AREVA

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AREVA NP Inc. Evaluation of Sleicher-Rouse Heat Transfer Correlation

The Sleicher-Rouse heat transfer correlation is used in S-RELAP5 for predicting convective heat transfer to single-phase vapor. During development of an AREVA NP Inc. (AREVA NP) boiling water reactor (BWR) loss of coolant accident (LOCA) methodology based on S-RELAP5, the behavior of the Sleicher-Rouse correlation relative to other single-phase vapor heat transfer correlations was reviewed and questioned whether the Sleicher-Rouse correlation was correct. It was also discovered that another industry code uses the Sleicher-Rouse correlation, but in an alternate form. To assess the effect of the alternate form of the Sleicher-Rouse correlation, a developmental version of S-RELAP5 was prepared and used to evaluate all current PWR Analyses of Record (AOR) for Realistic Large Break LOCA (RLBLOCA) and Small Break LOCA (SBLOCA). The evaluation for the 50.46 reporting was documented and transmitted to the customers of the affected plants.

In a phone call with the NRC in regard to the Sleicher-Rouse correlation 50.46 reporting, the NRC gave AREVA NP two actions to address SBLOCA analysis. Attachment A to this letter addresses the response to these actions.

If you have any questions related to this submittal, please contact Ms. Gayle F. Elliott, Product Licensing Manager. She may be reached by telephone at 434-832-3347, or by e-mail at gayle.elliott@areva.com.

Sincerely,

Pedro Salas
Director, Regulatory Affairs

Enclosures

cc: H. D. Cruz
Project 728

A002
NRR

Attachment A

NRC Action 1: Confirm that the limiting break has been identified for all SBLOCA AORs.

Action #1 Response:
All of the affected plant cases were run with the S-RELAP5 version containing the corrected Sleicher-Rouse correlation for only the break sizes surrounding the original (uncorrected Sleicher-Rouse correlation) limiting break size. Tables 1 and 2 show the break sizes analyzed around the limiting case for each Westinghouse (W) and Combustion Engineering (CE) affected plants, respectively. Additional break cases that were not included in the original AOR were run for Palisades, Millstone, and Fort Calhoun Cycle 24 to ensure the actual limiting break size has been identified within a 0.25-inch diameter refinement.

NRC Action 2: Confirm that CE 2700 MW class plants found the case that delays the Safety Injection Tanks injection the longest.

Action #2 Response:
Table 2 shows the safety injection tanks (SIT) injection time for all the analyzed CE cases with the corrected Sleicher-Rouse correlation. In all plants, the break size has been adequately refined (within 0.25 in diameter) to show the maximum peak clad temperature (PCT) and SIT discharge behavior with increasing break size. Except for SONGS and Fort Calhoun extended power uprate (EPU) SBLOCA analyses, all other CE plants analyses in Table 2 show the largest break size that results in the PCT occurring before the cold leg SIT discharge (or no discharge at all), and the smallest break size that results in the PCT occurring after the cold leg SIT discharge. This can be shown by comparing the maximum PCT and beginning SIT timings in Table 2 for the limiting break size and all the breaks prior:

- Break(s) prior to limiting, Max. PCT time < SIT Beginning Time or SIT never injects
- Limiting case break, Max. PCT time
- SIT Beginning Time

For Calvert Cliffs the SIT never discharges for break sizes smaller than the limiting one. In the case of Palisades, the SIT beginning time is very close to that of PCT time for most of the break sizes run, including the limiting case. For an equivalent diameter of 0.060 inches for Palisades, the SIT never injects.

For San Onofre Nuclear Generating Station (SONGS), the SIT start time becomes greater than the PCT time for break sizes smaller than 8.50-in in the original analysis, which were not run in the corrected Sleicher-Rouse correlation analysis. Again, only the cases surrounding the limiting case within the 0.25-inch diameter were examined.

For Fort Calhoun EPU, there is a modeling assumption in the S-RELAP5 code in which the angle of the hot leg bend is large enough to force the flow regime in that region to vertical position, whereas it would be horizontal if it were slightly less inclined. The vertical flow regime hinders flow back from the steam generator (SG), which results in less liquid in the core. This effect becomes more significant with large breaks, and it can force the PCT to the larger end of the break spectrum. Therefore, it is not necessary to refine the break spectrum around the 7.6-inch break.

Figures 1 through 10 show the maximum PCT trace, and accumulator discharge for the limiting break, and for the prior break, for all plants except SONGS and the Fort Calhoun EPU. For SONGS the smallest and largest break sizes analyzed are shown in Figures 11 and 12. Based on this explanation for Fort Calhoun EPU, plots were not necessary.

In conclusion, the smallest break size (diameter) case that cause the longest delays of the SIT injection are identified as follows:

- Calvert Cliffs - Less than 4.06 inches
- Fort Calhoun Cycle 24 - Less than 3.5 inches
- Millstone - Less than 3.83 inches
- Palisades - Less than 3.83 inches
- SONGS - Less than 8.5 inches
- St. Lucie EPU - Less than 3.65 inches
- Fort Calhoun EPU - Not Applicable

Overall, the SIT discharge timing with increasing break size behavior is consistent with the original analysis for all the plants shown in Table 2.

Table 1—PCT with Corrected S-R Correlation vs Break Size - W Plants

Break Size (inches)	Break Size (ft^2)	PCT with Corrected S-R Correlation (°F)
Sequoyah		
9.00	0.442	1358
9.75	0.518	1366
9.76	0.520	1348
9.77	0.521	1363
9.78	0.522	**1381**[1]
Robinson		
2.35	0.030	1422
2.40	0.031	**1473**
2.45	0.033	1366
Harris		
2.5	0.034	1630
2.6	0.037	**1631**
2.7	0.040	1543

[1] Break sizes larger than 9.78 inches were not analyzed since this break is 10 percent of the cold leg flow area, which is the upper limit of applicability for the SBLOCA methodology.

Table 2—PCT with Corrected S-R Correlation vs. Break Size - CE Plants

Plant	Break Size (in)	Break Size (ft^2)	Maximum PCT (°F)	Time of Maximum PCT (sec)	SIT Beginning Time (sec)
SONGS	8.97	0.439	1482	159	132
	8.98	0.440	1471	156	132
	8.99	0.441	**1496**	158	132
	9.00	0.442	1486	158	132
	9.01	0.443	1480	161	132
Fort Calhoun Cycle 24	3.0	0.049	960	2162	2430
	3.25	0.058	1046	1696	1730
	3.5	0.067	**1437**	1114	1090
	4.0	0.087	1232	797	776
Fort Calhoun EPU	7.0	0.267	1100	206	192
	7.6	0.315	**1525**[2]	168	152
St. Lucie EPU	3.6	0.071	1716	1962	1986
	3.65	0.073	**1780**	1871	1860
	3.7	0.075	1735	1852	1848
Calvert Cliffs	3.83	0.080	1464	1700	---
	4.06	0.090	1695	1520	1512
	4.28	0.100	1353	1584	1576
Palisades	3.32	0.060	1148	2646	---
	3.83	0.080	1625	1710	1707
	4.06	0.090	1304	1710	1710
	4.28	0.100	**1671**	1163	1162
	5.24	0.150	1093	810	809
Millstone	3.32	0.060	1619	2517	---
	3.58	0.070	1739	2465	2606
	3.83	0.080	**1801**	2063	2060
	4.28	0.100	1696	1475	1470

[2] The PCT would typically occur near the 3.5-inch diameter break, where high pressure safety injection is just significant enough to slow the rate of cladding temperature increase, and SIT injection leads to quench. The 7.6-inch PCT is due to a modeling assumption in the S-RELAP5 code, in which the angle of the hot leg bend in Fort Calhoun is large enough to force the flow regime in that region to vertical position, whereas it would be horizontal if it were slightly less inclined. The vertical flow regime hinders flow back from the SG; consequently, there is less liquid in the core. This effect becomes more significant with large breaks, and it can force the PCT to the larger end of the break spectrum. Because AREVA has determined the issue to be explainable, it is not necessary to examine the break spectrum around the 7.6-inch break.

