Response to
Request for Additional Information No. 30 Supplement 2, Revision 0

7/29/2008

U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 15.06.05 - Loss of Coolant Accidents Resulting From Spectrum of Postulated Piping Breaks Within the Reactor Coolant Pressure Boundary
Application Section: FSAR Ch 15
SRSB Branch

Question 15.06.05-20:

The limiting size for the SBLOCA has changed from 4” in ANP-10263 to 6.5” in the FSAR. Please explain what model assumptions resulted in this change of the limiting break size.

Response to Question 15.06.05-20:

Five additional break spectra (BS) analyses were performed in order to respond to this question. Sensitivity modifications were made in the small break loss of coolant accident (SBLOCA) model documented in ANP-10291P, “Small Break LOCA and Non-LOCA Sensitivity Studies and Methodology Technical Report,” November 2007. These sensitivity modifications were removed one-by-one in order to resemble the sample problem documented in ANP-10263PA, “Codes and Methods Applicability Report for the U.S. EPR,” August 2007. The modifications are as follows:

- BS1 The downcomer-to-hot-leg gap (bypass) was added
- BS2 The emergency feedwater (EFW) was assumed unavailable
- BS3 The hot legs were modeled with four nodes instead of five
- BS4 The reverse high loss coefficient (K) at the exit of the hot assembly was removed
- BS5 The counter current flow limitation (CCFL) at the steam generator (SG) tubes inlet was removed

The higher peak cladding temperature (PCT) results for the five break spectra are summarized in Table 15.06.05-20-1, and in Figure 15.06.05-20-1. The results indicate that, regardless of the modifications, the limiting breaks consistently occur in the 6-7 inch range. The fifth break spectrum (BS5) results, which resembles most closely the sample problem (although the nodalization is not identical), show a 24°F lower PCT for the 4 inch break compared to the 6.5 inch break. However, this difference is considered insignificant (see Figures 15.06.05-20-3 and 15.06.05-20-5).

The smaller breaks have higher PCTs in the original sample problem and in the sensitivities performed and documented in Table 15.06.05-20-1 below because of the assumption—in the sample problem—that the EFW is not available. Also, to a lesser extent, because the opening of the downcomer-to-hot leg (DC-HL) gap, which tends to increase the PCT for the smaller breaks and lower the PCT for the larger breaks. The change from four hot-leg nodes to five hot-leg nodes has the effect of changing the limiting break from 7 inches to 6.5 inches.

The 4 inch break is more limiting for the local oxidation and total oxidation because the 4 inch break stays uncovered longer than the 6.5 inch break, as shown in Figure 15.06.05-20-2 and Figure 15.06.05-20-4.

In conclusion, when the modifications made in the ANP-10291P SBLOCA model are removed, the break spectrum results show almost identical PCTs for the 4 inch (1542°F) and 6.5 inch (1566°F) breaks, with the 6.5 inch break the limiting case for the PCT, but only 24°F higher (see Table 15.06.05-20-1). Further conclusions from the break spectrum analyses are:

a. The maximum PCT for the U.S. EPR FSAR SBLOCA break spectrum is 1638°F, calculated for a 6.5 inch break with loss of offsite power (LOOP) coincident with reactor trip. The maximum PCT for the model with similar input as the sample problem is a less-limiting value of 1566°F, calculated for the 6.5 inch break. Both values are well below the 2200°F PCT limit specified in 10CFR50.46 (b)(1).

b. The peak cladding oxidation for the FSAR analysis is 0.383%, corresponding to the 6.5 inch break. In the model similar to the sample problem, the peak cladding oxidation is calculated as 0.374% for the 4 inch break. This value is less limiting than the analysis presented in U.S. EPR FSAR, Tier 2, Section 15.6.5 (see Table 15.06.05-20-2). Both are below the 17% limit specified in 10CFR50.46(b)(2).

c. For the FSAR analysis, the maximum core-wide cladding oxidation is 0.008974% for the 6.5 inch break. For the model similar to the sample problem, the maximum core-wide oxidation is 0.0104%, which is calculated for the 4 inch break. Both calculated values for core-wide cladding oxidation are less than the 1% limit specified in 10CFR50.46(b)(3) (see Table 15.06.05-20-3).

d. The new calculation shows that the core retains a coolable geometry based on satisfying the acceptance criteria (see items a, b, and c above). Thus, the coolable geometry criterion in 10CFR50.46 (b)(4) is satisfied.

e. For the new model, similar to the sample problem presented in ANP-10263PA, both the 4 inch and 6.5 inch breaks are limiting. The 6.5 inch break is limiting for PCT and the 4 inch break is limiting for local oxidation and maximum hydrogen generation.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Table 15.06.05-20-1—Break Spectra Results – Peak Cladding Temperature

Break Diameter (inches)	**Peak Cladding Temperature (°F)**					
	FSAR	**BS1** (DC-HL Gap)	**BS2** (DC-HL Gap, no EFW)	**BS3** (DC-HL Gap, no EFW, four Hot Leg Nodes)	**BS4** (DC-HL Gap, no EFW, four Hot Leg Nodes, no High Reverse K)	**BS5** (DC-HL Gap, no EFW, four Hot Leg Nodes, no High Reverse K, no CCFL at Tubes Inlet)
2.0	670	N/A	N/A	N/A	N/A	N/A
2.5	1042	N/A	1123	N/A	N/A	N/A
3.0	917	936	1334	1322	1324	1327
3.5	949	1167	1300	1398	1398	1400
4.0	1088	1031	1433	1526	1527	1542
4.5	1223	1302	1531	1542	1547	1367
5.0	1085	1337	1175	1468	1169	1380
5.5	1199	1360	1363	1284	1129	1108
6.0	1125	1021	1018	1498	1534	1228
6.5	**1638**	1282	1056	**1597**	**1595**	**1566**
7.0	1587	**1508**	**1588**	1540	1358	1349
7.5	1479	1495	1473	1495	1500	1504
8.0	1469	1453	1457	1447	1477	1449

Note: The highest peak cladding temperature for each case is in bold.

Table 15.06.05-20-2—Metal-Water Reaction – Local Maximum (%)

Break Diameter (inches)	**Peak Cladding Oxidation (%)**					
	FSAR	**BS1** (DC-HL Gap)	**BS2** (DC-HL Gap, no EFW**)**	**BS3** (DC-HL Gap, no EFW, four Hot Leg Nodes)	**BS4** (DC-HL Gap, no EFW, four Hot Leg Nodes, no High Reverse K)	**BS5** (DC-HL Gap, no EFW, four Hot Leg Nodes, no High Reverse K, no CCFL at Tubes Inlet)
2.0	N/A	N/A	N/A	N/A	N/A	N/A
2.5	2.59E-2	N/A	5.641E-2	N/A	N/A	N/A
3.0	5.286E-3	6.321E-3	0.16090	0.14965	0.15133	0.16313
3.5	5.458E-3	3.438E-2	0.10205	0.18724	0.19071	0.19215
4.0	1.551E-2	8.575E-3	0.19701	0.32565	0.32935	**0.37366**
4.5	4.855E-2	7.364E-2	0.29431	**0.32572**	**0.33434**	0.1201
5.0	1.176E-2	0.10323	0.23263	2.569E-2	2.425E-2	0.12432
5.5	3.064E-02	0.10905	0.11007	6.40E-2	1.638E-2	1.372e-2
6.0	1.758E-2	6.160E-3	6.135E-3	0.25085	0.25831	3.982E-2
6.5	**0.383**	6.149E-2	1.189E-2	0.32540	0.32633	0.29591
7.0	0.305	**0.21636**	**0.31199**	0.24025	7.464E-02	7.353E-2
7.5	0.165	0.20640	0.17424	0.17963	0.19344	0.19581
8.0	0.152	0.14011	0.16221	0.13576	0.16912	0.14845

Note: The highest peak cladding oxidation for each case is in bold.

