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Energy Systems

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

ATTENTION: T. R. QUAY

SUBJECT: RESPONSE TO NRC STAFF QUESTIONS ON PASSIVE CORE COOLING SYSTEM

Dear Mr. Quay:

Attached are responses to a number of NRC staff questions on the operation of the AP600 passive core cooling system. In some cases this response documents positions previously provided to the staff. The open items included are tabulated below with the Westinghouse status in the open item tracking system.

OITS #	Other #	OITS W Status
1261*	DSER 15.2-2	Action N
2028	Top 50 Item 32	Closed
2237*	April 19, 1997 meeting item	Action N
2597	RAI 440.358	Closed

* These items addressed together.

The NRC action noted above is to review and accept or comment on this response. These responses are provided to permit the NRC staff to complete preparation of input for FSER section 6.3. If you have any questions please contact Donald A. Lindgren at (412) 374-4856.

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

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jml

Attachment

cc: W. Huffman, NRC (w/Attachment)
N. J. Liparulo, Westinghouse (w/o Attachment)

Open Item Tracking System Item Number 1261 (DSER 15.2-2) and 2237 (April 19, 1997 Meeting item):

Issue: (1261) Westinghouse should address the sensitivities of various system elevations and configurations (by sensitivity studies, for example) to support the inspection, test, and analysis acceptance criteria (ITAAC) implementation.

(2237) The passive systems having relatively small driving force are sensitive to certain parameters, e.g., (1) effective of relative elevations and piping configurations on gravity injection and natural circulation capability, and (2) effect on surface roughness, coating, striping, and water coverage on the containment exterior shell on passive containment cooling system heat transfer capability. Provide sensitivity analysis of these parameters to develop acceptable bands for ITAAC verification.

Response:
The AP600 passive safety-related system designs have been performed with consideration for variations in parameters such as pipe routing, friction factors, equipment manufacturing variations and plant construction tolerances. These variations are bounded on both the minimum and maximum side for use in the SSAR safety analysis. The ITAAC criteria are consistent with the performance variations used in SSAR safety analysis.

(1) The impact on gravity injection and natural circulation from such variations have been evaluated for the low driving force passive features, including the PRHR HX, CMT, IRWST, containment recirculation, and PCS water drain performance. The evaluations included system design calculations and safety analysis. The ITAACs specify the following limits for these features:

- Minimum heat transfer from the PRHR HX
- Minimum and maximum line resistances of the CMT and the IRWST injection lines
- Maximum line resistances of the CMT cold leg balance and the containment recirculation lines
- Minimum elevation of the CMTs and IRWST
- Minimum and maximum flows from the PCCWST
- Minimum and maximum PCCWST standpipe heights

The minimum PRHR HX heat transfer considers a minimum elevation, actual pipe line pressure drop plus margins and maximum valve / component pressure drops. The minimum HX heat transfer used in SSAR safety analysis is consistent with this limit and in addition it degrades the HX for plugging of tubes. A maximum heat transfer is not specified in the ITAACs because PRHR HX heat transfer variation is not significant in the SSAR safety analysis.

The maximum CMT and IRWST injection line resistance considers actual piping pressure drop plus margins and maximum valve / component pressure drops. Each of these lines has an orifice whose resistance can be adjusted during pre-operational testing. These orifices compensate for the effects of manufacturing and construction tolerances. The minimum IRWST line resistance considers a significant reduction in the maximum resistance. The minimum CMT line resistance considers the use of the orifice to accommodate variations in the line resistance.

The maximum CMT cold leg balance and containment recirculation line resistances considers actual piping pressure drop plus margins and maximum valve / component pressure drops. Minimum line resistances are not specified because they would not significantly affect the SSAR safety analysis.

The minimum elevation of the CMTs and the IRWST consider construction tolerances and plant settlement / tilt. A maximum elevation is not specified because it would only be several inches higher and would not significantly affect the injection performance.

The minimum containment cooling water flow to the PCS distribution bucket above the containment shell at specific elevations of water within the PCCWST, considers actual piping and component pressure drops plus margins. The maximum PCS cooling water flow considers that each of the standpipe discharge lines has an orifice whose resistance will be adjusted during pre-operational testing to accommodate the effects of manufacturing and construction tolerances.

The minimum and maximum elevation of each PCCWST standpipe considers construction tolerances and plant settlement / tilt.

Changes will be made to the PCS ITAAC's to add maximum PCCWST flow and minimum / maximum PCCWST standpipe heights.

(2) The PCS water distribution and wetting performance have been designed to account for factors which may impact surface wetting. Factors such as surface defects, plate weld locations and code weld allowances, coating deviations including surface roughness have been considered in the design of the water distribution system. The minimum ITAAC wetting criteria is based on full scale prototype testing of the water distribution system which simulated construction variations. The ITAAC testing will confirm that the PCS provides wetting of the outside surface of the containment vessel by operating the system and measuring the coverage of the containment shell as constructed at the lowest flow rate within the first 72 hours. The minimum ITAAC wetting criteria is consistent with the wetting coverage used in the AP600 safety analysis.