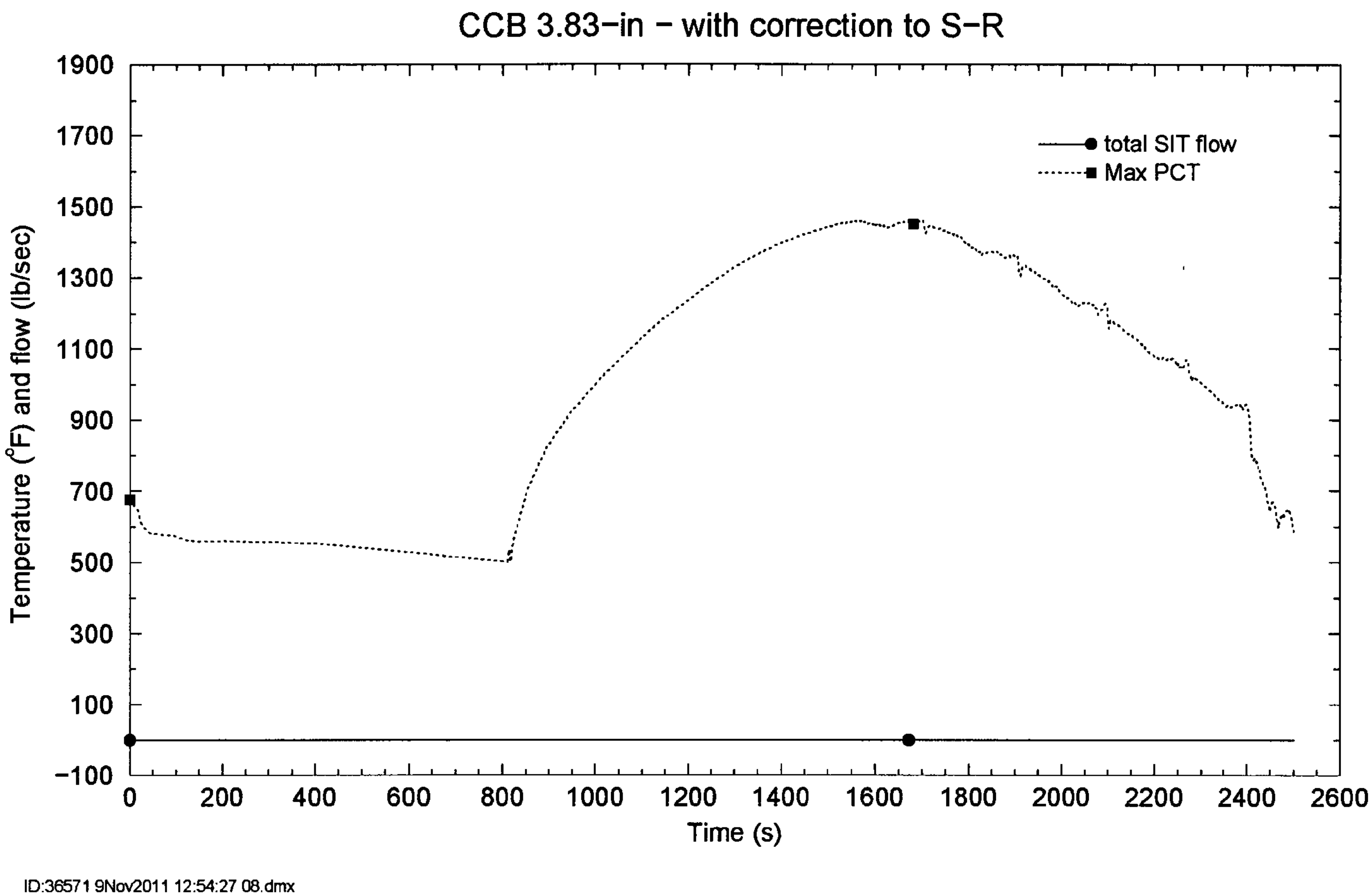

Figure 1. Calvert Cliffs PCT Trace and SIT Discharge Flow with Corrected Sleicher-Rouse correlation – 3.83-in Break

