ENCLOSURE 4

GSI-191 ACRS Slide Presentation – November 18, 2010 (Non-Proprietary)

Presentation to ACRS Sub Committee

AP1000™ Long-Term Cooling Debris Issue Resolution

November 18, 2010

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Remaining Four ACRS Questions:

1. #69; LTC Analysis Margins
   - *How much less LTC flow, more debris DP, can AP1000 tolerate*
2. #71; FA Debris Testing Sensitivities (fiber)
   - *Do large DP margins allow for more than 6.6# fiber*
3. #68; WC/T Modeling / Cases
4. #70; Boron Conditions / Limits
5. #71; FA Debris Testing Sensitivities (others)

Suggested order of discussion

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#69; LTC Analysis Margins

1. What is the margin between the worst-case COBRA/TRAC calculations presented and the flow that would lead to dry-out? In other words, how much would the debris bed loss factor have to be increased in order to lead to dry-out?
2. At what quality would dry-out be expected at the decay heat levels used to generate the table of COBRA/TRAC results presented by the staff?
3. What is the low-pressure, low-flow CHF correlation used in COBRA/TRAC?

#69; LTC Analysis Margins Response

- Two preliminary WC/T sensitivity cases executed with increased debris bed resistance
  - 1.7 and 2.6 times Case 10 resistance
  - Mixture level is in the upper plenum and no heatup is calculated

Case	Core Inlet Resistance k/A^2 (ft^{-4})	Core Inlet Flow (lbm/s)	Core Debris Bed dP (psi)	ADS-4 Quality (%)	Max Boron Conc. (ppm)	Approx Avg Quality near Top of Hot Assembly (%) (1)
6	430.6	83.0	4.1	37	4800	8
8	546.5	76.0	4.4	41	5100	11
9	645.8	70.0	4.5	45	5600	9
10	761.8	65.0	4.6 (2)	49	6100	12
New 1						
New 2						

(1)

(2)

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- New cases demonstrate considerable margin over and above the current LTC safety analysis limit (Case 10)

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#69; LTC Analysis Margins Response (cont.)

Comparison of Case 10 results and cases with higher resistance

Core Collapsed Level

Upper Plenum Collapsed Level

Hot Rod PCT

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#69; LTC Analysis Margins Response (cont.)

- CHF Correlations in WCOBRA/TRAC
  - Lower mass flux (< 30 g/cm^2-s)
    - Modified Zuber correlation as recommended by Bjornard and Griffith
  - Higher mass flux (> 30 g/cm^2-s)
    - Biasi correlations for low quality CHF, high quality CHF
- Additional assessment of CHF during LTC against Chang (1991) correlation
  - Correlation developed for low flow, low pressure conditions
  - Consider Case 10 power, flow conditions (8.6 hr after break, 65 lbm/s)
  - Similar to assessment of conditions during accumulator injection period of a SBLOCA

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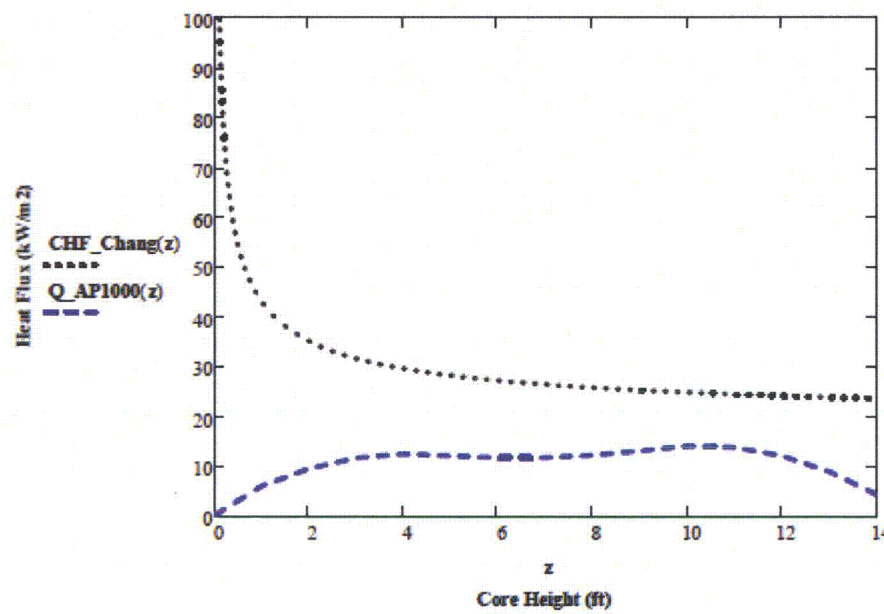
#69; LTC Analysis Margins Response (cont.)

