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Georgia Power
POWER GENERATION DEPARTMENT
VOGTLE ELECTRIC GENERATING PLANT

TRAINING STUDENT HANDOUT

TITLE: LOSS OF ALL AC POWER

NUMBER: LO-HO-37031-C-001

PROGRAM: LICENSED OPERATOR TRAINING

REVISION: 2

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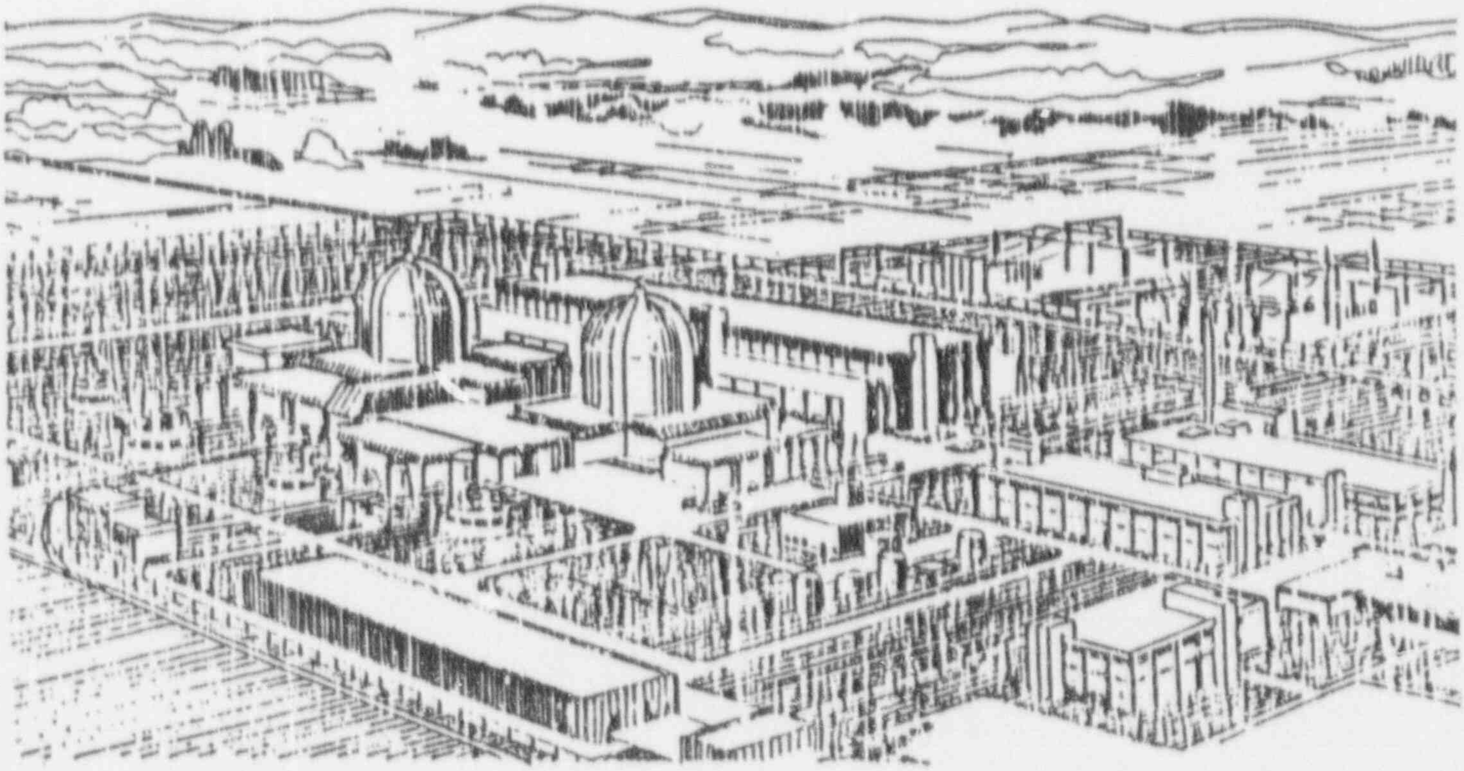
DATE: 9/12/88

REFERENCES:

1. WOG ERG HP VERSION, REV. 1
2. VEGP PROC. 19100-1, LOSS OF ALL AC POWER



STUDENT ______________________ DATE ______________

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I. PURPOSE STATEMENT:

Following completion of this lesson, the student will possess those knowledges systematically identified for the performance of Loss of All AC power tasks.

II. LIST OF OBJECTIVES:

1. Define "loss of all AC power" condition. Explain its immediate implications for operation of plant equipment.

2. State why the RCP is a primary concern during a loss of all AC condition.

3. Assuming a fixed leak size, state the impact of not starting a secondary side depressurization (plant cooldown) on the following parameters:

   a. RCP seal leakage
   b. RCS coolant mass
   c. Time to core uncovering

4. Describe the effect of a leak, concurrent with a loss of all AC power, on the following parameters:

   a. Pressurizer level
   b. Containment pressure
   c. Time to core uncovering

5. State the special concerns regarding the following items should the operator begin the secondary side depressurization:

   a. Return to critical condition
   b. Introduction of non-condensible gases

6. State from memory the immediate operator actions of EOP 19100.

7. State the bases for "Loss of All AC Power" procedure.

8 Using EOP 19100 as a guide, briefly describe how each step is accomplished.

9. Given the CAUTION statement from the EOP, state the bases for that CAUTION statement.

LO-HO-37031-02-C-001: Loss of All AC Power - Transient Analysis

Primary Concerns for Loss of All AC Power

A total loss of ac power at Plant Vogtle can result only from a loss of grid power from the high voltage distribution lines serving the station combined with a series of events that prevent the station emergency diesel generators from energizing the emergency ac busses. The immediate consequences of a loss of ac power are not severe unless the loss is accompanied by some other complicating event such as a loss of reactor coolant, a loss of secondary coolant, or a steam generator tube rupture. If ac power cannot be restored quickly, however, plant and public safety could be severely effected.

The degree of severity for a loss of all ac power depends primarily on the duration of the ac power outage and the response of the RCP shaft seals to the loss of seal cooling. A loss of ac power will cause a simultaneous loss of high pressure injection flow to the RCP seals and ACCW flow to the RCP thermal barrier. Loss of high pressure seal injection flow from the CCPs will result in outleakage from the RCS along the RCP shafts. Without power this coolant mass cannot be replaced and a continuous loss of reactor coolant occurs with time. Loss of RCP seal cooling could also cause degradation of the sealing capability of the RCP seals from overheating. Degradation of the sealing capability may result in an increase in leakage out of the RCS, from several gpm per RCP up to several hundred gpm per RCP. To mitigate the severity of a loss of all ac power, it is necessary to minimize RCS inventory loss over time and to restore ac power so that RCS inventory can be restored.