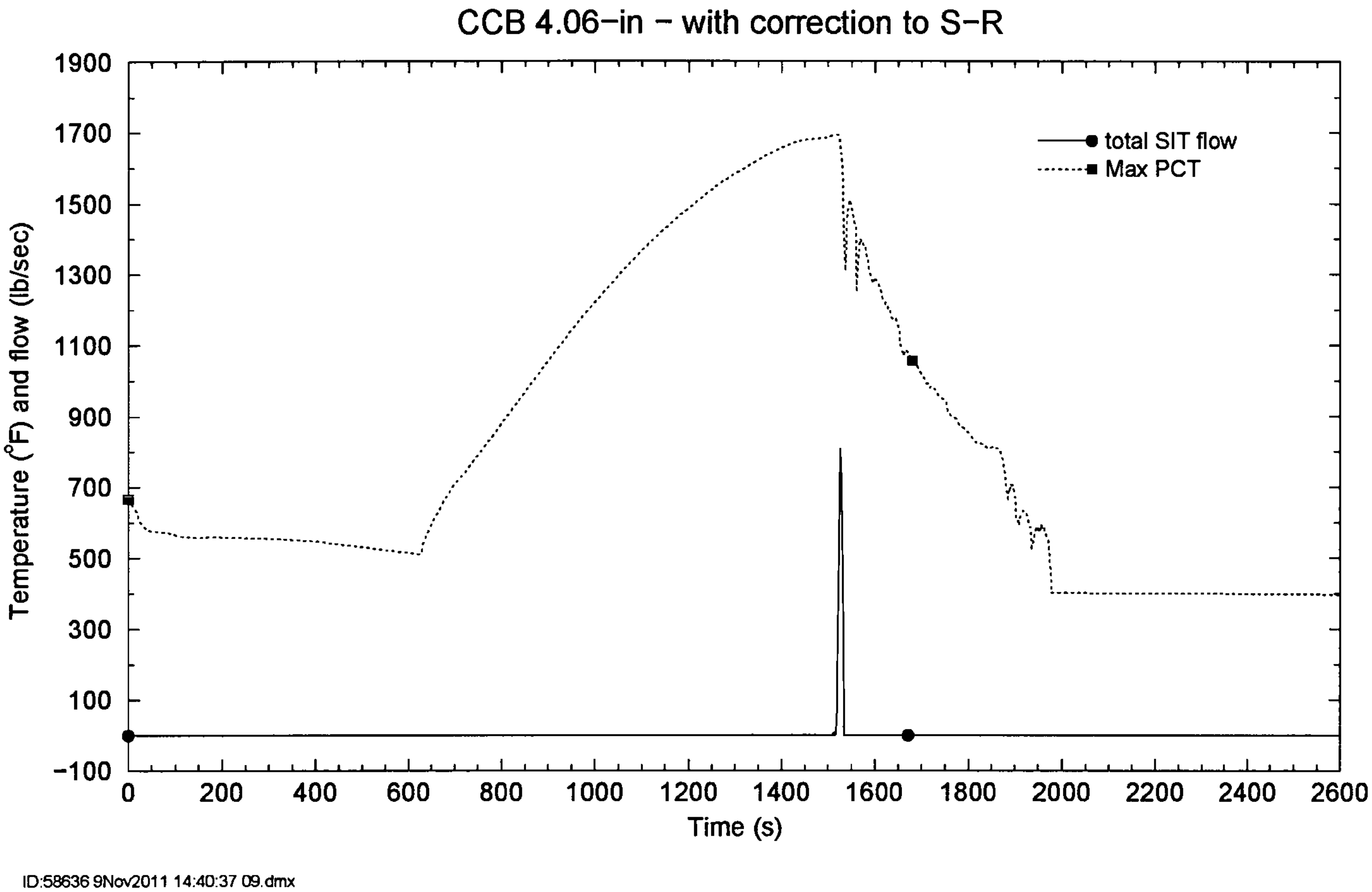

Figure 2. Calvert Cliffs PCT Trace and SIT Discharge Flow with Corrected Sleicher-Rouse correlation – 4.06-in Break

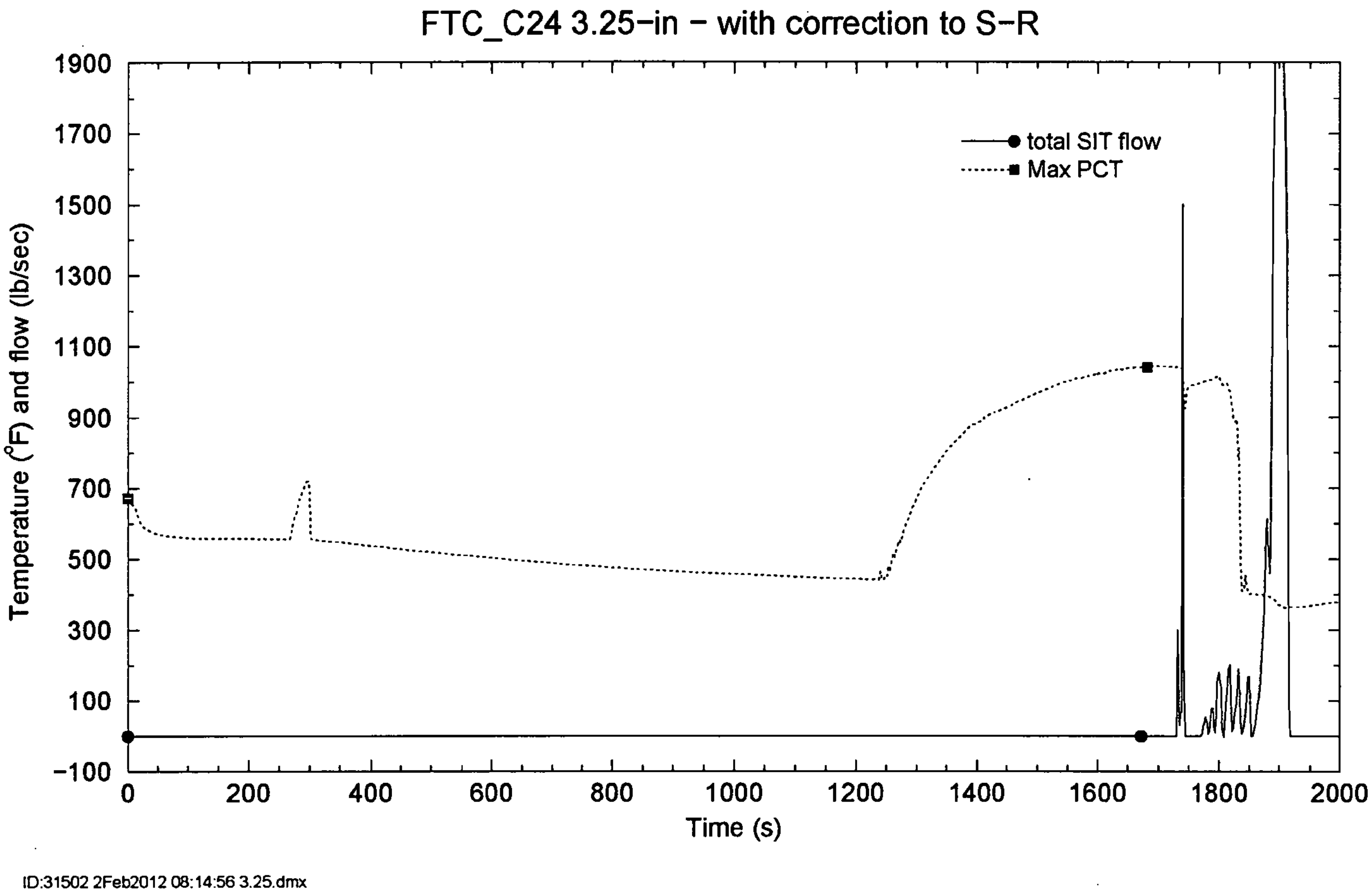

Figure 3. Fort Calhoun Cycle 24 PCT Trace and SIT Discharge Flow with Corrected Sleicher-Rouse correlation – 3.25-in Break

