NUREG/CR-6472
BNL-NUREG-52501

# Preliminary Phenomena Identification and Ranking Tables for Simplified Boiling Water Reactor Loss-of-Coolant Accident Scenarios

Prepared by
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Prepared for
U.S. Nuclear Regulatory Commission

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Manuscript Completed: September 1997
Date Published: April 1998

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**Prepared for**
**Division of Systems Technology**
**Office of Nuclear Regulatory Research**
**U.S. Nuclear Regulatory Commission**
**Washington, DC 20555-0001**
**NRC Job Code W6092**

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# ABSTRACT

For three potential Loss-of-Coolant Accident (LOCA) scenarios in the General Electric Simplified Boiling Water Reactors (SBWR) a set of Phenomena Identification and Ranking Tables (PIRT) is presented. The selected LOCA scenarios are typical for the class of small and large breaks generally considered in Safety Analysis Reports. The method used to develop the PIRTs is described. Following a discussion of the transient scenarios, the PIRTs are presented and discussed in detailed and in summarized form. A procedure for future validation of the PIRTs, to enhance their value, is outlined.

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# EXECUTIVE SUMMARY

This report documents the development of a set of preliminary Phenomena Identification and Ranking Tables (PIRTs) for Loss-of-Coolant Accidents (LOCA) in the General Electric (GE) Simplified Boiling Water Reactor (SBWR). PIRTs were first introduced as part of the Code Scaling, Applicability and Uncertainty evaluation methodology (CSAU). In that program they were primarily used as guide in the uncertainty quantification. More generally, PIRTs can be used to guide the development of research plans, for considering further code development needs, and for the planning of experiments.

The effort documented in this report considers a spectrum of LOCA scenarios, with primary focus on the effects of SBWR plant phenomena on reactor vessel parameters. The transients selected were a Main Steam Line Break (MSLB), with the break inside the containment. This accident presents the most severe large-break scenario. A Bottom Drain Line Break (BDLB) was selected as the break with the lowest break point, having the potential for continued loss of inventory, until containment and reactor vessel coolant levels are equalized, and a break in one line of the Gravity-Driven Cooling System (GDCS), which was reported by GE in the Standard Safety Analysis Report (SSAR) to result in the lowest coolant level in the reactor.

The PIRT team selected a logical breakdown of the accident scenarios into specific time phases, during which distinct events dominate the scenario. Further, a list of all important phenomena was compiled. Guided by NRC licensing criteria, like peak clad temperature, assessment criteria were established to assist in ranking the importance of the defined phenomena. The major assessment criterion was found to be coolant inventory in the reactor vessel. The ranking was initially performed by an internal BNL team and were than discussed and revised in several sessions with a team of outside consultants.

The resulting PIRTs with phenomena descriptions and ranking rationales are presented in the tables of Appendices B and C. There are 82 phenomena for three transients, each with five time phases, resulting in 1230 individual rankings. A combined summary table can be found in Table 5.1-1, and a composite PIRT, showing only the highest rank for each phenomenon is given in Table 6.1-1. Of the 82 phenomena 60 were ranked high at least in one case, indicating that high-fidelity models and firm experimental knowledge of these phenomena will be desirable, while main PIRT presented in this report were based on vessel inventory as an assessment criterion, a revised PIRT was also prepared with respect to containment pressure and is presented in Appendix E.

Further enhancement of the PIRTs through quantitative validation of the effects of key phenomena on the assessment parameters is recommended.

# ACKNOWLEDGMENT

The PIRT development, similar to related methods, is rather man-power intensive. Many people contributed in the course of this work and we apologize if somebody was overlooked. Our thanks and gratitude go to all who helped us develop this report.

The BNL team of engineers, producing the first pass of all three PIRTs consisted of the following participants (in addition to the authors):

Dr. B. Boyer, Dr. Y. Parlatan, and Dr. H. Khan.

In the meetings with outside consultants significant help to us was provided by many of the attendants, foremost,

Professors P. Griffith, MIT and V. Dhir, UCLA, Model Report.
N. Lauben and Dr. T. Lee, U.S. NRC,
Messrs. G. Wilson and C. D. Fletcher, INEL, and
Dr. R. Dowlati, Purdue University.

Our thanks go to all.

# ACRONYMS

| | |
|---|---|
| ADS | Automatic Depressurization System |
| BDLB | Bottom Drain Line Break |
| BNL | Brookhaven National Laboratory |
| BOP | Balance of Plant |
| CSAU | Code Scaling, Applicability and Uncertainty Evaluation |
| DPV | Depressurization Valve |
| DW | Drywell |
| FMECA | Failure Modes Effects and Criticality Analysis |
| GDCS | Gravity-Driven Cooling System |
| GDLB | GDCS Line Break |
| HAZOP | Hazards and Operability Analysis |
| IC | Isolation Condenser |
| LDW | Lower Drywell |
| LOCA | Loss-of-Coolant Accident |
| MSIV | Main Steam Isolation Valve |
| MSLB | Main Steam Line Break |
| NC | Non-Condensible |
| NRC | United States Nuclear Regulatory Commission |
| PCCS | Passive Containment Cooling System |
| PIRT | Phenomena Identification and Ranking Table |
| RCPB | Reactor Coolant Pressure Boundary |
| RPV | Reactor Pressure Vessel |
| RWCU/SDC | Reactor Water Cleanup/Shutdown Cooling System |
| SBWR | Simplified Boiling Water Reactor |
| SC | Suppression Chamber |
| SRV | Safety Relief Valve |
| SSAR | Standard Safety Analysis Report (see Chapter 7, References) |
| TAF | Top of Active Fuel |
| UDW | Upper Drywell |

# 1 INTRODUCTION

Brookhaven National Laboratory (BNL) is currently developing a set of Phenomena Identification and Ranking Tables (PIRTs) for the Simplified Boiling Water Reactor (SBWR). This report documents the current status of this effort. The PIRTs presented here are preliminary and the report includes an outline of planned efforts to further refine and finalize the tables.

A Phenomena Identification and Ranking Table lists all phenomena occurring in a specific transient, and ranks them according to their importance with respect to previously selected assessment criteria. The concept of PIRTs was first introduced in the development of the Code Scaling, Applicability and Uncertainty Evaluation methodology (CSAU), (Boyack et al., 1989). Details of the PIRT development under the CSAU program were presented by Shaw et al., 1988.

During the development of the CSAU methodology the PIRTs were developed for a large- break LOCA in a PWR and were used as a guide in the subsequent uncertainty quantification. However, as pointed out by Shaw et al. (1988), PIRTs, developed for a specific transient, can be used for any task requiring a knowledge of phenomena in that transient. In general a set of PIRTs for a specific plant can be used as an invaluable guide for the development of research plans, for considering further code development needs and for experiment-planning efforts.

In the current effort, the PIRTs for SBWR LOCA transients, being developed here, can be used to assure that the important phenomena are addressed in both, the codes being used for SBWR safety analysis and in the experimental data base.

A description of the SBWR and its main features can be found in Appendix A. The methodology of developing PIRTs is reviewed in Chapter 2. A description of the accident transients selected is given in Chapter 3, followed by a qualitative summary of the current PIRTs in Chapter 4. The detailed PIRTs are contained in Appendix B. Appendix E summarizes revised PIRT based on containment pressure as criterion. Chapter 5 provides a discussion of the results from the detailed PIRTs and describes early validation efforts. In Chapter 6 a summary is provided with conclusions based on the current state of this work and an outline of future plans.

# 2 PIRT METHODOLOGY

## 2.1 General PIRT Method

The development of PIRTs was first introduced with the development of the CSAU methodology. The procedure uses the collective experience of a panel of experts in the field, who develop the PIRTs in group meetings. Preferably, the panel members should have a diverse background, for instance including experimentalists and analysts as well as designers and operators of the selected reactor.

Following selection of a specific reactor and a specific transient, the group of experts will compile a list of all phenomena which occur during this transient, whatever their importance. The term "phenomenon" here must include all items that should ultimately be subject to ranking. This includes such diverse items as flashing in the core and hydrostatic head in the GDCS. Some of these are, strictly speaking, not phenomena but parameters. As definition, the common word phenomenon is substituted for all such entries in the PIRT tables, even if they are not true phenomena, but parameters, processes, or other conditions.

The transient is then subdivided into time phases, predominantly by considering periods during which different phenomena may be important, like blowdown or GDCS refill. In principle, the breakdown into time periods could differ for different transients, but the development of the PIRTs is significantly more efficient, if the same time periods can be applied for all transients to be evaluated.

For each time phase the relevant assessment criteria are established. These assessment criteria are derived from NRC licensing criteria (see for instance Fletcher et al., 1994), with the higher levels being based on NRC regulations or regulatory guidance:

Level 1: Protect public health and safety
Level 2: Limit fission-product release
Level 3: Limit fuel failure; limit containment breach
Level 4: Limit peak clad temperature; limit containment pressure and temperature

In this hierarchy, each lower-level criterion (higher number) must be defined such that all higher-order criteria are satisfied. Frequently the further substitution of "lower level" parameters is possible and more practical, where the lower-level parameters, if kept within specified bounds, assure that the safety criteria for higher-level parameters are not exceeded.

Based on the above breakdown of the transient into time periods, a ranking is given to each phenomenon in each time phase, considering the importance of its effect on the selected assessment criteria. These rankings can be numerical, for instance 0 to 9, or qualitative, for instance, "low," "medium," and "high."

In particular in its reliance on expert judgement, the method is in many ways similar to methods used in related applications. The Hazards and Operability Analysis (HAZOP), is used primarily in the chemical industry, and the Failure Modes Effects and Criticality Analysis (FMECA) is in use in the nuclear industry, primarily for reliability assessments (Lees, 1980).

A PIRT should always be considered as a "living document," to be reviewed and revised as further information becomes available or as plant operating experience is gained. The certainty and validity of the rankings will depend on how much knowledge is available. In early phases of development, the rankings may represent the initial judgement of the group of experts. One outcome of such early PIRT sessions will be the identification of items requiring further investigation and/or confirmation. This can be achieved, for instance, by comparison to existing experiments and/or through order-of-magnitude estimates and sample calculations.

## 2.2 Implementation for SBWR

The PIRTs presented here were originally developed by qualitative judgement of a group of seven to eight BNL mechanical, nuclear, and chemical engineers, all with significant experience in the nuclear reactor field and thoroughly familiar with the SBWR design. The available background information included various SBWR related papers and reports, extending from the SSAR and various reports by General Electric Nuclear Energy to open-literature publications. In particular, there were several reports and papers on various SBWR test facilities like GIRAFFE, GIST, PANTHER, and PUMA. The data base also includes reports on university test programs, studying condensation in the presence of noncondensibles in the PCCS as well as on structures and surfaces. Most of these publications are included in the reference section of this report.

As a representative set, three transients were selected here for the development of SBWR PIRTs. The Main Steam Line Break (MSLB), with break inside the containment, was selected as the worst large-break scenario. Of the small-break scenarios the Bottom Drain Line Break (BDLB) was selected, because of its potential for complete draining of the reactor vessel. The GDCS Line Break (GDLB) was selected as the small break, for which the lowest vessel water inventory was predicted in the SSAR (see Table 6.3-2, there).

Following the original internal development of PIRTs at BNL, the tables were subjected to review by outside consultants in formal meetings. Two meetings were held, each of two-day duration in May and in August of 1994. The first meeting served for familiarization with the SBWR design and included a review of the MSLB PIRT. The second meeting, covered the BDLB and GDLB PIRTs. Copies of the attendance sheets and agendas for the two meetings are given in Appendix C.

In most cases no disagreement arose between the original BNL rankings and the consultant's suggestions. However, in many cases the rankings were changed after technical discussion of the phenomena. In some instances no agreement was reached, as shown in the detailed PIRTs of Appendix B. This occurred mainly due to insufficient information being available at the time. The final ranking of these items was deferred until further sensitivity evaluations have been completed, as described in Chapter 4, Section 5.2 and in Appendix B.

The current PIRT was developed in parallel with the establishment of the capability for SBWR transient simulations using RELAP5. During the process of our work further information from the vendor became available. Where practical, some revisions were made as new results became available. However, the current rankings, as discussed and presented in Chapter 4 and Appendix B, must be considered as preliminary and should be subject to further validation.

