Designated original
C Tramell
6/24/88

WOG

Westinghouse Owners Group

Domestic Utilities
Alabama Power
American Electric Power
Carolina Power & Light
Commonwealth Edison
Consolidated Edison
Duquesne Light
Duke Power
Georgia Power
Florida Power & Light
Houston Lighting & Power
Kansas Gas & Electric
New York Power Authority
Northeast Utilities
Northern States Power
Pacific Gas & Electric
Portland General Electric
Public Service Electric & Gas
Public Service of New Hampshire
Rochester Gas & Electric
South Carolina Electric & Gas
Southern California Edison
Tennessee Valley Authority
Texas Utilities Electric
Union Electric
Virginia Power
Wisconsin Electric Power
Wisconsin Public Service
Yankee Atomic Electric

Foreign Utilities
Belgian Utilities
ENEL
Kansai Electric Power
Korea Electric
Nuklearna Elektrarna
Spanish Utilities
Swedish State Power Board
Taiwan Power

OG-88-24

June 20, 1988

Mr. Wayne Hodges
NRR Reactor Systems Branch
Mail Station P1-137
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Westinghouse Owners Group
Mid-Loop Operations Concerns

Dear Mr. Hodges:

The Westinghouse Owners Group conducted a program consisting of analyses and testing to support member utility efforts to address the issues raised in Generic Letter 87-12, "Loss of Residual Heat Removal While the Reactor Coolant System is Partially Filled". The results of this program identified some mid-loop operation concerns that were provided to each member in an early notification letter. Enclosed is a copy of that notification letter for your information, OG-88-21, dated May 27, 1988.

As agreed to in our meeting with you on April 28, 1988, a copy of the early notification letter is also being sent to the Chairmen of both the B&W and CE Owners Groups.

Very truly yours,

Roger A. Newton

Roger A. Newton, Chairman
Westinghouse Owners Group

RAN/dac

enclosure

cc: Westinghouse Owners Group Primary Representatives (1L, 1A)
Steering Committee (1L, 1A)
J.B. George (1L)
J.A. Triggiani (1L)
M.J. Wootten (1L) - WEC 542 W

B021
1/1

0253G

8806290163 880620
PDR ADOCK 05000003
P PDR

WOG

Westinghouse Owners Group

Domestic Utilities

Alabama Power
American Electric Power
Carolina Power & Light
Commonwealth Edison
Consolidated Edison
Duquesne Light
Duke Power
Georgia Power
Florida Power & Light
Houston Lighting & Power
Kansas Gas & Electric
New York Power Authority
Northeast Utilities
Northern States Power
Pacific Gas & Electric
Portland General Electric
Public Service Electric & Gas
Public Service of New Hampshire
Rochester Gas & Electric
South Carolina Electric & Gas
Southern California Edison
Tennessee Valley Authority
Texas Utilities Electric
Union Electric
Virginia Power
Wisconsin Electric Power
Wisconsin Public Service
Yankee Atomic Electric

Foreign Utilities

Belgian Utilities
ENEL
Kansai Electric Power
Korea Electric
Nuklearna Elektrarna
Spanish Utilities
Swedish State Power Board
Taiwan Power

OG-88-21

May 27, 1988

To: Westinghouse Owners Group Primary Representatives (1L, 1A)

Subject: Westinghouse Owners Group
Early Notification of Mid-Loop Operation Concerns

In response to NRC Generic Letter 87-12, "Loss of Residual Heat Removal (RHR) While the Reactor Coolant System is Partially Filled", the Westinghouse Owners Group is performing analyses and testing to support resolution of issues related to Item 5 and Enclosure 1 of the Generic Letter.

While more work is still underway in support of the resolution of this issue, based on the results of the completed analyses and testing effort, some major issues have been identified. The Westinghouse Owners Group Steering Committee feels that these issues are of significant importance that an early warning letter to inform individual utility members of these concerns prior to release of the final report is warranted.

Enclosed is a detailed discussion of the key issues and concerns related to operation of a PWR at mid-loop. Some precautions and high level recovery strategies to deal with these issues are also provided.

Please disseminate this information to the appropriate personnel in your organization.