Table 15.06.05-20-3—Metal-Water Reaction – Core Wide (%)

Break Diameter (inches)	Core-Wide Oxidation (%)					
	FSAR	**BS1** (DC-HL Gap)	**BS2** (DC-HL Gap, no EFW)	**BS3** (DC-HL Gap, no EFW, four Hot Leg Nodes)	**BS4** (DC-HL Gap, no EFW, four Hot Leg Nodes, no High Reverse K)	**BS5** (DC-HL Gap, no EFW, four Hot Leg Nodes, no High Reverse K, no CCFL at Tubes Inlet)
2.0	N/A	N/A	N/A	N/A	N/A	N/A
2.5	5.006E-4	N/A	1.001E-3	N/A	N/A	N/A
3.0	1.806E-4	1.879E-4	3.728E-3	3.39E-3	3.452E-3	3.716E-3
3.5	2.106E-4	6.221E-4	2.105E-3	4.268E-3	4.323E-3	4.407E-3
4.0	3.193E-4	2.173E-4	4.632E-3	8.877E-3	9.000E-3	**1.0393E-2**
4.5	8.999E-4	1.454E-3	7.810E-3	**8.932E-3**	**9.126E-3**	2.588E-3
5.0	3.543E-4	1.938E-3	5.380E-3	6.565E-4	6.301E-3	2.569e-3
5.5	6.715E-4	2.141E-3	2.157E-3	1.268E-3	6.167E-3	5.501e-4
6.0	5.462E-4	2.701E-4	2.701E-4	6.225E-3	1.144E-2	1.227E-3
6.5	**8.974E-3**	1.329E-3	2.667E-4	6.511E-3	6.427E-3	5.406E-3
7.0	7.619E-3	**4.378E-3**	**8.174E-3**	5.696E-3	5.487E-3	5.345E-3
7.5	3.388E-3	4.499E-3	3.487E-3	3.871E-3	2.883E-3	2.934E-3
8.0	2.45E-3	2.81E-3	2.871E-3	2.013E-3	2.560E-3	2.038E-3

Note: The highest core-wide oxidation for each case is in bold.

Figure 15.06.05-20-1—U.S. EPR SBLOCA Break Spectrum Comparison Figure – Peak Cladding Temperature

LOOP, FSAR vs. LOOP, DC-HL Gap, no EFW, four Hot Leg Nodes, no Reverse K, no CCFL at Tubes Inlet

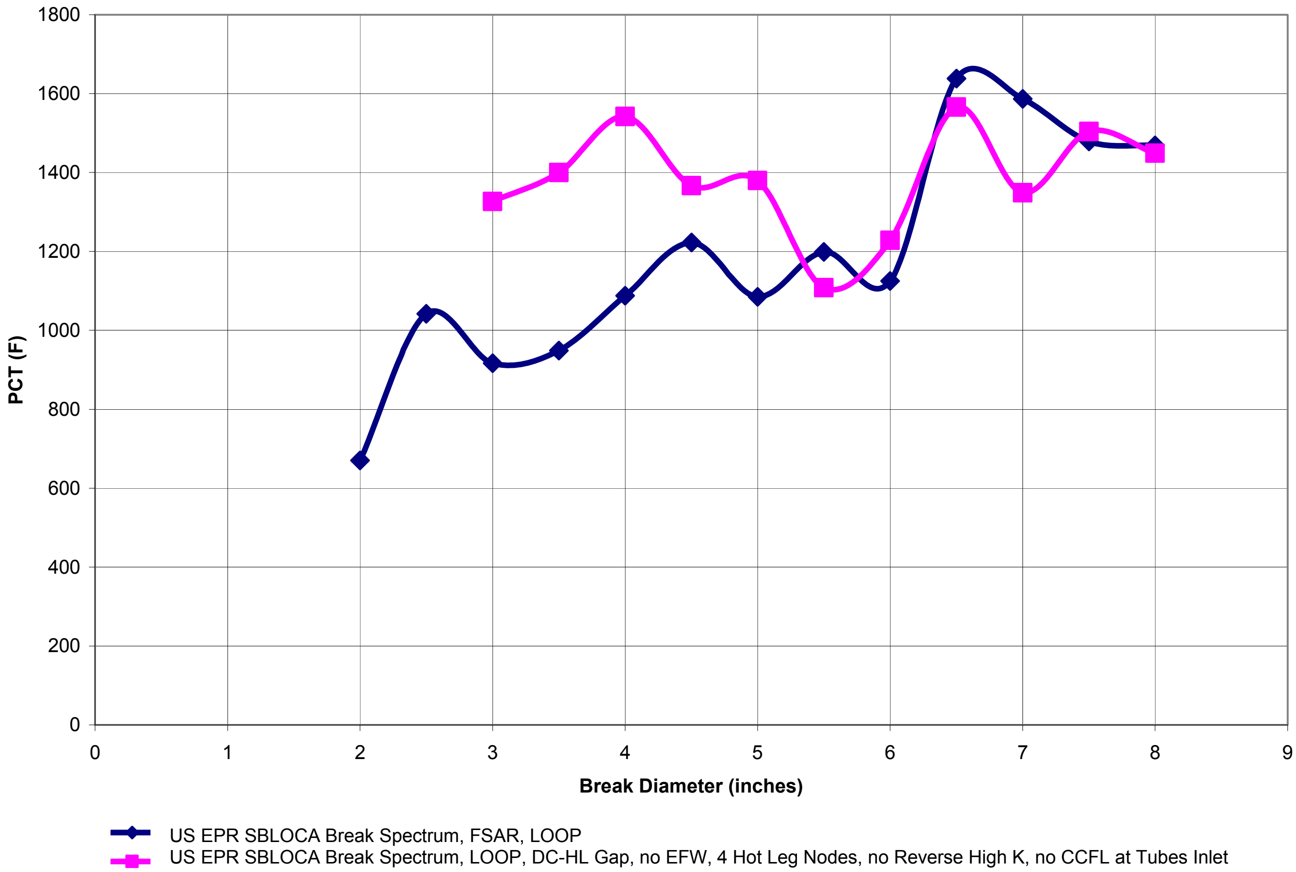


Figure 15.06.05-20-2—Hot Channel Collapsed Level

4.0 in. Break with DC-HL Gap, no EFW, four Hot Leg Nodes, no High K, no CCFL at Tubes Inlet

