ATTACHMENT

Calculation OSC-6521

Containment Response with 30 Minute Delay in LPSW Flow

Revision 3

002

UNCONTROLLED

Form 01077 (R3-94)

CERTIFICATION OF ENGINEERING CALCULATION

STATION AND UNIT NUMBER: Oconee Nuclear Station - Units 1, 2, and 3

TITLE OF CALCULATION: Containment Response with 30 Minute Delay in LPSW Flow

CALCULATION NUMBER: OSC - 6521

ORIGINALLY CONSISTING OF:

PAGES 1 THROUGH 12

TOTAL ATTACHMENTS 0 TOTAL MICROFICHE ATTACHMENTS 0

TOTAL VOLUMES 1 TYPE I CALCULATION/ANALYSIS ☐ Yes ■ No

TYPE I REVIEW FREQUENCY N/A

THESE ENGINEERING CALCULATIONS COVER QA CONDITION 1 ITEMS. IN ACCORDANCE WITH ESTABLISHED PROCEDURES, THE QUALITY HAS BEEN ASSURED AND I CERTIFY THAT THE ABOVE CALCULATION HAS BEEN ORIGINATED, CHECKED OR APPROVED AS NOTED BELOW:

ORIGINATED BY Thomas P. Yadon DATE 2-19-96

CHECKED BY Jan S. Mirousky DATE 2-19-96

APPROVED BY G. R. Swindlehurst DATE 2/22/96

ISSUED TO DOCUMENT MANAGEMENT TP Yadon DATE 3-18-96

RECEIVED BY DOCUMENT MANAGEMENT J. M Harris DATE 3-19-96

MICROFICHE ATTACHMENT LIST: ■ Yes ☐ No SEE FORM 101.4

REV. NO.	CALCULATION PAGES (VOL)			ATTACHMENTS (VOL)			VOLUMES		ORIG	CHKD	APPR	ISSUE DATE
	REVISED	DELETED	ADDED	REVISED	DELETED	ADDED	DELETED	ADDED	DATE	DATE	DATE	REC'D-DATE
1	7		13-28						TPY 3/22/96	JSM 3/27/96	GRS 4/11/96	
2	6,10	7-9	2A, 7-9						TPY 3/11/98	JSM 3/11/98	GRS 3/26/98	
3			2B, 29-48						TPY 8/21/98	JSM 8/21/98	GRS 8/21/98	

Form 101.2 Revision 1
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File/Calculation No.: OSC - 6521

REVISION DOCUMENTATION SHEET

Revision Number	Review Frequency Changed Yes/No	Revision Description
0	NO	Original Issue
1	NO	Appendix B added to include effect on NPSH determination; Filenames in
		Table 1 revised to DOS format
2	NO	Case B revised for inclusion in Oconee EQCM Manual; Case C deleted
3	NO	Appendix C added to document hot-leg break cases with revised input
		parameters

NUCLEAR ENGINEERING GROUP

ENGINEERING CALCULATION PROCEDURE APPLICABILITY CHECKLIST

Description of Analysis

The objective of this analysis is to determine the containment response to the limiting large break LOCA when the LPSW flow to the Low Pressure Injection (LPI) Coolers is delayed for 30 minutes following the initiation of sump recirculation mode. Worst-case assumptions for the Reactor Building Cooling Units (RBCUs) capacity will be used. The impact of this delay on the minimum long-term heat removal requirements for the RBCUs will be evaluated. The FATHOMS/DUKE-RS computer code is utilized for this analysis.

This calculation is QA Condition 1 (safety-related).

Determination of QA Condition 1 Applicability

YES	NO	
☐	■	Does this analysis determine the presence or absence of an unreviewed safety question?
■	☐	Does this analysis justify a change in a Technical Specification limit or verify the acceptability of a current Technical Specification limit?
■	☐	Does this analysis justify a design or a change in the performance or design of safety-related structures, systems, or components?
☐	■	Does this analysis modify or justify the licensing basis safety analysis?
☐	■	Is this analysis intended to provide the basis for, or input to, other safety-related analyses?

If the answer to any of the above questions is yes, then this analysis is safety-related and must be classified as a QA Condition 1 item. As such it must satisfy the requirements of NE-103 and EDM-101.

NUCLEAR ENGINEERING GROUP

ENGINEERING CALCULATION REVIEW CHECKLIST

YES	NOT APPLICABLE	
☑	☐	A description of the analysis has been entered on Form NE-103.1.
☑	☐	The QA Condition of the calculation has been determined on Form NE-103.1 and entered on Form EDM-101.1.
☑	☐	Design methods and procedures have been referenced.
☑	☐	Design criteria have been identified.
☑	☐	Input data and assumptions are valid and properly documented.
☑	☐	All computer programs are properly identified, documented, and executed consistently with their derivation.
☑	☐	All computer programs have been certified in accordance with NE-114 or NE-103 as appropriate.
☑	☐	The calculation has been presented in sufficient detail to permit an adequate review.
☑	☐	Calculation and analytical methodologies are consistent with approved methodologies and numerical results have been verified.
☑	☐	Conclusions and results are consistent with the calculations.
☑	☐	The required Reactivity Management section has been included and the reviewer agrees with its contents and conclusions.

Reviewed by: Jan S. Muransky Date: 2/19/96

ENGINEERING CALCULATION REVIEW CHECKLIST

YES	NOT APPLICABLE	
☒	☐	A description of the analysis has been entered on Form NE-103.1.
☒	☐	The QA Condition of the calculation has been determined on Form NE-103.1 and entered on Form EDM-101.1.
☒	☐	Design methods and procedures have been referenced.
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☒	☐	All computer programs have been certified in accordance with NE-114 or NE-103 as appropriate.
☒	☐	Calculation and analytical methodologies are consistent with approved methodologies and numerical results have been verified.
☒	☐	Conclusions and results are consistent with the calculations.
☒	☐	The required Reactivity Management section (per NSD-304) has been included and the reviewer agrees with its contents and conclusions.
☐	☒	UFSAR markups have been documented.
☐	☒	Current revision of generic REDSAR was used.
☐	☒	Revisions to generic REDSAR reference values, resulting from this calculation, have been documented and communicated appropriately.

Original Reviewed by:	[JS Muransky]	Date:	[2/19/96]
Rev. 1 Reviewed by:	[JS Muransky]	Date:	[3/27/96]
Rev. 2 Reviewed by:	J. S. Muransky	Date:	3/4/98
Rev. 3 Reviewed by:		Date:	
Rev. 4 Reviewed by:		Date:	
Rev. 5 Reviewed by:		Date:	
Rev. 6 Reviewed by:		Date:	

NUCLEAR ENGINEERING GROUP

ENGINEERING CALCULATION PROCEDURE APPLICABILITY CHECKLIST

YES	NOT APPLICABLE	TO BE COMPLETED BY REVIEWER
☑	☐	A description of the analysis has been entered on Form NE-103.1.
☑	☐	The QA Condition of the calculation has been determined on Form NE-103.1 and entered on Form EDM-101.1.
☑	☐	Design methods and procedures have been referenced.
☑	☐	Design criteria have been identified.
☑	☐	Input data and assumptions are valid and properly documented.
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☑	☐	Calculation and analytical methodologies are consistent with approved methodologies and numerical results have been verified.
☑	☐	Conclusions and results are consistent with the calculations.
☑	☐	The required Reactivity Management section (per NSD-304) has been included and the reviewer agrees with its contents and conclusions.
☐	☑	UFSAR markups have been documented.
☐	☑	Current revision of generic REDSAR was used.
☐	☑	Revisions to generic REDSAR reference values, resulting from this calculation, have been documented and communicated appropriately.

Yes	No	TO BE COMPLETED BY APPROVER
☐	☒	Is cross disciplinary review required? Signature A. R. [illegible] 8/21/98

Original Reviewed by:	[J.S. Muransky]	Date:	[2/19/96]
Rev. 1 Reviewed by:	[J.S. Muransky]	Date:	[3/27/96]
Rev. 2 Reviewed by:	[J.S. Muransky]	Date:	[3/11/98]
Rev. 3 Reviewed by:	J. S. Muransky	Date:	8/21/98
Rev. 4 Reviewed by:		Date:	

I. OBJECTIVE

The objective of this analysis is to determine the containment response to the limiting large break LOCA when the LPSW flow to the Low Pressure Injection (LPI) Coolers is delayed for 30 minutes following the initiation of sump recirculation mode. Worst-case assumptions for the Reactor Building Cooling Units (RBCUs) capacity will be used. The impact of this delay on the minimum long-term heat removal requirements for the RBCUs will be evaluated. The FATHOMS/DUKE-RS computer code is utilized for this analysis.

This calculation is QA condition 1.

II. DESCRIPTION OF ANALYSIS

The analyses documented in Reference 1 give the minimum RBCU heat removal rate requirements to meet Environmental Qualification criteria for the Reactor Building temperature and pressure at the Oconee Nuclear Station. The FATHOMS/DUKE-RS containment analysis code (Reference 2) was used for these analyses. All initial and boundary conditions, as well as all system flow rates, are documented in a summary table on pg. 20 of Reference 1. The LPSW flow rate through the LPI coolers assumed for these analyses was 5000 gpm, the nominal flowrate with one of the two LPI trains in use. It was desired to delay this flowrate for 30 minutes following the initiation of sump recirculation mode (Reference 3). In the original FATHOMS analyses in Reference 1, this flowrate was assumed for the entire sump recirculation period.

The effect of this delayed LPSW flow on the required RBCU heat removal rate to meet EQ criteria will be determined. A sufficient number of cases will be re-analyzed to quantify the impact of this delay on the containment pressure/temperature. Then, the effect of that impact on the RBCU requirements will be determined.

The cases will only be executed to the 86,000 second point. The pressure and temperature response of the Reactor Building up to that time will be compared with the EQ requirements given in Reference 4. It is not expected that a loss of LPSW flow for thirty minutes will have any impact on EQ requirements following the initial day following the event.

III. DETAILS OF ANALYSIS

The ONS FATHOMS base model (Reference 5) is utilized for this analysis. The mass and energy release data is again taken from Reference 6. The input conditions for the run are identical to those discussed on pgs. 13-19 of Reference 1 (and summarized on pg. 20), with two exceptions. No heat removal from the LPI cooler will be assumed for the period from 2808 seconds to 4608 seconds into the transient. This represents the first thirty minutes of the sump recirculation period.

A FATHOMS analysis was performed in 1993 to evaluate the impact of having no RBCU heat removal at all during the first 6000 seconds following a large-break LOCA. This analysis is documented in Reference 7. It showed that no EQ violations would occur in this time frame with no RBCU heat removal. It was intended that this analysis would address this time frame only. The analysis was used to justify reduced LPSW flows to the RBCUs in the first 30 minutes following a LOCA (the assumption of no RBCU heat removal at all was overly conservative). Since the Reference 1 analyses assumed full LPSW flow to the RBCUs throughout the transient, it is necessary to modify this assumption. Therefore, the RBCU heat capacity will conservatively be lowered during the first 30 minutes of all FATHOMS runs in this analysis. LPSW flows to the RBCUs may be found in the LPSW System Design Basis Document (Reference 8). Various flowrates are guaranteed at different times due to varying LPSW flow requirements from other systems. It is difficult to exactly quantify the effect of these reduced flows on the RBCU heat removal rates. Therefore, a general reduction in the nominal RBCU heat removal rate during the first 30 minutes is made for each case, as detailed below:

Nominal RBCU Heat Removal Capacity (x E6 BTU/hr)	Lowered RBCU Heat Removal Capacity During First 30 minutes (x E6 BTU/hr)
40	32
36	24
32	24
28	16

The RBCU heat removal rates given as a function of Reactor Building temperature and humidity in Appendix 2 of Reference 1 are still utilized in these analyses. The nominal capacities given above take into account the fouling of the RBCU coils.

The LPI Cooler heat removal rates given as a function of LPSW temperature, LPI flow, and LPSW flow in Appendix 1 of Reference 1 are utilized without modification. Only the data for a nominal heat removal rate of 93 E6 Btu/hr are used, as all cases conducted for this analysis assume the minimum LPI cooler heat removal rate of 93 E6 Btu/hr. This is a conservative assumption.

The Building Spray (BS) System is taken credit for in this analysis. The flows for this system which are documented in Reference 1 are again used here. A re-circ spray flow rate of 600 gpm is assumed.

Break Quality Matrices

Due to the lack of heat removal by the LPI coolers for the first 30 minutes into sump recirculation, the LPI water being injected into the core is much warmer than in the Reference 1 cases. Although still subcooled, the degree to which this water is subcooled is reduced below the range covered by the original break quality matrices generated for the Reference 1 cases. Therefore, it is necessary to generate additional matrices with reduced subcooling input values to cover this 30 minute period.

These matrices are generated by running the DRIVEBF2 code (Reference 9), an auxiliary code which runs multiple cases of BFLOW (Reference 10). The new DRIVEBF2 output files are attached on a diskette. The input files, documenting the subcooling range used, are shown in Appendix A.

Since a code restart is required for each new break quality matrix (placed in Group 23 of the FATHOMS/DUKE-RS input deck), the one-day simulation for this analysis is performed in three steps. The first step utilizes the original matrix for normal subcooling, since cool water is being injected directly from the Borated Water Storage Tank (BWST). This matrix is required for the period between 1800 seconds (the end of the RELAP5 mass and energy release input) and 2808 seconds (the start of sump recirculation).

The second step utilizes the new break quality matrix with reduced subcooling ranges. The LPI coolers receive no LPSW water during this step (between 2808 - 4608 seconds), so the core injection water subcooling is greatly reduced.

The third step returns to the original break quality matrix for the remainder of the first day of the analysis. Once LPSW flow is restored to the LPI coolers, the core injection water subcooling is back into the original range. This transition is assumed to occur instantly in this analysis.

Progression of Runs Performed

It is assumed that the delay in LPSW flow will only impact the first day of the containment response. Only this part of the transient is run in each case performed.

Since the cases with lower LPSW temperatures are limited by the EQ requirement at 100,000 seconds, and the cases with higher LPSW temperatures are limited at 20 days, it is reasonable to start at the lower range of LPSW temperatures and proceed upward in LPSW range. The cases documented in Reference 1 represent the minimum RBCU heat removal capacities as a function of LPSW temperature which can meet EQ requirements. Any change in the containment heat removal system which negatively impacts the containment temperature response may cause the response to worsen and violate these EQ requirements. If the delay in LPSW flow to the LPI coolers results in such a violation, the RBCU requirements will be increased and the case re-run. The analysis effort will be complete when it is determined that no further increase in RBCU requirements is necessary as result of this flow delay.

The compressed output files for all cases run in this analysis are enclosed on diskette. The file designations are given in Table 1. The 'b' and 'c' designations in the title refer to restarted runs for the same case.

IV. RESULTS

A summary of all cases run for this analysis is given in Table 1. The format of this table is identical to that in Table 1 of Reference 1. The files named in Table 1 are located at /nrsa1/tpy/fathoms/lpd. Rev. 2 TPY 3/11/98

The first case analyzed (Case A) was a re-run of Case 11 from Reference 1. This case assumed an LPSW temperature of 55°F, with a nominal RBCU capacity of 0.35 RBCU (or 28 E6 Btu/hr). The resulting temperature at the end of 1 day was 206.45°F. This case would not meet the EQ requirement of 200°F at 100,000 seconds. Therefore, the case was re-run an additional time, with an increase in the RBCU capacity to ~~0.40~~ 0.45 RBCU (~~32~~ 36 E6 Btu/hr).

When the case was re-run, the vapor temperature at the end of 1 day was ~~201.54~~ 196.25°F. This case (Case B) will meet the EQ requirement at 100,000 seconds. The vapor temperature response for this case is shown in Figure 1. It is overlaid with the vapor temperature response from Case 11 of Reference 1. The RBCU capacities for both cases are given on the figure for clarity. It is noted that the increase in RBCU capacity from 0.35 to ~~0.40~~ 0.45 compensates for the lower LPSW flow to the LPI cooler for the first 30 minutes of the sump recirculation period. The RBCU requirement at 55°F will therefore be increased to ~~0.40~~ 0.45 RBCU. ~~The new FATHOMS run was not continued any further, as the temperature response will be limited by the Case 11 response (which has a lower RBCU capacity). No further challenges to the EQ envelope are expected from this case.~~ Rev. 2 TPY 3/11/98

The Reactor Building pressure is shown in Figure 2. Again, the new FATHOMS case is compared with Case 11 from Reference 1. Since the response is identical to the Reference 1 case, the EQ long-term pressure requirement (given in Reference 9) is not challenged.

~~For Case C, the LPSW temperature was increased to 65°F, while keeping the nominal RBCU capacity at 0.40. This case is a re-run of Case 9 from Reference 1. The vapor temperature at the end of 1 day is 203.50°F. When the rate of decrease in building temperature is extrapolated, this case also meets the 100,000 second EQ requirement of 200°F. It should be noted that Case 9 from Reference 1 gave a temperature of 205.03°F at the end of 1 day. The possible causes for this change are discussed in the Comments section below.~~ Rev. 2 TPY 3/11/98

Cases D and E are re-runs of Cases 7 and 6, respectively, from Reference 1. Once again, the cases meet the EQ requirements at 100,000 seconds, giving lower containment temperatures at the 1-day point than the respective Reference 1 cases. It is concluded that no further runs are necessary, since for LPSW temperatures above 75°F, the limiting EQ criteria is the requirement at 20 days. The delay in LPSW flow has no impact on analyses limited at this point. The RBCU requirements given in Reference 1 for LPSW temperatures above 75°F are therefore unaffected.