The PIRTs, developed here, consider the effects of phenomena on all reactor vessel parameters. Because of the close coupling between containment and vessel during large parts of the transients, containment phenomena were considered in our evaluations, as they affected vessel parameters only.

# 3 ACCIDENT TRANSIENTS SELECTED

In this chapter the accident scenario for the three selected transients, the Main Steam Line Break (MSLB), the Bottom Drain Line Break (BDLB) and the GDCS Line Break (GDLB) will be described. A detailed description of the SBWR plant can be found in Appendix A. Figure 3.0-1 shows a schematic of the reactor vessel, including the most significant elevations of various components.

Following the PIRT procedure, as described in Chapter 2, all three transients were subdivided into distinct time phases, during which different phenomena will be typically dominant. The following was an effective general breakdown, which could be applied to all three transients:

1. Pre-Isolation:

   This phase extends from initiation of the accident to MSIV closure. The phase is generally short and dominated by choked flow at the break(s) and beginning of vent flow from the drywell to the suppression chamber.

2. Isolation:

   This phase is generally dominated by loss of inventory owing to break flow with depressurization, flashing, and level swell in the reactor. It ends with the opening of the ADS, generally on an $L_1$ water-level signal.

3. Depressurization:

   As the SRVs and DPVs are opened, more coolant inventory is discharged into the containment. The vessel depressurizes, until pressures in the reactor vessel and the containment are equal. This phase ends with GDCS initiation, 150 s after ADS initiation or on pressure equalization, whichever is later.

4. Refill:

   During this phase the GDCS tanks empty their coolant into the reactor vessel, which is slowly refilled. GDCS flow and single-phase coolant flow in the reactor dominate during this phase. It is defined to end with beginning of PCCS operation, which generally occurs after the GDCS tanks are essentially emptied and steaming has begun again in the core.

5. Long-Term Cooling:

   In this phase the steam produced by decay heat in the RPV is condensed in the PCCS, with condensate being returned via the GDCS tanks to the RPV and noncondensibles being purged into the suppression chamber. Evaporation in the core, PCCS performance, and intermittent operation of the vacuum breakers dominate this phase. This phase is defined to end at 72 h (TAPD Report, Rev. B).

## 3.1 Description of Main Steam Line Break LOCA

This scenario assumes a break of one main steam line to occur inside the containment, between the reactor vessel and the MSIV. The break occurs instantaneously as a double-guillotine break.

For this accident scenario results from recent RELAP5 runs, performed at BNL were available (Parlatan et al., 1995). The results shown here are extracted from that work. The approximate duration of each of the five time phases is given in Table 3.1-1. The purpose of this table is to indicate the relative length of the duration of each phase and to serve as guide to the figures presented below.

**Table 3.1-1 Approximate End Times for Event Phases During MSLB**

| Event Phase | End of Phase | Approximate End Time (s) |
|---|---|---|
| Pre-Isolation | MSIV Closure | 5 |
| Isolation | ADS Actuation | 580 |
| Depressurization | GDCS Actuation | 720 |
| Refill | PCCS Condensation Begins | 5,400 |
| Long-Term Cooling | Definition | 72 h |

During the Pre-Isolation Phase, coolant is discharged into the drywell from both sides of the break, since the two main steam lines are connected at a common header outside the containment. Some results from the RELAP5 runs are shown in Figs. 3.1-1 to 3.1-3. The MSIVs begin to close within about 0.5 s, on low reactor pressure or high differential pressure in the main steam line. They are closed at about five seconds (see Fig. 3.1-3), ending this phase of the accident scenario. Following the very rapid discharge of the steam inventory in the steam lines (< 1 s), the flow out of the reactor vessel is limited by the flow restrictors at the junction of vessel and steam-line (see Fig. 3.1-3). Reactor scram is expected to occur during this phase, on high drywell pressure. The horizontal vents clear in about one second (see Fig. 3.1-3). The integrated mass flow from the drywell into the suppression chamber equals the original gas mass in the upper drywell at about five seconds, suggesting rapid replacement of the original nitrogen with steam. The important parameters during this phase are the break flows from the RPV into the drywell and early non-uniform mixing of drywell nitrogen with incoming steam, as they affect the drywell pressure (see Fig. 3.1-2), which provides the scram signal.

During the Isolation Phase rapid depressurization is observed, due to the large break. Some results from the RELAP5 runs for this time period are shown in Figs. 3.1-4 to 3.1-8. The flow generally remains choked at the flow restrictor. If the two-phase level reaches the break, a mixture of liquid and vapor may be discharged into the containment. This phase continues till the ADS is activated, generally when the downcomer wide-range level reaches or exceeds $L_1$ for 10 s, which occurs here at about 580 s (see Fig. 3.1-7). The major phenomena during this phase are the break flow, directly determining the loss of inventory, and the heat rejection to the isolation condensers which is shown in Fig. 3.1-8. The return of cold condensate from the condensers will reduce the two-phase level in the RPV and may prevent liquid discharge at the break. With efficient heat removal via the ICs, the loss of inventory can remain limited, such that the depressurization signal (Level $L_1$) is only reached when the vessel pressure is already approaching the drywell pressure as can be seen in Fig. 3.1-5. In an MSLB scenario unchoking of the break flow may occur already during this time phase. In such cases, the actual ADS flow will be relatively unimportant, but the $L_1$ signal remains important, as initiator for GDCS draining.

The Depressurization Phase is generally unimportant in MSLB scenarios, and is essentially an extension of the Isolation Phase. At the time of ADS initiation, on an $L_1$ signal, the break flow amounts to only about 20 kg/s and the initial ADS flows are even smaller, since the reactor vessel pressure is already close to the drywell pressure.

The Refill Phase is timed to begin 150 s after initiation of the ADS, subject to pressure equilibration between reactor vessel and drywell, controlled by check valves in the GDCS lines. Some results from the RELAP5 simulations are shown in Figs. 3.1-9 to 3.1-11. As refill begins, steaming in the reactor vessel will essentially cease, with subcooled liquid entering the core and filling the reactor vessel. The refill flow is shown in Fig. 3.1-9. With the beginning of GDCS flow, the common pressure in the reactor vessel and in the containment is reduced, as steaming ceases (see Fig. 3.1-10) and the water level in the reactor rises. Usually, an overflow of subcooled liquid from the vessel into the drywell can be expected. After the GDCS tanks have been emptied, the reactor coolant will slowly heat up. As it approaches saturation temperature, steaming will resume, with vapor entering the drywell and proceeding from there to the PCCS, as indicated in Fig. 3.1-11. By definition, beginning of vapor flow to the PCCS marks the end of this phase. The most important phenomena during this phase are draining of the GDCS tanks and filling of the reactor vessel.

Some results from the RELAP5 simulations for the Long-Term Cooling Phase are presented in Figs. 3.1-12 to 14. During this time the vapor generated by decay heat will be transported to the PCCS, where it is condensed and returned to the RPV via the GDCS tanks and drain lines (see Fig. 3.1-13). The noncondensibles are routed through the PCCS to the suppression chamber, where they accumulate. During the later parts of this phase, with more efficient condensation, the common vessel and drywell pressure is expected to drop below the suppression-chamber pressure causing the vacuum breakers to open, returning some noncondensibles to the drywell. The most important phenomena during this phase are the PCCS condensation, in the presence of NCs, NC transport to the suppression chamber, and gas return from the suppression chamber to the drywell via the vacuum breakers.

## 3.2 Description of Bottom Drain Line Break LOCA

An instantaneous double-guillotine break of the bottom drain line is assumed to occur close to the reactor vessel. Since the bottom drain line is connected to the RWCU/SDC line, back flow through that line will occur, which is considered in the PIRTs of Chapter 4 and Appendix B as a second break. Thus, the effective break flow area corresponds to a two-inch-diameter break at the bottom drain plus a three-inch-diameter break of the RWCU/SDC line.

For this accident scenario preliminary RELAP5 runs, prepared at BNL early in 1994 were available for the first 2000 s, which extends into the GDCS refill time period. Some results from that work are shown in Figs. 3.2-1 to 3.2-6. The approximate duration of each of the five time phases is presented in Table 3.2-1. The purpose of this table is to indicate the relative length of the duration of each phase and to serve as guide to the figures presented below.

With break flow into the drywell, the drywell pressure will increase and is expected to reach the scram set point of 0.14 bar pressure rise within about eight to ten seconds. The SBWR design provides for a turbine trip with closing of the turbine stop valve and opening of the turbine bypass valve. The feedwater flow continues, matching the turbine bypass flow, with the bypass valve modulated to maintain the RPV pressure. In this scenario reactor flow and decay-heat rejection via the main condensers could be maintained for some time. Under such conditions this break would be a relatively benign event.

A more severe scenario assumes loss of preferred power simultaneously with the occurrence of the break (see SSAR). This would result in a turbine trip and scram within less than one second. The feedwater flow would begin to coast down simultaneously. This second scenario is the one typically evaluated as a LOCA.

The PIRT, developed here, primarily considers the second scenario. However, where readily practical, phenomena important in the first scenario are ranked corresponding to their importance in that sequence of events. This increases the generality of the PIRT and provides the capability to consider such scenarios in future applications. Only during the pre-isolation phase are these two different paths possible. Following closure of the MSIVs both transients follow an identical path. The RELAP5 simulations of this LOCA assumed the second scenario with loss of preferred power and scram at time zero.

**Table 3.2-1 Approximate End Times for Event Phases During BDLB**

| Event Phase | End of Phase | Approximate End Time (s) |
|---|---|---|
| Pre-Isolation | MSIV Closure | 80 |
| Isolation | ADS Actuation | 820 |
| Depressurization | GDCS Actuation | 1,000 |
| Refill | PCCS Condensation Begins | 4,000 (assumed) |
| Long-Term Cooling | Definition | 72 h |

During the Pre-Isolation Phase, coolant is discharged into the drywell from both breaks, with the bottom drain line flow directly entering the lower drywell. Isolation only occurs at about 80 s on an $L_2$ signal as indicated in Fig. 3.2-1. During the pre-isolation phase significant coolant flow continues to the turbine bypass valve with a corresponding rapid decrease in reactor pressure. (The SBWR design includes a low-pressure set point of 57 bar for scram and isolation, which would actually have caused isolation at about 14 s, but this signal was not included in the preliminary simulations of early 1994, which are presented here. While this does affect the time scale of the scenario, it is not expected to change the phenomena to be considered during the transient). The break flows into the drywell will result in a pressure increase there, and vent flow from the drywell to the suppression chamber will begin. With the vent system designed for large-break flows, only the top row of horizontal vents will clear partially, and apparently also intermittently. The most important phenomena during this time phase are the mass flows into and out of the reactor vessel, as they directly affect the inventory.

With the beginning of the Isolation Phase the pressure decrease is slowed significantly, as can be seen in Fig. 3.2-2, with coolant now leaving through the two small breaks only. Both break flows together amount to about 20 to 25 kg/s during this period (see Fig. 3.2-3), compared with 1,000 kg/s for a main steam line break. With a slow further pressure decrease, the coolant inventory decreases and the ADS set point of $L_3$ is finally reached at about 820 s, ending this time phase (see Fig. 3.2-1). The most important phenomena during this time period are the mass flows entering and leaving the vessel as well as the energy removal via the isolation condensers, which amounts to about 70 MW during a large portion of this time period.

The Depressurization Phase begins with opening of the DPVs and SRVs. It leads to final depressurization of the vessel, resulting in an equilibrium pressure between drywell and reactor vessel of about 2.4 bar, as can be seen in Fig. 3.2-4. The important parameters during this phase are the ADS flows from the RPV into the drywell and into the suppression pool. At this time the coolant flow from the ADS significantly exceeds the break flows.

After depressurization, the Refill Phase begins at about 1,000 s. GDCS flow is timed to begin 150 s after initiation of ADS operation, subject to pressure equilibration between reactor vessel and drywell, controlled by check valves in the GDCS lines. As refill begins, steaming in the reactor vessel will essentially cease, with subcooled liquid entering the core and filling the reactor vessel. With beginning GDCS flow, the pressure in the reactor vessel and in the containment is reduced, as steam is condensed and the level of subcooled water in the reactor vessel rises. When the level reaches the elevation of the RWCU/SDC line, coolant will spill from the second break, but with much larger GDCS flow entering, the level will rise above this elevation. After the GDCS tanks run empty, the reactor coolant level will slowly decrease to the RWCU/SDC line elevation and the core coolant will heat up. As it approaches saturation temperature, steaming will resume, with vapor entering the drywell and proceeding from there to the PCCS. By definition, beginning of vapor flow to the PCCS marks the end of this phase. The most important phenomena during this phase are draining of the GDCS tanks and filling of the reactor vessel.