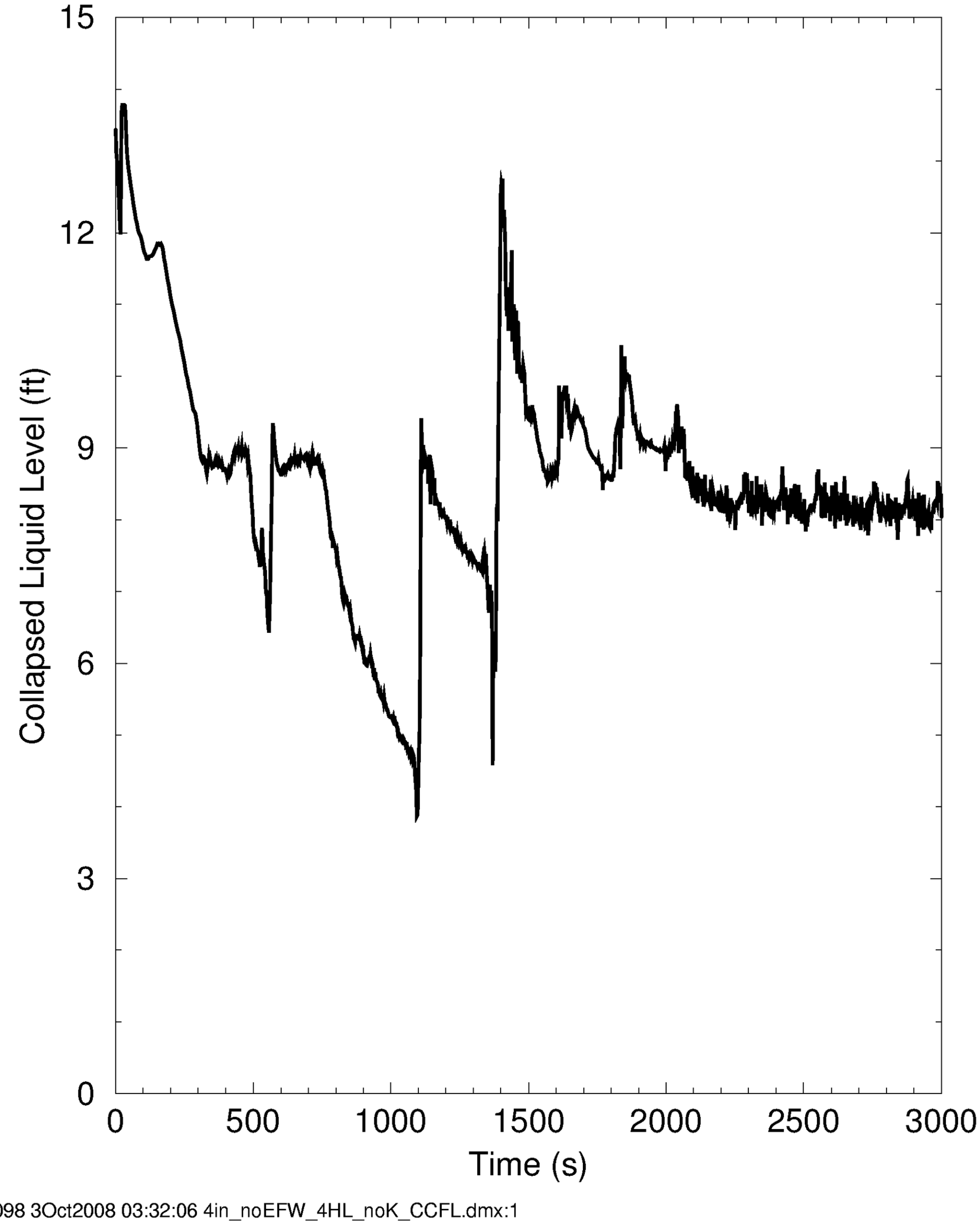


Figure 15.06.05-20-3—Peak Cladding Temperature

4.0 in. Break with DC-HL Gap, no EFW, four Hot Leg Nodes, no High K, no CCFL at Tubes Inlet

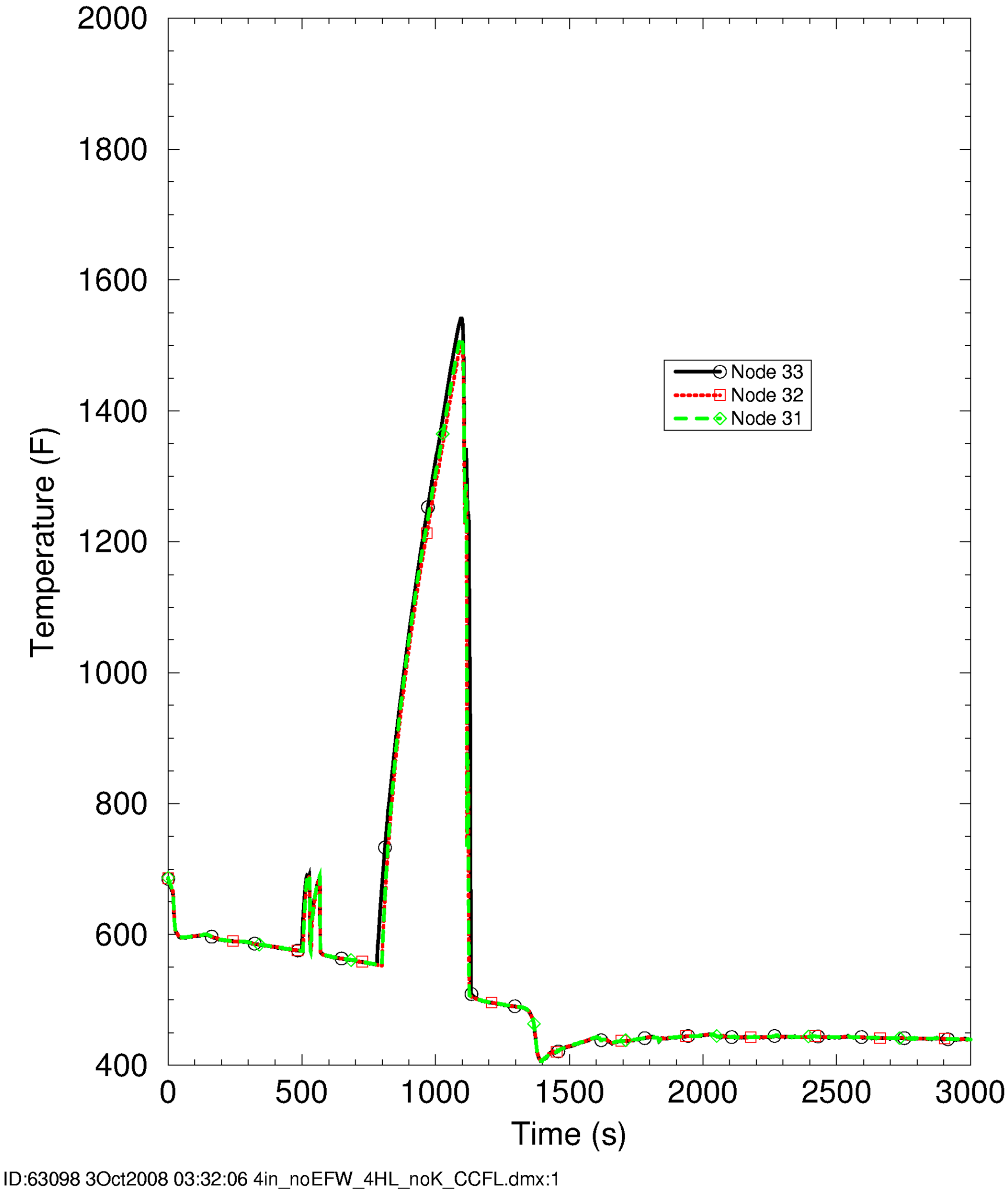
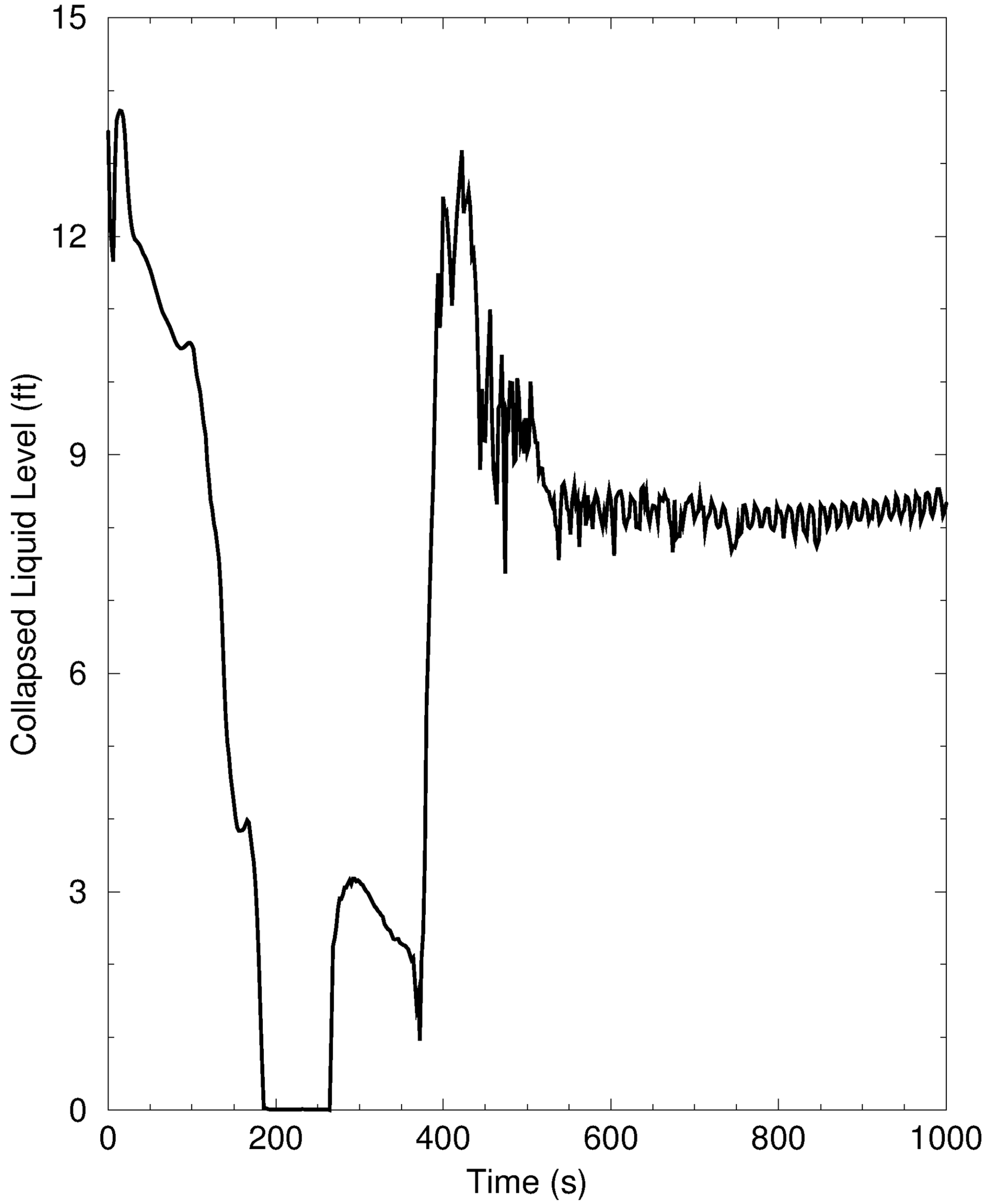


