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Preliminary Evaluation of Long-Term Cooling Considering Chemical Precipitation and Subsequent Impact on the Recirculating Fluid

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1. Introduction

Generic Safety Issue 191 (GSI-191) addresses a variety of concerns associated with the operation of the emergency core cooling system (ECCS) and the containment spray system (CSS) in the recirculation mode [1]. There has been concern that following a LOCA, chemical precipitate, fibrous and particulate debris within the sump could collect on the sump screen and block the flow of cooling water into the core. The effects of the debris that passes through the sump screen has also been noted as a point of concern. This debris could be ingested into the ECCS and flow into the RCS. The Pressurized Water Reactor Owners Group (PWROG) undertook a program to analyze the effect of debris and precipitates on core cooling for PWRs when the ECCS is realigned to recirculate coolant from the containment sump [2]. The objective of the program was to provide reasonable assurance that sufficient long term core cooling (LTCC) is achieved for PWRs, satisfying the requirements of 10CRF50.46 with respect to debris and chemical products that might be transported to the reactor vessel and core by the coolant recirculating from the containment sump. Chemicals may also deposit on the hot fuel rods and possibly insulate them and inhibit decay heat removal. PWROG developed a LOCA deposition model (LOCADM) to predict chemical deposition on fuel cladding due to the transport of debris and chemical products into the RCS and the core region by the coolant recirculated from the containment sump. Based on the LOCADM, this work performed a plant-specific LOCADM evaluation to show that the plant conditions would maintaine adequate LTCC capability.

2. Methods and Results

2.1 Long-Term Core Cooling (LTCC) Acceptance bases

Part of the resolution of GSI-191 involves defining the relevant LTCC bases. The LTCC acceptance criteria are consistent with the requirements of 10CFR50.46 (b)(4) and 10CFR50.46 (b)(5). These acceptance bases provide that local temperatures in the core are stable or continuously decreasing and that debris entrained in the cooling water supply will not affect decay heat removal.

LTCC bases are as follows

(1) The cladding temperature during recirculation from the containment sump will not exceed 800˚F.
(2) The deposition of debris and/or chemical precipitates will not exceed 0.050 inches in any fuel region.

At temperatures greater than 800˚F, rapid corrosion occurs along with higher hydrogen pickup rates, which can reduce cladding mechanical performance. The 0.05 inch thickness is the maximum acceptable thickness before bridging of adjacent fuel rods by debris is predicted to occur.

2.2 LOCA deposition model (LOCADM)

PWROG suggested the LOCADM as a calculation tool for predicting the build-up of chemical deposits on fuel cladding after a LOCA. The LOCADM predicts both the deposit thickness and cladding surface temperature as a function of time at a number of core location or nodes. A method to estimate the dissolution of containment materials has previously been developed in WCAP-16530-NP[3]. The same methods were used in the LOCADM to estimate the release of calcium, aluminum, and silicon from containment materials. The LOCADM provides worksheets and enables each plant to evaluate whether the plant is operating within the LTCC acceptance criteria after a LOCA. The flow paths considered in the LOCADM are shown in Fig. 1.

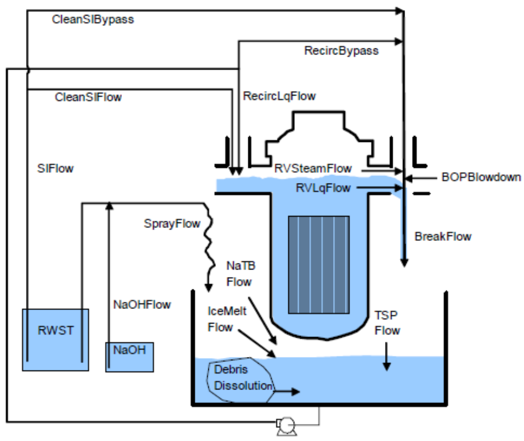

Fig. 1. Flow Paths Modeled by LOCADM

Coolant flow rates into the reactor mixing volume as a function of time must be provided by the user and are obtained from a plant's safety analysis for LTCC. The relative amounts of steam and liquid flow in the reactor mixing volume are calculated by the LOCADM.

2.3 Chemical precipitates and Debris deposited on fuel clad surfaces

Information such as containment materials, sump condition after LOCA and core data was surveyed in one of our Westinghouse plants. The gathered data were used as LOCADM input. Fig. 2. shows the core deposit mass and fuel temperature. The maximum scale thickness was 61 microns (0.0024inch). The maximum fuel temperature after recirculation started was 283.7 ˚F. Thus, LTCC was not compromised. Fig. 3. presents the maximum scale thickness with and without calcium silicate debris. The maximum scale thickness increased slightly when calcium silicate debris was taken into account, whereas the fuel temperature showed nearly identical value. Because the increase in the scale thickness was relatively small, it did not affect the fuel temperature.

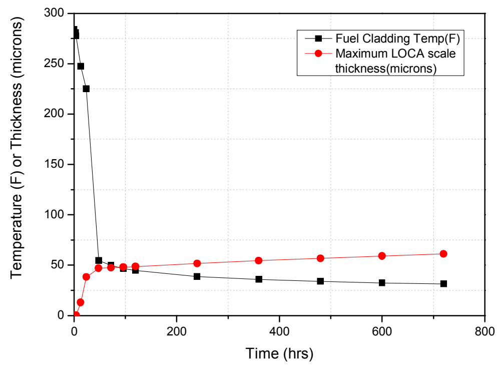

Fig. 2. Deposition mass thickness and fuel temperature with debris

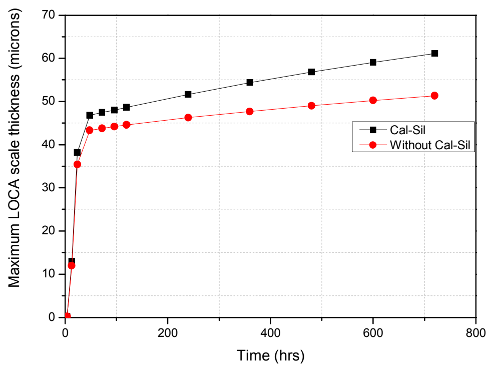

Fig. 3. Comparison of fuel thickness with Cal-Sil debris

3. Conclusions

To demonstrate that sufficient LTCC is achieved, a preliminary evaluation was performed to predict the accumulation of fuel cladding deposits from coolant impurities and the maximum clad temperature after a LOCA using a LOCADM based on plant-specific debris input.

Calculated results showed a plant with debris loads has adequate LTCC capability. With the presence of calcium silicate debris, the fuel scale thickness was greater than that without calcium silicate debris, but the maximum fuel temperature was not significantly affected. It was assumed that the amount of deposition was too small to influence the fuel temperature.

The LOCADM can be used by utilities to perform plant-specific evaluations. It is expected that each plant will be able to use this tool to show that acceptable fuel clad temperature will be maintained and to verify that the plant conditions are bounded by the debris load acceptance criteria.

REFERENCES

[1] USNRC, Generic Safety Issue 191(GSI-191), "Assessment of Debris Accumulation on Pressurized Water Reactor (PWR) Sump Performance."

[2] WCAP-16793-NP, Rev.1, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid, PWROG, April 2009

[3] WCAP-16530-NP-A, Rev.0, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191", PWROG, March 2008