ATTACHMENT 1 TO TXX-06125

RESPONSES TO REQUESTS FOR ADDITIONAL INFORMATION

FOR THE REPLACEMENT STEAM GENERATOR SUPPLEMENT TO TXU POWER'S LARGE AND SMALL BREAK LOSS OF COOLANT ACCIDENT ANALYSIS METHODOLOGIES

July, 2006

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I. INTRODUCTION

This document provides responses to the NRC request for additional information (RAI) in connection with the topical report (Ref. 3):

> ERX-04-004, "Replacement Steam Generator Supplement to TXU Power's Large and Small Break Loss of Coolant Accident Analysis Methodologies."

The format of the responses is as follows:

In the section entitled "LOCA QUESTIONS AND RESPONSES," each NRC LOCA-related question is reprinted and followed by its response. Any references within the NRC questions themselves are listed at the end of that section. That list is the same list of references the NRC submitted with the RAIs. Whenever new references are needed for a response, these are provided within the space for the response, just prior to it. These additional references are labeled according to the question number where the reference first appears. For example, Reference Q.7.g.(1) appears at the top of the response to Question 7, item (g), sub-item (1).

The section "COMPLETE SETS OF PLOTS FOR ADDITIONAL CALCULATIONS," contains complete sets of plots for all the additional runs performed to address the LOCA RAI questions. Each complete set is comprised of the original set of variables submitted in the topical (Ref. 3) as well as the set of variables whose plots were requested in Question 7.a (Q.7.a). A total of 180 (10 sets of 18) plots are provided.

The content of the remaining sections, "MISCELLANEOUS FIGURES" is self-explanatory, presenting figures which are not part of the complete sets of plots for the various runs.

Finally, as described at the top of page 2-1 of Reference [10] and in the NRC SER attached to it, the CPSES Small Break LOCA methodology is essentially an application of the SPC methodology of Ref.Q.7.g.(1), (also Ref. 1.1 of Reference [10]). None of the models have been changed with respect to the original SPC methodology.

II. LOCA QUESTIONS AND RESPONSES

The first LOCA question on the RAI list is Question number 7.

7. With respect to the changes in CPSES's small break loss of coolant accident (SBLOCA) methodology described in ERX-04-004, "Replacement Steam Generator Supplement to TXU Power's Large and Small Break Loss of Coolant Accident Analysis Methodologies," (Ref. 3), provide the following information.

a. As part of its break spectrum sensitivity study the licensee considered break sizes of 3, 4, and 5 inches. Provide the following plots for the 3, 4, and 5 inch breaks (and all other requested break sizes) as part of the SBLOCA analysis submittal.

I. Two-phase mixture level in the core vs. time,
II. Downcomer liquid level vs. time,
III. Steam temperature at the peak clad temperature (PCT) location vs. time,
IV. Heat transfer coefficient vs. time at the PCT location,
V. Condensation rate in the cold leg discharge injection sections vs. time,
VI. Break quality vs. time.

TXU Power Response:

The additional plots for the 3", 4" and 5" breaks are provided, along with the original sets submitted with Reference [3], in the section: "COMPLETE SETS OF PLOTS FOR ADDITIONAL CALCULATIONS". Those are sets: A-1 through A-18 (3" break), B-1 through B-18 (4" break), and C-1 through C-18 (5" break). That section also provides the plot sets of Reference [3] as well as the additional plots requested in Q.7.a, for all additional cases run in connection with this RAI.

b. Please provide the limiting top peaked axial power distribution for each break size analyzed.

TXU Power Response:

The limiting top peaked axial power distribution for each cycle is obtained as described on page 3-3 of Reference [10]. As explained on page 4-3 of Reference [3], the limiting axial power distribution for the Reference [3] calculations was obtained applying that approach to CPSES-1 cycle 11.

A plot of the actual limiting power shape for CPSES 1 cycle 11, "NOM Shape # 948", is Figure 1, provided in the section: "MISCELLANEOUS FIGURES."

c. **Analysis of integer break sizes does not assure the limiting small break has been identified. The SBLOCA limiting break is typically a break that depressurizes to an RCS pressure just above the accumulator actuation pressure, so that only high pressure safety injection (HPSI) terminates the PCT. The PCT for the limiting 4-inch break size was terminated by accumulator injection. As such, please provide an analysis of that break which depressurizes to an RCS pressure just slightly above the accumulator actuation pressure and show that this is not the limiting SBLOCA. Break sizes which differ by as little as 0.005 ft^2 can result in increases in PCT in excess of 50 F for break sizes in the ranges 2 - 5 inches. As necessary, please perform analysis of breaks between 3 and 4 inches, and 4 and 5 inches to assure the limiting break has been identified. Provide the analysis and a full complement of plots for each break size, including the limiting break.**

TXU Power Response:

In what follows, it should be kept in mind that CPSES has a relatively high accumulator set point pressure (around 600 psia).

A CPSES SBLOCA that depressurizes to an RCS pressure just above accumulator set point pressure would have to be smaller than 3". This is because the 3" break presented in Reference [3] was also terminated by accumulator injection, i.e. it was accumulator injection that led to the clad temperature turn around for the 3", the 4" and the 5" inch breaks. Yet, the 3" break PCT is lower than the 4", which was the limiting break for the analyses of Reference [3]. The logical conclusion from these observations is that the CPSES SBLOCA limiting analysis is terminated by accumulator injection. This is re-assuring because such an outcome is conservative relative to the scenario postulated in Q.7.c. This is because the transient would have terminated sooner (i.e. at a higher RCS pressure) and consequently have had a lower PCT, had it terminated due to pumped ECCS rather than accumulator injection. In order to provide further assurance that the limiting CPSES SBLOCA analysis is (conservatively as explained above) terminated by accumulator injection, consider the analysis of a 1.5" break conducted to address Q.7.d below. That analysis showed that a 1.5" break was still not small enough to prevent accumulator discharge (set F-1 through F-18). Therefore, a break for which the accumulators do not inject would have to be smaller than 1.5" and as that analysis shows, such breaks are not limiting.

Between 3" (0.049 ft^2) and 4" (0.087 ft^2) there are 7 break sizes differing by 0.005 ft^2 in area and between 4" and 5" (0.136 ft^2) there are 9 break sizes differing by 0.005 ft^2 in area. Therefore covering this entire range with such level of detail would require the analysis of 16 break sizes between 3 and 5 inches. This seems like an unreasonable burden given the margin between the large break and the small break LOCA PCT and the demonstration that the CPSES accumulators, given their high set point pressure, will discharge for breaks larger than 1.5".

During the March 29 teleconference the NRC clarified that the request for additional fractional break sizes would be met by TXU providing a couple of additional fractional break analysis results in the 3" to 5" range that would bracket the limiting break. TXU is presenting

two such breaks, since they confirm that the 4" break is limiting. One break is between 4" and 5" inches and another is between 3" and 4". The size for these fractional size bracketing breaks was determined by starting with the 4" limiting integer break and increasing and decreasing the break size by 2*0.005 ft^2 = 0.01 ft^2 in area. This process resulted in break diameters of 4.22" (0.097 ft^2) and 3.76" (0.077 ft^2). The PCTs for these breaks were 1555^{0}F for the 4.22" and 1530^{0}F for the 3.76". A full complement of plots for these breaks is provided in the section: "COMPLETE SETS OF PLOTS FOR ADDITIONAL CALCULATIONS". Set D-1 through D-18 is for the larger (4.22") break and set E-1 through E-18 is for the smaller (3.76") break.

Since TXU performs large and small break LOCA analyses for every fuel cycle reload, TXU could analyze fractional break sizes around the limiting integer size break for any cycle for which the small break LOCA PCT falls within 25^{0}F of the large break LOCA PCT (or if it is greater by any amount). This would be analogous to an existing provision in the methodology that triggers a cycle-specific time step study (Section 3.2.3 of Reference [10]).

During a June 14 phone call the NRC asked TXU to confirm that the oxidation acceptance criteria of 10 CFR50.46 for SBLOCA are addressed in the methodology. Also, a concern was brought up that is allayed by what has been discussed above about the CPSES SBLOCA terminating by accumulator injection. The concern was the theoretical possibility of the core remaining uncovered for a long time with clad temperatures below the PCT, but high enough to challenge the oxidation acceptance criteria. These requests are addressed in the following:

As shown in Figures A-7, B-7, C-7, D-7, E-7, G-7, H-7, I-7, J-7, for breaks of 3", 3.76", 4", 4.22", 5" and various sensitivities, the CPSES SBLOCA clad temperatures increase nearly monotonically[1] and rapidly after CHF in all cases. Mechanisms that might keep the rods at relatively high but constant temperatures, i.e., that would prevent rod temperatures from increasing rapidly in post CHF heat transfer mode are not operative during CPSES SBLOCA for two main reasons:

(1) System depressurization rates are relatively fast, even for the smallest breaks, e.g. the 3" break shown in Figure A-1. Even for the smallest breaks, the ultimate rod quench is due to accumulator injection. Thus, the clad temperature turns around very quickly once the relatively high accumulator set point pressure is reached (again see Figure A-1 for the 3" break).

(2) The limiting power shapes peak very near the top of the core. For the temperatures to linger at relatively high values, the uncovered portion of the core would have to be above the peak node, but below the top of the core. When the level is below the peak power node, the temperature increases at the rates seen in the smaller breaks, e.g., the 3" break shown in Figure A-7. Obviously, if the level is above the top of the core

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1 Inflections in the increase can occur due to water redistribution in the core, as discussed in Q.7.1 below, but this is not long lived

there will be no clad temperature increase. But also, due to the power shape, the region of potential concern is very small (12-10.25 = 1.75 ft), contains almost no power and therefore even if the level lingered there, there would be no heat up.

If CPSES SBLOCA clad temperatures were susceptible to remaining for relatively long periods of time at relatively high temperatures, this would be seen in the smaller breaks. However, the smallest breaks do not show this behavior at all. (See Figures A-7 and E-7 for the 3" and 3.76" breaks, respectively). Thus, once in CHF, rod temperatures take off and do not turn around until quenched[1]. As a result of this characteristic, the peak SBLOCA local oxidation has always coincided with the peak clad temperature (PCT). The table below illustrates this point for the relevant cases presented in this submittal.

Break Size	PCT (^{0}F)	OXIDATION[2] (%)
3.00 inch	1226	0.07 (0.008)
3.76 inch	1530	0.37 (0.036)
4.00 inch	1830	1.75 (0.211)
4.22 inch	1555	0.38 (0.038)
5.00 inch	1236	0.05 (0.004)

Finally, the SBLOCA methodology of Reference [3] does address the oxidation acceptance criteria of 10 CFR 50.46 (b) (2) and 10 CFR 50.46 (b) (3), as shown for example on page 4-2 of Reference [10] and in the table above.

2 Local Transient Oxidation. This value is added to the initial pre-transient steady-state oxidation, typically 8%, for comparison to the 17% limit specified in 10 CFR 50.46 (b) (2). Values in parenthesis are the total hot pin oxidation, which represent an upper bound to the values which must meet the 1% limit specified in 10 CFR 50.46 (b) (3).

d. Please show the HPSI head vs. flow injection capability for the case for a severed emergency core cooling system (ECCS) injection line. Also show the analysis and a full complement of plots for this break size.

TXU Power Response:

The HPSI head vs. flow for the case of a severed ECCS injection line transmitted to TXU by Westinghouse in Reference 2.12 of Reference [10] is the basis for the ECCS flow versus head used in the CPSES SBLOCA analyses. Per Reference 2.12 of Reference [10], this flow constitutes "... the minimum total flow through all SI branch lines, excluding the highest flow line. The highest flow line is assumed to have ruptured and will spill its flow". The ECCS flow vs. head for each loop used in the CPSES analyses is given in Table 2.6 of Reference [10].

As described in Section 2.4.1.3 of Reference [10], the CPSES ECCS is comprised of: (1) the centrifugal charging pumps/safety injection system (CCP), (2) the high head safety injection system (HHSI), (3) the low head residual heat removal system (RHR) and (4) the accumulators.

The HHSI line injects into the accumulator line which in turn connects to the cold leg. The accumulator line is a 10" line. The HHSI line is an 8" line for loops 2 and 3 and a 6" line for loops 1 and 4. The 10" and 8" sizes were not analyzed because they are beyond the SBLOCA scope, i.e., such breaks have large break rather than small break characteristics, e.g. none or very short-lived loop seal plugging, and therefore are not expected to be limiting, either in comparison with smaller breaks where the pressure hangs higher thereby minimizing ECCS injection or with respect to the large break LOCA, which maximizes inventory loss.

Regarding the 6" break, Reference [3] shows that the 5" break is already non-limiting due to the fact that the pressure drops very quickly to the accumulator set point for that break size. The RCS pressure would reach that set point even sooner for the 6" break. Note that CPSES accumulator set point pressure is relatively high (around 600 psi). Note also that, if the HHSI line were severed this would only cause loss of part of the broken loop ECCS, namely the HHSI flow. The remaining ECCS flow coming from the CCPs, enters the accumulator line directly at another location and would therefore not spill directly to containment if the 6" HHSI line were severed. Nevertheless, since the 5" break cannot cause the complete loss of either the HHSI or of the CCP flow, a 6" break in loop 1, simulating a severed HHSI ECCS line by assuming all HHSI flow to loop 1 is lost, was analyzed. The plots provided in the section: "COMPLETE SETS OF PLOTS FOR ADDITIONAL CALCULATIONS" (set G-1 through G-18) show this break to be similar to the 5" break and that this 6" break is not limiting.

The CCP line is 1.5", which is too small to be a limiting SBLOCA if it were severed. If this line were severed, the HHSI portion of the ECCS flow would still be available to the broken loop. Nevertheless, a 1.5" break in loop 1 simulating a severed CCP ECCS line by assuming all CCP flow to the broken loop 1 is lost, was analyzed. The plots provided in the section: "COMPLETE SETS OF PLOTS FOR ADDITIONAL CALCULATIONS" (set F-1 through F-18) show this 1.5" break is not limiting.

At a June 14 phone call a question was asked regarding the elevation of the break in the cold leg for the case of the severed 6" ECCS line (Figures G-1 through G-18). The concern was that since the severed ECCS line comes in at the top of the cold leg, it might vent more steam than the model, which might vent more two-phase since it draws from the middle of the cold leg pipe. This would potentially help clear the broken loop seal earlier in the model than in reality.

The break junction elevation in the cold leg is "centrally located" in the CPSES model. The other options are "upward oriented" and "downward oriented". While drawing from the center of the cold leg might facilitate loop seal clearing with respect to an "upward oriented" break which draws from the top of the cold leg, it is also true that a break at the top of the piping would discharge more steam and consequently depressurize faster and with less loss of inventory. In practice, drawing from the top as opposed to the center of the pipe would have no impact because the break flow is choked for the duration of the transient and the Moody model must override any upstream stratification. In order to confirm this last observation, the case of the severed 6" ECCS line (Figures G-1 through G-18) was re-run with the break junction option switch set to "upward oriented" from the usual "centrally located" setting. The results were virtually identical and there was no difference in PCT.

e. On page 4-4 of ERX-04-004 (Ref. 3), the discussion of the 4-inch break analysis indicates results showed all of the intact loop seals cleared but the broken loop did not. As the broken loop is the path of least resistance, it typically clears first. Provide validation and benchmarks against integral test data that supports this condition.

TXU Power Response:

While it is said on page 4-4 of Reference [3] that "all but the broken loop seal clear (Figure 4.8)", what actually happens, as shown in the cited figure (Figure 4.8 of Reference [3]), is that the broken loop seal clears first, followed shortly (within a minute) by the others. However, immediately after loops 2, 3 and 4 clear, the broken loop 1 seal re-plugs. The fact that the broken loop seal stays plugged for key portions of the transient is conservative for CPSES, as explained in the next paragraphs.

When the broken loop seal clears (and stays cleared for a significant amount of time) the most direct vent path is established from the upper plenum to the break, resulting in the fastest energy removal and depressurization rates. These factors increase ECCS injection and ultimately result in the accumulator set point being reached sooner. In addition, inventory loss is also minimized when the broken loop seal clears because the break flow has a higher void fraction and quality in that case. Last but not least, it appears that for CPSES, water distribution throughout the system tends to be more favorable when the broken loop seal clears. These factors tend to lower the PCT.

That is why it is said on page 4-4 of Reference [3] that "all but the broken loop seal clear (Figure 4.8)" to convey the key point that this break did not benefit from the factors discussed in the previous paragraph which tend to be associated with the broken loop seal being clear for an extended period of time. In other words, the purpose of the statement was to point out a conservative element of that SBLOCA calculation. But again, the broken loop seal does clear first, as shown in Figure 4.8 of Reference [3].

During the March 29 teleconference, the NRC clarified that although they recognized that clearing the broken loop was beneficial, their concern was that it might be even more beneficial to clear all three intact loops, while the broken loop remained plugged, as essentially occurred in the 4" break analysis of Reference [3](PCT1830^{0}F). TXU had previously had this concern as well and reported during the teleconference on an analysis of a 4" break (with some input changes relative to the base case of Reference [3]) that resulted in clearing only the broken loop seal and where all the other loop seals remained plugged. The result of that analysis was a lower PCT (1748^{0}F). Additional information on that analysis is provided in the response to the next question (Q.7.e.i) and the corresponding plots are provided in the section: "COMPLETE SETS OF PLOTS FOR ADDITIONAL CALCULATIONS" (set H-1 through H-18)

As discussed in the March 29 teleconference, locating an experiment where all loops except the broken loop clear will not help the review because TXU's point is not that the loop seal clearing configuration of the 4" base case presented in Reference [3] (also in figure set B-1 through B-18) would necessarily always occur, but rather, that for CPSES it results in a higher PCT than the case discussed in the previous paragraph (set H-1 through H-18), where only the broken loop seal cleared. The latter is the most likely loop seal clearing configuration, based on for example the S-UT-8 test. Nevertheless, the methodology has been benchmarked against at least one integral test involving loop seal phenomena. That was the S-UT-8 test at the Semiscale Mod-2A facility. In that benchmark, the loop seal phenomena were well predicted. This and several other benchmarks are presented in Appendix E of the topical report which is the subject of Reference Q.7.g.(1).

i. **Please provide the results of a case with only the broken loop cleared. If additional loops clear, in addition to the broken loop, provide validation and benchmarks against integral test data that supports this condition.**

TXU Power Response:

As mentioned above, the CPSES SBLOCA PCT tends to be lower when the broken loop seal clears (and stays clear for a significant amount of time). This is verified below for the limiting 4" break presented in Reference [3].

In order to demonstrate this point, a case in which ONLY the broken loop clears was run as follows: Three changes were made to the 4" base case break of Reference [3]: (1) MDAFW was provided to loops 2 and 3 instead of 1and 4, (2) ECCS to the broken loop 1 was turned off and (3) the intact loop seals were lowered to make them harder to clear. This is an artificial case, since items (2) and (3) involve physical changes which are not in the plant itself but all 3

changes were necessary in order to satisfy this RAI. The calculation results demonstrate that when the broken loop seal clears, the transient is less limiting than when it does not. The PCT for this case (1748^{0}F) is slightly lower than for the base case 4" break (1830^{0}F), as illustrated by the plots provided in the section: "COMPLETE SETS OF PLOTS FOR ADDITIONAL CALCULATIONS" (set H-1 through H-18).

Since not clearing the broken loop seal is conservative for CPSES, the CPSES model conservatively assigns auxiliary feedwater so as to minimize the chances of the broken loop seal clearing with respect to the other loops. As explained on page 4-12:

"The driving force for loop seal clearing is the pressure differential between the hot leg and the cold leg. The resisting force preventing the clearing is the amount of liquid in the loop seal, the water level, etc. This resistance to clearing is not the same in the four loop seals because: Loop 1 has the break, motor-driven auxiliary feedwater (MDAFW) and turbine-driven auxiliary feedwater (TDAFW); Loops 2 and 3 have only TDAFW and Loop 4 has MDAFW, TDAFW and the pressurizer...

Thus, because they have less feed water, loops 2 and 3 condense less water on the primary side of the tubes, so there is less water and consequently a lesser resistance to clearing the loop. Similarly the No. 1 loop seal has more water than it would have if the MDAFW were not connected to its steam generator and that is why the available MDAFW pump (1 pump is taken out by single failure) is deliberately connected to loops 1 and 4: in order to give loop 1 (which has the break) the least chance to clear.

Another factor that reduces the chances of clearing the broken loop seal is ECCS injection into the broken loop. This provides additional water to the loop seal making it more difficult to blow.

In spite of these modeling features, as shown in Figure 4.8 of Reference [3], the broken loop seal does clear first, followed shortly (within a minute) by the others which, when they blow, seem to cause the broken seal to re-plug. Thus, the broken loop is not clear for any significant portion of the transient. For CPSES, this results in a higher PCT than if the broken loop were clear and the others remained plugged and is therefore a conservative calculation.

f. **On page 4-9 of ERX-04-004, fluid in the hot legs and RSG was prevented from flowing back into the core. Please explain how the steam velocities can hold up water in the RSG inlet plenums following a SBLOCA in the 3-5 inch break size range. The velocities in this region, once the loop seals have cleared should be well below the flooding limit. Please show that the vapor velocities are sufficient to hold up the water in the hot legs and RSG's. Does this water then enter the core and provide cooling over the long term that artificially reduces the PCT during the long term? Please explain and discuss the justification/conservatism of the model presented in the submittal.**

TXU Power Response:

References:

Q.7.f.(1) V. H. Ransom, et. al., "RELAP/MODD2 Code Manual Volume 1: Code Structures, Systems Models and Solution Methods, NUREG/CR-4312, August 1985.
Q.7.f.(2) Y. Taitel and A. E. Dukler, "A Model of Predicting Flow Regime Transitions in Horizontal and Near Horizontal Gas-Liquid Flow," AIChE Journal, Vol. 22, pp. 47-55, 1976.

The water hold up in the (unplugged loops) steam generator inlet plena over the time period in question (450 to 650 seconds for the 4" limiting break) occurs as a natural consequence of the flow regimes in effect. It does not occur as a result of flooding. Typically, flooding occurs when a liquid film on a vertical wall is prevented from flowing downward due to the velocity of the vapor. Flooding is not applicable to this situation because, the flow pattern in the steam generator inlet plenum, which is a vertical volume, is vertically stratified flow in this time period of interest, which is not consistent with flooding. Rather, steam velocities and mass fluxes are low when vertical stratification occurs. In order to visualize the situation consider that the steam generator inlet plenum is being fed by the hot leg, which has a horizontally stratified flow pattern during this time. Thus, the horizontally stratified flow from the hot legs enters the steam generator inlet plenum from the side. The flow remains stratified by going from horizontally stratified in the hot leg to vertically stratified in the steam generator inlet plenum, with the liquid underneath, essentially stagnant, and the vapor flowing from the top upward into the tubes. During this time period, the total mass flow rate out of the inlet plenum into the tubes is approximately the same as the mass flow rate in from the hot legs and this gives the impression of liquid being "held up". Eventually, this liquid is scavenged out of the inlet plenum as droplets, which are entrained into the tubes flowing forward in an annular mist flow regime. As seen from the discussion above, this water does not re-enter the core.

Regarding demonstrating that vapor velocities are sufficient to hold up water in the hot legs and in the steam generator inlet plenum it must be stipulated that they are not sufficient for flooding since flooding is not the mechanism at play. Rather, for the horizontal volumes of interest, i.e. the relevant hot legs, the steam velocities are consistent with the horizontal flow map in ANF-RELAP, as described for example in Section 3.1.3.1.2 of Reference [Q.7.f.(1)]. This horizontal flow map is one developed by Taitel and Dukler, Reference [Q.7.f.(2)]. For the vertical volumes of interest, namely the relevant steam generators inlet plena, the vertical stratification criterion is given in for example in Section 3.1.3.1.1 of Reference [Q.7.f.(1)] and the velocities are consistent with this pattern.

Regarding explaining and justifying the conservatism of the model presented in the submittal, it is the same model already approved by the NRC in Reference [10] with respect to the phenomenology being discussed in this question. In fact it is the same model in all respects except for the changes addressed in Q.7.m.

g. **Describe how condensation of ECCS injection is modeled. Provide a reference or validation of the ECCS condensation model.**

TXU Power Response:

References:

Q.7.g.(1) Letter, Ashok Thadani (USNRC) to Gary Ward (SPC), "Acceptance for Referencing Topical Report XN-NF-82-49(P), Revision 1, "EXXON NUCLEAR COMPANY Evaluation Model EXEM PWR Small Break Model", July 1988.

Q.7.g.(2) V. H. Ransom, et. al., "RELAP/MODD2 Code Manual Volume 3: Developmental Assessment Problems, EGG-SAAM-6377, April 1984.

Item 2.4.2 in Reference Q.7.g.(1) reads as follows:

> "**2.4.2 <u>Condensation Heat Transfer</u>**
>
> **...ANF-RELAP uses the condensation heat transfer correlations from RELAP5/MOD2 without alteration. Thus the validity of these correlations has been verified by the full extent of the RELAP5 development and assessment effort (Ref.[Q.7.g.(2)]). We find the condensation heat transfer package in the code to be acceptable."**

As described at the top of page 2-1 of Reference [10] and in the NRC SER attached to it, the CPSES Small Break LOCA methodology is essentially an application of the SPC methodology of Ref.Q.7.g.(1), (also Ref. 1.1 of Reference 10) and, specifically, the condensation model is the same. Specific assessment of this condensation model is available in Sections 2.2.11 & 2.2.12 of Ref.Q.7.g.(2).

h. Since PCT appears to be very sensitive to loop seal behavior for CPSES, please show the sensitivity of loop seal nodalization to PCT for the limiting break. Please also address the impact of only one loop seal cleared. Provide validation and benchmarks against integral test data that supports this condition.

TXU Power Response:

The existing loop seal nodalization is part of the NRC-approved methodology for the original steam generators (OSGs), which is not affected by the introduction of the replacement steam generators (RSGs). It complies with the guidelines for ANF-RELAP nodalization. It does not involve a complex configuration but, rather, it is simply a "PIPE" component. In short: there is no theoretical basis to change the CPSES loop seal nodalization. Nevertheless, a calculation of the limiting break was performed, where the number of nodes in all loop seals was doubled from 4 to 8. That calculation's results are essentially the same as the base case's (PCT1841^{0}F vs.1830^{0}F). A full complement of plots for that calculation is provided in the section: "COMPLETE SETS OF PLOTS FOR ADDITIONAL CALCULATIONS" (set J-1 through J-18)

Regarding the clearing of only one loop seal, such a case is being provided in connection with the response to Q.7.e.i above. The plots for that case, in the section: "COMPLETE SETS OF PLOTS FOR ADDITIONAL CALCULATIONS" (set H-1 through H-18), showed that for CPSES, the loop seal clearing configuration for the limiting 4" break presented in Reference [3] was limiting. Benchmarks against integral test data involving loop seal phenomena are presented in Appendix E of the topical report which is the subject of Reference Q.7.g.(1). For example, in the benchmark for the S-UT-8 test at the Semiscale Mod-2A facility the loop seal phenomena were well predicted by this methodology.

Although the SBLOCA PCT can be sensitive to loop seal behavior, the loop seal behavior itself seems stable for a given calculation. Recall, that in order to obtain the case presented in Q.7.e.i above, which cleared only one loop seal, it was necessary to: (a) switch the loops receiving MDAFW, (b) eliminate ECCS to the broken loop and (c) bias the intact loop seals to prevent them from clearing. All this indicates the current loop seal clearing pattern for the limiting 4" break is stable. The nodalization study discussed in the first paragraph shows the same thing, since that run was nearly identical to the base case. The time step study and the core cross-flow resistance study also test the stability of the loop seal clearing pattern and they too confirm that the loop seals clearing pattern for the limiting 4" break is stable.

Based on the above, the current loop seal clearing configuration for the limiting 4" break is stable, not affected by loop seal nodalization and, in any case, is more limiting than the benchmarked loop seal clearing configuration, as discussed in Q 7.e and Q.7.e.i.