Very truly yours,

Roger A. Newton

Roger A. Newton, Chairman
Westinghouse Owners Group

Enclosure

JDC/mbs

cc: Analysis Subcommittee Representatives - (1L, 1A)
Operations Subcommittee Representatives - (1L, 1A)
Steering Committee - (1L, 1A)
J. B. George - (1L, 1A)
J. A. Triggiani - (1L)
M. J. Wootten - (1L)
File: MUHU-1066 - (1L, 1A)

0223G

MID-LOOP OPERATION CONCERNS

1. BACKGROUND

On July 9, 1987, the Office of Nuclear Reactor Regulation issued Generic Letter 87-12, "Loss of Residual Heat Removal (RHR) While the Reactor Coolant System (RCS) is Partially Filled." This letter deals with NRC concerns related to operation of a Pressurized Water Reactor (PWR) when the RCS water level is below the top of the reactor vessel, in particular when the water level is near the mid-loop elevation. At the Westinghouse Owner's Group general session meeting in late September of 1987, Westinghouse was authorized to perform analysis and testing related to Item 5 and Enclosure 1 of the NRC Generic Letter 87-12. Westinghouse has completed the analysis and testing and has issued a draft report that is currently in review by the Mid-Loop Operations Working Group. The final report is scheduled to be completed and available to the full WOG by mid-July following review and comment.

The intent of this letter is to summarize some important preliminary results that should be considered by utilities when performing certain types of maintenance while operating at or near mid-loop conditions. In particular, there is a concern with loss of RHR cooling scenarios in which there is a large cold leg side opening. This postulated scenario is worse if the loop with the opening is isolated on the hot leg side of the opening. A number of cautions for RHR operation, level indication, and vortex formation are also described.

2. CONCERNS REGARDING LOSS OF RHR SCENARIOS

2.1 Scenario 1: Large Cold Side Opening, Loop Isolated

The scenario considered here involves loss of RHR cooling when there is a large cold side opening and the loop with the opening is isolated on the hot leg side of the opening. The cold side opening could be caused by removal of a SG manway for SG tube inspection or maintenance or removal of a large cold leg check valve or loop isolation valve for repair or inspection. The loop would be considered isolated due to installation of SG nozzle dams or closure of the loop isolation valves.

The specific cases of primary concern include loss of RHR when either an opening in the SG manway with the hot side SG nozzle dam installed (or hot leg loop isolation valve closed); or an opening in the cold leg (e.g. check valve opening) with either the hot side or cold side or both SG nozzle dams installed (either or both hot leg and cold leg loop isolation valves closed). Under this postulated condition, the RCS will pressurize faster at the core exit than at the cold leg, following the loss of RHR cooling. RCS inventory will then be forced out of the cold side opening at a rapid rate. <u>Typically, the core will become uncovered within several minutes after the onset of boiling</u>. Because the SG nozzle dams (or closed loop isolation valves) do not allow a vapor vent path to the opening, the core will remain uncovered for a prolonged period of time unless actions are taken to restore RCS inventory in a timely manner.

For mid-loop operation prior to a typical refueling, the RCS would be expected to reach saturation in about 30 minutes after the loss of RHR cooling. However, at more limiting conditions for mid-loop operation (e.g., 48 hours after reactor shutdown, 140 F initial RCS temperature), the RCS could reach saturation in less than 10 minutes. In view of this potentially short time to the onset of boiling and core uncovery, it is important to emphasize the need to prevent loss of RHR cooling for this scenario. If RHR cooling is lost, recovery actions should be taken before boiling occurs to minimize the possibility of a prolonged core uncovery.

To avoid prolonged core uncovery for this scenario, <u>it was found that hot leg injection at a sufficiently high rate would be effective in suppressing boiling and refilling the RCS</u>. The hot leg injection flowrate is considered high enough if the core residual heat is less than the sensible heat required to raise the temperature of the makeup water to saturation. Determination of this condition is explained in the following example. For the 2-loop plant used in the WOG analysis, the injection flow required to match the core decay heat at 48 hours shutdown time following extended operation at 1520 MWt would be 62 lbm/sec or 450 gpm. This estimate is based on a core decay heat of 0.48% of full power or 7.3 MWt (6915 BTU/sec). The injection water is assumed to be heated from 100 F (a typical RWST temperature) to 212 F. This flow is typically within the capacity of one high-head SI pump for a 2-loop plant. One or possibly two high-pressure SI pumps would be required for comparable conditions in most 3-loop and 4-loop plants.

The analysis for the 2-loop plant demonstrated that the recovery with hot leg injection was successful even at a slightly lower flowrate (50 lbm/sec = 360 gpm). <u>It was not possible to demonstrate successful recovery using cold leg injection at a comparable flowrate</u> since the amount of cold water reaching the core was not adequate to suppress boiling.

For the case where the opening is in the SG manway and the loop with the opening is to be isolated, the scenario described above would be made less likely and less severe if the cold side SG nozzle dams are installed first and removed last. This simple change to the order in which the nozzle dams are installed will reduce the potential for core uncovery if RHR is lost during the installation, by keeping an open vent path for the longest period of time. If RHR is lost after the cold side SG nozzle dam has been installed, the time to core uncovery for this case will be prolonged, by preventing release of liquid inventory to the manway, until the nozzle dam fails. Nozzle dam failure would be caused by system pressurization due to boiling. It should be noted that nozzle dams could fail above pressures as low as 26 psig (typical test pressure). <u>They can not be counted on to prevent liquid release to the SG manway opening above their design pressure, during a loss of RHR event. Therefore, if RHR is lost when nozzle dams are installed, hot leg injection should be initiated prior to or within minutes after boiling starts</u>. Also it is strongly recommended that the RCS level should be raised above mid-loop, after nozzle dams have been installed to minimize the potential for loss of RHR under this configuration.

It is important to emphasize, once again, that utilities should take all precautions to prevent loss of RHR cooling during the configuration when there is a large cold side opening and the nozzle dams or the loop isolation valves (in the same loop with the opening) are installed or closed. If it becomes necessary to enter this configuration, the operator should be prepared to initiate hot leg injection <u>early</u> as described above.

2.2 Scenario 2: Large Hot/Cold Side Opening, Loop Not Isolated

For the case of the SG manway opening without the installation of the hot side SG nozzle dams (or closure of the hot leg loop isolation valves), the manway openings on either hot or cold sides of the SG would provide a large vent path for the air and steam. The time to core uncovery would be significantly greater than the previous case with the loop isolated. For all 2, 3, and 4-loop cases studied, the times to core uncovery, after accounting for potential spill, all exceed forty minutes based on boil-off of the water above the top of the fuel.

For the case of a large cold leg opening (e.g., 6" or 12" check valve opening) without any of the SG nozzle dams installed (or loop isolation valves closed), the RCS will pressurize until the water in the pump suction (loop seal) piping is expelled. The core may uncover briefly during this transient but not long enough for fuel temperatures to become excessive. After the loop seal clears, a vent path to the opening is provided and the core level will stabilize above the top of the active fuel. The RCS inventory will then be depleted at the boil-off rate. Establishing charging flow to an intact loop cold leg within 30 minutes following loss of RHR cooling at a rate exceeding the boil-off rate will typically be sufficient to prevent a subsequent core uncovery for this case. A makeup rate two to three times the boil-off rate is recommended to allow faster recovery. This rate is typically within the capacity of two positive-displacement charging pumps for most low-pressure plants or within the capacity of one centrifugal charging/SI pump injecting in the normal charging mode for most high-pressure plants. If the cold leg opening is in the loop with the charging connection, the operator should be instructed to use alternate charging. Alternatively, hot leg injection (as described in the previous scenario for loop isolated) could be used to restore RCS inventory.

However, if the opening is in the hot leg (e.g., due to removal of a SG manway or loop isolation valve), it is recommended that the operator use only normal or alternate charging to the cold leg. Hot leg injection for this latter case could be less effective as liquid may spill to containment.

3. CAUTIONS REGARDING RHR OPERATION WITH A PARTIALLY FILLED RCS

Work done in the testing phase of the WOG program indicates several points on which operations personnel should be informed.

1. As expected, vortex formation and consequential air entrainment is a function of RCS level (at the RHR inlet) and RHR flowrate. However, it was observed that once vortexing commences, return to level and flow operating conditions that precluded initial vortex formation may not be adequate to terminate an established vortex. The quickest way to eliminate the vortex would be to significantly reduce flow (if plant conditions permit) while increasing level. For plants with two RHR lines from the RCS, the operating RHR pump should be stopped; the other pump should be started at a low flowrate. For plants with a single RHRS inlet line, venting should be accomplished prior to second pump start.

2. The actual level at the RHR inlet connection has a significant effect on vortex formation. It is known that level gradients will exist in the RCS due to fluid momentum and density effects. Level measurement error can also be increased due to density effects. Therefore, the type and location of level instrumentation must be considered when operating near level and flow conditions known to be unacceptable.

3. Once air is entrained in the RHR system, it may be very difficult to eliminate. This is largely due to long horizontal piping from the RCS to the RHR pumps. In this piping, it takes a long time for trapped air to migrate back to the RCS. In addition, operation of a RHR pump at low flow rates will sweep only a minimal amount of air through the inlet pipe. If rapid removal of air from the RHR pipe is required, the RCS should be refilled (to the top of the hot leg), then one RHR pump operated at normal flows. This will sweep air through the pump. <u>Caution: pump performance indicators should be monitored closely after the RHR pump is started.</u>