed and feed. The operator should continue with steps 19 and 20 until an adequate secondary heat sink is obtained.

Step 22

The operator should isolate the RCS bleed path after an adequate secondary heat sink is obtained. Prior to closing the pressurizer PORVs the operator should record the core exit thermocouple temperature to establish a baseline for comparison with core exit temperature following pressurizer PORV closure. The operator should then close all pressurizer PORVs, or the corresponding block valve if a pressurizer PORV fails to close, and monitor core exit temperatures relative to the baseline temperature. If temperatures remain relatively stable, an adequate secondary heat sink is confirmed and the operator proceeds to step 23 to

terminate the RCS feed path. If temperatures increase by more than 15°F, an adequate secondary heat sink does not exist. The operator should then reopen all pressurizer PORVs and go to step 19 to continue attempts to establish an adequate secondary heat sink.

Note Before Step 23

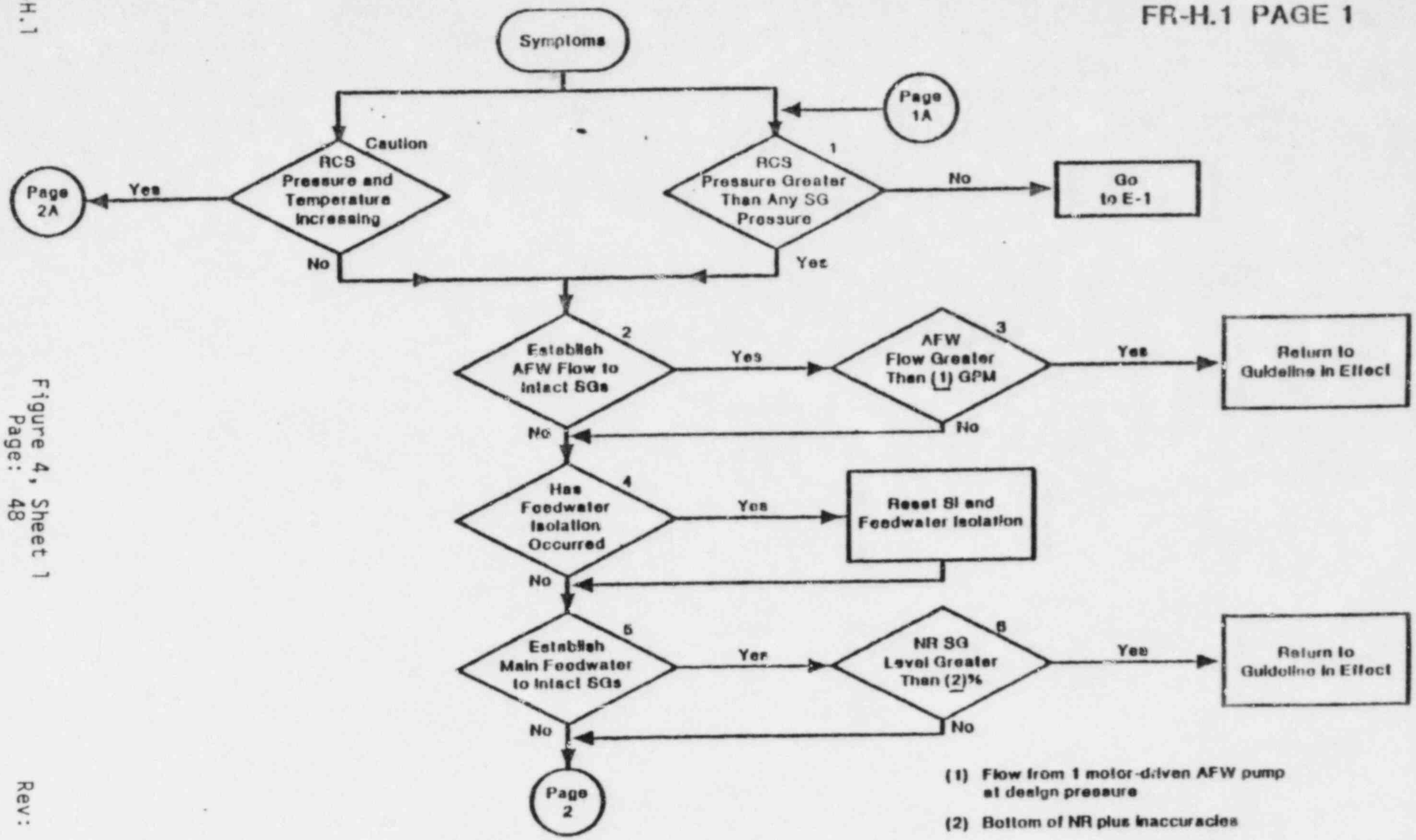
Steps 23 and 24 transition the operator to the optimal recovery guidelines to diagnose the plant condition and complete plant recovery. However, the RCS bleed and feed portion of guideline FR-H.1 requires unique operator actions (e.g. opening a pressurizer PORV to release reactor coolant to containment or depressurizing a steam generator to atmospheric pressure, etc.) that may complicate subsequent diagnosis of the plant condition and actions to complete plant recovery. This caution informs the operator that it may be necessary to modify the subsequent diagnostic and recovery guidance to account for plant conditions resulting from these unique operator actions that potentially result in symptoms of a loss of reactor coolant or loss of secondary coolant.