At a June 14 phone call the NRC said they would have preferred to see more nodes in the vertical portion of the volume immediately upstream of the pumps for the loop seal nodalization study discussed above. However, since they were not specific in the original request and TXU did double the number of nodes there, with the results showing almost no sensitivity, the NRC agreed there are no action items here. An additional request was made that TXU would make sure there was no SLUG regime flow in the loop seals during loop seal clearing. There was no slug regime flow in the loop seals at any time. Figure 2 in the "MISCELLANEOUS FIGURES" section of this document shows the only flow regime types to be: bubbly, stratified and mist, depending on the loop seal and time in the transient.

i. In the cross flow sensitivity study please identify the magnitude of the cross flow resistance for each case and describe/justify the method for calculating cross flow resistance.

TXU Power Response:

As stated in Section 3.2.2 of Reference [10], three values are used in the crossflow resistance study: nominal, 10 times nominal, and nominal divided by 10. As stated in the TER of Reference 1.1 of Reference [10], the standard methodology implemented in COBRA analyses is used for calculating nominal cross flow resistance. This methodology is based on textbook relationships for flow across tube banks and is provided in one of the two attachments to Reference Q.7.l.(1), pages 3-1 and 3-2. At a June 14 phone call the NRC asked what were References (2) and (3) mentioned in those pages. References (2) and (3) of pages 3-1 and 3-2 of one of the two attachments to Reference Q.7.l.(1) are pages 333 and 339, respectively of the same book:

Knudsen, James, G. and Katz, Donald, L., Fluid Dynamics and Heat Transfer, McGraw-Hill Book Company, New York, 1958.

j. Demonstrate that above the two-phase level no liquid is entrained in the steam leaving the two-phase surface via the drag model in RELAP5 that would artificially de-superheat the steam at the hot spot for the limiting SBLOCA.

TXU Power Response:

Item 2.2.3 of Reference Q.7.g.(1) reads in part:

"2.2.3 <u>Mixture Level Model</u>

...This [ANF-RELAP] model corresponds more closely with the physical situation for the presence of a mixture model than the model found in RELAP5/MOD2. In Appendix C of Reference 4 [Ref.Q.7.g.(2)], ANF documents the use of the code to calculate the results of the ORNL THTF level swell test (discussed in Section 2.3.3). Because of the good agreement between ANF [-RELAP] code calculations and THTF test data, the staff concludes that this code modification is acceptable for licensing analysis. "

As described at the top of page 2-1 of Reference [10] and in the NRC SER attached to it, the CPSES Small Break LOCA methodology is essentially an application of the SPC methodology of Ref.Q.7.g.(1), (also Ref. 1.1 of Reference [10]) and the mixture level model is the same.

Also, the additional figures requested in Q7.a.iii include the steam temperatures adjacent to the hottest clad temperature nodes. Plots of those temperatures (Figures 15 of the A through J sets, i.e. A-15, B-15... J-15) provided in the section: "COMPLETE SETS OF PLOTS FOR ADDITIONAL CALCULATIONS" show the steam is highly superheated with temperatures following those of the adjacent cladding.

k. For the 3-inch break, please explain why there is a 1700-second period of cooling after the initial heat up at 500 to 1000 seconds for the 3-inch break?

TXU Power Response:

The second period of cooling for the 3" break lasts approximately 700 not 1700 seconds. As discussed in the March 29 teleconference with the NRC, TXU assumes this is a typo and will answer the question accordingly. The initial heat up that began at 500 seconds is arrested around 900 seconds (Figure 4.19 of Reference [3]) when loop seal clearing begins to occur. As the loop seals clear, water in the loops is free to flow back into the core. When enough of this water gets there the rods undergo the preliminary quench that occurs near 1000 seconds. Figure 4.18 of Reference [3] shows the core collapsed level increase at this time, which results from this effect. The loop seal clearing allows the RCS pressure to drop more rapidly as shown in Figure 4.13 of Reference [3]. This in turn causes an increase in ECCS flow as shown in Figure 4.23 of Reference [3]. The additional water from the loops in combination with the increased ECCS flow slows down the inventory loss so that it takes from approximately 1000 seconds to approximately 1650 seconds for the collapsed core level to drop below its mid-point elevation (6 ft. Figure 4.18), which typically corresponds to the onset of critical heat flux shown to occur around that time (1650 seconds, Figure 4.19). This second heat-up typically is the main heat-up for CPSES, as discussed in the next question (Q.7.l).

l. The temperature profiles for CPSES, in the submittal, do not resemble SBLOCA PCTs for plants of this class and power level. Please explain and discuss why CPSES is unique.

TXU Power Response:

Reference:

Q.7.l.(1) R.A. Copeland (SPC) to Frank Orr (USNRC), "Response to NRC Concerns about SPC SBLOCA Model," March 17, 1994, RAC:94:037.

At the March 29 teleconference, the NRC agreed that lack of resemblance to "SBLOCA PCTs for plants of this class and power level" refers to the preliminary heat up that is seen prior to loop seal clearing for the RSG cases, an example of which would be the heat up between 300 and 500 seconds seen in Figure 4.7 of Reference [3].

While this pre-heat up makes the PCT temperature histories for the RSG appear unusual, it is not unique: it also appears, although less conspicuously, in other PCT histories. For example, in the PCT history for the sample application provided on page 31 of an attachment to Reference Q.7.l.(1). Other examples are the CPSES clad temperature histories for the OSGs, which use NRC-approved methodology and which can be seen in Figures 3.9 and 3.22 Reference [10].

In these examples, the "pre-heatups" appear as "blips" rather than "humps" but they are all due to water being temporarily held away from the core, e.g. in the loops, eventually finding its way back into the core when loop seals clear. The calculations where these "pre-heatups" are absent or small simply reflect that a larger fraction of the RCS inventory stays in the reactor vessel for the duration of the transient as opposed being temporarily held in the loops. In either case, i.e. whether this pre-heatup occurs or not, the actual heat up is similar because it either happens after water held in the loops returns to the vessel and is eventually lost via

break or, if that water remained in the core, after it is lost to the break. Thus, the "pre-heatup" is not the definitive heat up, i.e. the PCT doesn't occur in this phase because water held in the loops returns to the vessel when loop seals clear. The pre-heatup is more pronounced in the RSGs than in the OSGs because there is more water held in the loops in the RSGs due to their much larger steam generator tube volume and hence appears in the temperature profiles as an unfamiliar "hump", rather than the often ignored "blip". Note the RSGs are a Δ76 model, with an atypically large steam generator number of tubes/ tube-side volume (5532 vs. 4578 / 1303 ft^3 vs. 967 ft^3, see Table 2.1 of Reference [3]).

At a June 14 phone call the NRC asked what causes the dip in clad temperature around 900 seconds seen for example in Figure B-7, corresponding to the clad temperatures for the limiting 4inch break base case. This inflection is due to water redistribution between the Hot Assembly, Central Region and Average Core. Figures B-2, B-3 and B-4, respectively, show void fractions at three core elevations: bottom (nodes, 112, 130,150), lowest $\alpha = 1$ elevation (nodes, 122, 140, 160) and an intermediate elevation (nodes, 117, 135, 155) in each of these three core regions. At the time period of interest, around 900 seconds, the topmost elevation (nodes, 122, 140, 160) remain at $\alpha = 1$. This shows that no water has entered either of these three core regions from the top. Further evidence of this is provided in Figure B-5 that shows no liquid at this time in the upper plenum either. Similarly, there is no significant trend change in the void fractions in the lower elevations (nodes, 112, 130,150). Additional inspection of mass flow rates from the lower plenum to the various core regions (flows from volume 111 to 112, 130 and 150) also show no change over the period of interest. These observations indicate there was no change in the amount of water entering these three core regions either from above or from below. A look at the void fraction behavior at the intermediate elevation (nodes, 117, 135, 155) however, is revealing. While similar oscillations in void fraction are seen at that elevation in all three regions, the highest void fractions occur in the average core region, then in the central region and finally in the hot assembly. This hierarchy indicates net water movement away from the larger regions towards the hot assembly at intermediate elevations. A look at representative cross flows during the period of interest shows a step reduction in the outflow from the hot assembly. Figure B-15 shows a reduction in the hot channel superheat about the PCT elevation which is consistent with more of the upstream flow remaining in the hot assembly. Thus, these observations indicate that the inflection in temperature is due to a redistribution of flow between the various core regions, where outflow from the hot assembly region is temporarily reduced to satisfy energy and momentum conservation equations, most likely compensating for an earlier overshoot. Note that the cross flow resistance study (Figure 4.37 of Reference 3) identifies the limiting cross flow resistance. Heat transfer and flow regime flags in the core were examined but no significant changes occurred during the time period of interest that could account for the inflection in the clad temperature history.

It should be noted that this inflection in the clad temperature is not unique to CPSES, nor to TXU's application of the SPC methodology. For example, a similar inflection appears in the ruptured node clad temperature history for the sample application provided on page 31 of an attachment to Reference Q.7.1.(1) (mentioned above).

Also at the June 14 phone call the NRC asked TXU to investigate, with respect to the Appendix K lockout rule, the apparent return to nucleate boiling associated with the quench occurring due to loop seal clearing around 450 seconds in Figure B-7 showing clad temperatures for the limiting 4 inch break base case. This issue was previously addressed in item 3.0 of Reference Q.7.g.(1) which reads as follows:

> "3.0 COMPLIANCE WITH NRC REQUIREMENTS
>
> . . . the post-CHF heat transfer requirements of Appendix K specify return to nucleate boiling be locked out once CHF has occurred during blowdown. This requirement is not appropriate for SBLOCA."

m. In addition to the feedring RSG changes, the licensee is proposing two changes to its reactor vessel nodalization in the ANF-RELAP model for CPSES Unit 1. First, four upper downcomer nodes are collapsed into two nodes. Nodes 104 and 106 are being combined and nodes 100 and 102 are being combined. Second, " . . . the flow area between the upper downcomer and upper head "spray holes" is being updated to reflect more accurate, recently developed design information." These changes are only being proposed for the CPSES Unit 1 ANF-RELAP model.

i. Explain what evidence provides reasonable assurance these changes will accurately reproduce conditions at CPSES Unit 1.

TXU Power Response:

Both downcomer nodalizations (proposed and current) are essentially the same over more than $4/5^{ths}$ of the downcomer length, and after that both connect to single lower plenum node. Thus, these nodalizations are essentially the same because, even in the current nodalization, the downcomer is not azimuthally split for its entire length, rather, it becomes one node azimuthally just beneath the cold leg elevation. The only reason for the change is to provide a more uniform pressure boundary condition for the loop seals during loop seal clearing, as described in Q.7.m.ii.(1), (2) and Q.7.m.iii. (Note that based on the annular geometry of the region alone it is reasonable to expect an azimuthally uniform pressure distribution in the downcomer.)

Conditions at CPSES Unit 1 are currently modeled either way. Both configurations have an extensive track record. For example, the azimuthally split configuration is used for the small break LOCA in ANF-RELAP with the D-4 steam generators and has been approved by the NRC for use in that manner (Reference [10]).

By contrast, the single azimuthally configuration proposed here for the RSGs, was used in all the applicable benchmarks presented in the topical report which is the subject of Reference Q.7.g.(1). For example, Figure E.4.1in that topical report shows that both cold legs in the S-UT-8 test Semiscale Mod-2A model feed into a single downcomer node. The same is true for the LOFT L3-1 test as shown in Figure B.4.1 of the same topical report.

The change proposed to the flow area between the upper downcomer and upper head "spray holes" is an update to reflect more accurate design information that was obtained as a result of an unrelated activity. Additional information on this change is provided in Q.7.m.vi, and Q.7.m.vii. The rationale here is that the most accurate design information available should be used on general principle.

ii. The licensee states that collapsing the four downcomer nodes into two nodes " . . . makes the model more robust numerically for Δ76 applications, but does not significantly improve the numerics of the Unit 2 model."

(1) Why did the ANF-RELAP model, as modified for Δ76 steam generators, need to have its 'numeric robustness' improved?

TXU Power Response:

The methodology demonstration submitted via Reference [3] includes two sensitivity studies that are essentially tests for numerical robustness: the crossflow sensitivity study and the time step sensitivity study. Prior to consolidating the two sets of nodes that azimuthally split the upper 1/5th of the downcomer in two, the time step sensitivity (or "numeric robustness") for key Δ76 calculations was less than adequate. The proposed consolidation resolved the problem.

(2) Explain why collapsing the four downcomer nodes into two nodes affects the 'numeric robustness' of the Δ76 applications but not the D4 applications.

TXU Power Response:

The D-4 applications met numerical robustness tests including the crossflow sensitivity study and the time step sensitivity study, with the original nodalization and therefore did not require change. The Δ76 did not until the nodes were collapsed, as explained above in Q7.m.ii.(1).

The driving force for loop seal clearing is the pressure differential between the hot leg and the cold leg. The resisting force preventing the clearing is provided by the liquid in the loop seal, e.g. the water "plug" resistance. Thus, the mechanism for loop seal clearing involves a threshold, it either happens or doesn't. It is not a matter of degree and does not take place gradually. As a result of this threshold effect, differences in initial and/or boundary conditions may result in a different loop seal clearing sequence. This in and of itself may not impact the transient much, if similar loop seals are cleared for similar time periods. However, in the Δ76 prior to the proposed collapsing of the 2 downcomer nodes, the minor differences that occur in the clearing sequence may have been amplified by the fact that, once a loop seal cleared, the driving pressure differential for loop seal clearing was affected by the water that found its way back into the downcomer after the clearing. This effect might be more significant in the Δ76 than in the D-4 because of the following:

Prior to collapsing nodes, 2 loops see slightly different boundary pressures in the downcomer than the other 2 loops. After the nodes are collapsed, all four loops see the same boundary condition (pressure) in the downcomer. Thus, after the change, if one loop blows, that water affects all the other loops equally. However, prior to the change, one loop blowing affects the pressure more in the loop that it connects to via downcomer node. In the case of the Δ76, the large SG tube volume results in a correspondingly larger water volume being blown into the downcomer at the time of loop seal clearing. Thus, an otherwise minor clearing sequence difference associated with, say a time step study, now changes which loop clears next and which loops remain clear. Since the D-4 has a smaller SG tube volume, the slug associated with blowing a loop seal is correspondingly smaller and apparently does not affect what loop seals subsequently clear, even if loops attached to different downcomer nodes clear in a slightly different sequence.

It is also possible that for the D-4, the minor differences in the amount of liquid in the loops associated with the various sensitivity studies, in combination with the small variations in the driving pressure differential did not affect the loop seal clearing pattern because the liquid amounts were small and thus their relatively magnitudes were significantly different from each other, so that the clearing pressure thresholds were also significantly different from each other. Thus, fluctuations in magnitude did not affect hierarchy. Conversely, for the Δ76 with the larger volume, the resistance to loop seal clearing increased and became relatively similar among the loops. In this case, the clearing pressure thresholds also become similar in all loops and then minor variations in either one have a big impact on the loop seal clearing sequence itself.

iii. Nodes 104 and 106 are being collapsed into a single node. Nodes 104 and 106 each had two RCS cold leg inputs. Collapsing them into a single node will have all four RCS cold leg inputs being routed to a single node. Explain the impact of having all four RCS cold leg inputs being routed to a single node, include the rationale for the original model configuration.

TXU Power Response:

Both downcomer nodalizations (current and proposed) are essentially the same. They are exactly the same over more than 4/5^{ths} of the downcomer length and prior to entering the single lower plenum node. This is because for both nodalizations the downcomer is not azimuthally split for its entire length, rather, it becomes one node azimuthally just beneath the cold leg elevation.

The impact of collapsing the nodes is to provide a more uniform pressure boundary condition for the loop seals during loop seal clearing, as described in Q.7.m.ii.(1), (2) and Q.7.m.iii. (Note that based on the annular geometry of the region alone it is reasonable to expect an azimuthally uniform pressure distribution in the downcomer.)

The rationale for the original nodalization was that part of the connection between the nodes is partially blocked by hot legs in the region. However, the presence of the hot legs does not prevent the pressure in the upper downcomer region from being relatively uniform. Having all cold legs see the same pressure boundary condition, as previously explained, is the goal and therefore the variable of interest is the pressure. Still, another important consideration is that the reason the nodes were split in the original model was to make it more difficult for intact loop ECCS to find its way to the break. Thus, from the standpoint of the rationale for the original model, the proposed change is in the conservative direction.

iv. Where is the break location relative to the loop connections to the downcomer for the new model? Please provide the reference or sensitivity studies preformed to justify this unique original nodalization prior to this requested change (what is the impact of this change on the limiting SBLOCA PCT)?

TXU Power Response:

Based on the March 29 conference call, it appears the NRC's concern with "**this unique original nodalization prior to this requested change**" is that the break junction is connected to the vessel side as opposed to the pump side of the break. Alternatively, that the break junction is connected to the inlet of volume 495 where the NRC was concerned it might be more limiting to connect it to the outlet of volume 490 (see Figure 2.3 of Reference [10]).

The reason why the connections are as they are is that RELAP5/MOD2 guidance is not to connect more than one process model to the same volume. Since ECCS and BREAK FLOW are both process models and given that ECCS is connected to volume 490, then the BREAK FLOW is, logically, connected to the closest location to the break in the adjacent volume 495. It should be noted this nodalization is NOT unique to TXU and that the same configuration was used by SPC, e.g. Figure 4.1 of the topical report of reference Q.7.g.(1). As far we are aware, Framatome still uses this configuration.

With respect to the TXU application of the SPC model, the break location has not changed either. The break location relative to the loop connections is shown in Figure 2.3 of Reference [10]. This break location is part of an approved model as per SER dated 9/4/1996 and attached to Reference [10].

(Several years ago, in mid 1997, TXU performed a sensitivity study on this issue. It found that the NRC-approved configuration, i.e., that of Figure 2.3 of Reference [10], was more limiting)

(1) Are the hot leg nozzle gaps modeled in the SBLOCA analysis? Please explain and justify this modeling decision. Please describe and justify all of the hot side leakage paths modeled in the SBLOCA analyses.

TXU Power Response:

In addition to the "spray holes", discussed in Q.7.m.vi and Q.7.m.vii, the hot leg gaps are the only hot side leakage paths included in the Δ76 model. These leakage paths are modeled as shown in Figure 2.2 of Reference [10]. The justification for including these in the model is that they are there, i.e. that the most accurate design information available is used on general principle.

Based on the March 29 conference call, it appears the NRC has a concern that these gaps may change during the transient due to thermal expansion differentials. The area of each CPSES nozzle gap is very small 0.0038 ft^2. Nevertheless, in order to address this concern the NRC accepted TXU's proposal to analyze the limiting 4" break without the hot leg gaps. That calculation's results are slightly higher (approximately 50^0F) than the base case's, although the actual transient development is essentially the same. A full complement of plots for that calculation is provided in the section: "COMPLETE SETS OF PLOTS FOR ADDITIONAL CALCULATIONS" (set I-1 through I-18).

v. Where is the break location relative to the loop connections to the downcomer for the new model?

TXU Power Response:

Break location was discussed in the answer to the previous question, Q.7.m.iv. Again, the break location has not changed with respect to that in the NRC-approved model, shown in Figure 2.5 of Reference [10]. The NRC SER for that model is attached to Reference [10].

vi. What is the ". . . more accurate, recently developed design information" used to set the revised flow area between the upper downcomer and upper head "spray holes" and how is current value more conservative?

TXU Power Response:

Reference:

Q.7.m.vi. Westinghouse Letter "...Reactor Vessel Upper Head Region Bulk Fluid Temperature Design Basis," WPT-16476, October 8, 2003 (VL-04-002358).

The more accurate, recently developed design information was obtained as a result of an unrelated activity. It is Reference Q.7.m.vi.

The current value is more conservative because a preliminary calculation was performed for CPSES-2 with the current, NRC-approved, Reference [10] model, where only this parameter was changed to the value given in the above reference and the resulting PCT was lower. However, the fact that the value of this parameter is not being updated for CPSES-2 at this time is not the subject of the present LAR.

vii. What is the flow area of the upper head spray nozzles, for CPSES Unit 1 and Unit 2?

TXU Power Response:

Approximately 28 square inches, per Reference Q.7.m.vi above.

n. Explain how the increased size of the Δ76 tube bundle is apportioned between the existing nodes. Confirm that the increased size of the nodes does not violate any underlying assumptions of the models such as length or bend radii.

TXU Power Response:

Reference:

Q.7.n Siemens Power Corporation, "Guidelines for PWR Safety Analysis: Small Break LOCA Analysis (SRP 15.6.65) ," EMF-2062 (P), Rev. 0, June 17, 1998.

The tube bundle node dimensions in the ANF-RELAP model are defined according to the methodology guidelines of Reference Q.7.n. The tube bundle region is represented by a total of 8 vertical nodes; 4 oriented vertically upward and the remaining 4 oriented vertically downward. The top most nodes depict the U bend and are connected by a horizontal junction. This nodalization scheme is the same one used with the D-4 steam generator and is shown in Figure 2.3 of Reference 10. The ANF-RELAP tube bundle node dimensions for both the Δ76 and the D-4 steam generators are given below in Table 1. The two steam generators are shown in Figures 2.1 and 2.3 of Reference 3.

The relatively higher number of U-tubes in the Δ76 SG is reflected in the model via the larger flow area of 11.97 ft^2 compared to 10.46 ft^2 for the D-4 SG.

The average Δ76 U-tube length of 34.98 ft is distributed in the tube region model with 4 up-flow and 4 down-flow nodes as shown in Table 1, which is the same modeling approach used to represent the 28 ft average tube length of the D-4 SG.

The Δ76 SG total U-tube volume amounts to 837.7 ft^3 compared to the D-4 U-tube volume of 585.78 ft^3, and is apportioned according to the flow area and node lengths of Table 1.

The Δ76 nodes were verified to remain within the parameters of applicability of all conservation and constitutive equations (correlations).

Table 1 - ANF- RELAP SG U-Tube Nodalization		
	D-4 SG	Δ-76
Length (ft)		
Node 1	9.06	10.41
Node 2	7.25	10.41
Node 3	7.25	10.41
Nodes 4 & 5	4.44	3.77
Nodes 6 & 7	7.25	10.41
Node 8	9.06	10.41
Volume (ft^3)		
Node 1	94.77	124.59
Node 2	75.84	124.59
Node 3	75.84	124.59
Nodes 4 & 5	46.44	45.08
Nodes 6 & 7	75.84	124.59
Node 8	94.77	124.59
Flow Area (ft^2)		
Nodes 1 - 8	10.46	11.97
Orientation		
Nodes 1 - 4	+90	+90
Nodes 5 - 8	-90	-90

o. The licensee currently uses an ANF-RELAP model for its SBLOCA analysis, TXU Electric's RXE-95-001-P-A, "Small Break Loss of Coolant Accident Analysis Methodology," (Ref. 10). The licensee is proposing using the same nodalization for modeling the feedring RSG as is used for the preheater OSG, figure 2.3 of RXE-95-001-P-A. Figure 2.3 of RXE-95-001-P-A is a single loop diagram, please confirm that the four loop model represented by figure 2.2 of RXE-95-001-P-A is being used for the SBLOCA analysis.

TXU Power Response:

That is correct, the four loop model represented by Figure 2.2 of Reference [10] is being used for the SBLOCA analysis. Note that although Figure 2.3 of Reference [10] only shows loop 1, the broken loop, in order to allow for larger digits, that figure is a partial view of the 4-loop model, which is displayed in its entirety on Figure 2.2 of Reference [10].

8. **With respect to the changes in CPSES's large break loss of coolant accident (LBLOCA) methodology described in ERX-04-004, "Replacement Steam Generator Supplement to TXU Power's Large and Small Break Loss of Coolant Accident Analysis Methodologies," (Ref. 3), provide the following information.**

   a. **In the LBLOCA analysis, containment pressure can affect PCT. As such, no failure can result in the maximum spillage to the containment which can reduce containment pressure during the late reflood peak. Please provide a reference for the analysis of the no failure condition or provide an analysis to show that the containment minimum pressure analysis with no ECCS failure does not produce the most limiting PCT.**

TXU Power Response:

As explained in page 6-2 of Reference [3], the single failure considered in the large break LOCA analysis is the failure of 1 train of RHR, which is more limiting than the loss of 1 full train of ECCS. This is because the former results in the minimum containment pressure due to the actuation of 2 trains of containment spray, whereas in the latter case, only 1 train of containment spray injects. In order for the limiting single failure, namely the loss of 1 train of RHR, to result in a lower PCT than the case with no failure at all, it would be necessary for the incremental break flow resulting from a lower containment pressure associated with the additional condensation from the spillage of 2 rather than 1 train of RHR to be greater than the increment in make up flow due to the injection from 2 rather than 1 RHR train. Simple engineering judgment says this cannot be the case. Given that both scenarios: "loss of 1 RHR train," as well as "no failure" have 2 trains of containment spray running, the increment in break flow associated with increased condensation from the additional spillage of RHR is a second order effect and could not possibly offset the incremental RHR flow being injected in the no failure case, which has a direct or first order effect on flooding rate and consequently on the PCT.

b. **What are the effects of downcomer boiling on PCT for the limiting LBLOCA? Show that the limiting LBLOCA considers this condition. What is the worst single failure condition when downcomer boiling is a consideration? Describe and justify the analysis that lead to these conclusions.**

TXU Power Response:

Reference:

Q.8.b H.C. da Silva, P. Salim and W. G. Choe, "Effect of Downcomer Boiling on LOCA PCT for a 4-Loop PWR with a Large Dry Containment," 10th International Topical Meeting on Reactor Thermal Hydraulics (NUTHETH 10) Seoul, Korea, October 5-9, 2003.

According to the Reference [12] SER, item 3.3.2, TXU committed (Commitment Number 27266) to investigate this issue. According to the 2002 annual PCT report dated Dec 17, 2002, TXU communicated to the NRC that the impact of downcomer boiling was investigated within the corrective action program (SMF-2002-002036) and concluded that a PCT penalty was not warranted. The bases for that conclusion are described in Reference Q.8.b.

Thus, this is a generic issue that has already been addressed, as indicated in the previous paragraph. Also, since the current model has already been approved for use with the OSGs (Reference [10]) and since there is nothing about the RSGs that impacts downcomer boiling, this issue appears unrelated the present LAR. Finally, the RSGs have a lower primary side resistance which would have a beneficial effect on the core flooding rate and core liquid region inventory, which would be beneficial in regards to this issue.

c. **Replacement of the RSG's could represent an increased resistance in the loop during long term cooling following an LOCA due to the larger RSG's. Please show that the RSG's do not pose a more limiting condition for post-LOCA long term cooling performance such that the boric acid precipitation time does not decrease. A decrease in the timing to boric acid precipitation could result in less time for the operators to switch to simultaneous injection to control boric acid precipitation. Please describe the methods to evaluate boric acid precipitation and discuss the impact of the replacement steam generators on the timing (and hence EOP guidance) to switch to simultaneous injection.**

TXU Power Response:

On a first order basis, post-LOCA long term cooling will be not impacted by the RSGs, for the following reason: After an LBLOCA, the RCS depressurizes rapidly to near containment pressure and reflood and core quench occur early relative to the time required for the core boric acid concentration to approach its solubility limit. After reflood and core quench the system is in quasi equilibrium. It is during this period that the boric acid concentration begins to increase to significant levels. The RSGs would have no significant effect on the boric acid concentration during this quasi-equilibrium period because the rate of boric acid accumulation is dependent primarily on the boron concentration of the injected SI and the steaming rate in the core.

There would be a second order beneficial effect on post-LOCA long term cooling from the larger primary side volume of the RSGs. This would due to the pre-LOCA RCS inventory, which is a dilution source for the sump boric acid solution. The increased RSG primary side volume would slightly decrease the sump boric acid concentration and therefore would decrease the rate at which boric acid accumulates in the core region. The RSGs even at high tube plugging levels would have a significantly higher primary side volume when compared to the OSGs at no plugging.