Under normal operating conditions, the controlled leakage shaft seal system is cooled by independent and redundant cooling systems. Adequate seal cooling for continued RCP operation can be provided by either high pressure seal injection flow from the charging pumps or low pressure ACCW flow circulated through the RCP thermal barrier. Seal injection flow acts as a buffer to prevent reactor coolant from entering the pump seal and bearing section of the pump. A portion of seal injection flows down the shaft and into the RCS while the remainder flows up through the seal system. If seal injection to the RCP is lost, the hot reactor coolant can flow up the pump shaft. Under this condition, the RCP thermal barrier functions as a heat exchanger to cool the hot reactor coolant before it enters the RCP bearing and seal area.

The RCP is designed to accommodate the temporary loss of seal injection flow and ACCW flow that accompanies a loss of offsite power, including the normal time delays associated with re-establishing these RCP support systems on emergency ac power. This is accomplished by the volume of cool water in the seal area and the time that it takes to leak this water through the RCP seals prior to hot water entering the seals. The RCP is designed to accommodate the loss of support systems for one minute following loss of offsite power. Under the best conditions, the RCP design should preclude hot water from entering the seal area for several minutes.

If the RCP support systems are not restored before the introduction of hot reactor coolant into the seal system, the RCP seal leak rate becomes dependent on RCS temperature as well as the RCS pressure. At temperatures in excess of 300°F, RCP seal system sealing capability and sealing life may start to degrade with an increase in seal leakage flow. The probability of degradation in sealing capability and sealing life increases with increasing temperature above 300°F. Seal performance under high temperature conditions is unpredictable because of several interacting considerations, including the following:

- Seal O-ring material softens with increasing temperature, affecting the O-ring sealing ability and life

- Thermal gradients affect the faceplate tapers of the number 1 seal ring and runner and the shrink fit of the number 2 seal ring insert, thereby affecting sealing surfaces. Nonuniform thermal gradients and extrusion of O-rings may result in nonuniform sealing surfaces

- Leakage of reactor coolant through the seals could result in crud blockage of the seals

The industry has experienced few events in which both seal injection flow and thermal barrier ACCW flow have been lost. As a result, it is difficult to accurately predict RCP seal behavior. General conclusions drawn from the industry experience suggest that seal leakoff flow could be expected to increase above the normal indication range during the course of a prolonged loss of all ac power, likely going above the seal leakoff flow instrument upper range of 6 gpm. During the industry events, however, abnormally excessive leakage rates were not experienced before restoration of RCP support systems.

To evaluate the most severe consequences of a loss of all ac power to the RCP seal system, a conservative maximum RCP leakage rate has been estimated to be 300 gpm. This rate was estimated by assuming that total RCS pressure of 2235 psig exists across the RCP thermal barrier labyrinth seals with the controlled leakage seals totally ineffective in controlling leakage flow.

The high RCS temperatures and pressures characteristic of a plant no-load condition can lead to eventual RCP seal degradation and increased RCS inventory loss. This seal degradation can be mitigated by reducing the RCS pressure and temperature consistent with other plant constraints. Reducing

RCS pressure reduces leakage flow through the RCP seals, thereby reducing RCS inventory loss for a given seal condition.

Reducing RCS temperature reduces the thermal degradation of materials and thermal expansion effects that tend to degrade the seal system sealing capability and sealing life. Consequently, any actions to reduce RCS pressure and temperature during a loss of all ac power event will reduce RCS inventory loss and will increase the time to core uncovering.

RCP Seal System Cooling Restoration

After restoration of ac power, it is desirable to restore RCP seal cooling as soon as practical to reduce seal temperatures and mitigate potential continued degradation of the RCP seals. However, industry experience has shown that the restoration of seal cooling must be performed in a controlled manner to avoid thermally shocking the pump parts. Proper restoration of RCP seal cooling is important because it

- maximizes the availability of the RCPs if required for subsequent recovery actions.
- minimizes the possibility of seal damage that could limit subsequent plant operation due to down time to effect RCP repairs.

Industry experience has shown that the uncontrolled restoration of seal cooling to a hot RCP and the subsequent restart of the RCP can aggravate RCP damage and lead to bent shafts, damaged bearings, and damaged seals. The bent shafts are primarily attributable to the rapid introduction of cold seal injection flow into the seal area, which results in abnormal thermal gradients and thermal stresses across the RCP shaft. The bearing and seal damage are primarily caused by restarting of the RCPs following seal cooling restoration. The potential nonuniform sealing surfaces and seal crud blockage that may exist before RCP start can cause further bearing and seal damage if the RCP is started. Restoration of RCP seal cooling should be performed consistent with the limitations and requirements in the plant specific RCP Instruction Manual and plant procedures. These requirements are intended to minimize the potential for thermal shock to RCP parts. In general these requirements

- re-establish ACCW to the thermal barrier to reduce seal leakoff temperature to $\overset{220}{235}$°F or less.
- re-establish seal injection flow to reduce bearing temperature at a maximum rate of one °F per minute.

Following restoration of seal cooling, the RCP should not be started before a RCP status evaluation is completed. The purpose of the evaluation is to minimize potential RCP damage on restart. The plant should be taken to cold shutdown conditions under natural circulation to permit pump disassembly and visual inspection as part of this evaluation. An RCP should not be routinely started to recover from the loss of ac power event because any seal misalignment or crud blockage could aggravate RCP seal damage, potentially resulting in RCP seal failures and excessive seal leakage flow. The RCP should only be started if an extreme (red level) or severe (orange level) challenge to a Critical Safety Function is diagnosed from Status Tree monitoring and the operator is instructed to start an RCP in the associated Function Restoration Procedure. Under these conditions, the RCP support systems should be restored to as near normal conditions as possible before the RCP is started.

Loss of All AC Power - No Operator Action

At the onset of a total loss of ac power event, the response of plant process variables will be essentially the same as would occur immediately after a plant blackout: loop flow will coast down due to RCP trip, nuclear flux will decrease due to the reactor trip, steam generator level will decrease rapidly due to steam/feed flow mismatch and S/G shrink, and pressurizer level will decrease due to T_{ave} reduction. However, subsequent plant response can be considerably different. Because the steam dump system and potentially the steam generator ARVs will be disabled by the loss of ac power, secondary pressure will no longer be limited to the no-load steam pressure but will continue to rise to the secondary safety valve set pressure. Following the initial transient caused by the trip, the increase in steam temperature in conjunction with the loss of forced reactor coolant flow will tend to return plant average temperature and pressurizer level to something above no load values.

With a loss of all ac power there will be seal leakage. As a result, pressurizer level will not stabilize but will begin to fall. The rate at which the level decreases will depend on the magnitude of the seal leakage. Should the seals remain intact such that leakage rates are only several gallons per minute from each pump, the pressurizer level drop may only be noticeable over a period of hours. Should the seals deteriorate rapidly due to the loss of seal cooling, leakage rates could increase to several hundred gallons per minute and the pressurizer could empty in ten minutes or less. As long as all letdown paths from the RCS are isolated, the pressurizer level response is the best indicator of RCP seal conditions available to the operator.