Conservative Assumptions for Additional CHF Assessment:

- Minimum inlet flow
  - 65 lbm/s core flow
  - No credit for cross flow/chimney effects
- Hot assembly power
  - FdH=1.75
- 20°F inlet subcooling

CHF limit is not exceeded

Comparison of Chang (1991) CHF and AP1000 Case 10 Conditions



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#71; FA Debris Testing Sensitivities

How sensitive are the debris bed head loss to:

1. Flow rate
2. Fiber characteristics
3. Fiber loading
4. Chemical loading
5. Testing protocols

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#71; FA Debris Testing Sensitivities Response (cont.)

3. Fiber Amount

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#71; FA Debris Testing Sensitivities Relationship Between Fiber and DP

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#71; FA Debris Testing Sensitivities Response (cont.)

3. Fiber Amount (cont.)

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#68; WC/T Modeling / Cases

1. What are the lowest flows calculated by COBRA/TRAC for various accident scenarios using the same debris loading as is used for the DVI break calculations?
2. How do numerical (nodalization and time-step) convergence tests affect the oscillations seen in the COBRA/TRAC calculations?
3. Do DEDVIGB breaks lead to the lowest driving head conditions? Are there other accident scenarios (e.g., some cold leg breaks) that lead to lower driving heads due to incomplete filling of the downcomer?
4. If the bed resistance is made a function of velocity as seen in the experiments, how are the oscillations and the average flows and pressure losses affected?
5. If the bed resistance is made a function of flow rate through the debris beds formed, then do these effects change the worst-case scenarios? Does such a flow-dependent bed resistance parameterization lead to lower flows than would be calculated with a constant bed resistance for the worst-case scenarios?

#68; WC/T Modeling / Cases Response

1. & 3. Worst LOCA break location for LTC Analysis

- LOCAs in loop compartment are limiting for LTC when debris effects are considered
  - All latent debris is assumed to be transported to the loop compartment; most debris can enter core through flooded CL break
    - 90% of fiber can enter through DECL LOCA
    - 75% of fiber can enter through DEDVI LOCA
  - DEDVI line LOCA in PXS room is less limiting
    - Very little latent debris is located in room since it is very small
    - All water flowing into PXS from loop compartment is screened
    - Small debris source more important than lower flood level
      - Caused by additional flooded volume (PXS room); used in DCD as limiting LTC break location

#68; WC/T Modeling / Cases Response

1. & 3. Worst LOCA break location for LTC Analysis

- DEDVI LOCA and DECL LOCA in loop compartment have compensating impacts
  - DECL LOCA has lower flow resistance, more water recirc through break, can tolerate higher debris bed resistance
    - DECL LOCA results show much higher flows into downcomer and higher collapsed liquid levels in the inner vessel and downcomer compared to the DEDVI case
    - However DECL LOCA also transport more fiber into core (90%)
  - DEDVI LOCA has higher flow resistance, less water recirc through break, can tolerate lower debris bed resistance
    - However DEDVI LOCA transports less fiber into core (75%)
  - DEDVI LOCA is made bounding by assuming the larger amount of fiber transport (90%) – refer to APP-PXS-GLR-001 and APP-GW-GLR-079

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#68; WC/T Modeling / Cases Response

2. Oscillations in WC/T, nodalization sensitivity

- Previous core nodalization sensitivity studies similar to DCD case examined effect of 7, 10, 14 nodes in core
- Core collapsed liquid level was sensitive to the nodalization
- WC/T LTC model for debris sensitivity cases uses detailed nodalization (17 nodes in core)
  - 17 nodes based on AP1000 fuel design (grid location, etc)
  - Modeling consistent with validation against G1 and G2 boiloff tests