Finally, the RSGs have a lower primary side resistance which would have a beneficial effect on the core flooding rate and core liquid region inventory. Increased core liquid region inventory would decrease the boric acid concentration rate of increase in the core.

Regarding the TXU methodology for post-LOCA long term cooling, this part of 10 CFR 50.46 has never been submitted for review before and is not currently described or referenced in the FSAR. Consequently it is not an issue for this LAR. However, TXU participates in a WOG program that is currently developing a comprehensive methodology for post-LOCA long term cooling.

d. The licensee's current LBLOCA methodology is described in ERX-2000-002-P-A, "Revised Large Break Loss of Coolant Accident Analysis Methodology," (Ref. 11). Figures 2.2 and 2.5 describe the nodalization of the RCS, including steam generators. The licensee states that, "Suffice it to reiterate that Figures 2.2 and 2.5 remain unchanged, along with the entire nodalization of the LBLOCA methodology and simply the nodal geometrical information is changed to reflect the Δ76 rather than the D-4 steam generators." Explain what evidence provides reasonable assurance that merely revising the nodal geometrical information is sufficient to ensure the revised model will accurately reproduce Δ76 steam generator conditions at CPSES Unit 1.

TXU Power Response:

The Δ76 nodes were verified to remain within the parameters of applicability of all conservation and constitutive equations (correlations). Revising the nodal geometrical information is simply another way of stating that the same nodalization applied to the OSG is applied to the RSG. In any case, due to the nature of the transient, the steam generator nodalization has negligible, if any, impact on the large break LOCA. The RCS depletion is simply too fast and the secondary is thermally decoupled from the primary almost immediately after the break.

III. NRC RAI REFERENCES

1. TXU Power, letter dated February 17, 2005 from Mike Blevins, Senior Vice President & Chief Nuclear Officer to USNRC, re: Comanche Peak Steam Electric Station (CPSES), Docket No. 50-445, Request for review of Previously Submitted Licensee Topical Reports
2. TXU Power, letter dated January 25, 2005 from Mike Blevins, Senior Vice President & Chief Nuclear Officer to USNRC, re: "Comanche Peak Steam Electric Station (CPSES), Docket No. 50-445, Submittal of TXU Power's Application of Non-LOCA Transient Analysis Methodologies to a Feed Ring Steam Generator Design, Topical Report #ERX-04-005, revision 0."
3. TXU Power, letter dated January 25, 2005 from Mike Blevins, Senior Vice President & Chief Nuclear Officer to USNRC, re: "Comanche Peak Steam Electric Station (CPSES), Docket No. 50-445, Submittal of Supplement to the CPSES Loss of Coolant Accident (LOCA) Analysis Methodologies - Topical Report #ERX-04-004, revision 0."
4. RXE-91-001-A, "Transient Analysis Methods for Comanche Peak Steam Electric Station Licensing Applications," October 1993.
5. RXE-91-005-A, "Methodology for Reactor Core Response to Steamline Break Events," February 1994.
6. RXE-94-001-A, "Safety Analysis of Postulated Inadvertent Boron Dilution Event in Modes 3, 4, and 5," February 1994.
7. RXE-91-002-A, "Reactivity Anomaly Events Methodology," October 1993.
8. GL 83-11, Licensee Qualification for Performing Safety Analysis in Support of Licensing Actions.
9. WCAP-14882-P-A, "RETRAN-02 Modeling and Qualification for Westinghouse Pressurized Water Reactor Non-LOCA Safety Analysis."
10. TXU Electric's RXE-95-001-P-A, "Small Break Loss of Coolant Accident Analysis Methodology," September 1996.
11. ERX-2000-002-P-A, "Revised Large Break Loss of Coolant Accident Analysis Methodology," March 2000.
12. ERX-2001-005-N-P, "ZIRLO™ Cladding and Boron Coating Models for TXU Energy's Loss of Coolant Accident Analysis Methodologies," September 2002.

IV. COMPLETE SETS OF PLOTS FOR ADDITIONAL CALCULATIONS

This section contains "complete sets" of plots for the 3", 4" and 5" breaks as well as for all the additional cases run in connection with this RAI. Each "complete set" of plots is comprised of the variables that were plotted for the submittal (Reference [3]) as well as the additional variables requested in Q.7.a. Specifically, the plots provided in this section are:

A-1 Primary and Secondary System Pressures B 3-in Break
A-2 Hot Assembly Region Void Fractions B 3-in Break
A-3 Central Core Region Void Fractions B 3-in Break
A-4 Average Core Region Void Fractions B 3-in Break
A-5 Upper Plenum Liquid Fraction B 3-in Break
A-6 Hot Assembly Collapsed Water Level B 3-in Break
A-7 Hot Assembly Clad Temperatures B 3-in Break
A-8 Loop Seal Void Fractions B 3-in Break
A-9 Accumulator Mass Flow Rates B 3-in Break
A-10 Break Flow Rate B 3-in Break
A-11 Total Pumped ECCS Flow Rate B 3-in Break
A-12 TOODEE2 Clad Temperature B 3-in Break
A-13 Core Mixture Level B 3-in Break
A-14 Downcomer Liquid Level B 3-in Break
A-15 Hot Assembly Steam Temperatures B 3-in Break
A-16 Hot Assembly Heat Transfer Coefficients B 3-in Break
A-17 Condensation Rate in Cold Leg Discharge B 3-in Break
A-18 Break Quality B 3-in Break

B-1 Primary and Secondary System Pressures B 4-in Break
B-2 Hot Assembly Region Void Fractions B 4-in Break
B-3 Central Core Region Void Fractions B 4-in Break
B-4 Average Core Region Void Fractions B 4-in Break
B-5 Upper Plenum Liquid Fraction B 4-in Break
B-6 Hot Assembly Collapsed Water Level B 4-in Break
B-7 Hot Assembly Clad Temperatures B 4-in Break
B-8 Loop Seal Void Fractions B 4-in Break
B-9 Accumulator Mass Flow Rates B 4-in Break
B-10 Break Flow Rate B 4-in Break
B-11 Total Pumped ECCS Flow Rate B 4-in Break
B-12 TOODEE2 Clad Temperature B 4-in Break
B-13 Core Mixture Level B 4-in Break
B-14 Downcomer Liquid Level B 4-in Break
B-15 Hot Assembly Steam Temperatures B 4-in Break
B-16 Hot Assembly Heat Transfer Coefficients B 4-in Break
B-17 Condensation Rate in Cold Leg Discharge B 4-in Break
B-18 Break Quality B 4-in Break

G-13 Core Mixture Level B 6-in Break (no BL SI)
G-14 Downcomer Liquid Level B 6-in Break (no BL SI)
G-15 Hot Assembly Steam Temperatures B 6-in Break (no BL SI)
G-16 Hot Assembly Heat Transfer Coefficients B 6-in Break (no BL SI)
G-17 Condensation Rate in Cold Leg Discharge B 6-in Break (no BL SI)
G-18 Break Quality B 6-in Break (no BL SI)

H-1 Primary and Secondary System Pressures B 4-in Break (Only broken LS cleared)
H-2 Hot Assembly Region Void Fractions B 4-in Break (Only broken LS cleared)
H-3 Central Core Region Void Fractions B 4-in Break (Only broken LS cleared)
H-4 Average Core Region Void Fractions B 4-in Break (Only broken LS cleared)
H-5 Upper Plenum Liquid Fraction B 4-in Break (Only broken LS cleared)
H-6 Hot Assembly Collapsed Water Level B 4-in Break (Only broken LS cleared)
H-7 Hot Assembly Clad Temperatures B 4-in Break (Only broken LS cleared)
H-8 Loop Seal Void Fractions B 4-in Break (Only broken LS cleared)
H-9 Accumulator Mass Flow Rates B 4-in Break (Only broken LS cleared)
H-10 Break Flow Rate B 4-in Break (Only broken LS cleared)
H-11 Total Pumped ECCS Flow Rate B 4-in Break (Only broken LS cleared)
H-12 TOODEE2 Clad Temperature B 4-in Break (Only broken LS cleared)
H-13 Core Mixture Level B 4-in Break (Only broken LS cleared)
H-14 Downcomer Liquid Level B 4-in Break (Only broken LS cleared)
H-15 Hot Assembly Steam Temperatures B 4-in Break (Only broken LS cleared)
H-16 Hot Assembly Heat Transfer Coefficients B 4-in Break (Only broken LS cleared)
H-17 Condensation Rate in Cold Leg Discharge B 4-in Break (Only broken LS cleared)
H-18 Break Quality B 4-in Break (Only broken LS cleared)

I-1 Primary and Secondary System Pressures B 4-in Break (No HL Leakage Path)
I-2 Hot Assembly Region Void Fractions B 4-in Break (No HL Leakage Path)
I-3 Central Core Region Void Fractions B 4-in Break (No HL Leakage Path)
I-4 Average Core Region Void Fractions B 4-in Break (No HL Leakage Path)
I-5 Upper Plenum Liquid Fraction B 4-in Break (No HL Leakage Path)
I-6 Hot Assembly Collapsed Water Level B 4-in Break (No HL Leakage Path)
I-7 Hot Assembly Clad Temperatures B 4-in Break (No HL Leakage Path)
I-8 Loop Seal Void Fractions B 4-in Break (No HL Leakage Path)
I-9 Accumulator Mass Flow Rates B 4-in Break (No HL Leakage Path)
I-10 Break Flow Rate B 4-in Break (No HL Leakage Path)
I-11 Total Pumped ECCS Flow Rate B 4-in Break (No HL Leakage Path)
I-12 TOODEE2 Clad Temperature B 4-in Break (No HL Leakage Path)
I-13 Core Mixture Level B 4-in Break (No HL Leakage Path)
I-14 Downcomer Liquid Level B 4-in Break (No HL Leakage Path)
I-15 Hot Assembly Steam Temperatures B 4-in Break (No HL Leakage Path)
I-16 Hot Assembly Heat Transfer Coefficients B 4-in Break (No HL Leakage Path)
I-17 Condensation Rate in Cold Leg Discharge B 4-in Break (No HL Leakage Path)
I-18 Break Quality B 4-in Break (No HL Leakage Path)

