APT Blanket System Loss-of-Coolant Accident (LOCA) Based on Initial Conceptual Design - Case 2: with Beam Shutdown Only

by

L. L. Hamm

Westinghouse Savannah River Company
Savannah River Site
Aiken, South Carolina 29808

S. Y. Lee

M. A. Shadday

F. G. Smith, III

A document prepared for SENDING TO LANL at , , from - .

DOE Contract No. **DE-AC09-96SR18500**

This paper was prepared in connection with work done under the above contract number with the U. S. Department of Energy. By acceptance of this paper, the publisher and/or recipient acknowledges the U. S. Government's right to retain a nonexclusive, royalty-free license in and to any copyright covering this paper, along with the right to reproduce and to authorize others to reproduce all or part of the copyrighted paper.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

APT BLANKET SYSTEM LOSS-OF-FLOW ACCIDENT (LOFA) ANALYSIS BASED ON INITIAL CONCEPTUAL DESIGN -

Case 2: with Beam Shutdown only

L. Larry Hamm
Si Young Lee
M. Andy Shadday
Frank G. Smith, III

UNCLASSIFIED

DOES NOT CONTAIN
UNCLASSIFIED CONTROLLED
NUCLEAR INFORMATION

ADC &
Reviewing
Official:

William Smith Manager
(Name and Title)

Date: 7/31/98

Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831; prices available from (615) 576-8401.

Available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

WSRC-TR-98-0085

KEYWORDS:

*Accelerator Production of Tritium
Blanket System
Conceptual Design
TRAC Code
FLOWTRAN-TF Code
System Model
Detailed Bin Model
Safety Analysis*
RETENTION - Permanent

**APT BLANKET SYSTEM LOSS-OF-FLOW
ACCIDENT (LOFA) ANALYSIS BASED ON INITIAL
CONCEPTUAL DESIGN**

Case 2: with Beam Shutdown only

SAVANNAH RIVER TECHNOLOGY CENTER

L. Larry Hamm
Si Young Lee
M. Andy Shadday
Frank G. Smith, III

Publication Date: July, 1998

Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

SAVANNAH RIVER SITE

Prepared for the U.S. Department of Energy under Contract No. DE-AC09-96SR18500

DOCUMENT: WSRC-TR-98-0085
TITLE: APT BLANKET SYSTEM LOSS-OF-FLOW ACCIDENT
(LOFA) ANALYSES BASED ON INITIAL CONCEPTUAL
DESIGN - Case 2: with Beam Shutdown only

APPROVALS

L. L. Hamm Date: 7-16-98
L. Larry Hamm, Task Leader (EM&S Group/SRTC)

Si Young Lee Date: 7-20-98
Si Young Lee, Co-author (EM&S Group/SRTC)

M. Andy Shadday Date: 7/20/98
M. Andy Shadday, Co-author (EM&S Group/SRTC)

Frank G. Smith III Date: 7/20/98
Frank G. Smith, III, Co-author (PC&C Group/SRTC)

Cynthia P. Holding-Smith Date: 7/16/98
Cynthia P. Holding-Smith, Manager (EM&S Group/SRTC)

M. A. Ebra Date: 28 Jul 98
Martha A. Ebra, Manager (EDS/SRTC)

Mel R. Buckner Date: 7/21/98
Mel R. Buckner, Technical & Regulatory Lead (APT OPO)

The internal technical review function is being performed at the APT project level and is coordinated through LANL.

Table of Contents

1 Introduction	1
2 TRAC 1-D System Model	2
2.1 Scenario Description.....	3
2.2 Model Upgrades	4
2.3 Initial Conditions	4
2.4 Transient Boundary Conditions.....	4
2.5 Trips and Controls	4
2.6 TRAC Version.....	5
3 TRAC System Model Results	9
3.1 Modules	12
3.2 HR Loop and Pressurizer	12
3.3 RHR Loop.....	13
3.4 Cavity Vessel and Flood System	13
4 Evaluation Model	13
5 Evaluation Model Results	16
6 Conclusions	18
6.1 Comparison to Thermal/Hydraulic Design Criteria	19
6.2 Design Issues	19
6.3 Predicted Impact.....	20
7 References	20
Appendix A: TRAC Model Component Nomenclature	
Appendix B: LOFA (Case 2) TRAC Results	
Appendix C: TRAC Standard Input File for LOFA Case 2 (with Beam Shutdown Only)	
Appendix D: TRAC Graphics Input File for LOFA Case 2 (with Beam Shutdown Only)	

List of Figures

Figure 1-1	Decay heat power fractions of full power for various types of blanket modules.....	2
Figure 2-1	Top cross-sectional face map of 6 lumped blanket system modules	7
Figure 3-1	Primary HR mass flowrate for LOFA with a beam shutdown.....	9
Figure 3-2	Fixed inlet/outlet header fluid temperatures for LOFA with a beam shutdown.	9
Figure 3-3	Fixed inlet/outlet header saturation temperatures for LOFA with a beam shutdown.....	10
Figure 3-4	Individual module inlet mass flowrates for LOFA with a beam shutdown.	10
Figure 4-1	Deposited power profiles used in 1-D TRAC system model.	14
Figure 4-2	Integrated Module 1 power profile.....	14
Figure 5-1	System temperature based on evaluation model analysis (linear time scale).	16
Figure 5-2	System temperature based on evaluation model analysis (logarithmic time scale).	17

List of Tables

Table 2-1	Six lumped blanket module system model used for the present PSAR analysis.	5
Table 2.5-1	Trip signals used in the LOFA Case 2 simulation.....	6
Table 5-1	Heat-up times to reach onset of bulk boiling for four case studies.	16

1 Introduction

This report is one of a series of reports that document normal operation and accident simulations for the Accelerator Production of Tritium (APT) blanket heat removal system, [1-8]. These simulations were performed for the Preliminary Safety Analysis Report. This report documents the results of simulations of a Loss-of-Flow Accident (LOFA) where power is lost to all of the pumps that circulate water in the blanket region, the accelerator beam is shut off and neither the residual heat removal nor cavity flood systems operate. The accident simulations were performed, using TRAC to model transient behavior of the entire system and an evaluation model to model long term transient behavior in a blanket module. The evaluation model consisted of calculations to estimate the time it would take the APT blanket module to heat to boiling under adiabatic heat up conditions. The masses of lead, aluminum and water in the entire blanket module and the water mass in portions of the primary heat removal loop were estimated using data from the TRAC system model files. A nominal deposited power profile was used to estimate the power added to the system over time.

After the APT beam system shutdown, decay power drops rapidly. Figure 1-1 shows transient decay power after shutdown as a fraction of steady-state power for the 1700 MeV APT design with 13 tungsten ladders [9]. Results from a single long term TRAC system calculation were used to analyze the loss-of-flow accident and to provide starting conditions for the evaluation model. The system calculation provided a transient for total coolant flow having approximately 5% of the pre-incident flow 60 seconds after initiation of the loss-of-flow-accident.

Figure 1-1 Decay heat power fractions of full power for various types of blanket modules.

2 TRAC 1-D System Model

Current blanket system consists of 16 unique blanket modules based on the existing cruciform-type design components (the necessary design specifications required to develop a plate-type set of modules is currently not available but will be used in future revisions to these calculations). Each module is separately connected to the two fixed coolant headers. A lumping strategy was developed based on module similarity, deposited power levels, and locations that resulted in a total of six separate lumped modules and reduced computational effort requirements. The six lumped modules are, respectively: the first-row lateral modules; the second-row lateral modules; the decoupler / Row 1 downstream module; the Row 1 / Row 2 downstream module; the Row 2 / Row 2 downstream module; and the remaining low-power modules, which consist of the upstream module, the four bottom modules, and the two top modules. Figure 2-1 shows cross-sectional face map for the six module blanket system. Table 2-1 summarizes module description, thermal deposited power, and connection pipe size of each of the six blanket modules as modeled in the one-dimensional lumped approach. Figure A-1 shows the locations of all the six modules and the internal piping connections as included in the one-dimensional TRAC system model. The TRAC components and piping connections for the heat removal (HR), pressurizer, residual heat removal (RHR) blanket coolant systems, and cavity vessel flood system are also shown in Figs. A-2 to A-6. Table A-1 lists all the blanket system components, number of cells for the components, and the component descriptions for the present one-dimensional lumped blanket system model. The present six lumped module TRAC blanket system model includes 170 components and 152 junctions with 10 trip control signals using for the transient loss-of-flow accident (LOFA) simulation. Detailed TRAC system model descriptions are provided in Refs. [10,11].

2.1 Scenario Description

Current blanket coolant system has one primary heat removal (HR), one secondary HR, two 100% primary residual heat removal (RHR), and two 100% secondary RHR. Both the HR and RHR loops are connected to the large fixed headers (20.5 inch diameter) internal to the target/blanket cavity vessel. Under steady-state normal operating conditions, the blanket module system is connected to a single main primary loop, with three 50% pumps in parallel. Two pumps are normally operating and the remaining pump is available for immediate startup in the event of failure of a running pump. The coolant loop has two 50% heat exchangers in parallel. The two RHR primary loops are both sized to accommodate 100% of the decay heat removal requirements. Currently, the RHR components are sized for approximately 4% of the full power flow, 1569 kg/sec, under any design basis accident conditions. Each of the RHR primary loops has one heat exchanger and one pump. The current baseline design has the RHR systems shutdown in standby mode during normal operation to enhance the system's response to some design basis accident scenarios such as loss-of-flow accident (LOFA) and loss-of-coolant accident (LOCA). Normal operating conditions for the key blanket system parameters are shown in Appendix A.

For this scenario, it is assumed that the trip signal to shutdown the beam is initiated by a 5% reduction in pump pressure drop on either of the primary HR pumps. Signal detection occurs within tenths of a second following the initiating event. The trip signal

is activated approximately 0.2 seconds after the initiating event occurs. A conservative 1 second time delay to account for signal processing is assumed (i.e., best estimate values range within 0.1 to 0.2 second delays). The actual beam shutdown begins to occur at approximately 1.2 seconds after the initiating event occurs. Blanket deposited power levels rapidly decrease to approximately 1 to 3% of the pre-shutdown levels within 1 second of beam shutdown. The primary RHR pumps and the cavity flood system are assumed to be inoperable. That is, after beam shutdown, no other available accident mitigation options are activated. This scenario was simulated using the integrated 1-D TRAC system model described in Ref. [10] augmented by a simple evaluation model calculation.

