NRR-PMDAPEm Resource

From: Harrison Albon <awharrison@STPEGS.COM>
Sent: Tuesday, September 06, 2016 3:52 PM
To: Regner, Lisa
Subject: [External_Sender] STP draft response to SNPB 3-2 bullet 4 re 16" break bounding
Attachments: SNPB-3-02 followup - partial 2 Bullet 4.pdf

Lisa,

Here is another partial for discussion in the public call on 9/14.

Wayne

Hearing Identifier: NRR_PMDA
Email Number: 3064

Mail Envelope Properties (FC3FC22E-DF52-40BF-806A-7633810123B7)

Subject: [External_Sender] STP draft response to SNPB 3-2 bullet 4 re 16" break bounding
Sent Date: 9/6/2016 3:51:58 PM
Received Date: 9/6/2016 3:52:04 PM
From: Harrison Albon

Created By: awharrison@STPEGS.COM

Recipients:
"Regner, Lisa" <Lisa.Regner@nrc.gov>
Tracking Status: None

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Files	**Size**	**Date & Time**
MESSAGE	88	9/6/2016 3:52:04 PM
SNPB-3-02 followup - partial 2 Bullet 4.pdf		397348

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DRAFT Response to SNPB Follow-up RAI 3-2 (partial): Bullet 4 re 16" break being bounding (9/6/16)

1. **Follow-up SNPB-3-2 Accident Scenario Progression**

Initial RAI: *Provide a description of the accident progression of the accident scenarios being simulated using the LTCC EM. This description should start at the initiation of the break, define each phase, and the important phenomena occurring in that phase in the various locations of the RCS (e.g., core, reactor vessel, steam generators - both primary and secondary side, loops, pressurizer, pumps, containment)*

- Though only the 16-inch hot leg break analysis was provided, STPNOC did not justify or demonstrate that the 16 inch hot leg break bounds smaller hot leg breaks. Justify that the 16-inch hot leg break analysis bounds the smaller hot leg break scenarios.

STP Response

The 16-inch HLB LOCA scenario progression is described as part of the response to the SNPB-3-02. The accident progression simulated with the LTCC EM can be summarized as follow:

- Immediately after the break event, the primary system experiences a fast depressurization where water and steam are discharged from the break.
- Reactor scram and ECCS actuation occur, controlled by low pressure signal.
- Due to the location of the break, injection of liquid water from the cold side is sustained by the ECCS injection system (HHSI, Accumulators, and LHSI).
- Core liquid inventory increases rapidly after the actuation of the accumulators and SI pump. Pre-Core Blockage LTCC starts when the core is fully flooded (Core Collapsed Liquid Level = 14 feet).
- When RWST water is depleted, injection start from the sump (SSO time)
- The total liquid inventory in the core and in the primary system is sufficient to supply the liquid water to the core immediately after the core blockage event.
- Liquid inventory in the core decreases until flow through alternative flow paths (steam generators u-tubes) is established.
- Liquid water flow is maintained at the top of the core through the steam generators during the Post-Core Blockage LTCC.

Different important thermal-hydraulic parameters can be identified from the description provided. These parameters (listed and described below) can be used as figure of merit to confirm that the large break scenarios bound smaller hot leg breaks.

Sump Switchover time

The sump switchover (SSO) time and, subsequently, the core blockage time, is one of the most important parameters defining the thermal-hydraulic initial conditions of the reactor system for the post-core blockage LTCC phase. The SSO time is defined based on the RWST volume available for injection, and the injection rate of the SI system and CS system. The rate of injection has three[1] contributors:

- The High Head Safety Injection (HHSI) pumps
- The Low Head Safety Injection (LHSI) pumps
- The Containment Spray (CS) pumps

The rate of injection of the HHSI and LHSI depends on the pressure of the primary system and, based on the pump characteristics, is expected to increase at lower primary system pressures. The contribution of the CS pumps may be assumed to be constant throughout the accident progression[2]. The primary pressure during the accident progression is strongly dependent on the break size. In particular, larger breaks are expected to experience a faster depressurization, stabilizing the primary system at a lower pressure. Subsequently, the total ECCS injection is expected to be higher during large break scenario than smaller breaks. The SSO time for the three HLB scenarios simulated is reported in the table below.

	Break Size		
	16"	6"	2"
SSO Time (s)	1740	2302	3729

Decay Power at Core Blockage and Core Boil-off Rate

The LTCC EM calculates the decay power using the ANS-1979 model. Based on the considerations on the SSO time provided in the previous paragraph, the decay power at time of core blockage is higher for larger breaks since the core blockage event occurs earlier in the transient. The amount of water required to compensate the boil-off rate and cool down the reactor core during at the post-core blockage LTCC is relatively larger in the 16-inch HLB scenario than smaller break scenarios.