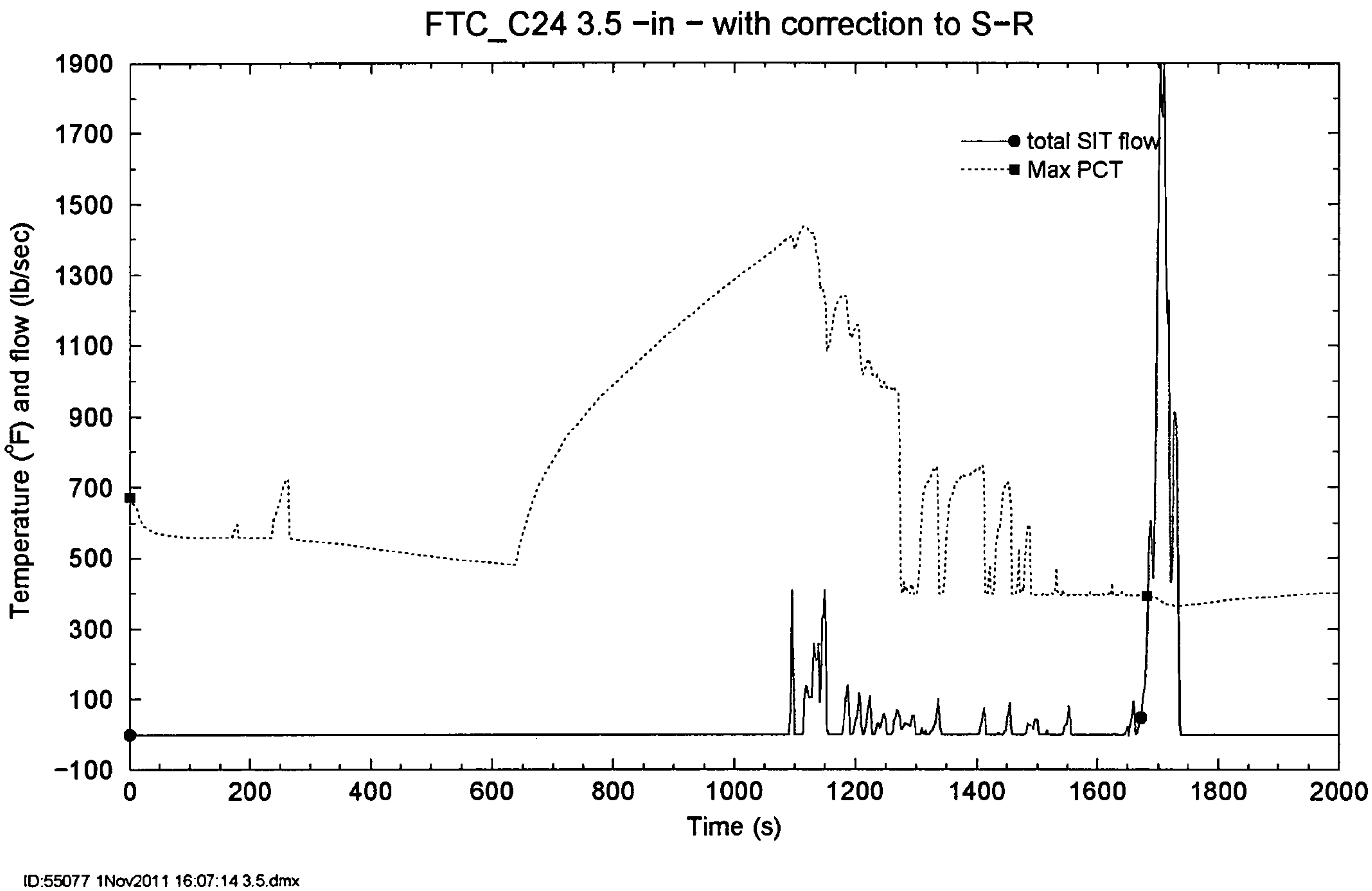

Figure 4. Fort Calhoun Cycle 24 PCT Trace and SIT Discharge Flow with Corrected Sleicher-Rouse correlation – 3.5-in Break

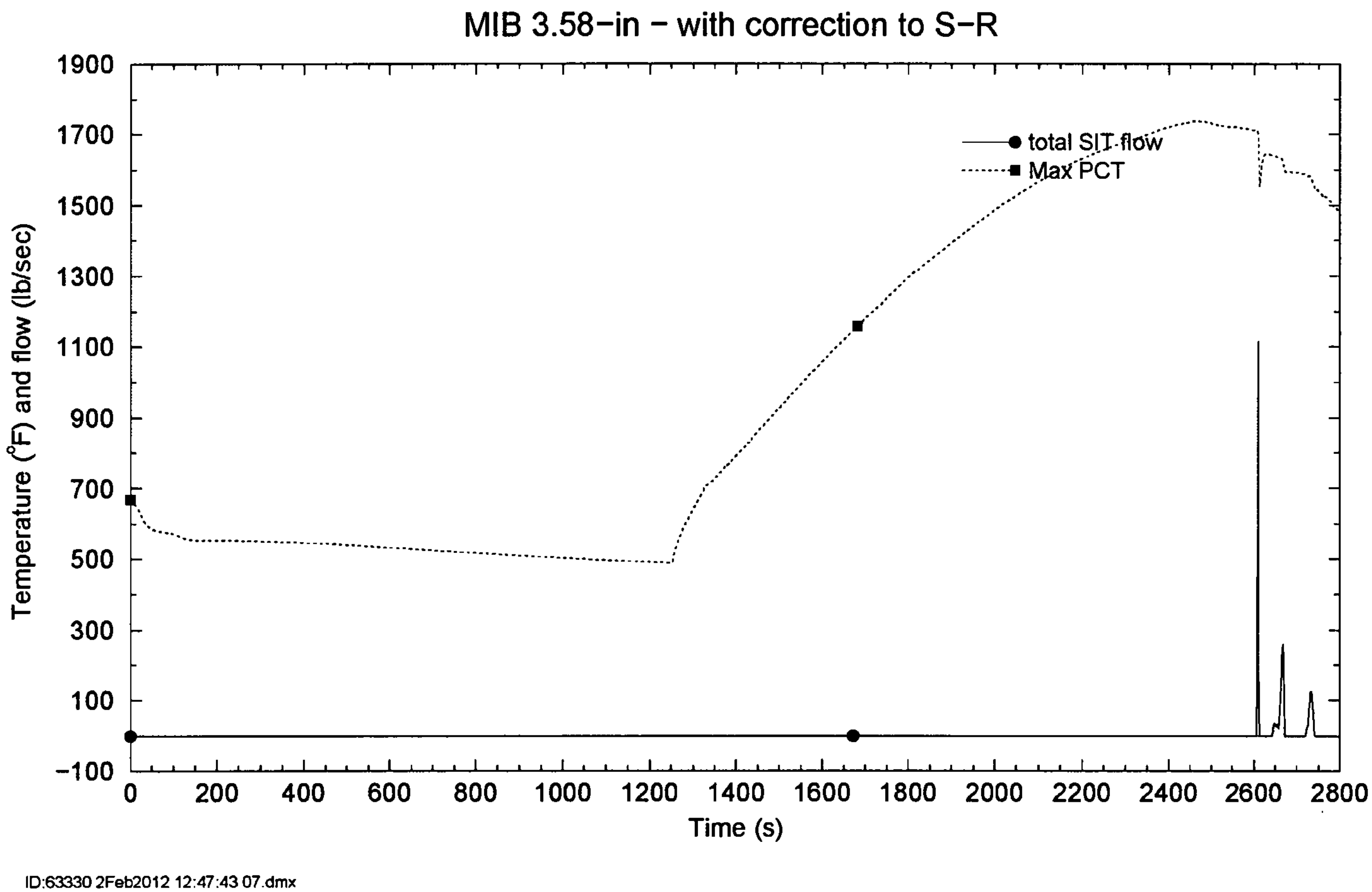

Figure 5. Millstone PCT Trace and SIT Discharge Flow with Corrected Sleicher-Rouse correlation – 3.58-in Break