Therefore, the effects of the 30 minute delay in LPSW flow to the LPI coolers following the initiation of sump recirculation mode have been quantified. The only increase in the required RBCU heat capacity to meet EQ criteria is an increase to ~~32~~ 36 E6 Btu (up from 28 E6) at an LPSW temperature of 55°F. Rev. 2 TPY 3/11/98

Case	INPUT					OUTPUT		FILE	
No.	LPI	RBCU	LPSW	BS		T(1 day)	EQ Criteria	NAME	
	(Btu/hr)	(Btu/hr)	(F)	(gpm)		(F)	Met?		
A	93 E6	28 E6	55	600		206.45	No	spb.33=	
B	93 E6	36 E6	55	600		196.25	Yes	spb.eqcm	
C	(deleted)								
D	93 E6	36 E6	70	600		202.26	Yes	spb.43=	
E	93 E6	40 E6	75	600		201.35	Yes	spb.53	

TABLE 1 - FATHOMS Runs For Minimum Long-term RBCU Requirements
LPSW Flow Delay for 30 minutes During Sump Recirculation

FIGURE 1

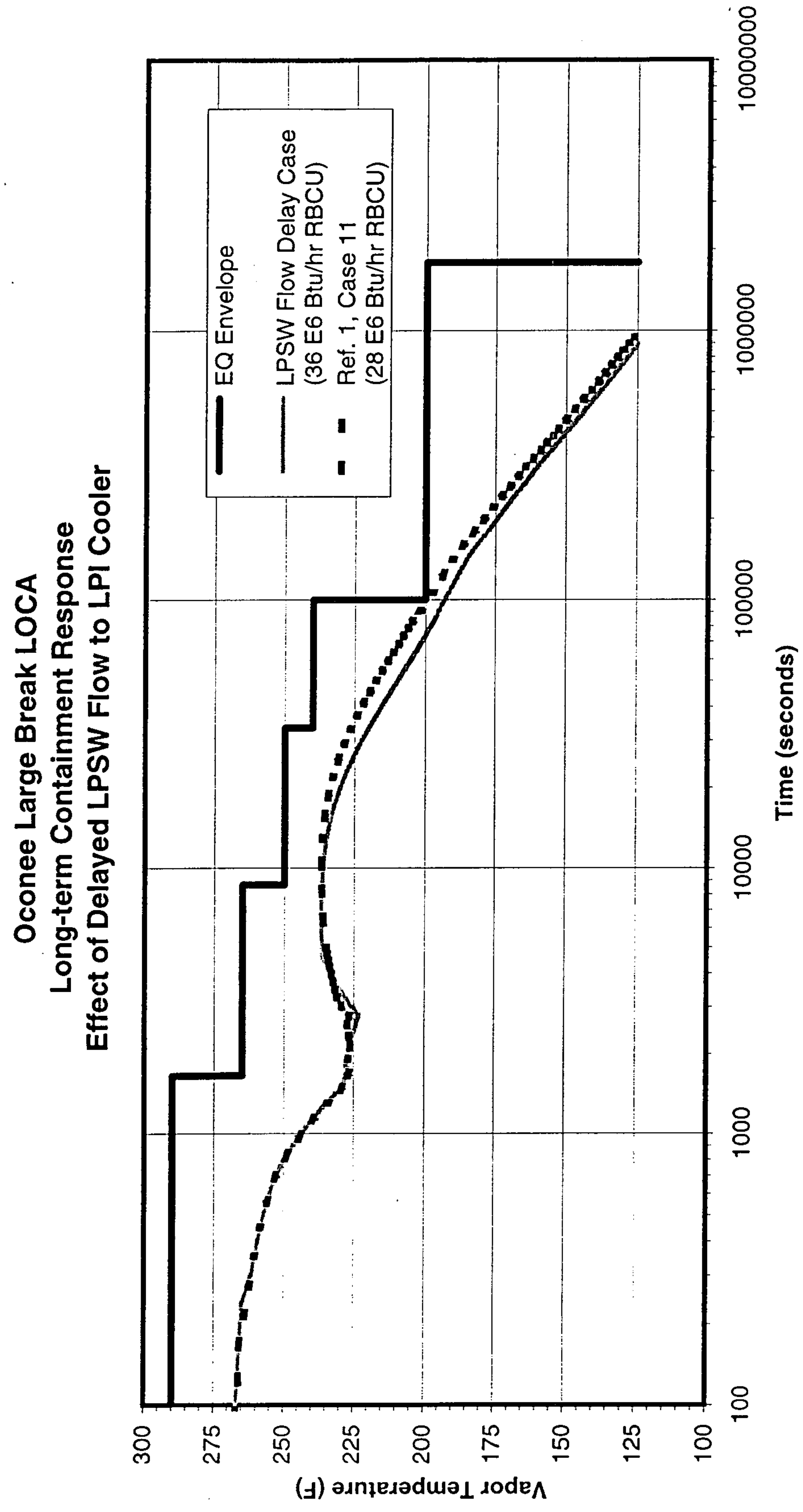
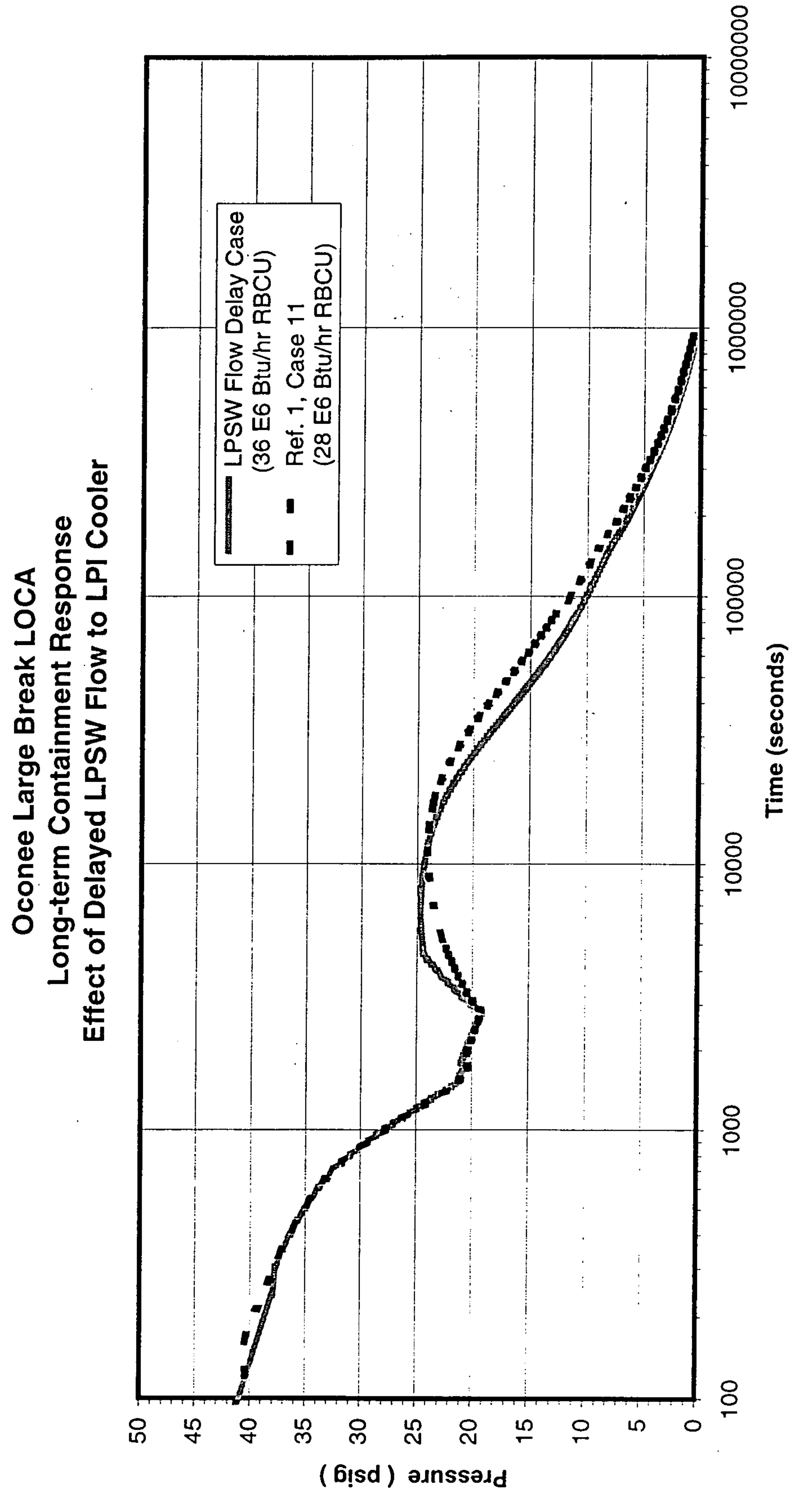

Oconee Large Break LOCA
Long-term Containment Response
Effect of Delayed LPSW Flow to LPI Cooler
EQ Envelope
LPSW Flow Delay Case
(36 E6 Btu/hr RBCU)
Ref. 1, Case 11
(28 E6 Btu/hr RBCU)
Vapor Temperature (F)
300
275
250
225
200
175
150
125
100
Time (seconds)
100
1000
10000
100000
1000000
10000000

FIGURE 2



Oconee Large Break LOCA
Long-term Containment Response
Effect of Delayed LPSW Flow to LPI Cooler
LPSW Flow Delay Case
(36 E6 Btu/hr RBCU)
Ref. 1, Case 11
(28 E6 Btu/hr RBCU)
Pressure (psig)
50
45
40
35
30
25
20
15
10
5
0
Time (seconds)
100
1000
10000
100000
1000000
10000000

V. COMMENTS

1. There are several factors contributing to the lower vapor temperature at the 1-day point for Cases C-E above, compared with Cases 9, 7, and 6 from Reference 1. They are discussed below, in decreasing order of probable importance: Rev. 2 TPY 3/11/99

   a) The lack of any LPI cooling from 2808 to 4608 seconds causes the sump temperature to increase, relative to the cases with no loss of LPI cooler heat removal. Although this temperature increase is offset slightly by the cooler water exiting the break (high break flow quality = more steam out the break = colder water exiting the break), the increase holds throughout the duration of the 1-day analysis; therefore, once the LPI cooler LPSW flow is re-established, the LPI cooler removes more energy throughout the analysis, relative to the original case. It is possible that somehow this delay causes the overall heat removal from the Reactor Building to be slightly more efficient, with the vapor temperature at 1 day actually lower than the case with no delay.

   b) The decrease in nominal RBCU capacity for the first 30 minutes has an impact on the vapor temperature, possibly enhancing the effect given above. Increased heat transfer to the concrete heat structures in the building, caused by warmer temperatures during the first day of the analysis, also has an impact on the 1-day vapor temperature difference observed.

   c) The FATHOMS code was re-certified between the time when the Reference 1 analyses and the current analyses were performed. The results of the test cases run for the re-certification effort revealed slight, but seemingly negligible, differences between the two code versions for the long-term ONS analysis case.

VI. REACTIVITY MANAGEMENT

The reactivity management aspects of a large-break LOCA have been considered previously from a design basis point of view. No new concerns are raised by the assumptions made in these analyses or the results of the FATHOMS analyses. The delay in LPSW flow to the LPI coolers has no impact on the boron concentrations in the Reactor Coolant System or Reactor Building sump. The results from previous analyses still apply for these concentrations.

VII. REFERENCES

1) OSC-5280, "FSAR Section 15.14.5 - LBLOCA Containment Cooling Requirements II", Rev. 0, Duke Power Company, May 13, 1993.

2) SDQA-30056-NGO.R00, "FATHOMS/DUKE-RS SDQA Plan", Rev. 0, Duke Power Company, January 30, 1996.

3) PROFS Note, T.R.Lee to R.E.Harris, Delay of LPSW Flow to LPI Coolers, January 29, 1996.

4) OSC-2784, "Fouled Cooler/High Lake Temperature Equipment Qualification Evaluation", Rev. 1, Duke Power Company, January 12, 1990.

5) OSC-3886, "FATHOMS Oconee Base Model", Rev. 1, Duke Power Company, July 22, 1991.

6) OSC-4082, "LBLOCA Long-Term Mass and Energy Release Analysis", Rev. 0, Duke Power Company, September 12, 1990.

7) OSC-5502, "LBLOCA Containment Response With No RBCUs", Rev. 0, Duke Power Company, August 20, 1993.

8) ONOE-8209, "Low Pressure Service Water (LPSW) System - Design Basis Documentation", Rev. 5, Duke Power Company, February 1996.

9) OSC-4044, "DRIVEBF2 Code Certification", Revision 1, Duke Power Company, January 19, 1993.

10) OSC-3849, "BFLOW Code Certification", Revision 4, Duke Power Company, October 27, 1992.

APPENDIX A
Revised BFLOW Matrix For Low Subcooling Values

The break quality matrices used for the analyses documented in Reference A-1 were generated with a range of subcooling values from 50 to 170°F. However, for the period in the analyses documented above when there is no LPSW flow to the LPI coolers, the water being injected into the core is subcooled less than 50°F. Therefore, an additional break quality matrix was required for this period in the analysis. The DRIVEBF2 code (Reference A-2) was utilized to generate this matrix.

The new matrix uses the ranges below for the process variables (decay heat, containment pressure, LPI flow, LPI subcooling). The LPI subcooling values are lower than those documented in Reference A-3.

Decay Heat (MW):	18. 25. 30. 35. 45. 55.
Cont. Pressure (psia):	16. 20. 25. 32. 41. 55.
LPI flow (lbm/sec):	270. 330. 390. 410. 630. 850.
LPI subc. (°F):	10. 20. 30. 40. 50. 60.

Of the 1296 cases executed by DRIVEBF2, 29 cases did not converge. For these values, interpolated break quality values are inserted in the break quality matrix. This is not expected to have a significant impact on the analysis.

The break quality matrix is included on the attached diskette, with the filename *case1q.out*.

References

A-1). OSC-5280, "FSAR Section 15.14.5 - LBLOCA Containment Cooling Requirements II", Rev. 0, Duke Power Company, May 13, 1993.

A-2.) OSC-4044, "DRIVEBF2 Code Certification", Revision 1, Duke Power Company, January 19, 1993.

A-3.) OSC-4081, "Post-Cold-Leg LOCA Break Quality Matrix Generation III", Duke Power Company, January 21, 1993.

APPENDIX B

Effect of 30 Minute Delay of LPSW Flow on RBS Pump NPSH Requirements

Following a LOCA, the Reactor Building Spray (RBS) pumps operate to aid in the de-pressurization of the Reactor Building. The cool water sprayed into the Reactor Building atmosphere condenses steam, decreasing the building pressure and transferring the vapor energy to the sump, where it may be removed from the building through the LPI coolers. At certain combinations of low building pressures combined with elevated sump temperatures, there is a concern whether sufficient net positive suction head (NPSH) exists for the RBS pumps to prevent pump cavitation. Following a cold leg break, there is sufficient building pressure to prevent NPSH concerns, due to the prolonged release of steam in this accident. However, for a hot leg break, the break site is flooded within 30 minutes of the accident, and there is no long-term steaming from the break. The core decay heat is removed from the Reactor Coolant System entirely through the injection water, which then exits the break. This allows building pressure to decrease much more rapidly following a break at this location. As decay heat is being removed through the injection water, this warm water heats the Reactor Building sump. This hot leg break scenario creates a combination of low post-accident building pressures and warm sump temperatures, which is more limiting for NPSH concerns than that created by the cold leg break.

The 30 minute delay of LPSW flow to the LPI coolers following the initiation of sump recirculation mode could have an effect on this concern by further increasing sump temperatures. The loss of LPSW flow causes a loss of LPI cooler heat removal. This water is injected to the core while subcooled by <50°F at times during this 30 minute interval. Since this water is heated to saturation, it will cause break flow temperature to increase. In turn, this causes the sump temperature to increase to a greater extent during this interval.

In this appendix, the hot leg break transient will be analyzed both with and without the 30 minute delay in LPSW flow. The impact of the 30 minute delay on the Reactor Building response will be determined.

DESCRIPTION OF ANALYSIS

The Reference B-1 analysis documents the containment response for a break in the cold leg piping. The hot leg break analysis is conducted in a similar manner as these cold leg break analyses. As a result of the different break location, the break flow matrices taken from the BFLOW code output are not utilized; the long-term hot leg break model in FATHOMS is utilized instead. This model assumes that the core decay heat is added directly to the injection flow, with this flow then exiting the break. If this flow reaches saturation, the remaining energy from core decay heat is used to boil the injection water. All the decay heat is used to heat this flow; there is no loss of reactor coolant system inventory.

The same initial conditions are utilized here as the Reference B-1 cold leg break analyses. The mass and energy release boundary conditions are taken from RELAP5 analyses documented in Appendix G of Reference B-2. The differences in the remaining boundary condition assumptions are described below. Where it is uncertain which boundary condition assumptions are conservative with respect to NPSH determination, several runs are performed.

DETAILS OF ANALYSIS

The FATHOMS Oconee base model (Reference B-3) is used for the Reactor Building model. The runs are conducted in three segments, with different flowpaths used in each segment, as was done in the Reference B-1 analysis. The first segment ends at 1800 seconds, which is the end of the RELAP5 mass and energy release data. The second segment lasts from 1800 to the beginning of sump recirculation mode; this time varies with analysis assumptions, as described below. The third segment lasts from the beginning of sump recirculation mode to 86,400 seconds. By this time, the sump temperature has decreased well below the region of concern for NPSH determination.

Reactor Building Initial Conditions

The Reactor Building initial conditions are unchanged from the Reference B-1 analyses. The same assumptions which maximize long-term building pressures and temperatures also maximize sump temperatures, so the assumptions from Reference B-1 are repeated in these analyses.