Step 23 and 24

The operator has restored secondary heat removal capability and terminated RCS bleed and feed heat removal. The challenge to the Heat Sink critical safty function has been mitigated and the operator should return to the optimal recovery guidelines to complete plant recovery. Steps 23 and 24 provide SI termination criteria which determine the optimal recovery guideline to which the operator should go to complete plant recovery. If the criteria in step 23 are satisfied, the operator goes to guideline ES-2.1 to terminate SI. This SI termination guideline is utilized since its SI reinitiation criteria are consistent with the SI termination criteria in guideline FR-H.1. If the criteria in step 23 are not satisfied, the operator maintains SI running and goes to guideline E-0 to diagnose the plant condition.

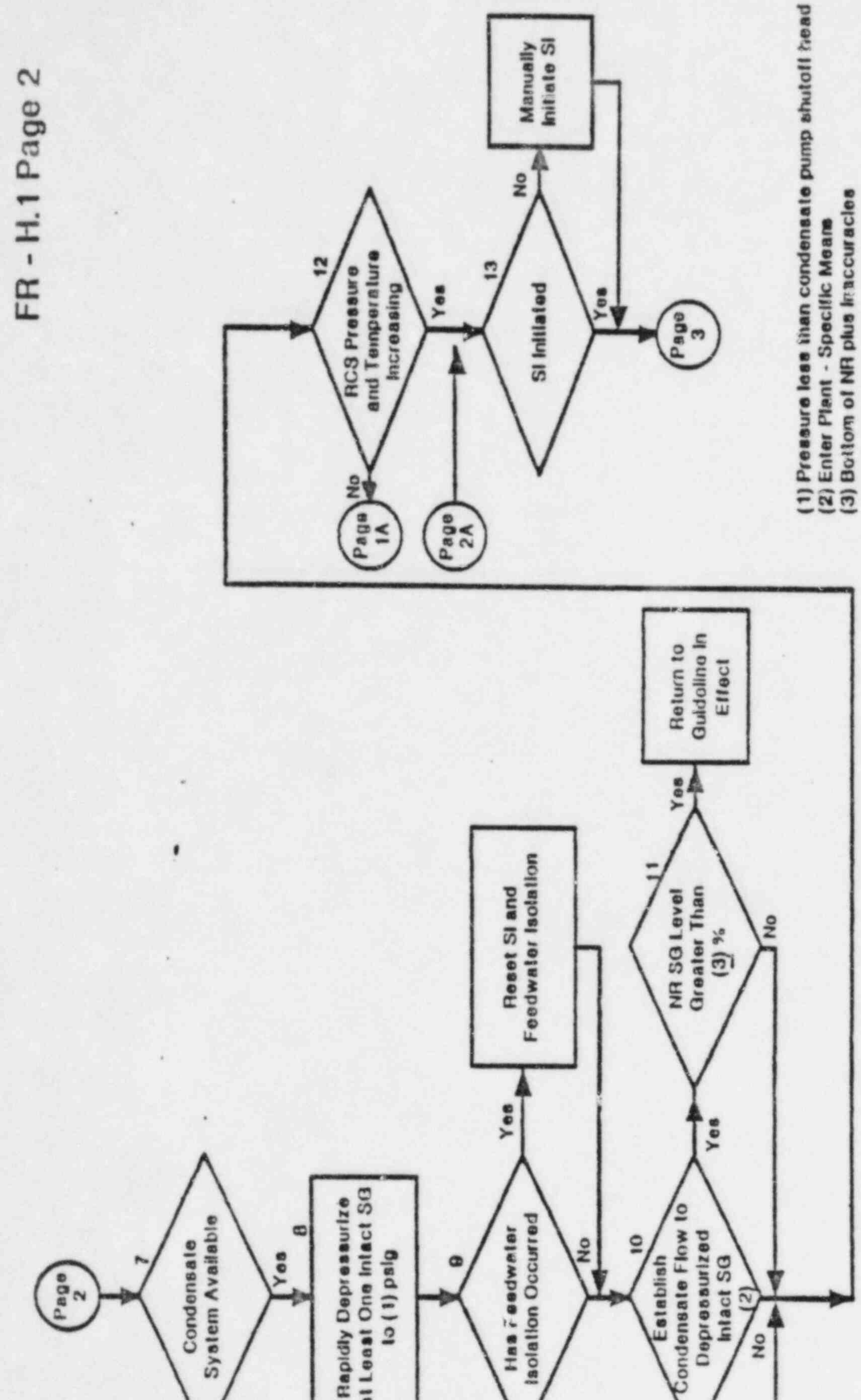
FR - H.1 RESPONSE TO LOSS OF SECONDARY HEAT SINK