#68; WC/T Modeling / Cases Response

Core Collapsed Liquid Level: Nodalization Sensitivity Case

Similar to DCD Case

7 core cells

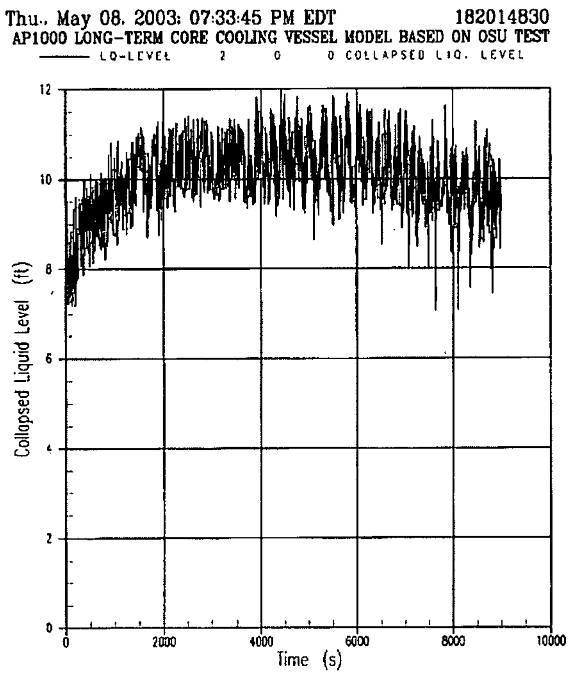

Figure 6.3.1.18 Core Level
(Case-1-2 : Multi-Channel, 7 node core)

10 core cells

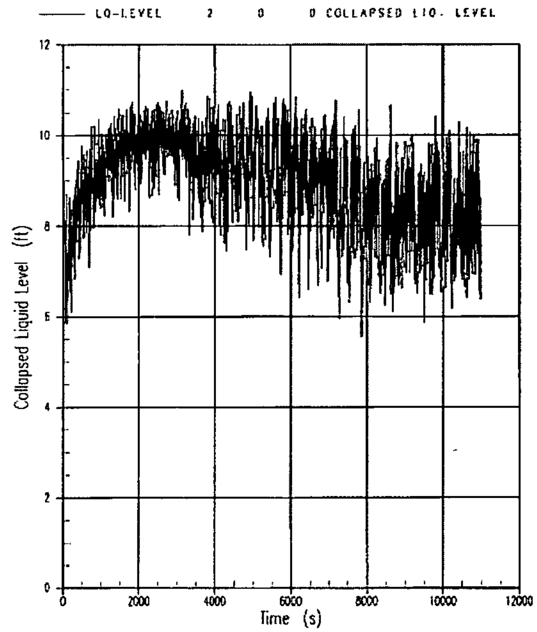

Figure 6.3.1.4 Core Level
(Case-1-1: Multi-Channel, 10 node core)

14 core cells

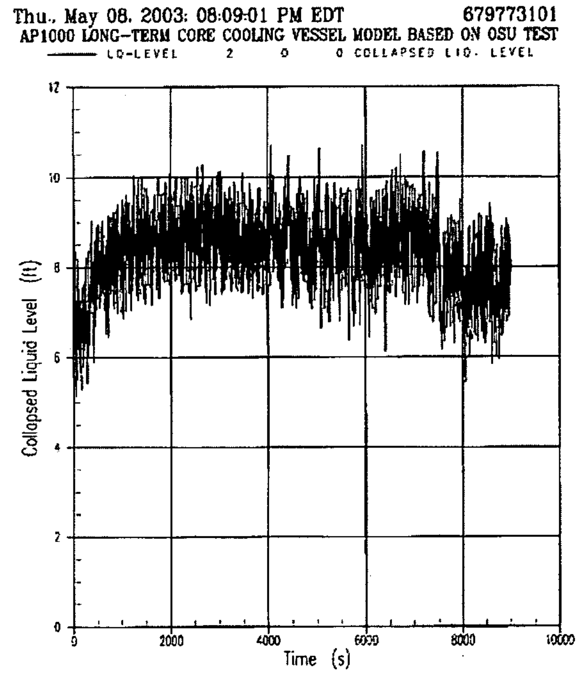

Figure 6.3.1.23 Core Level
(case1-3 : Multi-Channel, 14 node core)

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#68; WC/T Modeling / Cases Response

Void fraction at top of Hot Assembly: Nodalization Sensitivity Case

7 core cells

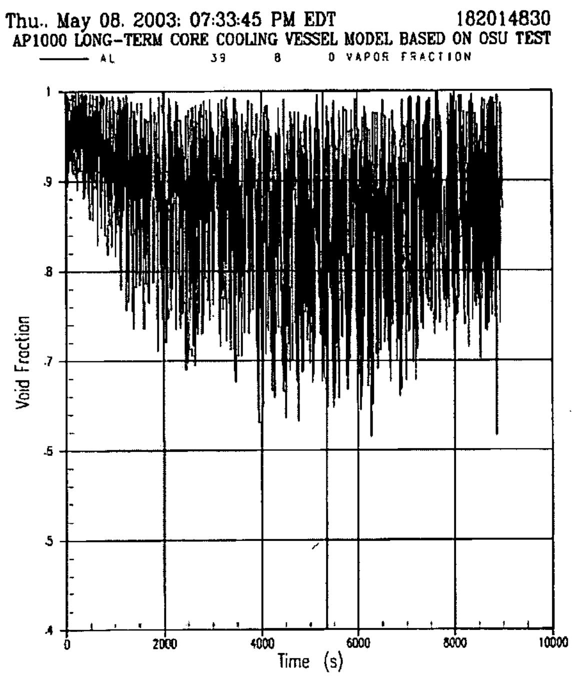

Figure 6.3.1.19 Vapor Fraction (Core Top, HA cell)
(case-1-2: Multi-Channel, 7 node core)