As one of the design basis accidents, TRAC analysis was performed for a loss of coolant flow accident due to the loss of power in the primary and secondary HR pumps. This was simulated by restarting a transient calculation from steady-state normal operation results obtained with the one-dimensional six integrated module blanket system model. For initiation of the LOFA simulation, the two primary and secondary HR pumps are tripped off without time delay at time zero. For this accident scenario, it was further assumed that the primary and secondary RHR pumps are not started even though the primary and secondary RHR pumps are supplied with on-site backup diesel power as well as a dc backup power supply. Detailed control signals for the key component operations are provided in Section 2.6.

2.2 Model Upgrades

Component action tables for the break component and check valves were updated to activate the action signals for hardware components such as check valves, pumps, heat structures in the six blanket modules, and fill boundaries to simulate the LOFA scenario. Normal steady-state operation conditions can be obtained by using either transient mode or constrained steady-state mode with definition of the monitoring parameters of specific components. For the present accident analyses the constrained steady-state (CSS) capabilities were added to the TRAC normal operation system model. Signal variables and trip signals of the system model were also updated by using the control procedure for the LOFA scenario as described in Ref. [10].

2.3 Initial Conditions

Before simulating the accident condition, steady-state results under normal operating (NO) conditions are required to provide the restart input to the transient simulation model of the LOFA. The steady-state NO conditions of the APT blanket system were obtained by specifying maximum pump rotational speeds of the two HR pumps with desired total liquid flowrate using as a monitoring parameter under the constrained steady-state (CSS) controller option. Initial temperatures for the pressurizer and the RHR system components were 40 C. Steady-state values under normal operating conditions for the key system parameters of the APT blanket system are listed in Appendix A with additional details provided in Ref. [1].

2.4 Transient Boundary Conditions

The TRAC system model for the steady state NO calculations is documented in Refs. [10,11]. The steady-state NO TRAC run was restarted in a transient mode to initiate the LOFA simulation. To establish an appropriate fly-wheel inertia for the primary heat removal pumps a parametric study was performed (i.e., varying the TRAC pump parameters) using the TRAC system model with the integrated six modules under the LOFA conditions. The inertia terms were set such that a 5% of pre-incident flowrate is achieved at 60 sec after pump deactivation occurs. System operation conditions of the secondary systems were simulated by using fill boundary condition with transient mass flowrate table at the inlet of the secondary sides of the two HR heat exchanger components.

2.5 Trips and Controls

Power to the two primary and secondary HR pumps was tripped off immediately to initiate the LOFA scenario, and the beam power was tripped off with 1.0 seconds time delay after the pressure difference between the suction side and the discharge side of each primary HR pump was reduced to 0.70788 MPa (102.7 psia) corresponding to 95% of the total pressure difference across the HR pump. The beam trip was simulated by changing the steady-state NO power in the heat structure of each blanket module to the time dependent decay power curve. Figure 1-1 shows transient decay power curves for the blanket heat structures. The beam power trips actually occurred about 1.21 seconds after the initiation of the transient accident so that the time to reduce 5% of the pressure difference across the HR pump is about 0.21 second. The RHR pumping power signal was not actuated. Check valves on the discharge sides of the HR pumps were actuated to avoid flow reversal immediately after the initiation of the LOFA accident. If flow reversal occurs during the accident condition, the HR and RHR check valves were set to be closed immediately. Table 2.5-1 lists all the trip signals and component controls used for the LOFA simulation.

2.6 TRAC Version

This transient model was run using TRAC-PF1/MOD2 version 5.4.28a [12]. A modified version of TRAC to generate graphics files was employed [11].

Table 2-1 Six lumped blanket module system model used for the present PSAR analysis.

Six Lumped Modules	Prototypic 16 Full Blanket Modules	Thermal Deposited Power Downflow / Upflow / Total Power	Pipe Size (inch)
Module 1	Front 1 st Lateral Dec. / Row 1 Module Back 1 st Lateral Dec. / Row 1 Module	8.222 MW / 15.768 MW / 23.990 MW	7.500
Module 2	Front 2 nd Lateral Row 2 / Row 3 Modules Back 2 nd Lateral Row 2 / Row 3 Modules	3.060 MW / 7.660 MW / 10.720 MW	4.750
Module 3	1 st Downstream Dec. / Row 1 Module	0.744 MW / 2.812 MW / 3.556 MW	3.750
Module 4	2 nd Downstream Row 1 / Row 2 Module	3.924 MW / 5.412 MW / 9.336 MW	5.375
Module 5	3 rd Downstream Row 2 / Row 2 Module	1.355 MW / 1.811 MW / 3.167 MW	6.000
Module 6	Low Power Modules Blanket Upstream Dec. / Row 2 Module Lower Front Dec. / Row 2 Module Lower Front Row 2 / Row 2 Module Lower Back Dec. / Row 2 Module Lower Back Row 2 / Row 2 Module Upper Front Row 2 / Row 2 Module Upper Back Row 2 / Row 2 Module	(Horizontal Flow) 0 MW / 5.712 MW / 5.712 MW	3.875
Total Deposited Power		17.305 MW / 39.175 MW / 56.480 MW	

Table 2.5-1 Trip signals used in the LOFA Case 2 simulation.

Trip Signal ID	Control Component	Signal Variables ID Number (Control Variable)	Signal Values
101	Fill boundary for secondary heat exchanger side	1 (time)	1.0×10^{-6} sec
102	Cavity flood system valve	10 (cavity vessel pressure)	valve closed
103	RHR check valve	1 (time) and action table (S-shaped forcing function)	1.0×10^{-6} sec
104	Heat structure	4 (the pressure difference between the suction and discharge sides of the primary HR pump) and time delay	1.0 sec time delay after 5% reduction of the pressure difference across the primary HR pump
105	RHR pump	not actuated	
106	Primary HR pump	no time delay	1.0×10^{-6} sec
107	Primary HR check valve	1 (time) and action table (S-shaped forcing function)	1.0×10^{-6} sec
108	Cavity vessel check valve	1 (time)	valve closed
109	Cavity vessel check valve on the HR side	1 (time)	valve closed
110	Cavity vessel vent valve	7 (pressurizer pressure)	valve closed

Figure 2-1 Top cross-sectional face map of 6 lumped blanket system modules

3 TRAC System Model Results

The LOFA model to simulate the loss of power for the primary and secondary HR pumps was run for 5600 seconds after the initiation of the accident. The TRAC calculations set the flowrate on the secondary side of the HR system such that a flow decay similar to the primary HR flow decay occurs for times up to approximately 100 seconds, while beyond 100 seconds its flowrate is set to zero. However, credit was taken for the thermal sink capacity of the light water trapped on the shell side of the primary HR heat exchangers. The heat capacity of water residing within the shell side of the primary heat exchangers represents a sizable portion of the total available heat capacity of the composite system (i.e., blanket module metal, module water, HR primary water, shell side water). Figures 3-1 through 3-4 show selected output from the TRAC results. Based on these figures the following brief summary can be seen:

- The initial primary HR loop mass flowrate of 1569 kg/s drops to a natural circulation value of approximately 12.8 kg/s after 2000 seconds as shown in Fig. 3-1. This flowrate gradually decreases (e.g., by 5600 seconds it is 12.0 kg/s) as the blanket cools and the driving force for the circulation diminishes.
- The fluid temperature difference between fixed headers is related to the overall thermal driving forces available to sustain natural circulation within the primary HR loop as shown in Fig. 3-2. Due to the presence of a check valve within the RHR primary loop, RHR flow remains stagnant. The temperature difference is 4.0 C at 2000 seconds and 3.5 C by 5600 seconds with an overall system heat-up rate of approximately 2 C per hour.
- Based on the fluid saturation temperatures presented in Fig. 3-3 and assuming the quasi-steady state behavior persists (i.e., constant heat-up rate), saturated boiling conditions are estimated to be reached in less than 60 hours. Sixty hours is an upper limit since the heat-up rate will continue to climb as the natural circulation rate diminishes. Figure 3-3 provides the fluid saturation temperatures at the fixed headers, due to their hydrostatic pressure increase saturation temperatures are approximately 170 C near the heated surfaces within the blanket bins.
- At the individual blanket module level, mass flowrates remain positive (i.e., no flow reversals are observed) as shown in Fig. 3-4. At these very low decay power levels metal temperatures remain only a few degrees above the local free stream coolant temperatures.
- As mentioned above, TRAC predicts a diminishing natural circulation pattern with a very slow heat-up of the coolant.

More complete results from the TRAC system calculation for the entire 5600 seconds of the transient are shown in Appendix B and are discussed in the following sections.

Figure 3-1 Primary HR mass flowrate for LOFA with a beam shutdown.

Figure 3-2 Fixed inlet/outlet header fluid temperatures for LOFA with a beam shutdown.

Figure 3-3 Fixed inlet/outlet header saturation temperatures for LOFA with a beam shutdown.

Figure 3-4 Individual module inlet mass flowrates for LOFA with a beam shutdown.

3.1 Modules

Figure A-1 shows the component layout of the internal blanket module system used in the TRAC system model. All of the modules are connected to the fixed headers. Primary coolant water is supplied to the hot blanket modules through the inlet fixed header and returned to the outlet fixed header. These two fixed headers are located inside the cavity vessel. Figures B-2a to B-7d show the transient results for pressures, fluid temperatures, liquid subcoolings, and void fractions for the three plenums (inlet, middle, and exit plenums) of each blanket module. None of the module channels have any void fraction within the liquid coolant through the transient accident period. The graphical results show a rapid transient response in the fluid pressure in the flow channels of all six blanket modules within the first few seconds of the accident. Fluid pressure increases at the module plenums following initiation of the LOFA as flow decays and the fluid reaches hydrostatic conditions. Initially, the fluid temperature in the modules rapidly decreases as 40 C water from the pressurizer enters the modules. Over the next several minutes, the fluid temperature at the module inlet plenums slowly decreases while fluid temperatures at the outlet plenums increase 1 to 4 C from decay heat generated in the modules. After 5 to 20 minutes depending on the module, the fluid temperatures at the module outlets decrease and begin to follow the decay heat curves.

Figs. B-26 through B-43 show detailed graphical results for the solid structures of the six blanket modules. Maximum lead temperature was 152 C during normal operation condition near the mid-plane of the first lateral module. Generally, solid temperatures were decreased quickly during the first few seconds after initiation of the loss of power, and then increase about 2 to 5 C over the next 5 to 20 minutes. The solid temperatures slowly approached steady-state equilibrium values following the trend of the decay heat curve shown in Fig. 1-1. Maximum aluminum cladding surface temperature was 93.5 C during normal operation condition at the mid-plane of the blanket module 1 and rapidly dropped to the minimum value (about 50 C) near the exit of the module 1 channel at the transient time of 50 seconds. Trends in the metal temperatures follow those in the cooling water with a rapid initial decrease followed by a slight increase over the next several minutes and a final slow decrease throughout the rest of the accident transient.