BWST Volume

Due to differing injection rate assumptions, there is not one specific time at which sump recirculation mode is entered in all cases for this analysis. Therefore, no unique BWST level is utilized in the FATHOMS BWST model, as was done in the Reference B-1 analysis. Instead, a large volume is used with water at the appropriate temperature to model the BWST, with no effort made at tracking level within the computer calculation. A hand calculation (detailed below) will determine at what point the sump recirculation switchover point is reached. The BWST water is initialized at 115°F, as in the Reference B-1 analysis.

Passive Heat Sink Data

The same heat sink data is used for the hot leg break analysis as was used in the Reference B-1 analysis. The Groups 2 and 3 heat structures are initialized at the same temperature and initial heat transfer characteristics as before. (These structures represent the primary and secondary side heat structures which are not in contact with the Reactor Coolant System [RCS] inventory. They are activated at 1800 seconds in the FATHOMS analysis.) Because there is more heat transfer out of the RCS into containment in the hot leg break, and these structures will be cooler in this break at any particular time than in the cold leg break, it is conservative to leave these structures with the same initial conditions as in the cold leg break analysis.

Boundary Conditions / System Flowrates

The junctions identified on pg. 9 of Reference B-1 are used again for the hot leg break analysis. Each junction is active during the same segment(s) as identified in the cold leg break analysis.

Building Spray Flow (Segment 1)

The RBS flow from Reference B-1 is not used here due to an updated flow uncertainty, as documented in Reference B-4. At a nominal flow rate of 1500 gpm, the positive uncertainty (the difference between actual flow and indicated flow, when the gauge is reading high) is 100.2 gpm. (The Units 2 and 3 uncertainties on pg. 36 of Reference B-4 are larger, and therefore used in this analysis.) The negative uncertainty (when the gauge is reading low) is 136.3 gpm. Therefore, for cases with the assumption that RBS flow is conservatively low, to minimize steam condensation in the containment atmosphere, the flowrate is calculated as:

$$\text{RBS flow (low)} = 1500 \text{ gpm} - 126.2 \text{ gpm} \quad = 1374.8 \text{ gpm} \quad (= 3.063 \text{ ft}^3/\text{sec})$$

For cases with the assumption that RBS flow is conservatively high, to drain the BWST in the shortest time, the flowrate is:

RBS flow (high) = 1500 gpm + 136.3 gpm = 1636.3 gpm (= 3.646 ft^3/sec)

This water is added to the containment atmosphere at a temperature of 115°F, as in the Reference B-1 analyses. The initiation times and droplet sizes for the RBS system also remain unchanged.

LPI/BS Discrepancy Flowpath (Segment 1)
In the RELAP5/GOTHIC cold leg break analyses, the LPI flow to the core is conservatively assumed low (nominal - uncertainty) to reduce core cooling. Likewise, the RBS flow was assumed low to reduce steam condensation in containment. However, conservatively high LPI and RBS flowrates (nominal + uncertainty) were simultaneously assumed to drain the Borated Water Storage Tank (BWST) in the shortest possible time for single-train injection. The discrepancy flow created by the use of these two assumptions (2 * uncertainty) was added directly to the sump via a separate flowpath.

In the hot leg break analysis, many of the cases analyzed will not make these simultaneous assumptions. Either low or high flowrates are assumed throughout these cases. Since low RBS flowrates will drain the BWST slower, a longer switchover time is calculated below for these cases.

Segment 2 Flowrates
For cases which use the same flowrate assumptions as those given in Reference B-1, the flowrates must still be recalculated due to the new LPI and RBS flow uncertainty data given in References B-4 and B-5. The cases which drain the BWST as rapidly as possible use the following flowrates for boundary condition 5, which removes water from the BWST during Segment 2:

LPI flow:	3000 gpm +	291 gpm =	3291 gpm	
HPI flow:	1000 gpm +	0 =	1000 gpm	
RBS flow:	1500 gpm +	133 gpm =	1633 gpm	
			5924 gpm	(= 13.199 ft^3/sec)

The LPI and HPI components of this flow are injected into the core. The broken HPI injection flowpath from the Reference B-1 analysis is not applicable to this hot leg break analysis, so the entire 1000 gpm of HPI flow is injected into the core with no spillage. With the uncertainty of the LPI flow and RBS flow reversed for cases which make this assumption to minimize containment cooling, this flow is divided as follows:

Injected flow:	3000 gpm + 1000 gpm - 117 gpm =	3883 gpm	(0.6555)
Sprayed flow:	1500 gpm - 126 gpm =	1374 gpm	(0.2319)
Discr. flow:	(117 + 291 + 133 + 126) gpm =	667 gpm	(0.1126)

For these cases, the switchover time to sump recirculation mode is:

Initial BWST level = 44.3 ft (Reference B-1, pg. 23)
Switchover setpoint = 7.68 ft (" , pg. 96)
Used inventory = (44.3 ft - 7.68 ft) (7606 gal / ft) = 278,500 gal
Assuming all injection/spray flow starts from time = 0 , switchover time =
278,500 gal / 5924 gpm = 47.0 minutes = 2820 seconds

As this is virtually the same time as used in the Reference B-1 analyses, the switchover points remain unchanged in the input decks for these cases.

Another subset of cases assumes that the flows from the BWST, as well as the actual injection/spray flows, are conservatively low. This eliminates the discrepancy flow. For these cases, the BWST depletion flows are:

LPI flow:	3000 gpm -	117 gpm =	2883 gpm	
HPI flow:	1000 gpm -	0 =	1000 gpm	
RBS flow:	1500 gpm -	126 gpm =	1374 gpm	
			5257 gpm	(= 11.713 ft^3/sec)

This flow is divided as follows:

Injected flow:	2883 gpm + 1000 gpm	= 3883 gpm (0.7386)
Sprayed flow:		= 1374 gpm (0.2614)
Discr. flow:		= 0 gpm (0.0)

For these cases, the switchover time to sump recirculation mode is:

278,500 gal / 5257 gpm = 53.0 minutes = 3180 seconds

Another set of cases assumes that RBS flow is maximized, while LPI flow remains at minimum flow levels. These cases were performed with high RBS flowrates because high flow are more limiting for NPSH criteria. For these cases, the BWST depletion flows are:

LPI flow:	3000 gpm -	117 gpm =	2883 gpm	
HPI flow:	1000 gpm -	0 =	1000 gpm	
RBS flow:	1500 gpm +	133 gpm =	1633 gpm	
			5516 gpm	(= 12.290 ft^3/sec)

This flow is divided as follows:

Injected flow:	2883 gpm + 1000 gpm	= 3883 gpm (0.7040)
Sprayed flow:		= 1633 gpm (0.2960)
Discr. flow:		= 0 gpm (0.0)

For these cases, the switchover time to sump recirculation mode is:

278,500 gal / 5516 gpm = 50.5 minutes = 3030 seconds

Core Decay Heat

A table for the core decay heat is entered in Card Group 13 of the input deck. The data is again taken from Reference B-6. The energy data for the Group 1 heat structures (those in contact with the RCS inventory) is taken from Reference B-2. This data only extends to 21,600 seconds; after this time, the Group 1 contribution is unchanged from the Reference B-1 analyses. Since this data is for a cold-leg break, and is higher, the use of this data is conservative.

Segment 3 Flowrates

Upon the beginning of sump recirculation mode, water is taken from the sump drain through boundary condition 10, cooled by the LPI coolers, and then injected into the core. The LPI flowrate of 2883 gpm (6.423 ft^3/sec) remains unchanged. The RBS flowrate, which is normally throttled back to 1000 gpm, is adjusted for flow uncertainty and the open drain valves (BS-15 and -20; see Reference B-7, pg. 20) as follows:

RBS Flow (minimum) = 1000 gpm - 126.7 gpm - 75 gpm = 798.3 gpm (1.779 ft^3/sec)

RBS flow (maximum) = 1000 gpm + 160.0 gpm - 75 gpm = 1085.0 gpm (2.417 ft^3/sec)

Note that 75 gpm is subtracted from both RBS flow assumption calculations. This 75 gpm represents flow that was removed from the sump but leaked through the open drain lines without getting to the RBS spray headers. Even in the maximum flow case, it is conservative to assume the full 75 gpm leakage, as this maximizes flow through the RBS pumps but minimizes actual flow through the spray headers (and reduces containment cooling) for this assumption.

Nitrogen Cover Gas

The assumptions and flowrates used in the Reference B-1 analyses for the core flood tank cover gas entering containment are unchanged.

LPI Cooler Data

The LPI Cooler heat transfer rates documented in Appendix 1 of Reference B-1 are used in the hot leg break analysis. The heat transfer coefficients used are calculated at an LPI flowrate of 2685 gpm; the flowrates used in the hot leg break analyses are higher, but these lower heat transfer coefficients are used for conservatism.

For periods when there is no LPSW flow through the LPI cooler secondary side (30 minutes following sump recirculation switchover), for cases where this is applicable, the heat transfer area on the primary side of the LPI cooler is reduced to 1.0E-6. This modeling technique eliminates all LPI cooler heat transfer for this interval, as if there were no cooling water flow on the secondary side of the cooler. The appropriate heat transfer area is re-entered in the input deck through a code restart upon the starting of the LPSW flow.

RBCU Data

The heat transfer rates in Appendix 2 of Reference B-1 are utilized for RBCU heat removal.

Progression of Runs Performed

It is uncertain exactly which flowrate and building cooling assumptions are conservative with respect to the determination of the limiting case for NPSH criteria. It is desired to reduce containment pressure and increase sump temperature, as this combination is the most limiting for NPSH concerns. The first case analyzed uses the same assumptions as Case 1 in Reference B-1. These are as follows (with containment cooling data given in Btu/hr for nominal conditions) :

CASE 1: LPI flow = (3000 - uncertainty)
RBS flow = (1500 - uncertainty) (1000 - uncertainty, re-circ)
Discr. flow = maximum (this minimizes containment cooling, while draining the BWST in the minimum possible time for single-train injection)
Containment cooling: RBCU=72 E6, LPI=93 E6, LPSW = 90°F

The containment cooling data assumed in Case 1 is the minimum required at an LPSW temperature of 90°F to meet EQ requirements, as given in Reference 1. The initial assumption is made that minimum containment cooling conditions are limiting with respect to NPSH criteria. Case 1A changes these conditions to the minimum at an LPSW temperature of 55°F:

CASE 1A: LPI flow = (3000 - uncertainty)
RBS flow = (1500 - uncertainty) (1000 - uncertainty, re-circ)
Discr. flow = maximum (this minimizes containment cooling, while draining the BWST in the minimum possible time for single-train injection)
Containment cooling: RBCU=32 E6, LPI=93 E6, LPSW = 55°F

In Case 2, the discrepancy flow is eliminated; in this case and all future cases, the flow leaving the BWST and the flow being injected in the core or sprayed into containment will be the same. This will change the time of switchover to sump recirculation mode relative to the Reference B-1 analyses.

CASE 2: LPI flow = (3000 - uncertainty)
RBS flow = (1500 - uncertainty) (1000 - uncertainty, re-circ)
Discr. flow = None; Swapover time = 3180 sec
Containment cooling: RBCU=72 E6, LPI=93 E6, LPSW = 90°F

In Case 2A, the uncertainty on the RBS flow is reversed; this drains the BWST more rapidly, and increases NPSH requirements.

CASE 2A: LPI flow = (3000 - uncertainty)
RBS flow = (1500 + uncertainty) (1000 + uncertainty, re-circ)
Discr. flow = None; Swapover time = 3030 sec
Containment cooling: RBCU=72 E6, LPI=93 E6, LPSW = 90°F

Case 5 is the first case with the 30 minute delay in LPSW flow to the LPI cooler. The other assumptions are identical to those in Case 2. (Note: Cases 3 and 4 are deleted.)

CASE 5: LPI flow = (3000 - uncertainty)
RBS flow = (1500 - uncertainty) (1000 - uncertainty, re-circ)
Discr. flow = None; Swapover time = 3180 sec; LPSW flow at 4980 sec
Containment cooling: RBCU=72 E6, LPI=93 E6, LPSW = 90°F

Cases 5C, 5G, and 5K are sensitivity cases on Case 5 for the containment cooling assumptions. Minimum cooling assumptions have been assumed in all previous cases. It is possible that increased cooling could lower building pressure and be more limiting with respect to NPSH requirements.

CASE 5C: Containment cooling: RBCU=72 E6, LPI=93 E6, LPSW = 70°F
CASE 5G: Containment cooling: RBCU=88 E6, LPI=93 E6, LPSW = 90°F
CASE 5K: Containment cooling: RBCU=120 E6, LPI=93 E6, LPSW = 90°F

Case 6 is another minimum containment cooling sensitivity case taken from Case 5 with the 30 minute LPSW flow delay. This case again has the minimum containment cooling requirements for an LPSW temperature of 55°F.

CASE 6: LPI flow = (3000 - uncertainty)
RBS flow = (1500 - uncertainty) (1000 - uncertainty, re-circ)
Discr. flow = None; Swapover time = 3180 sec; LPSW flow at 4980 sec
Containment cooling: RBCU=32 E6, LPI=93 E6, LPSW = 55°F
0.4

Case 7 is another re-run of Case 5, with the uncertainty on the RBS flowrate reversed.

CASE 7: LPI flow = (3000 - uncertainty)
RBS flow = (1500 + uncertainty) (1000 + uncertainty, re-circ)
Discr. flow = None; Swapover time = 3030 sec; LPSW flow at 4830 sec
Containment cooling: RBCU=72 E6, LPI=93 E6, LPSW = 90°F

RESULTS

The building pressure, vapor temperature, and sump temperature responses are shown in Figures B-1, B-2, and B-3 for Cases 1,1A, and 2 only. The remainder of the cases show the same general trend as illustrated in these figures. In each figure, the start of sump recirculation mode is visible, as containment cooling decreases somewhat at this point. There are no cases illustrated in these figures with the 30 minute LPSW delay; these trends are evaluated for this delay earlier within this document with respect to EQ limitations.

The peak pressure shown in Figure B-1 is 55 psig. The reason that this curve does not approach 59 psig as in the Reference B-8 analysis is that the same containment conditions are not assumed. In this analysis, assumptions are made to maximize long-term containment temperatures and pressures, and not short-term pressure, as was done in Reference B-8.

Figures B-4 through B-7 show the Reactor Building pressure as a function of sump temperature following switchover (NPSH curve). In all cases, there is an increase in sump temperature upon the start of sump recirculation mode. Therefore, the curves will move to the right on each figure, and then down and to the left as building pressure and sump temperature decreases. For cases where a 30 minute delay in LPSW flow is assumed, there is a sharp increase in pressure during this 30 minutes; these curves will move upward and to the right, before moving down and leftward upon the initiation of LPSW flow.

In Figure B-4, the NPSH curves for Cases 1, 1A, and 2 are shown. Each of these cases assumes minimum RBS flowrates. (It should be noted again that the actual flow through the spray headers is 75 gpm less than that shown on each figure, due to the open drain valves BS-15 and -20.) Case 1A is well above the other curves due to differing containment cooling assumptions. Cases 1 and 2 start at different points, due to the differing discrepancy flow assumptions, but converge quickly. It is therefore concluded that the effects of the LPI/RBS discrepancy flow assumption are all but negligible where long-term containment response (be it EQ or NPSH requirement analysis) is concerned. Although the time of switchover is 5 minutes later in Case 2, there is no long term impact due to this difference.

In Figure B-5, the NPSH curve for Case 2A is shown. This case assumes a maximum RBS flowrate. This curve is slightly to the left of the corresponding curve for Case 2 in Figure B-4. This is due to the higher RBS flowrate assumption.

Figure B-6 shows the NPSH curves for Cases 5, 5C, 5G, 5K, and 6. These cases assume a 30 minute delay in LPSW flow to the LPI cooler. In each curve, the upward trend shows the increase in building pressure during this delay. Case 6 is an outlier of the Case 5 set, due to the lower LPSW temperature. It is apparent from this figure (as is shown in Case 1A, Figure B-4) that it is conservative to assume high LPSW temperatures to maximize sump temperatures and minimize building pressures when determining limiting NPSH conditions.

Also apparent from Figure B-6 is the fact that the increased building cooling, in the form of decreased LPSW temperatures or increased RBCU capacity, has little impact on limiting NPSH conditions. Each curve (among Cases 5, 5C, 5G, and 5K) follows the same trend during the period of decreasing building pressure / sump temperature. As the pressure drops below about 8 psig, each curve starts to diverge due to the impact of the differing containment cooling (LPI/ RBCU) capabilities between cases.

In Figure B-7, the NPSH curve for Case 7 is shown. This case assumes maximum RBS flowrates, together with a 30 minute delay in LPSW flow to the LPI cooler. This curve is again slightly to the left of those shown in Figure B-6 due to the increased RBS flow. No sensitivities are done for this case with respect to containment cooling, as the same trends will doubtless hold true.

In conclusion, the curves shown in Figures B-4 through B-7 are provided to determine if adequate NPSH is present for the RBS / LPI pumps. The effect of the 30 minute delay in LPSW flow to the LPI cooler is visible in that the curves are slightly further to the right and lower in certain regions of the NPSH curves. There is no long-term impact of this delay.