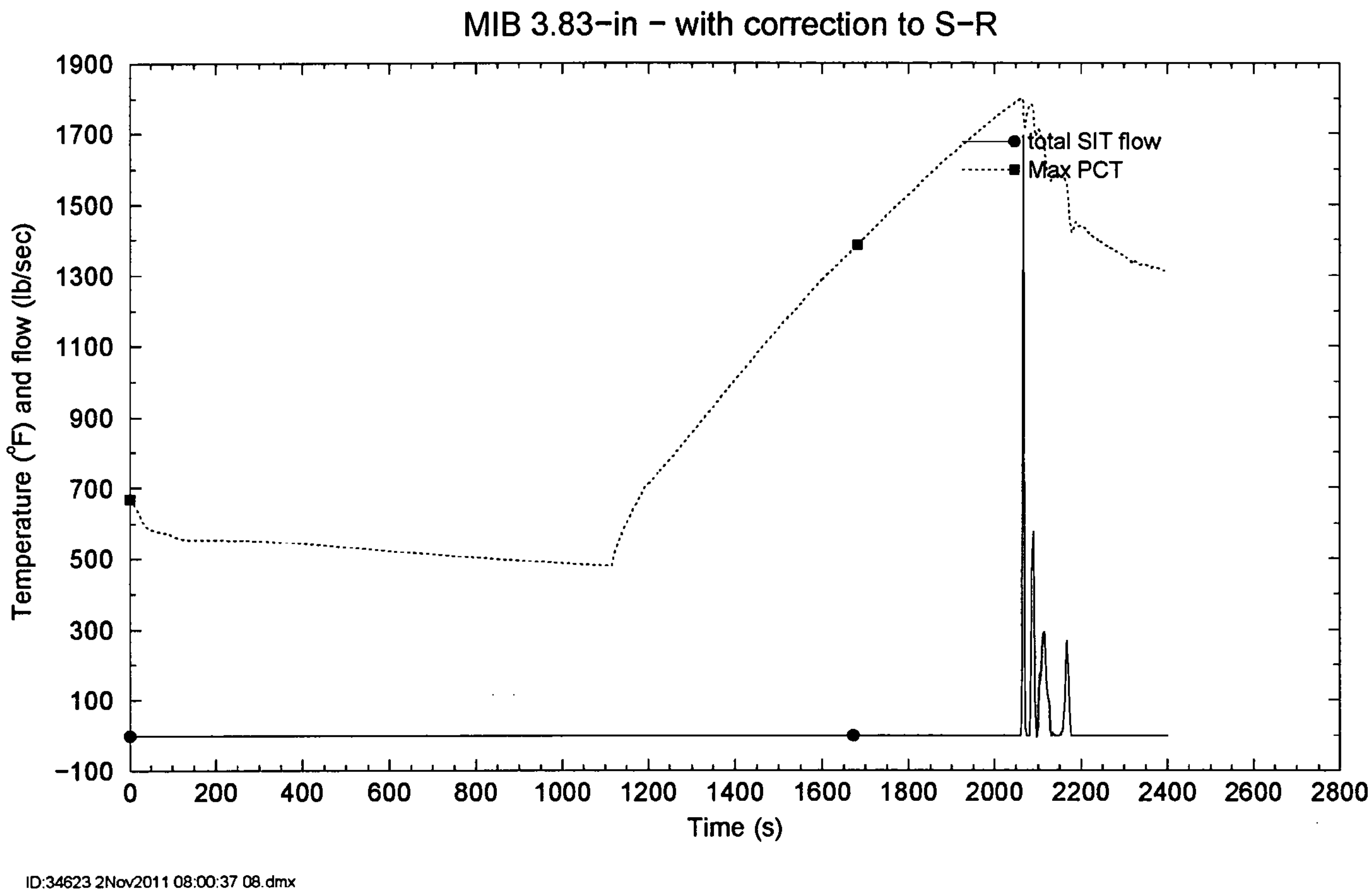

Figure 6. Millstone PCT Trace and SIT Discharge Flow with Corrected Sleicher-Rouse correlation – 3.83-in Break

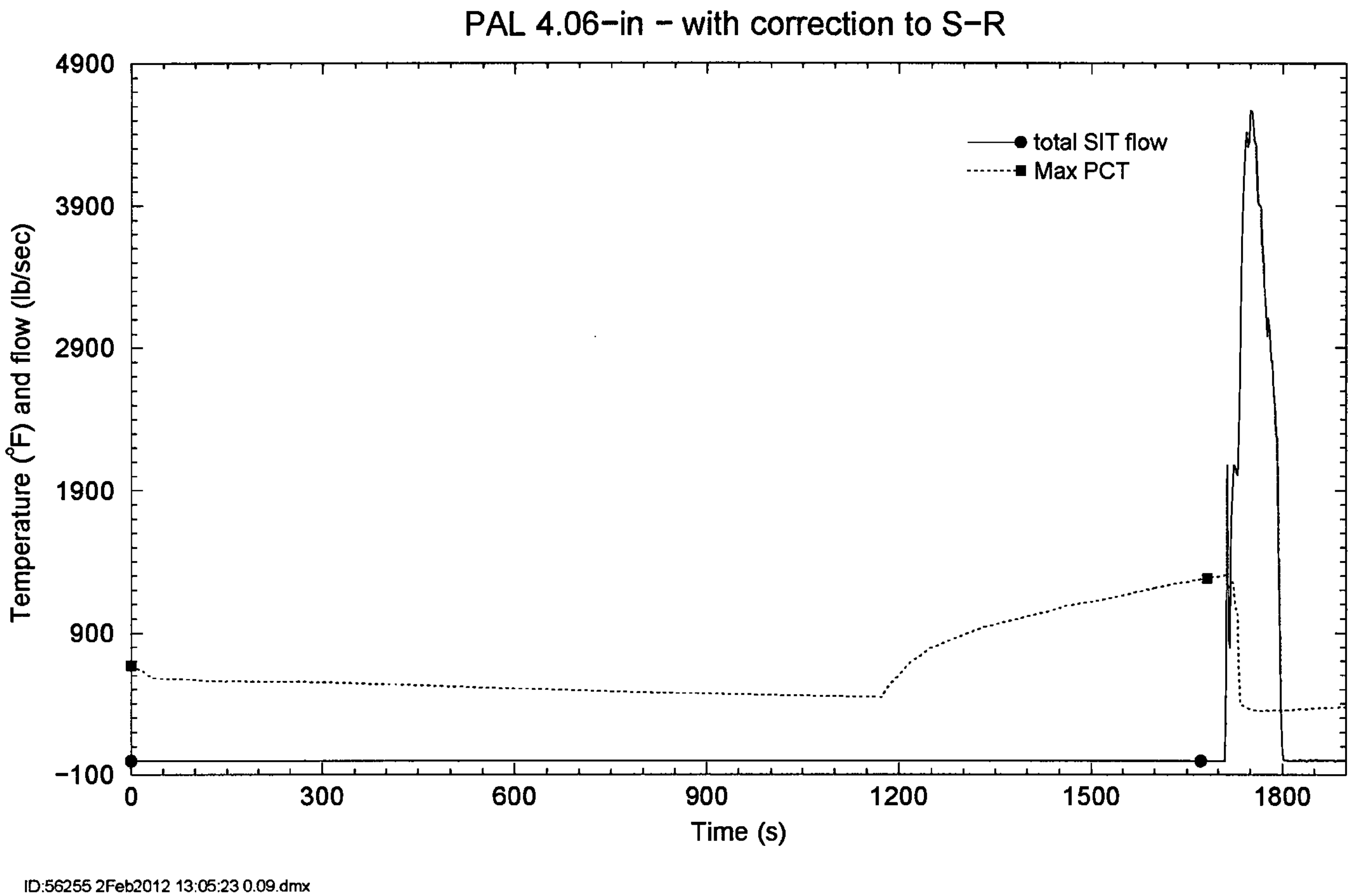

Figure 7. Palisades PCT Trace and SIT Discharge Flow with Corrected Sleicher-Rouse correlation – 4.06-in Break