Figure 15.06.05-20-4—Hot Channel Collapsed Level

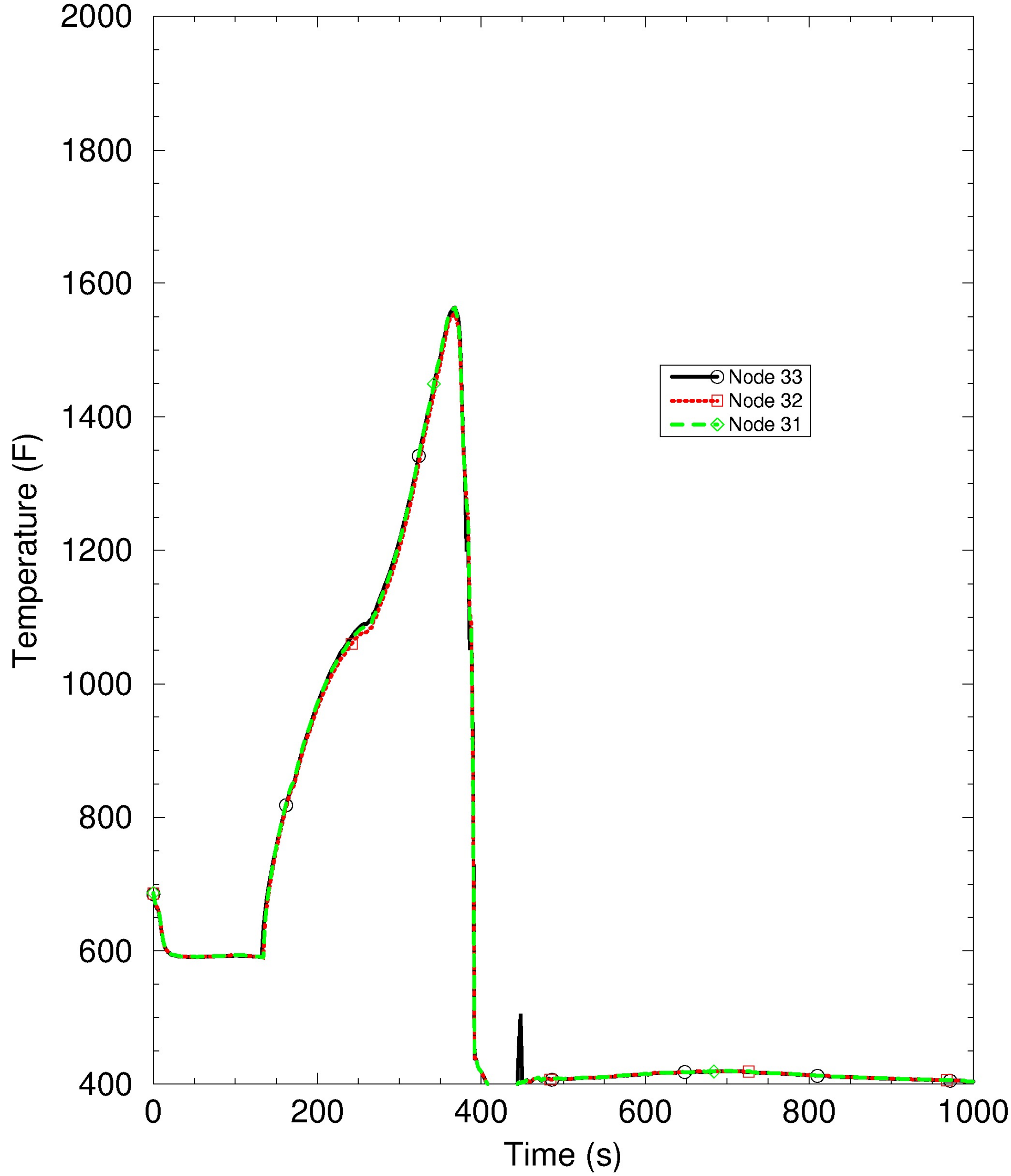
6.5 in. Break with DC-HL Gap, no EFW, four Hot Leg Nodes, no High K, no CCFL at Tubes Inlet



ID:16576 24Sep2008 20:39:11 6_5in_noEFW_4HL_noK_CCFL.dmx:1

Figure 15.06.05-20-5—Peak Cladding Temperature

6.5 in. Break with DC-HL Gap, no EFW, four Hot Let Nodes, no High K, no CCFL at Tubes Inlet



ID:16576 24Sep2008 20:39:11 6_5in_noEFW_4HL_noK_CCFL.dmx:1

Question 15.06.05-24:

The SBLOCA calculations assume no leakage paths between the hot legs and the vessel downcomer. Please justify this assumption and discuss its impact on the analysis and related safety conclusions.

Response to Question 15.06.05-24:

The AREVA NP small break loss of coolant accident (SBLOCA) methodology assumes that the downcomer-hot leg (DC-HL) gaps are open during the SBLOCA event, and the associated DC-HL bypass flows are included in the downcomer-upper head (DC-UH) bypasses. The SBLOCA sample problem in ANP-10263PA, "Codes and Methods Applicability Report for the U.S. EPR," August 2007, explicitly modeled the DC-HL bypass flow paths.

Modeling of the DC-HL gaps was changed so that the gaps are assumed to be closed during the SBLOCA event. The associated initial DC-HL bypass flow during normal operation is included in the guide tube bypass flow so that the total core bypass flow is preserved. The reason for changing the treatment of the DC-HL gaps for the FSAR analysis is based on the expectation that the gaps close during the depressurization of the primary system. The NRC has indicated in Reference 1 that it does not allow credit for the hot-leg nozzle gaps in the SBLOCA model, because it believes the leakage path "minimizes the depth and duration of uncovery of the core" by venting steam to the break, thereby "reducing PCT during the long term."

To confirm the conservatism of eliminating the bypass, the DC-HL gap was opened and a break spectrum analysis with this modification was performed. Table 15.06.05-24-1 presents the bypass values used in the reanalysis, while Table 15.06.05-24-2 presents the results of the break spectrum compared with the FSAR results.

The comparison shows that the peak cladding temperature for the limiting break presented in U.S. EPR FSAR, Tier 2, Section 15.6.5 of the FSAR bounds the limiting break calculated for the break spectrum with DC-HL bypass open. The limiting break for this case is the 7.0 inch break with a PCT of 1508°F, versus 1638°F for the 6.5 inch break limiting break case in U.S. EPR FSAR, Tier 2, Section 15.06.05.

Table 15.06.05-24-1—Core Bypass Flow

Bypass Region	Target Values for Bypass Flow (% of total flow)
Upper Downcomer to Upper Head	0.33
Heavy Reflector + Baffle Face Flow	1.24
Control Rod Guide Tube	2.83 + 0.06 = 2.89
Upper Downcomer to Hot Legs	1.04

Table 15.06.05-24-2—Break Spectrum for Nodalization with DC-HL Open

Break Diameter (in)	Break Area (ft^2)	FSAR PCT (°F)	DC-HL Open PCT (°F)	Time of PCT (s)	Metal-Water Reaction	
					Local Maximum (%)	Core Wide (%)
3.0	0.0491	917	936	2968.40	6.321E-3	1.879E-4
3.5	0.0668	949	1167	1645.50	3.438E-2	6.221E-4
4.0	0.0873	1088	1031	1253.10	8.575E-3	2.173E-4
4.5	0.1104	1223	1302	867.94	7.364E-2	1.454E-3
5.0	0.1364	1085	1337	674.78	0.10323	1.938E-3
5.5	0.1650	1199	1360	560.78	0.10905	2.141E-3
6.0	0.1963	1125	1021	471.40	6.160E-3	2.7015E-4
6.5	0.2304	1638	1282	390.67	6.149E-2	1.329E-3
7.0	0.2673	1587	1508	311.03	0.21636	4.378E-3
7.5	0.3068	1479	1495	266.83	0.20640	4.499E-3
8.0	0.3491	1469	1453	234.06	0.14011	2.81E-3