3.2 HR Loop and Pressurizer

Figure A-2 shows the HR system component layout used for the one-dimensional TRAC system model. Transient behaviors for key thermal-hydraulic parameters of the two internal fixed headers are graphically shown in Figs. B-1a to B-1d. As the primary HR liquid flowrate decreases quickly with the loss of pumping power, the hot leg pressure increased rapidly to 107 psia at about 60 seconds after the loss of power. The hot-leg fixed header pressure is slightly higher than the cold-leg fixed header pressure by the elevation height difference. Cold-leg fixed header temperature decreases by 2.5 C during first 35 seconds after the accident due to the incoming pressurizer cold water (40 C) and the rapid decay of in primary coolant water flowrate. Both of the fixed headers had zero voidage during the entire transient simulation period.

Transient behavior for important thermal-hydraulic parameters of most external balance of plant (BOP) components are shown in Figs. B-8a to B-25e. The results show that

liquid flowrates for the two primary HR pumps are reduced to about 5% of the normal full flowrates through the primary HR loop at about 60 seconds after the loss of pumping power. Initially, the fluid temperature at the pump suction side decreases rapidly as shown in Fig. B-8b as cold water from the pressurizer (40 C) enters the loop. The temperature increases about 1.5 C between 10 and 20 minutes into the accident as water heated in the modules circulates to the pumps. At this time, coolant liquid flowrate of the primary HR system is only about 13 kg/s from natural convection. Figs. B-9a to B-10e show the transient behaviors of the two primary HR pumps during the LOFA simulation time. The two HR pumps show near-symmetric behavior with no cavitation during this accident.

Figure A-3 shows the component layout for the pressurizer system connected to the inlet fixed header external to the cavity vessel. The initial fluid temperature of the pressurizer was assumed to 40 C. Figs. B-15a to B-15e show the transient behavior of the key thermal-hydraulic parameters for the pressurizer and surge line during the loss of the pumping power accident. From the results, the liquid in the pressurizer was not drained completely during the accident so that gas inside the pressurizer is not entrained into the heat removal system loop. Void fraction in the surge line of the pressurizer was zero during the transient accident to satisfy the design requirement for the pressurizer component. No void was entrained into the primary HR loop through the surge line of the pressurizer during the entire transient time of the LOFA accident.

3.3 RHR Loop

Figure A-4 shows the TRAC layout for the RHR system. The initial temperature for the RHR system was 40 C. The RHR system has check valve on the RHR pump discharge side to prevent flow reversal during the LOFA scenario. During the LOFA Case 2 accident, the RHR system remains stagnant at the initial temperature.

3.4 Cavity Vessel and Flood System

Figure A-5 shows the TRAC component layout that shows the heat transfer connections between the blanket module heat structures and the cavity vessel. Figure A-6 shows the TRAC component layout for the cavity vessel and flood system. During the LOFA Case 2 accident, the cavity flood system pool is stagnant with an ambient temperature of 40 C. The cavity vessel has no liquid phase with ambient temperature saturated at about 5 psia during the LOFA accident scenario.

4 Evaluation Model

The transient behavior of the blanket system was predicted using the integrated system model out to approximately 5600 seconds into the LOFA (i.e., slightly over 1.5 hours). By this point in time a quasi-steady state behavior had been achieved. Based on these system model results and a supporting simplified conservative evaluation model (EM), the transient behavior was extended out to 25 days beyond the initiating event for a variety of case studies. This solution strategy was chosen based on the belief that simulation times on the order of days were unattainable using the integrated system model and that the predictive capability of TRAC to accurately model the natural circulation patterns diminishes as the temperature driving forces diminish. The EM

approach uses the TRAC results at the early times where the solution is still considered valid and extends it to long times through conservative modeling assumptions.

In the 1-D TRAC system model, all the heat sources and sinks along the length of the coolant loops are not modeled in detail. Consequently, for safety analyses, natural circulation behavior predicted by this model should not be relied on when thermal driving forces become small. Therefore, the TRAC analyses beyond $t = 5600$ seconds into the transient are not used. At this time, the flow is assumed to have stagnated and lumped energy balance calculations are performed to estimate the time to saturation. Various adiabatic cases were studied by varying the amount of coolant participating in the heat-up process.

To perform this portion of the analysis, deposited power decay curves were generated and integrated over time to determine the total amount of heat released as a function of time. Figure 4-1 summarizes the decay curves used for the six composite lumped modules in the TRAC system model. For the purposes of this calculation, the deposited power curve for Module 1 was used to estimate the average deposited power. As shown in Fig. 4-1, this decay curve falls approximately in the middle of the possible values and represents close to the average power decay. This curve was integrated over time to obtain the total power deposited in the system. Figure 4-2 shows the integrated Module 1 decay curve starting at 5400 seconds. The total power was then distributed to the system mass and the temperature increase calculated. For these calculations, 6.46×10^4 kg of lead and 3.64×10^3 kg of aluminum were determined to be present in the APT blanket region.

Starting with a uniform system temperature of 50 C, sensible heat-up calculations were performed assuming that increasing amounts of available coolant participate in the heat-up process.

Four cases were investigated:

1. Power deposition in the blanket metal structures and the water in the module flow channels;
2. Power deposition in the metal and flow channel water plus the water within the piping from the fixed headers to the blanket modules;
3. Power deposited in the metal, blanket water and piping water plus the water in the primary heat removal loop;
4. Power deposited in the metal, blanket water, piping water and primary heat removal loop water plus the water in the secondary side of the primary loop heat exchangers.

In all four cases, it was assumed that the homogenized system of metal and water could instantaneously reach equilibrium with the deposited power. As would be expected, these four cases are in the order of decreasing severity. Assuming that more water is available to absorb some of the deposited energy decreases the rate of temperature rise in the system. For each case, calculations were made until fluid saturation was reached. From the hydrostatic pressure in the module channels, the saturation temperature was estimated to be 170 C. The calculations assume that adiabatic heating starts at 5400 seconds.

Figure 4-1 Deposited power profiles used in 1-D TRAC system model.

Figure 4-2 Integrated Module 1 power profile.

5 Evaluation Model Results

The times to reach saturation conditions are tabulated in Table 5-1 and the transient responses are plotted in Figs. 5-1 and 5-2. Figure 5-2 plots the data using a logarithmic scale for the time to better separate the two cases where the system quickly heats up. The amount of water used in each of the case calculations is listed in Table 5-1.

For an extreme case that assumes all of the power is deposited entirely in the metal and the water present in the module cooling channels, the temperature reaches 170 C within about 6 hours. At the other extreme, taking credit for all of the water in the blanket modules, in the primary heat removal system and in the secondary side of the primary heat exchangers, the heating time extends to greater than 25 days. The actual situation clearly lies between these two extremes. In the early part of the LOFA accident, there is still significant water circulation as the pumps coast down. Therefore, an analysis using all of the available coolant is appropriate (case 4). However, later in the accident, as the forced circulation stops, deposited heat is primarily absorbed by the blanket metal and the water in the blanket modules (case 1). As the blanket modules become hotter than the rest of the primary coolant circulation loop a natural convection flow around the loop is established. Therefore, we expect all of the coolant inventory to participate to some extent in the heat transfer process. Assuming that the actual behavior is bounded by the two intermediate cases analyzed (cases 2 and 3), we would estimate that it will take on the order of several days for the blanket module to heat to boiling when flow is lost in the primary cooling system.

Results from this simple analysis then support the belief that one or more days are available to take corrective actions prior to reaching saturation conditions. At the very low decay power levels one plus days after beam shutdown (i.e., approximately 0.2% or less), boil-off rates will significantly extend the corrective action period prior to experiencing the onset of temperature excursions within the blanket module materials.

Without taking any corrective measures, the above results indicate that peak metal temperatures for lead and aluminum within the bins of the blanket modules remain below their local fluid saturation temperatures for one or more days (i.e., approximately 170 C). Current thermal/hydraulic design criteria impose transient metal temperature limits on lead and aluminum of 327.5 C and 150 C, respectively, based on a limit for no more than a 10k hour exposure.

In the above calculations, credit was taken only for the safety class beam shutdown system. The above conservative calculations indicate that no margin exists to prevent the loss of coolable geometry unless some sort of corrective measures are taken within the first one or two days. This duration of time is very long (60 hours to just reach the onset of bulk boiling) and it is unrealistic to assume that the accident will be allowed to progress this long without additional administrative measures, such as:

- restoring AC power to the facility;
- bringing in temporary power supplies to operate the RHR or cavity flood systems;
- replenishing primary HR coolant that is boiled-off through purification lines; or
- reducing system pressure using controls to the pressurizer gas supply system. Reducing system pressure to atmospheric would allow the onset of bulk boiling to occur at approximately 120 C; thus, maintaining a coolable blanket geometry with the impact of reducing the available boil-off times that are significant.

Based purely on the conservative exposure assessment above, the RHR or cavity flood systems would not in-and-of-themselves be required to be designated a safety-class function. However, the potential loss-of-coolable blanket module geometries could result in a significant impact to the neighboring target ladders. To ensure no unwanted side-effects occur, either the RHR system or the cavity flood system should be designated a safety-class function. For this particular event sequence, the choice is somewhat arbitrary. However, based on considerations to be discussed under event sequence #4, the RHR system becomes the preferred choice for mitigation. The RHR system is design for operation in standard shutdown modes; whereas, the cavity flood system is design as an engineered safety system that would require additional maintenance be performed prior to restarting the facility.

Table 5-1 Heat-up times to reach onset of bulk boiling for four case studies.

Case	1	2	3	4
Material Considered	Modules only	plus internal piping	plus primary HR piping	plus shell side of HXs
Water, kg/10 ³	6.97	17.88	65.99	113.23
Time to reach 170 C	6 hours	17 hours	178 hours	>25 days

Figure 5-1 System temperature based on evaluation model analysis (linear time scale).

Figure 5-2 System temperature based on evaluation model analysis (logarithmic time scale).

6 Conclusions

Results are presented for an accident analyses of a LOFA initiated by loss-of-power with beam shut down but without RHR or cavity flood. Prevention of the release of radioactive material to the environment is associated with maintaining a coolable blanket geometry throughout the event sequence. BDBA event sequences, those without either an active intact RHR or cavity flood system, result in the loss of a coolable blanket geometry. The frequencies of all such event sequences are estimated to be in the beyond extremely unlikely range.

For the LOFA Case 2 analysis, the following SSC is credited:

- beam shutdown is determined to serve a safety class function.

