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SUBJECT: Forwards partial response to NRC 800708 ltr,Question 1 re natural circulation cooldown.Encl 1 explains how reactor vessel upper head can be cooled by drain & fill procedure. Encl 2 & 3 describes analytical model & model results.

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FLORIDA POWER & LIGHT COMPANY

August 25, 1980
L-80-277

Office of Nuclear Reactor Regulation
Attention: Mr. Thomas M. Novak
Assistant Director for Operating Reactors
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Novak:

Re: St. Lucie Unit 1
Docket No. 50-335
Natural Circulation Cooldown

In order to respond to question 1 of the NRC letter dated July 8, 1980 concerning the above subject, Florida Power & Light contracted with our NSSS vendor to analyze the June 11, 1980 natural circulation cooldown event. Enclosure 1 to this letter contains an explanation of how the reactor vessel upper head can be cooled by a drain and fill procedure. This analysis accounts for the relatively stagnant fluid in the upper head as requested in the letter. A description of the analytical model used for the analysis and the model results are provided as requested as Enclosures 2 and 3.

We have demonstrated that we can safely cool down the reactor on natural circulation using the drain and fill method while remaining well within the cooldown limits as specified in the plant Technical Specifications. Our NSSS vendor has assured us that, based on their analyses to this point, this method is an efficient means to bring the unit to the cold shutdown condition on natural circulation and furthermore, that this method presents no safety problems. We have, however, directed our NSSS vendor to conduct additional engineering work on this method. This additional work and the work necessary to answer the remainder of the questions will require a substantial effort which will take longer than the 60 days mentioned in your information request letter. We will provide an update on this work and a response schedule for the remaining questions by September 15, 1980.

Very truly yours,

Robert E. Uhrig

Robert E. Uhrig
Vice President
Advanced Systems & Technology

REU/PLP/cph

cc: Mr. J. P. O'Reilly, Region II
Harold F. Reis, Esquire

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ENCLOSURE 1

REACTOR VESSEL UPPER HEAD

COOLING VIA DRAIN AND FILL

UPPER HEAD COOLING VIA DRAIN AND FILL

Voiding in the reactor vessel upper head may occur during natural circulation conditions by lowering the RCS pressure by using the auxiliary sprays in the pressurizer. Voiding the upper head flushes hot upper head fluid into the cooler RCS where it is mixed with the RCS water. Any steam bubbles flushed out will condense well before the slow natural circulation rates could carry them to the SG tubes; hence, there is no mechanism whereby the voiding into the loop could alter or impede the natural circulation cooling process. The water flushed out of the upper head will act as a piston, causing a corresponding surge of water from the RCS into the pressurizer. This insurge of water into the pressurizer will raise the pressurizer water level. The amount of pressurizer water level rise will depend on the amount of upper head fluid flashed to steam which remains in the upper head, where it is not in thermal contact with the cooler loop water. The amount of upper head fluid flashed depends on the pressure drop caused by the pressurizer sprays. The entire process is strongly coupled since the pressurizer pressure is influenced both by the spray, which "starts" the process, and by the insurge which is caused by the lowered pressurizer pressure and the corresponding upper head flashing. Obviously, this process occurs only after the RCS pressure has been lowered to the saturation pressure corresponding to the upper head thermal state.

The process may be stopped when the upper head is sufficiently voided or when the pressurizer water level has reached an appropriate level. When this point is reached, the process may be readily halted by stopping the sprays. The insurge will now compress the pressurizer steam space, raising its pressure, which acts both to stop the insurge and to halt the flashing in the upper head. At this point the surge may be reversed by charging the RCS: the elevation head difference between the RV upper head and the elevated pressurizer will cause the charging flow (which acts as a piston on the RCS water) to preferentially feed the upper head. The mixing of the colder loop water with the hot upper head fluid cools the upper head and causes a corresponding outsurge of water from the pressurizer. Hence, the pressurizer water level will fall as the loop is charged when there is still steam in the upper head. This process may be continued until the upper head is solid or until the pressurizer water level falls to an acceptably low level. A solid upper head condition will be immediately reflected by an increasing pressurizer water level as charging the loop is continued. The entire drain and fill cycle may be repeated until the thermal state of the upper head has been lowered to a point acceptable for entering shutdown cooling.