SSAR Changes: None.

Item Number 2028 (Top 50 #32):

NRC Statement: The SSAR identifies that the IRWST can be used to supply cooling water to the Spent Fuel Pool. The concern is that if the water is used for spent fuel cooling it would not be available for cooling of fuel in the reactor vessel. This mode is only used for the case of a full core off load when there is not fuel in the core.

Response: SSAR revision 11 does not specify use of incontainment refueling water storage tank (IRWST) water for spent fuel pool normal or emergency makeup. SSAR revision 11 incorporates design features that extend the minimum passive safety-related spent fuel cooling from 72 hr to 7 days without offsite support. To achieve the longer time, safety-related connections are provided from the cask washdown pit (CWP) and the passive containment cooling water storage tank (PCCWST) to the spent fuel pool (SFP). Water from the CWP is only required during refueling outages and for several months following refueling when spent fuel decay heat is high. Water from the PCCWST is only needed for SFP makeup during refueling shutdowns when spent fuel decay heat is high (when PCS water cooling is not required for passive containment cooling). The IRWST is reserved for cooling of fuel in the reactor; it is not used for SFP makeup.

The AP600 technical specifications require the IRWST to be full during Modes 1, 2, 3, 4, 5. In Mode 6 with the upper internals in place and the refueling cavity less than full, the volume of water in the IRWST and the refueling cavity must be at least equal that required in the Modes 1, 2, 3, 4, 5. The IRWST has four safety-related level instruments, each with indication and low alarms in the main control room. The low alarms are above the minimum technical specification level.

In a meeting subsequent to the RAI, the NRC asked if inadvertent draining of the IRWST is modeled in the AP600 PRA. The probability of initiating a IRWST drain and not isolating it is considered insignificant, and therefore is not quantified in the PRA. The only significant drain path of the IRWST located outside of containment is through a single line to the SFS. This line is normally isolated by two closed containment isolation MOVs. These valves are periodically opened to allow a SFS pump to recirculate the IRWST for purification or sampling. Miss-alignment of SFS valves could result in pumping of the IRWST into the SFP. Redundant SFP high level alarms and redundant IRWST low level alarms provide ample input to the operators to alert them to the IRWST drain. In this situation the IRWST level would decrease at a rate of 0.5 in / min, which provides ample time for the operators to stop the transfer of water by stopping the SFS pumps, closing the containment isolation valves, or taking local manual action to close valves or to correct the aligning the SFS lines.

SSAR Changes: None required.

Item Number 2597 (RAI 440.358):

NRC Statement: 440.358 The design and logic of the AP600 safety injection system has the potential to lead to conditions and potential systems interactions that have not been addressed to date by Westinghouse's analyses or testing. Specifically, the staff is concerned about plant recovery procedures following core makeup tank (CMT) initiation in non-loss-of-coolant-accident (LOCA) transients, and in LOCA transients where Stage 4 automatic depressurization system (ADS) actuation has been prevented by use of the normal residual heat removal (RHR) system.

a. During a non-LOCA event, CMT injection may be initiated by either low pressurizer level or pressure signals. The CMT will then recirculate until steps are taken to terminate the transient. Depending on the time that the CMTs have operated, a substantial quantity of hot water may be transferred into the CMTs. Evidence from the NRC's confirmatory testing program suggests that under these conditions, reduction in primary system pressure, which could be caused by using non-safety-related systems to cool the reactor cooling system (RCS), could trigger flashing in the CMTs. This could, in turn, cause the CMTs to begin to drain and would also push hot water and steam back from the pressure balance line into the cold legs.

Depending on RCS conditions, introduction of hot fluid back into the cold leg might lead to thermal-structural or fluid-structural interactions. In addition, draining of the CMTs by this mechanism could lead to unintended actuation of the ADS.

Have the dynamic effects of such an event been considered in the loop piping design? Discuss the margins available.

b. Westinghouse has stated its intention, during some circumstances in small break LOCAs, to use the RNS for forced, low-pressure coolant injection to create sufficient backpressure on the CMT discharge check valves to inhibit CMT draining, and subsequent 4th stage ADS actuation. As in the scenario described above, termination of CMT draining at an intermediate stage could lead to having two substantial volumes of hot water that could subsequently flash upon further reductions in RCS pressure, causing unanticipated systems interactions, and possibly resumption of CMT draining leading to 4th stage ADS actuation.

Discuss how normal, off-normal, or emergency procedures provide guidance to operators with regard to stabilizing the CMTs under such scenarios.