The decrease in pressurizer level will also be accompanied by a decrease in RCS pressure. Without the benefits of charging/SI pumps and pressurizer heaters, the loss of coolant through the seals will deplete the inventory of hot water in the pressurizer causing pressure to trend downward with the level. This trend will continue until the pressurizer is empty, at which time flashing will occur either in the head of the reactor vessel or in the RCS hot leg piping. At this point the rate of pressure decay will be reduced due to the larger volume of hot water available for flashing in either of these locations. The depressurization will continue until eventually the entire RCS is saturated at approximately the setpoint pressure of the steam generator safety valves. The rate of the pressure decay, like the pressurizer level transient, will be controlled by the amount of leakage from the RCP seals.

Once the entire RCS saturates, cooling through the steam generator safety valves will maintain RCS pressure and, therefore, RCP leakage at essentially constant values. Seal leakage will continue to deplete the RCS inventory, ultimately draining the upper head and causing steam voids to form in the steam generator U-tubes. Significant voiding in the U-tubes will stop natural circulation through the RCS coolant loops and reflux boiling will be required between the core and the steam generators to remove decay heat. If ac power is still not restored, this situation will continue until enough inventory is lost to prevent the removal of decay heat; an inadequate core cooling condition may occur.

Loss of All AC Transient - With Operator Controlled Cooldown

The scenario described above is based on the assumption that following the loss of ac power, heat is removed only through the steam generator safety valves. Without the ability to replenish water lost through the RCP seals, this situation will eventually result in saturation of the RCS and a stabilization of temperature and pressure at values slightly above the conditions in the steam generator. Without operator intervention, the chances of core damage are greater than if the operator takes action to reduce RCS pressure and temperature. Reducing the RCS pressure and temperature reduces RCP seal leakage, extending the time to uncovering of the reactor core. This increases the time available to restore ac power before inadequate core cooling can occur. In addition to reducing the amount of water lost from the RCS, reducing the RCS pressure and temperature will reduce the differential pressure and temperature to which the RCP seals are exposed, thereby reducing the rate and magnitude of the seal degradation. Finally, decreasing the RCS pressure with secondary cooling can allow injection of the water in the passive low pressure accumulators to replenish some of the lost RCS inventory. Thus, there are advantages to having an operator take timely action to cool the RCS in the event of a complete loss of ac power; the analyses described in subsequent sections have considered this option. In those analyses, cooling below the safety valve setpoint conditions is assumed to be accomplished by coordinated manual or local control of the steam generator ARVs and the turbine-driven AFW pump.

There are several restrictions that must be observed if an operator takes action to manually cool a plant without having normal shutdown systems available. One restriction relates to the potential for returning the reactor core to a critical condition because of the effects of negative moderator feedback. Without ac power, the systems normally used to borate the RCS are unavailable. Unless pressure can be reduced sufficiently to allow accumulator injection, the only sources of negative reactivity to maintain the core subcritical are the control/shutdown rods. There may be situations in which it is not possible to depressurize below the accumulator injection pressure without also returning the core to a critical low power state. Such situations could arise because of the combined effects of low system boron concentration and high negative moderator feedback that occur late in core life. If a loss of all ac power occurred late in core life with all rods inserted and additional boration unavailable, the temperature at which the core would return critical, could be higher than saturation temperature at the accumulator injection pressure. Depressurization to the accumulator injection pressure via secondary depressurization would not be possible immediately following the loss of ac power event. Fortunately, the extent of this problem is limited by the effects of negative reactivity added to the core by xenon buildup. Assuming the event occurs from an equilibrium power condition, xenon production in the core will gradually reduce the core criticality temperature until the operator can reduce RCS pressure sufficiently to allow accumulator injection into the system.

A second limitation to conducting a controlled cooldown following a loss of all ac power is the possibility of introducing non-condensible gases into the RCS. Under normal plant shutdown conditions with ac power available, the accumulator injection lines are isolated before reducing RCS pressure below 1000 psig. This is done to prevent the accumulator contents from entering the RCS. Isolation of the injection lines will not be possible without ac power. Thus, following a total loss of ac, depressurization to a pressure low enough to allow complete purging of the accumulators must be avoided. The operator's only means of doing this should be by controlling the amount of steam being released from the steam generators. If seal leakage from the RCPs becomes very large, the operator may not be able to control RCS pressure and introduce nitrogen into the system.

Transient Analyses

The response of the Westinghouse nuclear steam supply system (NSSS) to a loss of all ac power has been analyzed to identify the behavior of important variables. This analysis has included computer scenarios in which a limited set of potential RCP leak flows and steam generator depressurization (cooldown) rates have been evaluated. The important assumptions and simplifications used in the analyses are described below.

- RCP Seal Leakage

  As RCS conditions changed during the analyses the break flow also changed as dictated by critical flow correlations for subcooled and saturated water. This approach was chosen to produce a realistic representation of the response of an RCP seal leak particularly should the seals be degraded by overheating and subsequent erosion of the sealing surfaces, extrusion of O-rings, etc.

A more important assumption made in the analyses was that the RCP seal leak was assumed to start at the pre-selected rate as soon as ac power was lost. No time delay was included to simulate the effects of gradual seal degradation. In an actual loss of ac power event, seal degradation phenomenon, if it occurs at all, could extend over periods of time lasting from several minutes to hours.

o Manually Controlled Cooldown of the RCS

Part of the analyses of this section relate to the effects of cooling the RCS using steam generator atmospheric relief valves (ARVs) and the turbine-driven auxiliary feedwater (TDAFW) pump. In the event of a total loss of ac power, manual and possibly local control of both the ARVs and the TDAFW pump may be required. Therefore, the dynamics of the cooldown will not be as orderly as would normally be the case with automatic control systems in service. However, in the analyses no attempt was made to characterize the effects of manual/local system operation. All cooldown sequences were assumed to proceed in an orderly manner at a constant cooldown rate of approximately 100°F/hr in the steam generator secondary.

o Decay Heat Power

The level of decay heat following any reactor trip will depend on the recent power history as well as the total burnup of the core. All the analyses assume long term reactor operation at full power.

o Reactor Coolant System Response

To illustrate RCS response following a loss of ac power, six loss of ac power scenarios are analyzed using the LOFTRAN code. The scenarios were selected to show RCS response to

- different RCP seal leakage rates.
- effect of operator action to depressurize (cooldown) the secondary to reduce RCP seal leakage.