ENCLOSURE 2

ANALYTICAL MODELING OF THE DRAIN AND FILL PROCESS: MODEL DESCRIPTION

COMPUTER MODELING OF THE DRAIN AND FILL PROCESS: MODEL DESCRIPTION

A computer simulation of the drain and fill process has been performed. The essence of the problem is the recognition of the possibility of steam in the upper head region. In a more general sense, the possibility of both steam and water in the upper head must also be addressed. Accordingly, it is reasonable to model the upper head as a pressurizer. The simulation model used herein consisted of two separate pressurizer models, one for the pressurizer and one for the upper head. The two nodes are connected together via a third node, representing the rest of the RCS. A momentum equation is used to hydraulically calculate the flow rates between the RCS and the pressurizer; a separate momentum equation is similarly used to calculate the flow rates between the RCS and the upper head region. The RCS node properties are calculated at each time step by simultaneously solving the conservation equations for the node (mass, energy, and volume). The RCS node can also accept time input values for charging and letdown. Decay heat and primary to secondary heat transfer are represented by inputting a known RCS temperature vs. time; this allows for the consideration of loop shrinkage as the cooldown proceeds. Each "pressurizer" (e.g., the pressurizer and the upper head) model is the same model used and described in CEN-128.*

Metal to water/steam heat transfer is modeled in both the pressurizer and the upper head. Cooling of the fluid in the region between the nozles and the UGSSP is also modeled. The pressurizer model used is a very flexible non-equilibrium model, and can model a wide variety of thermodynamic states. The presurizer model state capabilities are:

PRESSURIZER STATES

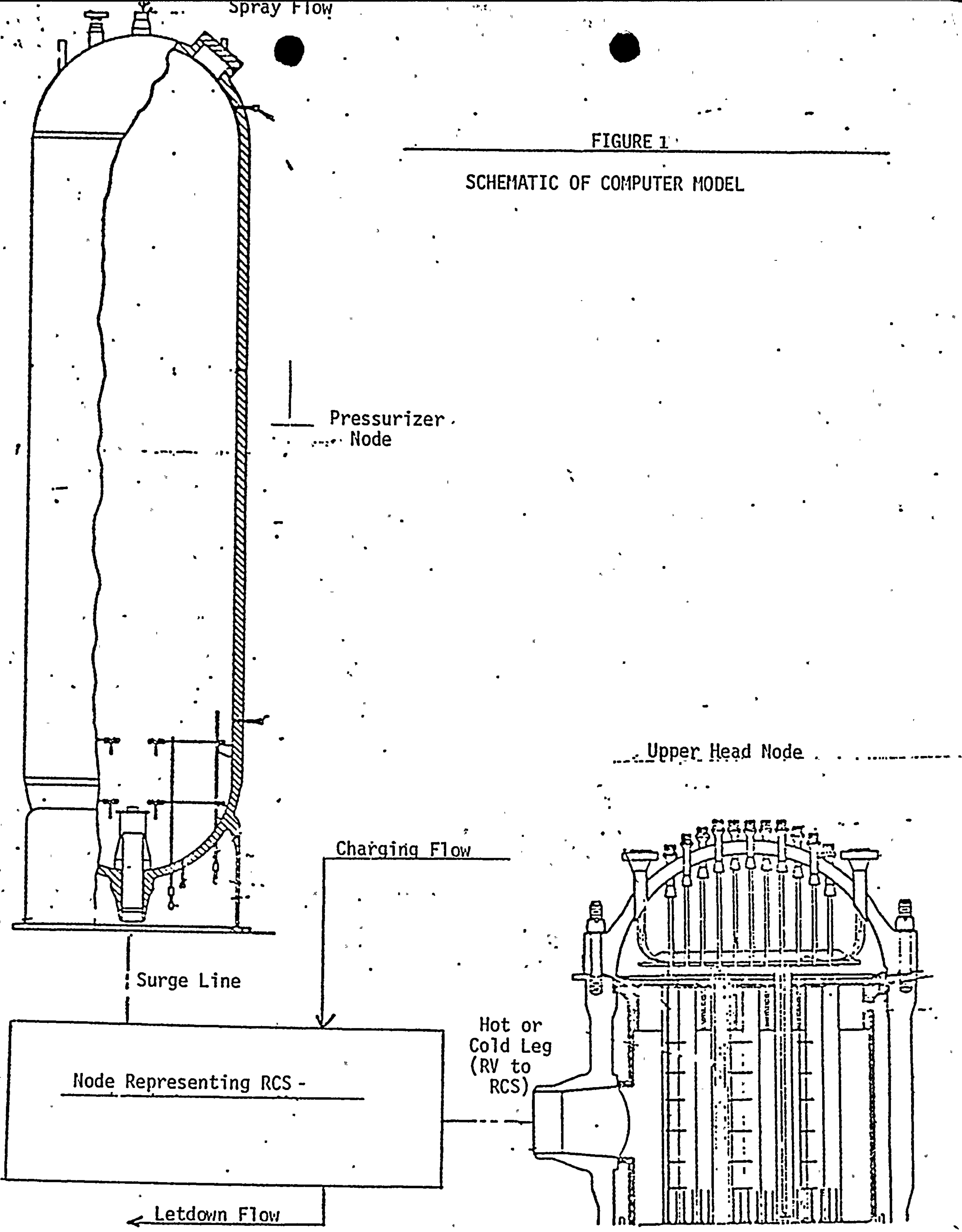
CONDITIONS	WATER	STEAM
1	SUBCOOLED	SUPERHEATED
2	SATURATED	SUPERHEATED
3	SUBCOOLED	SATURATED STEAM
4	SATURATED	SATURATED STEAM
5	NONE	SUPERHEATED
6	NONE	SATURATED STEAM
7	SUBCOOLED	NONE
8	SATURATED	NONE