The preliminary BDLB simulations did not extend into the Long-Term Cooling Phase, but qualitatively it is not expected to proceed differently from the corresponding time phase of the MSLB scenario, described in Section 3.1. The vapor generated by decay heat will be transported to the PCCS, where it is condensed and returned to the RPV via the GDCS tanks and drain lines. The noncondensibles are routed through the PCCS to the suppression chamber, where they accumulate. During the later parts of this phase, with more efficient condensation, the common vessel and drywell pressure is expected to drop below the suppression-chamber pressure, causing the vacuum breakers to open, returning some noncondensibles to the drywell. The most important phenomena during this phase are the PCCS condensation in the presence of NCs, NC transport to the suppression chamber, and gas return from the suppression chamber to the drywell via the vacuum breakers. The bottom drain line flow will stop once the lower drywell is filled with water and the upper drywell and reactor vessel coolant levels have reached an equilibrium. Should the water level ever fall to within one meter of TAF ($L_{0.5}$), the equalization lines will open, introducing suppression-pool water into the reactor vessel, and indirectly into the drywell.

## 3.3 Description of the GDCS Line Break LOCA

This LOCA is postulated to begin with a break of one GDCS line, between the GDCS line valves and the inlet into the reactor vessel. As part of this accident, one of the three GDCS tanks will not be available for refilling of the reactor vessel, thus, significantly reducing the coolant available for refill. No simulations were available for this accident scenario at this time. Qualitatively the sequence should closely follow the BDLB scenario, except for the lack of a bottom drain, and with less coolant being available during the refill phase. Apart from the break flows, which obviously differ between the BDLB and the GDLB scenarios and the timing of different events, none of the PIRT rankings of either the BNL team or of the consultants differed between the two scenarios, as reflected in the tables of Chapter 4.