Response sensitivity to RCP seal leakage rates was shown through analysis of three leakage rates: moderate rate of 50 gpm per pump, maximum rate of 300 gpm per pump, and a minimum rate of 5 gpm per pump. The moderate rate was selected to illustrate the various plant responses that accompany a loss of ac power event. The maximum and minimum rates were selected to show the boundaries of plant response for a loss of ac power event. Each seal leakage was analyzed without operator-controlled cooldown and with operator-controlled cooldown. For each scenario, figures are included to show the response of pressurizer level, RCS pressure, RCS temperatures, steam generator pressure and RCP seal leakage. Important times and transient events are noted on the figures, where appropriate. The six loss of ac power scenarios are:

CASE	SCENARIO
1	Seal leakage = 50 gpm/RCP at nominal RCS conditions Cooldown = No secondary depressurization/cooldown
2	Seal leakage = 50 gpm/RCP at nominal RCS conditions Cooldown = Secondary temperature reduced from saturation temperature at safety valve setpoint pressure to 470°F at 100°F/hr, starting when pressurizer level drops to 10% of span**
3	Seal leakage = 300 gpm/RCP at nominal RCS conditions Cooldown = No secondary depressurization/cooldown
4	Seal leakage = 300 gpm/RCP at nominal RCS conditions Cooldown = Secondary temperature reduced from saturation temperature at safety valve setpoint pressure to 470°F at 100°F/hr, starting when pressurizer level drops to 10% of span**
5	Seal leakage = 5 gpm/RCP at nominal RCS conditions Cooldown = No secondary depressurization/cooldown
6	Seal leakage = 5 gpm/RCP at nominal RCS conditions Cooldown = Secondary temperature reduced from saturation temperature at safety valve setpoint pressure to 470°F at 100°F/hr, starting 10 minutes after reactor trip

NOTE: The analyses are based on a plant design in which the initial reactor vessel upper head temperature equals the temperature of the hot leg (this is conservative for Plant Vogtle because the head is at T_C initially in the transient while forced flow is coasting down).

Case 1

Case 1 presents RCS response to an assumed RCP seal leakage rate of 50 gpm/pump without operator action to cool down the secondary. Pressurizer level response is shown in Figure 1. Pressurizer level decreases steadily at a rate of approximately 1.5%/minute until the pressurizer empties at about 32 minutes. At approximately this time, the water in the reactor vessel upper head starts to flash and retards the pressure decay. Eventually, the upper head cools sufficiently to allow pressure to decay to the saturation pressure of the fluid in the hot leg piping. Flashing also occurs in the hot leg piping. This happens at about 80 minutes after the start of the transient. Steam generator pressure increases rapidly to the safety valve set pressure and remains there throughout the transient. Leakage from the RCP seals starts at a relatively high value and continues throughout the transient but trends downward as the pressure decays. After about 2 hours as the entire RCS approaches saturation, RCP seal leakage stabilizes at a rate equal to approximately 30% of its initial flow.

Case 2

Case 2 presents the effects of superimposing a secondary cooldown on the Case 1 transient. The cooldown is initiated at about 30 minutes when the pressurizer level has dropped to 10% of span. The cooldown rate of the steam generator secondary is approximately 100°F/hr and is assumed to be accomplished via coordinated manual control of the steam generator ARVs and the turbine-driven AFW pump. Results of the analysis along with important times and events are shown in Figure 2.

There are several differences to be noted in the results for Case 2. As expected, RCS pressure drops much more rapidly once the secondary cooldown is initiated. Also because of the cooldown, subcooling is maintained in the reactor cold leg piping for a slightly longer period of time. This is due both to the cooling effects from the steam generator and the cold accumulator water which starts to enter the system after RCS pressure decay. The reactor vessel upper head cools in about 85 minutes. The primary benefit of the cooldown is illustrated by the RCP leak flow. The leak flow stabilizes at about 23% of its initial value for about a 25% reduction in the stable leakage rate calculated in Case 1 when no cooldown is assumed. More importantly, this difference exists at about 1 hour after reactor trip and continues throughout the transient. The effect of this difference is that considerably more water remains in the RCS in the case where a cooldown is initiated. For a 4-loop plant this difference amounts to roughly 600 lbs in the first 2 hours after the loss of ac power occurs.

Case 3

Case 3 is the same as Case 1 except that the assumed initial RCP leakage rate is 300 gpm/pump. Case 3 results are shown in Figure 3. Obvious differences are the speed at which pressurizer level drops (8.5%/minute versus 1.5%/minute) and the earlier times of saturation in the RCS (7 to 30 minutes versus 40 to 140 minutes). Essentially, the trends are the same for all variables only they are accelerated in time for this larger leak rate.

Case 4

Case 4 presents the effects of superimposing a 100°F/hr cooldown on Case 3 results. Results for Case 4 are shown in Figure 4. The comparisons noted between Cases 1 and 2 also hold for Cases 3 and 4: a more rapid decrease in RCS pressure, slightly longer period of subcooling in the cold leg piping, and about a 20-25% reduction in pump leakage beyond approximately 30 minutes. For Plant Vogtle, the saving of water in the RCS due to cooldown for this case amounts to approximately 22000 lbs over the first 2 hours of the transient.

Cases 5 and 6

Cases 5 and 6 assume an initial RCP leakage rate of 5 gpm/pump. Results of Cases 5 and 6 are shown in Figures 5 and 6 respectively. The situations presented are identical to the transients discussed above with the exception that the cooldown in Case 6 is started 10 minutes after trip rather than when the pressurizer level drops to 10%. The key point to note in these results is the extended period of high pressure in the RCS following the cooldown. This is the result of the "pressurizer effect" of the reactor vessel upper head inventory. In the previous case, leakage is primarily responsible for cooling of the reactor vessel upper head inventory by allowing it to drain into the loops and circulate through the steam generators. In these low leakage cases, the leak rates prohibit this and upper head cooling is controlled primarily by bypass flow into the head. Under natural circulation conditions, this effect is small, greatly slowing the cooling process. The effect of the increased pressure is to prevent flashing in the upper head until beyond 5.5 hours in the transient without cooldown and to extend the time of hot leg flashing beyond 5.5 hours into the case including a cooldown. As with the preceding cases, the cooldown results in reducing RCP seal leakage and conserving RCS inventory.

Pressurizer Level Response

As discussed in the preceding paragraphs, pressurizer level is one of the important RCS process variables. Before initiation of a cooldown, pressurizer level can be used by the operator to estimate the rate of RCS inventory loss. If the RCS outflow paths are isolated, pressurizer level can be used to estimate RCP seal leakage and indirectly monitor the condition of the RCP seals. This information is valuable since it is likely that RCP seal leakage will exceed the limited upper range of the seal leakoff flow instruments.

The decrease in pressurizer level is directly related to RCS inventory loss. By monitoring the rate of pressurizer level decrease and estimating the time it will reach the bottom of the instrument span, an operator can roughly estimate the magnitude of RCS inventory loss. If the RCS is isolated, this inventory loss is due to RCP seal leakage. In this manner, pressurizer level may assist the operator in evaluating the condition of the RCP seals. Figure 7 is included to illustrate the relationship between RCS inventory loss and pressurizer level decrease. Figure 7 shows the time required for the pressurizer level to decrease to 10% of instrument span for the spectrum of potential RCP seal leakage rates.