The following technical safety requirements (TSRs) are identified during the LOFA analyses:

- The beam must be shut down when the flow in the blanket primary HR coolant loop is XX% of the nominal flow. This is the theoretical limit and the actual limit must be set accounting for the instrument errors and instrument delays. It is conceivable that further delay can be accommodated while preventing the loss in coolable blanket geometry. However, additional analyses are needed to justify further delays. The beam shutdown based on the flow rate reduction is a safety class TSR.

In the LOFA Case 2 analyses, all the consequence calculations are performed conservatively. In the quantification of the control points, in general, best-estimate analyses (TRAC) are used.

The following are some of the planned future analyses to supplement the results presented in this appendix:

- Assessment of the TRAC lumping strategies by additional component analyses driven by the boundary and initial conditions obtained from systems analyses. Note that the LOFA is a slow transient and the lumping strategy based on quasi-steady calculations is probably adequate. Nonetheless, this must be demonstrated by a few transient component and sub-system analyses.
- Verification of TRAC constitutive packages for low flow conditions using representative separate effects data.
- Sensitivity analyses to support quantification of safety margins and uncertainties.

6.1 Comparison to Thermal/Hydraulic Design Criteria

Simulations performed using the TRAC system model and the FLOWTRAN-TF detailed bin model show that the APT blanket modules maintain a coolable geometry during the LOFA scenario. The thermal/hydraulic (T/H) design criteria, along with the basis for their development, is discussed in Refs. [13]. For LOFA the T/H onset criteria are based on meeting very strict phenomenological limits with a high degree of confidence, as follows:

- for local heated surfaces within the module components, the onset-of-significant-voids [OSV]) at a three sigma confidence level; and
- for the remaining unheated piping sections of the blanket system, the onset-of-bulk-boiling [OBB]) at a three sigma confidence level.

Additional (steady-state derived) material design criteria are imposed on the maximum lead and aluminum (Series 6061 - Type T6) metal temperatures acceptable for the module components. The limiting values for these parameters are 327.5 C and 115 C for lead and aluminum, respectively. These material design criteria ensure that a coolable geometry can be maintained throughout the expected lifetime of each module unit. Less strict exposure dependent temperature limits can also be applied. Material limits for the plate-type structures have been tentatively set to: (1) 115 C for steady-state normal operation or indefinite times of exposure; and (2) 170 C for exposures less than 10,000 hours.

Confidence bounds are required to establish the acceptable level of probability of exceeding these criteria. The results presented in this report represent primarily best estimate values (however, some parameters were set to their estimated upper bounds, such as power density). Quantification of overall uncertainties and then their corresponding confidence levels (i.e., operating and modeling uncertainties) have not yet been performed. Future efforts to perform a response surface analysis are planned. At that time quantification of safety margins will be determined.

6.2 Design Issues

Adequate safety margin is provided by the reference 1 plate-type design to allow the APT blanket section to withstand the LOFA scenarios analyzed for a time period of

several days. In particular, the maximum aluminum temperature remained below 170 C over this time period. The maximum aluminum temperature exceeded 170 C if the accident was allowed to proceed beyond this time frame. Since it is reasonable to assume that additional action can be taken to further cool the blanket region during this time period, the current APT design provides adequate protection against this accident event.

6.3 Predicted Impact

Anticipated blanket conditions during LOFA Case 2 fall within all specified thermal/hydraulic design criteria for time periods of several days. During this time no on-site or off-site impact to people or the environment would occur from conditions within the blanket region of the APT as a result of this LOFA. Beyond several days, metal temperatures within the blanket module can exceed the limits imposed to ensure structural integrity. If this is allowed to occur slumping of the blanket plates can damage the helium tubes and target ladders leading to the release of hazardous and radioactive materials that would impact the environment. However, the analysis presented in this report shows that several days are available in which to take additional action to mitigate the accident event and prevent undesirable consequences.

7 References

1. L. L. Hamm, S. Y. Lee, M. A. Shadday, and F. G. Smith, III, "Normal Operation (NO) of APT Blanket System and its Components, Based on Initial Conceptual Design," Westinghouse Savannah River Company, WSRC-TR-98-0057 (July 1998).
2. L. L. Hamm, S. Y. Lee, M. A. Shadday, and F. G. Smith, III, "APT Blanket System Loss-of-Flow Accident (LOFA) Analyses Based on Initial Conceptual Design - Case 1: with Beam Shutdown and RHR," Westinghouse Savannah River Company, WSRC-TR-98-0058 (July 1998).
3. L. L. Hamm, S. Y. Lee, M. A. Shadday, and F. G. Smith, III, "APT Blanket System Loss-of-Coolant Accident (LOCA) Analysis Based on Initial Conceptual Design - Case 1: External HR Break Near Inlet Header," Westinghouse Savannah River Company, WSRC-TR-98-0059 (July 1998).
4. L. L. Hamm, S. Y. Lee, M. A. Shadday, and F. G. Smith, III, "APT Blanket System Loss-of-Coolant Accident (LOCA) Analysis Based on Initial Conceptual Design - Case 2: External HR Break at Pump Outlet with Pump Trip," Westinghouse Savannah River Company, WSRC-TR-98-0060 (July 1998).
5. L. L. Hamm, S. Y. Lee, M. A. Shadday, and F. G. Smith, III, "APT Blanket System Loss-of-Coolant Accident (LOCA) Analysis Based on Initial Conceptual Design - Case 3: External HR Break at Pump Outlet without Pump Trip," Westinghouse Savannah River Company, WSRC-TR-98-0061 (July 1998).
6. L. L. Hamm, S. Y. Lee, M. A. Shadday, and F. G. Smith, III, "APT Blanket System Loss-of-Coolant Accident (LOCA) Analysis Based on Initial Conceptual Design - Case 4: External Pressurizer Surge Line Break Near Inlet Header," Westinghouse Savannah River Company, WSRC-TR-98-0062 (July 1998).
7. L. L. Hamm, S. Y. Lee, M. A. Shadday, and F. G. Smith, III, "APT Blanket System Loss-of-Coolant Accident (LOCA) Analyses Based on Initial Conceptual Design - Case 5: External RHR Break Near Inlet Header," Westinghouse Savannah River Company, WSRC-TR-98-0063 (July 1998).

8. L. L. Hamm, S. Y. Lee, M. A. Shadday, and F. G. Smith, III, "APT Blanket System Internally Dry Flooded Cavity Accident (IDFCA) Based on Initial Plate-Type Design - Demonstration of Bin Heat Conduction Capability," Westinghouse Savannah River Company, WSRC-TR-98-0064 (July 1998).
9. G. Willcutt, "Decay Power Fractions for 1700 MeV Design," e-mail memo from Los Alamos National Laboratory, March 20, 1997.
10. L. L. Hamm, S. Y. Lee, M. A. Shadday, and F. G. Smith, III, "APT Blanket System Model Based On Initial Conceptual Design - Integrated 1D TRAC System Model," Westinghouse Savannah River Company, WSRC-TR-98-0053 (July 1998).
11. L. L. Hamm, S. Y. Lee, M. A. Shadday, and F. G. Smith, III, "TRAC Code Modifications made for APT Blanket Safety Analyses," Westinghouse Savannah River Company, WSRC-TR-98-0054 (July 1998).
12. Safety Code Development Group, "TRAC-PF1/MOD2: An Advanced Best Estimate Computer Program for Pressurized Water Reactor Thermal-Hydraulic Analysis," Los Alamos National Laboratory report LA-12031-M, Vol. 1 (NUREG/CR-5673), (July 21, 1993).
13. L. L. Hamm, S. Y. Lee, M. A. Shadday, and F. G. Smith, III, "APT Blanket System Safety Analysis Methodology," Westinghouse Savannah River Company WSRC-TR-98-0052 (May 1998).

Appendix A: TRAC Model Component Nomenclature

Table A-1 Blanket System Component Descriptions in TRAC Model.

System	Component Type	Comp #	No of Cells	Descriptions
HR	Fixed Header (FH)	380	1	coolant Supply FH
		340	1	coolant Return FH
	Pressurizer (Pzr)	760	1	Pzr surge line 1 connected to Supply FH 380
		761	2	Pzr surge line 2
		762	1	Pzr surge line 3
		763	1	Pzr surge line 4
		764	1	Pzr surge line 5
		765	13	Pzr surge line 6
		766	9	primary Pzr
	Hot Leg Loop	20	1	pipe connected to Return FH340
		21	1	plenum for potential break loc.
		22	7	pipe connection to external loop
		23	1	pipe connect. for potential break
		24	13	connection pipe
		25	1	connection pipe
		26	2	pipe connected to two pumps
		27	1	plenum for two pump connection
		28	2	pump#1 suction pipe
		29	7	pump#2 suction pipe
		30	2	pump located at cell face 2
		31	2	pump located at cell face 2
		32	3	check valve located at pump#1 discharge
		33	3	check valve located at pump#2 discharge
		34	1	pump outlet plenum
		36	1	connect. pipe between pump and pipe
		37	1	HX connect. pipe for potential break
		38	1	pipe connect. to two HX's inlet plenum
		40	1	plenum
	HX	48	3	HX #1 inlet pipe
		50	4	HX #1 1 st pass
		52	3	HX #1 middle header
		54	4	HX #1 2 nd pass
		49	3	HX #2 inlet pipe
		51	4	HX #2 1 st pass
		53	3	HX #2 middle header
		55	4	HX #2 2 nd pass
		710	1	HX #1 secondary side fill
		711	4	HX #1 2 nd pass secondary side
		712	3	HX #1 middle header secondary side
		713	4	HX #1 1 st pass secondary side
		714	1	HX #1 secondary side break BC
		730	1	HX #2 secondary side fill BC

Table A-1 Blanket System Component Descriptions in TRAC Model (continued).