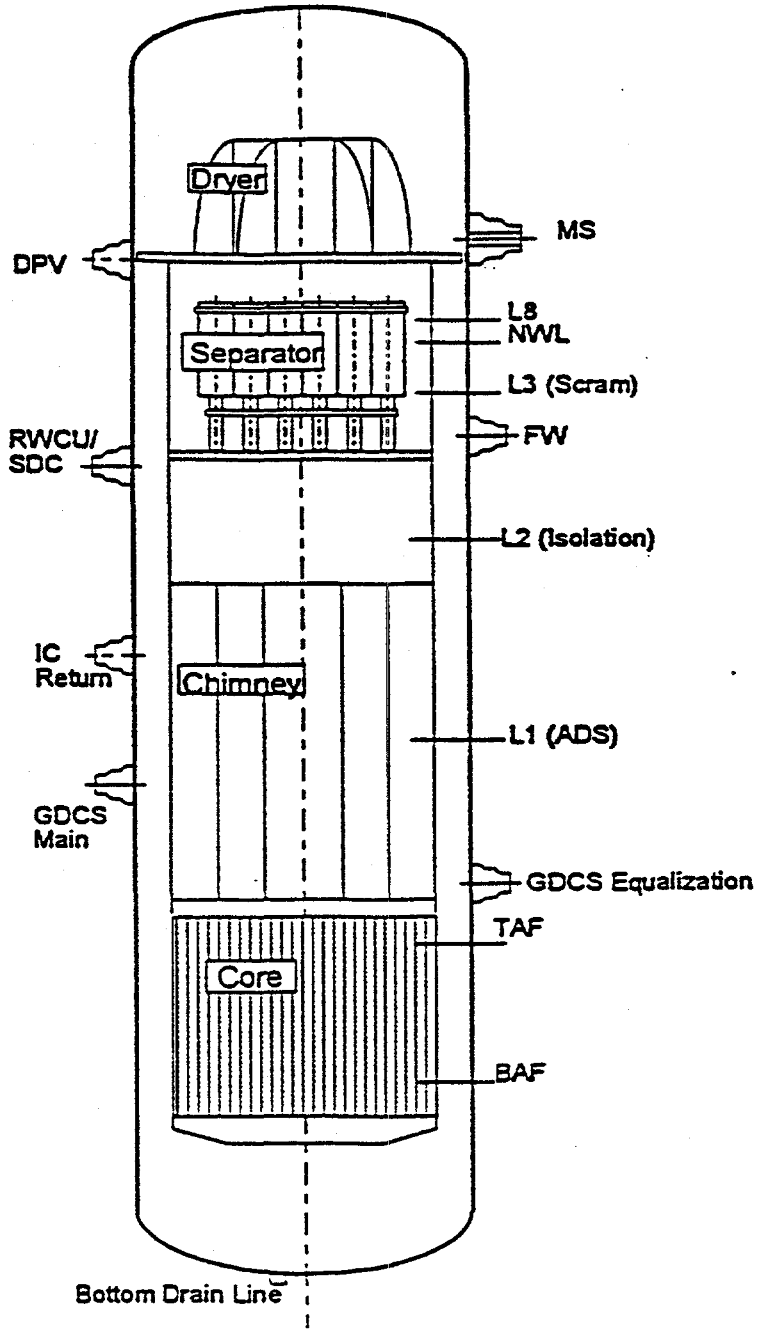


**Figure 3.0-1 Schematic of SBWR Reactor Vessel**

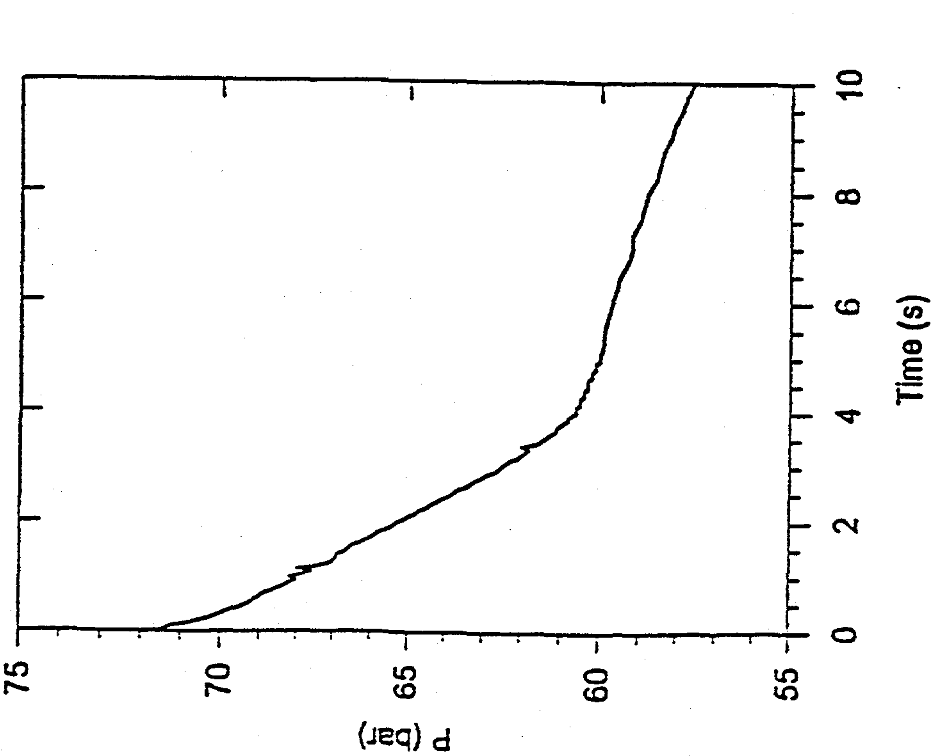


Figure 3.1-1 Steam Dome Pressure During a Main Steam Line Break

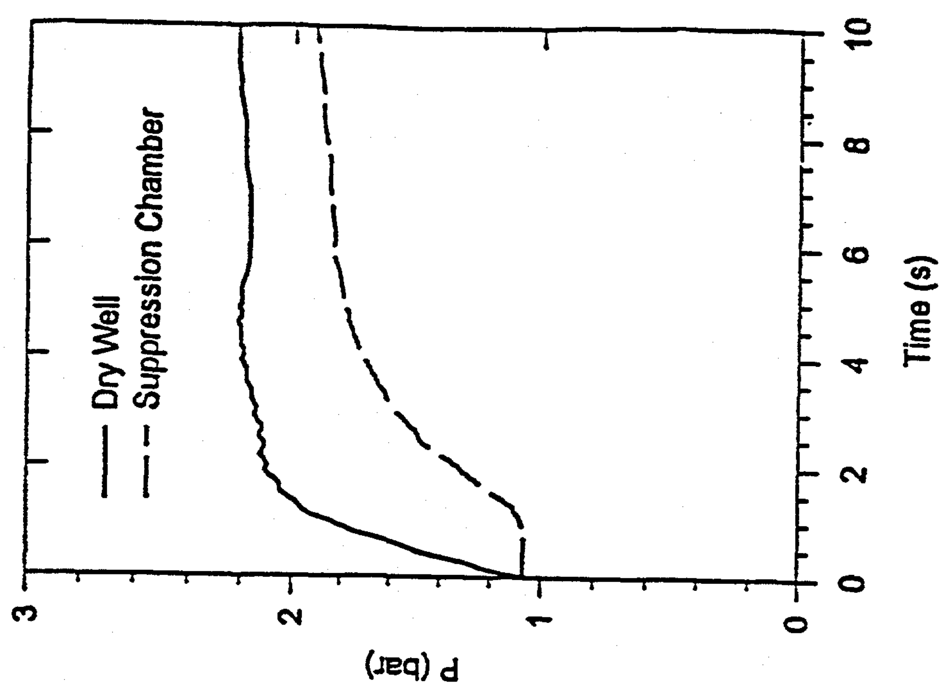


Figure 3.1-2 Containment Pressures During a Main Steam Line Break

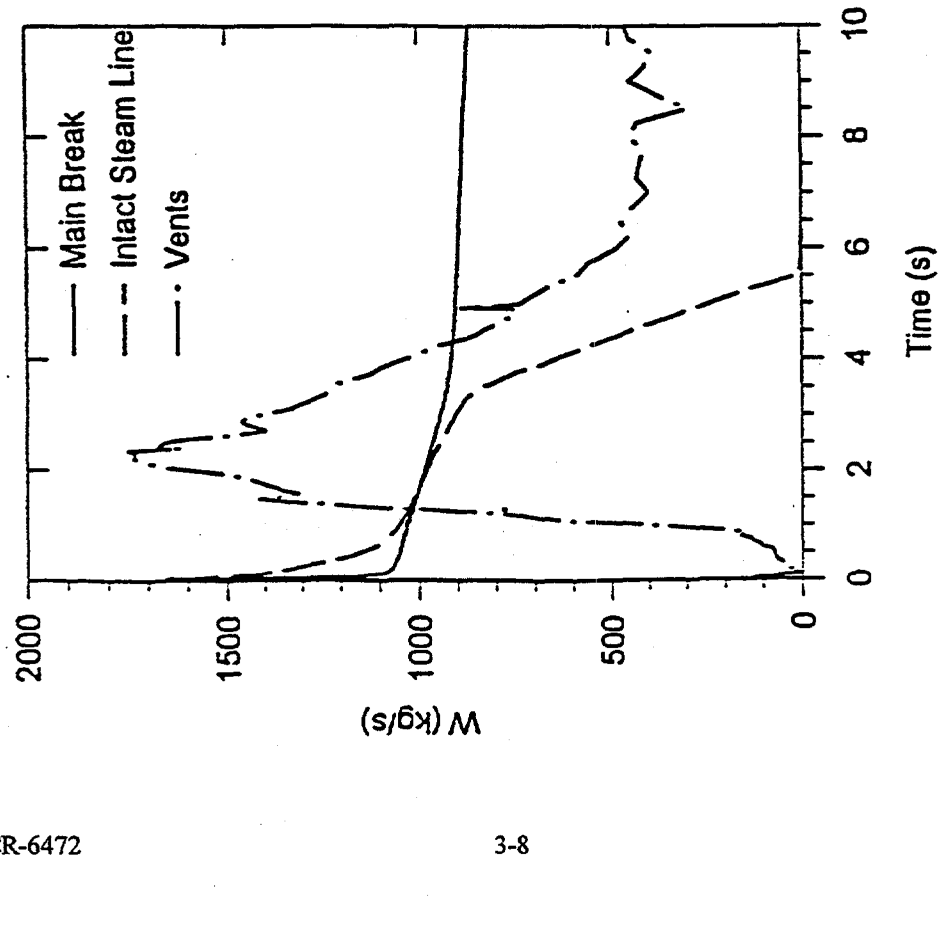


Figure 3.1-3 Break Flows and Vent Flow During a Main Steam Line Break

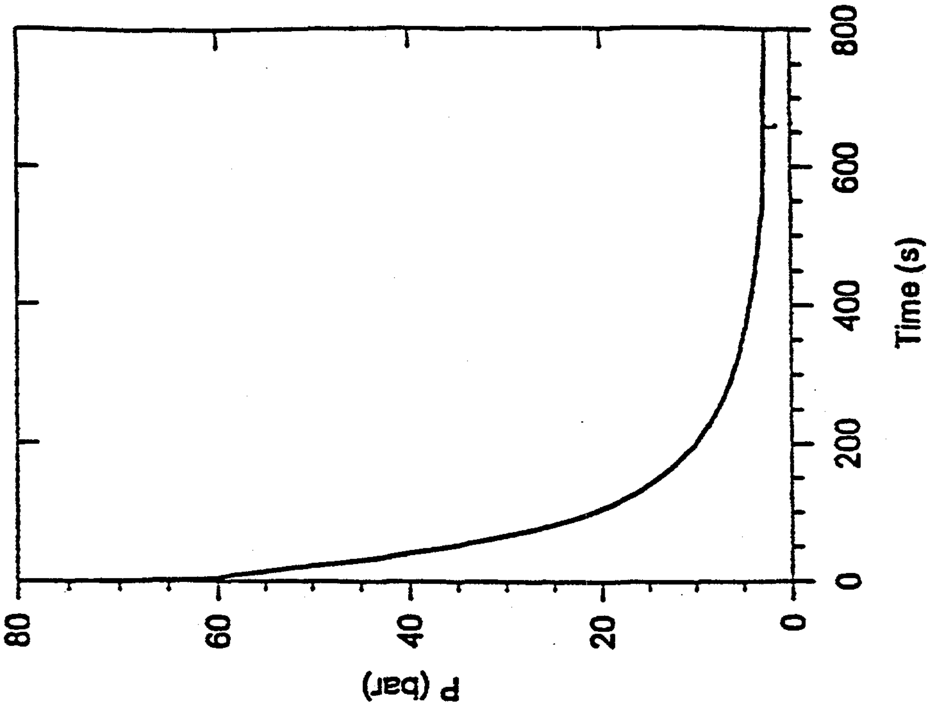


Figure 3.1-4 Steam Dome Pressure During a Main Steam Line Break

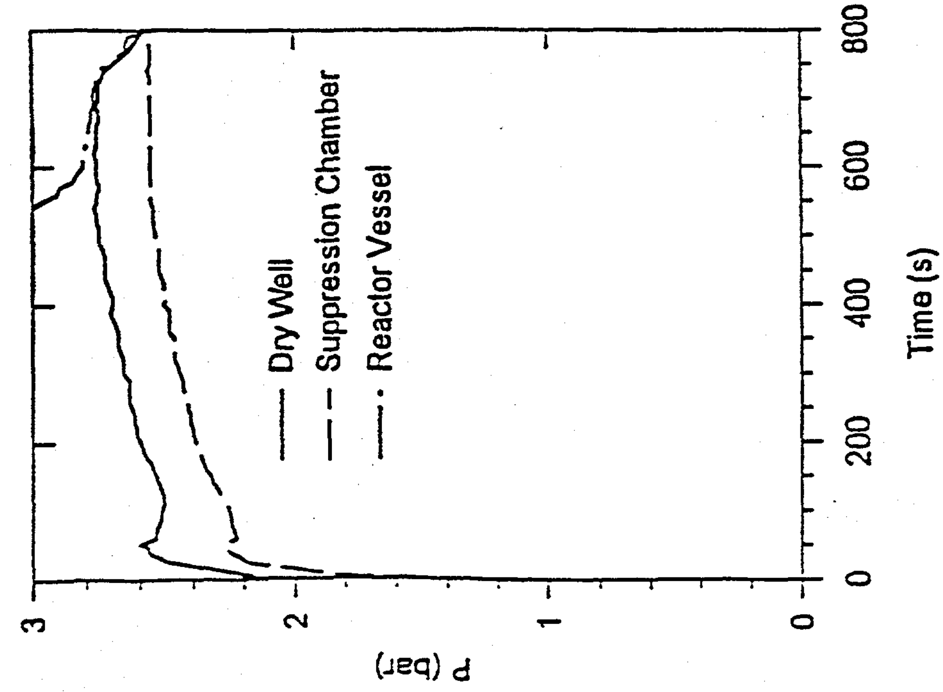


**Figure 3.1-5 Containment Pressures During a Main Steam Line Break**

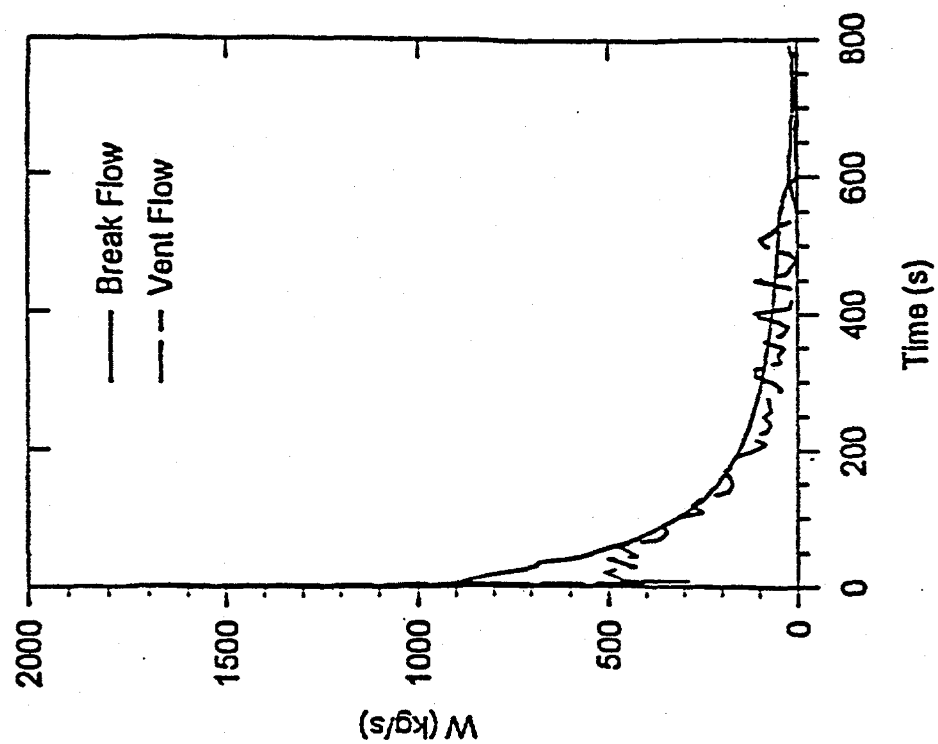


**Figure 3.1-6 Break Flow and Vent Flow During a Main Steam Line Break**

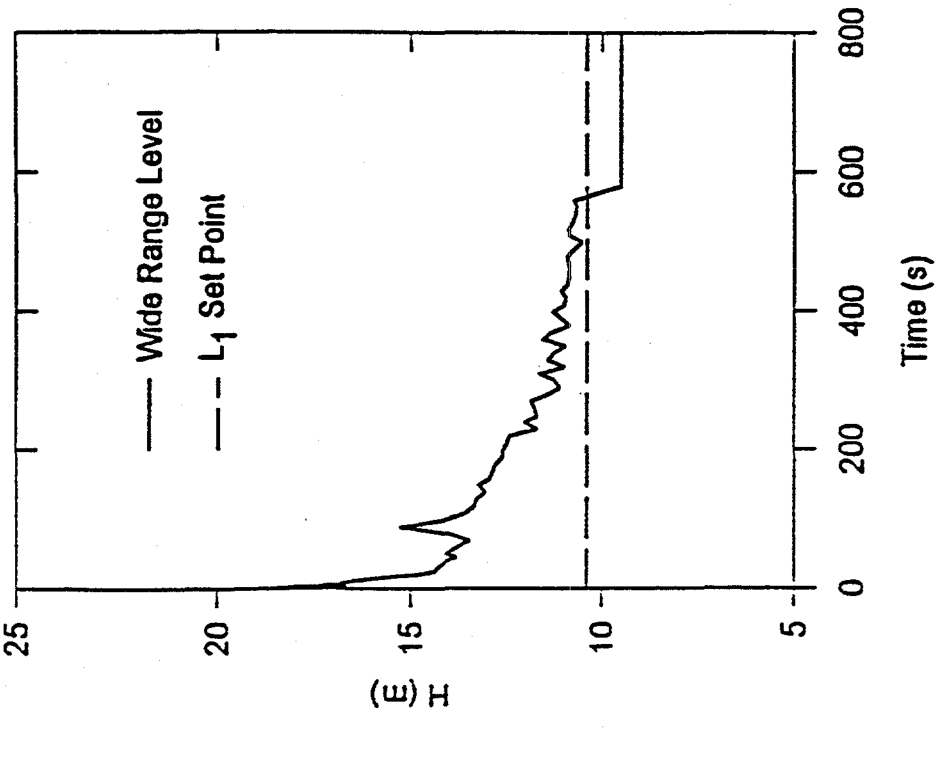


**Figure 3.1-7 Wide Range Downcomer Level During a Main Steam Line Break**

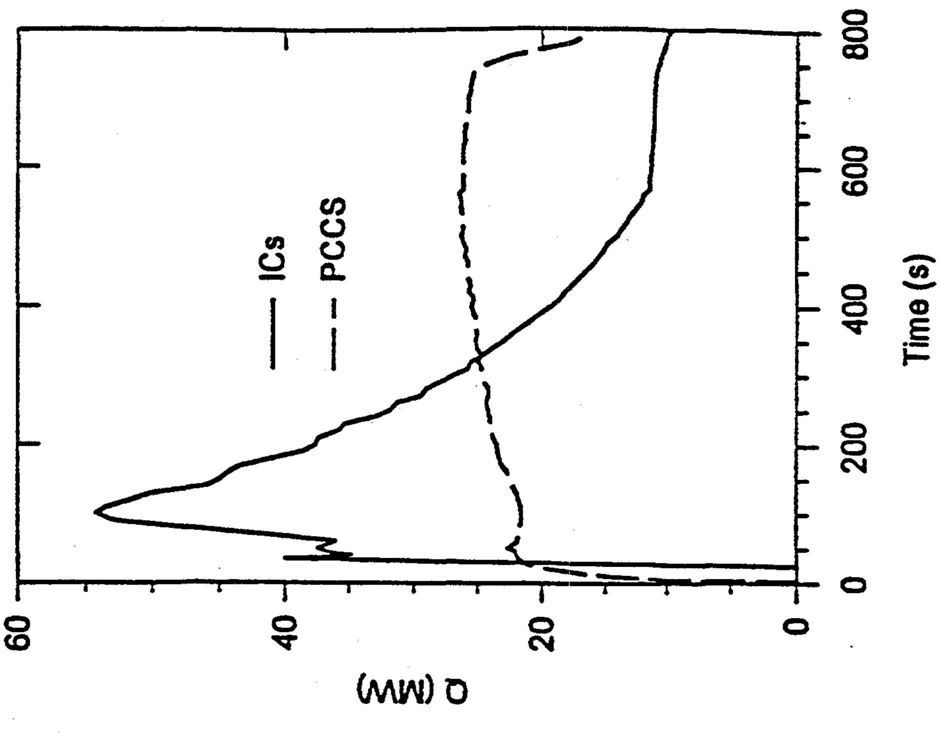


**Figure 3.1-8 Heat Removal via ICs and PCCS During a Main Steam Line Break**

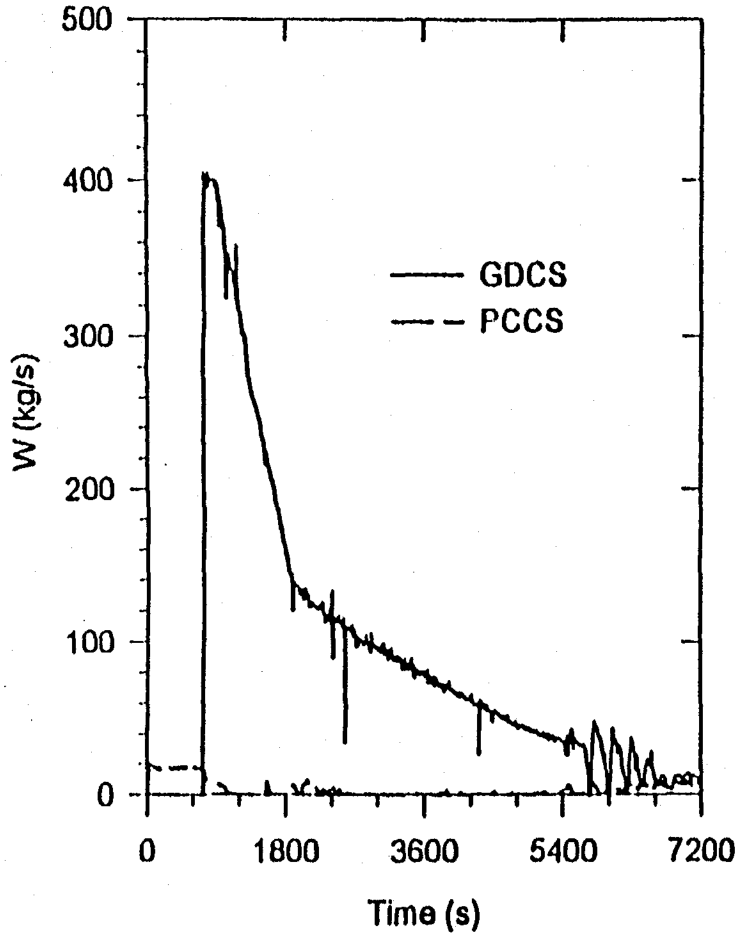


Figure 3.1-9 GDCS and PCCS Flows During a Main Steam Line Break

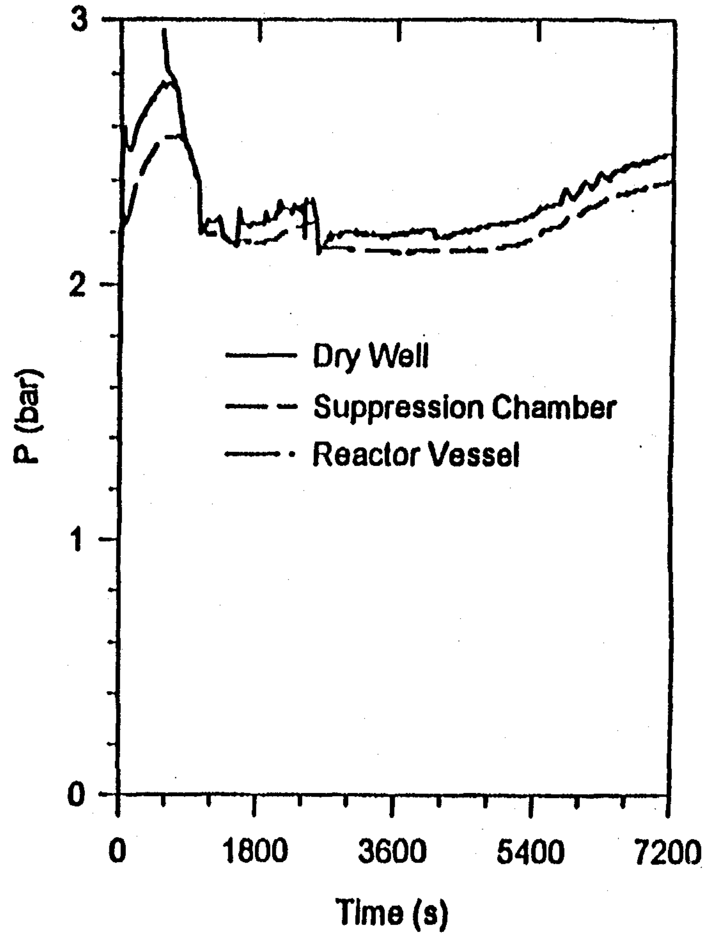


Figure 3.1-10 Containment Pressures During a Main Steam Line Break

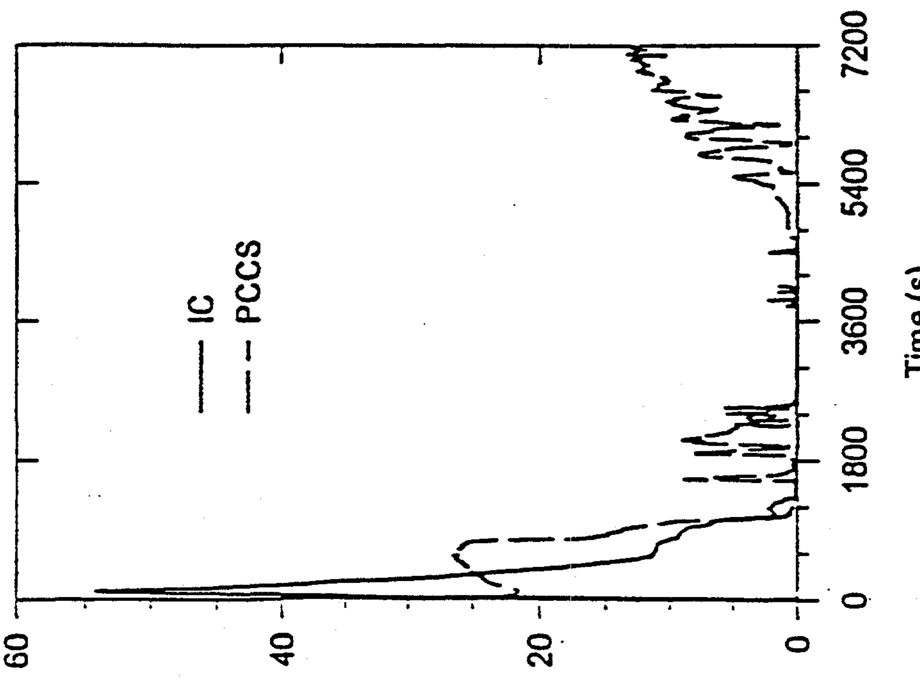


**Figure 3.1-11 Heat Removal via ICs and PCCS During a Main Steam Line Break**

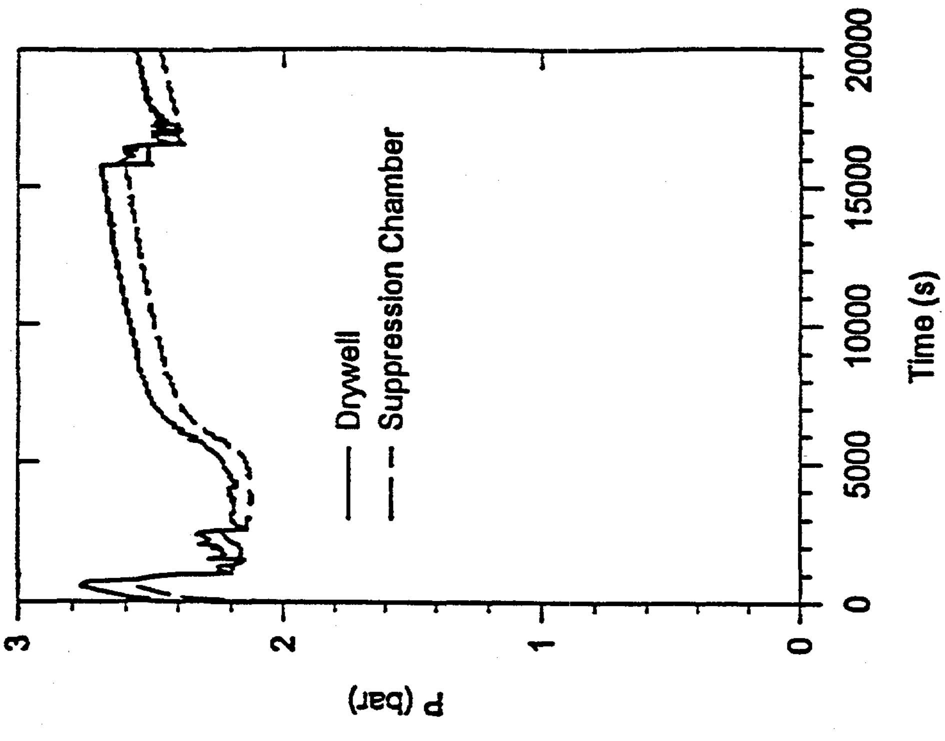


**Figure 3.1-12 Containment Pressures During a Main Steam Line Break**

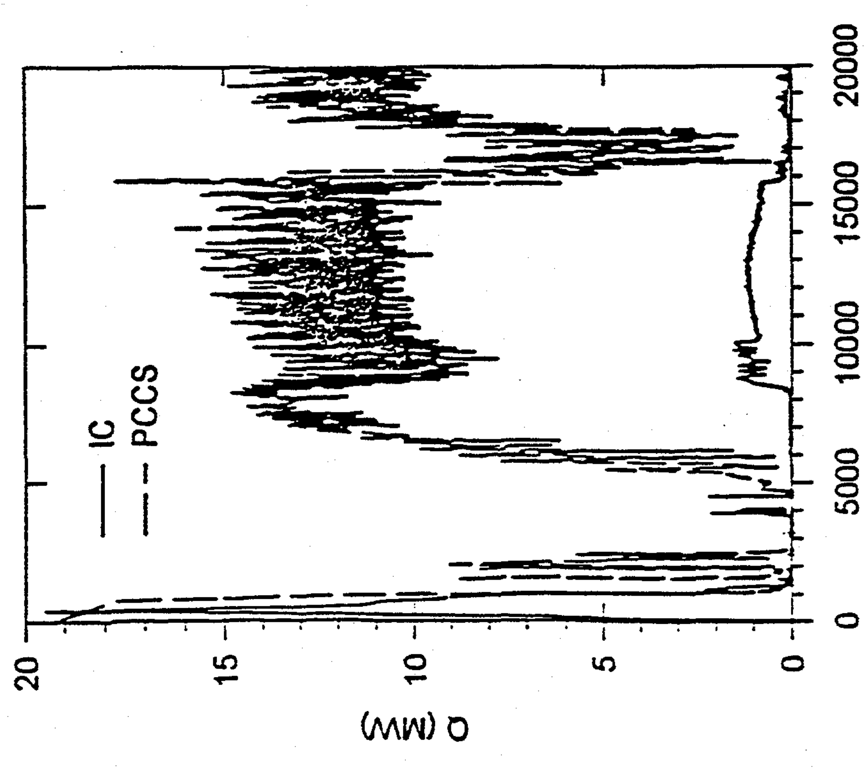


**Figure 3.1-13** Heat Removal via ICs and PCCS During a Main Steam Line Break

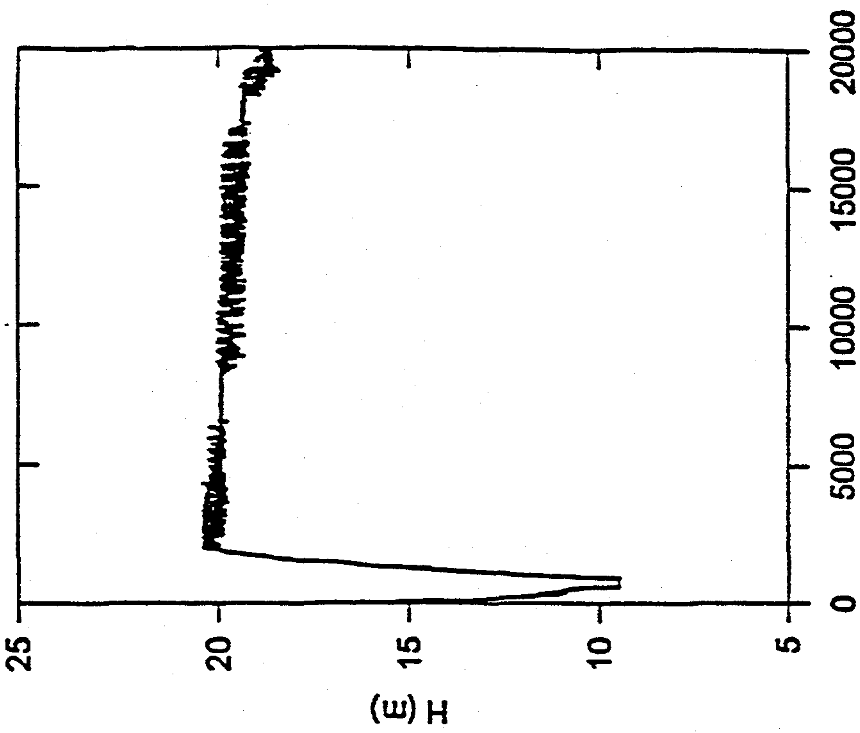


**Figure 3.1-14** Wide Range Downcomer Level During a Main Steam Line Break

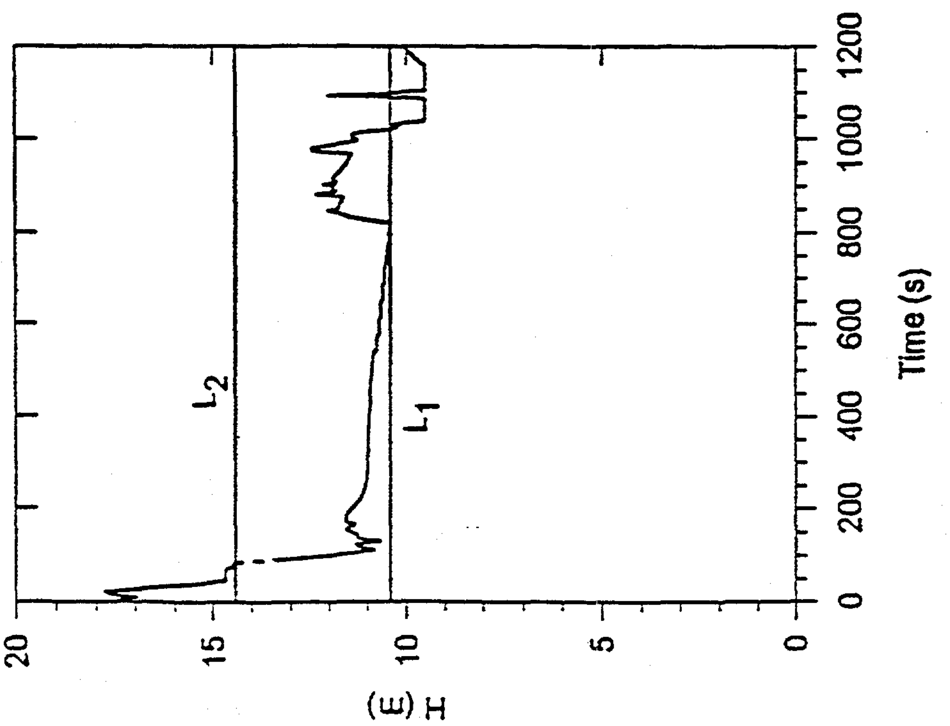


**Figure 3.2-1** **Wide Range Level During a Bottom Drain Line Break**

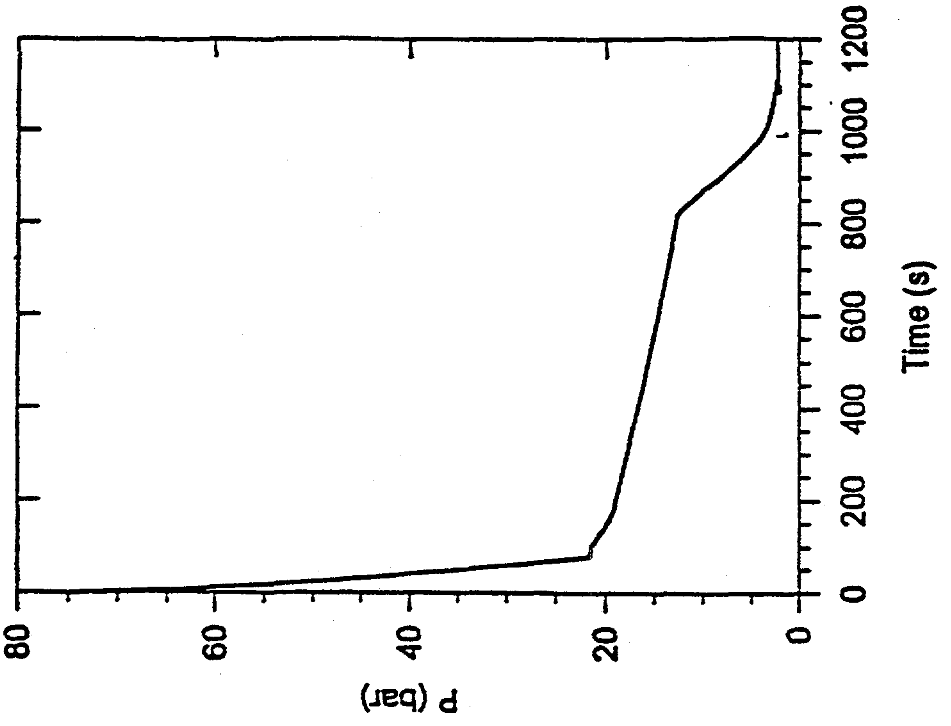


**Figure 3.2-2** **Steam Dome Pressure During a Bottom Drain Line Break**

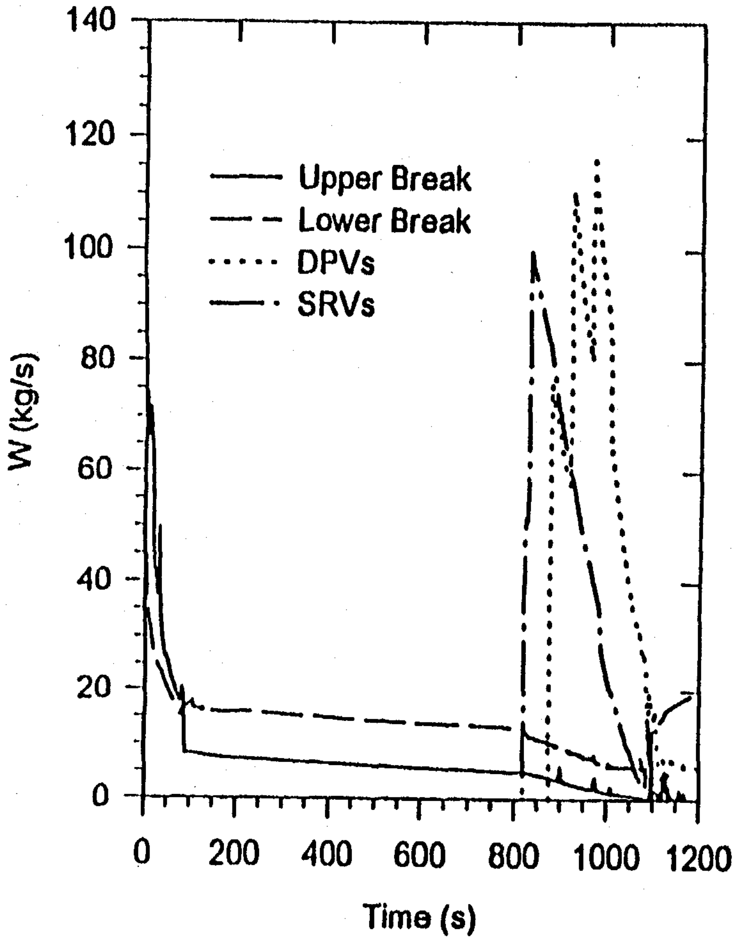


**Figure 3.2-3** **Break Flows and ADS Flows During a Bottom Drain Line Break**

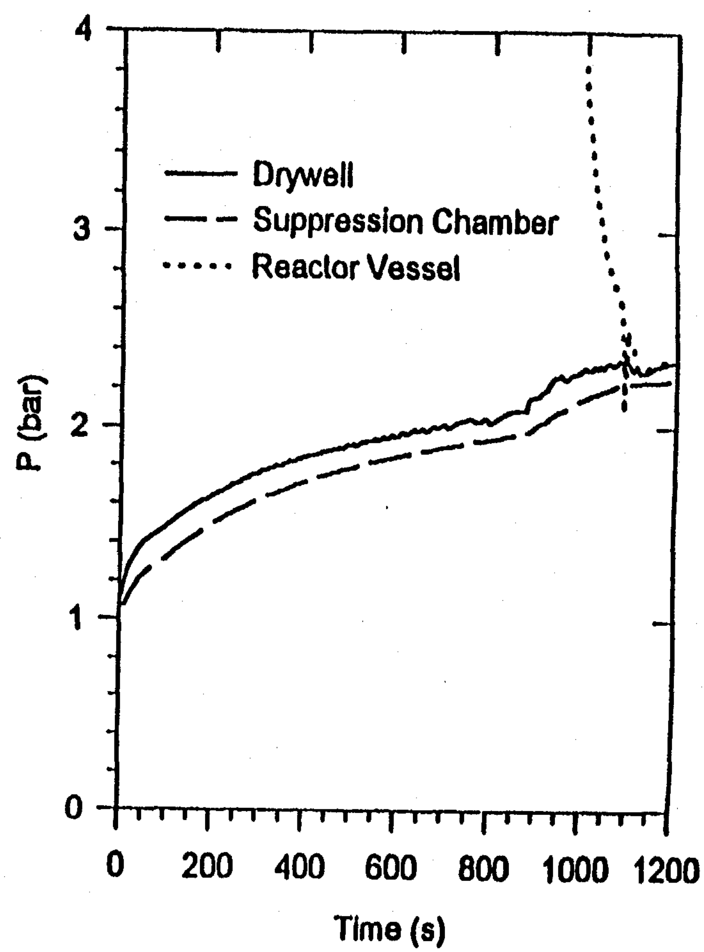


**Figure 3.2-4** **Containment Pressures During a Bottom Drain Line Break**

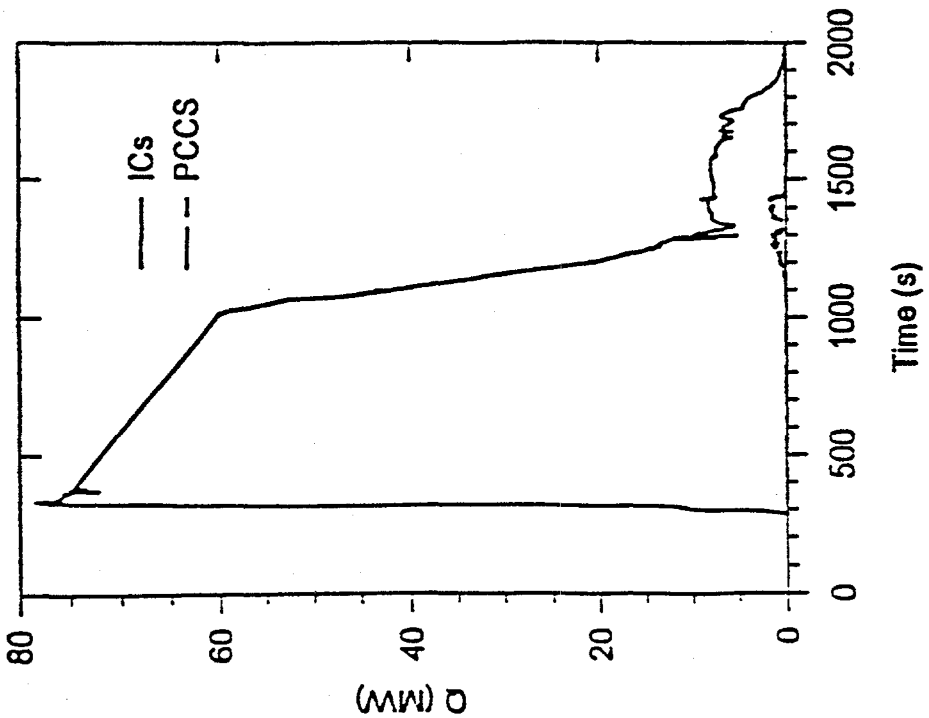


**Figure 3.2-5 Heat Removal via ICs and PCCS During a Bottom Drain Line Break**

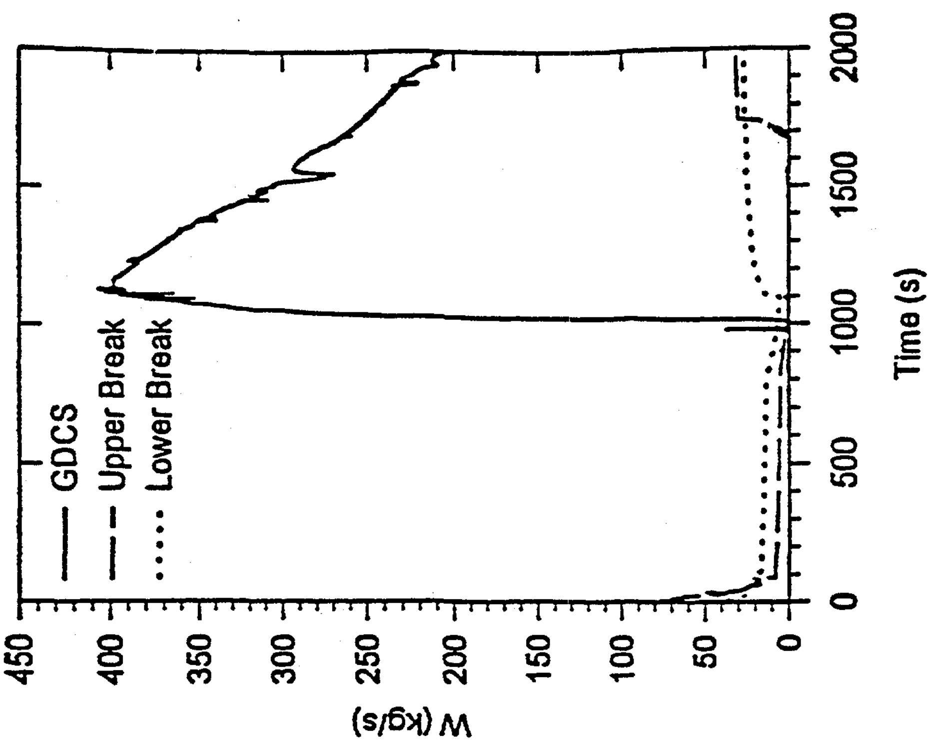