The core decay power at the time of core blockage for the three HLB scenarios simulated is reported in the table below.

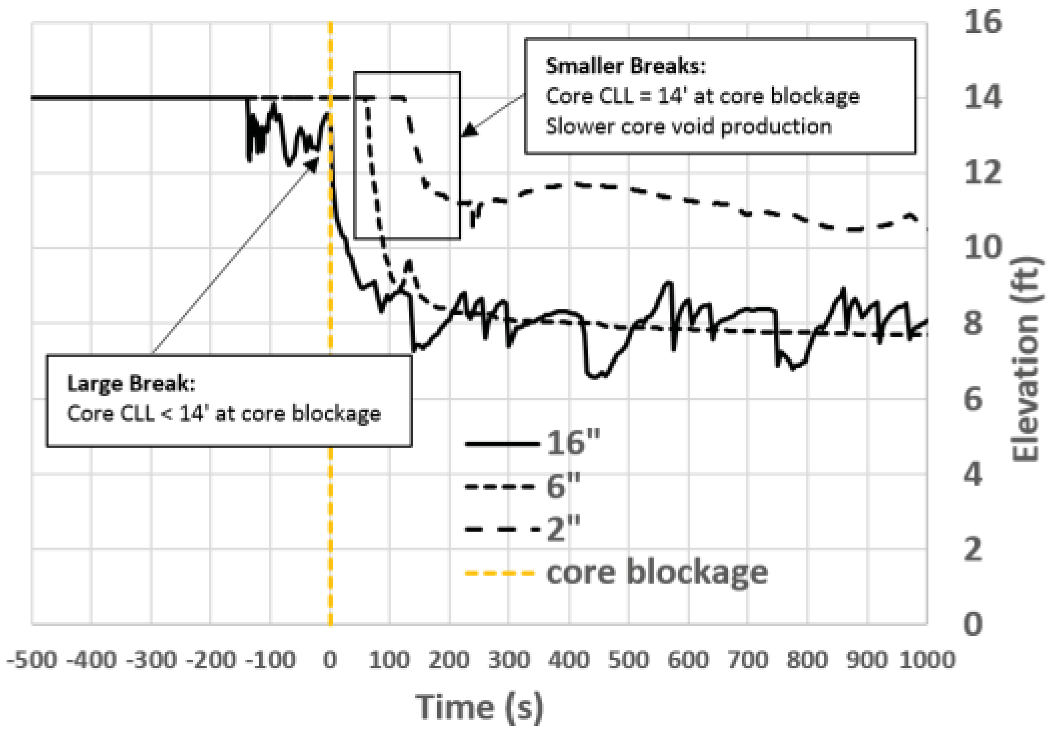
	Break Size		
	16"	6"	2"
Decay Power @ Core Blockage (MW)	68.25	63.01	54.92

[1] Accumulators do not contribute to the RWST depletion

[2] The CS pumps injection volumetric flow rate rumps up at pump startup and stabilizes to a nominal value defined by the pump and injection pipeline characteristics.

<u>Core Collapsed Liquid Level (CLL)</u>

In the seconds after the core blockage, the liquid water in the core reaches saturation and starts boiling. The boil-off rate depends on the core decay power (as mentioned in the previous sections). The steam leaving the core is replaced by liquid water entering the top of the core in opposite direction. Higher boil-off rates are expected right after the core blockage during larger break scenarios and, subsequently. The core mass inventory during the post-core blockage LTCC is expected to be smaller for larger break scenarios. In the following figure, the core collapsed liquid level is plotted for the cases simulated. In the figure, the core blockage time is set to zero for all the break scenarios to facilitate the comparison. Due to the higher decay power at the SSO (occurring 360 seconds before the core blockage time) in large breaks, voids are created in the core even before the core blockage time. The core collapsed liquid level decreases rapidly after the core blockage time in large breaks due to the smaller water inventory at the top of the core. Smaller breaks (6" and 2" in the figure) would have a core fully covered at the core blockage time (core collapsed liquid level = 14 ft) and a larger inventory of water available at the top of the core. This effect, combined with a lower decay power level in the core, allows a slower decrease in the core liquid inventory, which will stabilize to a higher level.