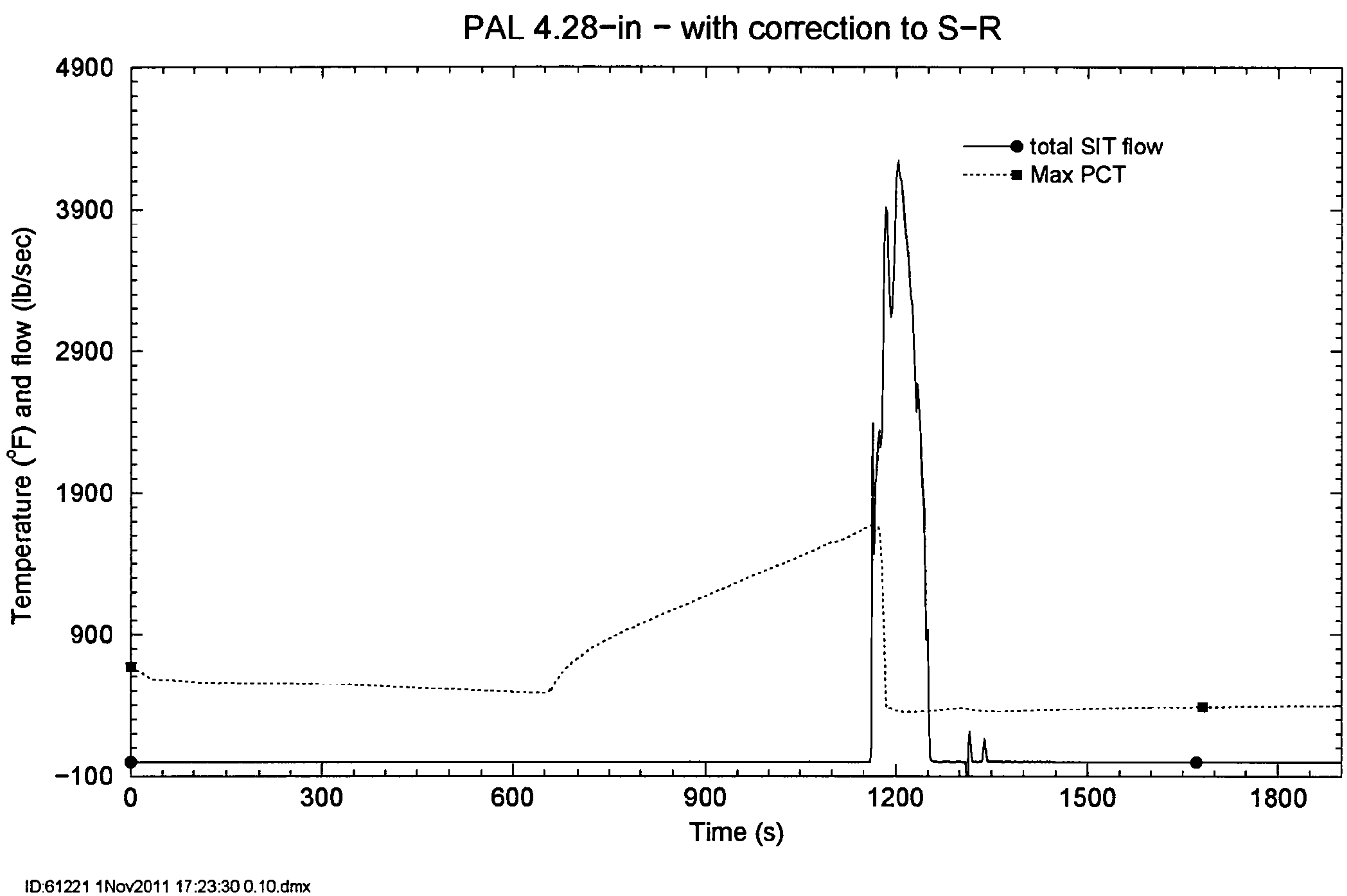

Figure 8. Palisades PCT Trace and SIT Discharge Flow with Corrected Sleicher-Rouse correlation – 4.28-in Break

