Safety Evaluation Report for

H. B. Robinson Steam Electric Plant Unit No. 2

Natural Circulation Cooldown

Background

On June 11, 1980, St. Lucie Unit 1 experienced a natural circulation cooldown event which resulted in the formation of a steam bubble in the upper head region of the reactor vessel. This resulted in the generation of an NRC Generic Letter dated May 5, 1981 to all PWR licensees. The licensees were to provide an assessment of the ability of their facility's procedures and training program to properly manage similar events. This assessment was to include:

(1) A demonstration (e.g., analysis and/or test) that controlled natural circulation cooldown from operating conditions to cold shutdown conditions conducted in accordance with their procedures, should not result in reactor vessel voiding.

(2) Verification that supplies of condensate grade auxiliary feedwater are sufficient to support their cooldown method, and

(3) A description of their training program and the revisions to their procedures.

Evaluation

The licensees refer to a study that was performed by Westinghouse for the Westinghouse Owners Group. This Westinghouse study evaluates the potential for steam formation in Westinghouse NSSS's and recommends modifications to the operator guidelines. These recommendations have been incorporated into the Westinghouse Operator Guidelines. The licensees conclude that use of these guidelines will result in a natural circulation cooldown without upper head voiding.

The results of the Westinghouse report, W-OG-57 (Reference 5), are applicable to all 2, 3, and 4 loop plants. The report concludes that in previous analyses for operating guidelines and safety analyses, void formation in the upper head is explicitly accounted for if it is calculated to occur. These previous analyses indicate that voiding is not a safety concern because the voids will collapse when they come in contact with the subcooled region of the vessel.

The present analysis differentiates between $T_{hot}$ and $T_{cold}$ plants. $T_{cold}$ plants are those which have sufficient flow between the downcomer and the upper head such that the temperature of the upper head is approximately the same as the cold leg temperature. $T_{hot}$ plants have an upper head temperature between the hot leg and cold leg temperature. This SER will deal with the $T_{hot}$ analysis because the Robinson plant is considered to be a $T_{hot}$ plant.

The analysis is done using the WFLASH code. The WFLASH code has 2-phase capability and can track void propagation. The analysis assumes a best estimate model and an inverted top hat upper support plate design. The initial upper head temperature is conservatively set equal to the hot leg temperature. Metal heat addition to the upper head area from the vessel and internals is taken into account. It is assumed that the reactor coolant pumps are stopped at the beginning of the transient.

The analysis is done for two cooldown rates, 25°F/hr and 50°F/hr. An analysis is also done which accounts for the effect of the Control Rod Drive Mechanism (CRDM) cooling fans. These fans blow air across the vessel head and provide some additional cooling of the upper head.

One of the conditions that must be met during a cooldown is that the primary system pressure be 400 psia when the primary system temperature is 350°F. These are conditions which would permit the Residual Heat Removal System (RHRS) to be used. The analyses without the CRDM fans show that neither cooldown rate can meet this condition without upper head voiding unless the depressurization is halted when the primary temperature reaches 350°F and the upper head is given time to cool off. A hand calculation shows this cool-off period is approximately 20 hours for a 25°F/hr cooldown rate and is approximately 27 hours for a 50°F/hr cooldown rate.

An additional analysis includes the effect of the CRDM cooling fans and results in a significant increase in the rate of cooldown of the upper head. The CRDM cooling fans provide cooling of the CRDM magnetic jack coil winding. The system consists of axial fans that pull containment air past the coil housings and across the Reactor Vessel Head. The analysis was based on a hand calculation. This calculation assumed that the CRDM fan cooling system removes 780KW at full power. This energy removal is equal to an upper head cooldown rate 32°F/hr when the upper head temperature is 600°F. Assuming that the cooldown rate is proportional to the temperature difference between the upper head metal and the containment atmosphere, the CRDM fans would cool the upper head at a rate of 17°F/hr when the upper head fluid is 350°F.