A sketch of the model is provided as Figure 1.

*CEN-128: "Response of Combustion Engineering Nuclear Steam Supply System to Transients and Accidents", April 1, 1980.

FIGURE 1

SCHEMATIC OF COMPUTER MODEL



(not to scale)

ENCLOSURE 3

RESULTS OF COMPUTER SIMULATION OF THE DRAIN AND FILL PROCESS

COMPUTER SIMULATION OF THE DRAIN AND FILL PROCESS: RESULTS

The computer model previously described has been used to simulate the St. Lucie I natural circulation cooldown transient. The initial conditions for the transient were taken from field data; the initial conditions for the upper head thermal state during the cooldown have been estimated from this data. The data used is shown in Table 1.

The results of simulating the St. Lucie I cooldown/depressurization event are shown on the Figures as listed below:

Figure 2: Pressurizer Pressure

Figure 3: Pressurizer Indicated Level

Figure 4: Upper Head Liquid Volume

Figure 5: Temperature: Upper Head Water and Loop Hot Legs

The scenario simulated on Figures 2, 3, 4 and 5 was not intended to duplicate the entire plant cooldown of June 11, 1980. Such a simulation was not possible since all the data regarding the cooldown was not available in time to respond to the NRC questions. However, the qualitative agreement of the simulated pressurizer response (Figures 2 and 3) is very good when compared to the actual plant data during the first spray/charging operation from 0600 (time = 0 on the simulated plots) to 0730 except for the two small peaks in the plant pressurizer level curve at about 0715; no attempt was made to reproduce these two peaks. Not attempting to duplicate these peak shifts the simulated curve earlier in time by about 20 mnutes, so that the simulated pressurizer level curve reaches the 65% "setpoint" somewhat before the plant data did. After 0730 plant time; the simulated scenario was intended only to investigate the thermal response of the upper head fluid. The simulated scenario is shown in Table 2. The notes on Table 2 explain the scenario, the procedures which were modeled, and the results which were obtained.

TABLE 1

INITIAL CONDITIONS

Time after trip:	3.5 hours*
Pressurizer pressure, psia	1140
Pressurizer level, %	37
RCS temperature, °F (T_{hot})	350
Upper head fluid temperature, °F	520**
Upper head wall temperature, °F	520***
Upper head volume, ft^3	1000****

* 0600 plant time

** Estimated from plant data, based on the fact that the RCP's were "bumped" when T_{hot} was approximately 520°.

*** The RCP's were "bumped" shortly after the reactor was tripped. The heat transfer from the walls to the fluid is such that the walls would be essentially at the fluid temperature 3.5 hours later when the computer simulation was started.