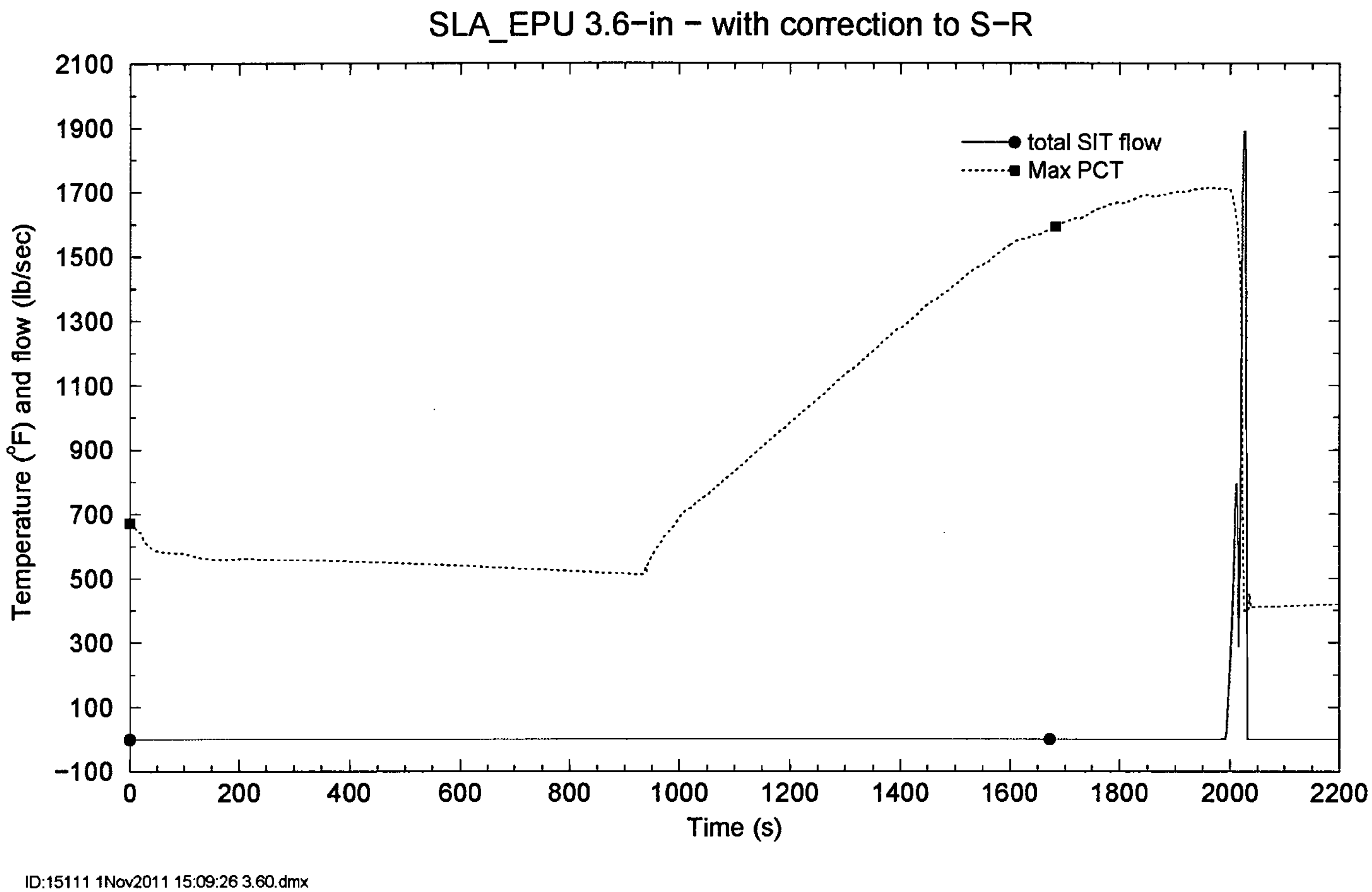

Figure 9. St Lucie EPU PCT Trace and SIT Discharge Flow with Corrected Sleicher-Rouse correlation – 3.6-in Break

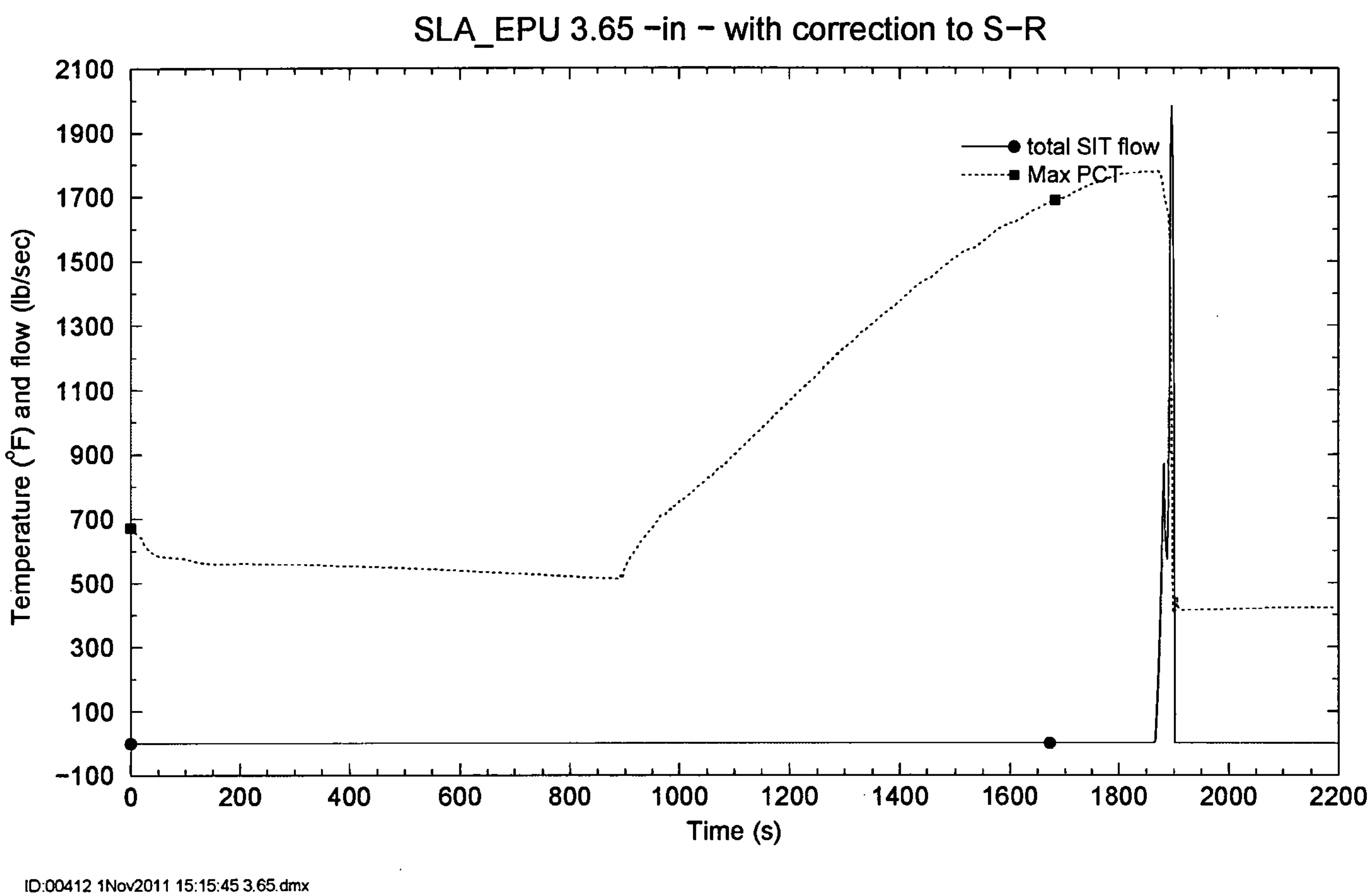

Figure 10. St Lucie EPU PCT Trace and SIT Discharge Flow with Corrected Sleicher-Rouse correlation – 3.65-in Break