**Figure 3.2-6 GDCS Flow and Break Flows During a Bottom Drain Line Break**

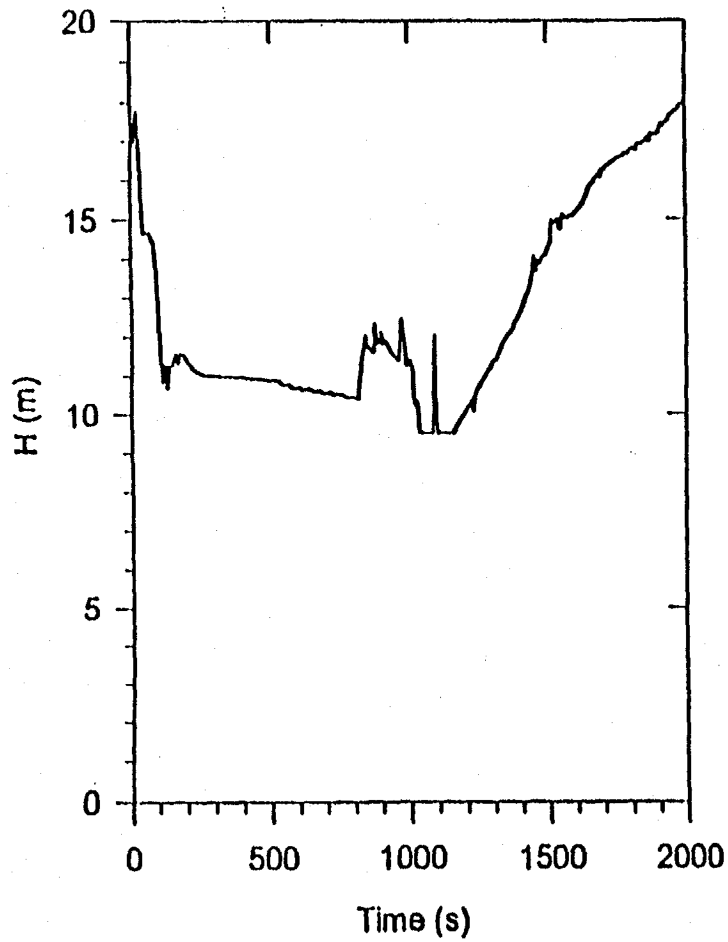


Figure 3.2-7 Wide Range Level During a Bottom Drain Line Break

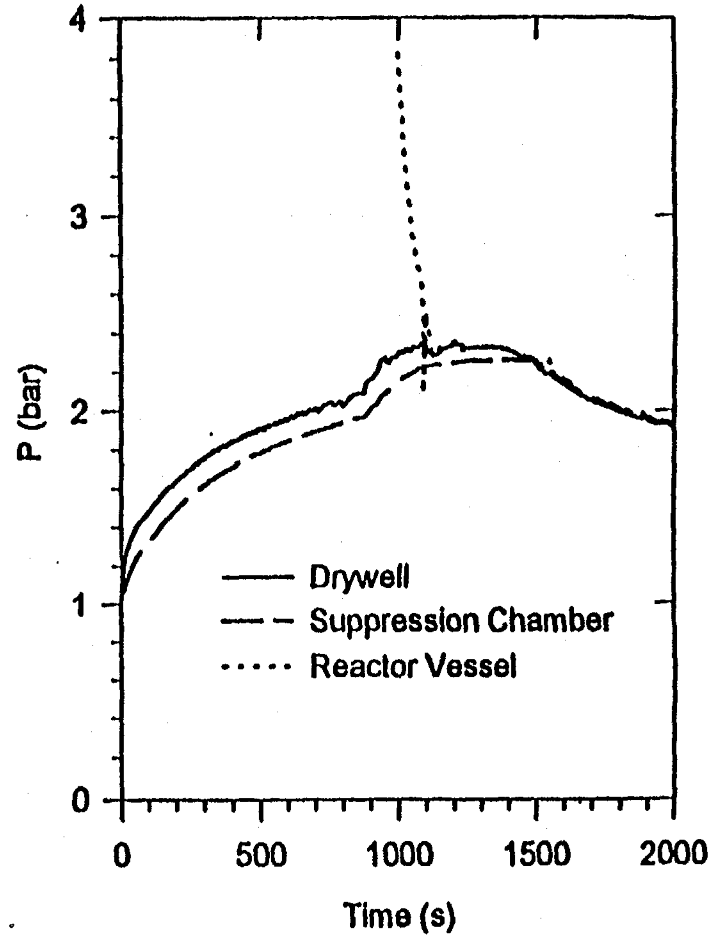


Figure 3.2-8 Containment Pressures During a Bottom Drain Line Break

# 4 PRELIMINARY PIRTS

## 4.1 Assessment Criteria

The ranking of phenomena for a given transient and during a particular time phase must be based on well-defined assessment criteria. These criteria are derived from NRC licensing criteria. The highest-order criteria of Level 1 to Level 4 were already stated in Chapter 2, and are repeated here for completeness:

- Level 1: Protect public health and safety
- Level 2: Limit fission-product release
- Level 3: Limit fuel failure; limit containment breach
- Level 4: Limit peak clad temperature; limit containment pressure and temperature

In this hierarchy, each lower level criterion (higher number) must be defined such that all higher-order criteria are satisfied.

In this work our focus was on the effects of the total system transient on reactor vessel parameters. Therefore, only the peak clad temperature enters as a Level 4 parameter and containment phenomena are considered as they affect reactor vessel parameters.

Using the peak clad temperature limit of Level 4, parameters and conditions must be identified which can serve as further lower-level criteria. The new lower-level criteria must satisfy the condition that whenever they are satisfied, the peak clad temperature limit and all higher-order criteria must also be satisfied. (At the levels of clad temperatures to be encountered here, the other licensing criteria of 10CFR50.46, clad oxidation, hydrogen generation, and maintaining coolable geometry will be satisfied and do not have to be considered any further at this time.)

It has been suggested in the SSAR that no fuel or clad damage will result if a sufficient coolant inventory is maintained in the reactor vessel to keep the core covered at all times. The equalization lines between the downcomer and the suppression pool limit the lowest reactor water level to 1 m above TAF ($L_{0.5}$). To assess the validity of the above claim, a simplified computation was made using the