As shown in Tables 15.06.05-24-2, 15.06.05-20-2, and 15.06.05-20-3, the SBLOCA with the DC-HL bypass open results in a higher PCT and greater amount of metal-water reaction in the break range 3 to 5.5 inches than in the FSAR analysis. For the 4 inch break, the PCT and the amount of metal-water reaction results are comparable. The reason that smaller breaks have higher PCT with the DC-HL gap open can be seen in the case of the 5 inch break. The 5 inch break case with the gap open is more limiting for the PCT due to the loop seal clearing time. For the FSAR analyses, all four loops cleared before 400 seconds. When the gap is present, two loop seals clear at 360 seconds, while Loop 1 and Loop 4 clear later at 670 seconds due to the DC-HL bypass path for venting (see Figure 15.06.05-24-1 and -2). The first PCT peak is more limiting when the DC-HL gap is not present because there is more core level depression when there is no venting and the loops are plugged (see Figure 15.06.05-24-3). The PCT is higher because the loops clear later than in the FSAR analyses (see Figure 15.06.05-24-4). For the larger breaks (6.5 inch and 7.0 inch, which are limiting for U.S. EPR) there is only one heatup period, and there is greater core uncovery when the DC-HL gap is closed, as shown in Figure 15.06.05-24-5 and Figure 15.06.05-24-6. After the loop seals clear, recovery is to a lower level, and subsequently higher PCT, as shown in Figure 15.06.05-24-7 and Figure 15.06.05-24-8.

For larger small breaks (6.0 inch to 8.0 inch, which are limiting for the U.S. EPR), the open DC-HL gap results in lower PCTs than those in the FSAR. Hence, modeling with the DC-HL gap closed leads to more conservative results for the limiting break range.

References for 15.06.05-24:

1. Letter U.S. NRC to M.R. Blevins (TXU Power), "Comanche Peak Steam Electric Station, Units 1 and 2 - Safety Evaluation Regarding TXU Generation Company LP Request for Review of Topical Reports (TAC No. MC6899)," March 15, 2007, (ADAMS Accession No. ML070720034).

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Figure 15.06.05-24-1—Loop Seal Void Fraction (DC-HL Gap Open) – 5.0 in. Break

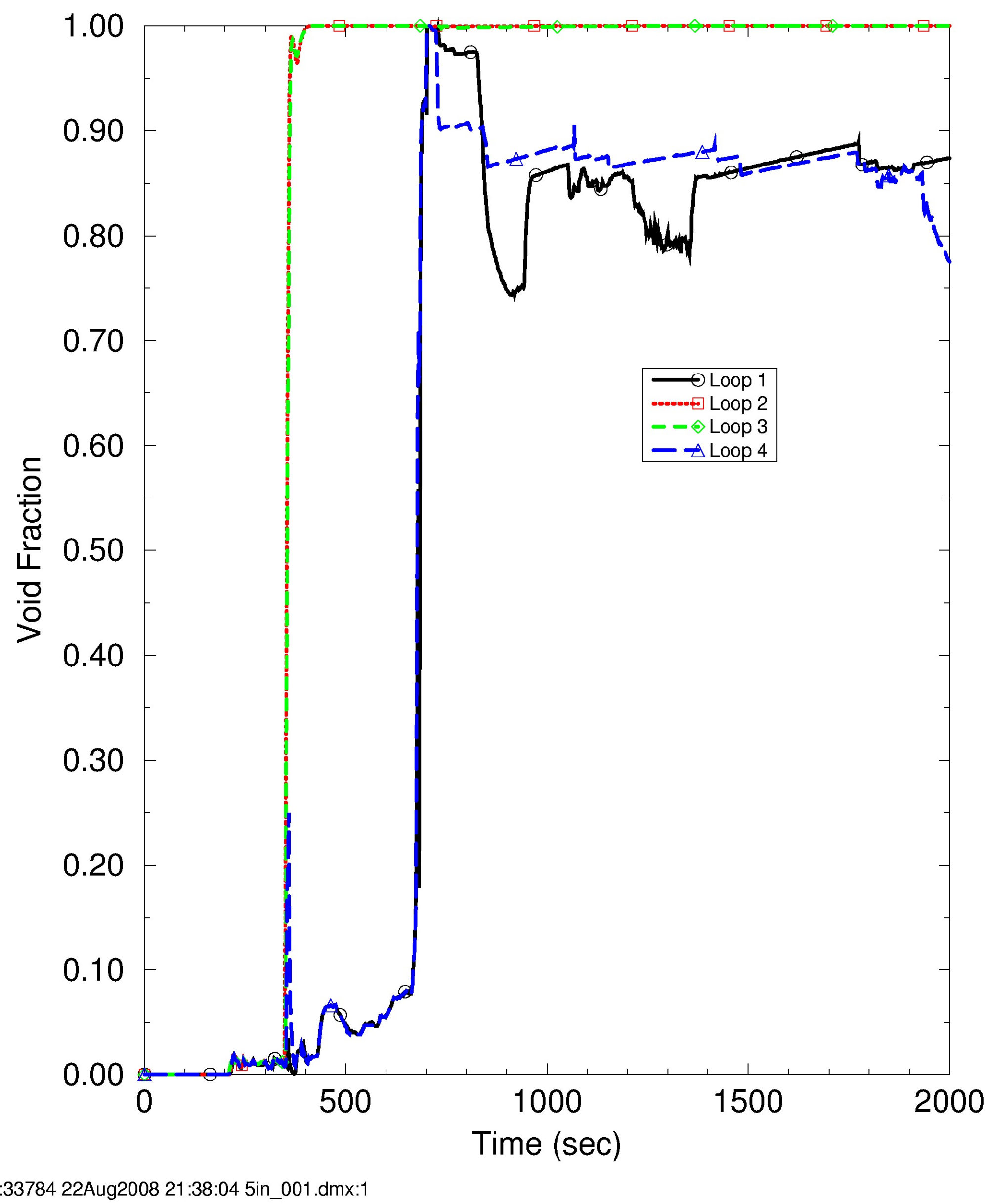


Figure 15.06.05-24-2—Loop Seal Void Fraction (DC-HL Gap Closed)