10 core cells

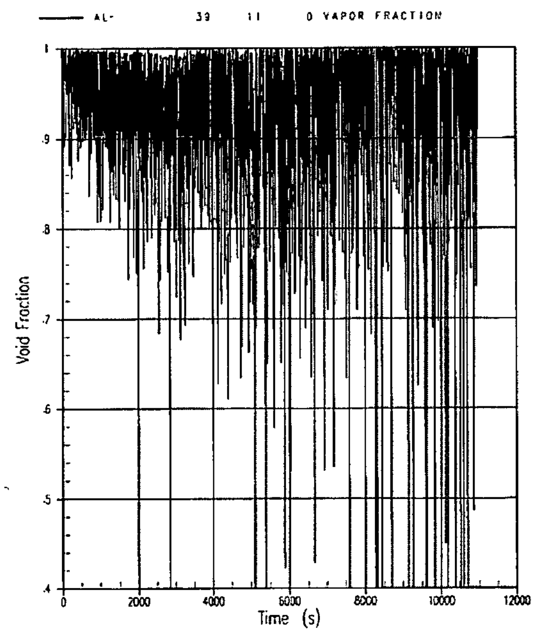

Figure 6.3.1.7 Vapor Fraction (Core Top, HA cell)
(Case-1-1: Multi-Channel, 10 node core)

14 core cells

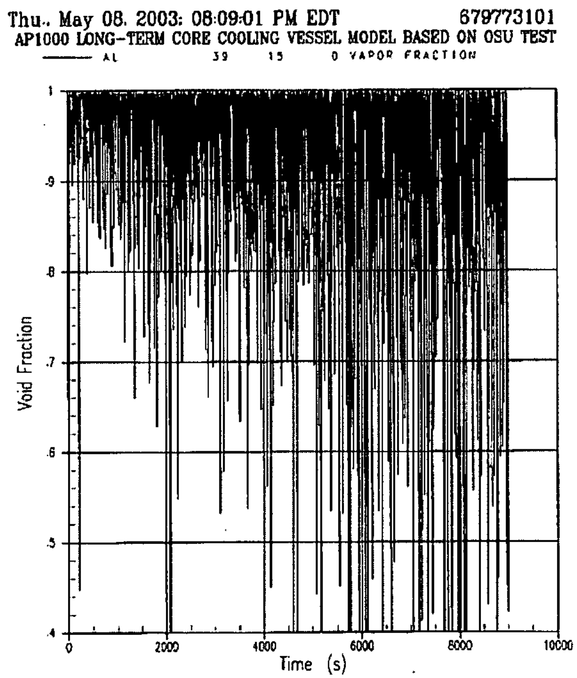

Figure 6.3.1.24 Vapor Fraction (Core Top, HA cell)
(Case-1-3: Multi-Channel, 14 node core)