Containment Response

A loss of all ac power will effect the containment environment because of RCP seal leakage. Even in the worst case, these effects will be moderate. Calculations of the response of a 4-loop dry atmospheric containment (Plant Vogtle) to moderate (50 gpm/pump) and large (300 gpm/pump) leak rates show that in the first hour even the larger leak rate results only in a pressure rise of 3 psi and an increase in containment temperature of less than 40°F. The calculations were made assuming that heat was removed from the atmosphere only by passive containment heat sinks. Ultimately, should the leak not be terminated, the heat sinks will saturate and containment conditions could again increase. However, the time required for this to occur is beyond the time where core cooling problems would occur due to lost RCS inventory. Results of the containment analyses are:

BEST ESTIMATE CONTAINMENT RESPONSE
FOLLOWING LOSS OF ALL AC POWER WITH RCP LEAKAGE

PRESSURE RISE (PSI)	
50 GPM/RCP	1.0
300 GPM/RCP	3.1
VAPOR TEMPERATURE RISE (°F)	
50 GPM/RCP	14
300 GPM/RCP	38
SUMP TEMPERATURE RISE (°F)	
50 GPM/RCP	27
300 GPM/RCP	66

NOTE: 300 GPM/PUMP case analyzed to 60 minutes
50 GPM/PUMP case analyzed to 300 minutes

Core Cooling Response

Whether or not a secondary depressurization is initiated, the RCS will continue to depressurize until ac power is restored: the pressurizer will continue to empty and there will be a progressive saturation of the reactor vessel upper head, the hot leg piping, and eventually the entire RCS. At some point, natural circulation will stop and heat will be removed via reflux boiling between the core and steam generators. Ultimately, if ac power continues to be unavailable, enough water will be lost through the pump seals to uncover the reactor fuel and an inadequate core cooling condition may occur. Until ac power is restored and plant equipment can be made available to restore RCS inventory, this scenario can only be delayed; it cannot be not stopped. To illustrate the time within which ac power must be restored, analyses were performed for Cases 3 and 4 to evaluate the time to core uncovering. The results for RCS pressure, reactor vessel upper head mixture level and reactor vessel mixture level are shown in Figures 8 and 9.

The time to core uncovering as a function of total RCS inventory loss is shown in Figure 10. This figure shows both the scenarios where the secondary is manually depressurized to reduce RCS inventory loss and permit injection of accumulator contents and the scenarios where manual depressurization is not implemented. This figure provides a rough estimate of the time to core uncovering for different rates of RCS inventory loss.

Palisades Loss of AC Power Event

On January 8, 1984, the Palisades Nuclear Plant experienced a complete loss of offsite and onsite ac power. The event was precipitated by the need to isolate a faulty switchyard breaker. To isolate the breaker, it was necessary to interrupt the offsite power supply to the plant. At the time of the event, Palisades was in a refueling outage with all fuel removed from the reactor and the no. 2 diesel generator was inoperable. The no.1 diesel generator was operable but the service water pump powered from the no. 1 diesel generator was inoperable as a result of maintenance.

When the shift supervisor interrupted the offsite power supply to the plant, the operators did not realize cooling water to the operable DG was not available. The control room alarm indication which should have warned the operators was apparently masked by the large number of simultaneous alarms received when the offsite power was interrupted. Approximately 50 minutes later the DG overheated and was manually tripped. Once the DG was tripped, all station power was lost, with the exception of the station batteries and their associated dc and preferred ac busses. The loss of ac power caused a loss of plant communications, fire protection, security, and habitability systems as well as the fuel pool cooling system. Compensatory measures were promptly taken upon loss of the normal security systems. The loss of communications was considered the most serious consequence of this event. The restoration of ac power was delayed as a result of an inoperable main transformer (out for maintenance) and a malfunction of one of the startup supply breakers.

While operating procedures required two operable diesel generators before removing offsite power, operating procedures did not specifically delineate equipment availability requirements for this defueled condition. The shift supervisor violated the procedure and proceeded with the evolution after evaluating fuel cooling. The fuel pool was known to heat up very slowly and to require days without active cooling before the high temperature alarm would be reached. The shift supervisor, however, failed to fully recognize the importance of the other support systems (communication, fire protection) to the overall safety of the plant. The procedural requirements were reviewed as part of the evaluation of fuel cooling and it was determined their intent was to minimize risk to fuel integrity when the fuel was in the reactor vessel.

The licensee initiated many corrective actions as a result of this event (see Palisades Licensee Event Report (LER) 84-001). One of the more important was a review of the management control of equipment for plant conditions not covered by the requirements of the Technical Specifications. The review specifically addressed electrical system requirements during cold shutdown to ensure sufficient equipment remains available to maintain the plant in a safe condition and to meet the commitments of the Site Emergency, Security, and Fire Protection Plans.

Loss of AC Power and Emergency Plan Implementation

Following the loss of onsite and offsite ac power at Palisades, the Emergency Procedures were not implemented in a timely manner because the importance of the various support systems had not been recognized.

At Plant Vogtle, any of the following conditions require entry into the NUE class of emergency:

- Loss of offsite or onsite ac power
- Indications or alarms not functional in control room to an extent requiring plant shutdown or other significant loss of assessment or communication capability.

The following are conditions to enter the ALERT classification:

- Loss of offsite and onsite power
- Loss of all dc power

The following are conditions to enter the SITE-AREA classification:

- Loss of all offsite and onsite power for more than 15 min.
- Loss of all vital onsite DC power for more than 15 min.

Should the RCP seals fail, the RCS boundary may have to be declared breached or challenged and an alert class emergency declared. This would be indicated by containment rad monitors increasing rapidly to off-scale high or the containment vent effluent rad monitors at the high setpoint. It would also be indicated if a low RVLIS level caused a red or orange condition on the core cooling critical safety function status tree. The radiation boundaries must also be declared challenged or breached if loss of power leads to a loss of the ability to monitor the barrier and verify its integrity.

50 gpm/RCP

Figure 1. (CASE 1)