**** Estimated from plant field data; correlated with geometrical data.

TABLE 2: SIMULATION SCENARIO

Time Frame (Hours)	Plant Operation	Notes
0 to 0.60 (First spray cycle)	Auxiliary spray at 44 gpm terminated at pressurizer level of 90%, time varying letdown, no heaters*, no charging.	Actual plant operating data, except for heaters. Upper head almost totally voided.
0.60 to 1.23 (First charging cycle)	No auxiliary spray, no letdown, no heaters* charging RCS at 44 gpm, charging terminated at pressurizer level of 65%.	Actual plant operating data, except for heaters. Upper head refilled to about 2/3 liquid, significant upper head cooling.
1.23 to 1.33 (Second spray cycle)	Same as first spray cycle, but spray terminated at pressurizer level of 80% and no letdown.	Upper head affected only slightly due to short amount of spray time.
1.33 to 2.13 (Second charging cycle)	Same as first charging cycle, charging also terminated at pressurizer level of 65%.	Effect on upper head more moderate than in first charging cycle, due to initial inventory in region at start of cycle.
2.13 to 2.18 (Third spray cycle)	Same as second spray cycle; spray also terminated at pressurizer level of 80%.	See note regarding second spray cycle
2.18 to 2.95 (Third Charging Cycle)	Same as first and second charging cycles, charging terminated at pressurizer level of 65%.	See note regarding second charging cycle.
2.95 to 3.95** ((letdown cycle)	No auxiliary spray, no charging, no heaters*, letdown at 128 gpm.	Upper head is solid at end of third charging cycle; pressurizer is at 80% level at that time. Spray and charging have been accumulating so system inventory needs to be relieved. Note that letdown flashes the upper head by reducing system pressure, analogous to the operation of the pressurizer spray.

(SEE NEXT PAGE FOR NOTES)

* Heaters were not used in the simulation in order to conservatively estimate RCS subcooling margin. The minimum RCS subcooling obtained during the simulation was 54°F, at 3.95 hours.

** End of simulation; hot leg temperature satisfied shutdown cooling temperature criterion. Upper head is voided and may be refilled by charging. Before charging, it would be necessary to repressurize the system via pressurizer heaters in order to prevent a loss of subcooling in the RCS. If the system is repressurized to 290 psia (shutdown cooling pressure criterion of 275 psig), the upper head will not flash as it is already cooled below Tsat (290 psia) = 414°F. Further charging of the RCS, if desired, will further drop the upper head temperature as an added safety factor. It is estimated that the upper head temperature would drop to approximately 320°F if the loop were to be charged again.

FIGURE 2

PRESSURIZER PRESSURE VS. TIME

Note: Time zero on this plot corresponds to 0600 hours plant time.

