REFERENCE 3

DEC 11 1989

Roger Newton, Chairman
Westinghouse Owners Group
Box 2046
Milwaukee, Wisconsin 53201

SUBJECT: "LOSS OF RHRS COOLING WHILE THE RCS IS PARTIALLY FILLED," WCAP-11916, JULY 1988, AND OTHER RELATED WESTINGHOUSE OWNERS GROUP ACTIVITIES

Dear Mr. Newton:

You provided us with copies of the subject report in November, 1988. While no review was requested, we reviewed the report because of its impact upon activities discussed in Generic Letters 87-12 and 88-17. Our evaluation is provided as enclosure 1. Overall, we find WCAP-11916 to be a timely and appropriate response to the concerns raised in the generic letters.

We contracted with the Idaho National Engineering Laboratory to assist in the review. Their review is provided in enclosure 2. Idaho stated, and we agree, that "Overall, the broad scope of WCAP-11916 indicates that Westinghouse and the Westinghouse Owners Group recognize that the potential for loss of RHRS capability exists, that losses of RHRS capability can lead to serious complications in cooling the reactor core, and that this issue must be addressed in a timely manner." "The methodologies for applying the results of the thermal-hydraulic analyses to individual plants are clearly written and well-conceived." WCAP-11916 results, when considered with our minor Enclosure 1 comments, are appropriate for use in responding to the GL 88-17 recommendations.

We understand you have issued procedures guidance for reduced inventory operation and that you are preparing background documentation for that guidance. We would appreciate receiving a copy of any of this material that may be readily available.

We commend you for these forward-looking efforts and we look forward to a continuation of this approach to nuclear safety.

/S/

Ashok C. Thadani, Director
Division of Systems Technology
Office of Nuclear Reactor Regulation

Enclosures:
Evaluation of WCAP-11916

cc w/enclosures:
Lawrence Walsh, Seabrook Station
Alan Ladieu, Yankee Atomic Electric

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"Overall, the broad scope of WCAP-11916 indicates that Westinghouse and the Westinghouse Owners Group recognize that the potential for loss of RHRS [residual heat removal system] capability exists, that losses of RHRS capability can lead to serious complications in cooling the reactor core, and that this issue must be addressed in a timely manner."

"The methodologies for applying the results of the thermal-hydraulic analyses to individual plants are clearly written and well-conceived."

"Overall, WCAP-11916 is very thorough and well-written, and provides the licensees with valuable information regarding prevention of and recovery from losses of RHRS capability."

Plant and scale model data are reported that cover flow phenomena in the RCS, and air ingestion and vortex formation at the RHR inlet nozzle. These data are used to correlate RCS level and RHR flow rate relative to air ingestion into RHR suction pipes, to establish level variations within the RCS, to provide insight into operations to restore RHR operation if RHR should be lost, and to provide bases for plant operating procedures for reduced RCS inventory operation. Analyses are provided that address time to boiling, RCS pressurization, core uncovery, and related topics. Our review of WCAP-11916 is provided below.

B. AIR INGESTION CORRELATION AND RHR LEVEL - The WCAP-11916 air ingestion correlation is stated to be both reasonable and conservative for limiting air entrainment to maintain acceptable RHR pump operation. Usage is qualified in that [illegible]monded operating limits are not intended to replace operating exp[illegible]perating at low RHR system intake flowrates during mid-loop op[illegible] stated to greatly reduce the risk of entraining air.

We agree that reduced RHR flow rate is effective in reducing the risk of air ingestion, and we support this change for reduced RCS inventory operation. Industry experience leads us to believe that RHR systems have been operated with unrecognized air ingestion and we consequently recommend that licensees carefully review any operations outside the safe region as determined by the

WCAP correlation. We further believe the air ingestion correlation to be of a best estimate nature, and suggest a small safety factor be applied in determining a lower bound for RCS level. Finally, we observe that RCS water level should be maintained as high as is consistent with other needs so as to minimize the chance of losing RHR due to air ingestion or inadvertent loss of RHR inventory. The limiting upper water level may be to maintain a gas communication space via the pressurizer surge line when the head is on the reactor vessel.