ONS Hot Leg Break Analysis
Building Pressure

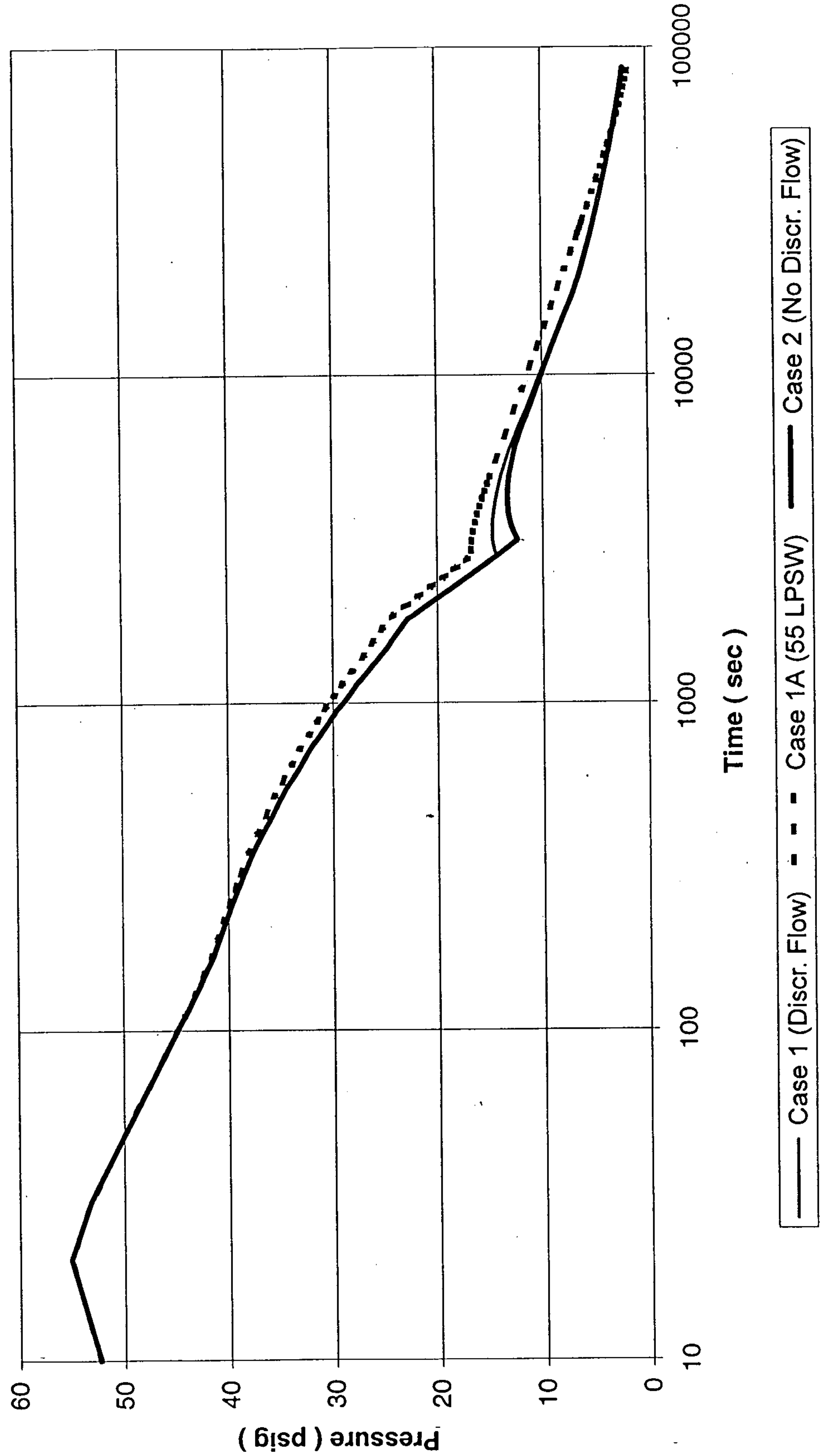


FIGURE B-1

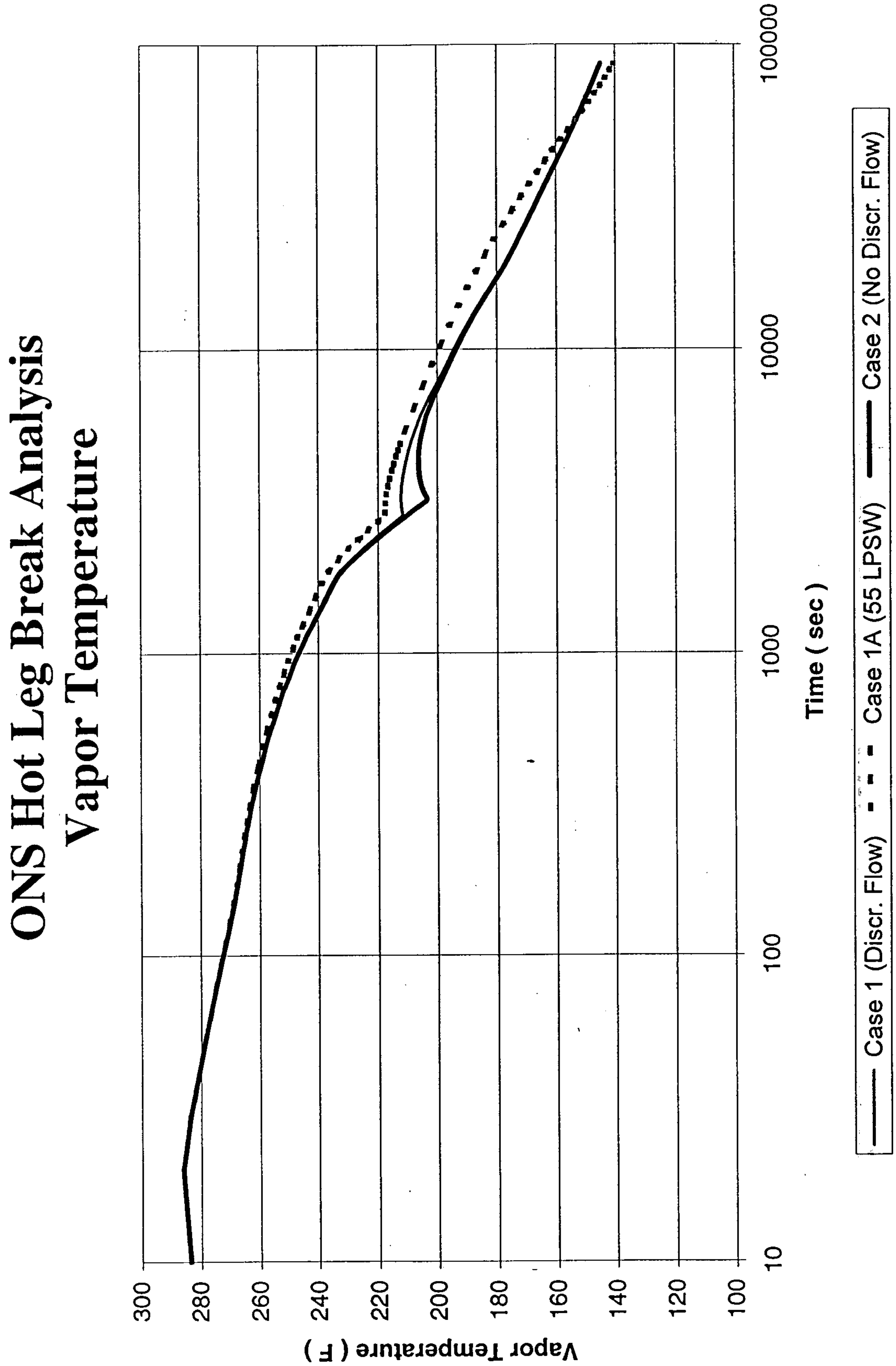

ONS Hot Leg Break Analysis
Vapor Temperature
Vapor Temperature (F)
300
280
260
240
220
200
180
160
140
120
100
10
100
1000
10000
100000
Time (sec)
Case 1 (Discr. Flow)
Case 1A (55 LPSW)
Case 2 (No Discr. Flow)

FIGURE B-2

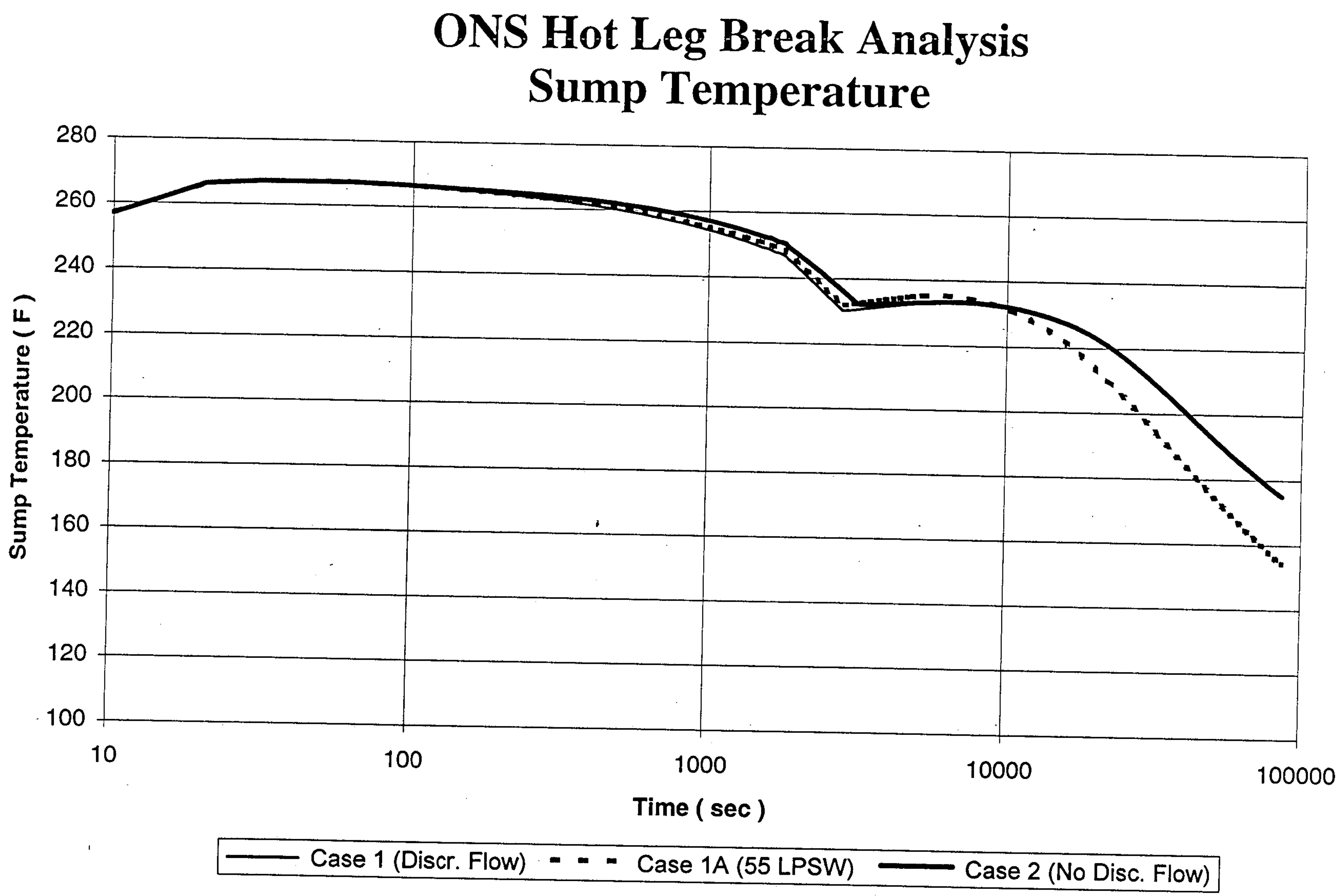

ONS Hot Leg Break Analysis
Sump Temperature
Sump Temperature (F)
280
260
240
220
200
180
160
140
120
100
10
100
1000
10000
100000
Time (sec)
Case 1 (Discr. Flow)
Case 1A (55 LPSW)
Case 2 (No Disc. Flow)

FIGURE B-3

ONS Hot Leg Break Analysis

Building Pressure Vs. Sump Temperature for Building NPSH

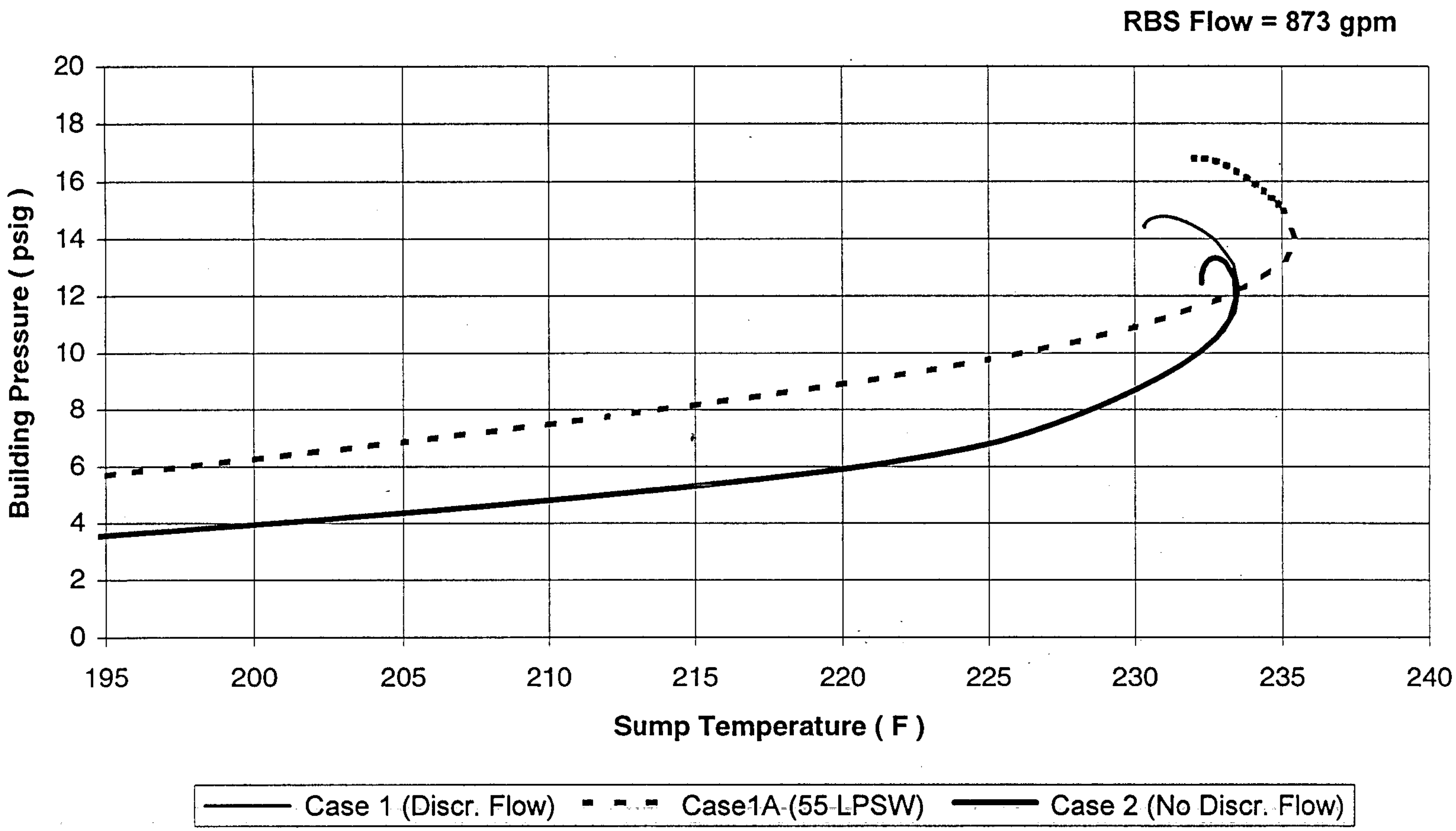


FIGURE B-4

ONS Hot Leg Break Analysis

Building Pressure Vs. Sump Temperature for Building NPSH

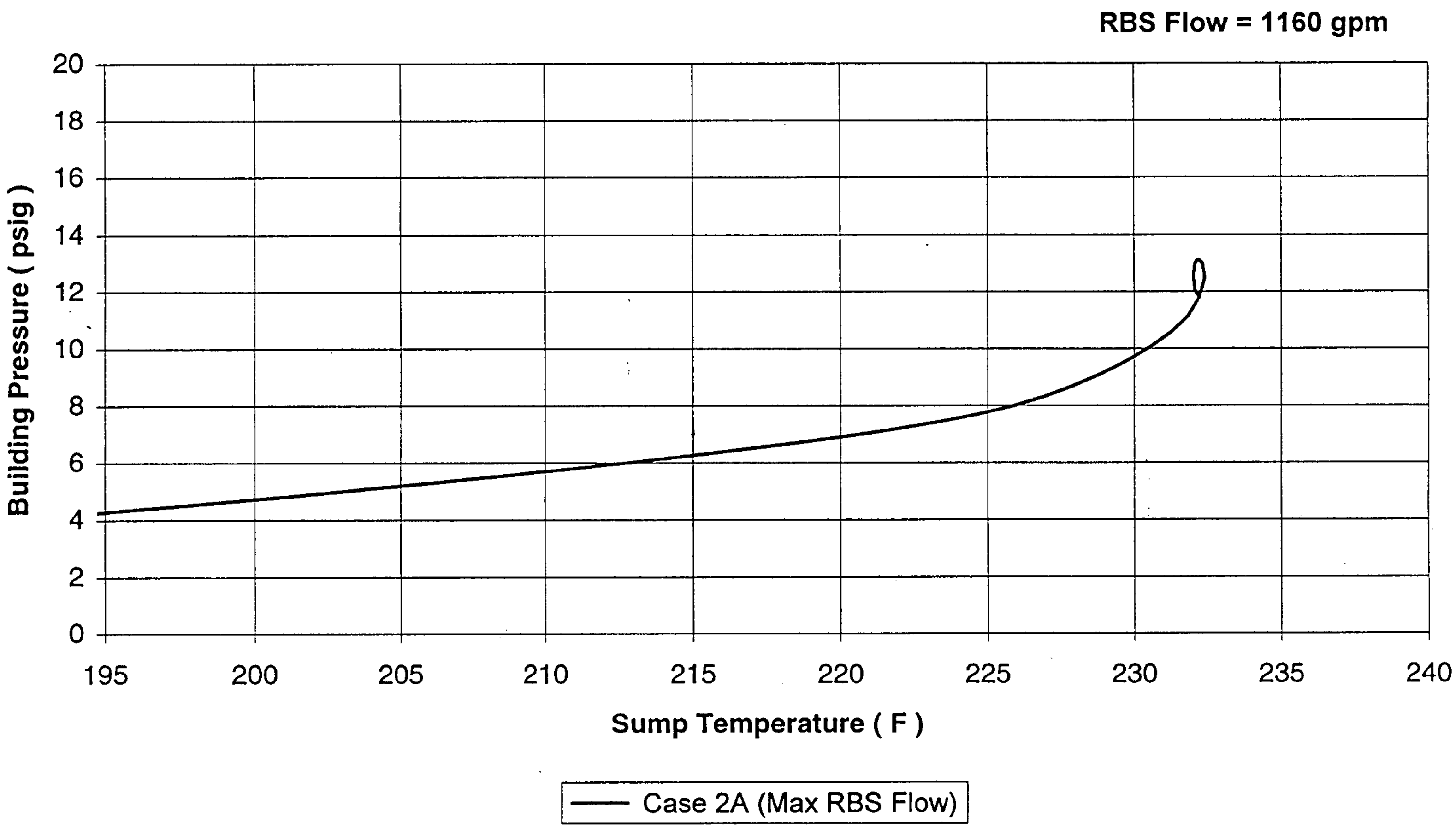


FIGURE B-5

ONS Hot Leg Break Analysis

Building Pressure Vs. Sump Temperature for Building NPSH
30 Minute Delay in LPSW Flow to LPI Cooler