Response: The following addresses both NRC concerns.

a. During a non-LOCA event the CMT's can recirculate and heatup. If the CMTs continue operating for about an hour, the CMT's will completely heatup to the RCS cold leg temperature. In most cases, the nonsafety-related systems will be available and allow the plant to return to power operation without going to a cold shutdown. The availability of nonsafety-related systems will allow termination of safety-related system operation in accordance with emergency procedures; the CMT outlet isolation valves will be closed when the SI termination criteria is satisfied. The CMT's temperature and boron concentration will be adjusted to return them to their technical specification limits. Restoring the CMT temperature and boron concentration is accomplished by injecting cold, borated water from the CVS makeup pumps into the CMTs. The hot water in the CMT is purged out of the top of the CMT to the RCS CL. The CVS letdown is operated to remove the water added to the RCS through the CMTs. Once the CMTs are cooled to 120 F and borated to 3400 ppm, the technical specification limits are satisfied and the plant can return to power.

   If the plant is shut down to cold conditions instead of returned directly to power operation, abnormal operating procedures will instruct the operators to maintain the RCS pressure above the saturation pressure of the CMTs. In order to complete entry into cold shutdown conditions, the operators will have to cool down the CMTs. If the operators do not follow this procedure CMT flashing may occur; however, unnecessary ADS actuation is not anticipated. In such a situation, the operators are expected to depressurize the RCS in a controlled fashion. A controlled RCS depresurization together with the large CMT diameter will result in little, if any, CMT water being carried out of the CMT. If the RCS pressure is reduced to the RNS operating pressure (300 psia) with the CMTs fully heated up to the RCS cold leg temperature (540 F), about 18% of the CMT water may flash to steam and vent through the cold leg balance line to the RCS. The CMT level setpoint that actuates ADS is 67% which requires a 33% drop. Note that CMT water would not be pushed out the discharge line because the discharge valves would be closed.

Significant thermal-structural or fluid-structural interactions resulting from steam flowing back to the cold leg through the balance line, are prevented by the proper use of abnormal operating procedures. Even if the abnormal operating procedures are not followed, the interactions are expected to be small because the controlled RCS depressurization minimizes the rate of steam generation and the water in the top of the cold leg, where the CMT line connects, will be relatively hot. In the unlikely event that steam from the CMT balance line enters the cold leg when it is full of subcooled water, the fluid-structural interaction is acceptable based on the screening criteria in NUREG CR 6519 (Screening Reactor Steam / Water Piping Systems for Water Hammer, NUREG CR 6519, 11/96). One of the conditions necessary for steam bubble induced water hammer is an horizontal pipe with an L/D of 24 or greater; the L/D of the cold leg is less than 12. As a result, potentially damaging water hammer will not occur.

b. During a small LOCA the CMTs can also recirculate and heatup. If the LOCA is small enough, ADS actuation could occur after the CMTs are fully heated up. In this situation, ADS stages 1, 2 and 3 would be actuated. With the RNS properly aligned and started by the operators, ADS 4 would not be actuated. Assuming both RNS pumps are running and all ADS stage 1, 2, 3 valves are open, the RCS pressure would be about 50 psig. The CMTs level would be 40 to 50% and the water would be saturated at this RCS pressure.

Emergency procedures control when the operators are permitted to close the CMT discharge isolation valves. If the break size / location allows, the pressurizer level will be increased to above the low level CMT actuation setpoint to provide CMT re-actuation capability. After the CMT discharge valves are closed, the operators will be instructed to fill the CMTs with cold borated water from the CVS. If the operators do not follow this procedure, ADS stage 4 actuation is not anticipated to occur even assuming that the RCS is depressurized to atmospheric pressure. Assuming that the operators depressurize the RCS to atmospheric pressure with the CMTs filled to 40% level with saturated water at 100 psig (higher than the anticipated 50 psig), the CMT level would decrease about 5%. Since the ADS 4 actuation setpoint is 20%, this provides good margin.

Significant thermal-structural or fluid-structural interactions resulting from steam flowing back to the cold leg through the balance line, are prevented by the proper use of abnormal operating procedures. Even if the abnormal operating procedures are not followed, the interactions are expected to be small because the controlled RCS depressurization minimizes the rate of steam generation and the water in the top of the cold leg, where the CMT line connects, will be relatively hot. In the unlikely event that steam from the CMT balance line enters the cold leg when it is full of subcooled water, the fluid-structural interaction is acceptable based on the screening criteria in NUREG CR 6519 (Screening Reactor Steam / Water Piping Systems for Water Hammer, NUREG CR 6519, 11/96). One of the conditions necessary for steam bubble induced water hammer is a horizontal pipe with an L/D of 24 or greater; the L/D of the cold leg is less than 12. Another condition necessary for water hammer is a pressure above 100 psia; in this mode of operation the RCS / CMT pressure will be less than 100 psia. As a result, potentially damaging water hammer will not occur.

SSAR Changes: None required.