FR-H.1 PAGE 1

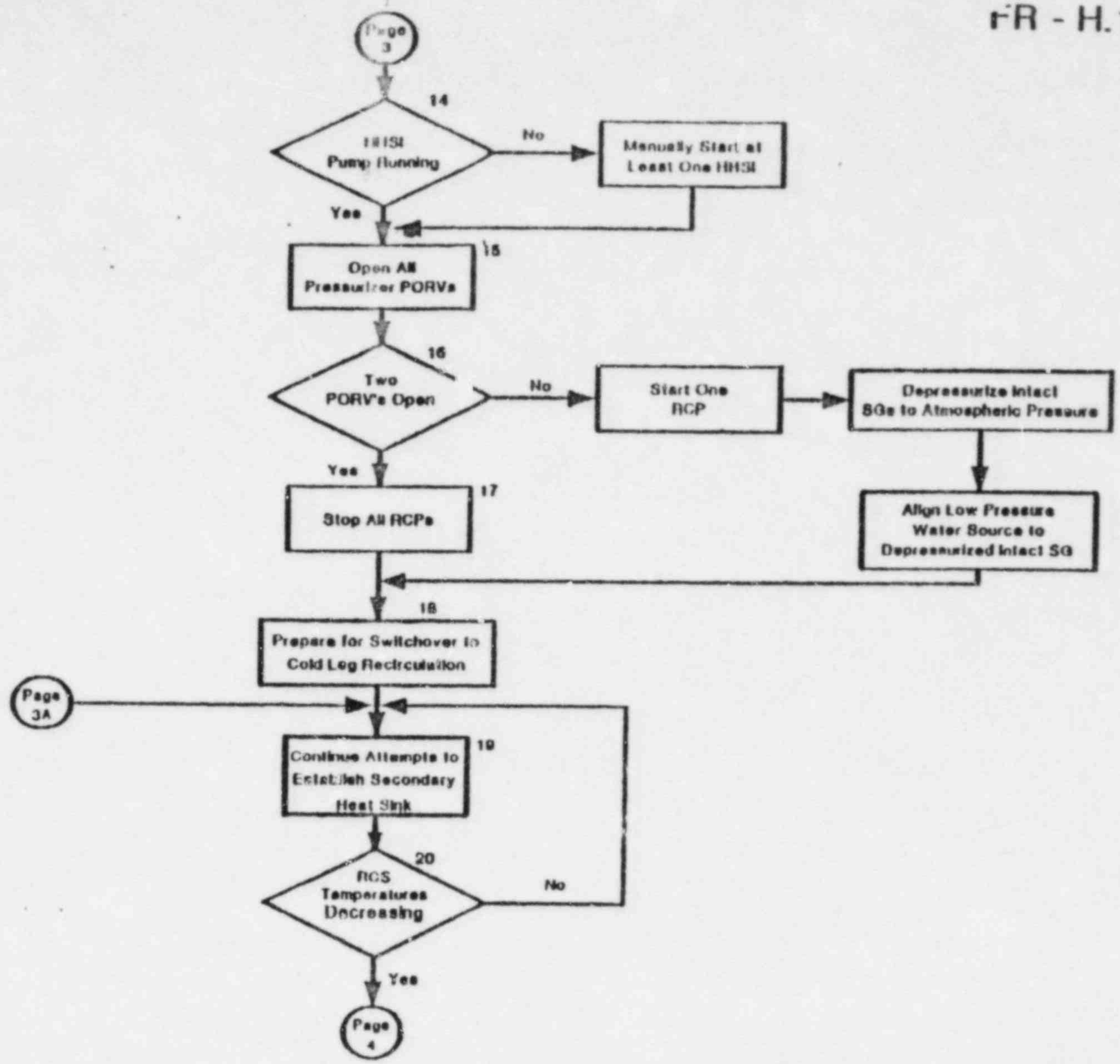


(1) Flow from 1 motor-driven AFW pump at design pressure

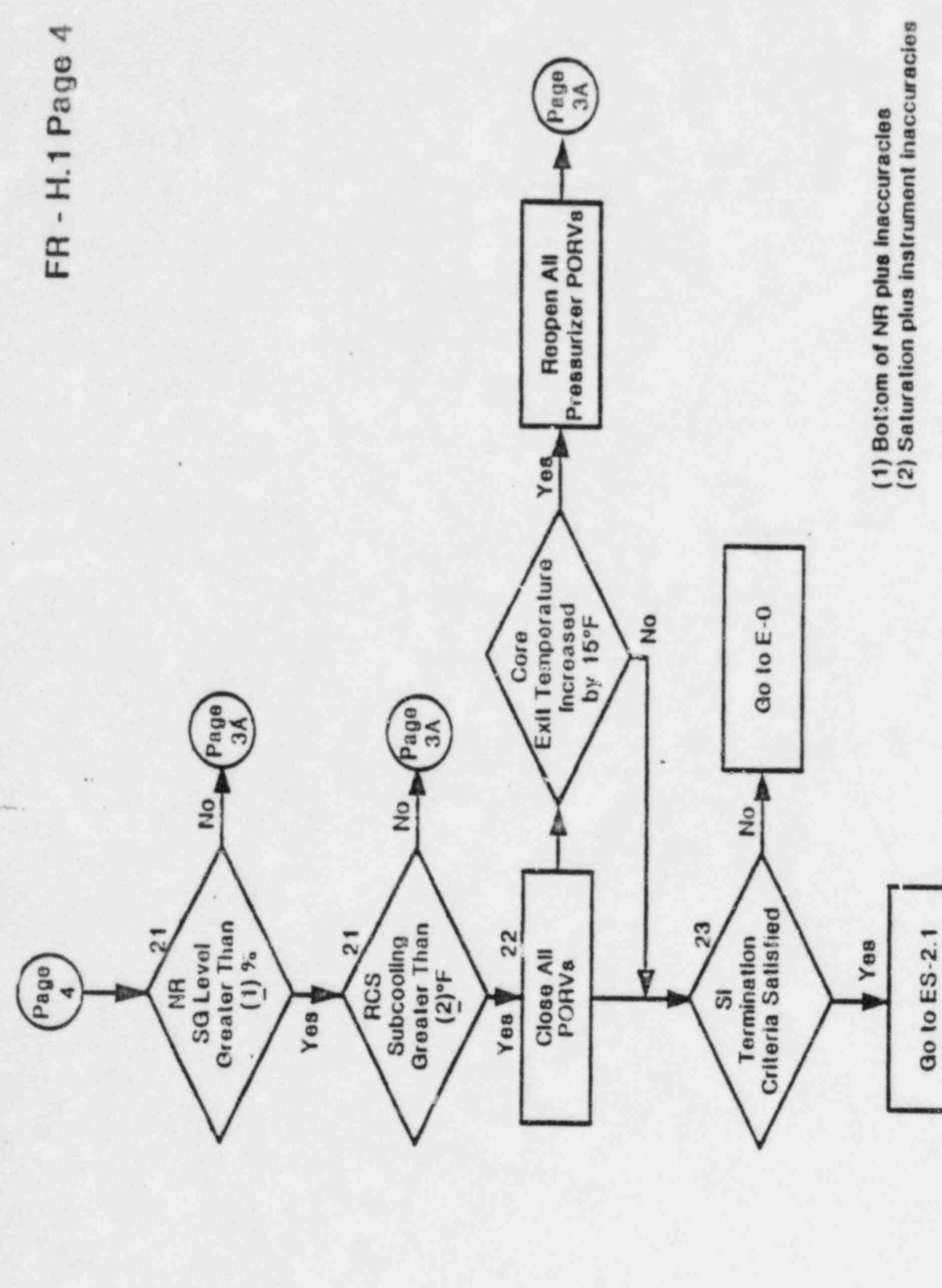
(2) Bottom of NR plus inaccuracies


FR - H.1 Page 2
Page 2
7
Condensate System Available
No
Yes
8
Rapidly Depressurize at Least One Intact SG to (1) psig
9
Has Feedwater Isolation Occurred
Yes
Reset SI and Feedwater Isolation
No
10
Establish Condensate Flow to Depressurized Intact SG (2)
No
Yes
11
NR SG Level Greater Than (3) %
Yes
Return to Guideline In Effect
No
12
RCS Pressure and Temperature Increasing