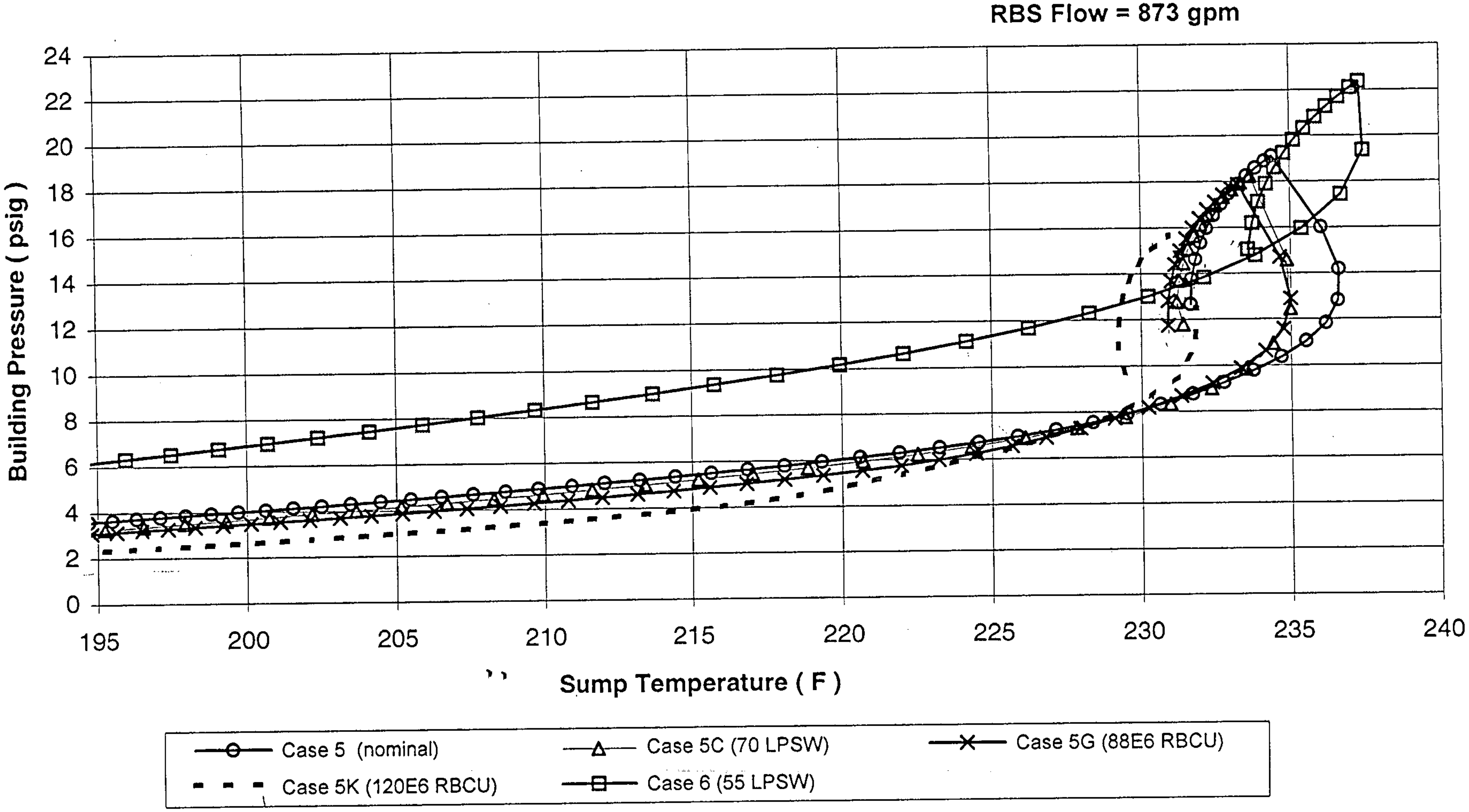


FIGURE B-6

ONS Hot Leg Break Analysis

Building Pressure Vs. Sump Temperature for Building NPSH
30 Minute Delay in LPSW Flow to LPI Cooler

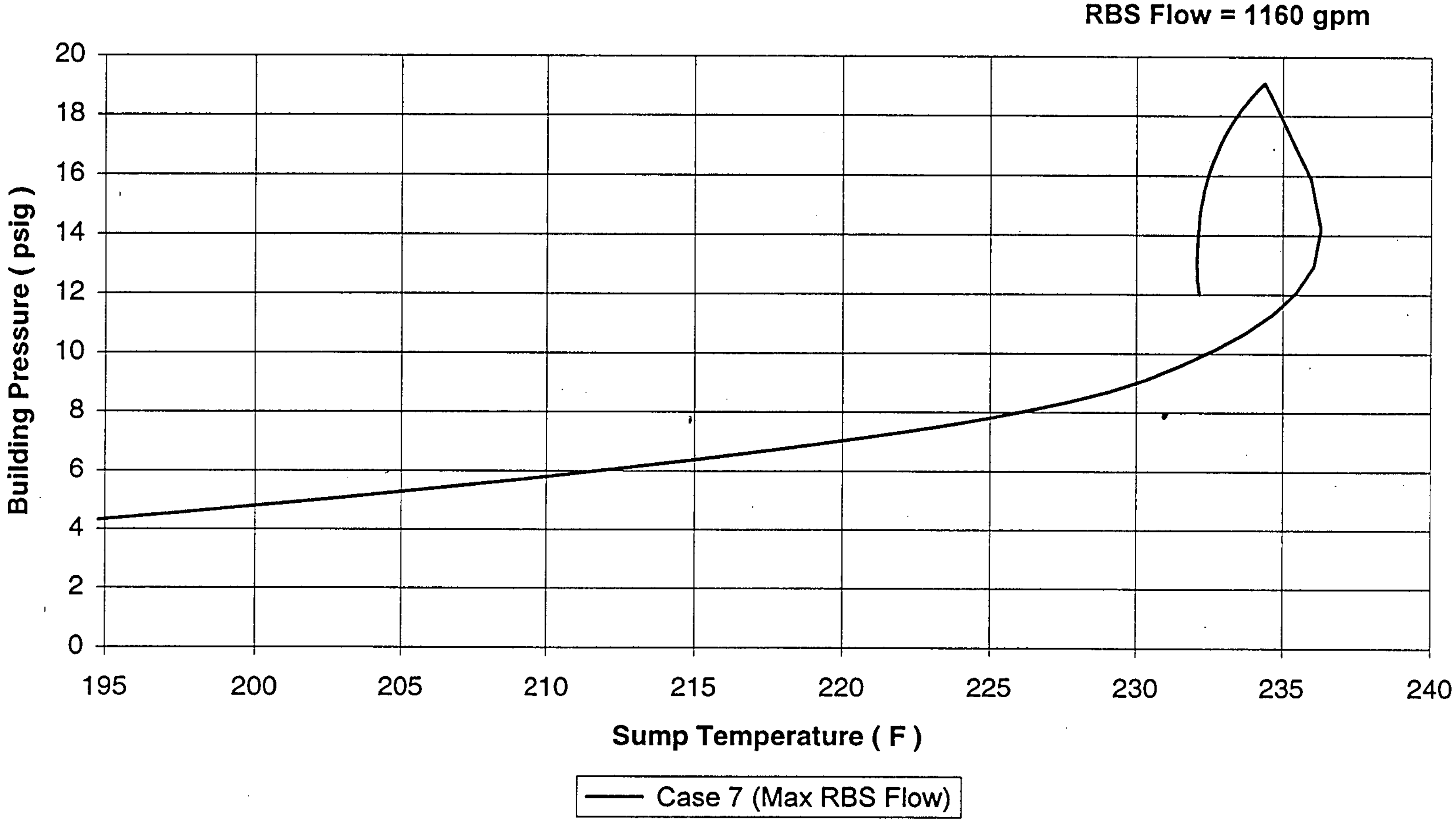


FIGURE B-7

By: TPY 3/22/96

Comments

1. No runs are analyzed for the case with two LPI trains in operation. It is anticipated that since the second LPI train would greatly increase core cooling and removal of decay heat from the building, the NPSH curves would be well to the left of those shown in Figures B-4 to B-7 due to the cooler sump water. Although switchover to sump recirculation mode would be reached quicker, the injection of the entire BWST inventory in a fraction of the time of the one-train case would result in cooler sump temperatures.

2. The 75 gpm flow of RBS water through the drain lines is not considered in these analyses prior to sump recirculation mode. It is judged that the difference between the cases analyzed here with no drain line flow and a case with 75 gpm lower RBS flow through the headers would be negligible. This is similar to the determination made above that the discrepancy flow modeled in Case 1 has no long-term impact on the containment response.

3. The actual BS flow uncertainties documented in Reference B-4 for a nominal 1000 gpm flowrate are slightly smaller (1 to 2 gpm) than those assumed in the FATHOMS analyses. This discrepancy is in a conservative direction, since there would actually be slightly more flow than assumed in the analyses.

4. The compressed output files for all cases analyzed are attached on the enclosed diskette, with the names *case1.out* to *case7.out* (as identified above).

References

B-1. OSC-5280, "FSAR Section 15.14.5 - LBLOCA Containment Cooling Requirements II", Rev. 0, Duke Power Company, May 13, 1993.

B-2. OSC-4082, "LBLOCA Long-term Mass and Energy Release Analysis", Rev. 1, Duke Power Company, April 11, 1996.

B-3. OSC-3886, "FATHOMS Oconee Base Model", Rev. 1, Duke Power Company, July 22, 1991.

B-4. OSC-4084, "BS Flow Loop Instrument Accuracy Calculation for BS FT-0002A and BS FT-0003A", Rev. 2, Duke Power Company, March 22, 1996.

B-5. OSC-3566, "LPI Flow Loop Instrument Accuracy Calculation for Instruments FT-004P and FT-005P", Rev. 3, Duke Power Company, March 22, 1996.

B-6. OSC-3984, "Decay Heat Power with Uncertainty for 440-Day Cycles", Rev. 1, Duke Power Company, October 3, 1993.

B-7 OSS-0254.00-00-1034, "Reactor Building Spray System - Design Basis Documentation", Rev. 1, Duke Power Company, October 17, 1995.

B-8. OSC-4475, "FSAR Section 15.14.5 - LBLOCA Peak Containment Pressure Analysis", Rev. 0, Duke Power Company, May 6, 1992.

APPENDIX C

Effect of Revised Containment Analysis Input Parameters on RBS/LPI Pump NPSH Requirements

This appendix is a continuation of the Appendix B calculations to determine the containment response following a large hot leg break LOCA. This break scenario has been identified as the most limiting for RBS and LPI pump NPSH concerns due to the combination of low post-accident building pressures and warm sump temperatures.

The effects of changes in several parameters are examined in this Appendix. These parameters include the initial building temperature, initial building pressure, the BWST temperature, and the length of time in which no LPSW flow is supplied to the LPI coolers following the initiation of sump recirculation mode. The analyses documented in Appendix B assumed a 30 minute LPSW delay, with nominal, rather than limiting, assumptions for long-term containment analyses for initial building pressure and temperature.

DESCRIPTION OF ANALYSIS

The FATHOMS/DUKE-RS containment analysis code (Reference C-1) was used for these analyses. They are conducted in a similar manner to those in Appendix B. One difference is that the mass and energy release data taken from the RELAP5 code (Reference C-2) is utilized only for the first 400 seconds of the transient. After this time, the long-term hot leg break model in FATHOMS is used to determine the mass and energy release from the pipe break. The reasons for and adjustments required by this analysis variation are discussed below.

The mass and energy release boundary conditions are taken from RELAP5 analyses documented in Appendix G of Reference C-3. The methodology utilized is consistent with that given in the Duke topical report DPC-NE-3003-PA (Reference C-4). The SER for this topical report was issued on March 15, 1995.

DETAILS OF ANALYSIS

The FATHOMS Oconee base model (Reference C-5) is used for the Reactor Building model. The runs are conducted in three segments, with different flowpaths used in each segment, as was done in the Reference C-6 analysis. The first segment ends at 400 seconds; during this segment, the RELAP5 mass and energy release data is utilized. The second segment lasts from 400 seconds to the beginning of sump recirculation mode; the FATHOMS long-term hot leg break model is utilized starting from the beginning of this segment. The third segment lasts from the beginning of sump recirculation mode to 86,400 seconds. By the end of this segment, the sump temperature has decreased well below the region of concern for NPSH determination, and the analysis is terminated.

<u>Reactor Building Initial Pressure and Temperature</u>
Oconee Technical Specification 3.6.4 allows the Reactor Building (RB) pressure to be between -2.45 and +1.2 psig while the reactor is critical. It is conservative for this analysis to assume a low initial building pressure. This minimizes the building pressure throughout the analysis, without any considerable effect on the sump temperature. In the bases for T.S. 3.6.4, the process through which this low initial vacuum pressure could be reached is discussed.

The majority of cases performed for this analysis assume an initial RB pressure of -1.0 psig. Following discussions with station personnel and a search of plant operating data, the minimum indicated Reactor Building pressure experienced during recent plant operating history was determined to be -0.5 psig, while the historical low atmospheric pressure reading at Oconee was determined to be -0.7 psig. The uncertainty value for the narrow range RB pressure instrument loop (taken from Reference C-7) at -0.5 psig is +/-0.5 psi. The lowest possible RB pressure is the sum of these three components [(-0.5) +(-0.7) + (-0.5)], or -1.7 psig. An evolution from an initial RB temperature of 160°F at the minimum atmospheric pressure of -0.7 psig to a pressure of -1.7 psig through a normal cooldown (assuming the volume remains constant, and the steam contribution to the RB partial pressure is minimal at these low pressures) brings the final temperature down to about 116°F, as determined below:

$$P_1 / P_2 = T_1 / T_2$$

$$\frac{14.0 \text{ psia}}{13.0 \text{ psia}} = \frac{(160 + 459)}{(T_2 + 459)}$$

$$T_2 = 116°F$$

However, this initial RB temperature of 116°F would also be the initial temperature of the steel and concrete structures within the Reactor Building. Since it is also desired to reduce the amount of energy that will be absorbed by the passive heat structures in the Reactor Building, an initial temperature of 160°F is selected as the initial RB temperature for the majority of cases documented in this Appendix. Based on discussions with plant personnel, this maximum is selected based on recent operating history for Units 1 and 2. An initial pressure of -1.0 psig is assumed for all cases with an initial RB temperature of 160°F; it is judged that this is a conservatively low initial RB pressure to correspond with an initial RB temperature as high as 160°F. The initial Reactor Building temperature for Unit 3 is assumed to be 125°F. The assumption is higher for Units 1 and 2 because the auxiliary Reactor Building cooling units (ARBCs) have been temporarily shut down for these units, but are operating at Unit 3.

One sensitivity case is performed at the extreme low initial Reactor Building pressure of -2.45 psig, which is the minimum allowed per Oconee Technical Specification 3.6.4. Again, it is not expected that this pressure will ever be experienced while the plant is at full power. An initial Reactor Building temperature of 80°F is assumed for this case, as this is the corresponding temperature at which this Reactor Building vacuum is possible, as discussed in the Bases section of Oconee Technical Specification 3.6.4.

Containment Free Volume

A containment free volume (CFV) of 1,897,900 ft^3 is assumed for all cases performed for this appendix. This represents the measured CFV of 1,790,000 ft^3 (Reference C-5), plus a 1% measurement uncertainty. It is conservative to assume a high CFV value because this minimizes Reactor Building pressure. This value is implemented in the FATHOMS input deck by increasing the cross-sectional area by 1%.