LEAKAGE WITHOUT SECONDARY DEPRESSURIZATION

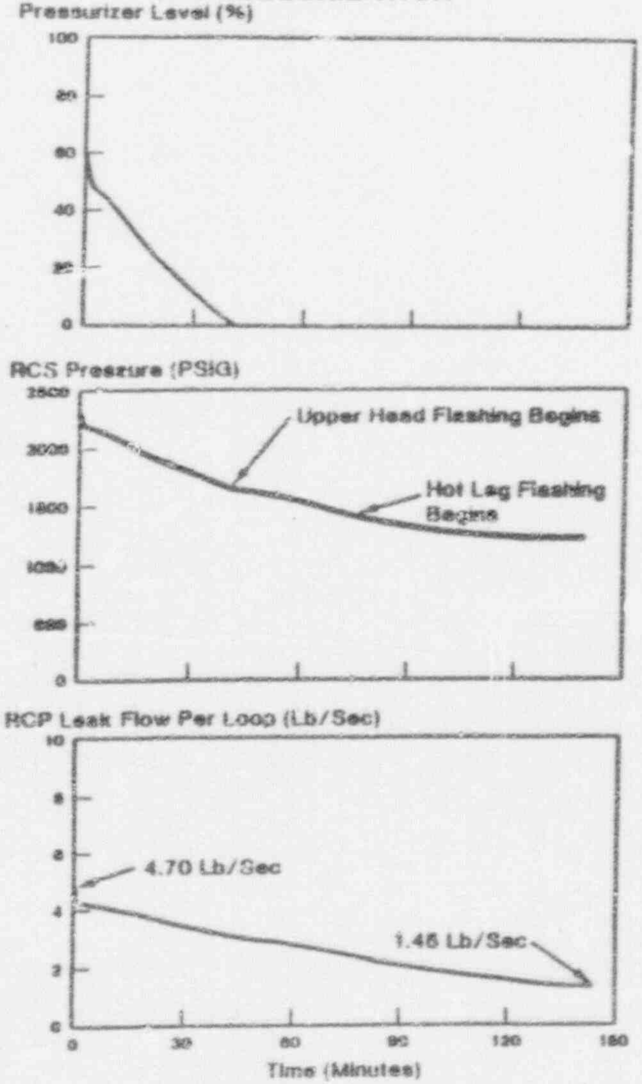
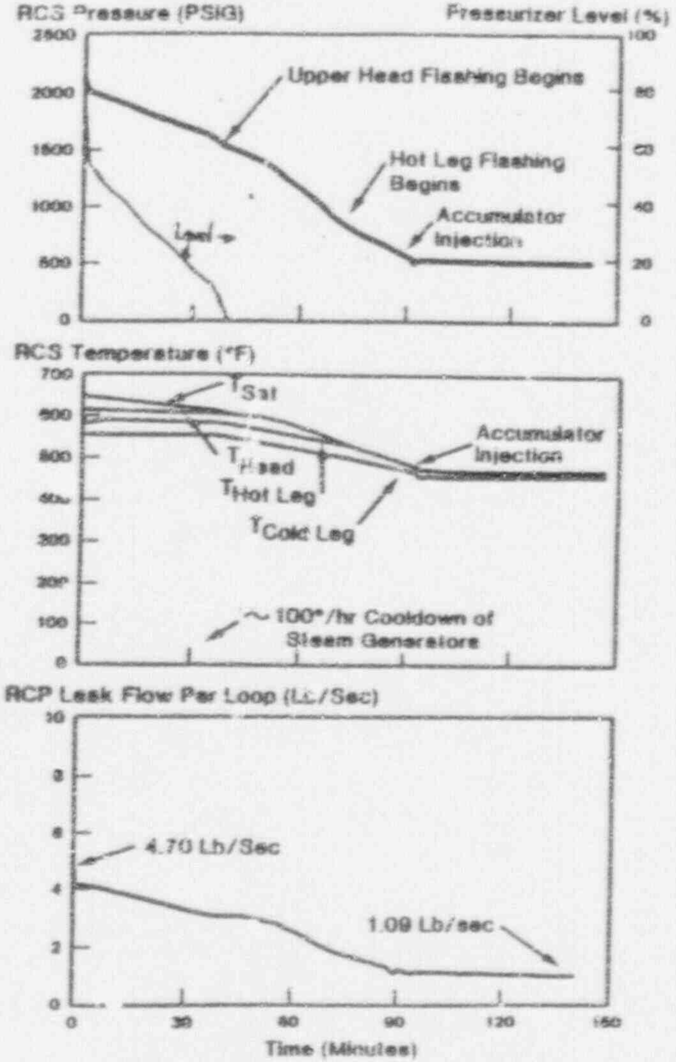


Figure 2. (CASE 2)

LEAKAGE WITH SECONDARY DEPRESSURIZATION



FIGURES 1 AND 2

300 gpm/RCP

Figure 3. (CASE 3)

LEAKAGE <u>WITHOUT</u> SECONDARY DEPRESSURIZATION

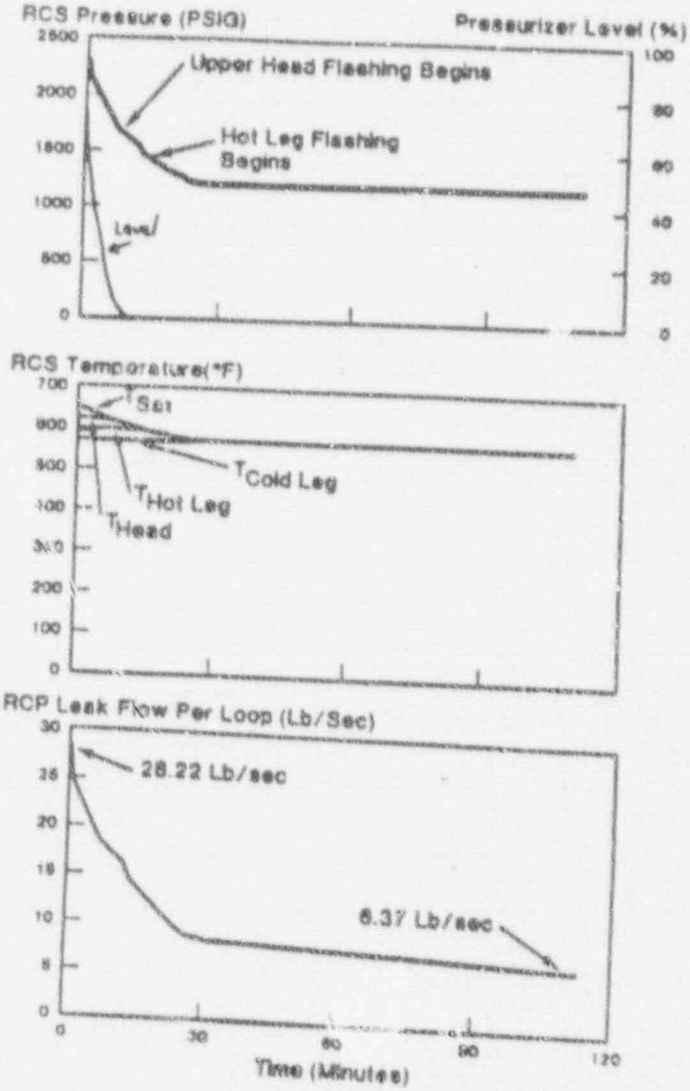
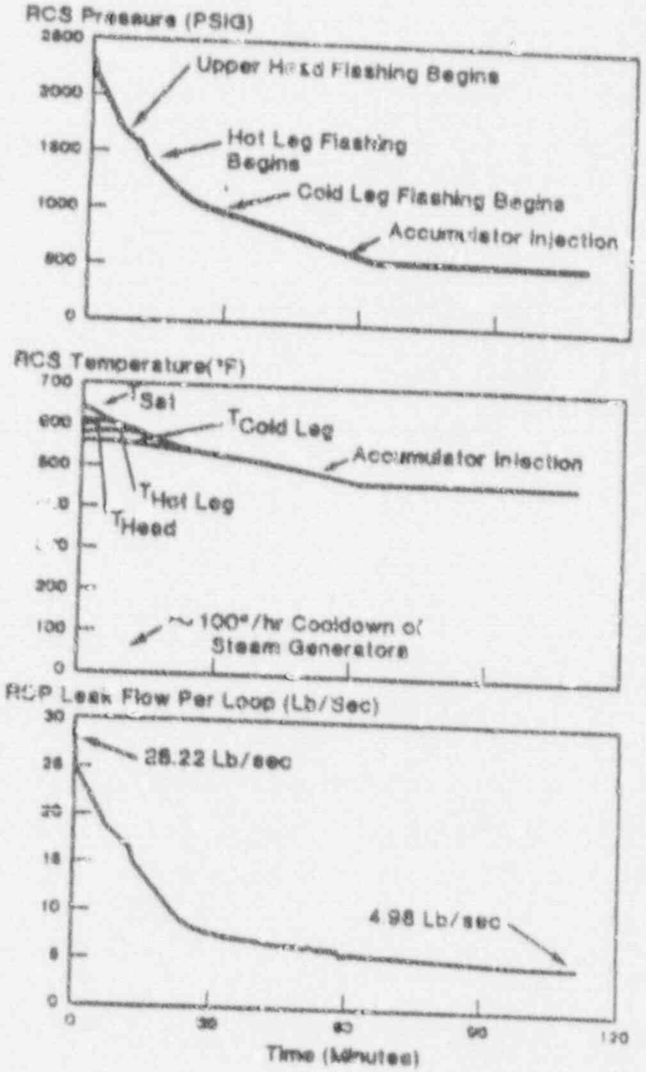