System	Component Type	Comp #	No of Cells	Descriptions
		731	4	HX #2 2 nd pass secondary side
		732	3	HX #2 middle header secondary side
		733	4	HX #2 1 st pass secondary side
		734	1	HX #2 secondary side break BC
HR	Cold Leg Loop	56	3	HX #1 outlet pipe
		57	6	HX #2 outlet pipe
		60	3	HX outlet plenum merged after two HX's
		62	1	cold leg pipe
		63	1	cold leg pipe
		64	13	cold leg pipe located outside cavity wall
		65	1	pipe for cold leg pipe break
		66	1	horizontal cold leg pipe penetration
		67	1	plenum for internal break on HR loop
		854	2	HR isolation valve for internal break
		69	1	plenum for internal LOCA simulation
		68	5	pipe connect. to FH 340 inside cavity
Cavity Vessel	Cold Leg Loop	850	2	valve located bet. cavity vessel and HR
		852	2	valve located bet. cavity vessel and HR
			1	plenum for cavity vessel connection
		828	3	cavity vent valve
		802	1	break component for cavity vent pressure BC
		823	11	pipe for cavity lower section simulation
		824	1	plenum for cavity connection
		840	2	valve to connect cavity line to Module 1
		825	4	pipe for cavity middle section simulation
Cavity Pool	Cavity Flood Line	820	13	pipe for cavity pool connection to cavity vessel
		821	2	cavity flood line valve
		822	1	flood line pipe inside cavity vessel
	Cavity Flood Pool	801	1	break component for cavity pool BC
		810	10	pipe for top cavity pool section
		811	1	plenum for middle cavity pool section
		812	7	pipe for lower cavity pool section
		813	1	plenum for cavity pool bottom
RHR	RHR Loop	621	1	pipe located to return FH
		623	10	pipe located inside the cavity vessel
		624	1	pipe located outside the cavity vessel
		625	18	pipe bet. RHR pump and pipe comp. #624
		630	2	RHR pump located at face 2
		640	3	check valve located at pump discharge
		652	4	HX tubes
		660	16	pipe at the cold leg side
		661	1	pipe located before cavity vessel
		662	8	cold leg pipe inside cavity vessel

Table A-1 Blanket System Component Descriptions in TRAC Model (continued).

System	Component Type	Comp #	No of Cells	Descriptions
		663	1	cold leg pipe connected to supply FH
		672	1	fill for HX secondary side BC
		671	4	HX secondary shell side
		673	1	break comp. for HX secondary side BC
Module	Module 1 Flow	454	7	pipe connected to supply FH
		80	1	plenum for potential internal break simulation at Module 1
		375	5	pipe connection bet. Supply FH and Module 1 upper plenum
		370	1	upper plenum for Module 1 downcomer
		360	5	Module 1 downflow region
		350	1	middle plenum bet. Module 1 downflow and upflow regions
		300	5	Module 1 upflow region
		330	1	upper plenum for module 1 upflow region
		335	5	connection pipe after Module 1 upper plenum
		429	4	pipe connected to return FH
	Module 2 Flow	173	7	pipe connected to supply FH
		81	1	plenum for potential internal break simulation at Module 2
		82	3	pipe connection
		172	1	upper plenum for Module 2 downcomer
		158	6	Module 2 downflow region
		147	1	middle plenum bet. Module 2 downflow and upflow regions
		102	6	Module 2 upflow region
		133	1	upper plenum for module 2 upflow region
		136	7	pipe connected to return FH
	Module 3 Flow	415	7	pipe connected to supply FH
		85	1	plenum for potential internal break simulation at Module 3
		86	3	pipe connection
		479	1	upper plenum for Module 3 downcomer
		478	5	Module 3 downflow region
		418	1	middle plenum bet. Module 3 downflow and upflow regions
		409	5	Module 3 upflow region
		423	1	upper plenum for module 3 upflow region
		417	7	pipe connected to return FH
	Module 4 Flow	485	7	pipe connected to supply FH
		87	1	plenum for potential internal break simulation at Module 4
		88	3	pipe connection
		489	1	upper plenum for Module 4 downcomer

Table A-1 Blanket System Component Descriptions in TRAC Model (continued).

System	Component Type	Comp #	No of Cells	Descriptions
		480	6	Module 4 downflow region
		419	1	middle plenum bet. Module 4 downflow and upflow regions
		412	6	Module 4 upflow region
		483	1	upper plenum for module 4 upflow region
		484	7	pipe connected to return FH
Module	Module 5 Flow	513	7	pipe connected to supply FH
		89	1	plenum for potential internal break simulation at Module 5
		90	3	pipe connection
		510	1	upper plenum for Module 5 downcomer
		507	6	Module 5 downflow region
		503	1	middle plenum bet. Module 4 downflow and upflow regions
		500	6	Module 5 upflow region
		508	1	upper plenum for Module 5 upflow region
		511	7	pipe connected to return FH
	Module 6 Flow	541	7	pipe connected to supply FH
		83	1	plenum for potential internal break simulation at Module 6
		84	1	pipe connection
		538	1	upper plenum for Module 6 decoupler
		535	5	Module 6 downcomer region
		531	1	middle plenum bet. Module 6 decoupler and main heated regions
		528	5	Module 6 main heated region
		536	1	upper plenum for module 6 main heated region
		539	12	pipe connected to return FH
	Module 1 Heater Structure	901	5	Al tube structure in Row 1
		951	5	Lead zone with Al cladding in Row 1
		984	5	Al tube structure in decoupler
	Module 2 Heater Structure	905	6	Al tube structure in Row 2
		955	6	Lead zone with Al cladding in Row 2
		916	6	Al tube structure in Row 3
		966	6	Lead zone with Al cladding in Row 3
	Module 3 Heater Structure	911	5	Al tube structure in Row 1
		961	5	Lead zone with Al cladding in Row 1
		988	5	Al tube structure in decoupler
	Module 4 Heater Structure	912	6	Al tube structure in Row 1
		962	6	Lead zone with Al cladding in Row 1
		931	6	Al tube structure in Row 2

Table A-1 Blanket System Component Descriptions in TRAC Model (continued).

System	Component Type	Comp #	No of Cells	Descriptions
		978	6	Lead zone with Al cladding in Row 2
	Module 5 Heater Structure	913	6	Al tube structure in Row 2
		963	6	Lead zone with Al cladding in Row 2
		932	6	Al tube structure in Row 2
		979	6	Lead zone with Al cladding in Row 2
	Module 6 Heater Structure	915	5	Al tube structure in Row 2
		965	5	Lead zone with Al cladding in Row 2

Table A-2 Steady State Conditions.

Parameter	Units	Calculated Values
Total power deposited in blanket modules	MW	56.5
Total flow rate	kg/sec gpm	1569 25252
Pressure in cold-leg fixed header	MPa psia	0.7325 106.24
Pressure in hot-leg fixed header	MPa psia	0.4563 66.180
Pressurizer (cell #1) pressure	MPa psia	0.7311 106.03
Pump #1 suction pressure	MPa psia	0.2751 39.90
Pump #1 discharge pressure	MPa psia	1.0356 150.20
Pump #2 suction pressure	MPa psia	0.2958 42.91
Pump #2 discharge pressure	MPa psia	1.0409 150.97
Temperature in cold-leg fixed header	C F	49.43 121.0
Temperature in hot-leg fixed header	C F	58.03 136.5
Max. fluid temperature of the hottest module	C F	71.95 161.5

Figure A-1 6 blanket module layout for safety analysis.

Figure A-2 TRAC component layout for the cavity vessel and blanket module heat structures.

Figure A-3 TRAC component layout for the cavity vessel and cavity flood system.

BLANKET SAFETY ANALYSES FOR LOFA

(CASE 2: WITH BEAM SHUTDOWN ONLY)

Figure A-4 TRAC component layout for blanket primary HR coolant loop.

Figure A-5 TRAC component layout for blanket primary RHR coolant loop.

BLANKET SAFETY ANALYSES FOR LOFA

(CASE 2: WITH BEAM SHUTDOWN ONLY)

Figure A-6 TRAC component layout for blanket primary pressurizer and surge line.

WESTINGHOUSE SAVANNAH RIVER COMPANY

BLANKET SAFETY ANALYSES FOR LOFA

(CASE 2: WITH BEAM SHUTDOWN ONLY)

Report: WSRC-TR-98-0085

Section: Appendix A

Date: 07/14/98

Page: 12 of 12

(This Page Intentionally Left Blank)

Appendix B: LOFA (Case 2) TRAC Results

Appendix B1 LOFA (Case 2) TRAC Plenum Component Figures

The following figures are from a TRAC simulation for Case 2 of a LOFA (with beam shutdown only):

Figure B-1a Fixed header fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-1b Fixed header fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-1c Fixed header fluid subcoolings for a LOFA (Case 2: with beam shutdown only).

Figure B-1d Fixed header void fractions for a LOFA (Case 2: with beam shutdown only).

Figure B-2a Module 1 plenum fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-2b Module 1 plenum fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-2c Module 1 plenum fluid subcoolings for a LOFA (Case 2: with beam shutdown only).

Figure B-2d Module 1 plenum void fractions for a LOFA (Case 2: with beam shutdown only).

Figure B-3a Module 2 plenum fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-3b Module 2 plenum fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-3c Module 2 plenum fluid subcoolings for a LOFA (Case 2: with beam shutdown only).

Figure B-3d Module 2 plenum void fractions for a LOFA (Case 2: with beam shutdown only).

Figure B-4a Module 3 plenum fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-4b Module 3 plenum fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-4c Module 3 plenum fluid subcoolings for a LOFA (Case 2: with beam shutdown only).

BLANKET SAFETY ANALYSIS FOR LOFA

(CASE 2: WITH BEAM SHUTDOWN ONLY)

Figure B-4d Module 3 plenum void fractions for a LOFA (Case 2: with beam shutdown only).

Figure B-5a Module 4 plenum fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-5b Module 4 plenum fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-5c Module 4 plenum fluid subcoolings for a LOFA (Case 2: with beam shutdown only).

Figure B-5d Module 4 plenum void fractions for a LOFA (Case 2: with beam shutdown only).

Figure B-6a Module 5 plenum fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-6b Module 5 plenum fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-6c Module 5 plenum fluid subcoolings for a LOFA (Case 2: with beam shutdown only).

Figure B-6d Module 5 plenum void fractions for a LOFA (Case 2: with beam shutdown only).

Figure B-7a Module 6 plenum fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-7b Module 6 plenum fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-7c Module 6 plenum fluid subcoolings for a LOFA (Case 2: with beam shutdown only).

Figure B-7d Module 6 plenum void fractions for a LOFA (Case 2: with beam shutdown only).

Appendix B2 LOFA (Case 2) TRAC Pipe, Pump, and Valve Component Figures

The following figures are from a TRAC simulation for Case 2 of a LOFA (with beam shutdown only):

Figure B-8a Primary HR hot-leg piping fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-8b Primary HR hot-leg piping fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-8c Primary HR hot-leg piping fluid subcoolings for a LOFA (Case 2: with beam shutdown only).

Figure B-8d Primary HR hot-leg piping liquid mass flowrates for a LOFA (Case 2: with beam shutdown only).

Figure B-8e Primary HR hot-leg piping void fractions for a LOFA (Case 2: with beam shutdown only).

Figure B-9a Primary HR pump 1 fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-9b Primary HR pump 1 fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-9c Primary HR pump 1 fluid subcoolings for a LOFA (Case 2: with beam shutdown only).