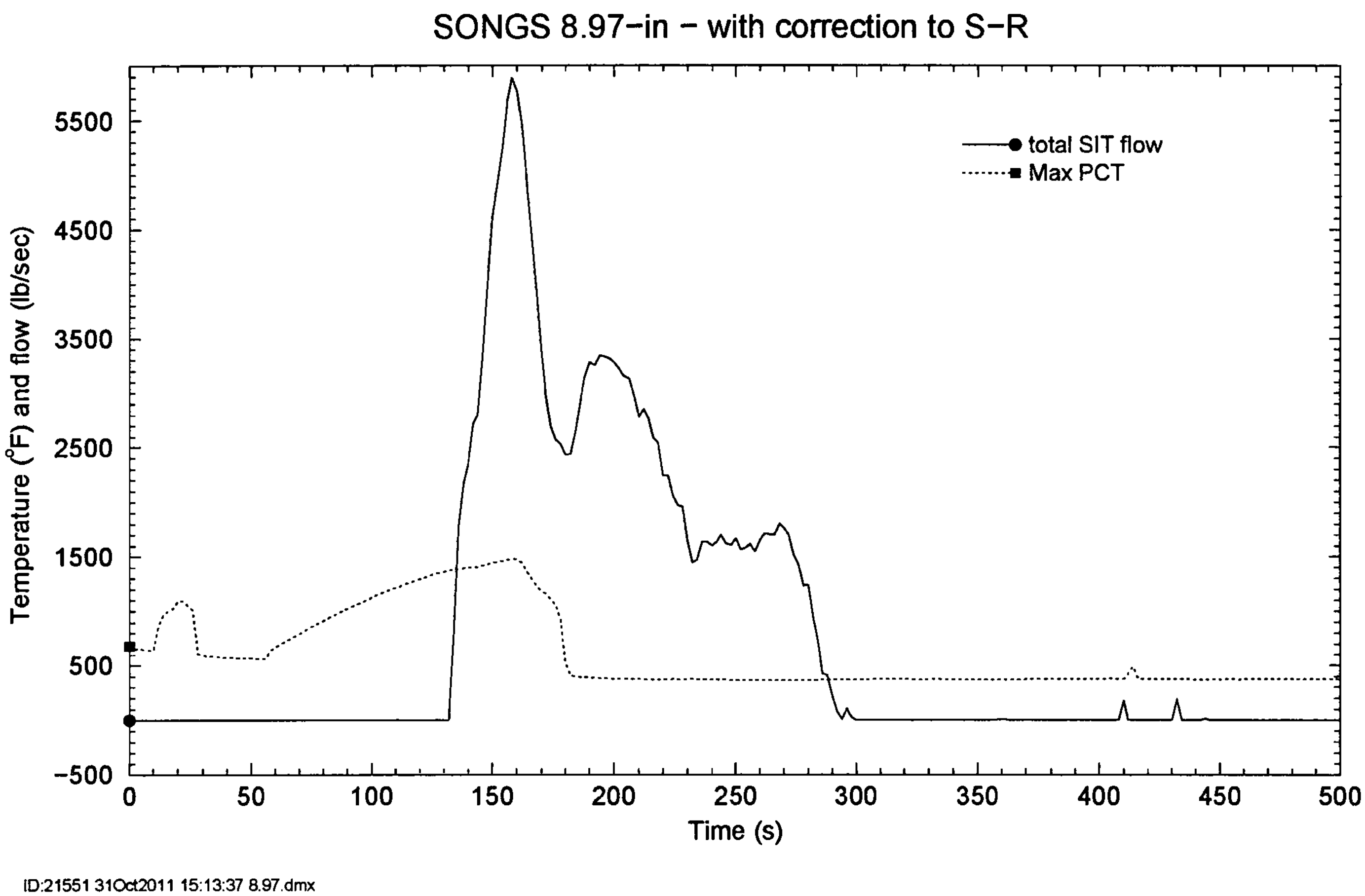

Figure 11. SONGS PCT Trace and SIT Discharge Flow with Corrected Sleicher-Rouse correlation – 8.97-in Break

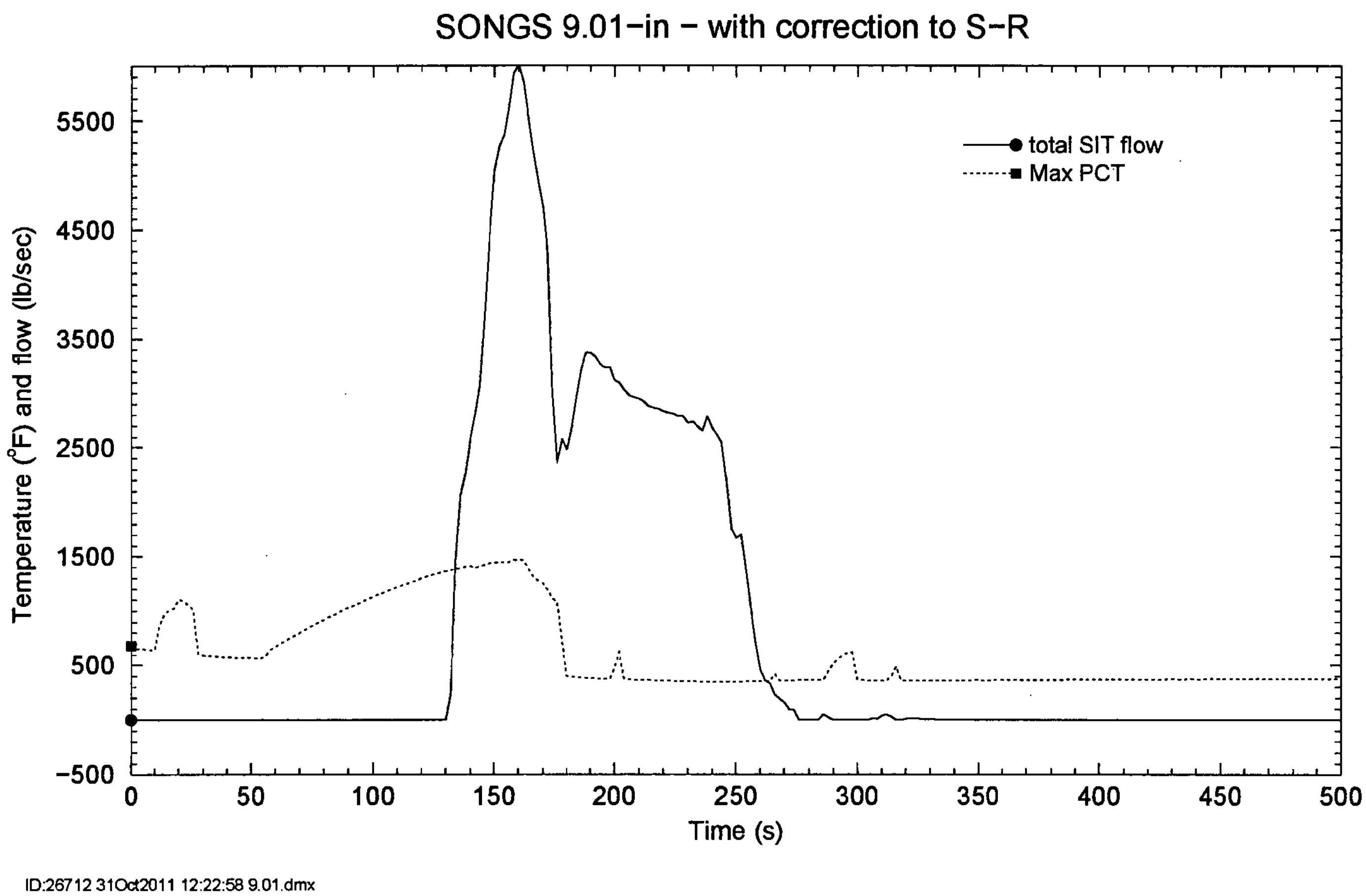

Figure 12. SONGS PCT Trace and SIT Discharge Flow with Corrected Sleicher-Rouse correlation – 9.01-in Break