C. AIR INGESTION SYMPTOMS - The plant test data suggest that the first symptom of air entrainment is noise at the RHR pump, followed by a drop in suction pressure, and finally by oscillations in suction pressure, flow rate, or motor current. The authors recommend that RHR noise be monitored when entering into a level/flow combination where experience is limited. We concur. We also suggest monitoring pump noise when reducing inventory while in a mid-loop configuration to guard against inaccurate level indication.

D. RCS RESPONSE TO LOSS OF RHR - Analyses are reported covering time to boiling following loss of RHR, RCS pressurization rate, and time to core uncovery for various RCS configurations. These show that boiling can initiate in less than 10 minutes, although time for more likely conditions is 20 to 30 minutes. A large cold leg opening with hot legs isolated can lead to core uncovery several minutes after boiling starts. More likely is core uncovery later than 30 minutes following loss of RHR for large cold side openings and in excess of one hour for hot side openings.

This knowledge is valuable for procedures preparation and for training. Its application should include the influence of the RCS pressure boundary configuration and usability of SGs, and it should be used in conjunction with indicated temperature and level. Care should be used with indicated level since RCS behavior can introduce errors that depend on the instrument and its connection to the RCS. Vessel temperature indication should be accurate under all conditions in which an adverse containment environment does not occur.

We expect procedures writers will consider the effect of the containment environment upon actions which must take place inside containment. Although GL 88-17 recommended containment closure prior to core uncovery, closure actions may be limited after initiation of boiling due to steam in the containment.

WCAP-11916 shows that RCS pressure can reach 400 psia about an hour after loss of RHR if the RCS is closed and the steam generators (SGs) are empty, and that providing water to SGs can significantly reduce pressurization rate. We agree, although we believe there may be film coefficient and gas transport modeling difficulties that cause pressure to be over-predicted when there is water in the SGs. The WCAP results appear to be inconsistent with the Diablo Canyon event pressurization, where the SGs apparently limited RCS pressure to a few psi (Ref. 8). As identified in the WCAP, pressurization behavior strongly influences gravity makeup from water storage tanks, and an over-prediction, if real, could erroneously eliminate gravity feed as a inventory addition option.

E. DETERMINATION OF VENT ADEQUACY - WCAP-11916 showed that a pressurization of several psi can eject much of the RCS inventory when there is a cold leg opening in the RCS pressure boundary, and that such a pressurization can prevent cold leg injection water from reaching the core. Large, low resistance hot leg vents are necessary to compensate for the low steam density and large steam flow rates that occur during boiling if pressurization is to be avoided. Consequently, licensees should fully consider vent paths to accurately determine backpressure. Two examples will illustrate typical considerations.

Consider an open pressurizer manway. An unrestricted opening of this size might be adequate, but the surge line diameter is smaller and there is heater hardware in the lower pressurizer. These must be considered. Changing conditions may also change pressurization behavior. Suppose RCS boiling initiates with hot leg water covering the surge line connection at the hot leg. Water will be forced into the pressurizer, causing a pressure elevation in the upper reactor vessel. If there is a cold leg opening, water may remain in the pressurizer long enough to cause early core uncovery.

Often, licensees provide a path to the pressurizer relief tank (PRT) and remove the rupture disk to provide an opening to containment. There are a number of potential restrictions via this path in addition to the disk opening. For example, water in the PRT can cause several feet of water backpressure since, if the spargers are covered, there is little communication between the relief tank inlet and the disk opening.