Figure 4. (CASE 4)

LEAKAGE <u>WITH</u> SECONDARY DEPRESSURIZATION



5 gpm/RCP

Figure 5. (CASE 5)

LEAKAGE WITHOUT SECONDARY DEPRESSURIZATION

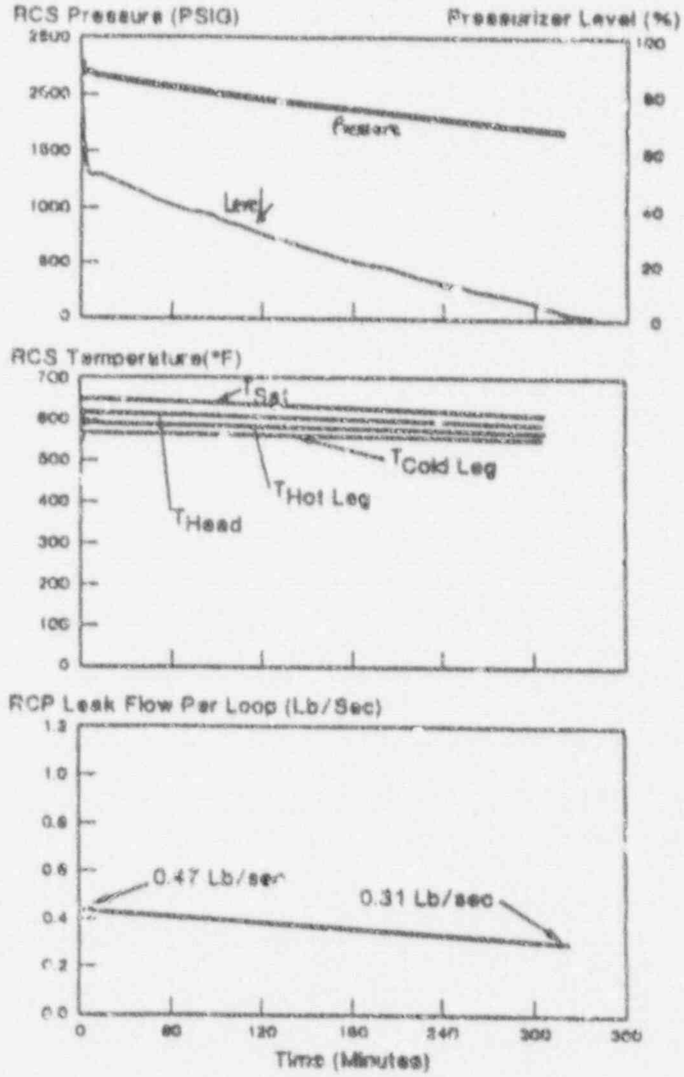


Figure 6. (CASE 6)

LEAKAGE WITH SECONDARY DEPRESSURIZATION

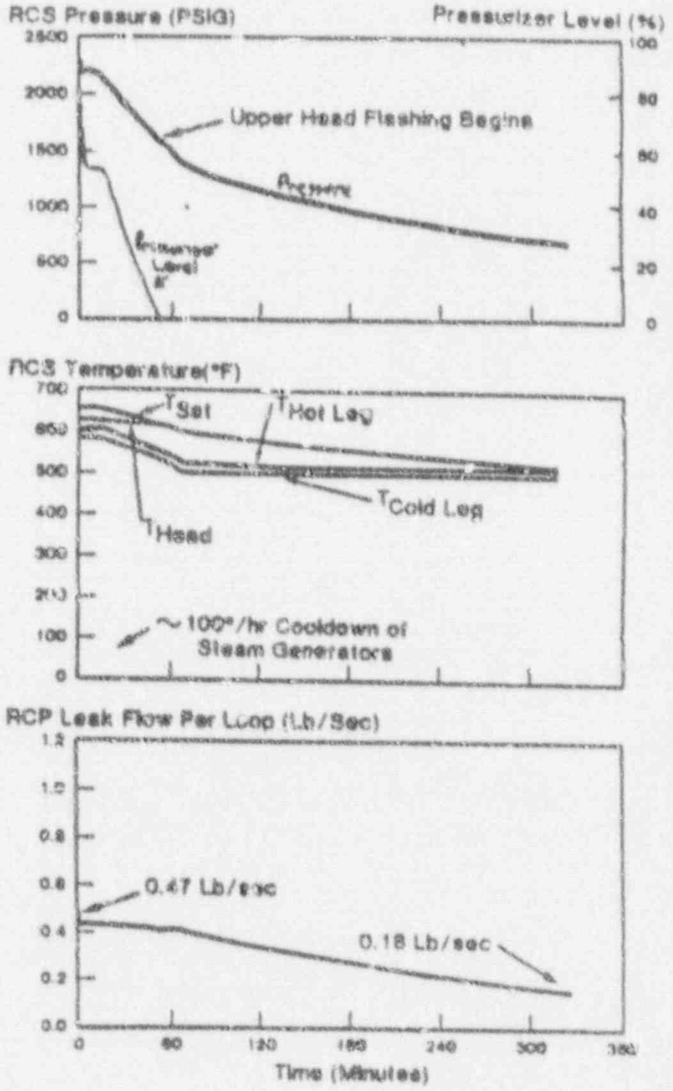
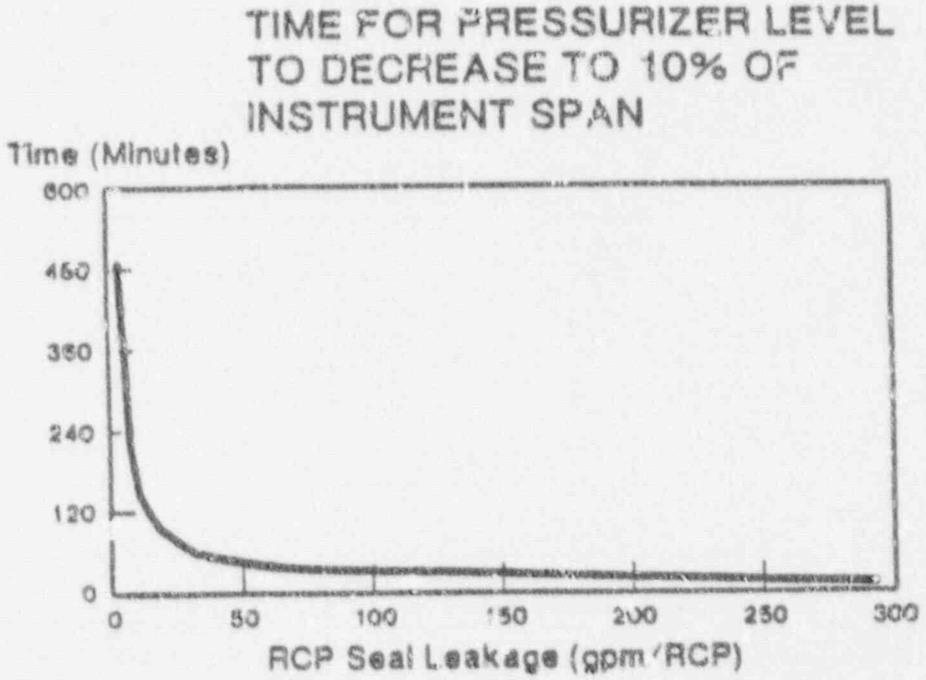


