Safety Evaluation Report for Crystal River Unit 3

Regarding Generic Letter 81-21

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 NRC Generic Letter 81-21, 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.

The licensee responded to this request in references 1 through 4. The following is our evaluation of the licensee's responses to the concerns outlined above.

Evaluation

To prevent reactor vessel upper head void formation during a natural circulation cooldown, the reactor coolant system (RCS) pressure must be maintained above the saturation pressure corresponding to the reactor vessel upper head fluid temperature. The licensee provided, in reference 4, an analysis of the reactor vessel upper head temperature during a natural circulation cooldown. The analysis was performed by GPU for the TMI-1 Nuclear Generating Station. Since the TMI-1 and Crystal River Unit 3 (CR-3) reactor vessels are virtually identical, the licensee concluded that the results are appropriate for CR-3. This analysis was utilized by the licensee to identify improvements to the natural circulation cooldown procedure needed to assure that voids will not form in the reactor vessel upper head during the cooldown.

The analysis of the upper head cooldown was performed using the HEATING6 (Reference 5) computer code. HEATING6 is a multi-dimensional, generalized heat conduction code. The reactor vessel head was modeled in two dimensions, R-Z geometry, based on symmetry about the center control rod drive. The primary components of the model are the plenum cover, upper head water mass, the vessel wall, the vessel head, the vessel insulation, and the control rod drive leadscrews, guide tubes and nozzles.

In performing the analysis, the initial temperatures for the upper head fluid and metal were assumed to be 604°F which corresponds to the hot leg temperature at 100% power. The reactor coolant pumps were tripped at the start of the analysis and a flow coastdown to a natural circulation flow of 3% was used. Coolant flow through the control rod drive guide tubes was assumed to be 8%

of the system loop flow. The guide tube flow was assumed to mix only in the first 20.5 inches above the plenum cover. Natural convection heat transfer coefficients were utilized at all metal-water interfaces in the upper head. Thermal mixing, as a result of natural convection within the upper head, was simulated via an effective thermal conductivity for the water.

The analysis covered the natural circulation cooldown from 604°F to the decay heat removal system (DHRS) cutin point for CR-3. To allow operation of the DHRS, RCS pressure and temperature must be reduced to 284 psig and 280°F, respectively. To prevent void formation in the reactor vessel upper head at the time of DHRS cutin, the upper head fluid temperature must be reduced to less than 417°F. This temperature corresponds to the saturation temperature at 284 psig.

Two analyses were performed to calculate the thermal response of the reactor vessel head as a function of cooldown rate in the RCS. The cooldown rates imposed on the RCS were 10°F/hr and 50°F/hr and were continued until the RCS temperature reached 204°F. Using an RCS cooldown rate of 10°F/hr, the licensee concluded that it would take approximately 24 hours before the head temperature was reduced below 417°F. At a 50°F/hr RCS cooldown rate, the head was cooled below 417°F in approximately 7 hours.

The staff reviewed the approach utilized by the licensee. We find the methods utilized and the assumptions made to be reasonable. Therefore, we find the cooldown analyses acceptable.

Based upon the analysis results, the licensee committed to revise its emergency operating procedures to reflect a cooldown rate during natural circulation of greater than 10°F/hr but less than 50°F/hr. In addition, the data from the 50°F/hr cooldown analysis will be included in the pressure/temperature limits for a natural circulation cooldown. This case was found to yield the highest reactor vessel head temperatures, and thereby the highest system pressure needed to prevent upper head flashing, for a given RCS temperature.

We conclude that appropriate implementation of these modifications into the plant-specific procedures will be adequate for the operator to safely conduct a natural circulation cooldown without upper head void formation.

While Generic Letter 81-21 requested that the licensee demonstrate that a natural circulation cooldown could be performed without upper head void formation, the staff also requested that the licensee demonstrate that the procedures also provide guidance to the operator to recognize and respond to an upper head void should one occur. The licensee identified specific portions of its Natural Circulation Procedure which includes guidance on recognizing void formation and actions to be taken should a void form. The procedure states that a reactor vessel head void can be recognized by a rapid and possibly erratic increase in pressurizer level. Should this occur, the procedure prescribes stopping the depressurization and increasing RCS pressure to allow for bubble collapse and thereby return of pressure control to the pressurizer. In addition, the procedure requires that a subcooling margin of at least 50°F, at pressures less than 1500 psig, be maintained in order to prevent void formation in the hot leg which could potentially lead to an interruption of natural circulation. The staff finds the guidance to be acceptable.

The licensee judged, in references 3 and 4, that the CR-3 condensate-grade auxiliary feedwater supplies are sufficient to support a natural circulation cooldown. CR-3 has a technical specification minimum water volume of 150,000 gallons in the condensate storage tank. This would support a 15 hour cooldown. In addition, the licensee identified two other potential sources: the condenser hotwell (100,00 gallons) and the demineralizer water tank (200,000 gallons). Since the licensee's analyses show a maximum cooldown time of approximately 32 hours, we also have concluded that CR-3 has adequate condensate-grade AFW supply.

The licensee also provided in reference 1 a description of its training program dealing with reactor vessel upper head voiding. The operators have been trained on the use of the Natural Circulation Cooling Procedure, including recognition and mitigation of an upper head void. We conclude that the licensee's training program adequately addresses upper head voiding during a natural circulation cooldown.

Conclusion

Upper head voiding, in itself, does not present any safety concerns provided 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 performed without voiding.

The licensee's analysis showed it would take less than 32 hours to allow the reactor vessel upper head to cool sufficiently to prevent upper head void formation during a natural circulation cooldown. The staff concludes that the licensee has demonstrated its ability to cooldown without voiding and has shown it has sufficient condensate supply to support such a cooldown.

The licensee identified changes to be made in the natural circulation cooling procedure. The staff finds that upon appropriate implementation of these changes, the licensee's procedures will be adequate to perform a safe natural circulation cooldown.

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References

1. Letter, W. A. Cross (FPC) to D. G. Eisenhut (NRC), "Generic Letter No. 81-21-Natural Circulation Cooldown," November 18, 1981.

2. Letter, G. R. Westater (FPC) to J. F. Stolz (NRC), "Generic Letter No. 81-21-Natural Circulation Cooldown," July 28, 1983.

3. Letter, P. Y. Baynard (FPC) to J. F. Stolz (NRC), "Generic Letter No. 81-21-Natural Circulation Cooldown," May 23, 1984.

4. Letter, E. C. Simpson (FPC) to J. F. Stolz (NRC), "Response to NRC Generic Letter No. 81-21-Natural Circulation Cooldown," December 20, 1985.

5. HEATING6: A Multi-Dimensional Heat Conduction Analysis with the Finite-Difference Formulation, RSIC #RCR-199.