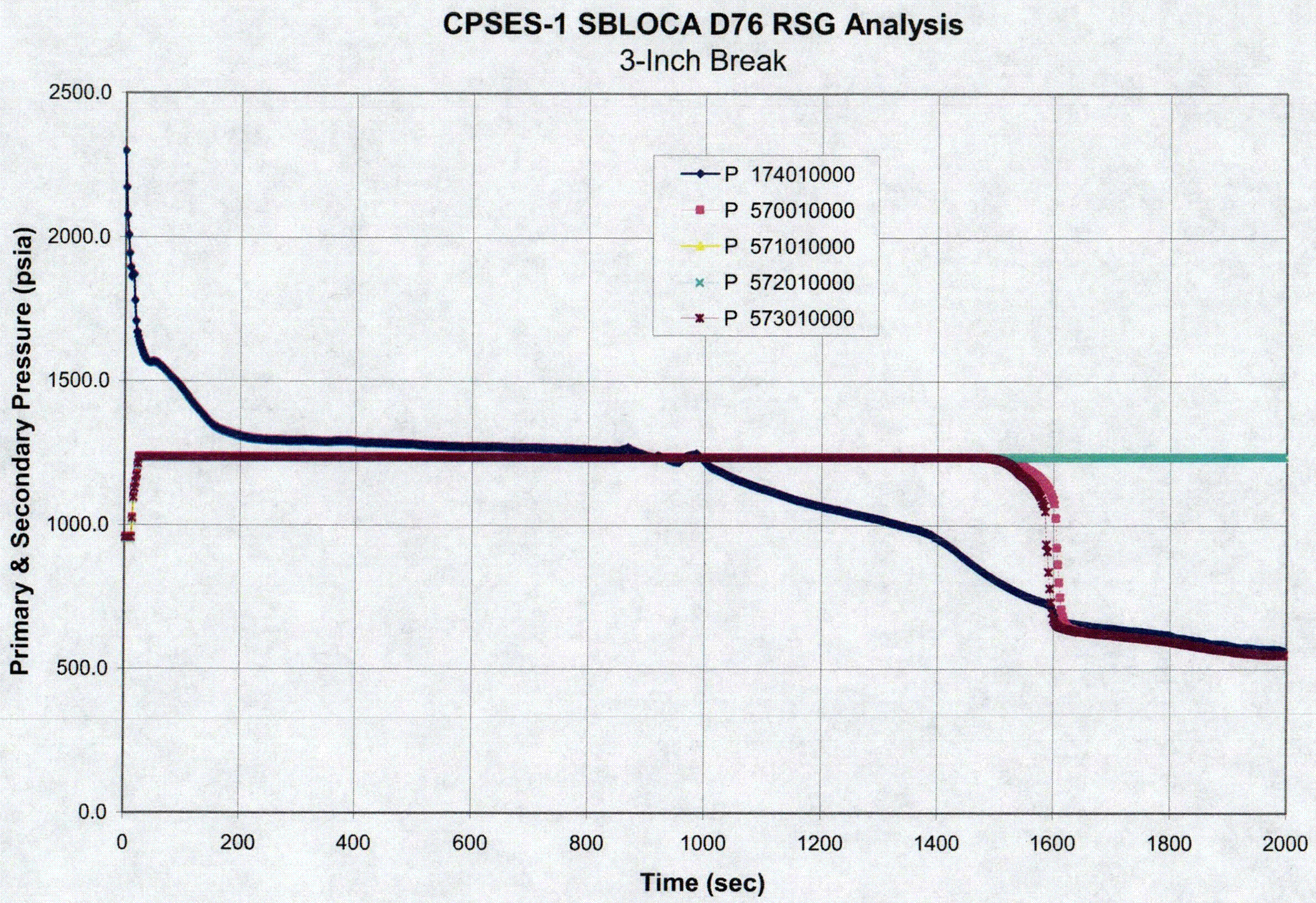

Figure A-1 Primary and Secondary System Pressures – 3-in Break

C01

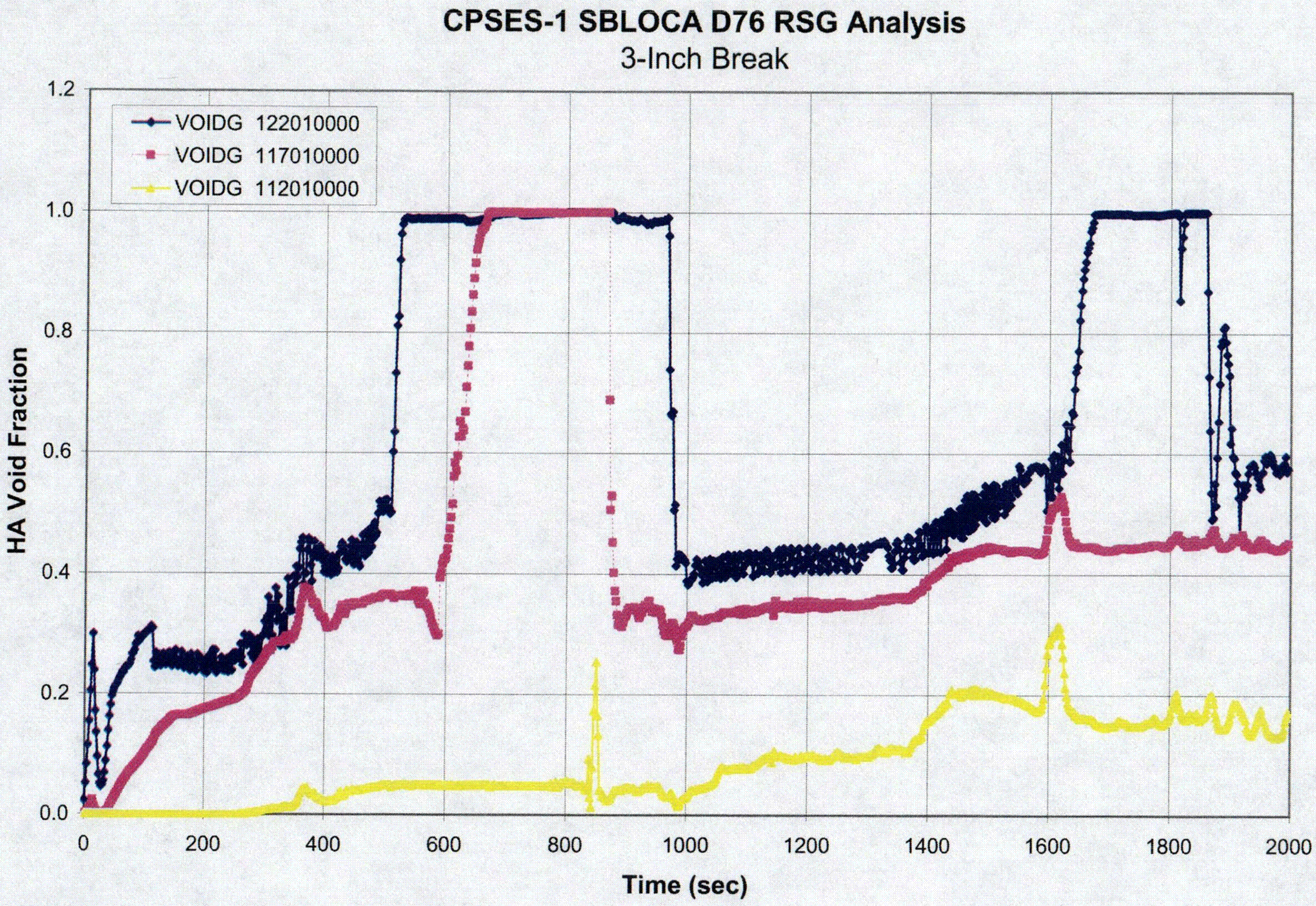

Figure A-2 Hot Assembly Region Void Fractions – 3-in Break

C02

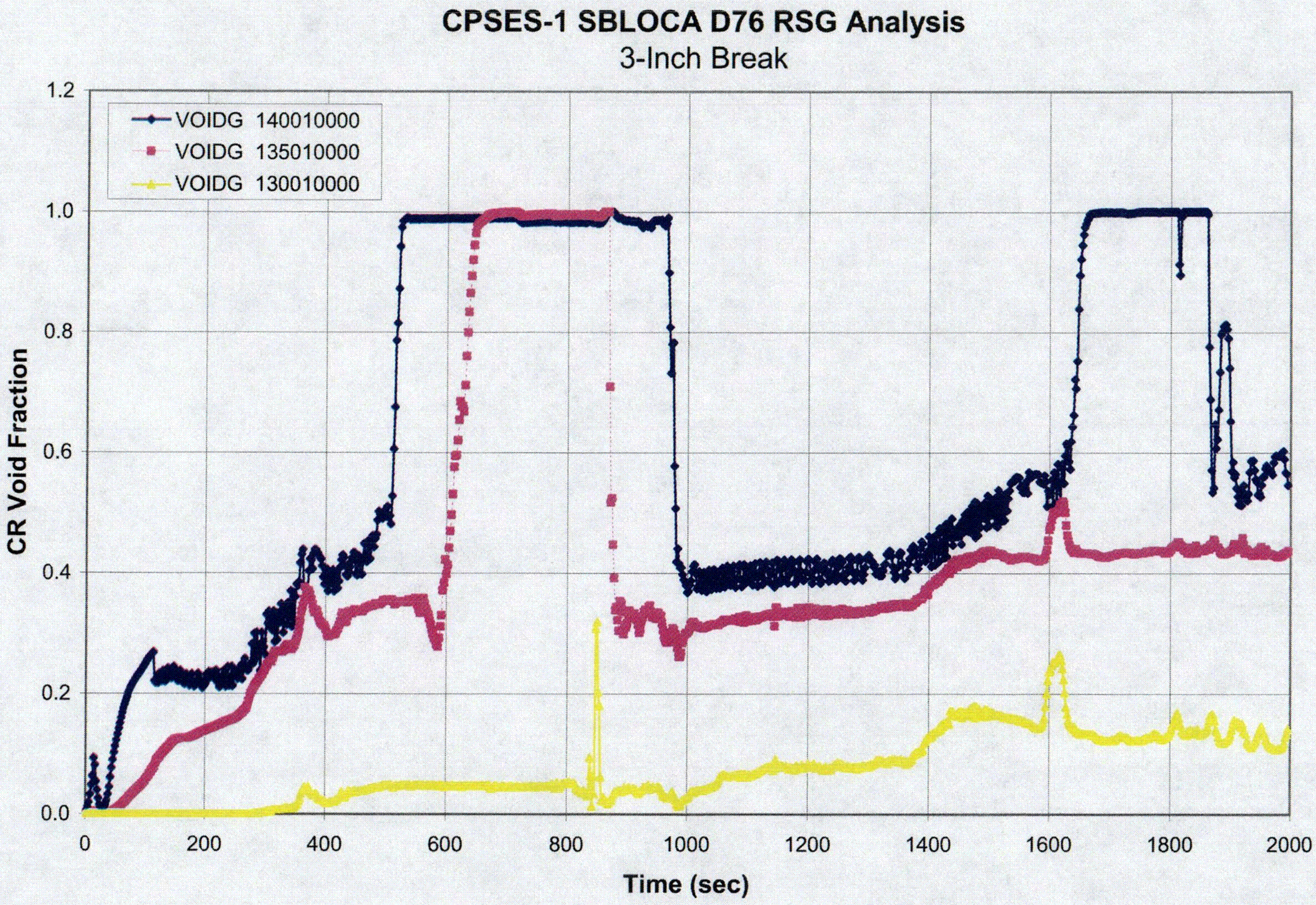

Figure A-3 Central Core Region Void Fractions – 3-in Break

C03

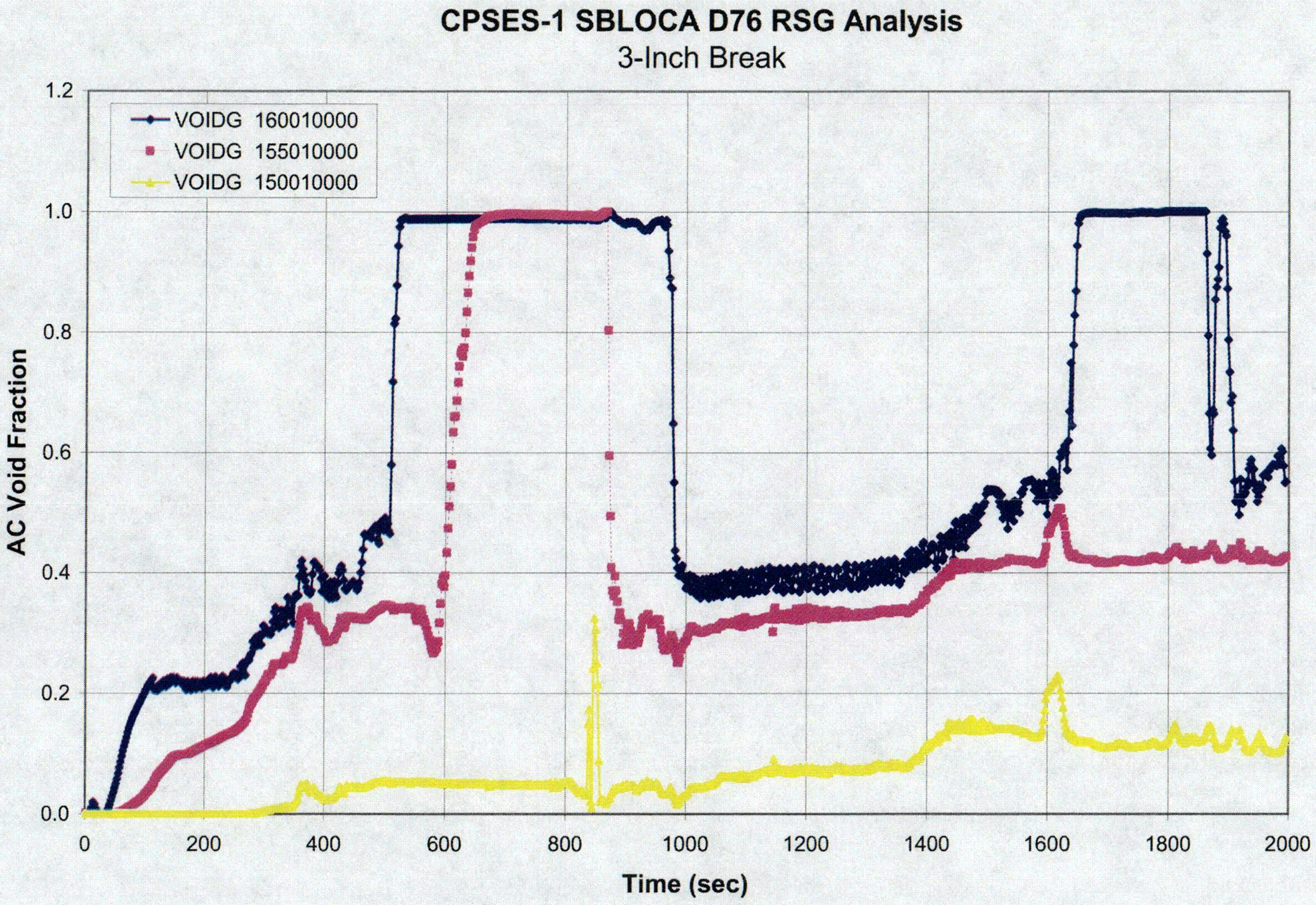

Figure A-4 Average Core Region Void Fractions – 3-in Break

COF

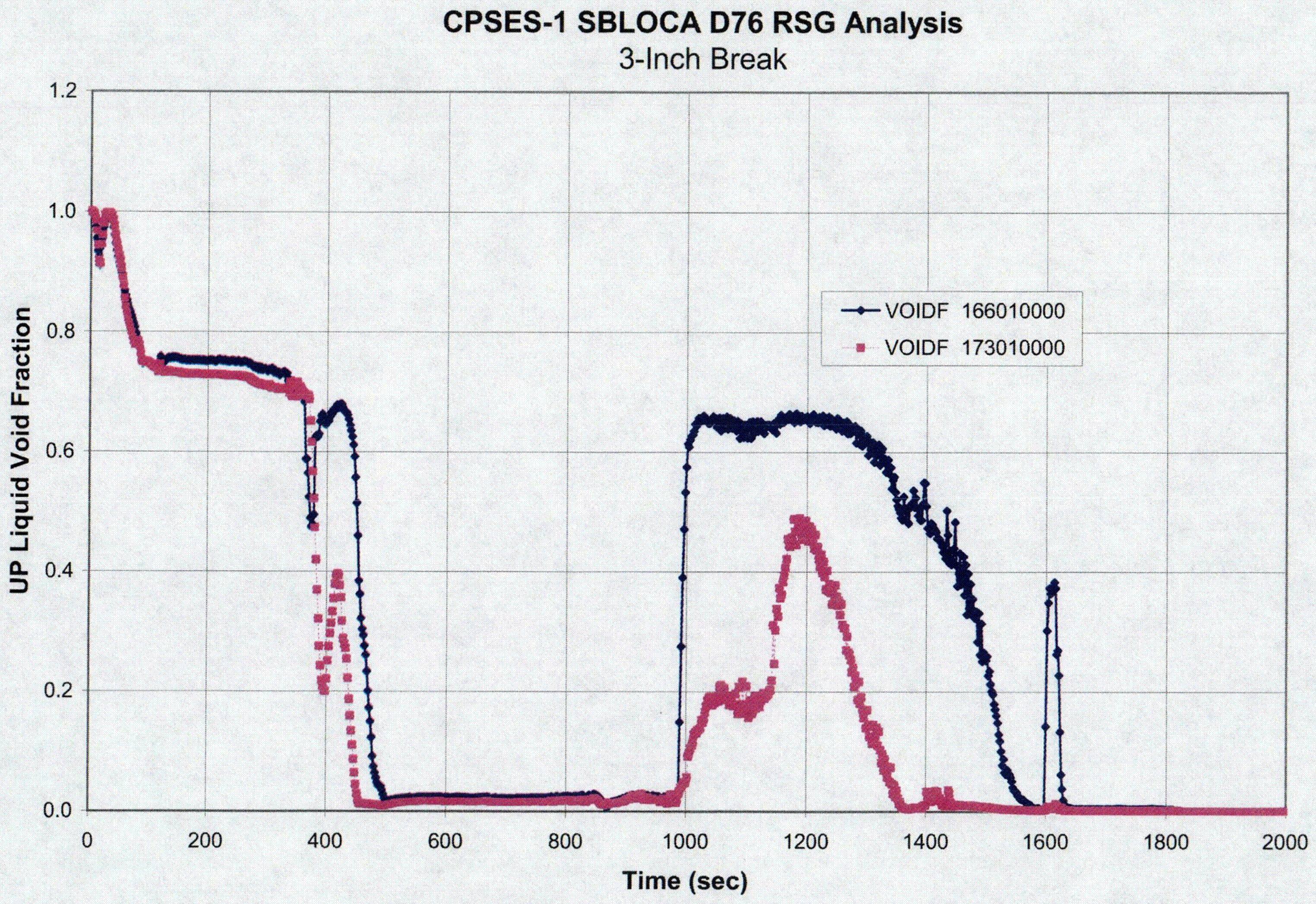

Figure A-5 Upper Plenum Liquid Fraction – 3-in Break

C05

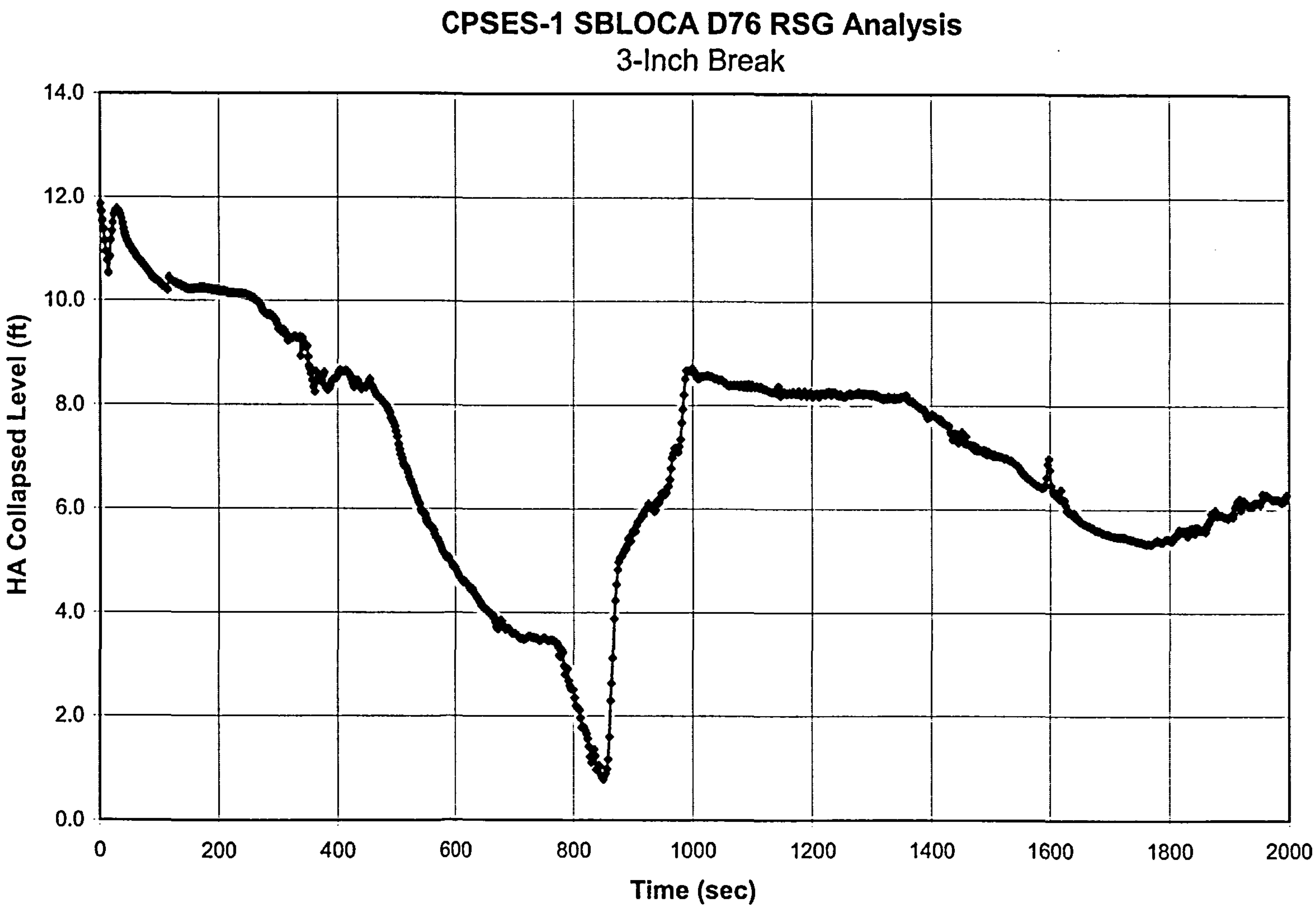

Figure A-6 Hot Assembly Collapsed Water Level – 3-in Break

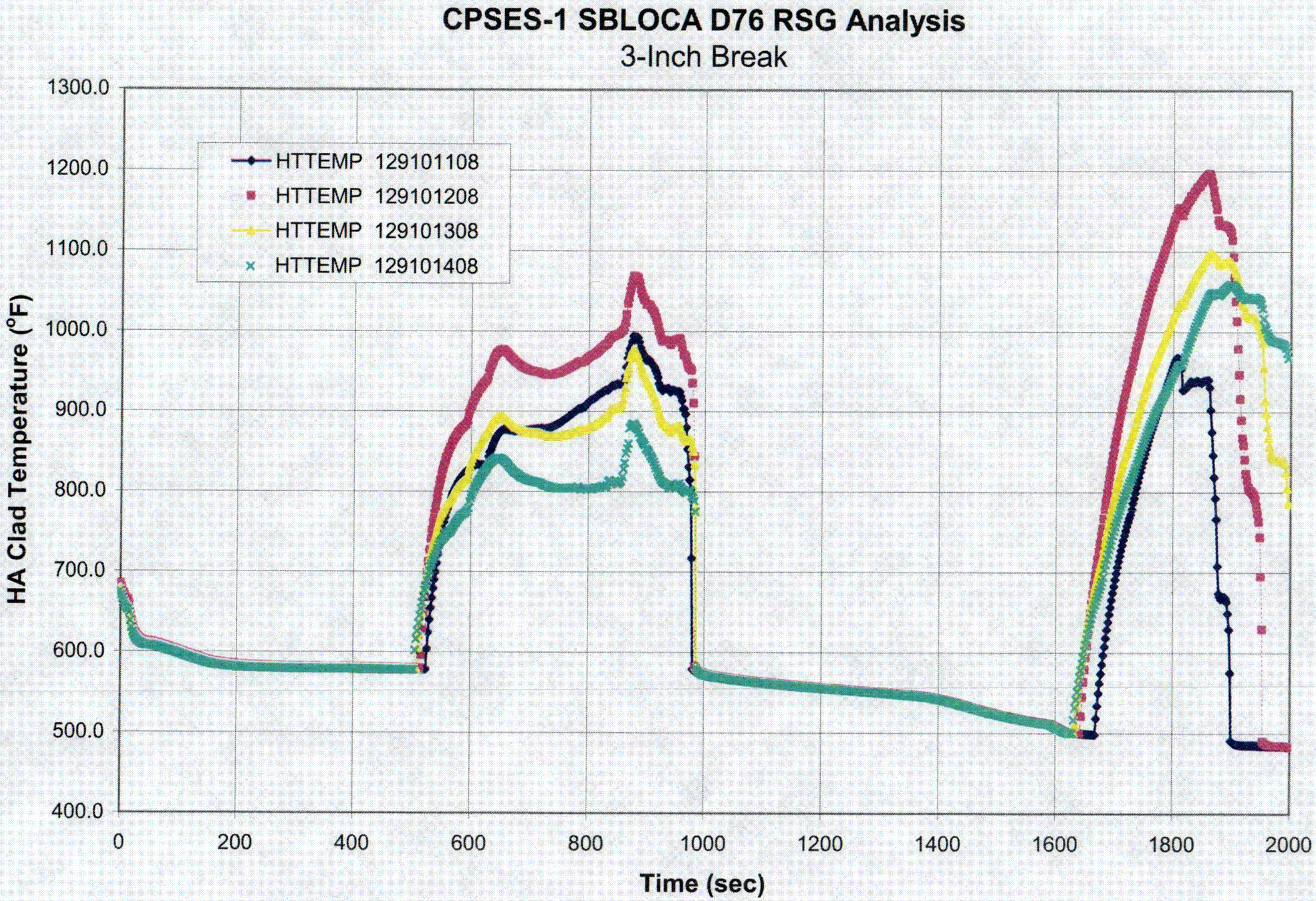

Figure A-7 Hot Assembly Clad Temperatures – 3-in Break

coe

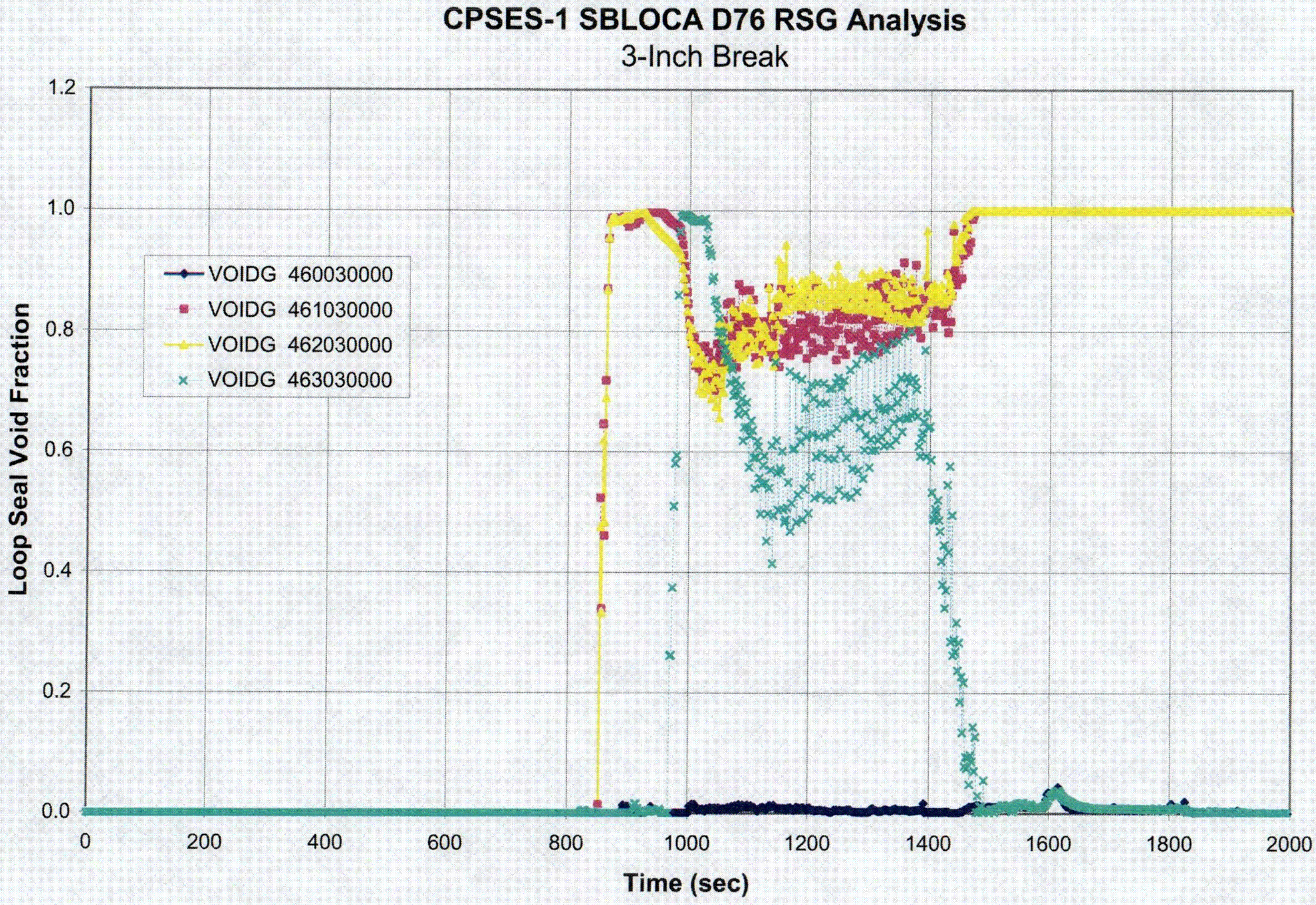

Figure A-8 Loop Seal Void Fractions – 3-in Break