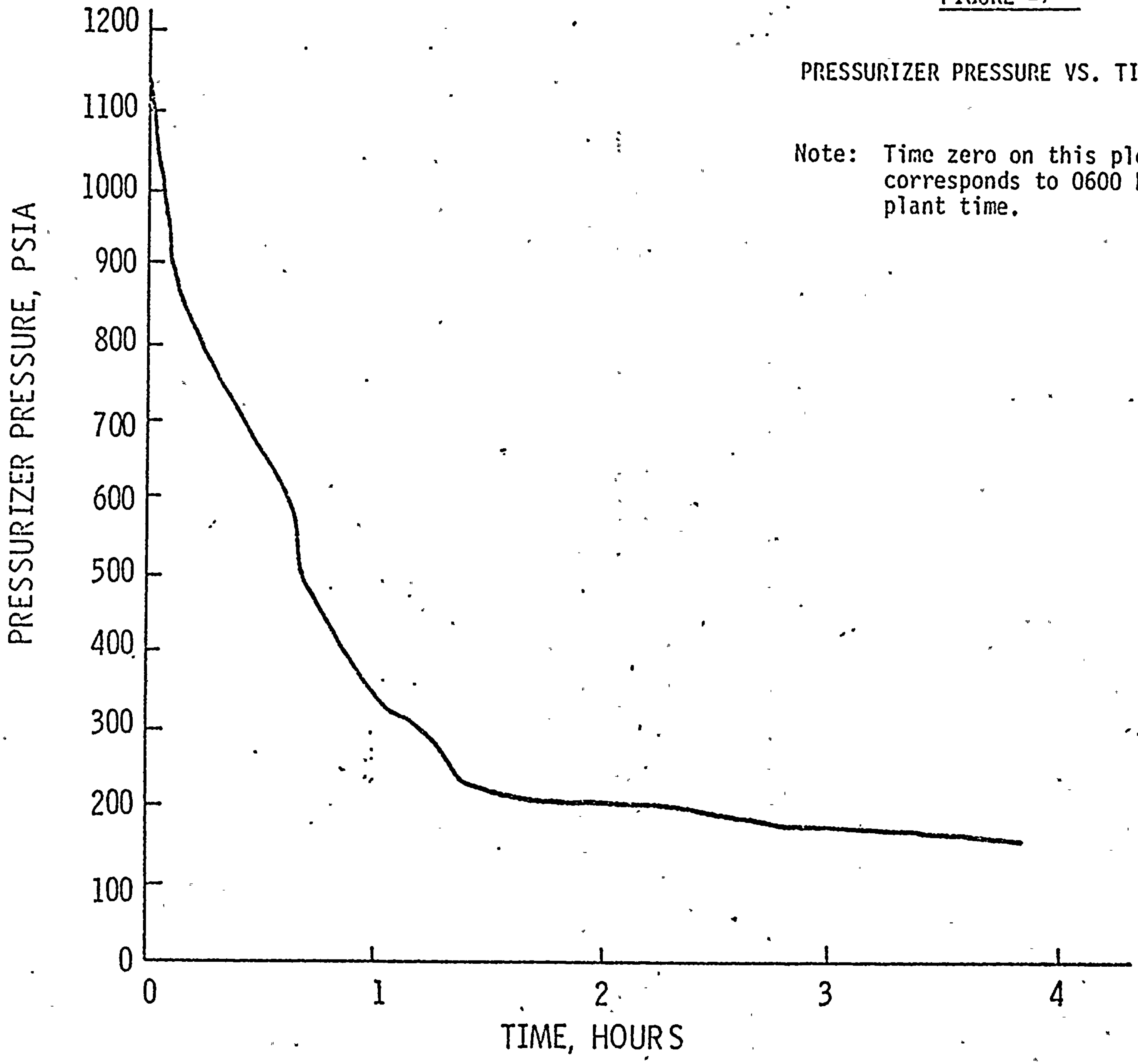


FIGURE 3

PRESSURIZER LEVEL VS. TIME

Note: Time zero on this plot corresponds to 0600 hours plant time.