BNL RELAP5 model of the SBWR. With an initial downcomer wide range water level above the core, and with constant pressure in the steam dome, core steaming was caused by constant decay heat, corresponding to the decay heat value at 800 s after scram. The clad temperatures for a peak power channel are shown in Fig. 4.1-1 as function of collapsed downcomer water level. The results show that the clad temperature does not begin to rise until the downcomer level reaches 4.2 m, which is significantly below the elevation of TAF (6.5 m). This suggests that if a sufficient coolant inventory is maintained in the reactor vessel, excessive clad temperatures are not anticipated. Therefore, it was decided to use the vessel inventory as the main assessment criterion of Level 5. Should a scenario be identified in the future, where high peak clad temperatures can occur in spite of sufficient coolant inventory, then some of the rankings may have to be revised. This applies in particular those phenomena, which are connected with core heat transfer.

The primary parameters affecting the vessel inventory during the various time phases were established by the PIRT team as lower-level parameters. The resulting tables of assessment criteria for the three transients and for each of the five time phases are presented in the tables of Appendix B in Tables B.1-1 to 10.

## 4.2 Ranking Procedure

The detailed PIRTs for each transient, and for five time phases each, are given in Appendix B as follows:

| | | |
|---|---|---|
| Tables B.2-1 to 5 | for the | Main Steam Line Break, |
| Tables B.2-6 to 10 | for the | Bottom Drain Line Break, and |
| Tables B.2-11 to 15 | for the | GDCS Line Break. |

These PIRTs are augmented by several tables presented in Appendix C, describing the component definition and geometry, describing the phenomena, and providing ranking rationales.

For the current preliminary PIRTs a qualitative ranking scale was employed, primarily using three ranks 'Low' (L), 'Medium' (M) and 'High' (H). Where a phenomenon was clearly not applicable or physically impossible, the designation 'not applicable' (n/a), was used. After internal ranking by the BNL team the rankings were discussed with outside consultants. In most instances agreement was reached. Where this was not always the