Based on these analyses the Westinghouse report makes the following conclusions and recommendations for operator guidelines:

1. If the CRDM cooling effect is included the operator can reach shutdown cooling entry conditions without void formation if a 25°F/hr cooldown rate is used. The operator should maintain 50°F subcooling in the system.

2. If the CRDM fans are not available the operator should commence a 25°F/hr cooldown and should depressurize such that 50° subcooling is maintained until the system reaches 1900 psi. At this point the depressurization rate will be changed so that a 200°F subcooling margin is maintained until the systems reaches 1200 psi. At this time the depressurization should be stopped. When the primary temperature reaches 350°F, a 20-hour cool-off period should be allowed before depressurization.

The Robinson submittal concludes that its procedures will be reviewed to incorporate the recommendations made above. These revisions were implemented by January 31, 1982. The technical specification minimum in the condensate storage tank is 35,000 gallons (19% level). This will provide for 2 hours of operation at hot standby. This tank is normally maintained at the 90% level. This auxiliary feedwater supply is backed up by the two non-condensate water sources. These are the Service Water System and, if offsite power is not available, the Water Treatment System. Both these sources can provide an unlimited supply of water. The staff concludes that the condensate-grade supply backed up by the Service Water System and Water Treatment System provides an adequate supply of water.

The Westinghouse analysis which included the effect of the CRDM fan cooling was performed on a generic rather than a plant specific basis. The capacity of the CRDM cooling system at these plant may differ from that used in the generic analysis. (The analysis assumed that the system was operating at full capacity removing 12KW/drive mechanism). The system is not safety grade and during a loss of offsite power event the system may or may not be capable of being powered by the diesel generator. The licensees, however, have sufficient condensate supplies to support an extended cooldown.

The Robinson submittal concludes that its operators receive adequate training to properly execute a natural circulation cooldown. This training includes a review of the natural circulation procedure, a review of the St. Lucie event with an emphasis on what causes voiding and why it is undesirable, and simulator training on natural circulation cooldown.

The staff emphasizes the importance of training and procedures in resolving this issue. The review of generic guidelines was part of the TMI Action Item I.C.1, Generic Review of Vendor Guidelines. The Westinghouse Owners Group Emergency Response Guidelines includes ES-0.2, Natural Circulation Cooldown. This guideline incorporates the results of the analyses previously discussed. These guidelines were reviewed and approved by issuance of the Reference 3 Safety Evaluation Report. The staff concludes that if the licensees appropriately implement the generic emergency guidelines into their plant-specific procedures, adequate procedures will be available for the operator to safely conduct a controlled natural circulation cooldown even if limited upper head voiding should occur. The staff concludes the licensees' training programs adequately address natural circulation cooldown.

## Conclusion

Upper head voiding, in itself, does not present any safety concerns provided that the operator has adequate training and procedures to recognize and react to the situation. Voiding in the upper head makes RCS pressure control more difficult and therefore if the situation warrants, natural circulation cooldown should be done without voiding.

The Westinghouse analysis concludes that a 20 hour cool-off period is necessary to cooldown on natural circulation without void formation when the CRDM fans are not available. Natural circulation tests are planned for Diablo Canyon. These tests will provide experimental verification of the upper head cool-off rate calculations. The staff concludes the licensees have demonstrated their ability to cooldown on natural circulation without upper head void formation and have sufficient condensate supplies.

This SER did not attempt a review of operator procedures since this effort is being conducted under TMI Action Item I.C.1, Generic Review of Vendor Guidelines. The staff finds that upon acceptable implementation of the NRC-approved Westinghouse Owners Group Emergency Response Guidelines, the licensees' procedures will be adequate to perform a safe natural circulation cooldown.

References

1. Generic Letter 82-21, "Natural Circulation Cooldown," May 5, 1981.

2. Utley, E. E. to D. G. Eisenhut, "Response to NRC Generic Letter No. 81-21, Natural Circulation Cooldown," November 19, 1981.

3. Generic Letter 83-22 dated June 3, 1983, Safety Evaluation of "Emergency Response Guidelines."

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