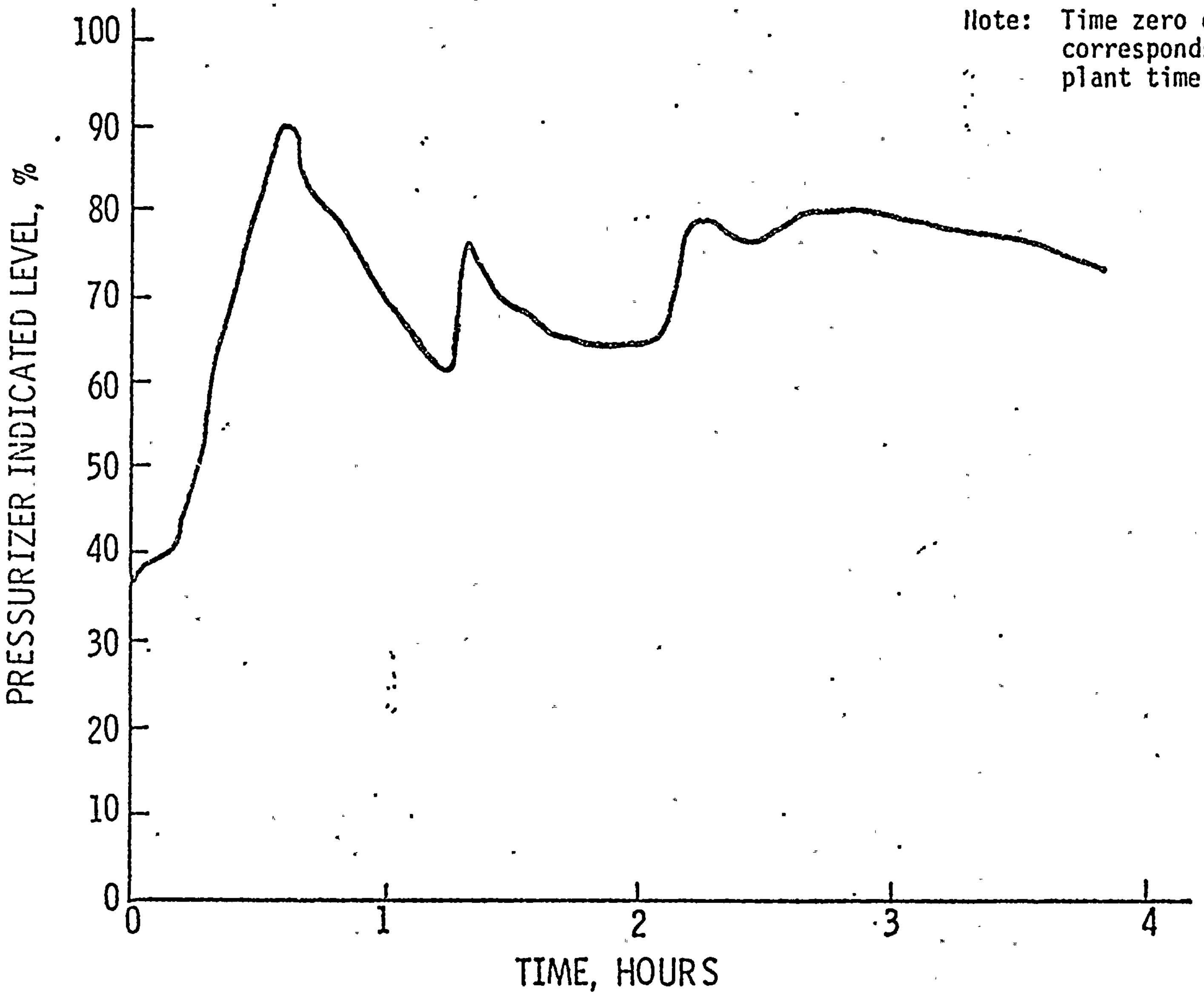


FIGURE 4

UPPER HEAD LIQUID VOLUME VS. TIME

Note: Time zero on this plot corresponds to 0600 hours plant time.