C07

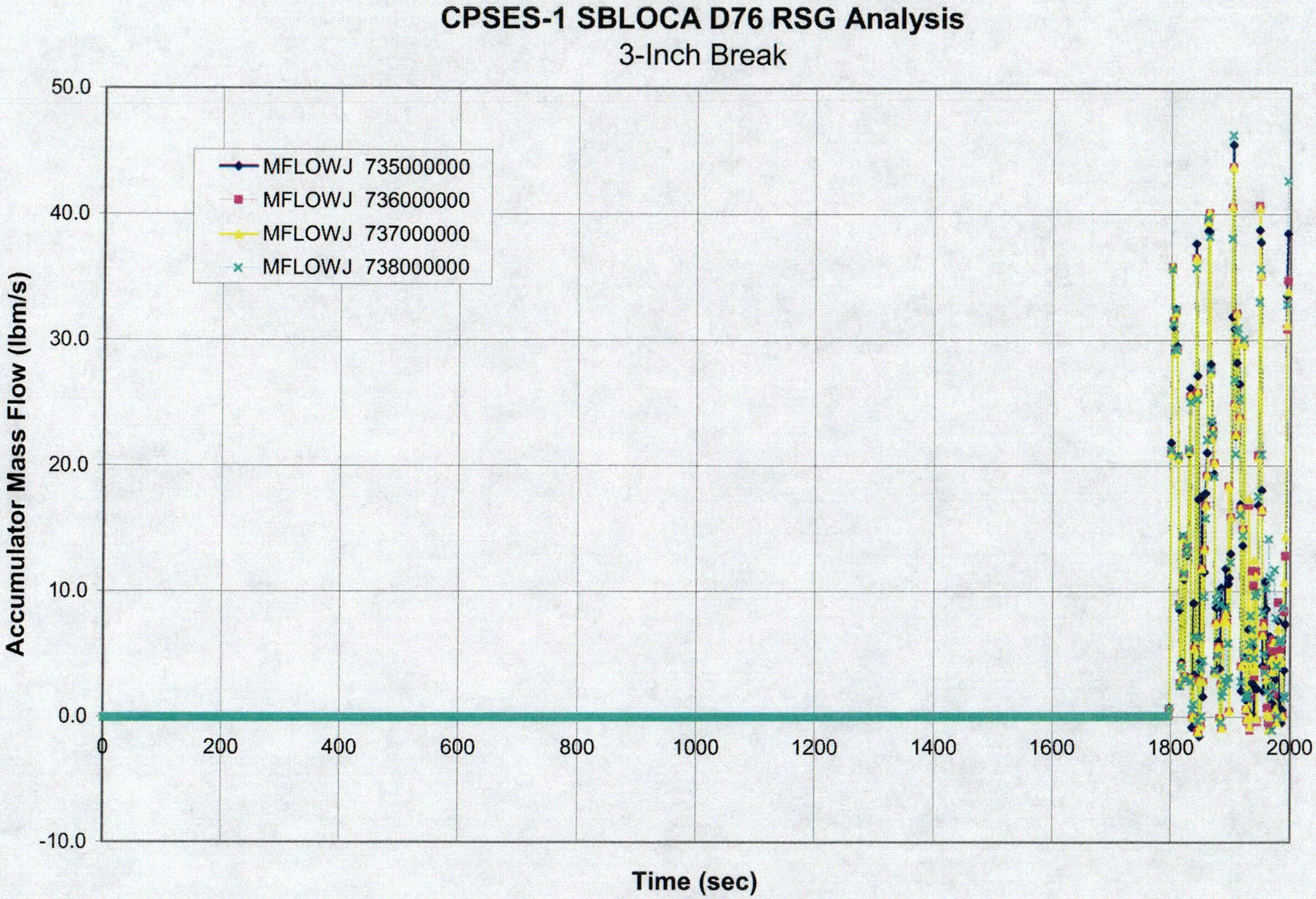

Figure A-9 Accumulator Mass Flow Rates – 3-in Break

C08

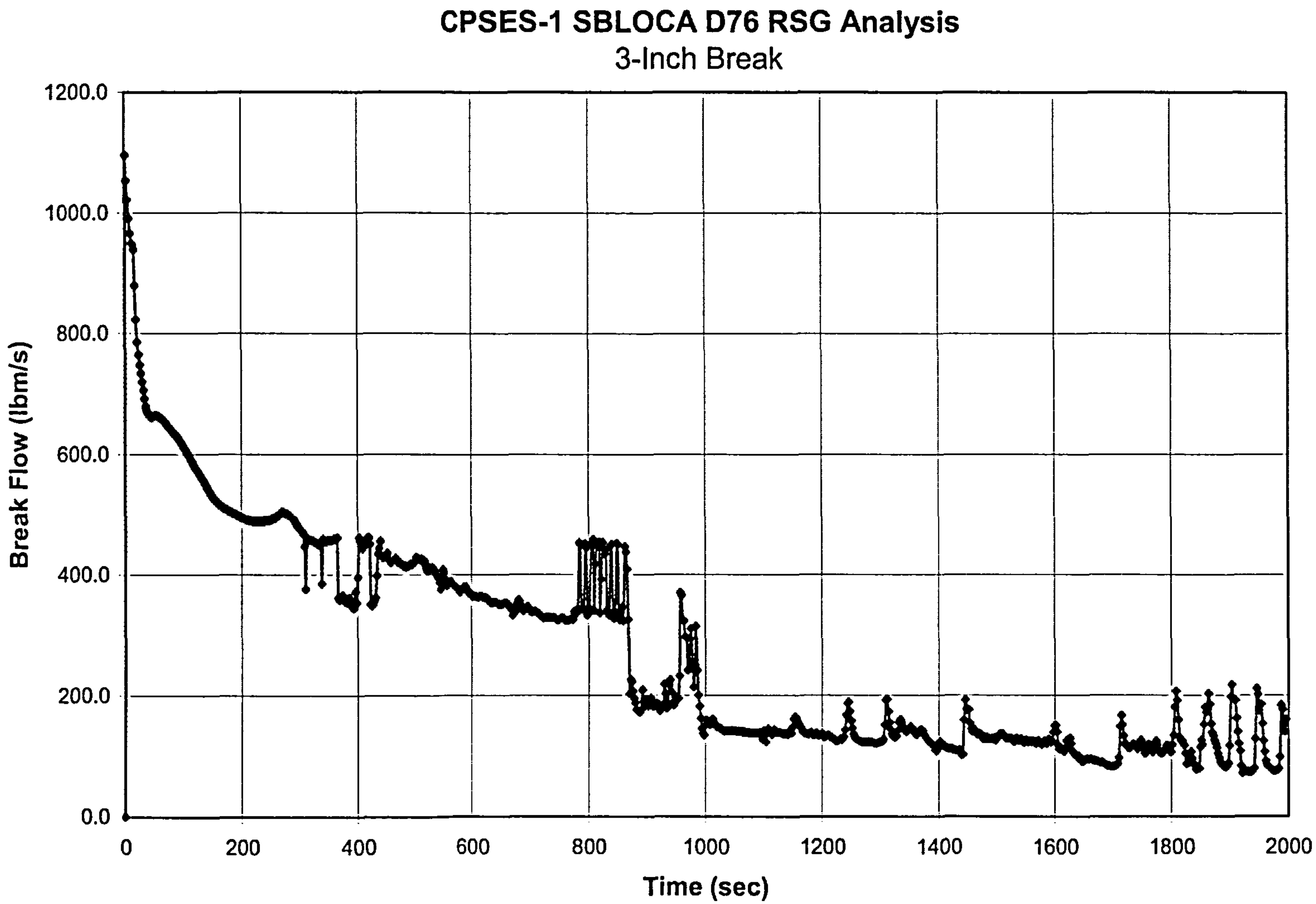

Figure A-10 Break Flow Rate – 3-in Break

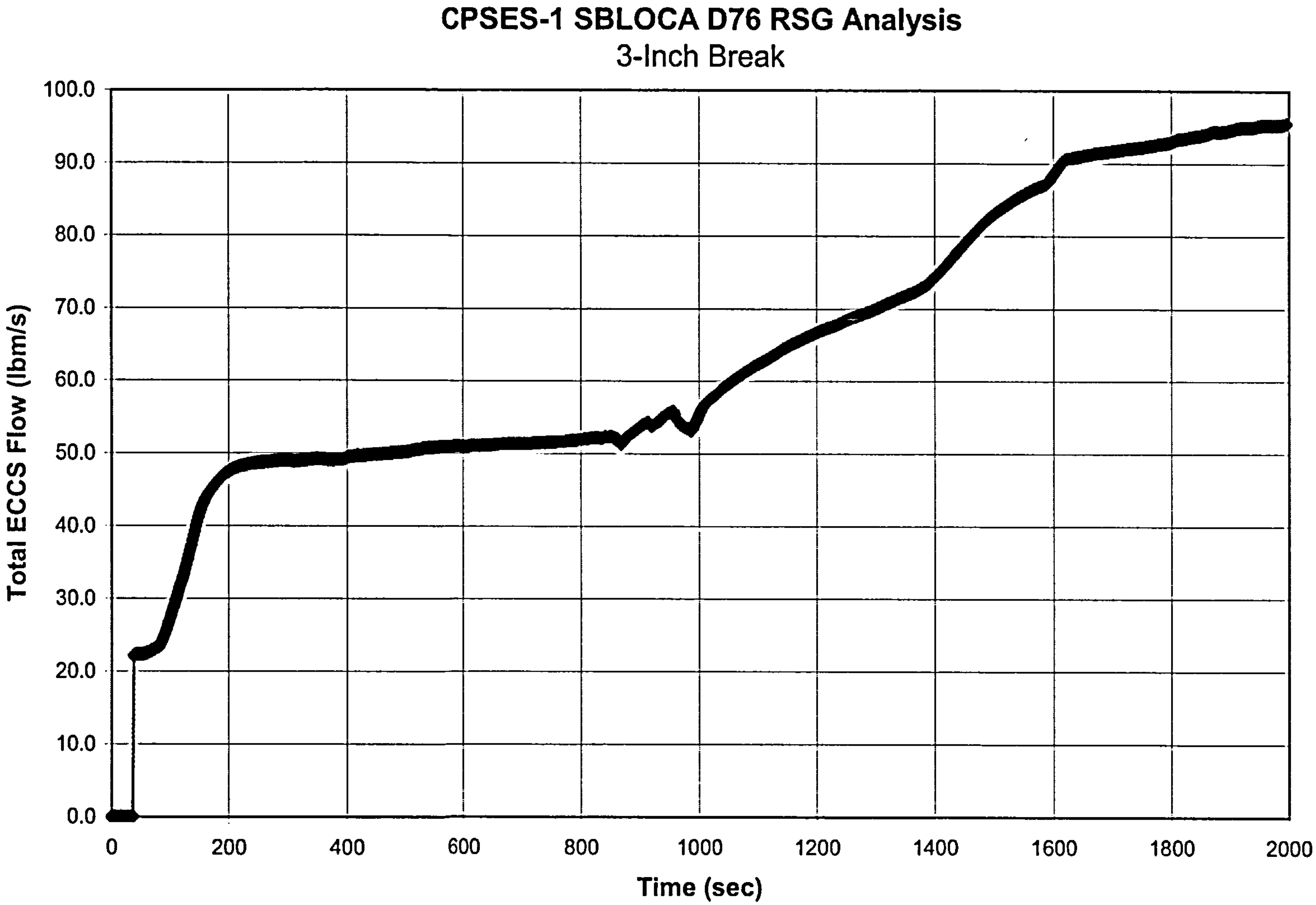

Figure A-11 Total Pumped ECCS Flow Rate – 3-in Break

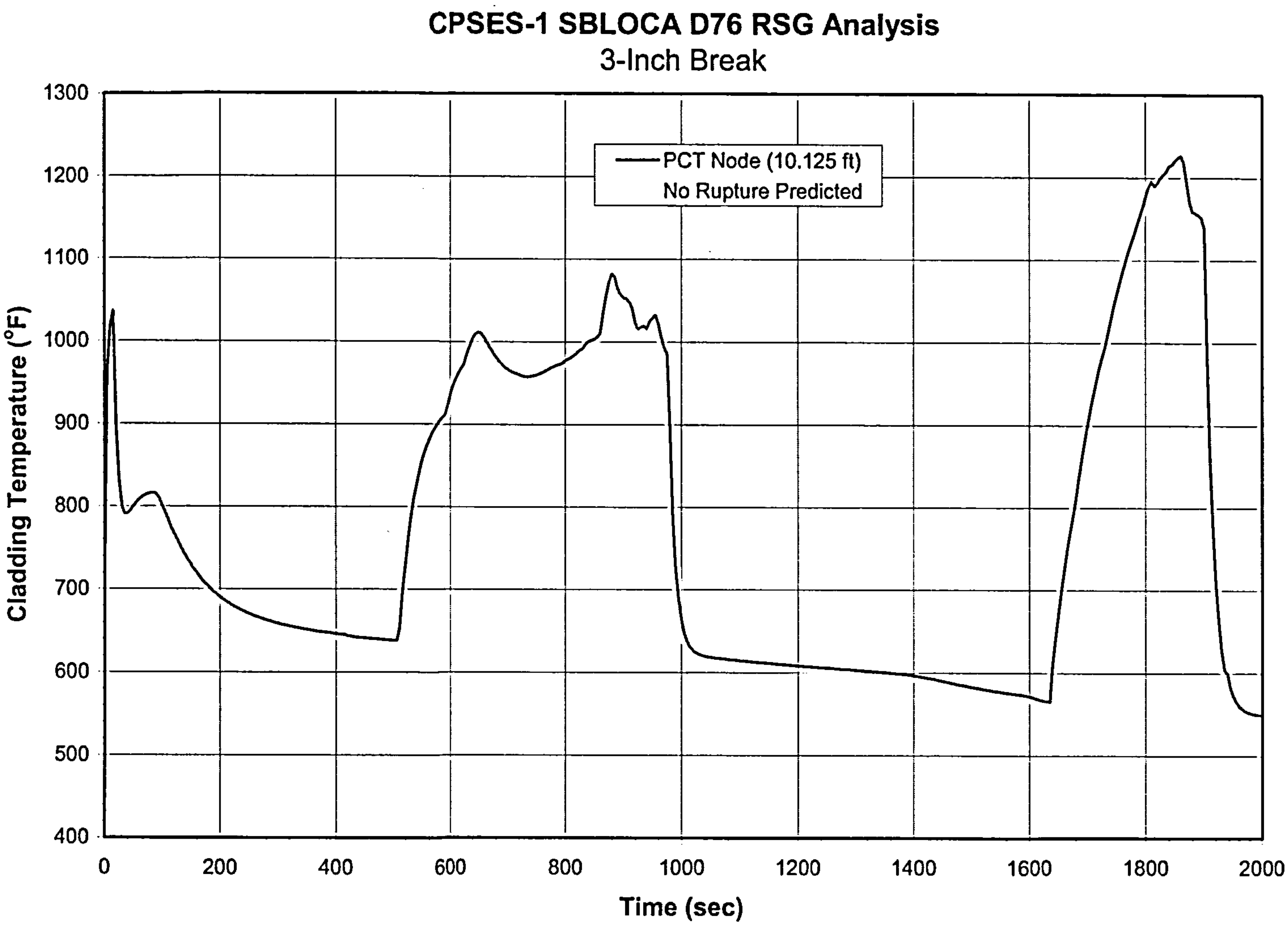

Figure A-12 TOODEE2 Clad Temperature – 3-in Break

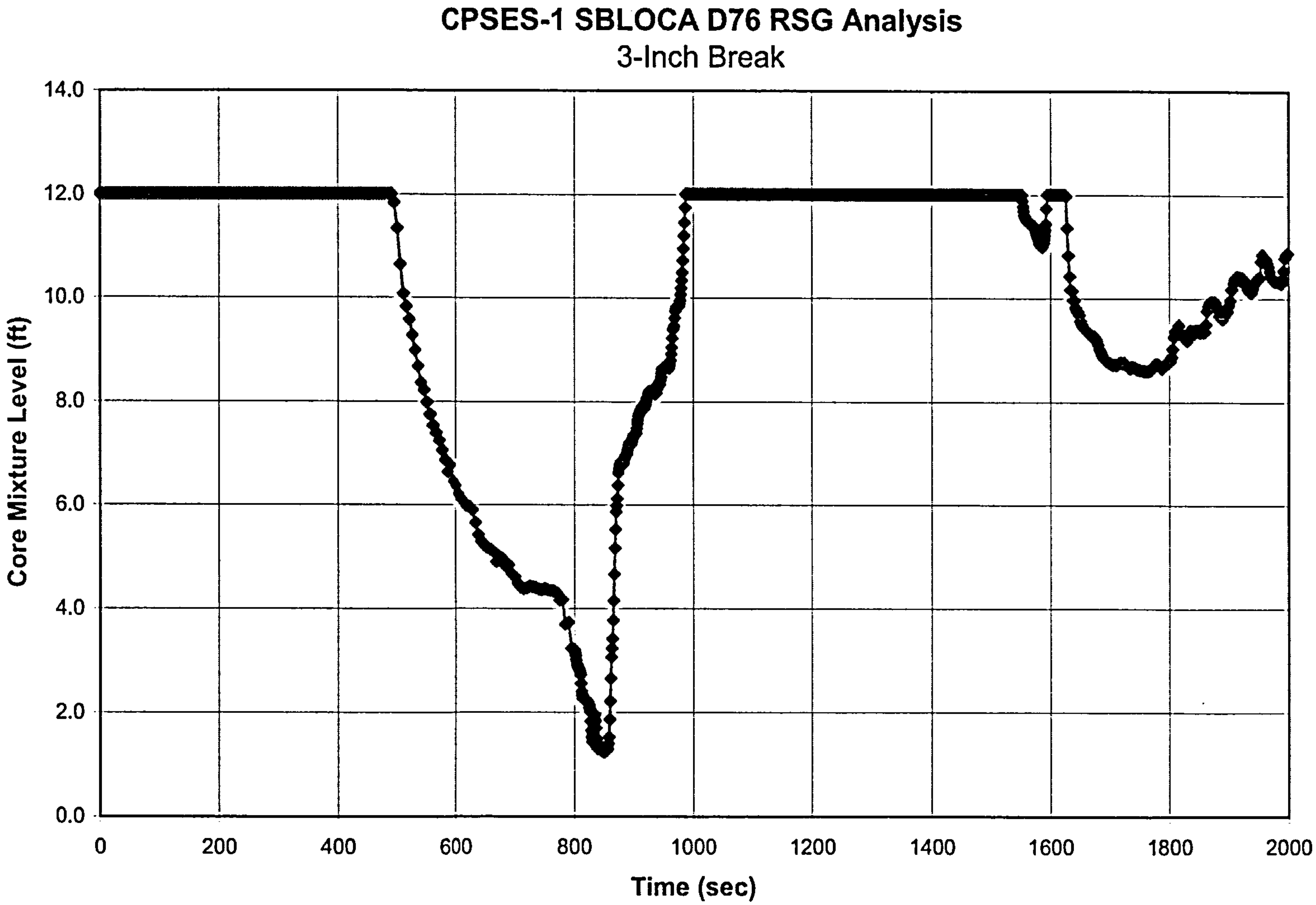

Figure A-13 Core Mixture Level – 3-in Break

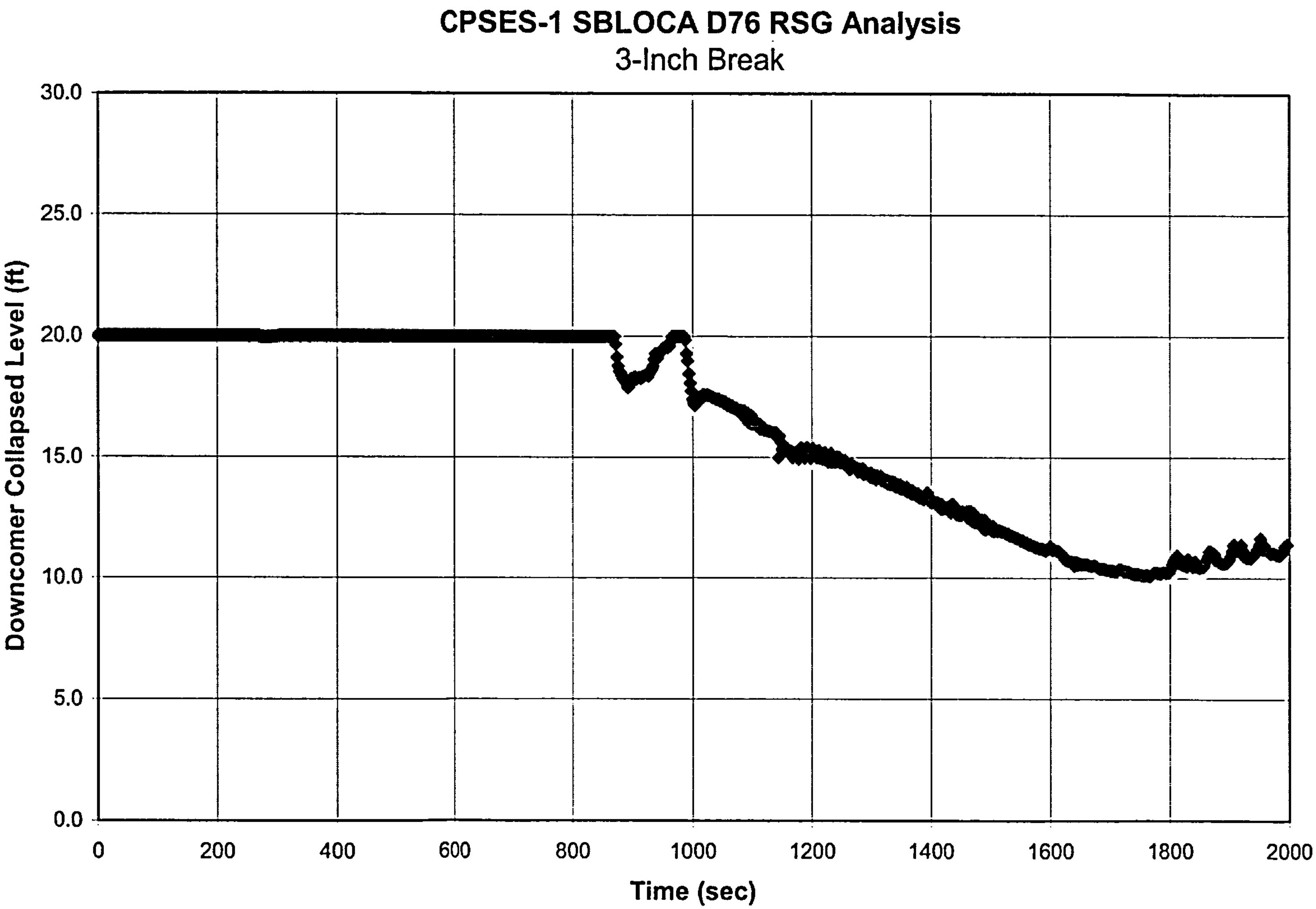

Figure A-14 Downcomer Liquid Level – 3-in Break

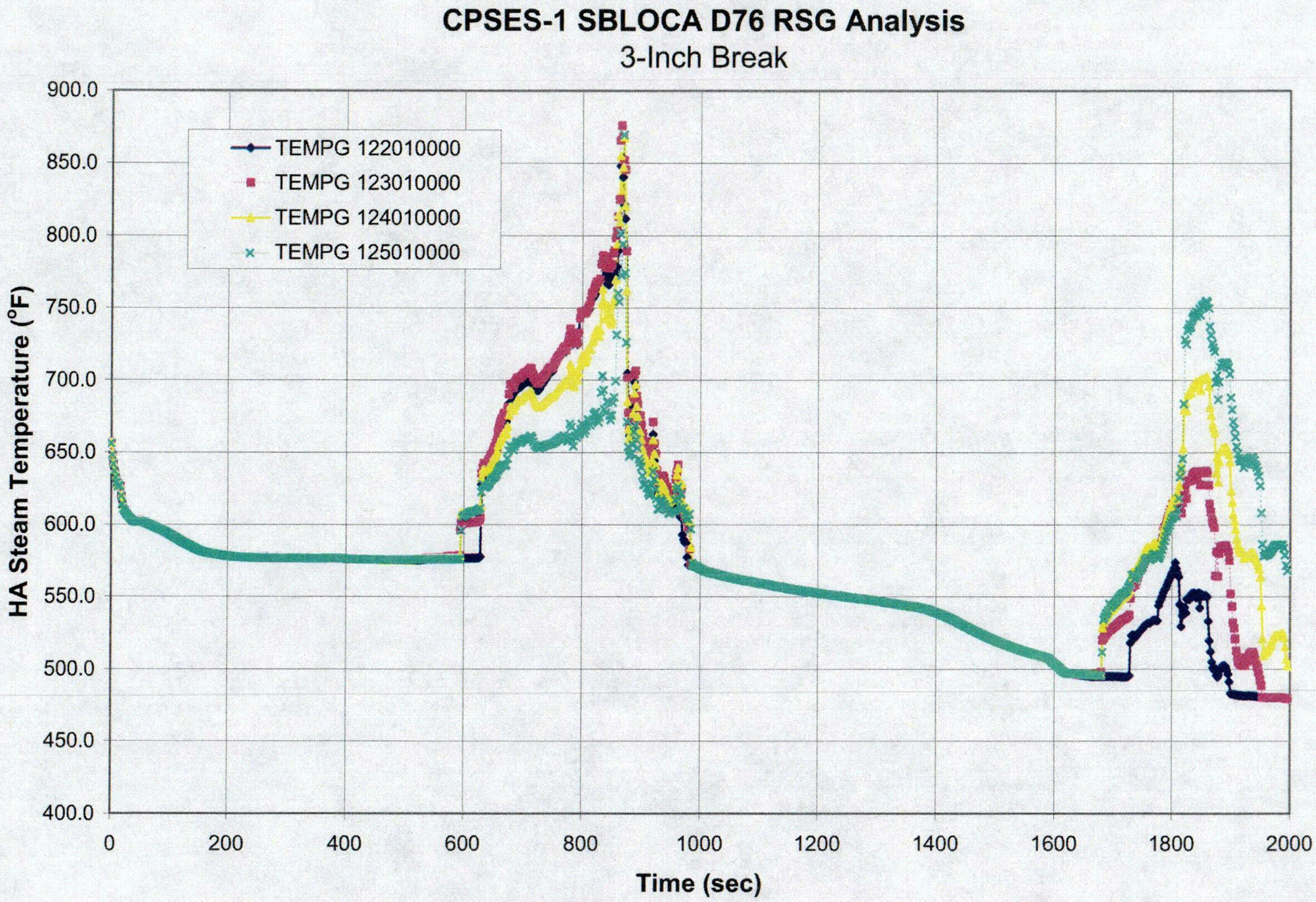

Figure A-15 Hot Assembly Steam Temperatures – 3-in Break

C09

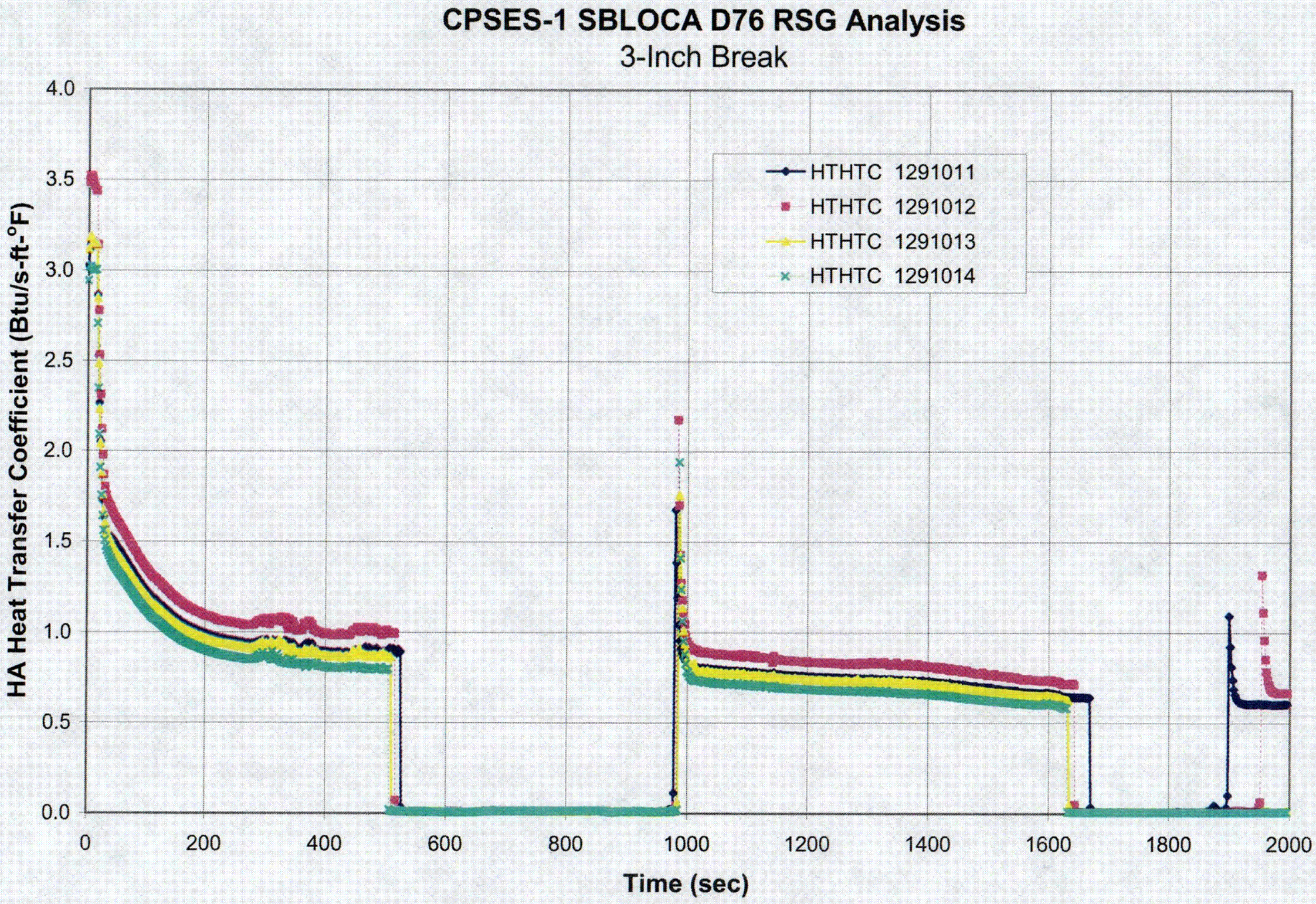

Figure A-16 Hot Assembly Heat Transfer Coefficients – 3-in Break

C10

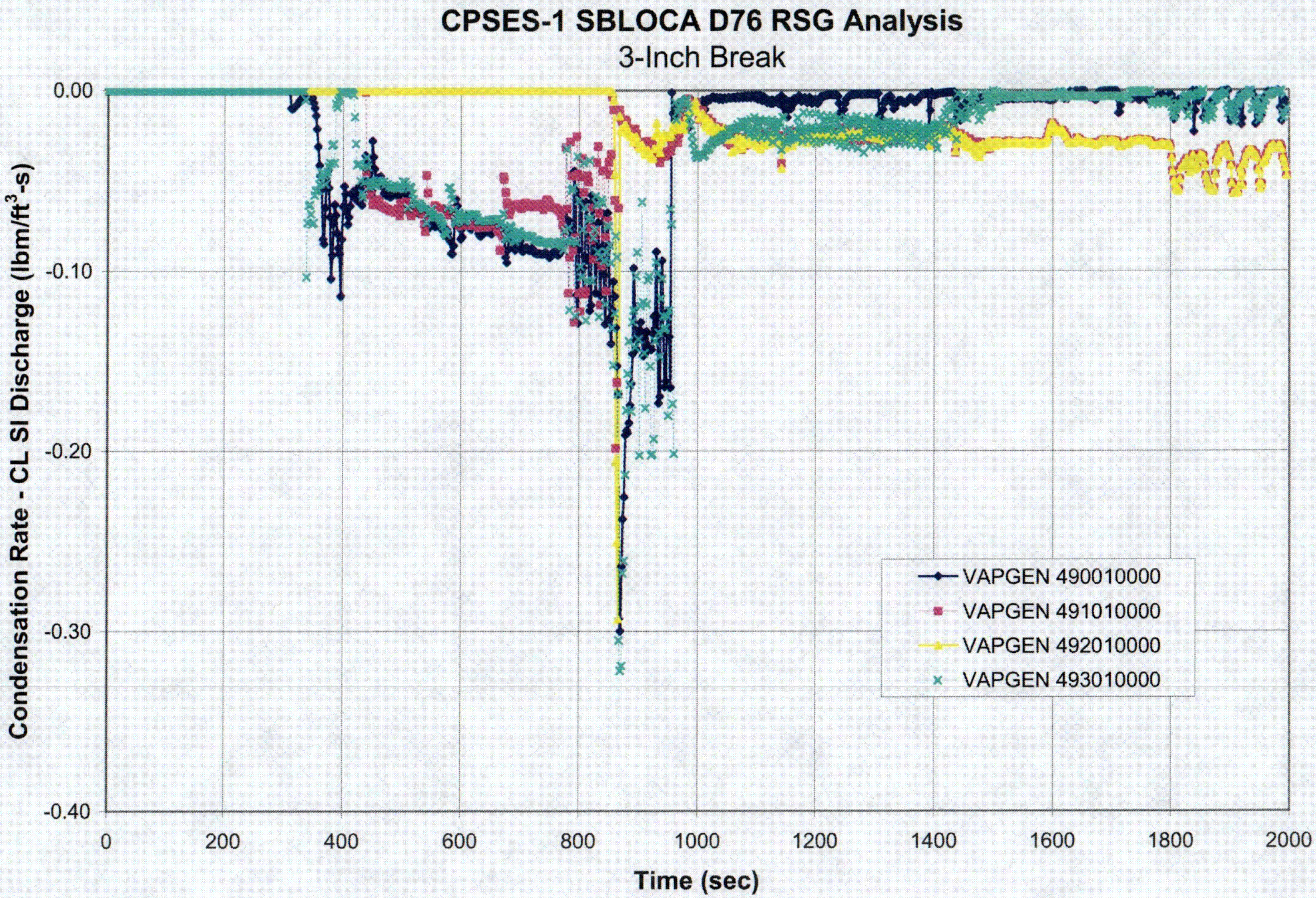