Figure B-9d Primary HR pump 1 liquid mass flowrates for a LOFA (Case 2: with beam shutdown only).

Figure B-9e Primary HR pump 1 void fractions for a LOFA (Case 2: with beam shutdown only).

Figure B-10a Primary HR pump 2 fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-10b Primary HR pump 2 fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-10c Primary HR pump 2 fluid subcoolings for a LOFA (Case 2: with beam shutdown only).

Figure B-10d Primary HR pump 2 liquid mass flowrates for a LOFA (Case 2: with beam shutdown only).

Figure B-10e Primary HR pump 2 void fractions for a LOFA (Case 2: with beam shutdown only).

Figure B-11a Primary HR pump discharge piping fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-11b Primary HR pump discharge piping fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-11c Primary HR pump discharge piping fluid subcoolings for a LOFA (Case 2: with beam shutdown only).

Figure B-11d Primary HR pump discharge piping liquid mass flowrates for a LOFA (Case 2: with beam shutdown only).

Figure B-11e Primary HR pump discharge piping void fractions for a LOFA (Case 2: with beam shutdown only).

Figure B-12a Primary HR heat exchanger inlet piping fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-12b Primary HR heat exchanger inlet piping fluid temperatures for a LOFA
(Case 2: with beam shutdown only).

Figure B-12c Primary HR heat exchanger inlet piping fluid subcoolings for a LOFA
(Case 2: with beam shutdown only).

Figure B-12d Primary HR heat exchanger inlet piping liquid mass flowrates for a LOFA (Case 2: with beam shutdown only).

Figure B-12e Primary HR heat exchanger inlet piping void fractions for a LOFA (Case 2: with beam shutdown only).

Figure B-13a Primary HR heat exchanger outlet piping fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-13b Primary HR heat exchanger outlet piping fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-13c Primary HR heat exchanger outlet piping fluid subcoolings for a LOFA
(Case 2: with beam shutdown only).

Figure B-13d Primary HR heat exchanger outlet piping liquid mass flowrates for a LOFA
(Case 2: with beam shutdown only).

Figure B-13e Primary HR heat exchanger outlet piping void fractions for a LOFA (Case 2: with beam shutdown only).

Figure B-14a Primary HR cold-leg piping fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-14b Primary HR cold-leg piping fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-14c Primary HR cold-leg piping fluid subcoolings for a LOFA (Case 2: with beam shutdown only).

Figure B-14d Primary HR cold-leg piping liquid mass flowrates for a LOFA (Case 2: with beam shutdown only).

Figure B-14e Primary HR cold-leg piping void fractions for a LOFA (Case 2: with beam shutdown only).

Figure B-15a Primary HR pressurizer and surge line fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-15b Primary HR pressurizer and surge line fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-15c Primary HR pressurizer and surge line fluid subcoolings for a LOFA (Case 2: with beam shutdown only).

Figure B-15d Primary HR pressurizer and surge line liquid mass flowrates for a LOFA (Case 2: with beam shutdown only).

Figure B-15e Primary HR pressurizer and surge line void fractions for a LOFA (Case 2: with beam shutdown only).

Figure B-16a Primary RHR pump fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-16b Primary RHR pump fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-16c Primary RHR pump fluid subcoolings for a LOFA (Case 2: with beam shutdown only).

Figure B-16d Primary RHR pump liquid mass flowrates for a LOFA (Case 2: with beam shutdown only).

Figure B-16e Primary RHR pump void fractions for a LOFA (Case 2: with beam shutdown only).

Figure B-17a Primary RHR heat exchanger fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-17b Primary RHR heat exchanger fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-17c Primary RHR heat exchanger fluid subcoolings for a LOFA (Case 2: with beam shutdown only).

Figure B-17d Primary RHR heat exchanger liquid mass flowrates for a LOFA (Case 2: with beam shutdown only).

Figure B-17e Primary RHR heat exchanger void fractions for a LOFA (Case 2: with beam shutdown only).

Figure B-18a Module 1 channel fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-18b Module 1 channel fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-18c Module 1 channel fluid subcoolings for a LOFA (Case 2: with beam shutdown only).

Figure B-18d Module 1 channel liquid mass flowrates for a LOFA (Case 2: with beam shutdown only).

Figure B-8e Module 1 channel void fractions for a LOFA (Case 2: with beam shutdown only).

Figure B-19a Module 2 channel fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-19b Module 2 channel fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-19c Module 2 channel fluid subcoolings for a LOFA (Case 2: with beam shutdown only).

Figure B-19d Module 2 channel liquid mass flowrates for a LOFA (Case 2: with beam shutdown only).

Figure B-19e Module 2 channel Module 2 channel void fractions for a LOFA (Case 2: with beam shutdown only).

Figure B-20a Module 3 channel fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-20b Module 3 channel Module 3 channel fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-20c Module 3 channel fluid subcoolings for a LOFA (Case 2: with beam shutdown only).

Figure B-20d Module 3 channel liquid mass flowrates for a LOFA (Case 2: with beam shutdown only).

Figure B-20e Module 3 channel void fractions for a LOFA (Case 2: with beam shutdown only).

Figure B-21a Module 4 channel fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-21b Module 4 channel fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-21c Module 4 channel fluid subcoolings for a LOFA (Case 2: with beam shutdown only).

Figure B-21d Module 4 channel liquid mass flowrates for a LOFA (Case 2: with beam shutdown only).

Figure B-21e Module 4 channel void fractions for a LOFA (Case 2: with beam shutdown only).

Figure B-22a Module 5 channel fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-22b Module 5 channel fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-22c Module 5 channel fluid subcoolings for a LOFA (Case 2: with beam shutdown only).

Figure B-22d Module 5 channel liquid mass flowrates for a LOFA (Case 2: with beam shutdown only).

Figure B-22e Module 5 channel void fractions for a LOFA (Case 2: with beam shutdown only).

Figure B-23a Module 6 channel fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-23b Module 6 channel fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-23c Module 6 channel fluid subcoolings for a LOFA (Case 2: with beam shutdown only).

Figure B-23d Module 6 channel liquid mass flowrates for a LOFA (Case 2: with beam shutdown only).

Figure B-23e Module 6 channel void fractions for a LOFA (Case 2: with beam shutdown only).

Figure B-24a Mid-plane module fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-24b Mid-plane module fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-24c Mid-plane module fluid subcoolings for a LOFA (Case 2: with beam shutdown only).

Figure B-24d Mid-plane module liquid mass flowrates for a LOFA (Case 2: with beam shutdown only).

Figure B-24e Mid-plane module void fractions for a LOFA (Case 2: with beam shutdown only).

Figure B-25a Module inlet fluid pressures for a LOFA (Case 2: with beam shutdown only).

Figure B-25b Module inlet fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-25c Module inlet fluid subcoolings for a LOFA (Case 2: with beam shutdown only).

Figure B-25d Module inlet liquid mass flowrates for a LOFA (Case 2: with beam shutdown only).

Figure B-25e Module inlet void fractions for a LOFA (Case 2: with beam shutdown only).

Appendix B3 LOFA (Case 2) TRAC Heat Structure Component Figures

The following figures are from a TRAC simulation for Case 2 of a LOFA (with beam shutdown only):

Figure B-26 Module 1 upflow section bottom and top maximum lead metal temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-27 Module 2 upflow section bottom and top maximum lead metal temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-28 Module 3 upflow section bottom and top maximum lead metal temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-29 Module 4 upflow section bottom and top maximum lead metal temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-30 Module 5 upflow section bottom and top maximum lead metal temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-31 Module 6 down-stream section bottom and top maximum lead metal temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-32 Module 1 upflow section bottom and top maximum aluminum metal temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-33 Module 2 upflow section bottom and top maximum aluminum metal temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-34 Module 3 upflow section bottom and top maximum aluminum metal temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-35 Module 4 upflow section bottom and top maximum aluminum metal temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-36 Module 5 upflow section bottom and top maximum aluminum metal temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-37 Module 6 down-stream section bottom and top maximum aluminum metal temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-38 Module 1 upflow section top-plane surface and fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-39 Module 2 upflow section top-plane surface and fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-40 Module 3 upflow section top-plane surface and fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-41 Module 4 upflow section top-plane surface and fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-42 Module 5 upflow section top-plane surface and fluid temperatures for a LOFA (Case 2: with beam shutdown only).

Figure B-43 Module 6 upflow section top-plane surface and fluid temperatures for a LOFA (Case 2: with beam shutdown only).

WESTINGHOUSE SAVANNAH RIVER COMPANY

BLANKET SAFETY ANALYSIS FOR LOFA

(CASE 2: WITH BEAM SHUTDOWN ONLY)

Report: WSRC-TR-98-0085

Section: Appendix B

Date: 07/14/98

Page: 72 of 72

(This Page Intentionally Left Blank)

Appendix C: TRAC Standard Input File for LOFA Case 2 (with Beam Shutdown only)

The file listed below represents the TRAC code "tracin" file that corresponds to the LOFA Case 2 (with beam shutdown only) for the blanket system. This input deck assumes that a TRAC restart file ("trcrst") exists based on normal operation (NO).