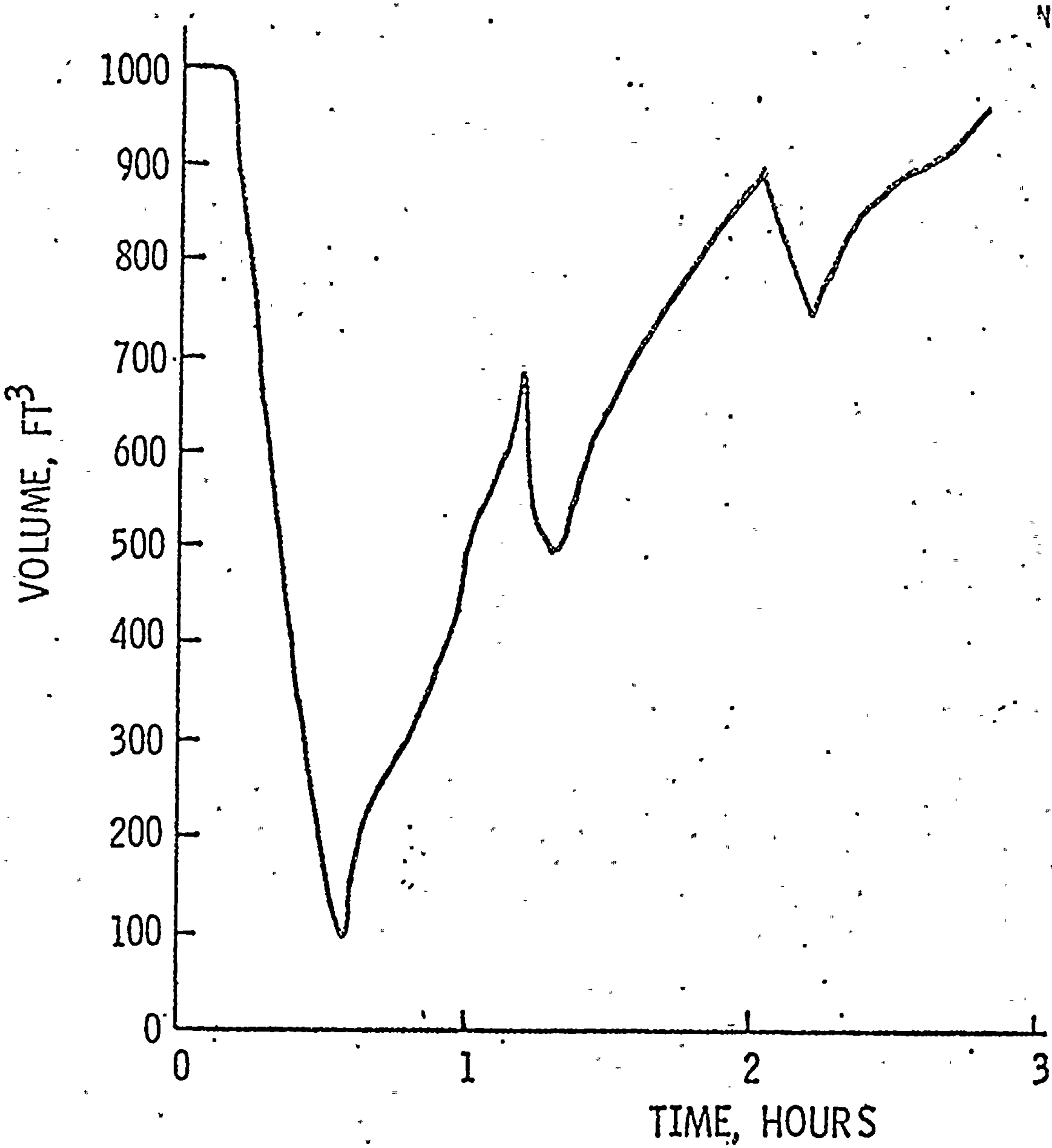
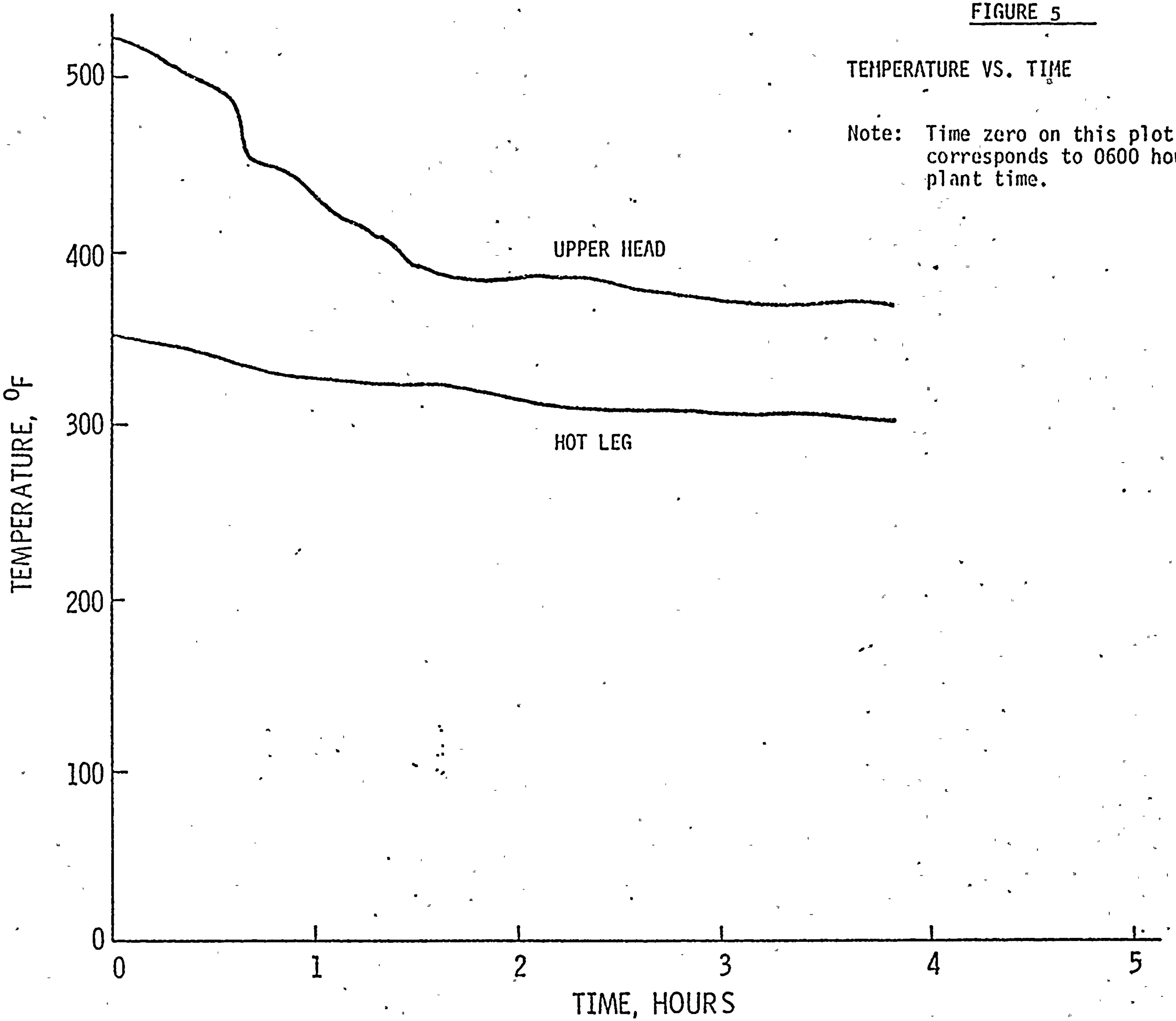