No
Page 1A
Yes
Page 2A
13
SI Initiated
No
Manually Initiate SI
Yes
Page 3
(1) Pressure less than condensate pump shutoff head
(2) Enter Plant - Specific Means
(3) Bottom of NR plus inaccuracies

FR - H.1 Page 3



AS


FR - H.1 Page 4
Page 4
21
NR SG Level Greater Than (1) %
No
Page 3A
Yes
21
RCS Subcooling Greater Than (2)°F
No
Page 3A
Yes
22
Close All PORVs
Core Exit Temperature Increased by 15°F
Yes
Reopen All Pressurizer PORVs
Page 3A
No
23
SI Termination Criteria Satisfied
No
Go to E-0
Yes
Go to ES-2.1
(1) Bottom of NR plus inaccuracies
(2) Saturation plus instrument inaccuracies

5.0 REFERENCES

1. WCAP-9600, "Report on Small Break Accidents for Westinghouse NSSS Systems", Westinghouse Nuclear Safety Department, June 1979.

2. WCAP-9744, "Loss of Feedwater Induced Loss of Coolant Accident Analysis Report", W. Tauche, May 1980.

3. WCAP-9914, "PORV Sensitivity Study For LOFW-LOCA Analyses, S. Dederer, July 1981.

Attachment 3

Technical Bases for Controlled Primary Depressurization (OA-2) for Small LOCA Sequences in the Millstone - 3 Probabilistic Safety Study