F. ALTERNATE MEANS OF DECAY HEAT REMOVAL - One or more methods are identified in WCAP-11916 for increasing RCS inventory following loss of RHR, with some variation depending upon the RCS configuration. If RHR cannot be easily reestablished, at least one alternate mode of decay heat removal is identified. Two are necessary to comply with GL 88-17 recommendations.

The potential for cold leg injection failure due to steam flow from the vessel clearly requires that hot leg injection be provided as an option in procedures.

G. LEVEL VARIATION WITHIN THE RCS - The magnitude of level differences within the RCS is shown to be roughly 1 or 2 inches, which is stated to be significant. This should be considered in applying the air ingestion correlation to account for level variation between instrument locations and level at the RHR suction pipe entrance.

III. REFERENCES

1. T. S. Andreychek, et al., "Loss of RHRS Cooling While the RCS is Partially Filled," Westinghouse Electric Corporation, WCAP-11916 Rev 0, July 1988.

2. F. J. Miraglia, "Loss of Residual Heat Removal (RHR) While the Reactor Coolant System (RCS) is Partially Filled (Generic Letter 87-12)," letter from NRC to all holders of operating licenses or construction permits for pressurized water reactors, July 9, 1987.

3. D. M. Crutchfield, "Loss of Decay Heat Removal (Generic Letter No. 88-17), 10 CFR 50.54(f)," letter from NRC to all holders of operating licenses or construction permits for pressurized water reactors, October 17, 1988.

4. M. E. Waterman, "Technical Evaluation Report, WCAP-11916, 'Loss of RHRS Cooling While the RCS is Partially Filled,'" EG&G Idaho, Inc., EGG-EAST-8681, September 1989.

5. P. A. Newton, "Westinghouse Owners Group, Early Notification of Mid-Loop Operation Concerns," letter to Westinghouse Owners Group Primary Representatives (1L, 1A), OG-88-21, May 27, 1988.

6. C. E. Rossi, "Possible Sudden Loss of RCS Inventory During Low Coolant Level Operation," NRC Information Notice 88-36, June 8, 1988.

7. R. A. Newton, "Westinghouse Owners Group, Reactor Coolant System Mid-Loop Operation, Summary of Jure 23, 1988 Meeting with NRC," letter to Executive Advisory Committee, Westinghouse Owners Group Primary Representatives, OG-88-30, July 14, 1988.

8. "Loss of Residual Heat Removal System, Diablo Canyon, Unit 2, April 10, 1987," U.S. Nuclear Regulatory Commission, NUREG-1269, June 1987.

ENCLOSURE 1

NRC STAFF EVALUATION OF WCAP-11916 REV. 0
"LOSS OF RHRS COOLING WHILE THE RCS IS PARTIALLY FILLED"

EVALUATION COMPLETED NOVEMBER, 1989

I. SUMMARY

WCAP-11916 (Ref. 1) was written under the direction of the Westinghouse Owners Group (WOG) Analysis Subcommittee with guidance from the WOG Operations Subcommittee. It's stated purposes are to provide ". . . information applicable to the fluid systems performance when the RCS [reactor coolant system] is partially filled and thermal hydraulic analysis of the RCS following the loss of RHR [residual heat removal] during operations with the RCS loops partially filled." "It is intended that the WOG plants participating in this program will be able to utilize the results of this report based on the categorization applicable to their particular plant." The work was initiated to provide information requested in Generic Letter (GL) 87-12 (Ref. 2) and is applicable to the recommendations of GL 88-17 (Ref 3).

We find WCAP-11916 to be thorough and well-written. It provides the licensees with valuable information regarding prevention of and recovery from loss of RHR. WCAP-11916 results, when applied with consideration of the comments provided in this enclosure, are appropriate for use in responding to the GL 88-17 recommendations. The results may be used based upon the plant categorizations described in WCAP-11916.

II. EVALUATION OF WCAP-11916

A. OVERVIEW - The Idaho National Engineering Laboratory (INEL) reviewed WCAP-11916. INEL states (Ref. 4), and we agree, that: