Westinghouse Electric Corporation

Energy Systems

Box 355
Pittsburgh Pennsylvania 15230-0355

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Document Control Desk
U. S. Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: T. R. QUAY

SUBJECT: PLAN TO ADDRESS UNCERTAINTY OF TEMPERATURE PROFILES FOR THERMAL STRATIFICATION.

Dear Mr. Quay:

During the meeting on December 5 and 6, 1996 on the NRC staff design review of AP600 piping design, an issue was raised about the uncertainty of the temperature profiles used in the evaluation of thermal stratification for three piping segments. Westinghouse took as an action item to reduce the uncertainty of the temperature profiles or to evaluated the lines using conservative bounding assumptions. Westinghouse has developed a plan to address the uncertainty of the temperature profiles. The outline of this plan including the methods to be used is attached.

This plan is provide for your information and to assist in the planning for review. Please contact Donald A. Lindgren at (412) 374-4856 with any questions or comments about this issue.

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

/jml

attachment

cc: D. Jackson, NRC (w/attachment)
G. DeGrassi, Brookhaven National Laboratory (w/attachment)

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INTRODUCTION

In our December 5, 1996 meeting at the NRC offices in Rockville, the AP600 thermal stratification calculation GW-PLC-001, Revision 0 was reviewed by the NRC consultant (Giuliano DeGrassi of Brookhaven National Laboratory). The three open items which are identified in the calculation were discussed. These open items relate to uncertainties in the temperature distribution of the normal residual heat removal suction line, the passive residual heat removal return line, and the automatic depressurization system stage 4 lines. The NRC has requested that these open items be addressed in the design phase. The proposed approach to address these open items is to use computational fluid dynamics (CFD) computer software (CFX 4 and FLOWTRAN) as discussed below.

PROPOSED COMPUTATION FLUID DYNAMICS (CFD) EVALUATIONS

Normal Residual Heat Removal (RHR) Line

Description of Concern

The normal RHR suction line extends vertically downward approximately 3 feet from the bottom of the hot leg piping, and then slopes slightly downward over a distance of about 73 feet to the branch side of a tee connection. The vertical drop over the 73 foot span is about 1.25 feet. Each run side of the tee then extends horizontally approximately 5 feet to an isolation valve, which is closed during normal power operation. This line includes 20", 12" and 10" nominal pipe sizes.

The normal RHR suction piping may be cold trapped upstream of the closed isolation valves, since the length of piping from the hot leg connection to the isolation valves is relatively long, and the piping is sloped downward from the hot leg, which may prohibit convective currents from heating the entire length of piping. Additionally, there is a potential for thermal stratification due to the convective currents heating a portion of the 73 foot section of sloped piping.

Description of Proposed CFD Evaluation

CFD analysis will be performed to determine the temperature distribution (axially and diametrically) in the sloped section of piping between the hot leg connection and the closed isolation valves. The hot leg piping contains fluid at 600°F which has a high flow rate during normal power operation. Such flow will induce turbulence into the normal RHR piping which will maintain the piping at the hot leg temperature over a distance of 10 to 25 pipe inside diameters from the hot leg connection. The CFD evaluation will conservatively assume that turbulent diffusion heats the piping from the hot leg connection to the 12" side of the 20" x 12" reducer (a length of approximately six feet), since this will maximize the length of piping that may be stratified. Therefore, a boundary temperature of 600°F will be assumed at the 12" side of the 20" x 12" reducer. The piping beyond this point will be subject to conductive heating through the pipe metal, fluid convection, and heat losses to the environment. Heat losses will consider conduction through the piping insulation, and convection and radiation to the ambient air. The closed valves will be modeled as zero velocity boundaries with heat transfer through the pipe metal area. Heat transfer across the valve disk is considered to be negligible.

The pipe metal temperature distribution resulting from the CFD evaluation will be used in a stress analysis of the normal RHR suction piping.

Passive Residual Heat Removal (PRHR) Return Line

Description of Concern

The 10" PRHR return line extends from the PRHR heat exchanger outlet nozzle to the steam generator channel head inlet nozzle. This piping is routed horizontally or downward from the heat exchanger (elevation 110.0') to an elbow just below the steam generator connection (elevation 102.4'), and then extends upward approximately 3.5 feet to a nozzle on the steam generator channel head (elevation 105.9'). This piping has two parallel isolation valves at elevation 108.5' which are closed during normal operation.

The steam generator PRHR nozzle is located between the two steam generator outlet nozzles, near the bottom of the steam generator channel head. Turbulence from the RCL flow will be assessed and included in the CFD model.

A 3" purification line connects to the PRHR return line at elevation 104.8', near the steam generator nozzle. This line may or may not have flow during normal power operation. If the line is in operation, the flow rate is about 100 gpm and the flow temperature is about 440°F. This equates to about 0.5 feet per second in the 10" PRHR return line.

The combined effects of turbulence from RCL flow within the steam generator channel head, turbulent thermal diffusion from the purification line flow, and pipe metal thermal conduction could result in heating and thermal stratification in the horizontal piping directly below the steam generator.

Description of Proposed CFD Evaluation

CFD analysis will be performed to determine the temperature distributions (axially and diametrically) in the piping directly below the steam generator, including the horizontal piping at elevation 102.4'. The steam generator channel head contains fluid at 535°F, therefore a boundary temperature of 535°F will be assumed at the nozzle connection. Upper and lower bound fluid turbulence from the RCL flow within the steam generator channel head will be modeled by estimating the turbulent energy transported into the piping from the steam generator tubes and generated at the pump inlet nozzles. Upper and lower bound purification line flow rates of 100 gpm and zero gpm will be assumed, and input as fluid velocities injecting 440°F flow into the PRHR line. The piping will be subject to conductive heating through the pipe metal, fluid convection, and heat losses to the environment. Heat losses will consider convection and radiation to the ambient air. This piping is uninsulated except for a short section from the steam generator nozzle down to the 3" purification line branch connection.

The CFD model will extend from the steam generator nozzle to the elbow which joins the piping at elevation 102.4' to the vertical riser. The fluid boundary conditions at the end of this elbow are assumed to be adiabatic with zero flow rate to provide an upper bound for the hot fluid temperature.

The upper and lower bounds on steam generator channel head turbulence and purification line flow rate will provide upper and lower bound temperatures for the piping at elevation 102.4'. These results will be used to determine whether stratified loadings are possible and if thermal cycling may occur.

The pipe metal temperature distributions resulting from the CFD evaluation will be used in a stress analysis of the passive RHR return piping.

Automatic Depressurization System (ADS) Stage 4 Lines

Description of Concern

The ADS Stage 4 lines extend upward and horizontally from the hot legs to a horizontal section of piping, which is the high point of the line. This portion of the line is insulated. From the high point, the lines slope downward at a 45 degree angle over a length of about 1.5 feet, and then extend horizontally to normally closed squib valves V004A through V004D, which isolate the lines. This portion of the line is not insulated. The intent of the sloped piping is to provide a cooler water seal at the inlet of the valves. The sloped piping may not be sufficiently long to provide a cold trap. Therefore, thermal stratification may be possible in the horizontal piping which contains the valves. Temperature indicators are located on the top of the horizontal piping, between the valves, and would detect the presence of hot fluid and thermal transients. The piping is 10" nominal size in the area of concern.

Description of Proposed CFD Evaluation

CFD analysis will be performed to determine the temperature distribution (axially and diametrically) in the 1.5 foot section of sloped piping and the horizontal piping up to the squib valves. The CFD model will include the horizontal piping at the high point of the line, the sloped section of piping and the horizontal section of piping containing the valves. The hot leg piping contains fluid at 600°F which has a high flow rate during normal power operation. Therefore, the end of the horizontal piping (at the high point of the line) which is closest to the hot leg is assumed to be at 600°F due to turbulent diffusion and convective currents. A boundary temperature of 600°F and a constant pressure of 2250 psia are assumed at this location. The piping from this point to the squib valves will be subject to conductive heating through the pipe metal, fluid convection, and heat losses to the environment. Heat losses will consider conduction through the piping insulation for the portion of the line which is insulated, and convection and radiation to the ambient air. The fluid boundary conditions at the squib valves are assumed to be zero flow rate with heat transfer through the pipe metal area.

The temperature distribution resulting from the CFD evaluation will be used in a stress analysis of the ADS Stage 4 lines.