Passive Heat Sink Data

The nominal areas and volumes for the concrete and steel structures in the Reactor Building are used for these analyses, minus a measurement uncertainty of 1%. It is conservative for these analyses to minimize the amount of energy absorbed by the concrete and steel, and to keep this energy in the Reactor Building. This effect is larger than the effect of reducing the Reactor Building pressure which would be achieved by maximizing these values. Therefore, conservatively small areas and volumes are selected for the passive heat conductors. The initial temperature for these structures is the same as the initial RB temperature for each individual case analyzed.

The Groups 2 and 3 heat structures are initialized at the same temperature and initial heat transfer rates as in the Appendix B analyses. (These structures represent the primary and secondary side heat structures which are not in contact with the Reactor Coolant System [RCS] inventory.) These heat structure groups are necessary so that all the energy in these structures at the end of the RELAP5 analysis is accounted for in the FATHOMS analysis. The Group 1 heat structures (those in contact with the RCS inventory) are discussed below.

BWST Volume and Initial Temperature

The calculations for Case 7, documented in Appendix B, determine at what time the sump recirculation switchover point is reached. This value of 3030 seconds is assumed for all analyses documented in this appendix. The BWST water is initialized at 100°F, based on discussions with plant personnel. This represents the maximum temperature experienced during recent plant operating history (90°F), plus an instrument uncertainty allowance of 9.44°F . (This uncertainty for the BWST temperature instrument loop is taken from Reference C-8.) This value is rounded up to an even 100°F for conservatism.

Boundary Conditions / System Flowrates

The junctions identified on pg. 9 of Reference C-6 are used again for the hot leg break analysis. Each junction is active during the same segment(s) as identified in the cold leg break analysis.

Building Spray Flow (Segment 1)

The high RBS flow calculated in Appendix B is used in Segment 1 for all cases documented in this Appendix:

RBS flow (high) = 1500 gpm + 136.3 gpm = 1636.3 gpm (= 3.646 ft^3/sec)

This water is added to the containment atmosphere at a temperature of 100°F, with an assumed average droplet size of 2.3 E-3 ft (700 μm) (Reference C-5).

LPI/BS Discrepancy Flowpath (Segment 1)

A conclusion was reached in the Appendix B documentation that the LPI/RBS Discrepancy flow had no substantial effect on the post-LOCA containment response. This conclusion was that although previous analyses had assumed that it was conservative to drain the BWST as quickly as possible, and that all flows draining the BWST should be assumed at their maximum value, that this effect is actually negligible on the containment response (compare Cases 1 and 2 in Appendix B, Figures B-1 and B-2). This non-mechanistic discrepancy flow, implemented to drain the BWST as quickly as possible but not take credit for the extra flow in the containment cooling calculations, is not utilized in these analyses.

Segment 2 Flowrates

The LPI/HPI/RBS flows calculated for Case 7 in Appendix B, which is the base case for these analyses, are repeated below:

Case 7 assumes that RBS flow is maximized, while LPI flow remains at minimum flow levels during this segment. This case was performed with high RBS flowrates because high flows are more limiting for NPSH criteria. For this case, the BWST depletion flows are:

LPI flow:	3000 gpm -	117 gpm =	2883 gpm	
HPI flow:	1000 gpm -	0 =	1000 gpm	
RBS flow:	1500 gpm +	133 gpm =	1633 gpm	
			5516 gpm	(= 12.290 ft^3/sec)

This flow is divided as follows:

Injected flow:	2883 gpm + 1000 gpm	= 3883 gpm (0.7040)
Sprayed flow:		= 1633 gpm (0.2960)
Discr. flow:		= 0 gpm (0.0)

The switchover time to sump recirculation mode is:

278,500 gal / 5516 gpm = 50.5 minutes = 3030 seconds

Core Decay Heat

A table for the core decay heat is entered in Card Group 13 of the input deck. The data is taken from Reference C-9. (Prior to 400 seconds, decay heat is accounted for in the RELAP5 heat analysis.)

Group 1 (RCS) Heat Structures

The energy contribution from the Group 1 heat structures is taken from Reference C-3. Since these heat structures are in contact with the RCS inventory, the energy transferred from these structures to the RCS inventory is added to the core decay heat in the FATHOMS input. The data in Reference C-3 extends from 1,800 to 21,600 seconds. After this time, the Group 1

contribution is assumed to be the same as in the Reference C-6 cold-leg break analyses. There will be no substantial differences in the cooldown rates of the Group 1 structures between the large cold-leg and hot-leg break transients after this much elapsed time.

In the analyses documented in Appendix B, the FATHOMS long-term hot leg break mass and energy release model becomes active at 1800 seconds, when the RELAP5 data terminates. In the RELAP5 analysis (Reference C-6), the BWST temperature assumed was 115°F. It is desired to assume a lower temperature of 100°F for this analysis. Therefore, the RELAP5 data is terminated at 400 seconds in all analyses documented in this Appendix. At this time, the RCS pressure and Reactor Building pressure have equalized, and the mass flow rate exiting the break should be equal to the flow entering the RCS through the LPI system (steady-flow conditions). The FATHOMS long-term hot leg break mass and energy release model is used after 400 seconds, as it was used after 1800 seconds in the Appendix B analyses. This introduces no error in the calculation, as both codes would be calculating the same flow rates and energy transfer. Moreover, this allows implementation of the lower BWST temperature for the LPI water at 400 seconds, relative to the 1800 seconds which would be used if the RELAP5 data were used for its original duration. There remains a period (Segment 1) where the LPI flow is being injected at 115°F rather than the desired 100°F due to the original RELAP5 analysis assumption; this warmer portion of BWST water is conservative for this analysis.

Decay heat data from 400 seconds to 86,400 seconds is inserted in the Group 13 FATHOMS input. Added to this is the contribution from the Group 1 heat structures from the RELAP5 analysis. The Group 1 cooldown curve from Reference C-3, Appendix G (Figure G-19) is utilized to determine this contribution. A curve fit has been applied to the data in this curve to extrapolate data from 1800 seconds onward. This curve fit will be utilized to extract the cooldown rates from 400 to 1800 seconds for implementation into the FATHOMS input.

Since this curve is the energy content of the Group 1 heat structures as a function of time, the slope of this curve represents the cooldown rate. If the curve fit equation is

$$y = -3.74783E{+}06 \ln(x) + 6.06717E{+}07,$$ [Ref. C-3, Appendix G, Figure G-19]

then the cooldown rate is equal to

$$dy/dx = -3.74783E{+}06 / x$$

A table for the Group 1 heat structures cooldown rate as a function of time for the period not included in Reference C-3 is given in Table C-1.

Segment 3 Flowrates

Upon the beginning of sump recirculation mode, water is taken from the sump drain through boundary condition 10, cooled by the LPI coolers, and then injected into the core. The RBS flowrate, which is normally throttled back to 1000 gpm, is adjusted for flow uncertainty and the open drain valves (BS-15 and -20; see Reference C-10, pg. 20) as follows:

RBS flow (maximum) = 1000 gpm + 160.0 gpm - 75 gpm = 1085.0 gpm (2.417 ft^3/sec)

Note that 75 gpm is subtracted from both RBS flow assumption calculations. This 75 gpm represents flow that was removed from the sump but leaked through the open drain lines without getting to the RBS spray headers. Even in the maximum flow case, it is conservative to assume the full 75 gpm leakage, as this maximizes flow through the RBS pumps but minimizes actual flow through the spray headers (and reduces containment cooling) for this assumption.

A high LPI flow rate of 3291 gpm is assumed during Segment 3. This is the nominal flow rate of 3000 gpm plus an instrument uncertainty of 291 gpm, as shown on pg. 15 of Appendix B. The high flow rate is assumed because the high LPI/RBS flow combination is the most restrictive for NPSH determination. It should be noted that a low flow rate is assumed for the LPI flow prior to sump re-circ initiation.

Nitrogen Cover Gas

The assumptions and flowrates used in the Reference C-3 analyses for the core flood tank cover gas entering containment are unchanged.

LPI Cooler Data

The LPI Cooler heat transfer rates for an LPI flow rate of 3291 gpm are calculated using the LPI.WK1 spreadsheet (Reference C-11). The heat transfer coefficients as a function of LPI cooler inlet temperature for this LPI flow and an LPSW temperature of 85°F are given in Table C-2. The nominal minimum LPI cooler heat transfer rate of 93 E6 Btu/hr is assumed; that is, the maximum allowable tube plugging level and degree of fouling for the operating LPI cooler is assumed to minimize heat transfer out of the building. LPSW flows through the LPI cooler are fixed at 5000 gpm by the methodology utilized.

For periods when there is no LPSW flow through the LPI cooler secondary side (30 minutes following sump recirculation switchover), for cases where this is applicable, the heat transfer area on the primary side of the LPI cooler is reduced to 1.0E-6 ft^2. This modeling technique eliminates all LPI cooler heat transfer for this interval, as if there were no cooling water flow on the secondary side of the cooler. The appropriate heat transfer area is re-entered in the input deck through a code restart upon the initiation of the LPSW flow to the cooler.

RBCU Data

The heat transfer rates in Appendix 2 of Reference C-6 are utilized for RBCU heat removal.

Progression of Runs Performed

Because a high RBS flow rate is most limiting for NPSH concerns, the case from the Appendix B analyses to be re-examined will be Case 7. This case assumed low LPI flow rates but high RBS flowrates. The LPI flow will be adjusted to a high value during sump recirculation mode, as discussed above.

The first set of runs performed is for the initial Reactor Building pressure of -1.0 psig, with an initial Reactor Building temperature of 160°F. These cases cover Units 1 and 2, as the ARBCs are not operating in these units, and higher RB temperatures are possible. To summarize, the following flow rates and cooling system capacities are assumed:

CASES 7Y:	LPI flow (injection from BWST) = (3000 - uncertainty) LPI flow (sump recirculation mode) = (3000 + uncertainty) RBS flow (injection from BWST) = (1500 + uncertainty) RBS flow (sump recirculation mode) = (1000 + uncertainty, re-circ) Discr. flow = None; Swapover time = 3030 sec; LPSW flow at 4830 sec Containment cooling: RBCU=variable, LPI=93 E6, LPSW = 85°F

The LPSW temperature assumption of 85°F is based on discussions with plant personnel regarding recent plant operating history, plus an instrument uncertainty allowance of 3°F. The RBCU capacity is varied with each case, from a low of 60 E6 Btu/hr (the lowest allowable per Reference C-6 at an initial RB temperature of 170°F) to the design value for two clean RBCUs of 160 E6 Btu/hr. Adjustments to these capacities are made in each case to model different levels of fouling on the RBCU coils. The 85°F LPSW temperature is also accounted for, using the table in Appendix 2 of Reference C-6. These cases, with the input deck titles and corresponding RBCU assumptions, are given below:

Case 7Y-8560	60.8 E6 Btu/hr (0.76 RBCU)
Case 7Y-8580	80 E6 Btu/hr (1.0 RBCU)
Case 7Y-85100	100 E6 Btu/hr (1.25 RBCU)
Case 7Y-85120	120 E6 Btu/hr (1.5 RBCU)
Case 7Y-85160	160 E6 Btu/hr (2.0 RBCU)

Another case is executed for the minimum initial RB pressure of -2.45 psig. As discussed above, this low pressure is only possible through an evolution taking the RB temperature down to 80°F. The following cooling assumptions are made for this case:

Case 7W	72 E6 Btu/hr (0.9 RBCU), 90°F LPSW, 103°F BWST temp.

These assumptions are conservative with respect to those discussed above.

Two cases are executed for Unit 3. The initial RB temperature assumption is lowered to 125°F; this is the maximum average RB temperature when the ARBCs are operating. This temperature is assumed as the initial RB temperature in the Reference C-6 analyses. The RBCU capacity is varied from the minimum of 52 E6 Btu/hr (see Reference C-6, Figure 4 at 85 LPSW, 800 gpm RBS re-circ flow) to a maximum of 160 E6 Btu/hr:

Case 8-52	52 E6 Btu/hr (0.65 RBCU)
Case 8-160	160 E6 Btu/hr (2.0 RBCU)

Two sets of sensitivity runs are performed, which are variations on Case 7Y-85160 above. The first is a variation in the time following switchover when no LPSW water is supplied to the LPI cooler. All previous cases assumed a delay time of 30 minutes. A set of sensitivity runs is performed with shorter delay times, as follows:

Case 7Y-85160-20d	20 minute delay
Case 7Y-85160-10d	10 minute delay
Case 7Y-85160-0d	0 minute delay (instant LPSW flow to LPI cooler)

Another sensitivity run is performed to examine a different initial RB pressure and temperature. As discussed above, a cooldown from an initial RB temperature of 160°F to the minimum RB pressure of -1.0 psig, combined with an atmospheric pressure of 14.0 psia, results in a RB pressure of -1.7 psig, but with a temperature of about 116°F. For this sensitivity case, the initial RB pressure and temperature are assumed to be -1.7 psig and 125°F.

Case 9 (Modified initial P-T, 160 E6 Btu/hr RBCU)

RESULTS

The building pressure, vapor temperature, and sump temperature responses as a function of time are shown in Figures C-1, C-2, and C-3 for Case 7Y-8560 as a representative case. The remainder of the cases show the same general trends as illustrated in these figures. In each figure, the start of sump recirculation mode is visible, as containment cooling decreases at this point.

The peak pressure shown in Figure C-1 is 55 psig. The reason that this curve does not approach 59 psig as in the Reference C-12 analysis is that the same containment conditions are not assumed. In this analysis, assumptions are generally made to maximize long-term containment temperatures, and not short-term pressure, as was done in Reference C-12.

Figures C-2 and C-3 give the vapor and sump temperature responses as a function of time. The trends shown here are repeated in each case analyzed. The interruption in LPSW flow at the start of sump recirculation mode is visible as an increase in each parameter due to steaming of water exiting the break. The cooldown is resumed (more gradually, in the case of the sump temperature in Figure C-3) upon restoration of this LPSW flow to the LPI cooler.

Figure C-4 shows the Reactor Building pressure as a function of sump temperature following switchover (NPSH curve) for the set of Case 7Y runs. In all cases, there is an increase in building pressure and sump temperature upon the start of sump recirculation mode, as decay heat removal is temporarily lost until LPSW flow to the LPI coolers is restored. Therefore, the curves will move up and to the right on each figure, and then down and to the left as building pressure and sump temperature decreases with restoration of LPSW flow. (It should be noted again that the actual flow through the spray headers is 75 gpm less than that shown on each figure, due to the open drain valves BS-15 and -20.)

The trend visible in C-4 is that, as more RBCU heat removal is available, the cooldown process results in sump temperatures slightly lower and RB pressures slightly lower. It is not possible to define one RBCU capacity value as "limiting", as this curve demonstrates that the most limiting point with respect to NPSH determination changes as the RBCU capacity changes.

Analyses previously documented in Appendix B demonstrate that for lower LPSW temperatures, this family of curves would be higher on these axes; the RB pressure at a given sump temperature would be higher for lower LPSW temperatures. Changes in RBCU capacity would have the same effect of changing the critical NPSH limiting points. Therefore, the selection of a limiting high LPSW temperature of 85°F is appropriate.

Figure C-5 shows the NPSH curves for Case 7W, with an initial RB pressure of -2.45 psig and an initial RB temperature of 80°F. This curve is above and to the left of the corresponding curve in Figure C-4 (minimum RBCU cooling capacity) due to the decreased initial RB temperature. The sump temperature is cooler and RB pressure higher relative to a comparable case from those discussed above. Therefore, the initial RB pressure/temperature assumption for this case is not the limiting assumption for NPSH consideration. No further sensitivity runs are done for this case, as the same trends will hold true as above.

In Figure C-6, the NPSH curves for the Unit 3 Cases (8-52 and 8-160) are shown. These curves are slightly to the left of those shown in Figure C-4 due to the decreased initial RB temperature. The NPSH requirements for Unit 3 are therefore not as limiting as those for Units 1-2. No further sensitivities are done for this case with respect to containment cooling, as the same trends will doubtless hold true.

The impact of the 30 minute delay in LPSW flow to the LPI coolers is examined in Figure C-7. Cases with 0, 10 minute, and 20 minute delays are overlaid with the base case. Some increase in RB pressure is visible even in the case with no LPSW delay, as there is some flashing of water exiting the break due to the higher decay heat levels. All cases eventually start to decrease in RB pressure as well as sump temperature. However, the case with the 30 minute delay has the highest sump temperatures combined with the lowest RB pressures due to the increased interruption in LPSW flow. There is obviously more energy in the building to be removed in this case relative to the others, leading to higher sump temperatures. The curves shown in Figure C-7 demonstrate that it is conservative for NPSH considerations to assume the maximum 30 minute delay in LPSW flow to the LPI cooler. Since all curves in Figure C-7 converge at some point, these analyses again demonstrate that there is no long-term impact on the containment response caused by this delay.

Figure C-8 shows the NPSH curve for the alternate initial RB conditions of -1.7 psig and 125°F discussed above. The curve for the sensitivity case is overlaid with the curve from Case 7Y-8560. The sensitivity case response shows a lower sump temperature relative to the base case, with higher RB pressures for a given sump temperature at all points. Therefore, the results of this sensitivity case are bounded by the base case, with initial RB conditions of -1.0 psig and 160°F.