Figure A-17 Condensation Rate in Cold Leg Discharge – 3-in Break

C15

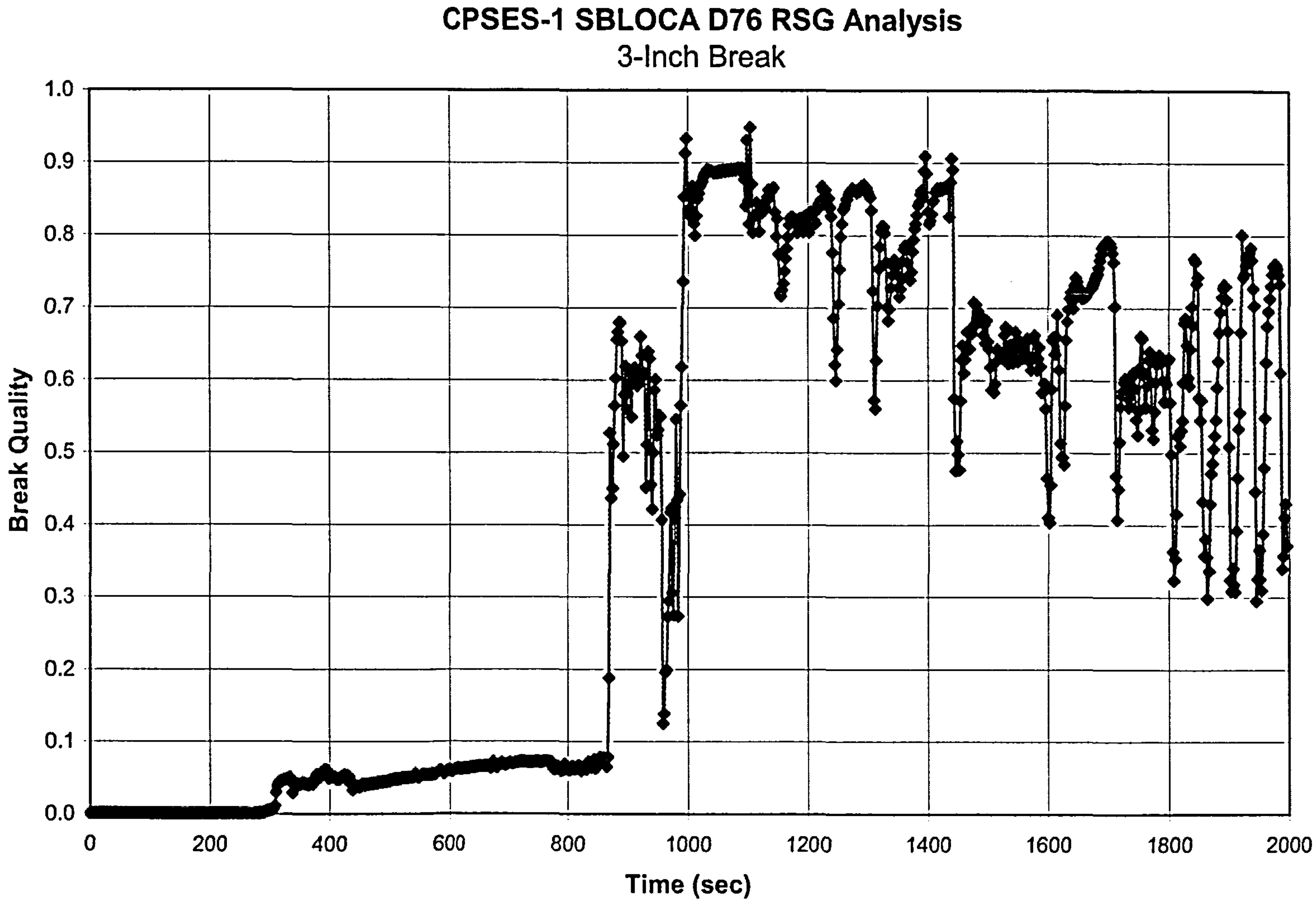

Figure A-18 Break Quality – 3-in Break

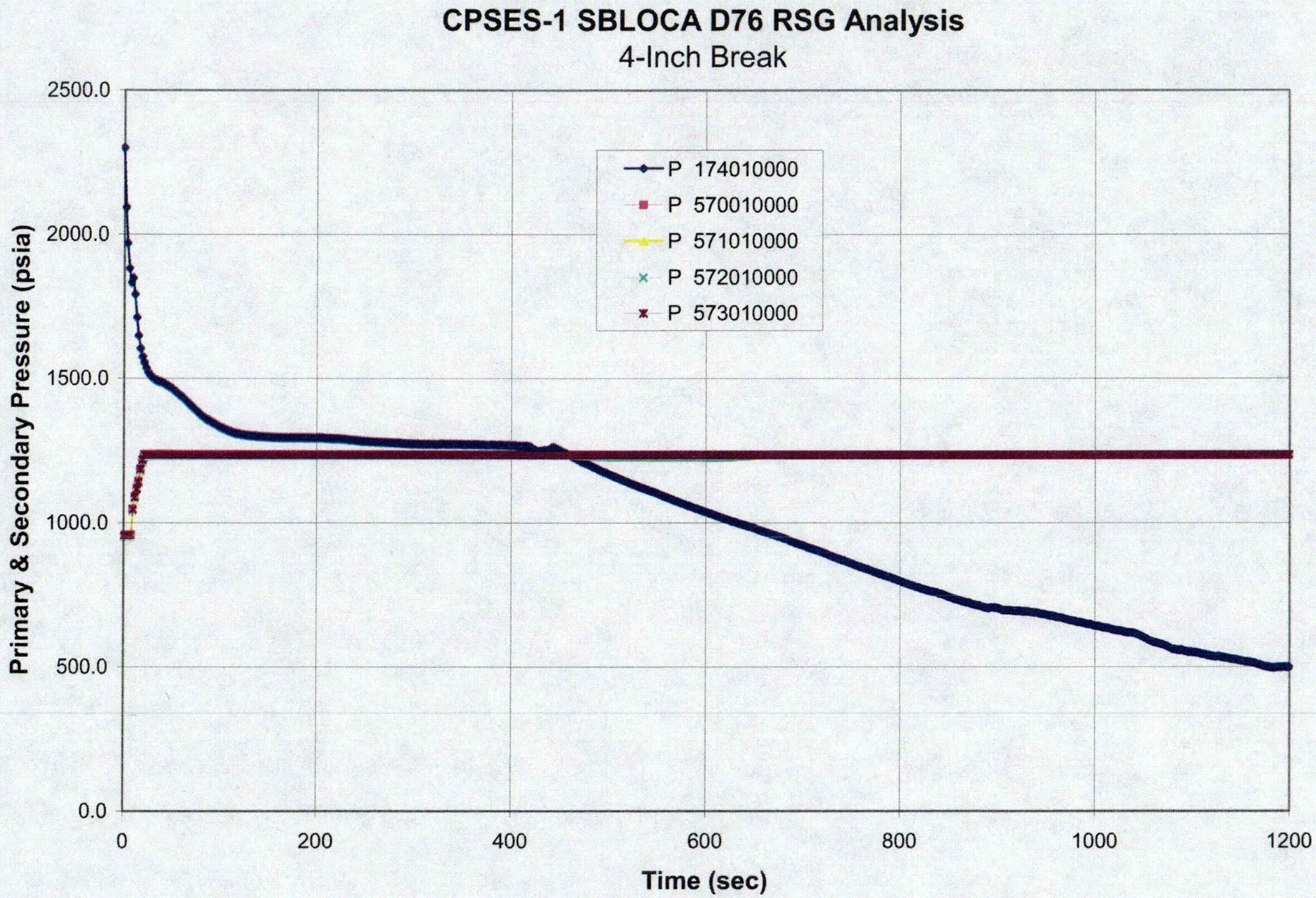

Figure B-1 Primary and Secondary System Pressures – 4-in Break

C12

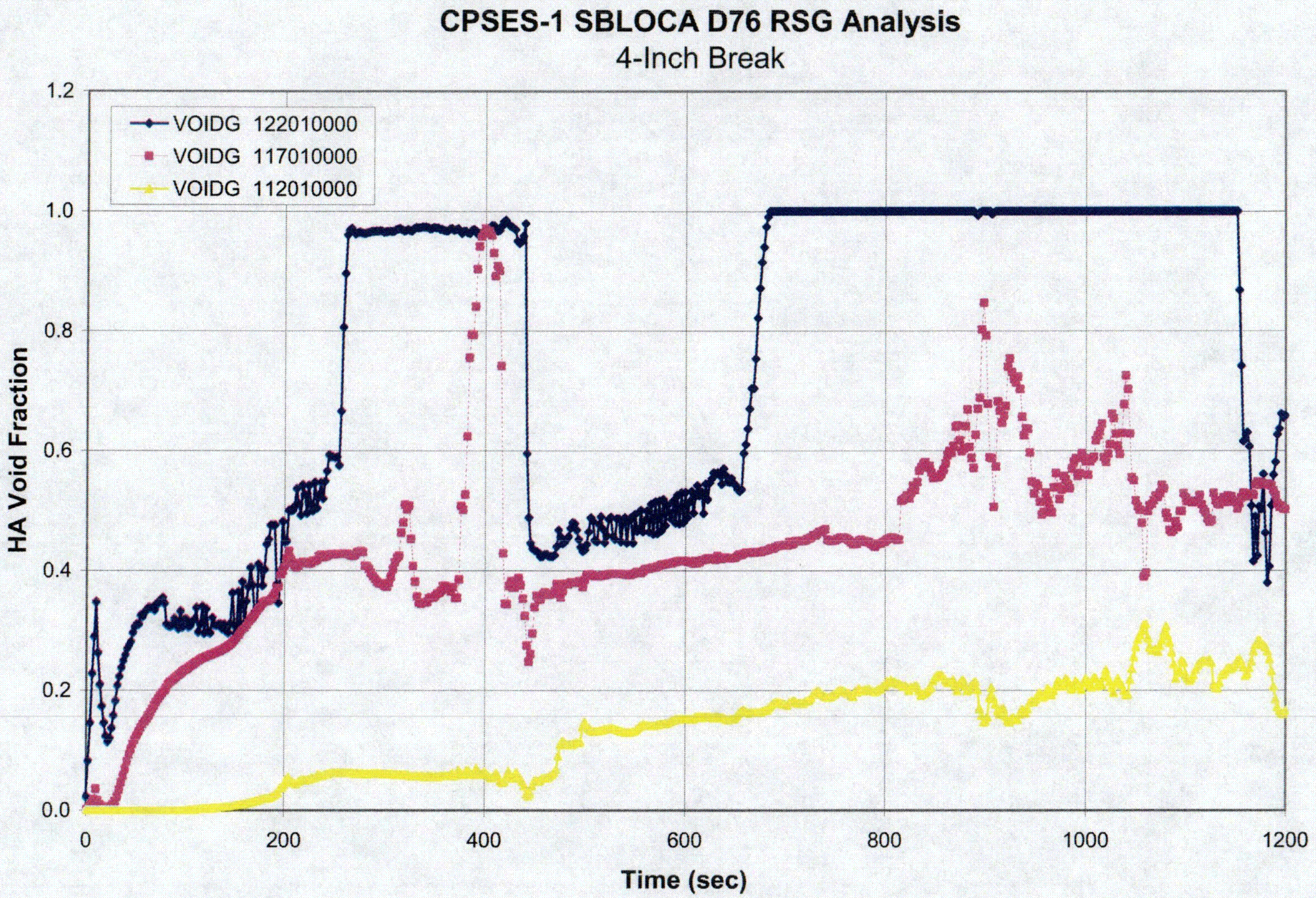

Figure B-2 Hot Assembly Region Void Fractions – 4-in Break

C13

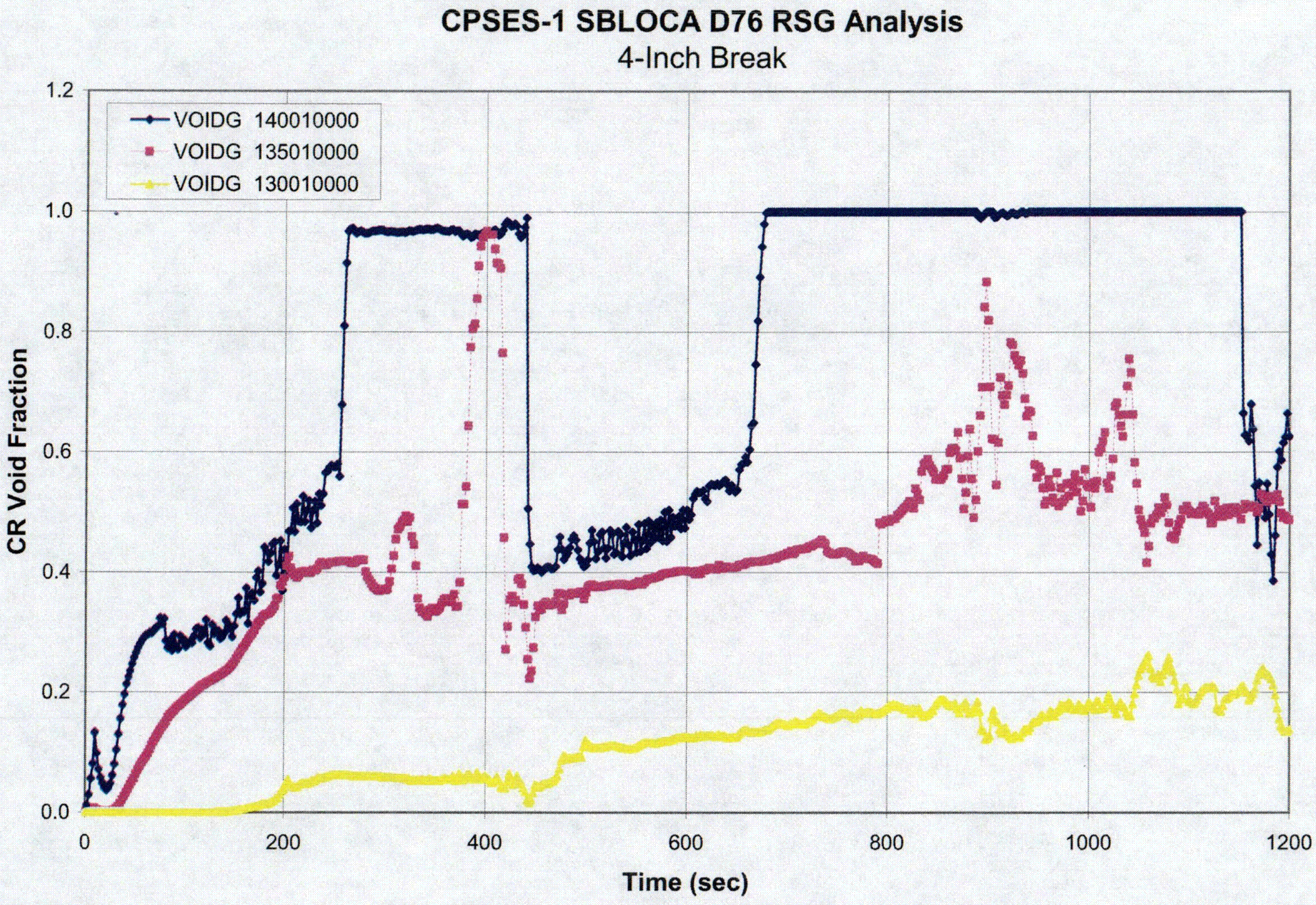

Figure B-3 Central Core Region Void Fractions – 4-in Break

C14

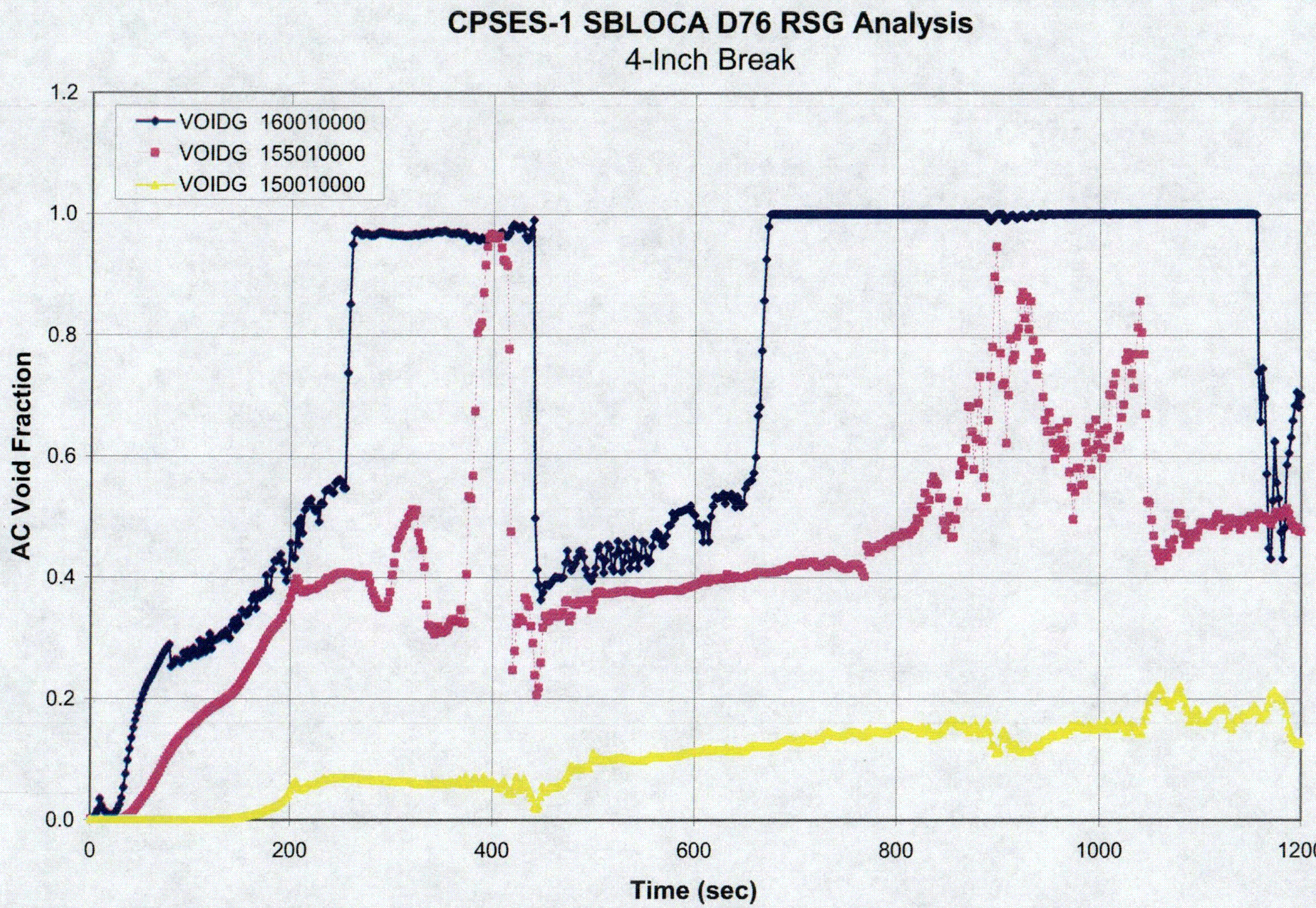

Figure B-4 Average Core Region Void Fractions – 4-in Break

C15

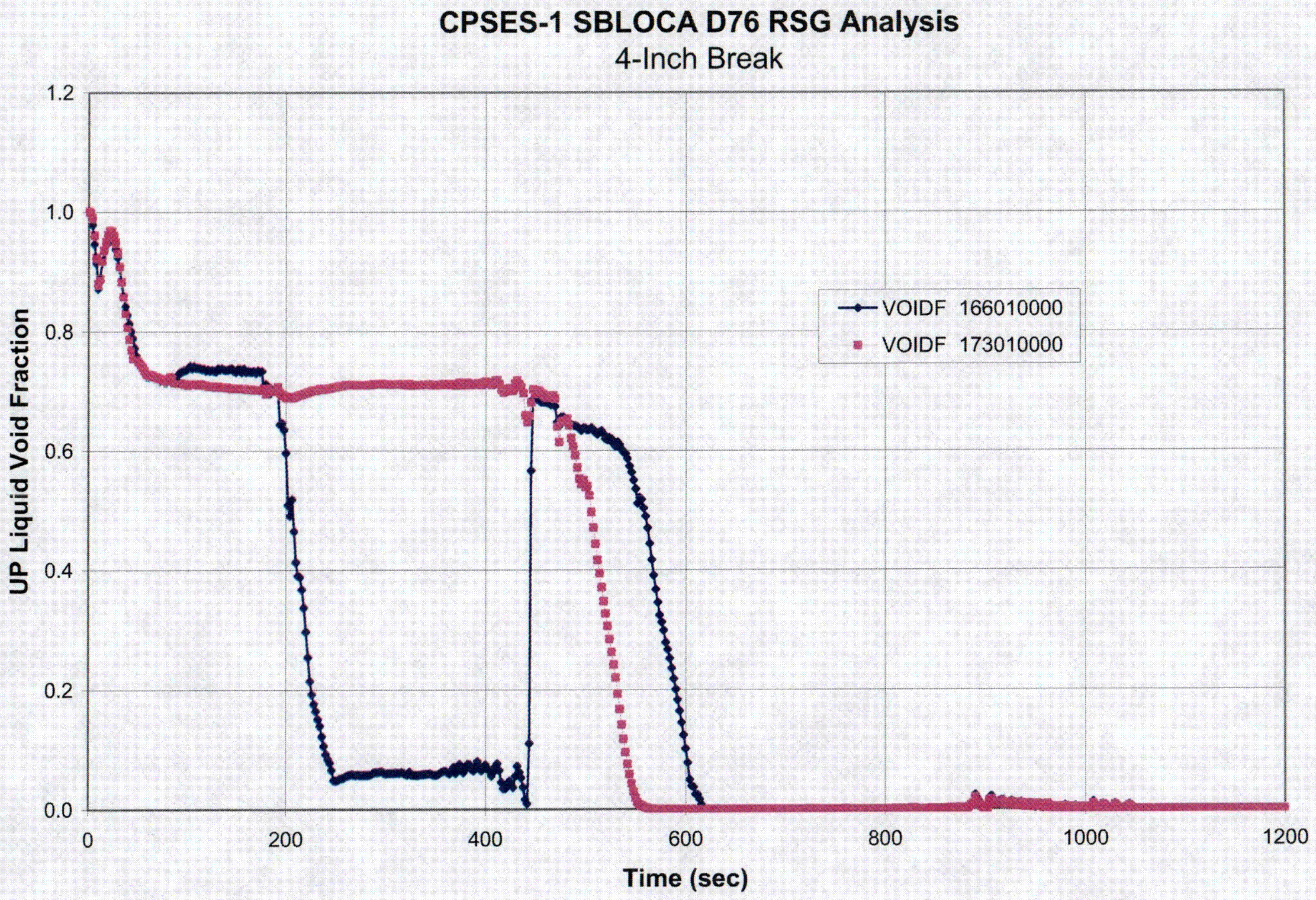

Figure B-5 Upper Plenum Liquid Fraction – 4-in Break

C16

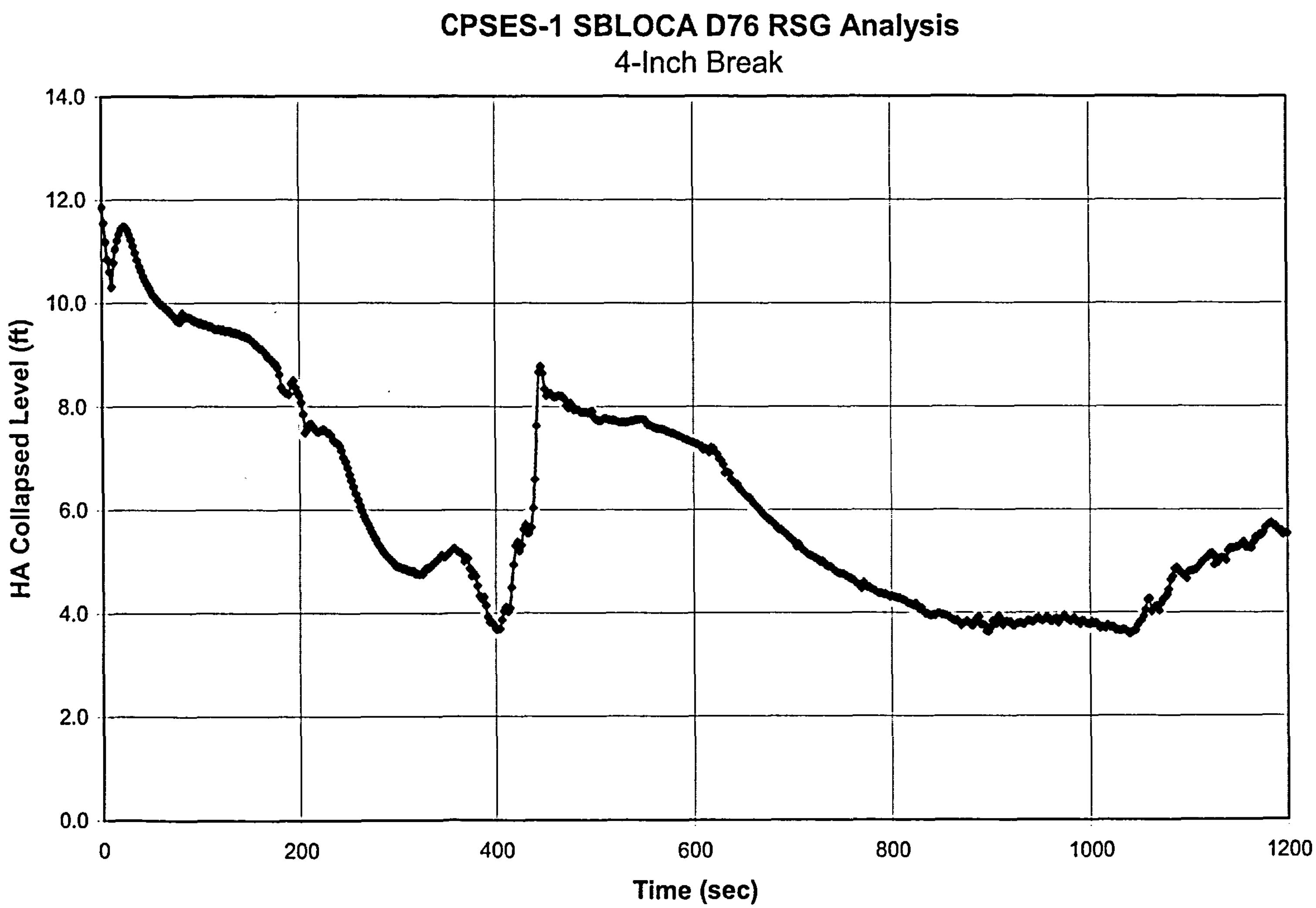

Figure B-6 Hot Assembly Collapsed Water Level – 4-in Break

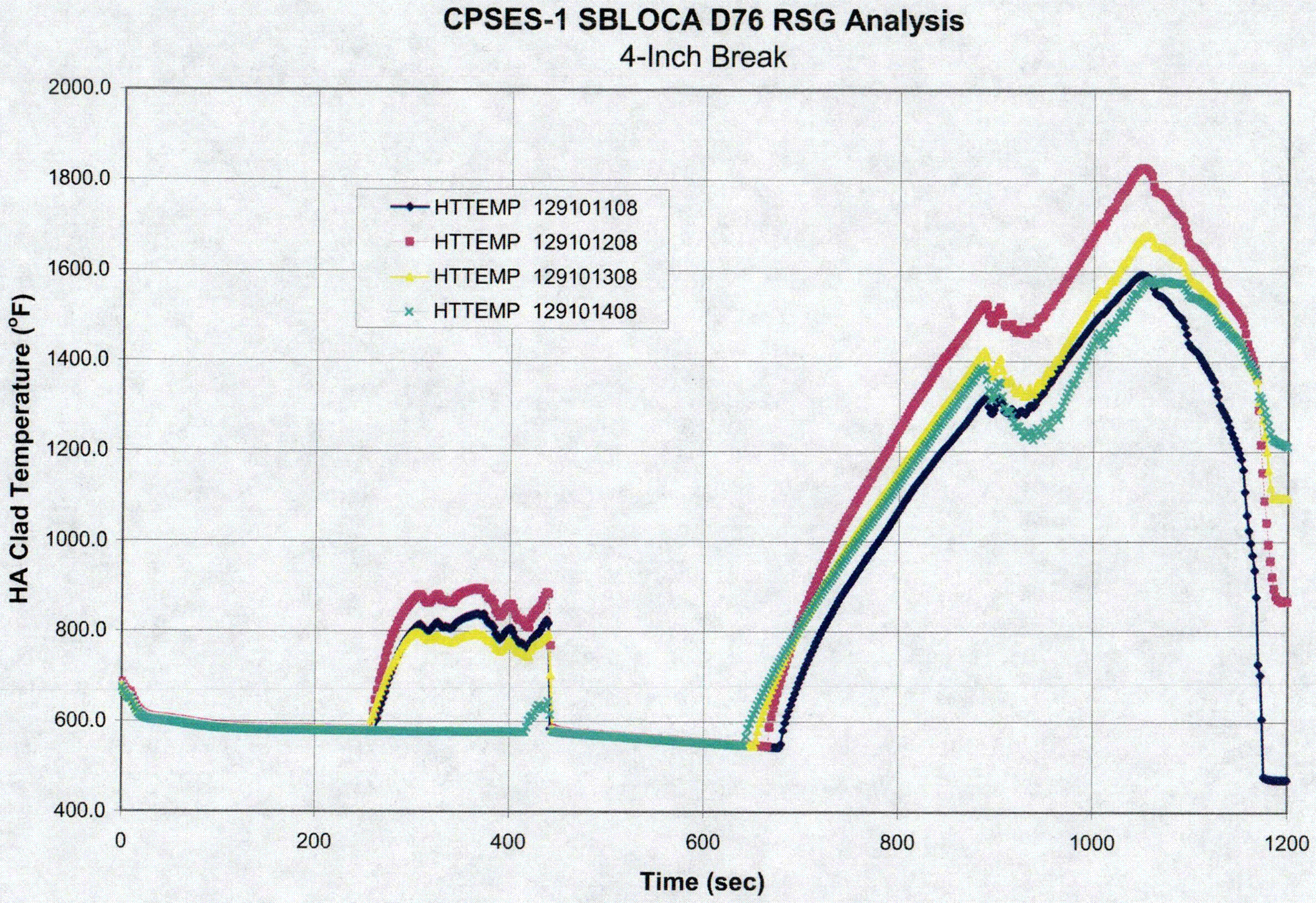