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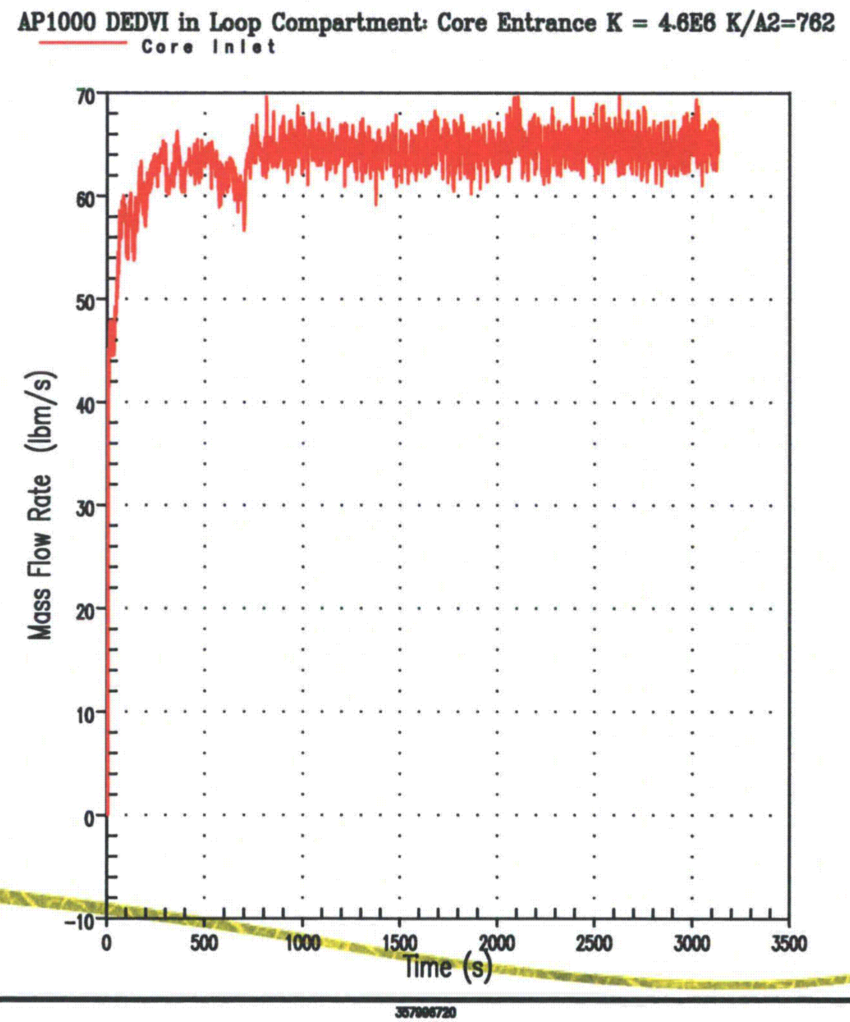
#68; WC/T Modeling / Cases Response

4. & 5. WC/T modeling of DP based on flow^2 vs. test results

- Flow rate into core in WC/T Sensitivity Case 10 does not vary significantly
- DVI line flows vary more
  - Oscillations in downcomer level accommodate these variations



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#68; WC/T Modeling / Cases Response

4. & 5. WC/T modeling of DP based on flow^2 vs. test results

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FA Debris Bed Resistance

- Calc debris bed resistance

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#70; Boron Conditions / Limits

1. What happens to boron concentration levels and deposition in the event of dry-out? (Addressed in November Full Committee meeting. Need explicit reference.)
2. What are the conditions in outlet quality and flow rate at which boron precipitation becomes a concern?

#70; Boron Conditions / Limits Response

- Dryout does not occur in AP1000 core post-LOCA in:
  - Current analysis limit (Case 10) with ADS-4 vent quality 49%

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#70 Response (cont.)

- WCOBRA/TRAC cases with 64% and 79% ADS-4 vent quality (continued)

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#70 Response (cont.)

- WCOBRA/TRAC cases with 64% and 79% ADS-4 vent quality (continued)

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#71; FA Debris Testing Sensitivities

How sensitive are the debris bed head loss to:

1. Flow rate
2. Fiber characteristics
3. Fiber loading
4. Chemical loading
5. Testing protocols

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#71; FA Debris Testing Sensitivities Response

1. Flow Rate

- This sensitivity is thoroughly discussed in the FA debris testing WCAP-17028 in Sections 5.2 and 9.1.4

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#71; FA Debris Testing Sensitivities Response (cont.)

2. Fiber Characteristics

- This sensitivity is thoroughly discussed in the FA debris testing WCAP-17028 in Section 9.1.1

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#71; FA Debris Testing Sensitivities Response (cont.)

4. Chemical Loading

- This sensitivity is thoroughly discussed in the FA debris testing WCAP-17028 in Section 9.1.2

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#71; FA Debris Testing Sensitivities Response (cont.)

5. Testing Protocols

- This sensitivity is thoroughly discussed in the FA debris testing WCAP-17028 in Section 9.1.5

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AP1000 GSI-191 Conclusions

- Significantly reduced the sources of post -LOCA debris by design
- GSI-191 testing & evaluations are very conservative
- The head loss across the fuel assemblies shows significant margin
  - Tests show >71% margin to the current analysis limits (core DP)
  - Margin increases to [ ]a,c with extended LTC analysis limit (core DP)
- NRC staff issued AFSER for DCD Chapter 6 (including GSI-191)
- *WEC has addressed remaining four ACRS questions*
  - *Additional LTC analysis margin was identified, [ ]a,c times more resistance*
  - *Estimated DP margins would allow LTC with [ ]a,c fiber (vs 6.6 lb)*

AP1000 provides reasonable assurance of providing LTC following a LOCA

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