	Decay Heat (Power frac.)	Decay Heat (Btu/sec)	Gr. 1 energy content (Btu)	Gr. 1 cooldown rate Eqn.	Total decay heat (Btu/sec)
360	0.0265075	64520	3.8612E+07	-10411	74931
400	*0.0259725*	63218	3.8217E+07	-9370	72587
420	0.025705	62567	3.8034E+07	-8923	71490
480	0.0250212	60902	3.7533E+07	-7808	68710
540	0.0244099	59414	3.7092E+07	-6940	66355
600	0.023549	57319	3.6697E+07	-6246	63565
900	0.0216906	52796	3.5177E+07	-4164	56960
1200	0.0201145	48959	3.4099E+07	-3123	52082
1500	0.0188693	45928	3.3263E+07	-2499	48427
1800	0.0178604	43473	3.2580E+07	-2082	45555
2100	0.0170185	41423	3.2002E+07	-1785	43208
2400	0.0163149	39711	3.1501E+07	-1562	41273

ONS HOT LEG BREAK
DECAY HEAT CONTRIBUTION TO FATHOMS ANALYSIS

TABLE C-1

Cooler 2A 93 x 10^6 Btu/hr 812 unplugged tubes Fouling factor= 0.00285 A = 3665.4 ft^2

LPSW	LPI flow	LPI temp	U
90	3291	250	242.9
		235	240.8
		220	238.8
		205	237.1
		190	235.0
		170	231.6
		145	226.7
		120	221.3

REVISED LPI COOLER HEAT REMOVAL RATES

TABLE C-2

ONS Hot Leg Break Analysis
Building Pressure

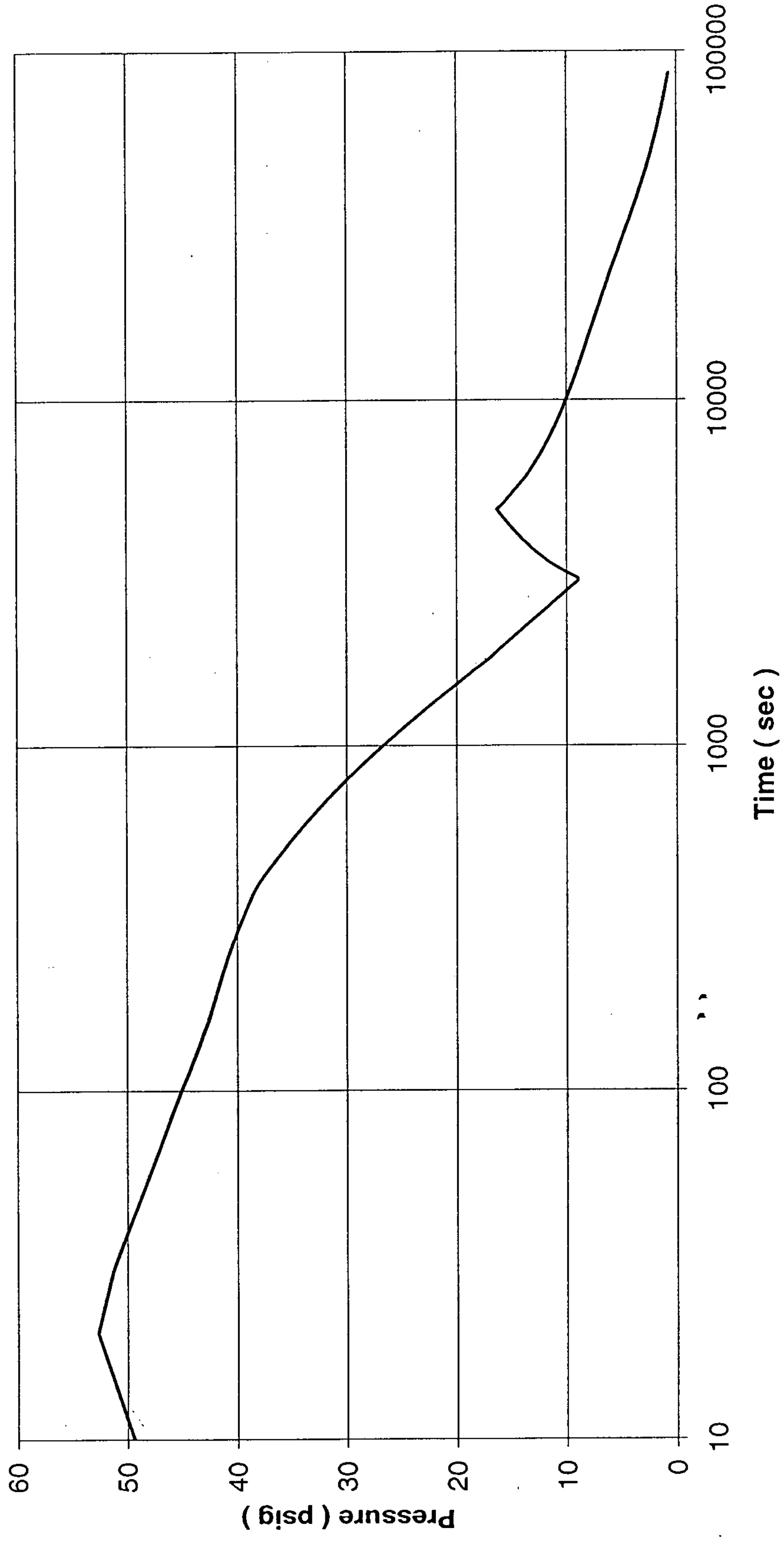


FIGURE C-1

ONS Hot Leg Break Analysis
Vapor Temperature

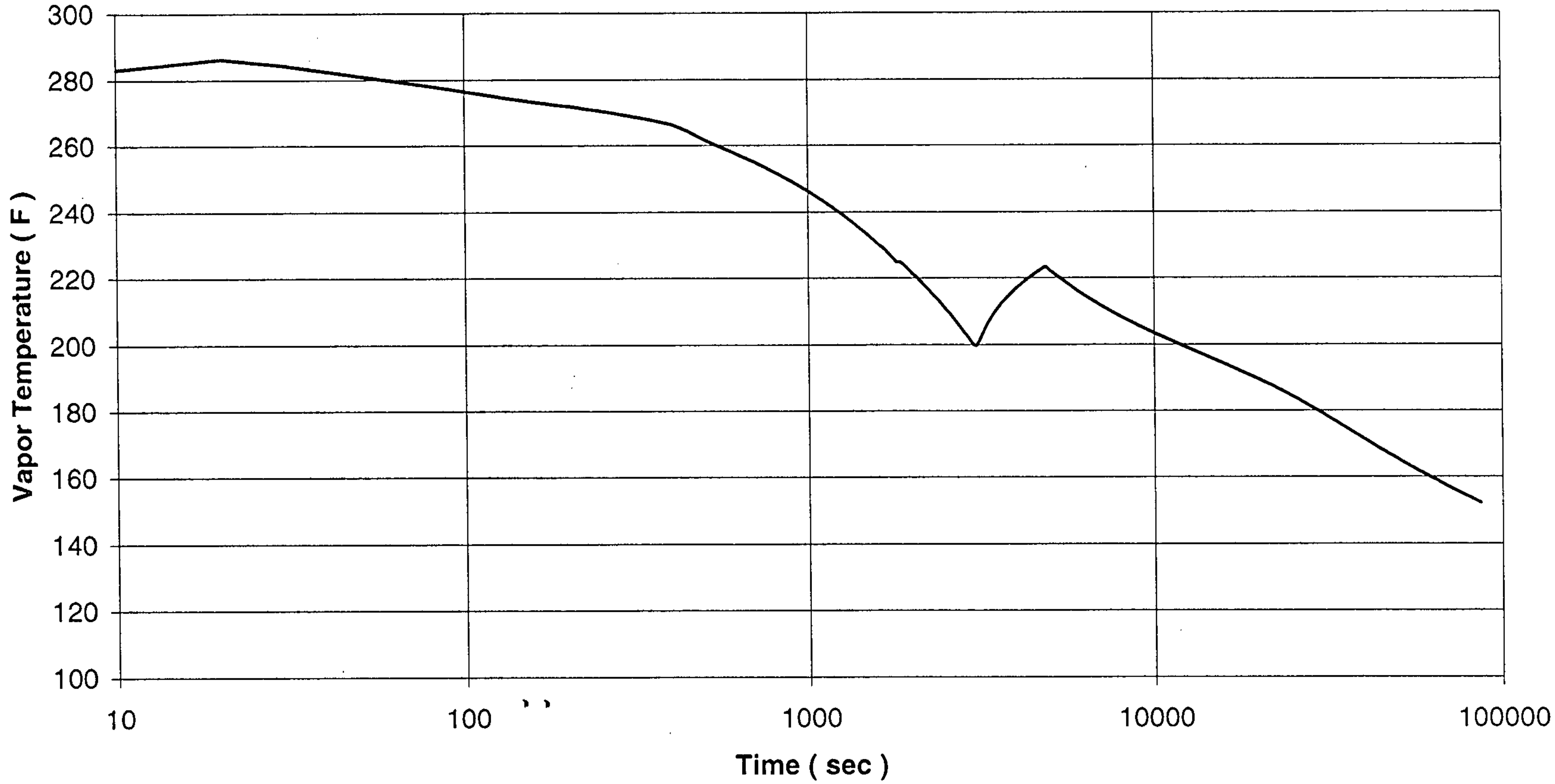


FIGURE C-2

ONS Hot Leg Break Analysis
Sump Temperature

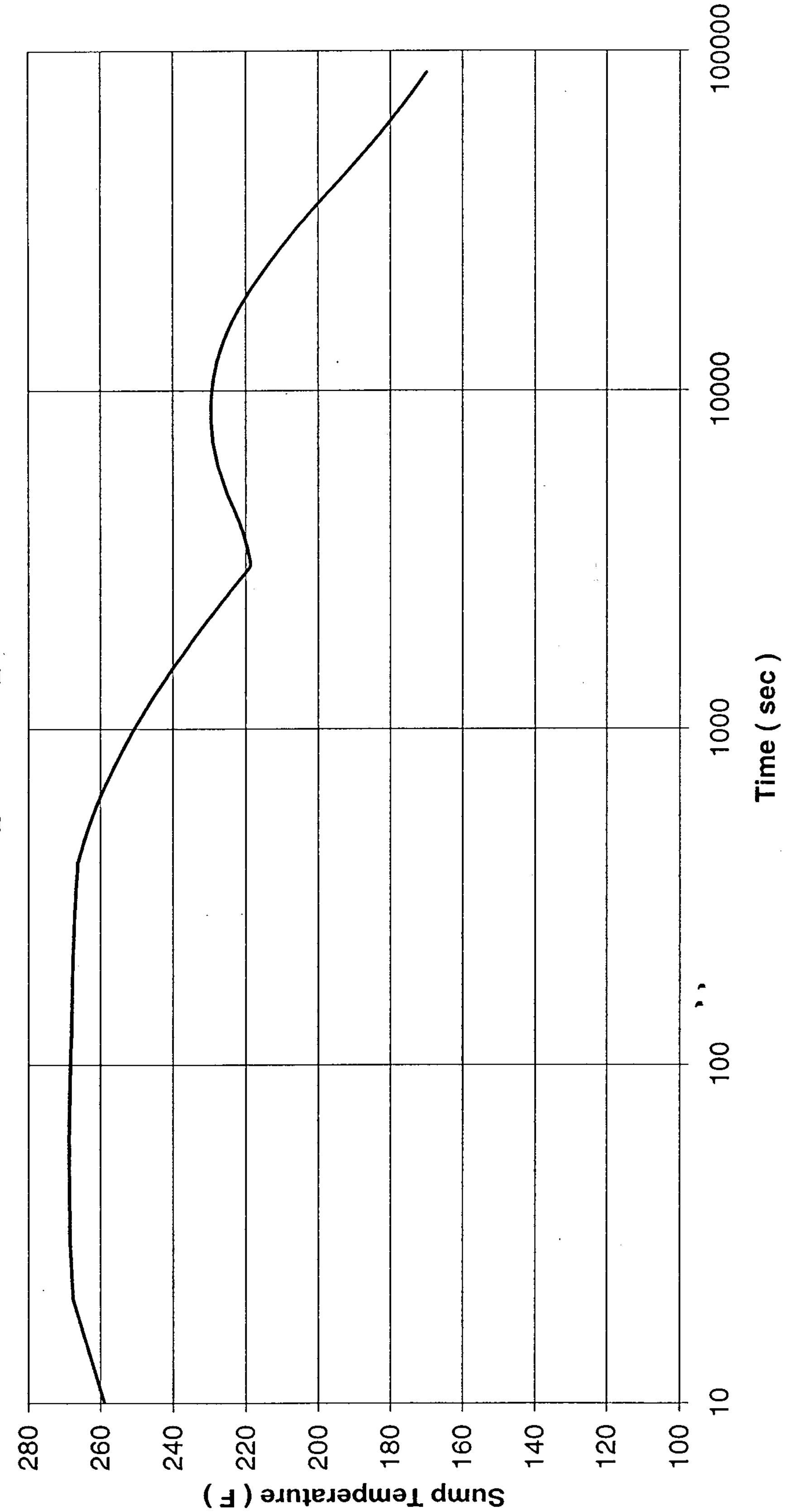


FIGURE C-3

ONS Hot Leg Break Analysis

Building Pressure Vs. Sump Temperature for Building NPSH
30 Minute Delay in LPSW Flow to LPI Cooler

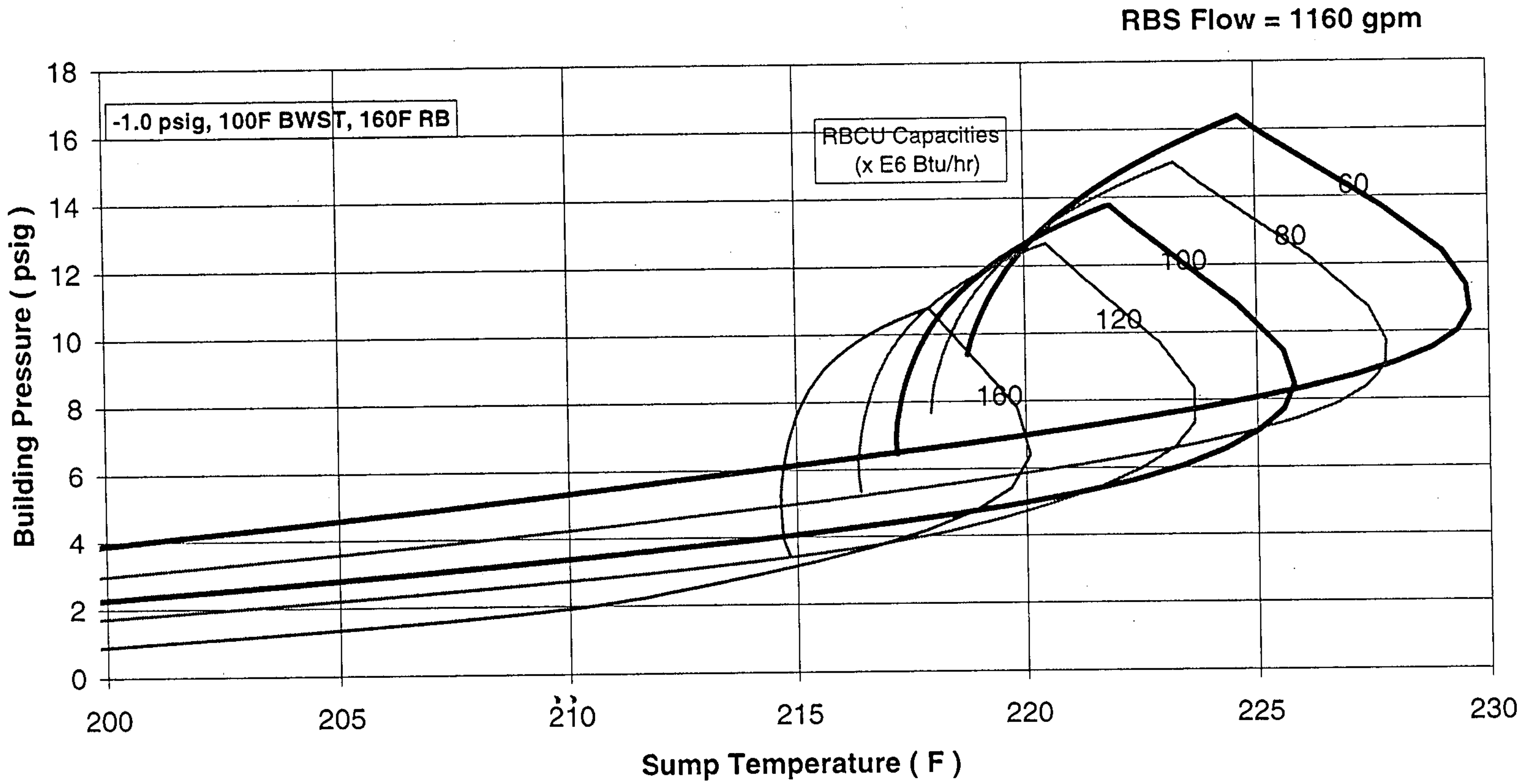


FIGURE C-4

ONS Hot Leg Break Analysis

Building Pressure Vs. Sump Temperature for Building NPSH
30 Minute Delay in LPSW Flow to LPI Cooler