Figure B-7 Hot Assembly Clad Temperatures – 4-in Break

C17

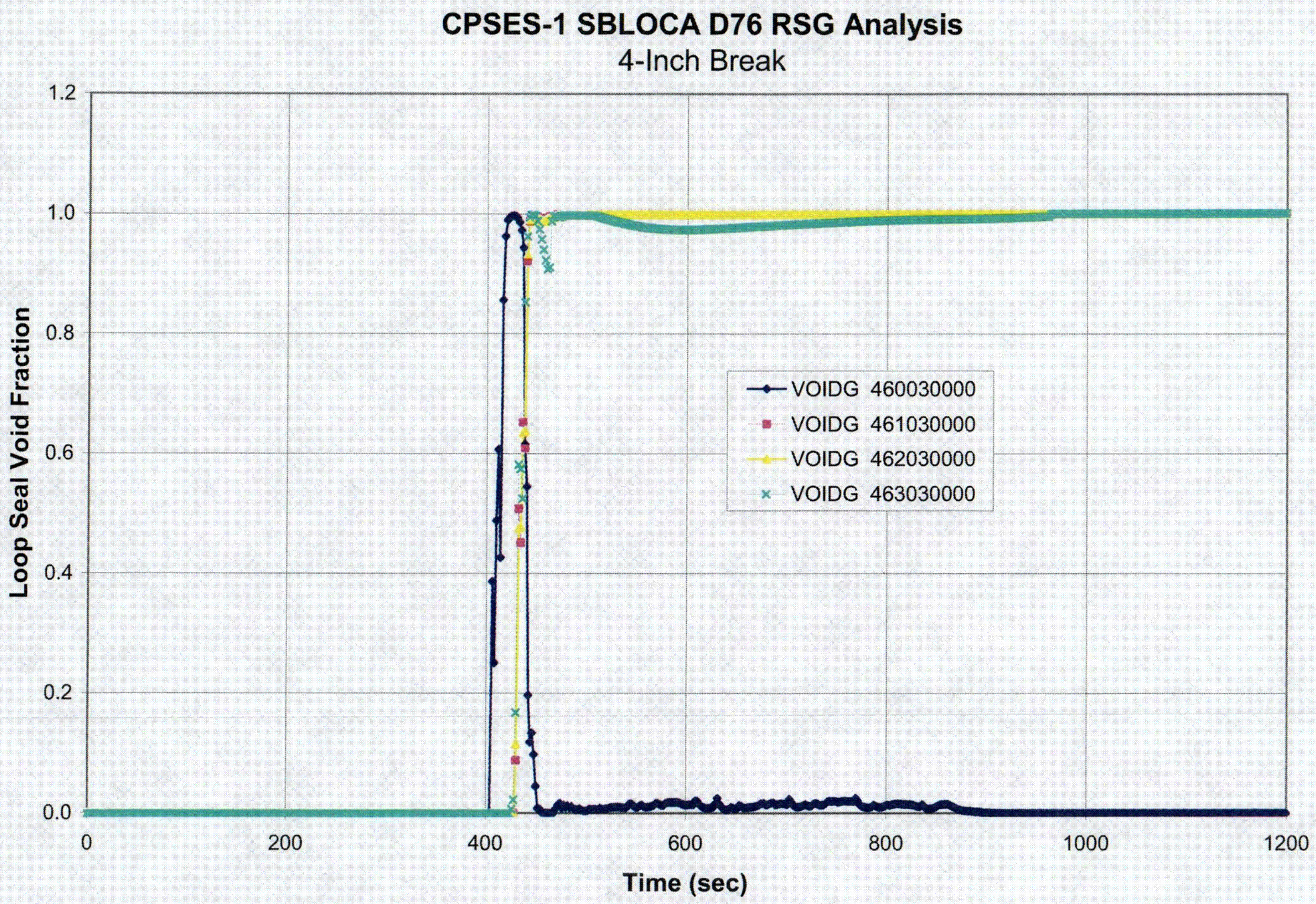

Figure B-8 Loop Seal Void Fractions – 4-in Break

C18

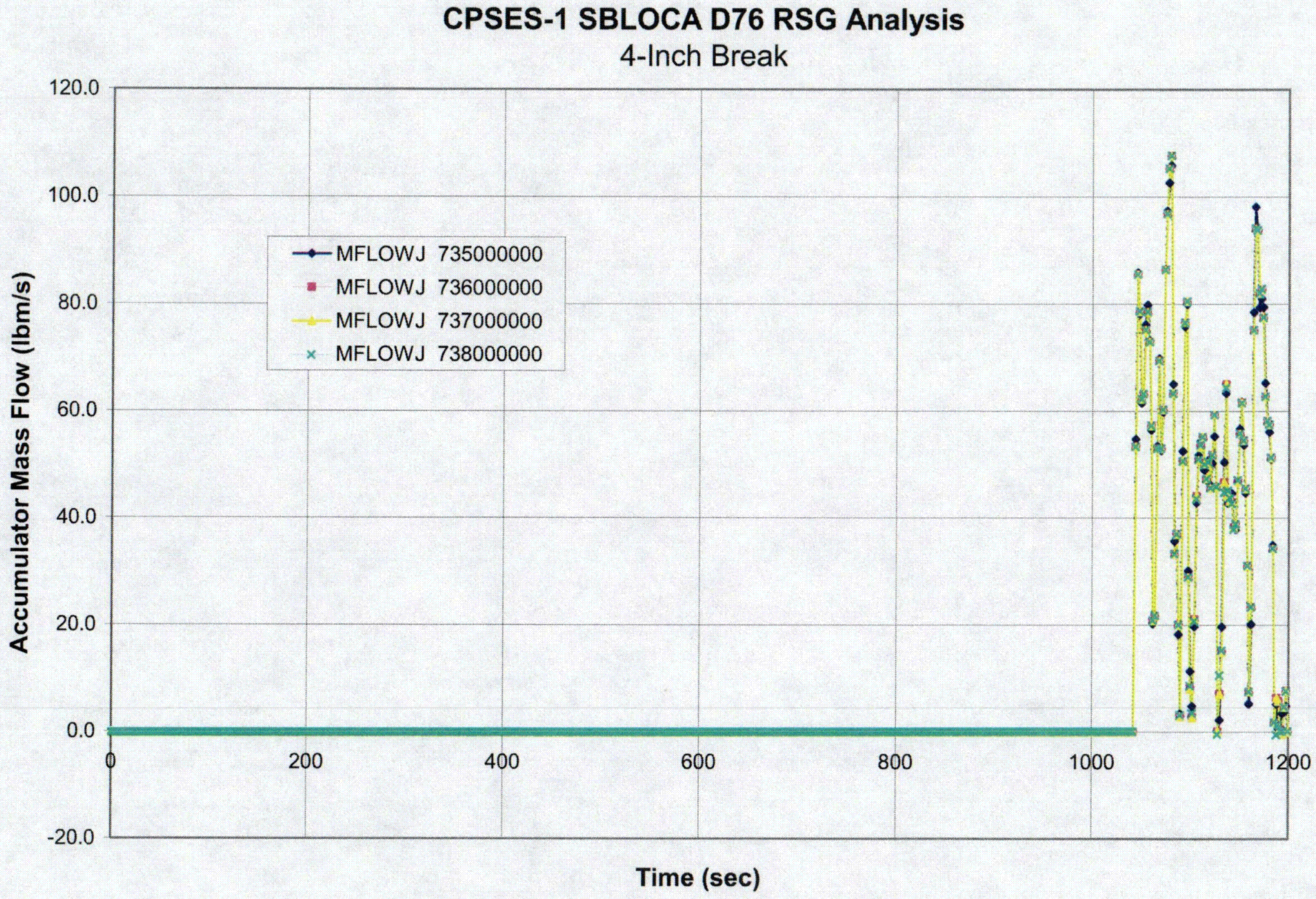

Figure B-9 Accumulator Mass Flow Rates – 4-in Break

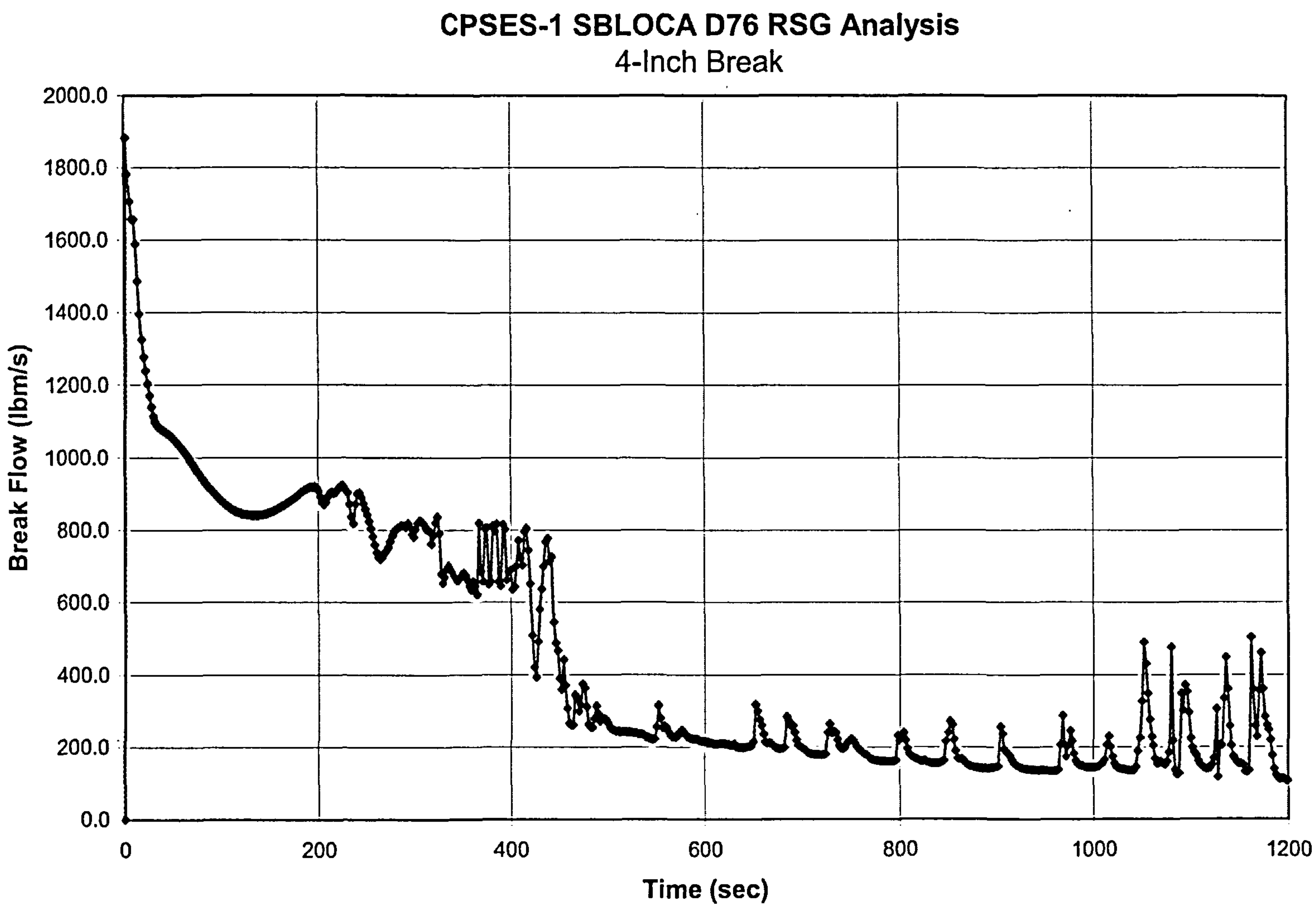

Figure B-10 Break Flow Rate – 4-in Break

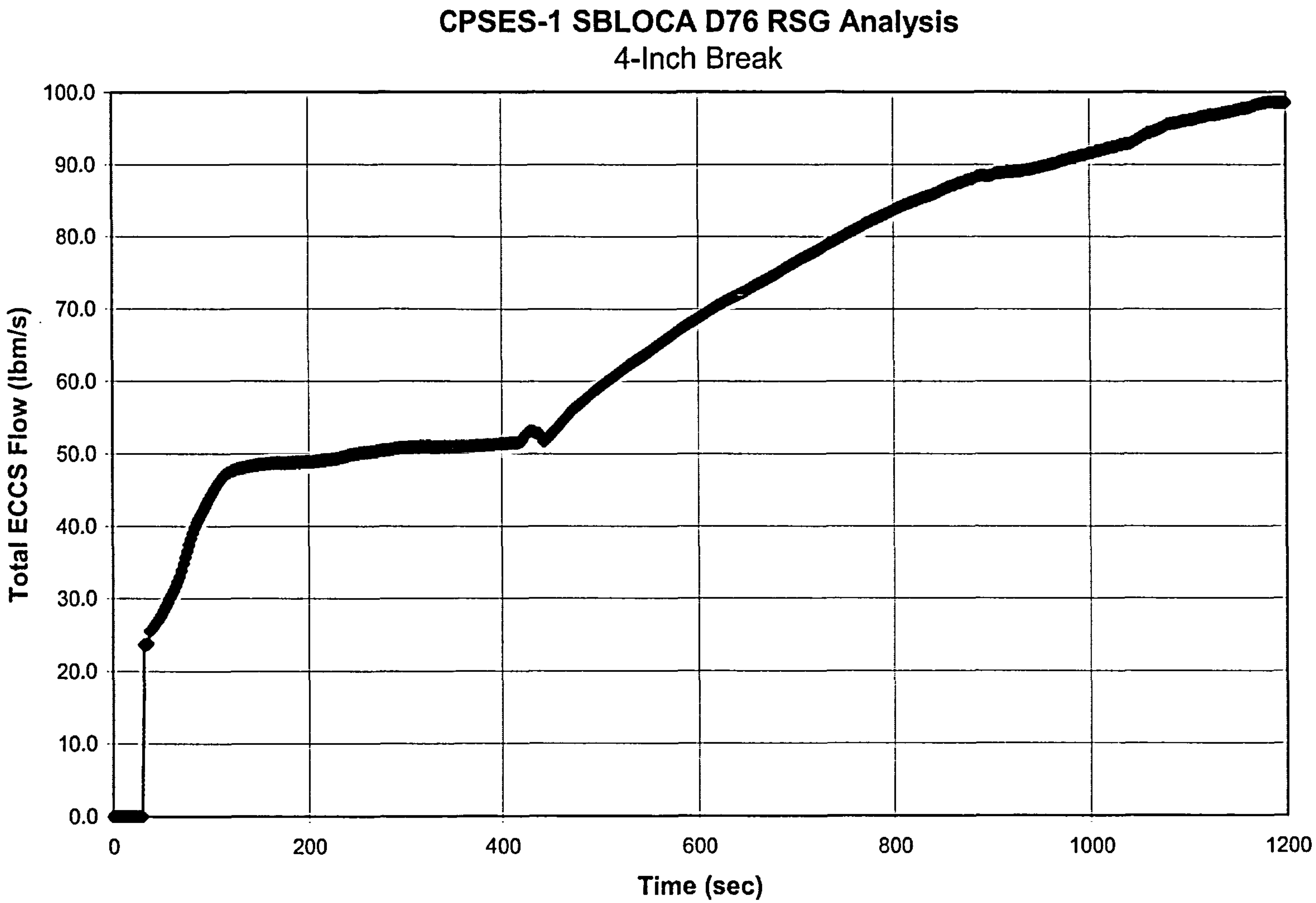

Figure B-11 Total Pumped ECCS Flow Rate – 4-in Break

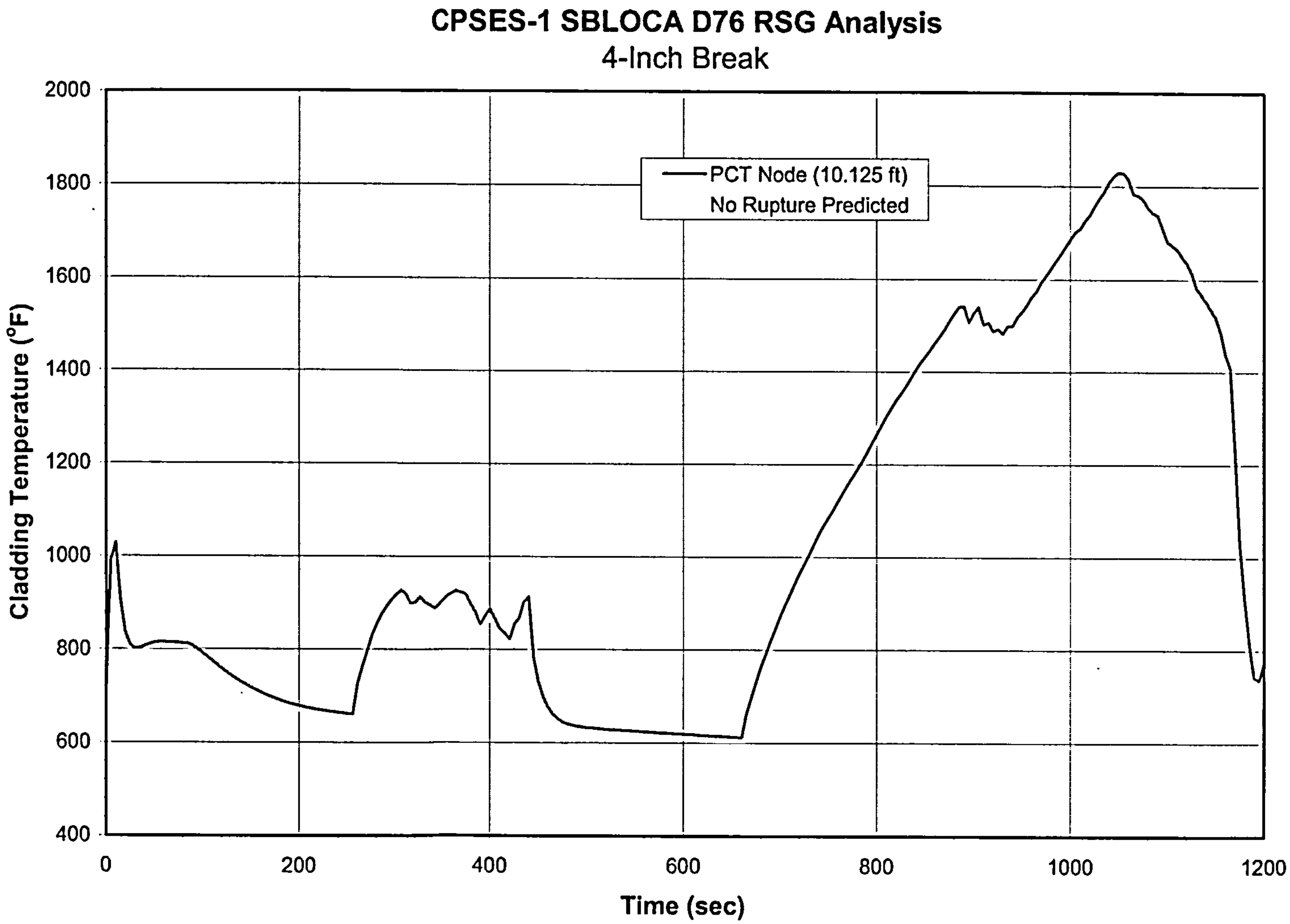

Figure B-12 TOODEE2 Clad Temperature – 4-in Break

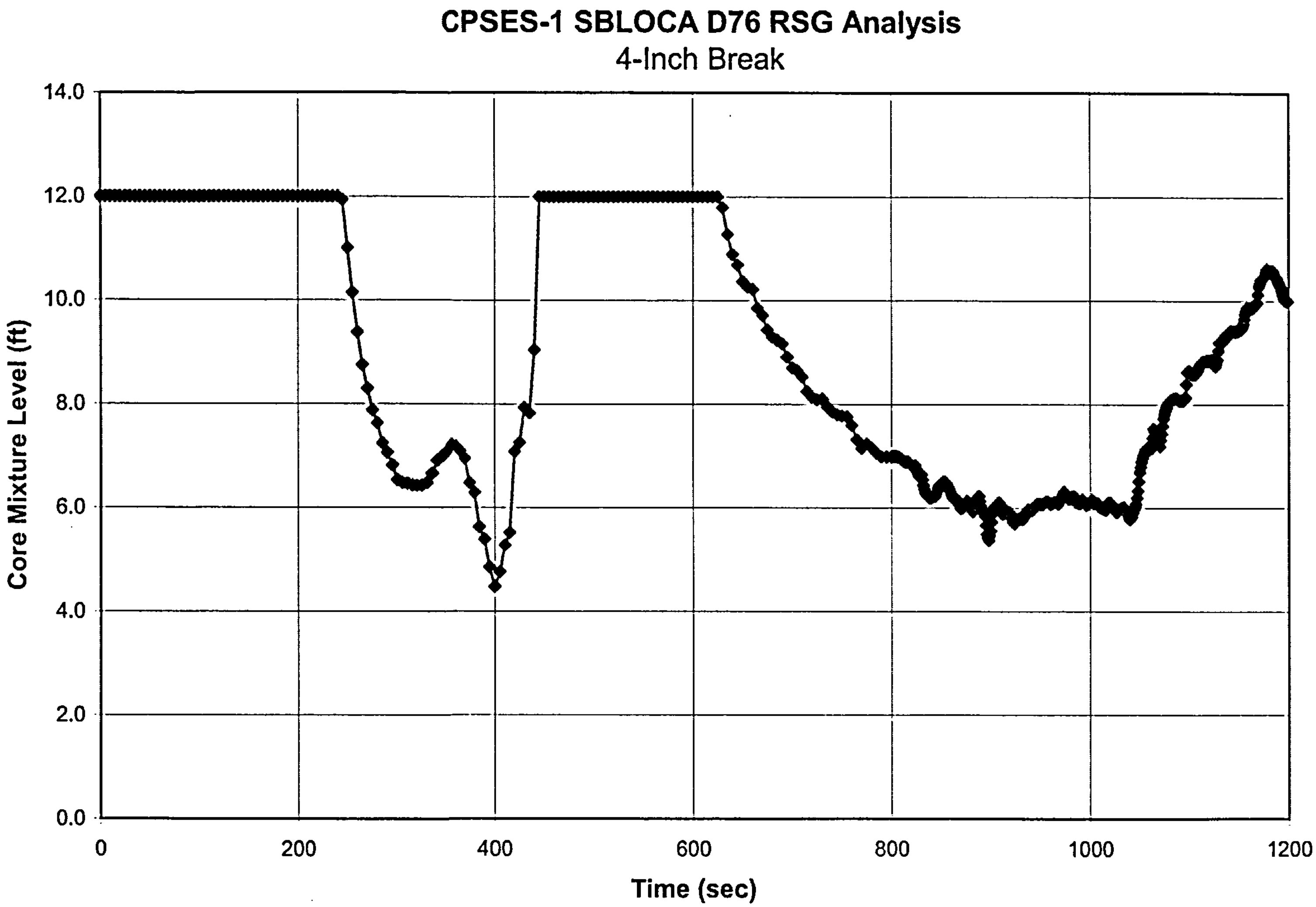

Figure B-13 Core Mixture Level – 4-in Break

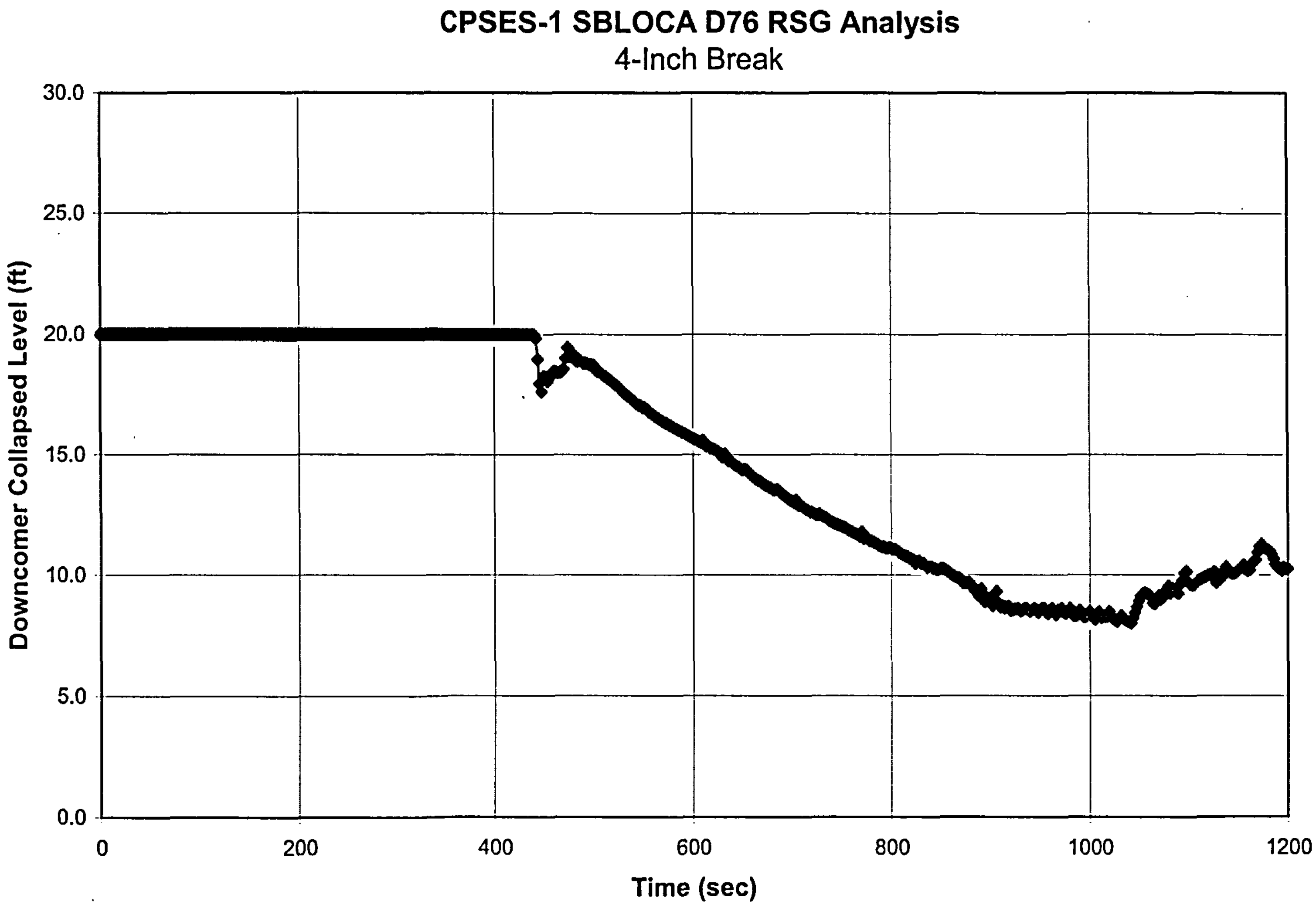

Figure B-14 Downcomer Liquid Level – 4-in Break

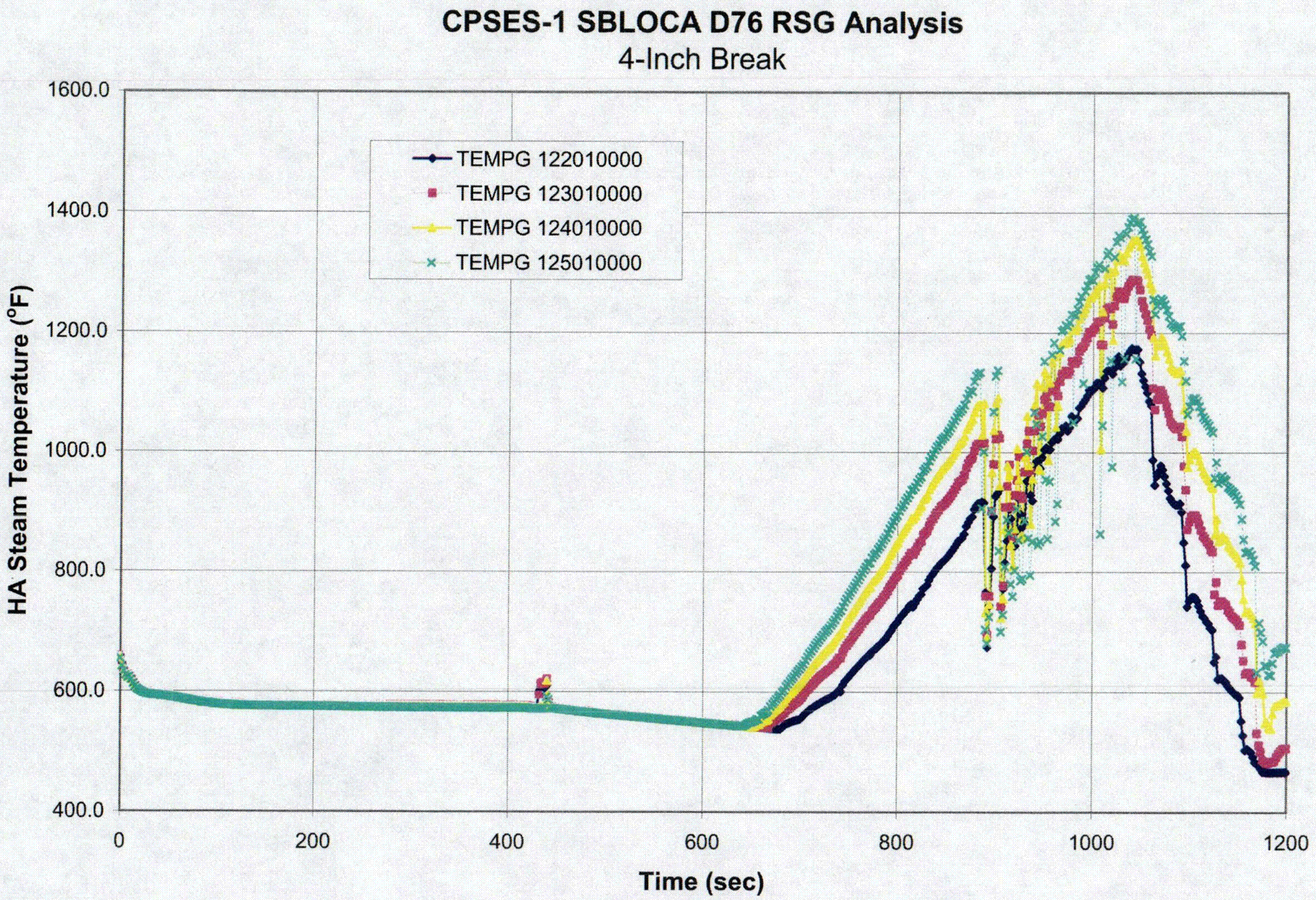

Figure B-15 Hot Assembly Steam Temperatures – 4-in Break

C20