case, if the rankings by BNL and the advisors differed and the highest ranking was M, that rank is used in the preliminary PIRTs. Where differences could not be resolved, and the highest rank was H, that rank was used, but this is emphasized in the PIRTs, by marking those cases as $H^*$. Most of the remaining disagreements were due to lack of quantitative information, and could be resolved through future sensitivity studies. Appendix B gives more details on these items.

Following the detailed PIRTs a combined PIRT is given in Table B.2-16, summarizing all three transients and five time phases in one table for ready comparison. To improve readability, all "n/a" rankings have been left blank here.

## 4.3 Discussion of PIRTs

In this section a brief qualitative discussion of the PIRTs will be given for each transient, considering the importance of the various phenomena during each time phase. For details the reader is referred to the tables of Appendix B. The PIRTs are supported by descriptions of the components and their geometries (Table C.1-1) and by definitions of the phenomena (Table C.2-1).

Since the primary energy source is core power, whether as critical power or as decay heat, this item was always ranked high, as the most important source, controlling the transient.

### 4.3.1 Main Steam Line Break

A description of this accident scenario is given in Section 3.1. The assessment criteria for the five time phases are presented in Tables B.1-1 to 5. The detailed PIRTs are found in Tables B.2-1 to 5. The ranking rationales are summarized in Table C.3-1.

During the Pre-Isolation Phase the choked coolant flows, form both ends of the break, and the coasting-down feedwater flow are of most significance, because of their direct impact on the primary assessment criterion, the vessel inventory. The vessel and core coolant flow is still close to the original flow circulation, while the core power generation decreases rapidly following scram. Therefore, all in-vessel flow parameters, including flashing and evaporation, are ranked medium or low. In the containment, nonequilibrium mixing of steam with nitrogen is considered important, owing to its direct effect on the drywell pressure, which could provide the scram signal, anticipated within a few tenths of a second.