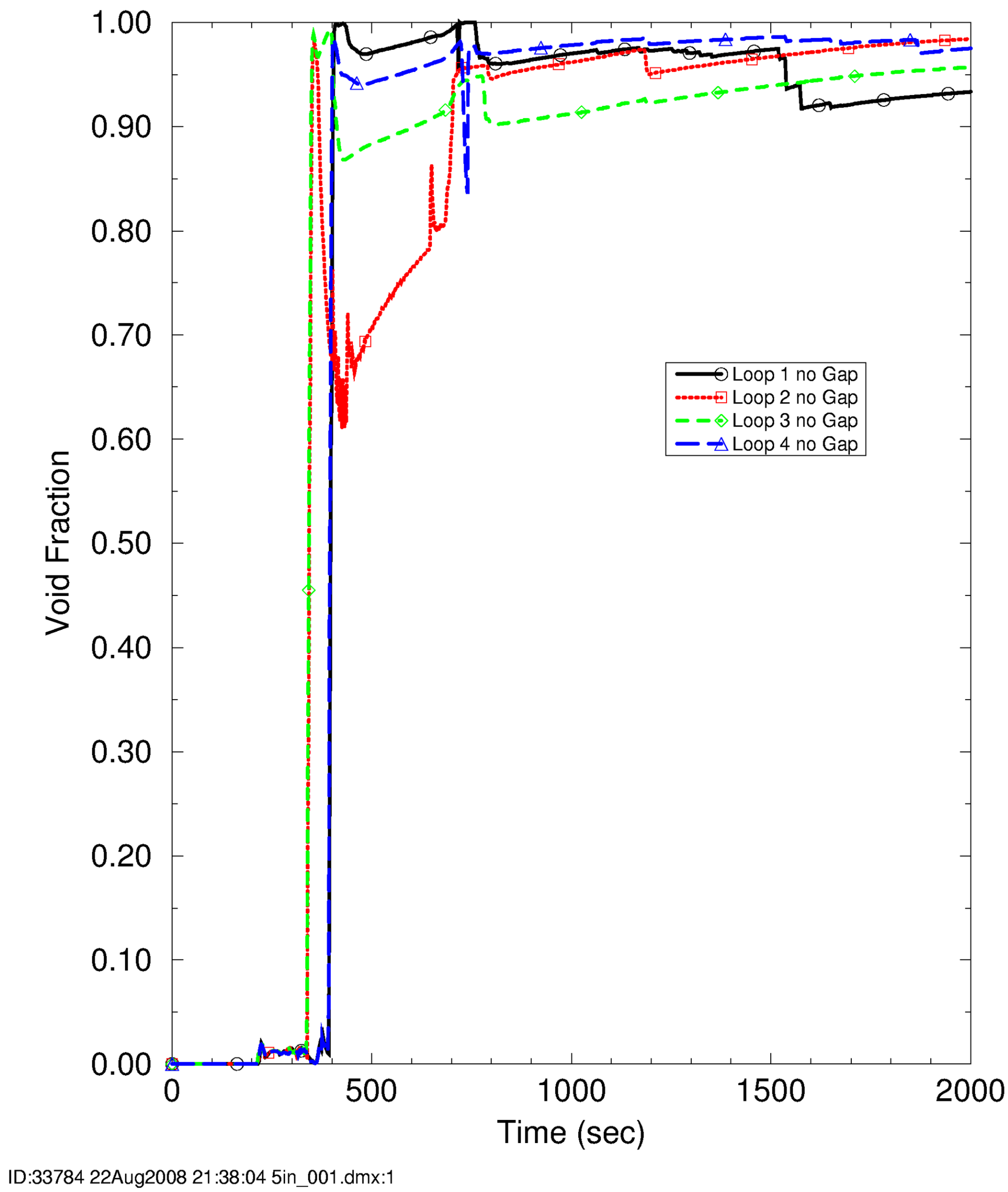


Figure 15.06.05-24-3—Hot Assembly Collapsed Level – 5.0 in. Break

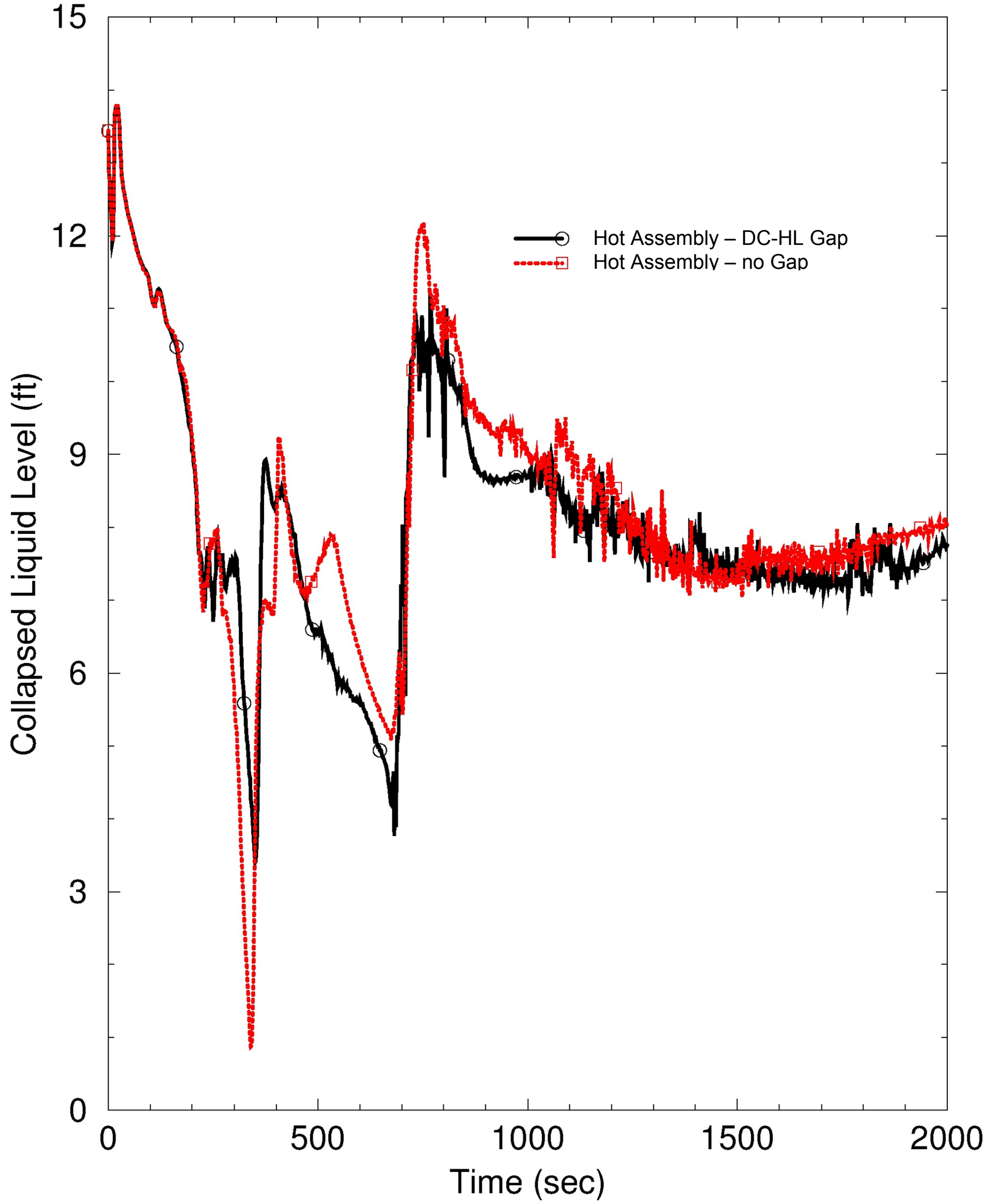


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Figure 15.06.05-24-4—Peak Cladding Temperature Comparison – 5.0 in. Break