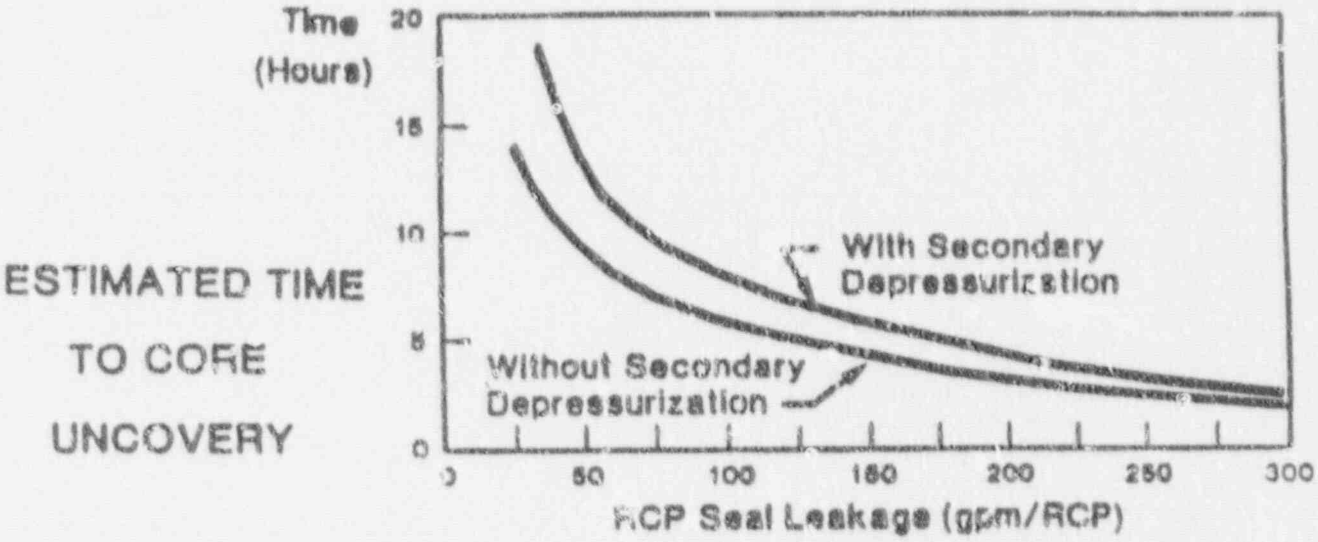
FIGURE 7



TIME FOR PRESSURIZER LEVEL TO DECREASE TO 10% OF INSTRUMENT SPAN

LO-HO-37031- -C-001

FIGURE 10



300 gpm/RCP

Figure 8. (CASE 3)

LEAKAGE WITHOUT SECONDARY DEPRESSURIZATION

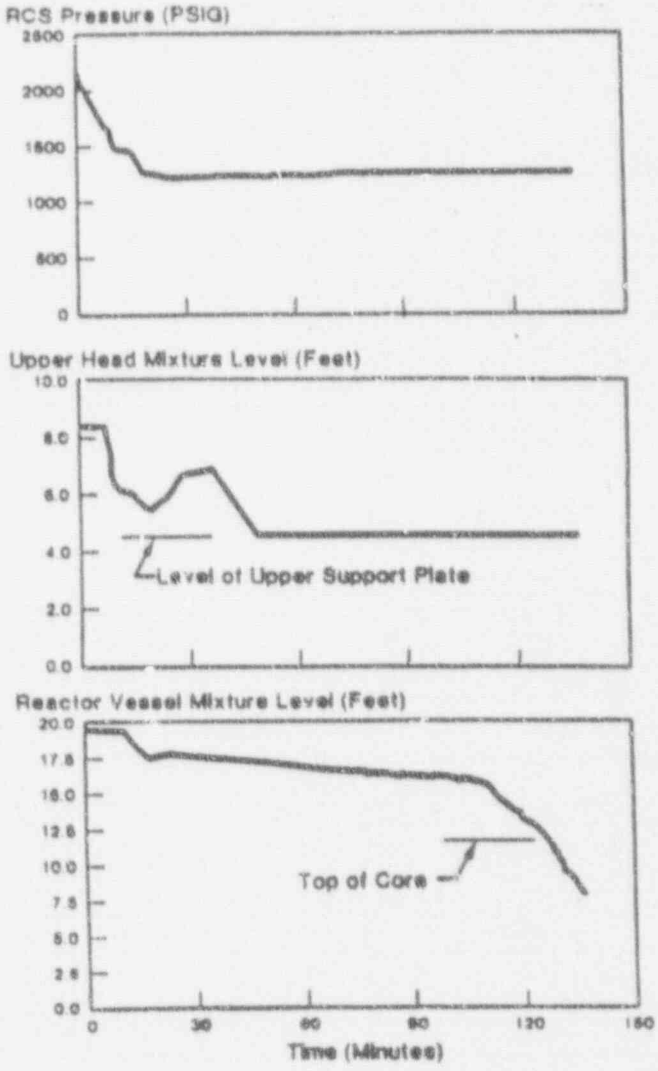


Figure 9 (CASE 4)

SEAL LEAKAGE WITH SECONDARY DEPRESSURIZATION