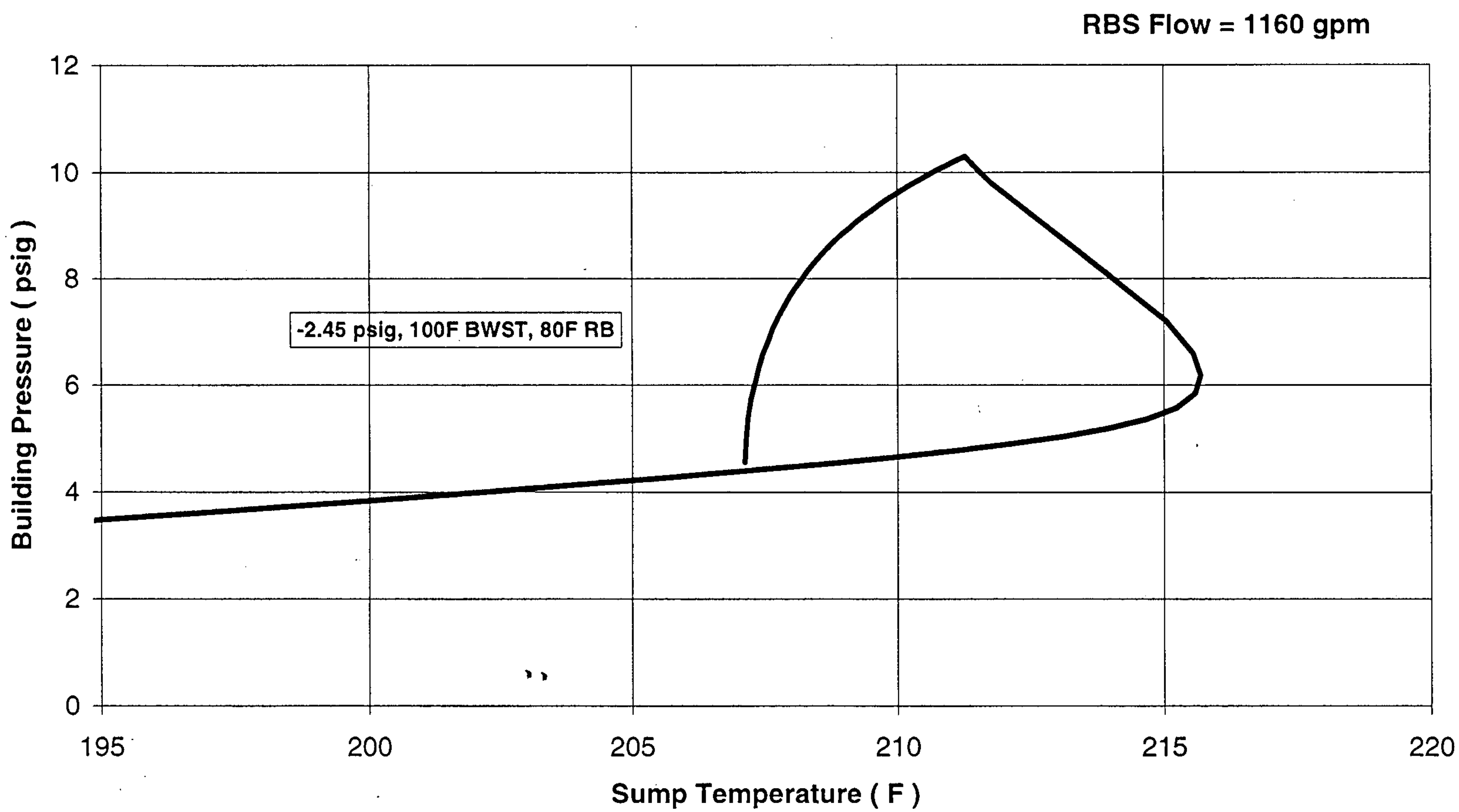


FIGURE C-5

ONS Hot Leg Break Analysis

Building Pressure Vs. Sump Temperature for Building NPSH
30 Minute Delay in LPSW Flow to LPI Cooler

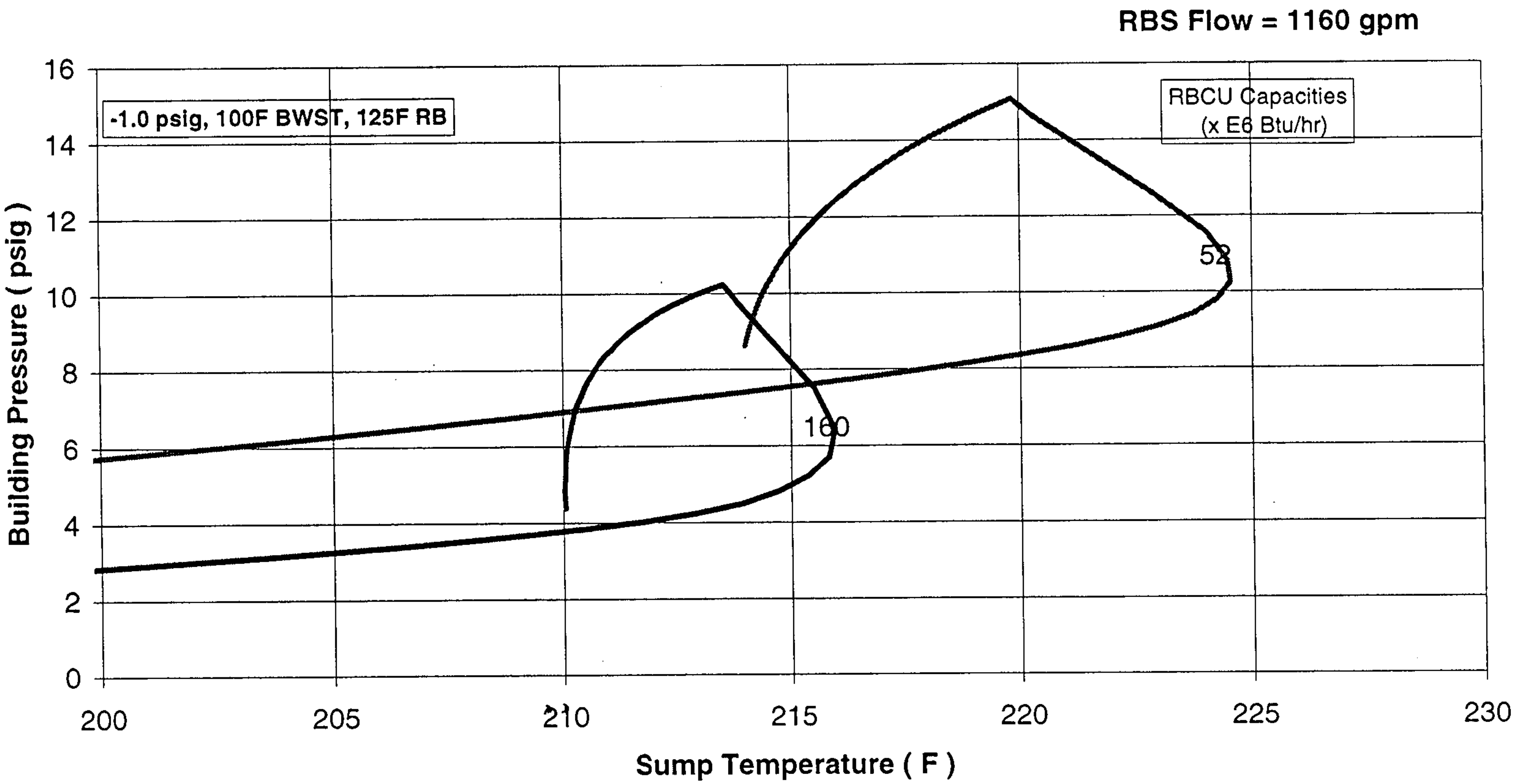


FIGURE C-6

ONS Hot Leg Break Analysis

Building Pressure Vs. Sump Temperature for Building NPSH
Effect of Delay in LPSW Flow to LPI Cooler

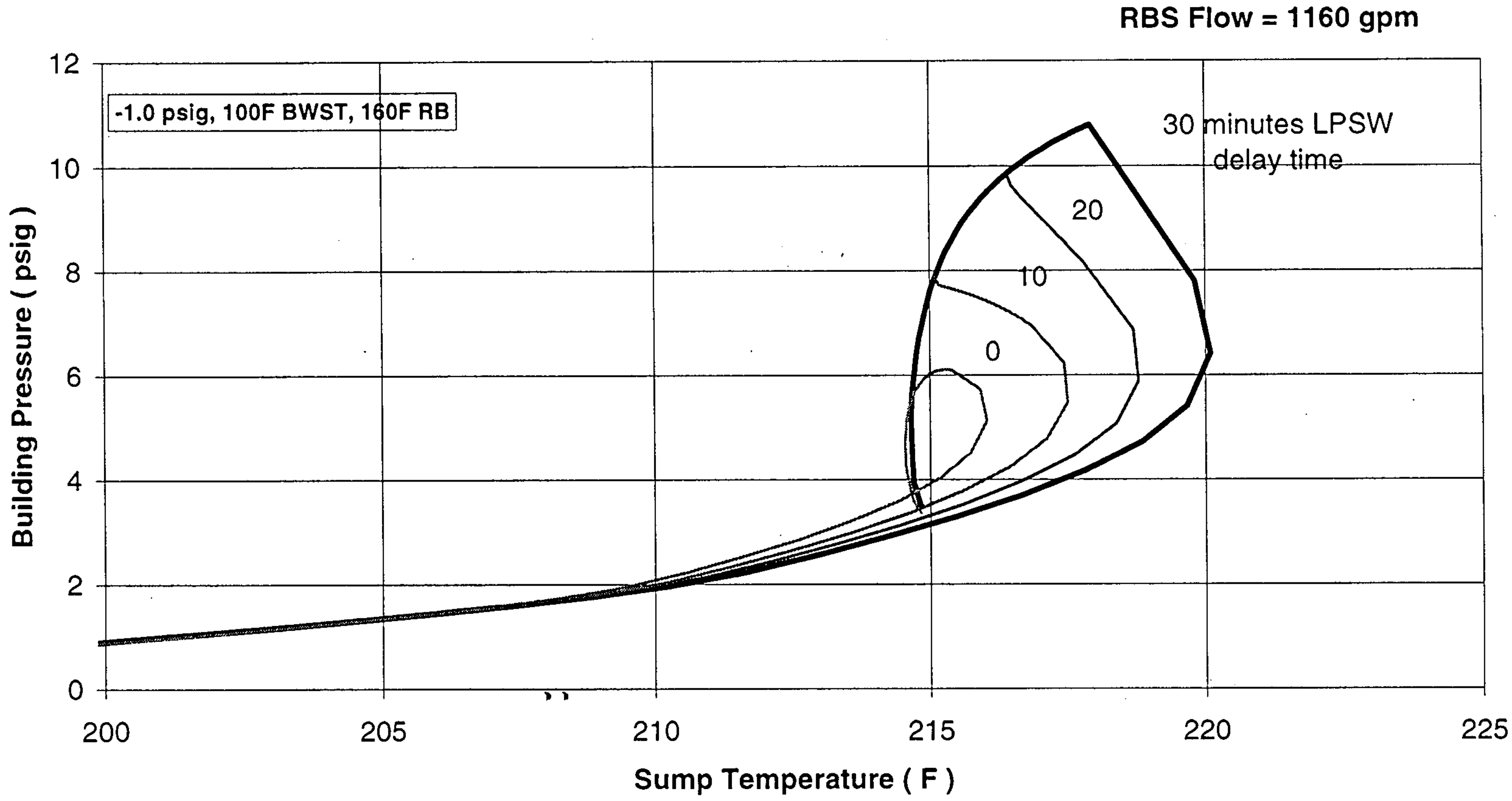


FIGURE C-7

ONS Hot Leg Break Analysis

Building Pressure Vs. Sump Temperature for Building NPSH
30 Minute Delay in LPSW Flow to LPI Cooler

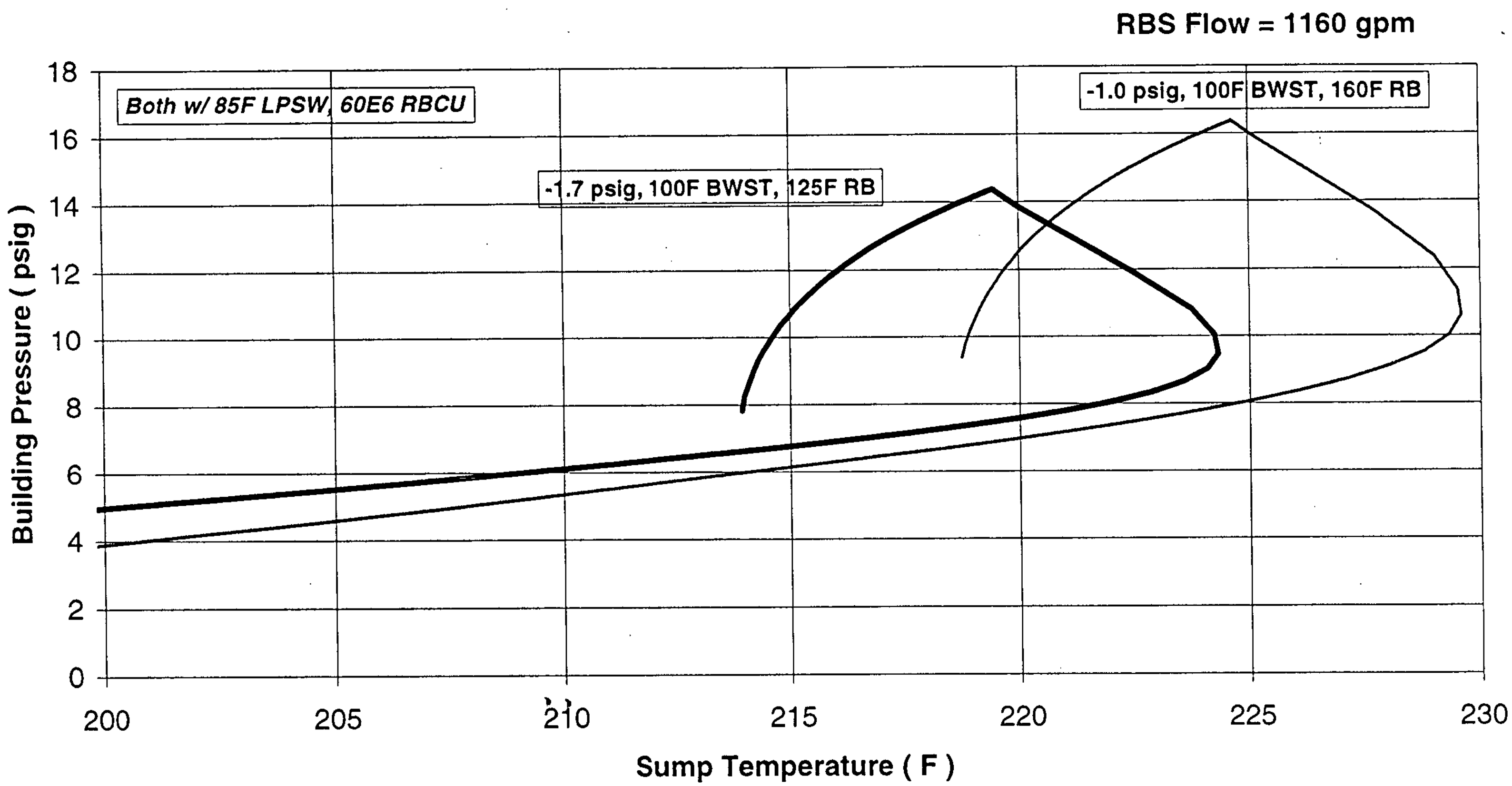


FIGURE C-8

Comments.

1. No runs are analyzed for the case with two LPI trains in operation. It is anticipated that since the second LPI train and additional RBCU capacity would greatly increase core cooling and removal of energy from the building, the NPSH curves would be to the left of those shown in Figures C-4 to C-7 due to the cooler sump water. Although switchover to sump recirculation mode would be reached at an earlier point in the two-LPI/RBS train case, the injection of the entire BWST inventory in a fraction of the time of the one-train case would result in cooler sump temperatures. There would be less decay heat energy transferred from the core in the two-train case at the time of sump re-circ switchover, contributing to the reduced sump temperature.

2. The 75 gpm flow of RBS water through the drain lines is not considered in these analyses prior to sump recirculation mode. It is judged that the difference between the cases analyzed here with no drain line flow and a case with 75 gpm lower RBS flow through the headers would be negligible. This is similar to the determination made in Appendix B that the LPI/RBS discrepancy flow has no long-term impact on the containment response.

3. The compressed output files for all cases analyzed are attached on the enclosed diskettes, with the names as identified above.

Assumptions

- The CFV value is increased from its nominal value by 1%, to 1,897,900 ft^3.

- The most limiting initial RB pressure/temperature combination which is achievable through normal physical and/or operating processes, with respect to RBS pump NPSH, is an initial pressure of -1.0 psig and an initial RB temperature of 160°F. This temperature represents the average temperature in the entire Reactor Building. All passive heat structures are initialized at this temperature, throughout their entire thickness, regardless of location. Plant operating data and meteorological data histories were consulted in the determination of these assumptions.

- The passive heat sink area and volume values are decreased from their nominal values by 1%. This is to minimize the steam condensation onto these structures, and energy transferred into these structures through conduction. The Uchida heat transfer correlation for the passive heat sinks is utilized for these analyses.

- The BWST temperature is assumed to be 100°F. A conservatively high BWST switchover setpoint of 7.68 ft is assumed.

- Conservatively high RBS and RBCU actuation times are assumed for all analyses, as given in Reference C-5. The calculation of sump recirculation switchover time above conservatively assumes that all core injection and RBS flow was initiated at 0 seconds.

- Conservatively high RBS system flowrates are assumed throughout these analyses. A total of 75 gpm is assumed to pass through the open RBS drain lines, as described above.

- A conservatively high LPSW temperature of 85°F is assumed. The LPI cooler is assumed to have the maximum number of plugged tubes and degree of fouling allowable. A delay of 30 minutes at the start of switchover is assumed, during which there is no heat removal by the LPI cooler. A range of RBCU capacities are assumed, from the minimum allowed for environmental qualification criteria, to the maximum design capacity for clean coolers.

- A conservatively low LPI flowrate is assumed during the BWST injection phase. This has no long-term effect on the analysis. A conservatively high LPI flowrate is assumed during sump recirculation mode, as this made the NPSH criteria more restrictive.

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