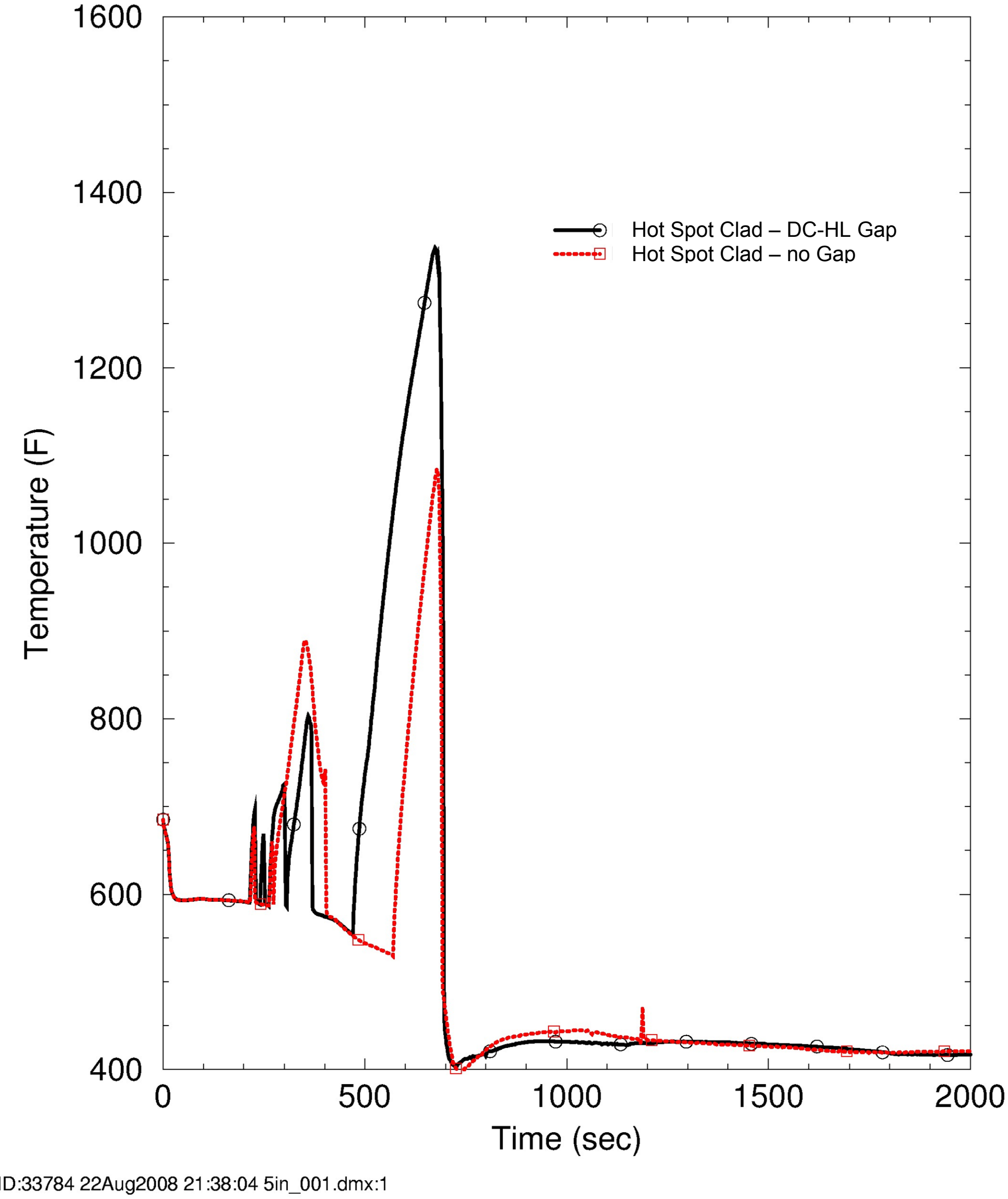

Figure 15.06.05-24-5—Hot Assembly Collapsed Level Comparison – 6.5 in. Break

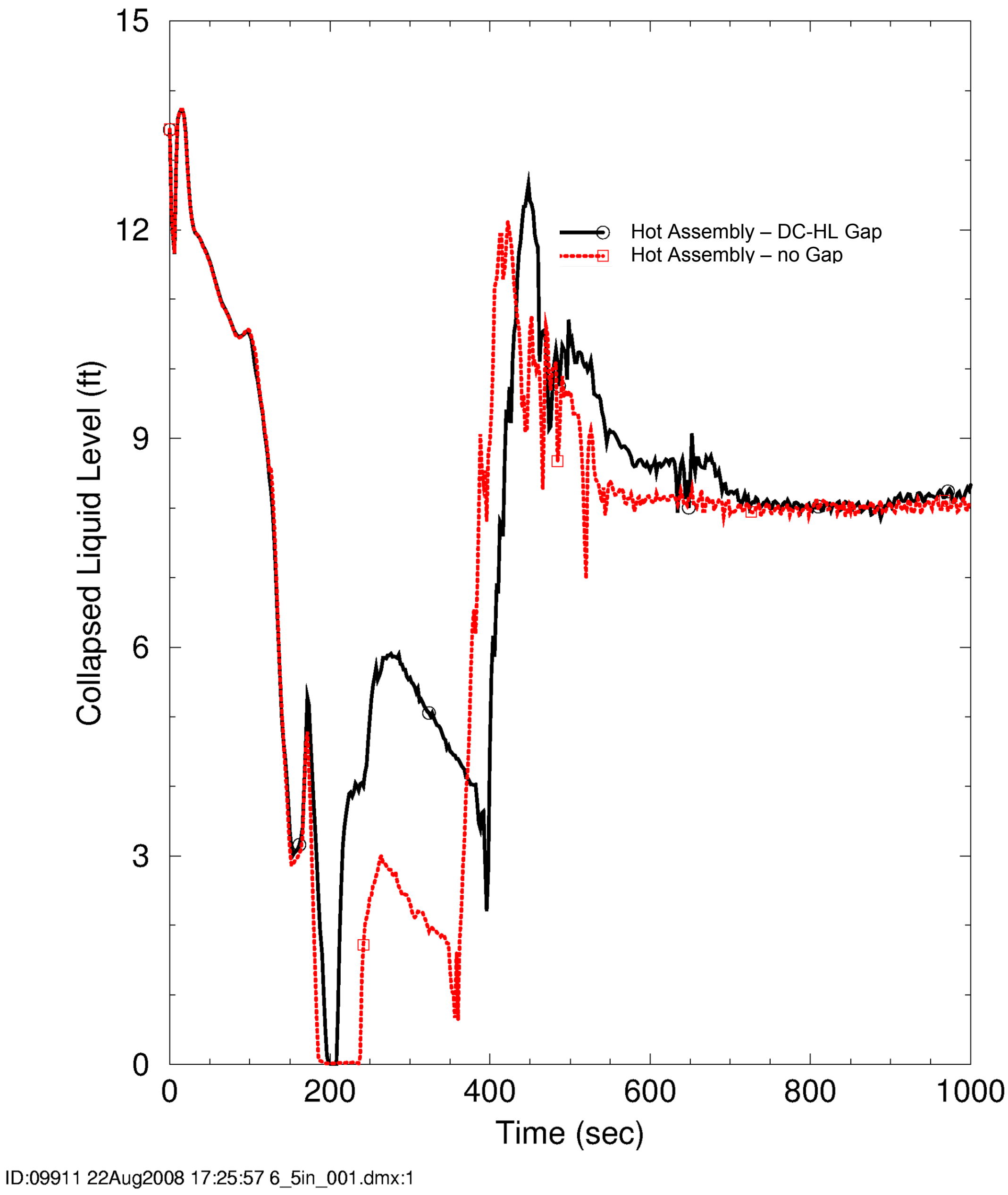

Figure 15.06.05-24-6—Hot Assembly Collapsed Level Comparison – 7.0 in. Break

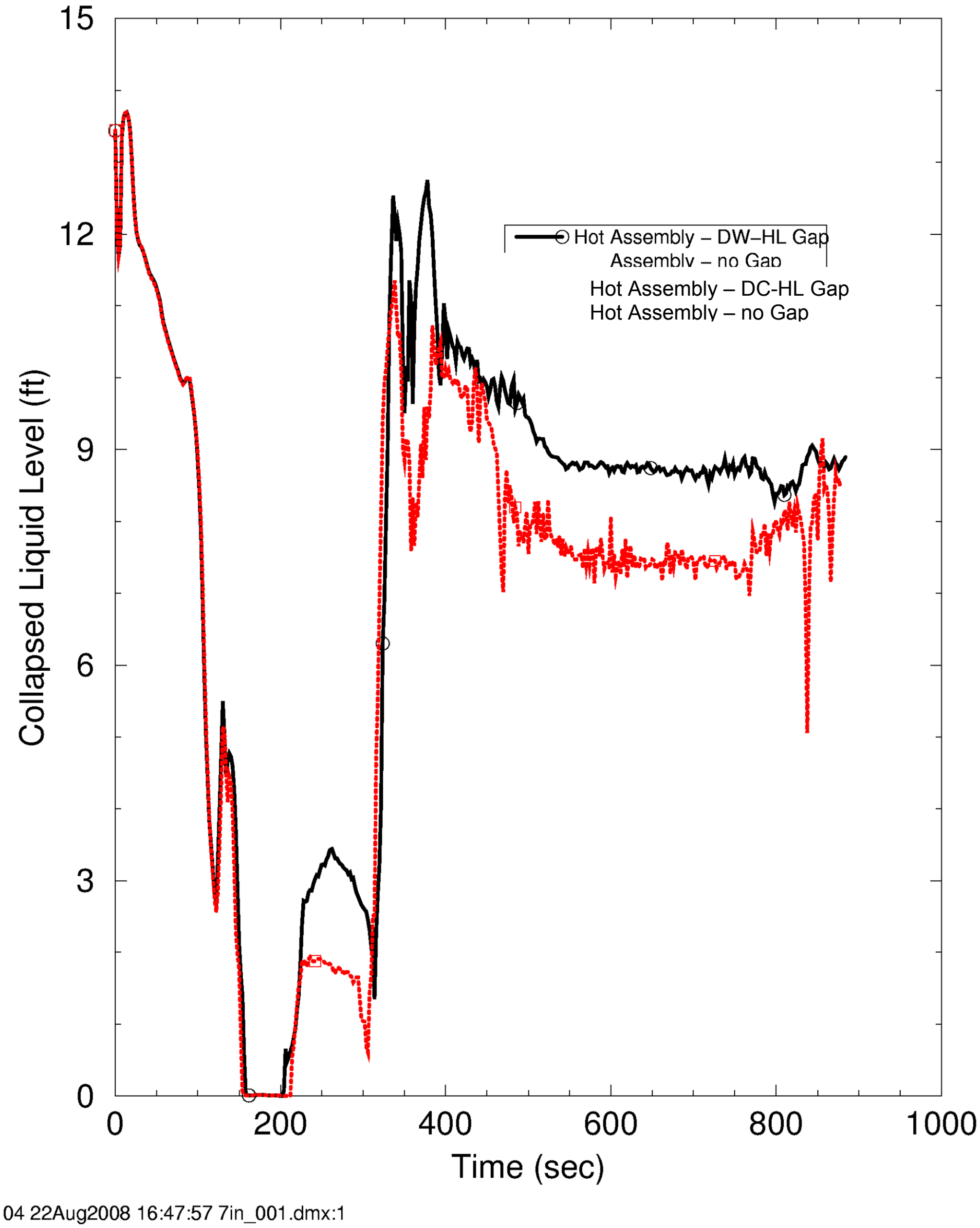

Figure 15.06.05-24-7—Peak Cladding Temperature Comparison – 6.5 in. Break