Input file tracin:

```

*
free format
*
*****
* main data *
*****
*
*          numtcr          ieos          inopt          nmat          id2o
*              37              0              1              2              0
*
* APT Lumped Blanket Model
* 6 Module Lumped Model with Primary Coolant Loop and RHR Loop
* 6 Modules - Lateral(R1/Dec) Module, R2/R3 Module,
*              3 Backstop Modules, Low Power Module (12/18/1997)
* Hydraulic RHR Loop added as of 12/22/1997
* - This is based on check valve with flow reversal control logic.
* Number of material = 2 (Al and Pb)
* - This is single combined mod model without He comp (12/12/1997)
* - Aluminum, lead material table got from Ref. (3/5, 1997)
* - This is 1 module loop model without primary coolant and RHR loops
* - adding two upper modules (L14B-back / L14F-front) as of 7/18/1997.
* - Row2/3 power updated (4/23/1997).
* - R2/R3 axial power distribution has been updated
*   as of 4/25/1997.
* - Al and lead material properties updated already.
* - Unit cell cal. should be checked.
* - K-loss values for each comp and elevation levels need be checked.
* - Control signal variable was added (4/25/1997).
* - Module 5 6 7 8 connection to fixed header was updated (5/28/97).
* - Blanket primary loop pipe size (14 inch) was updated (5/28/1997).
* - Lower modules(module 15 16 17 18) were added/updated (5/29/1997).
* - Backstop 1st module was updated (5/29/1997).
* - Backstop 2nd and 3rd modules were updated (5/30/1997).
* - R2/R3 lateral modules were updated from 9 to 11 bins (6/3/1997).
* - Lateral module 1 to 4 decay powers were updated (6/23/1997).
* - Power for each module was updated from the 6/9/97 e-mail except
*   for snout and top modules (6/26/97).
* - Decay power fraction for each module was updated from the 6/9/97
*   e-mail except for snout and top modules (6/26/97).
* - Power for each module was updated from the 6/9/97 e-mail
*   for snout module (7/8/97).
* - Decay power fraction for each module was updated from the 6/9/97
*   e-mail for snout module (7/8/97).
* - Single loop to connect two front lateral modules was updated
*   (7/16/97).
* - Single loop to connect two back lateral modules was updated
*   (7/16/97).
*
*
*
*
*****

```

BLANKET SAFETY ANALYSIS FOR LOFA

(CASE 2: WITH BEAM SHUTDOWN ONLY)

* namelist data *

*

```
&inopts nrslv=1, nhtstr=25, iconht=0, iadded=10, ielv=1, ipowr=-1,
      tpowr=10, igas=1, noair=0, nlt=12, ikfac=1, ithd=1, nsend=80000 &
```

*

```

*      dstep      timet
      -1          0.0000e+00
*      stdyst      transi      ncomp      njun      ipak
      0            1          140          120          1
*      epso        epss
      1.0000e-04    1.0000e-04
*      oitmax      sitmax      isolut      ncontr      nccfl
      50           50          0           2           0
*      ntsv        ntcb        ntcf        ntrp        ntcp
      7            0           0           7           1
*
*****
* component-number data *
*****
*
* iorder*
*
      760 s * pipe      pressurizer surge line1
      761 s * pipe      pressurizer surge line2
      762 s * pipe      pressurizer surge line3
      763 s * pipe      pressurizer surge line4
      764 s * pipe      pressurizer surge line5
      765 s * pipe      pressurizer surge line6
      766 s * pipe      primary pressurizer
      767 s * break     pressurizer boundary
*
* HR hot leg
      20 s * pipe      HR pump suction pipe
      21 s * plenum     HR pump suction pipe (bk)
      22 s * pipe      HR pump suction pipe
      23 s * pipe      HR pump suction pipe (bk)
      24 s * pipe      HR pump suction pipe
      25 s * pipe      HR pump suction pipe (bk)
      26 s * pipe      HR pump suction pipe
* HR pumps
      27 s * plenum     HR pump suction plenum
      28 s * pipe      HR pump #1 inlet pipe
      30 s * pump       HR pump #1
      32 s * pipe      HR pump #1 outlet pipe
      29 s * pipe      HR pump #2 inlet pipe
      31 s * pump       HR pump #2
      33 s * pipe      HR pump #2 outlet pipe
      34 s * plenum     HR pump discharge plenum
* HR pump-to-hx piping
      36 s * pipe      HR pump discharge pipe
      37 s * pipe      HR pump discharge pipe (bk)
      38 s * pipe      HR pump discharge pipe
* HR hx's
      40 s * plenum     HR hx inlet plenum
      48 s * pipe      HR hx 1 inlet pipe
      50 s * pipe      HR hx 1 tubes 1st pass
      52 s * pipe      HR hx 1 mid-header
      54 s * pipe      HR hx 1 tubes 2nd pass
      56 s * pipe      HR hx 1 outlet pipe
      49 s * pipe      HR hx 2 inlet pipe
      51 s * pipe      HR hx 2 tubes 1st pass
```

BLANKET SAFETY ANALYSIS FOR LOFA

Date: 07/14/98

(CASE 2: WITH BEAM SHUTDOWN ONLY)

Page: 3 of 8

53	s	* pipe	HR hx 2 mid-header
55	s	* pipe	HR hx 2 tubes 2nd pass
57	s	* pipe	HR hx 2 outlet pipe
60	s	* plenum	HR hx outlet plenum
* HR cold leg			
62	s	* pipe	HR hx discharge pipe
63	s	* pipe	HR hx discharge pipe (bk)
64	s	* pipe	HR hx discharge pipe
65	s	* pipe	HR hx discharge pipe (bk)
66	s	* pipe	HR hx discharge pipe
67	s	* plenum	HR hx discharge pipe (bk)
68	s	* pipe	HR hx discharge pipe
* HR hx Secondary Side			
710	s	* fill	HR hx Secondary Side-1
711	s	* pipe	HR hx Secondary Side-1
712	s	* pipe	HR hx Secondary Side-1
713	s	* pipe	HR hx Secondary Side-1
714	s	* break	HR hx Secondary Side-1
730	s	* fill	HR hx Secondary Side-2
731	s	* pipe	HR hx Secondary Side-2
732	s	* pipe	HR hx Secondary Side-2
733	s	* pipe	HR hx Secondary Side-2
734	s	* break	HR hx Secondary Side-2
*			
621	s	* pipe	RHR hot leg sect 1 (bk)
623	s	* pipe	RHR hot leg sect 2
624	s	* pipe	RHR hot leg sect 3 (bk)
625	s	* pipe	RHR hot leg sect 4
630	s	* pump	RHR primary pump
640	s	* valve	RHR pump discharge valve
652	s	* pipe	RHR primary heat exchanger tubes
660	s	* pipe	RHR cold leg sect 1
661	s	* pipe	RHR cold leg sect 2 (bk)
662	s	* pipe	RHR cold leg sect 3
663	s	* pipe	RHR cold leg sect 4 (bk)
* RHR hx Secondary Side			
672	s	* fill	RHR hx Secondary Side
671	s	* pipe	RHR hx Secondary Side
673	s	* break	RHR hx Secondary Side
*			
300	s	* pipe	L1 Blanket Row1
330	s	* plenum	L1 Blanket Row1 Plenum
335	s	* pipe	L1 pipe conn. 330 - 340
340	s	* plenum	L1 outlet header
350	s	* plenum	L1 lower plenum
360	s	* pipe	L1 decoupler
370	s	* plenum	L1 decoupler upper plenum
375	s	* pipe	L1 pipe conn. 370 - 380
380	s	* plenum	L1 inlet header
429	s	* pipe	L1 connect hot header-tee
454	s	* pipe	L1 connect cold header-tee
*			
173	s	* pipe	L1 Blanket Row1
172	s	* plenum	L1 Blanket Row1 Plenum
158	s	* pipe	L1 pipe conn. 330 - 340
147	s	* plenum	L1 outlet header
102	s	* pipe	L1 lower plenum
133	s	* plenum	L1 decoupler
136	s	* pipe	L1 decoupler upper plenum
*			
541	s	* pipe	L1 Blanket Row1
538	s	* plenum	L1 Blanket Row1 Plenum

BLANKET SAFETY ANALYSIS FOR LOFA

(CASE 2: WITH BEAM SHUTDOWN ONLY)

535	s	* pipe	L1 pipe conn. 330 - 340
531	s	* plenum	L1 outlet header
528	s	* pipe	L1 lower plenum
536	s	* plenum	L1 decoupler
539	s	* pipe	L1 decoupler upper plenum
*			
415	s	* pipe	L1 Blanket Row1
479	s	* plenum	L1 Blanket Row1 Plenum
478	s	* pipe	L1 pipe conn. 330 - 340
418	s	* plenum	L1 outlet header
409	s	* pipe	L1 lower plenum
423	s	* plenum	L1 decoupler
417	s	* pipe	L1 decoupler upper plenum
*			
485	s	* pipe	2nd DNS Blanket Row1
489	s	* plenum	2nd DNS Blanket Row1 Plenum
480	s	* pipe	2nd DNS pipe conn. 330 - 340
419	s	* plenum	2nd DNS outlet header
412	s	* pipe	2nd DNS lower plenum
483	s	* plenum	2nd DNS decoupler
484	s	* pipe	2nd DNS dec upper plenum
*			
513	s	* pipe	Third DNS Blanket Row1
510	s	* plenum	Third DNS Row1 Plenum
507	s	* pipe	Third DNS pipe conn. 330-340
503	s	* plenum	Third DNS outlet header
500	s	* pipe	Third DNS lower plenum
508	s	* plenum	Third DNS decoupler
511	s	* pipe	Third DNS dec upper plenum
*			
901	s	* rod	annular aluminum rod
951	s	* rod	cylindrical lead rod
984	s	* rod	cylindrical lead rod
*			
905	s	* rod	annular aluminum rod
955	s	* rod	cylindrical lead rod
916	s	* rod	cylindrical lead rod
966	s	* rod	cylindrical lead rod
*			
915	s	* rod	annular aluminum rod
965	s	* rod	cylindrical lead rod
*			
911	s	* rod	annular aluminum rod
961	s	* rod	cylindrical lead rod
988	s	* rod	cylindrical lead rod
*			
912	s	* rod	annular aluminum rod
962	s	* rod	cylindrical lead rod
931	s	* rod	cylindrical lead rod
978	s	* rod	cylindrical lead rod
*			
913	s	* rod	annular aluminum rod
963	s	* rod	cylindrical lead rod
932	s	* rod	cylindrical lead rod
979	s	* rod	cylindrical lead rod
*			
919	s	* rod	annular ss rod
920	s	* rod	annular ss rod
921	s	* rod	annular ss rod
922	s	* rod	annular ss rod
971	e	* rod	annular ss rod
*			

BLANKET SAFETY ANALYSIS FOR LOFA

(CASE 2: WITH BEAM SHUTDOWN ONLY)

* material-properties data *

*

*

* matb * 51 52e

* ptbln * 2 6e

*

* lead material

*

prptb(1,i)	prptb(2,i)	prptb(3,i)	prptb(4,i)	prptb(5,i)
2.7300e+02	1.1374e+04	1.2970e+02	3.4592e+01	2.8000e-01
1.0000e+10	1.1374e+04	8.9538e+02	3.3382e+01	2.8000e-01

e

*

* aluminum material

*

prptb(1,i)	prptb(2,i)	prptb(3,i)	prptb(4,i)	prptb(5,i)
2.7300e+02	2.6990e+03	8.6985e+02	2.1046e+02	5.0000e-02
3.0000e+02	2.6990e+03	8.9000e+02	2.1046e+02	5.0000e-02
3.7300e+02	2.6990e+03	9.4140e+02	2.1046e+02	5.0000e-02
4.7300e+02	2.6990e+03	9.9538e+02	2.2175e+02	5.0000e-02
6.7300e+02	2.6990e+03	1.0900e+03	2.2845e+02	5.0000e-02
1.0000e+10	2.6990e+03	1.2000e+03	2.3000e+02	5.0000e-02

e

*

*

* CSS data

*

*

* control-parameter data *

*

* signal variables

*

* time

idsv	isvn	ilcn	icn1	icn2
1	0	0	0	0

*

* pressure difference across RHR check valve

idsv	isvn	ilcn	icn1	icn2
2	-21	640	1	2

*

* Elapse time since RHR pump activated

idsv	isvn	ilcn	icn1	icn2
3	0	0	0	0

*

* Elapse time since HR pumps activated

idsv	isvn	ilcn	icn1	icn2
4	-21	31	2	1

*

* pressure difference across HR check valve

idsv	isvn	ilcn	icn1	icn2
5	-21	32	1	2

*

* pressure difference across HR check valve

idsv	isvn	ilcn	icn1	icn2

BLANKET SAFETY ANALYSIS FOR LOFA

Date: 07/14/98

(CASE 2: WITH BEAM SHUTDOWN ONLY)