FIGURE 5

TEMPERATURE VS. TIME

Note: Time zero on this plot corresponds to 0600 hours plant time.



CONCLUSIONS

The following general conclusions have been drawn from these results:

1) Possible methods to cool the upper head region and expedite natural circulation cooldown are:

   a) "Bump" or use the RCP's, if offsite power is temporarily available.

   b) Provide additional condensate storage to support the extended time required for cooldown via heat conduction only.

   c) Cool the upper head via a drain and fill procedure.

2) The drain and fill procedure is effective in cooling the upper head as the upper head region is more totally voided via a depressurization process (spray or letdown). More voiding in the head region leaves less liquid inventory to mix with and heat the incoming RCS water when charging is in progress. Many "small" drain and fill cycles may not be as effective as a few larger cycles if the small cycles are centered around a relatively large liquid inventory in the upper head.

3) Any steam in the upper head region can be completely collapsed if the system pressure is raised sufficiently. If this is done via charging, then pressurizer level response will rapidly become "normal". The knowledge that the upper head is totally in a liquid state is useful since the pressurizer liquid level (i.e., liquid volume) response to voiding the upper head directly corresponds to the volume of steam left in the upper head via any voiding which does occur.

4) The system response to spraying the pressurizer when the upper head liquid is saturated is quite rapid both from the field data and from the simulation data. This is because the pressurizer spray acts directly on the steam in the pressurizer. However, the field data generally shows a much more rapid response to charging the RCS than does the simulated data. This difference when charging is due to the fact that some of the insurge to the upper head region will necessarily go through the CEA shrouds, where it is possible for the cold RCS water to directly come in contact with the steam in the upper head due to the elevation of the holes in the shrouds above the UGSSP. In other words, some of the insurge can act as a spray to the upper head steam when the upper head liquid level is below the elevation of the holes in the shrouds. This "spray" effect was not modeled as a conservatism in order to demonstrate the adequacy of the drain and fill procedure with the thermal inertia of the upper head water included. Note also that if the water level is above the holes then there will be no "spray" effect in the upper head. The rapid responses of the field data following charging imply that the liquid level in the upper head was generally below the level of the holes, thus always giving a "spray" effect when charging. In either case, the system response to charging is faster when there is less liquid in the upper head. 5) As noted in Table 2, the combination of the field data and the simulation results shows that both the RCS and the upper head can be brought to

shutdown cooling conditions after: a) enough time for the RCS to cool has elapsed and b) after the upper head has been drained and filled several times. Once this has been accomplished, it is possible to enter shutdown cooling without further voiding of the upper head.