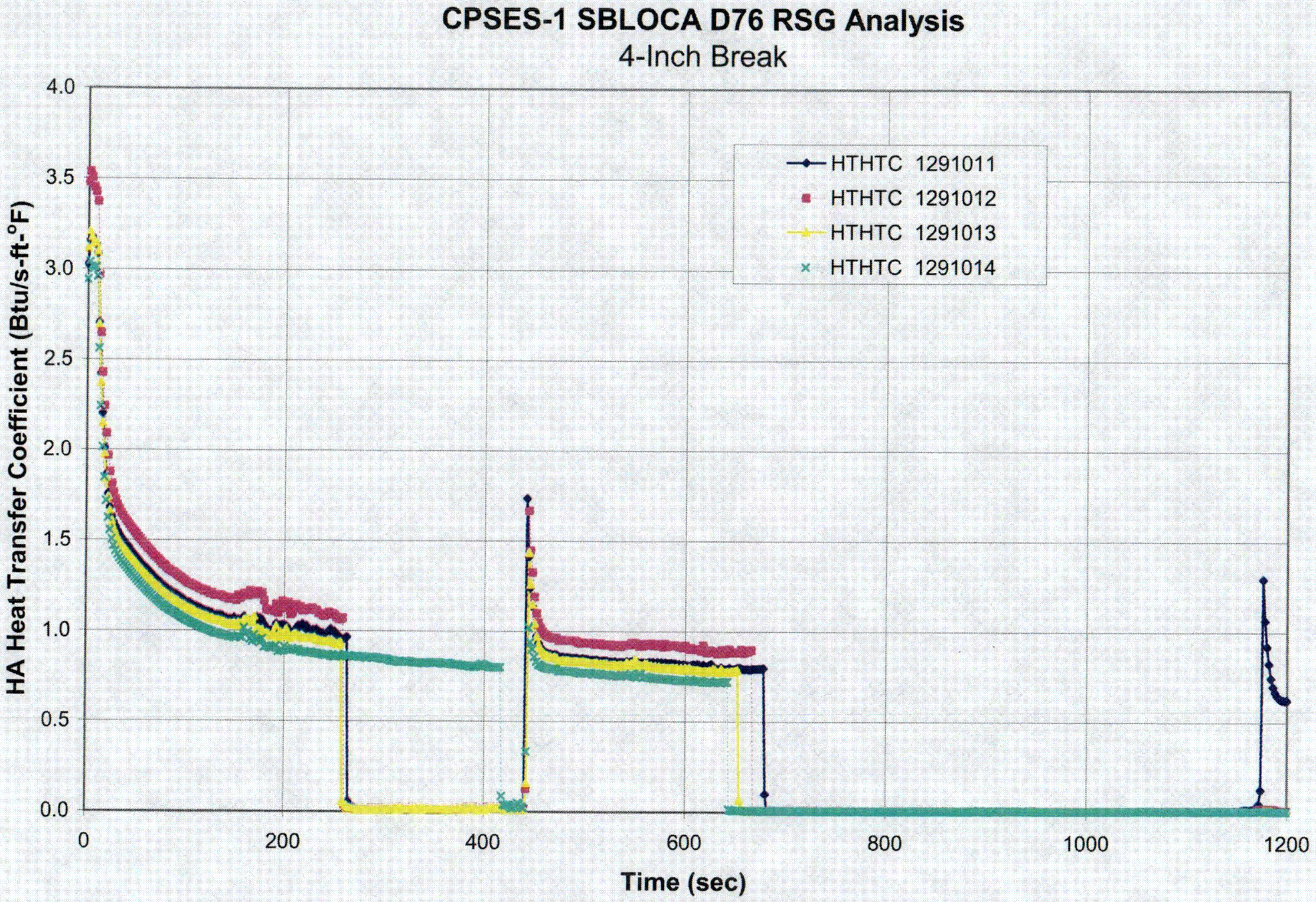

Figure B-16 Hot Assembly Heat Transfer Coefficients – 4-in Break

C21

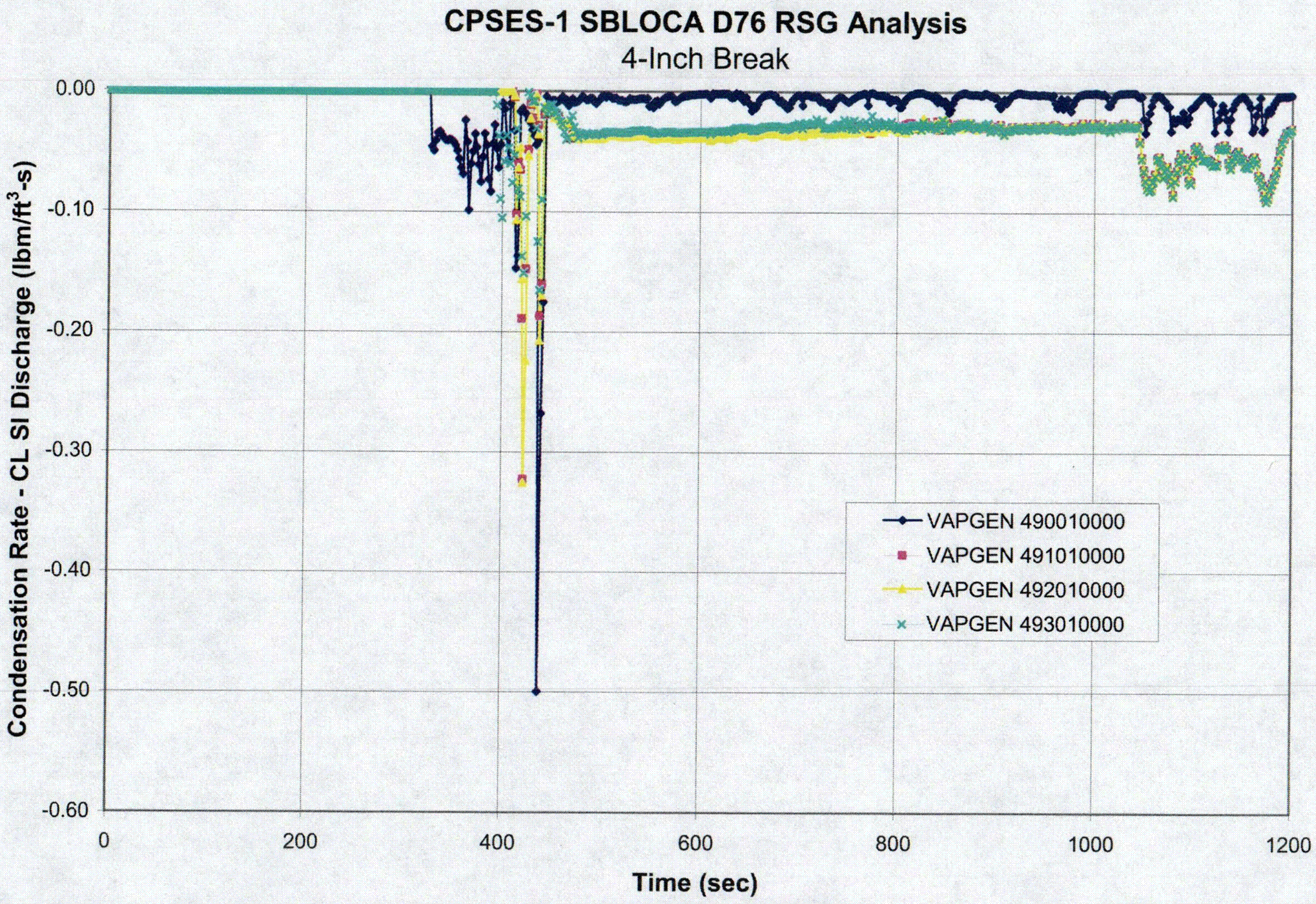

Figure B-17 Condensation Rate in Cold Leg Discharge – 4-in Break

C22

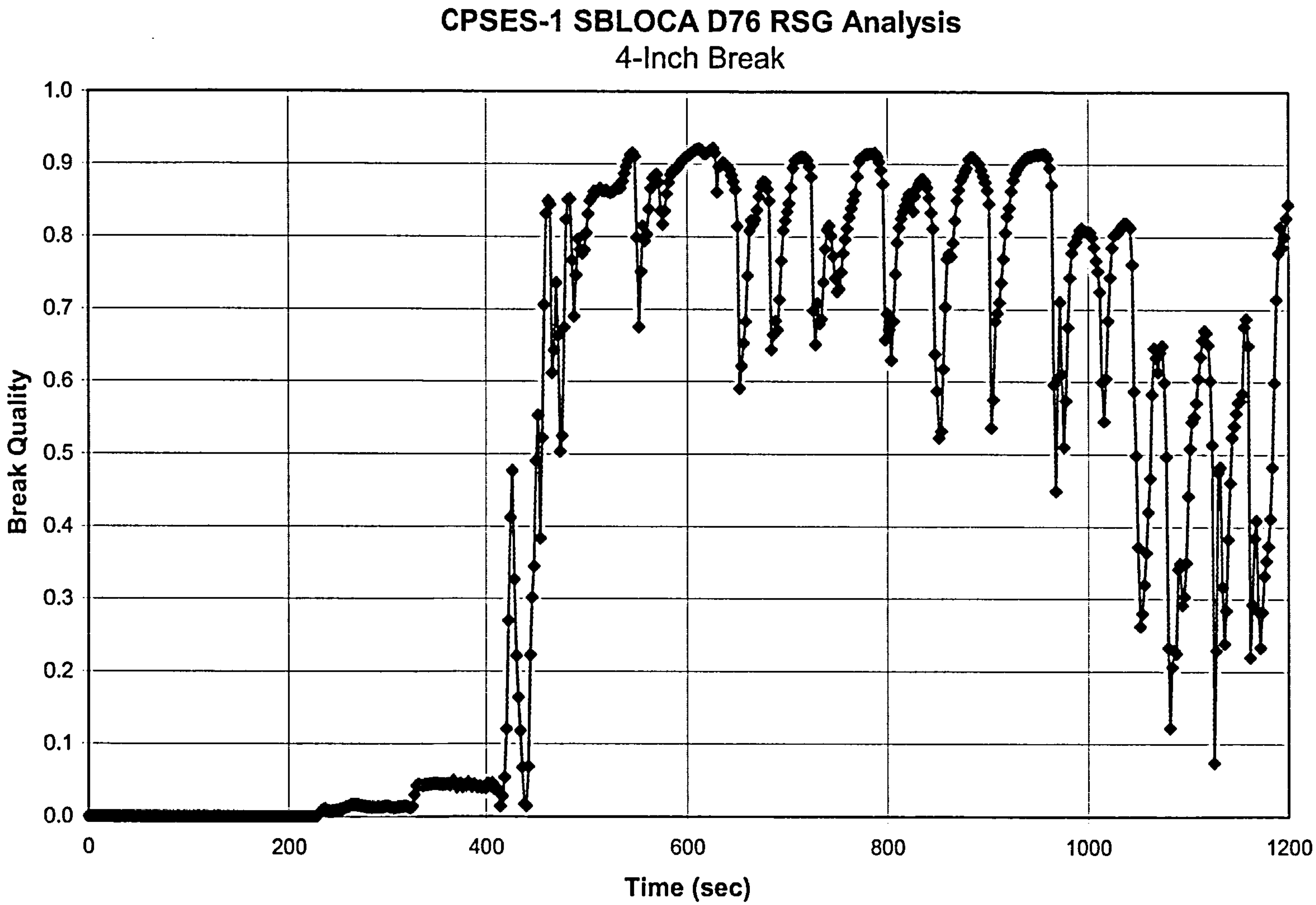

Figure B-18 Break Quality – 4-in Break

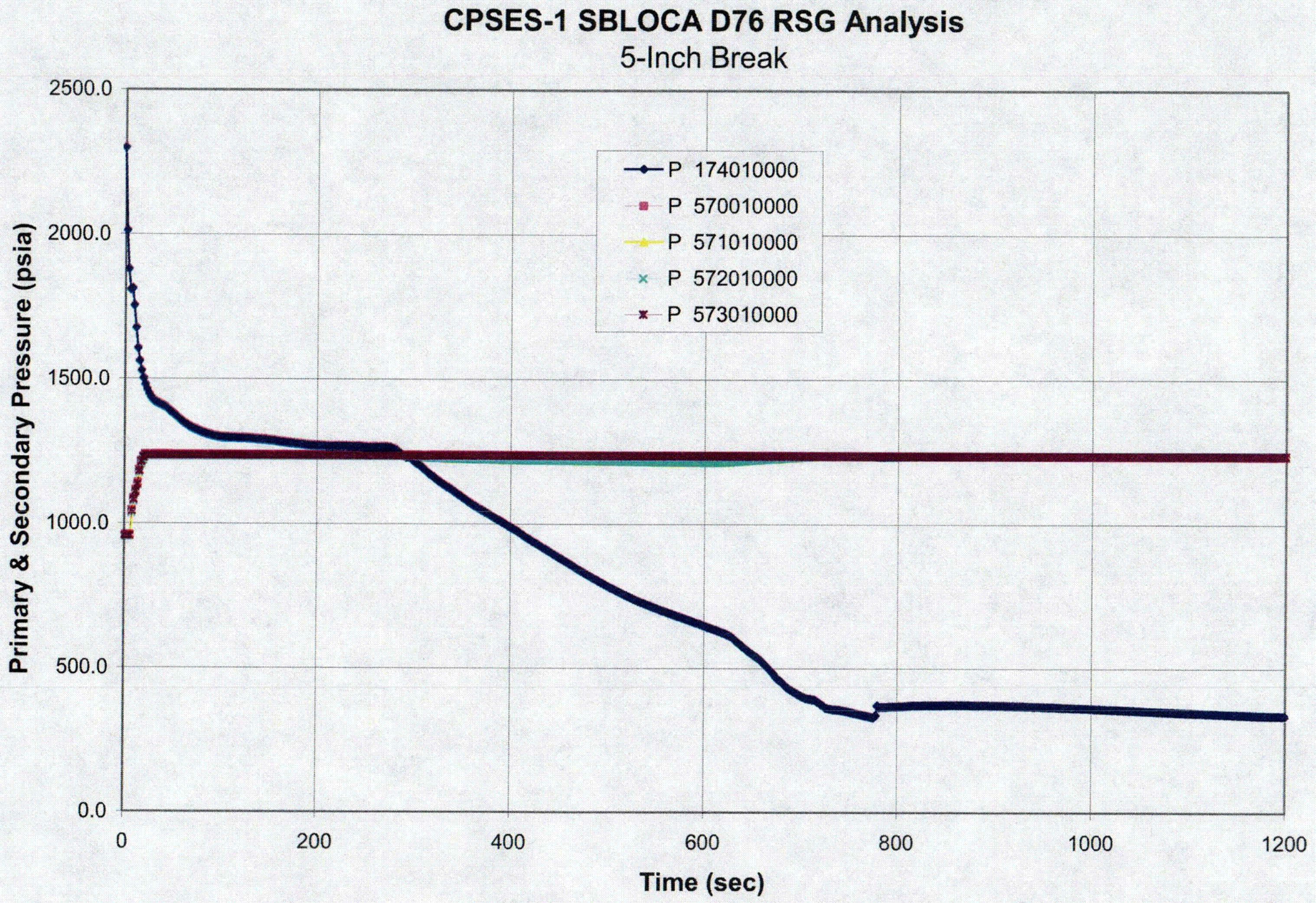

Figure C-1 Primary and Secondary System Pressures – 5-in Break

C23

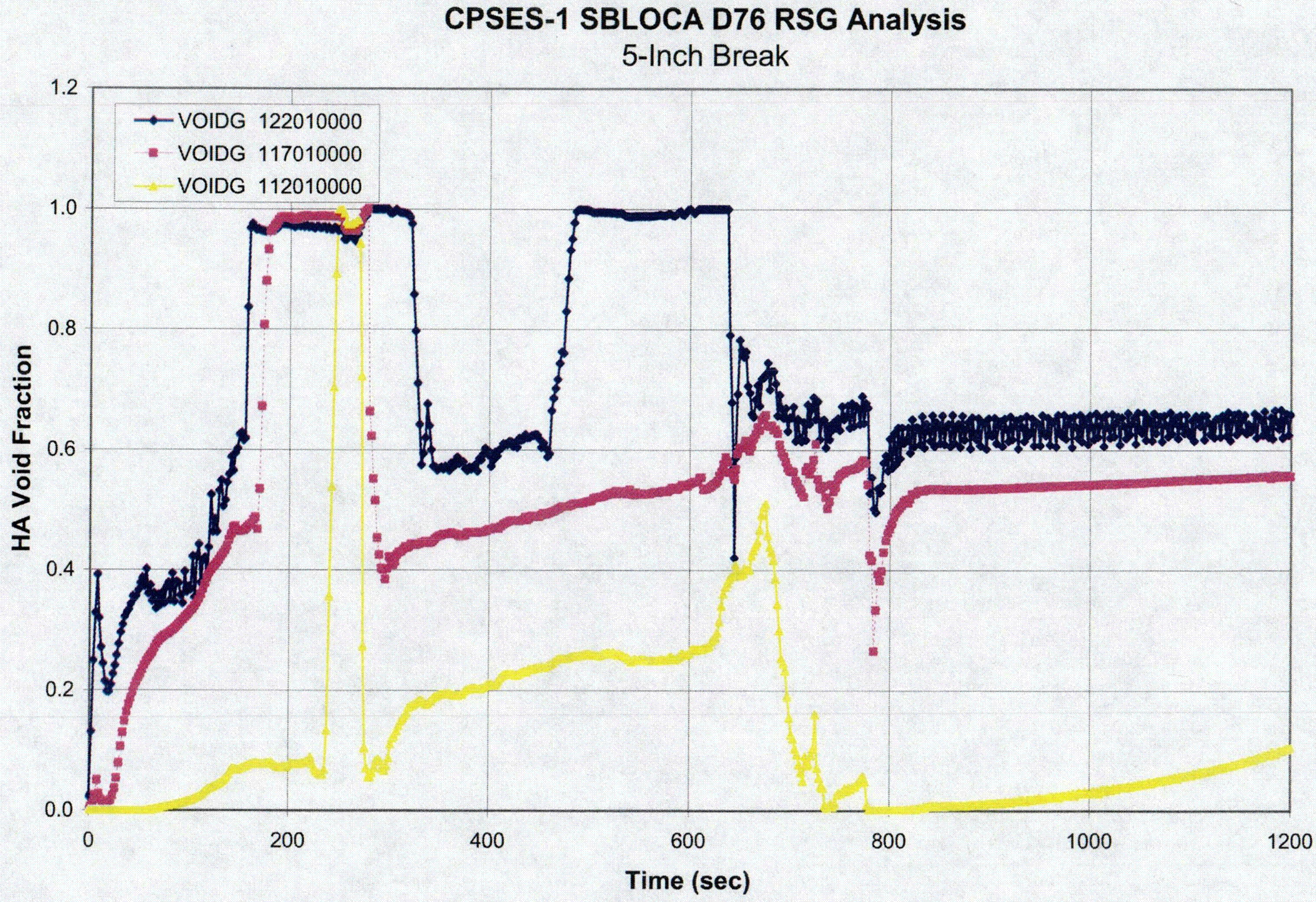

Figure C-2 Hot Assembly Region Void Fractions – 5-in Break

C24

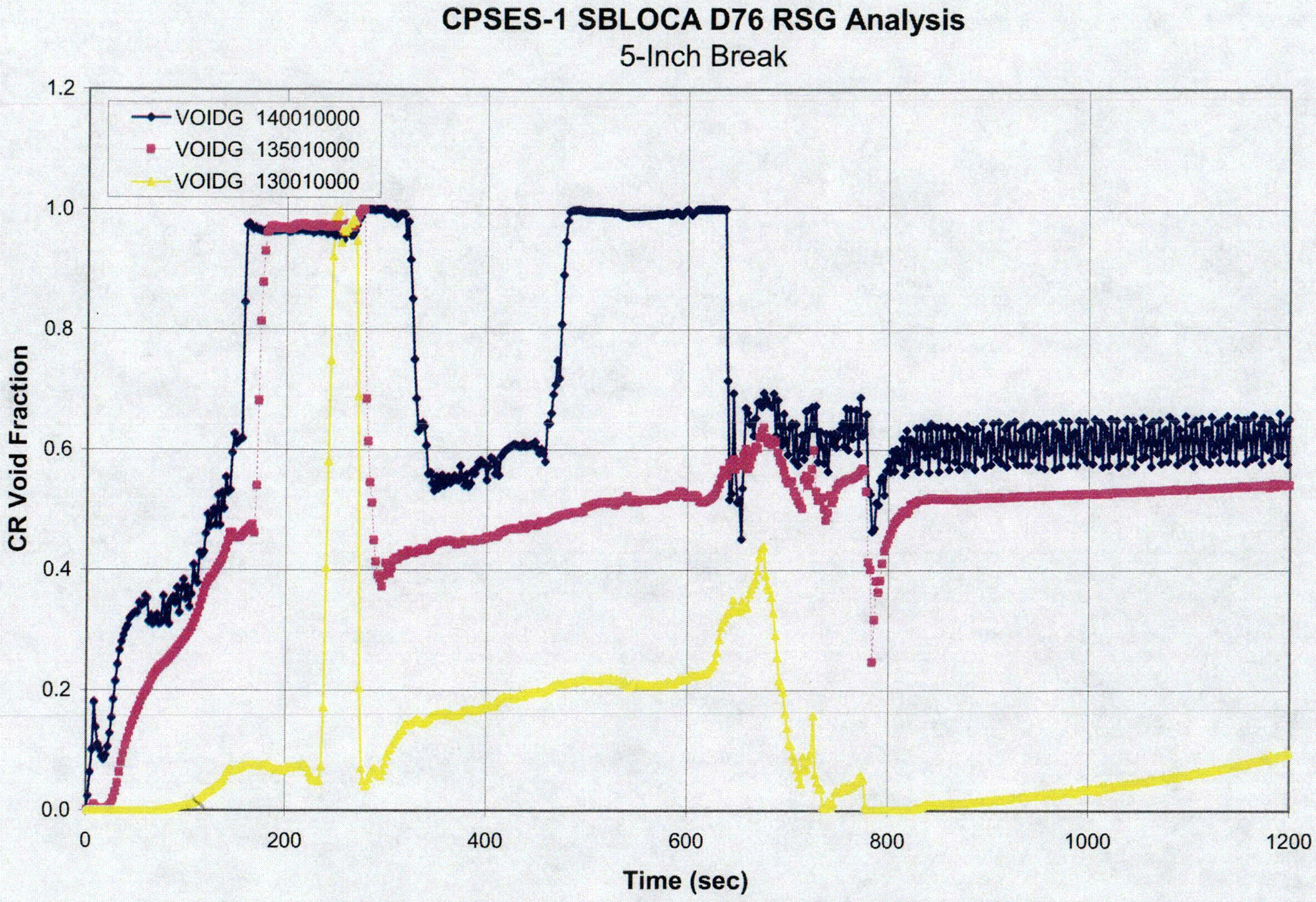

Figure C-3 Central Core Region Void Fractions – 5-in Break

C25

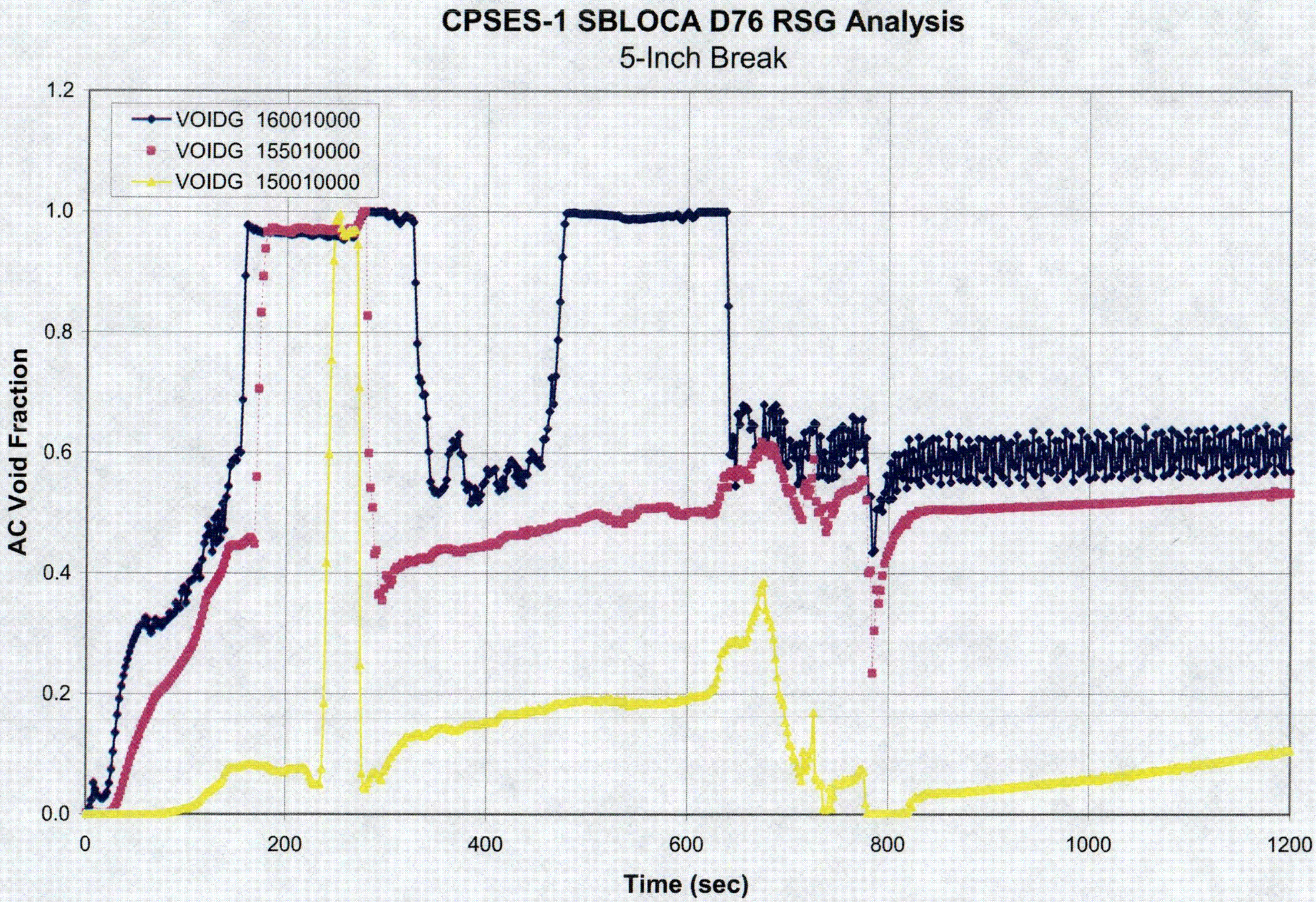

Figure C-4 Average Core Region Void Fractions – 5-in Break

C26

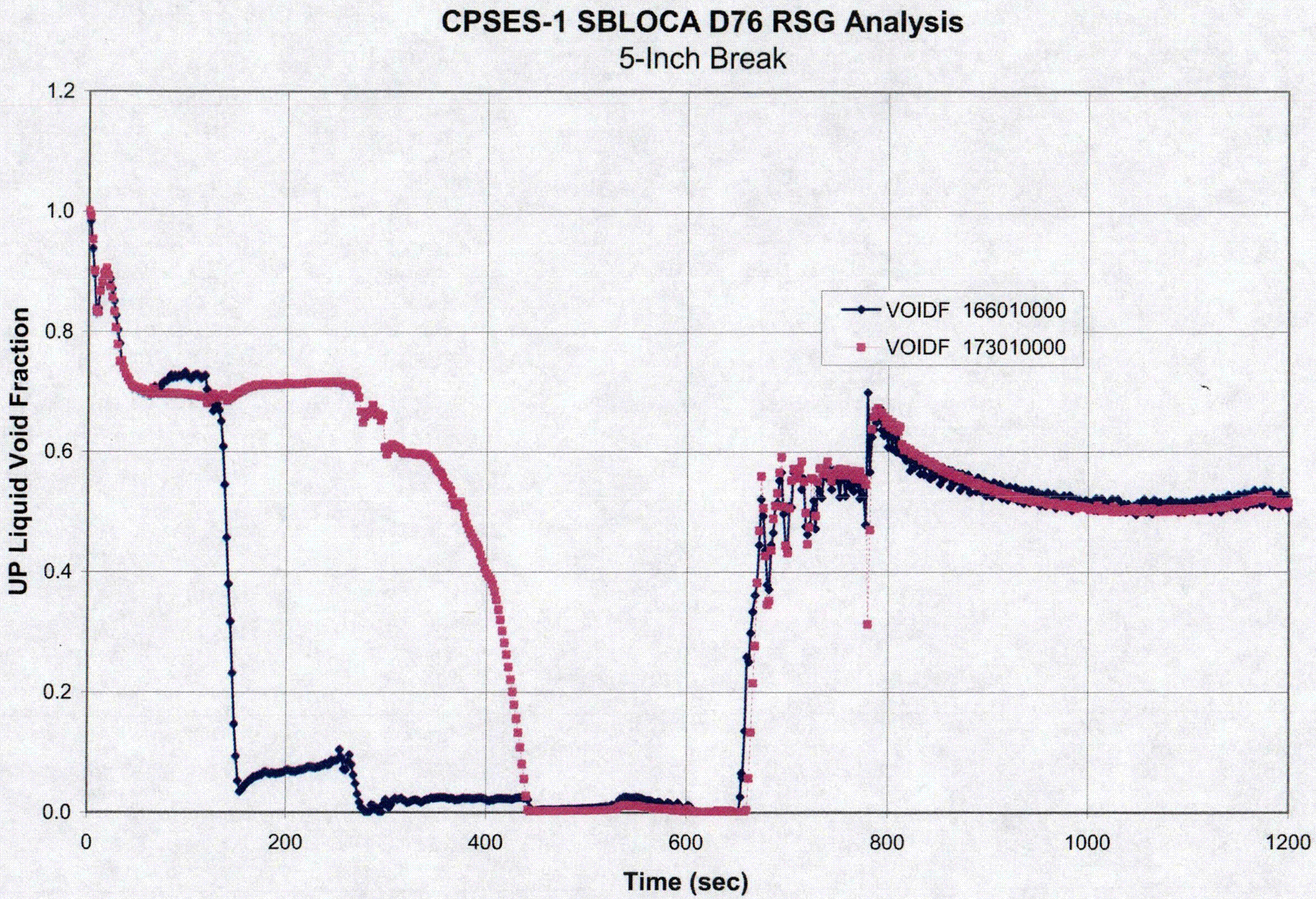

Figure C-5 Upper Plenum Liquid Fraction – 5-in Break