Page: 6 of 8

6	-21	33	1	2
* pressure, cold leg at plenum, component 761				
* idsv	isvn	ilcn	icn1	icn2
7	21	68	1	1

*

* control-block data *

*

* trips

* trips from off to on at time given by setp(2), fill BC

* ntse	ntct	ntsf	ntdp	ntsd
1	0	0	0	0

0

*

* component data *

*

end

*

* time-step data *

*

* dtmin	dtmax	tend	rtwfp
1.0000e-07	1.0000e-03	2.0000e-02	1.0000e+01
* edint	gfint	dmpint	sedint
1.0000e-01	5.0000e+00	1.0000e+06	1.0000e+06

*

* dtmin	dtmax	tend	rtwfp
1.0000e-07	2.0000e-02	1.0000e+01	1.0000e+01
* edint	gfint	dmpint	sedint
5.0000e-01	5.0000e+00	1.0000e+06	1.0000e+06

*

* dtmin	dtmax	tend	rtwfp
1.0000e-07	3.0000e-01	6.0000e+01	1.0000e+01
* edint	gfint	dmpint	sedint
2.0000e+00	5.0000e+00	1.0000e+06	1.0000e+06

*

* dtmin	dtmax	tend	rtwfp
1.0000e-07	3.0000e-01	1.0000e+02	1.0000e+01
* edint	gfint	dmpint	sedint
4.0000e+00	5.0000e+00	1.0000e+06	1.0000e+06

*

* dtmin	dtmax	tend	rtwfp
1.0000e-07	5.0000e-01	1.5000e+02	1.0000e+01
* edint	gfint	dmpint	sedint
1.0000e+01	5.0000e+00	1.0000e+06	1.0000e+06

*

* dtmin	dtmax	tend	rtwfp
1.0000e-07	5.0000e-01	6.0000e+02	1.0000e+01
* edint	gfint	dmpint	sedint
5.0000e+01	5.0000e+00	1.0000e+06	1.0000e+06

*

* dtmin	dtmax	tend	rtwfp
1.0000e-07	1.0000e+00	3.6000e+03	1.0000e+01
* edint	gfint	dmpint	sedint
1.0000e+02	2.0000e+01	1.0000e+06	1.0000e+06

*

BLANKET SAFETY ANALYSIS FOR LOFA

(CASE 2: WITH BEAM SHUTDOWN ONLY)

*	dtmin	dtmax	tend	rtwfp
	1.0000e-07	1.0000e+00	5.6000e+03	1.0000e+01
*	edint	gfint	dmpint	sedint
	2.0000e+02	2.0000e+01	1.0000e+06	1.0000e+06
*				
*	endflag			
	-1.0000e+00			

WESTINGHOUSE SAVANNAH RIVER COMPANY

BLANKET SAFETY ANALYSIS FOR LOFA

(CASE 2: WITH BEAM SHUTDOWN ONLY)

Report: WSRC-TR-98-0085

Section: Appendix C

Date: 07/14/98

Page: 8 of 8

(This Page Intentionally Left Blank)

Appendix D: TRAC Graphics Input File for LOFA Case 2 (with Beam Shutdown only)

The file listed below represents the TRAC code "graphin" file that corresponds to the LOFA case 2 (with beam shutdown only) for the blanket system. This input deck contains the various graphics points selected for output to the "tecsum.grf" file.

Input file tracin:

```

/ npoints /
  88
/ component      cell      ictype      itee/
  340             1         1           1      Fixed outlet header
  380             1         1           1      Fixed inlet header

  454             2         0           1      Module 1 pipe
  173             2         0           1      Module 2 pipe
  415             2         0           1      Module 3 pipe
  485             2         0           1      Module 4 pipe
  513             2         0           1      Module 5 pipe
  541             2         0           1      Module 6 pipe

  300             1         0           1      Module 1 Row1
  102             1         0           1      Module 2 Row2
  409             1         0           1      Module 3 Row1
  412             1         0           1      Module 4 Row1
  500             1         0           1      Module 5 Row2
  528             1         0           1      Module 6 Low Power

  300             3         0           1      Module 1 Row1
  102             3         0           1      Module 2 Row2
  409             3         0           1      Module 3 Row1
  412             3         0           1      Module 4 Row1
  500             3         0           1      Module 5 Row2
  528             3         0           1      Module 6 Low Power

  300             5         0           1      Module 1 Row1
  102             6         0           1      Module 2 Row2
  409             5         0           1      Module 3 Row1
  412             6         0           1      Module 4 Row1
  500             6         0           1      Module 5 Row2
  528             5         0           1      Module 6 Low Power

  370             1         1           1      Module 1 Inlet Plenum
  350             1         1           1      Module 1 Middle Plenum
  330             1         1           1      Module 1 Outlet Plenum
  172             1         1           1      Module 2 Inlet Plenum
  147             1         1           1      Module 2 middle Plenum
  133             1         1           1      Module 2 Outlet Plenum
  479             1         1           1      Module 3 Inlet Plenum
  418             1         1           1      Module 3 Middle Plenum
  423             1         1           1      Module 3 Outlet Plenum
  489             1         1           1      Module 4 Inlet Plenum
  419             1         1           1      Module 4 Middle Plenum
  483             1         1           1      Module 4 Outlet Plenum
  510             1         1           1      Module 5 Inlet Plenum
  503             1         1           1      Module 5 Middle Plenum
  508             1         1           1      Module 5 Outlet Plenum
  538             1         1           1      Module 6 Inlet Plenum

```

BLANKET SAFETY ANALYSIS FOR LOFA

Date: 07/14/98

(CASE 2: WITH BEAM SHUTDOWN ONLY)

Page: 2 of 4

531	1	1	1	Module 6 Middle Plenum
536	1	1	1	Module 6 Outlet Plenum
26	1	0	1	Hot leg pump suction line
30	1	0	1	PCL Pump 1 Suction
30	2	0	1	PCL Pump 1 Discharge
31	1	0	1	PCL Pump 2 Suction
31	2	0	1	PCL Pump 2 Discharge
32	2	0	1	PCL Pump 1 check valve
33	2	0	1	PCL Pump 2 check valve
37	1	0	1	PCL Pump to HX
48	2	0	1	PCL Hx 1 inlet
56	2	0	1	PCL Hx 1 outlet
49	2	0	1	PCL Hx 2 inlet
57	2	0	1	PCL Hx 2 outlet
62	1	0	1	Cold leg Hx discharge line
66	1	0	1	Cold leg Hx discharge line
630	1	0	1	RHR Pump Suction
630	2	0	1	RHR Pump Discharge
640	3	0	1	RHR Hx inlet
660	1	0	1	RHR Hx outlet
761	1	0	1	Pzr Pressure Signal
766	1	0	1	Pzr Bottom Pressure
951	1	3	1	Hot Module (1) upflow inside
951	5	3	1	Hot Module (1) upflow inside
951	1	3	2	Hot Module (1) upflow outside
951	5	3	2	Hot Module (1) upflow outside
955	1	3	1	Hot Module (2) upflow inside
955	6	3	1	Hot Module (2) upflow inside
955	1	3	2	Hot Module (2) upflow outside
955	6	3	2	Hot Module (2) upflow outside
961	1	3	1	Hot Module (3) upflow inside
961	5	3	1	Hot Module (3) upflow inside
961	1	3	2	Hot Module (3) upflow outside
961	5	3	2	Hot Module (3) upflow outside
962	1	3	1	Hot Module (4) upflow inside
962	6	3	1	Hot Module (4) upflow inside
962	1	3	2	Hot Module (4) upflow outside
962	6	3	2	Hot Module (4) upflow outside
963	1	3	1	Hot Module (5) upflow inside
963	6	3	1	Hot Module (5) upflow inside
963	1	3	2	Hot Module (5) upflow outside
963	6	3	2	Hot Module (5) upflow outside
965	1	3	1	Hot Module (6) upflow inside
965	5	3	1	Hot Module (6) upflow inside
965	1	3	2	Hot Module (6) upflow outside
965	5	3	2	Hot Module (6) upflow outside

INPUT NOTES:

npoints - number of locations (points) within TRAC model graphics requested
 component - component id number containing specified graph point
 cell - cell number with in component where graphics requested
 ictype - type of component:

BLANKET SAFETY ANALYSIS FOR LOFA

(CASE 2: WITH BEAM SHUTDOWN ONLY)

(0 for fill, pipe, pressurizer, pump, tee, turb, value)
(1 for plenum)

OUTPUT NOTES:

tsec	- Time into simulation (sec)
Psia	- Cell center pressure (psia)
Qf	- Liquid volumetric flowrate at cell face (gpm)
tl	- Liquid phase temperature (C)
tsub	- Liquid subcooling (C)
tsat	- Liquid saturation temperature (C)
rol	- Liquid phase density (kg/m ³)
vl	- Liquid phasic velocity at cell face (m/s)
Pa	- Cell center pressure (Pa)
qf	- Liquid volumetric flowrate at cell face (m ³ /s)
void	- Gas void fraction (-)
Qg	- Gas volumetric flowrate at cell face (gpm)
qg	- Gas volumetric flowrate at cell face (m ³ /s)
tv	- Gas phase temperature (C)
rov	- Gas phase density (kg/m ³)
vv	- Gas phasic velocity at cell face (m/s)
pair	- Partial pressure of non-condensable in gas phase (psia)

WESTINGHOUSE SAVANNAH RIVER COMPANY

BLANKET SAFETY ANALYSIS FOR LOFA

(CASE 2: WITH BEAM SHUTDOWN ONLY)

Report: WSRC-TR-98-0085

Section: Appendix D

Date: 07/14/98

Page: 4 of 4

(This Page Intentionally Left Blank)