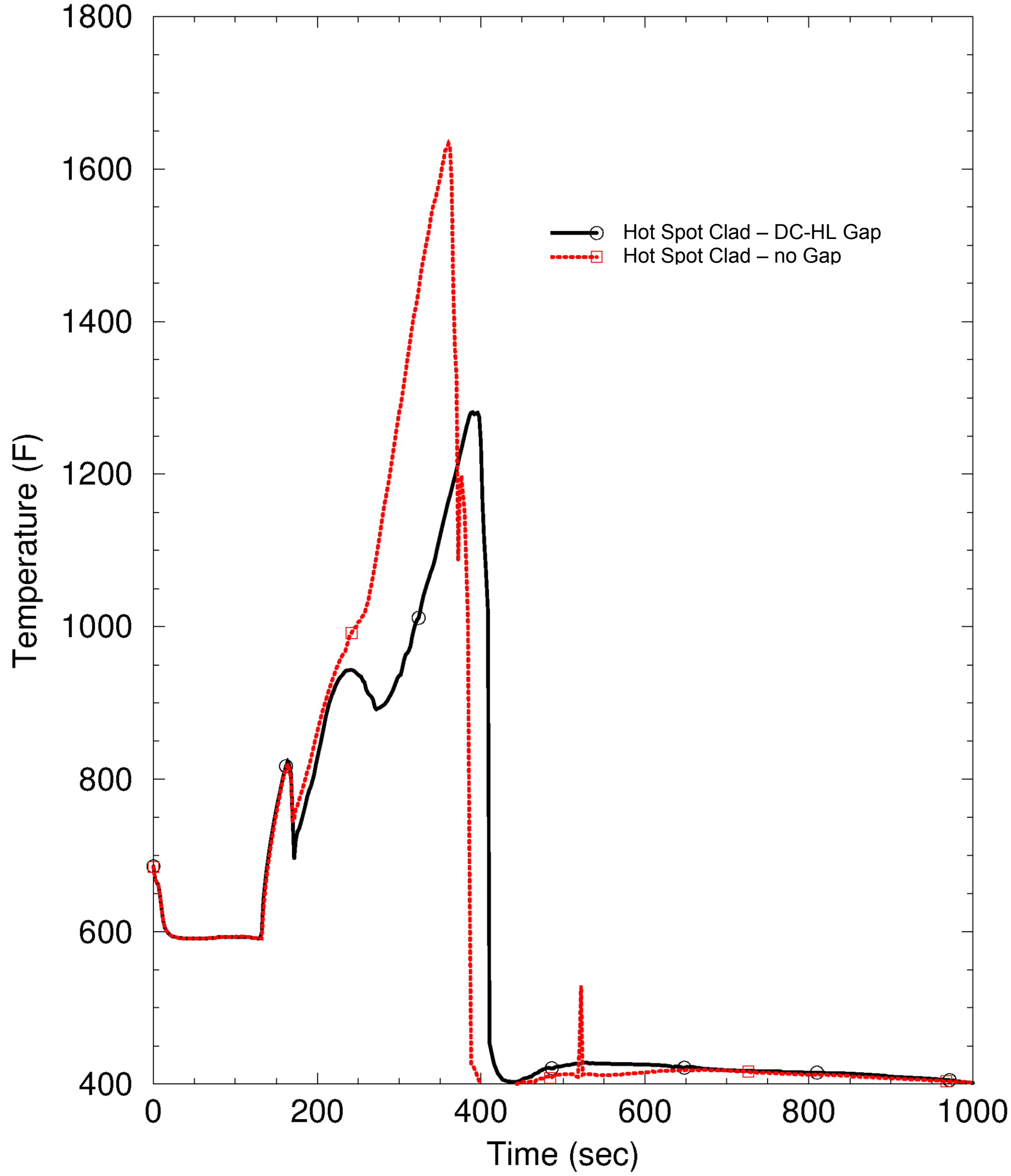

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Figure 15.06.05-24-8—Peak Cladding Temperature Comparison – 7.0 in. Break

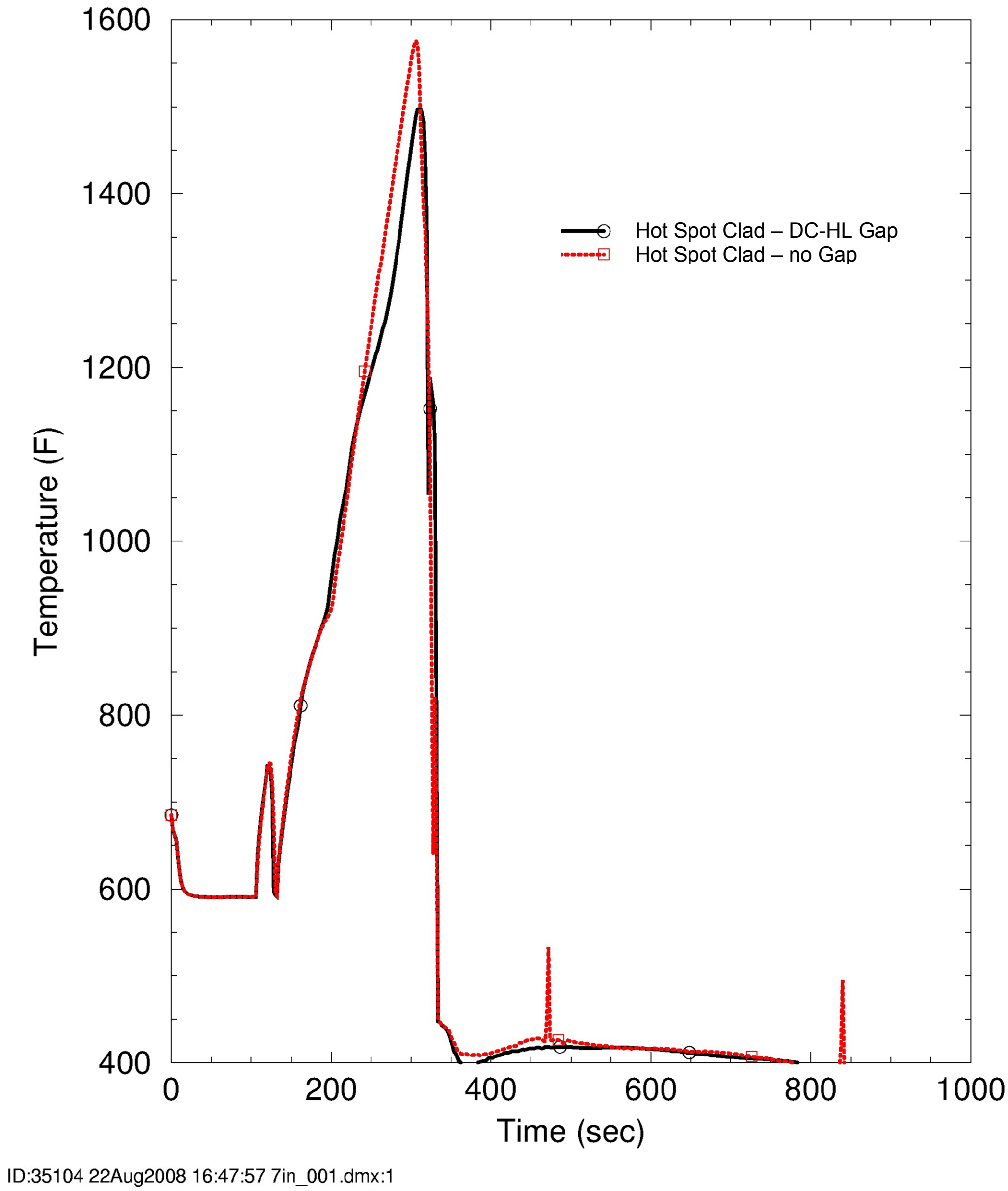

Figure 15.06.05-24-9—Comparison SBLOCA Break Spectrum FSAR, LOOP vs. LOOP, with DC-HL Gap