Other Considerations: Boundary Conditions

The simulations of the 6" and 2" HLB scenarios and core blockages are executed under the same boundary conditions of the large break (16") scenario. RWST volume available for injection, RWST water temperature, ECCS injection characteristics, and all other boundary conditions are imported from the 16" break simulation. Of particular importance is the sump pool temperature profile which is also assumed to be the same of the one imposed as boundary condition for the large hot leg break. Considerations on the heat transfer mechanisms in the reactor containment, and simulation results of different break sizes available in literature [1] show that the sump pool temperature at the SSO time is relatively lower for smaller breaks compared to large breaks.

The cladding temperature for the three accident scenarios simulated (16", 6", and 2" HLB) is shown in the figure below. In the figure, the following features can be seen:

- During the pre-core blockage LTCC and before the SSO time, cladding temperature are determined by the amount of flow forced through the core. The flow is lower for smaller breaks (no LHSI pumps running due to the high pressure of the primary system[3]). Subsequently, cladding temperature of small breaks (2" in the figure) is found to be higher than larger breaks.
- At SSO, the increase in the injection temperature produces an increase of the cladding temperature. ECCS flow is still forced through the core from the bottom.
- When core and core bypass is fully blocked, cladding temperature rises. Subcooled and saturated heat transfer regimes are seen in the core for the scenarios simulated. During the post-core blockage LTCC phase, the cladding temperature stabilizes to a level slightly above the saturation temperature at the pressure of the core. Differences in the cladding temperature shown in the figure below are due to the difference in the primary pressure.

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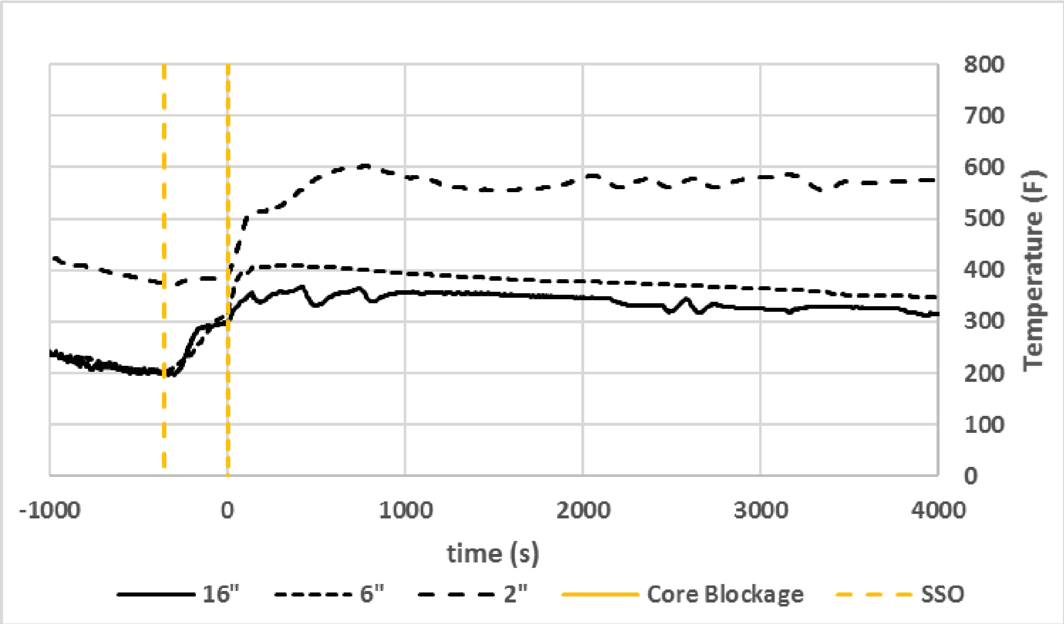
[3] No manual operations to cool down and depressurize the primary system are modeled in the LTCC EM. This condition generates a relatively high pressure of the primary system and a subsequent low ECCS flow rate through the core.



Final Remarks and Conclusions

The simulations of the three HLB scenarios are execute under the same boundary conditions. The important phenomena observed in the simulations are similar. Nevertheless, the large break scenario shows bounding initial conditions for the post-core blockage LTCC simulation, specifically in regards to the status of important thermal-hydraulic parameters of the reactor system at the SSO time:

- Decay power level,
- Water inventory in the core (Core CLL)
- Water inventory in the primary system

The arguments and discussion provided above confirm that the overall simulation results for the large HLB LTCC scenario are bounding the ones for smaller breaks.

[1]. NUREG/CR-6770, "GSI-191: Thermal-Hydraulic Response of PWR Reactor Coolant System & Containments to Selected Accident Sequences". August 2002. (http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6770/)