The isolation phase is characterized by loss of inventory from choked flow at the break. In addition entrainment of liquid coolant with the break flow is ranked high. The Loss-of-coolant is partly balanced by incoming feedwater flow, but this is coasting down and will only affect the balance of coolant inventory very early in the phase. Nevertheless, the feedwater flow is ranked high. In the core flashing and evaporation will occur. This affects the internal core coolant circulation and the reactor pressure, which in turn affects the break flow and the loss of inventory. Flashing and void distribution in the downcomer and in the chimney affect the buoyancy force and the core flow. All are ranked high. Because of significant level swell, phase separation and flooding in the separator are ranked high, since they control the amount of liquid entrainment in the break flow. The isolation condensers remove a significant amount of energy at this time. Therefore, all heat-transfer and natural-circulation phenomena for the ICs are ranked high. With the return of condensate from the ICs direct contact condensation in the downcomer can be important. With choked flow at the break, containment phenomena have no influence on vessel parameters and all containment phenomena are ranked either low or not applicable.

The Depressurization Phase is only an extension of the previous phase for this accident scenario, since at the time of ADS actuation the reactor vessel pressure is already very close to the drywell pressure (see Fig. 3.1-5). The rankings generally follow those for the preceding time phase, except that subcritical flow at the break and ADS flow phenomena are ranked high now too. As the natural-circulation loop between core and downcomer weakens, the internal flow circulation in the core gains in importance and is ranked high here. With unchoking of coolant flows from the vessel into the containment, coupling between vessel and containment phenomena is established. In particular the coolant flows between vessel and containment will now be affected by the containment pressure. However, most of the loss of inventory has already occurred during the Isolation Phase and the value of the final equilibrium pressure is not of much effect on in-vessel phenomena. Therefore, all containment phenomena affecting containment pressures are ranked medium.

In the GDCS Refill Phase all GDCS related phenomena are ranked high, since refill of the reactor vessel from the GDCS tanks is the main event of this time phase. With the vessel being filled with subcooled coolant, most vessel phenomena are ranked low or not applicable. Only the subcritical flow through the openings connecting the vessel with the containment (break and DPVs), core internal flow circulation and downcomer stored energy are considered of medium importance.

The Long-Term Cooling Phase is dominated by steaming in the core, vapor transport to the PCCS, condensation in the presence of noncondensibles, and return of the condensate to the reactor vessel. Correspondingly, all PCCS-related phenomena are ranked high. Except for core power, all vessel phenomena are ranked low or not applicable. With PCCS operation being very sensitive to the drywell and suppression-chamber pressures, phenomena associated with the amount of noncondensibles in the containment are ranked high, owing to their direct effect on drywell and suppression-chamber pressures. The vacuum breakers are expected to function during this period and the related phenomena are ranked high. The equalization lines would normally not be expected to open during this transient. However, if required, flow through these lines would be very important and is ranked high.

### 4.3.2 Bottom Drain Line Break

A description of this accident scenario is given in Section 3.2. The assessment criteria for the five time phases are presented in Tables B.1-6 to 10. The detailed PIRTs are found in Tables B.2-6 to 10. The ranking rationales are summarized in Table C.3-2.

During the Pre-Isolation Phase all coolant flows into and out of the reactor vessel are rated high. These are the two critical break flows, the coasting-down feedwater flow and the flow to the turbine stop valve or to the turbine bypass valve. The Pre-Isolation Phase can last for about 80 s, and possibly even longer. With the rapid depressurization, level swell is anticipated. Therefore, liquid entrainment at the upper break as well as with the flow to the condenser are a possibility, and are ranked high. Flashing and void distribution is ranked high in all vessel components, which have this phenomenon assigned to them, since it affects the vessel pressure, and thus, the break flows and the coolant inventory. For the same reason evaporation in the core is ranked high. Phase separation in the separator is ranked high, since it affects the amount of liquid entrainment in the break flow. Similarly entrainment in the downcomer is ranked high, since this is the component directly connected to the break. Since high drywell pressure is one of the possible scram signals, all phenomena in the drywell directly affecting its pressure are ranked high.

The isolation phase is characterized by loss of inventory from choked flow at the two breaks, which are ranked high. It is not certain whether the feedwater flow might continue into this phase. However, owing to its direct effect on inventory, it is ranked high. The isolation condensers remove a significant amount of energy at this time and all heat transfer as well as natural circulation for the ICs is ranked high. With the return of condensate form the ICs to the downcomer, direct contact condensation in the downcomer can be important. With the incoming cold condensate from the ICs and possibly also feedwater, fluid mixing and entrainment in the downcomer are ranked high. As long as the flow remains choked flow at the break, containment phenomena have no influence on vessel parameters and all containment phenomena are ranked either low or not applicable.

As the Depressurization Phase begins and the ADS valves open, their coolant flow rate is much higher than the break flows. The flows will be critical initially but must unchoke during this time phase. Therefore, all ADS flows are ranked high and the break flows are ranked medium. With the increasing depressurization rate flashing and void distribution in the vessel is ranked high again, as is phase separation in the separators. The amount of heat removal by the ICs is decreasing during this time phase and the connected phenomena are ranked medium. Toward the end of this phase, as the flows unchoke, the containment pressure can affect reactor parameters. But, this only affects the end of this phase and the absolute value of the final vessel and drywell equilibrium pressure is not of great significance for vessel parameters. Therefore, all containment phenomena affecting drywell and vessel pressure are ranked medium.

In the GDCS Refill Phase all GDCS related phenomena are ranked high since refill of the reactor vessel from the GDCS tanks is the main event of this time phase. With the vessel being filled with subcooled coolant, most vessel phenomena are ranked low or not applicable. Only the subcritical flow through the openings connecting the vessel with the containment (break and DPVs), are considered of medium importance. As the vessel is filled above the elevation of the RWCU/SDC break elevation, coolant spilling occurs and this is ranked high. Aside form the GDCS most containment phenomena are ranked low, except water accumulation in the lower drywell, which is ranked medium since it continuously receives coolant directly from the two breaks.

The Long-Term Cooling Phase is essentially identical for all LOCA transients. It is dominated by steaming in the core, vapor transport to the PCCS, condensation in the presence of noncondensibles and return of the condensate to the reactor vessel. Correspondingly, all PCCS related phenomena are ranked high. Except for core power, most vessel phenomena are ranked low or not applicable. The are only two exceptions: the flow through the bottom break will persist until the liquid coolant levels in the vessel and in the drywell have been equalized, and it was ranked medium; spilling from the upper break will last until the reactor coolant level decreases to that elevation, and it was ranked high. With PCCS operation being very sensitive to the drywell and suppression-chamber pressures, phenomena associated with the amount of noncondensibles in the containment are ranked high, due to their direct effect on drywell and suppression-chamber pressures. The vacuum breakers are expected to function during this period and the related phenomena are ranked high. The equalization lines might open during this transient, and if required, flow through these lines would be very important. It is ranked high.

### 4.3.3 GDCS Line Break

The description of this accident scenario is given in Section 3.3. The assessment criteria for the five time phases are included in Tables B.1-6 to 10. The detailed PIRTs are found in Tables B.2-11 to 15. The ranking rationales are summarized in Table C.3-3.

The rankings for the GDCS line break are almost all identical to the bottom drain line break. The exceptions arise from the lack of a second break and from the different break locations. The only break here is connected to the downcomer, like the second (upper) break of the BDLB scenario, but at a lower elevation.

Correspondingly, the rankings of the main break here are identical to those for the second break in the BDLB scenario. Critical break flow and entrainment are ranked high during the Pre-Isolation and Isolation Phases, and medium during the depressurization phase, since the ADS flow then dominates. During the GDCS Refill and Long-Term Cooling Phases spilling of coolant out of the break is ranked high. In fact, it is even more important here due to the much lower elevation of the break. During the Depressurization Phase lower plenum flashing and void distribution are ranked medium rather than high in this scenario, since the lower plenum here is not directly connected to a break. Owing to the absence of a bottom break, drywell water accumulation is ranked medium rather than high during the Long-Term Cooling Phase.

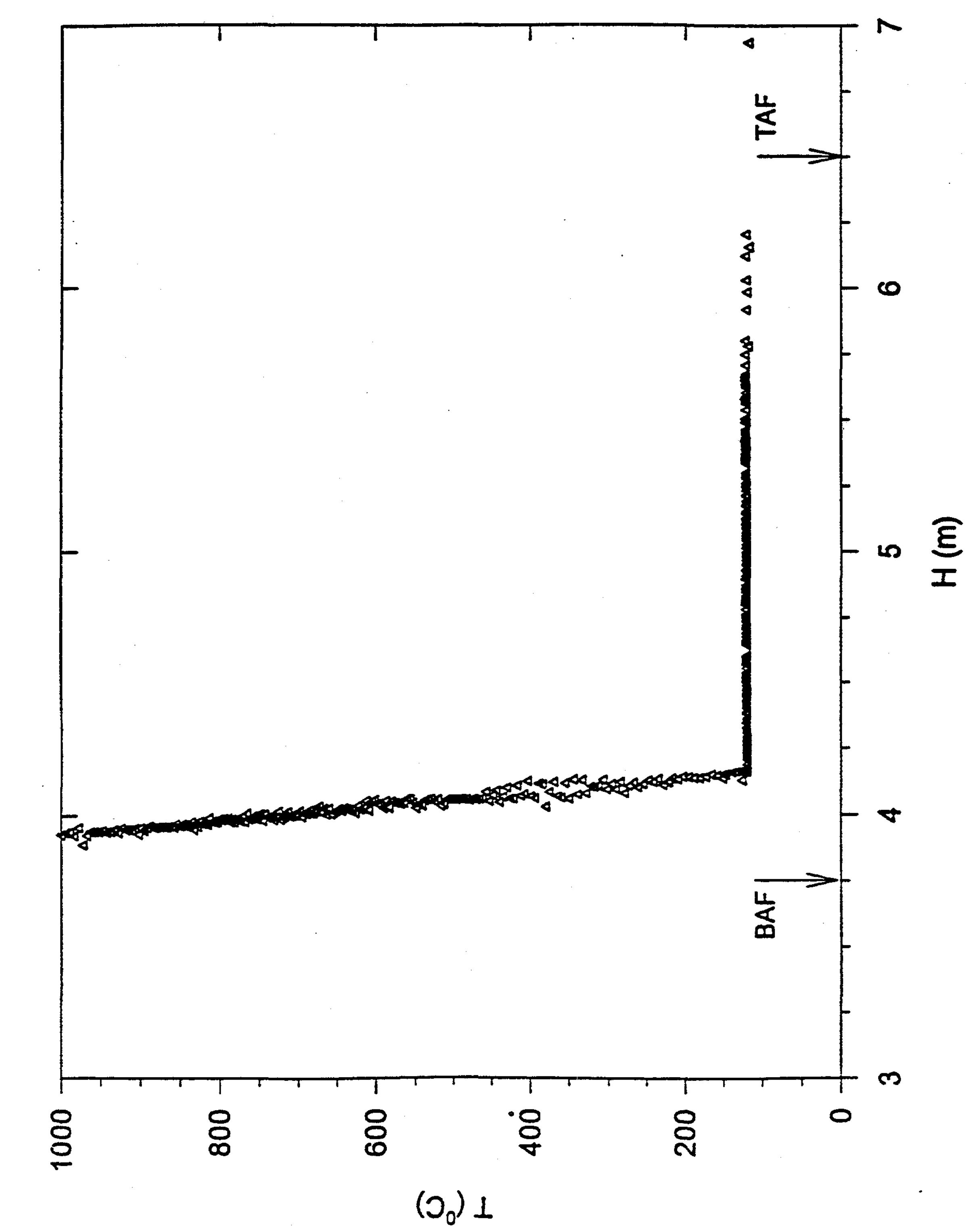


**Figure 4.1-1 Clad Temperature as a Function of Wide Range Downcomer Level**

# 5 REVIEW OF PIRT RESULTS AND INITIAL VALIDATION

In this chapter a synopsis of the PIRT results of Chapter 4 is presented, ordered by time phase (Section 5.1), followed by results of some initial PIRT validation efforts (Section 5.2).

## 5.1 Summary of PIRT Findings by Time Phase

The PIRTs for all three LOCA scenarios are shown summarized in Table 5.1-1. For improved legibility all "not-applicable" (n/a) entries were left blank. (Since there are no blank rankings in the PIRTs, all blanks here indicate an "n/a" ranking.) As in Chapter 4, core power is always ranked high, as the main source input driving all transients during all time phases. It will not be mentioned in the individual segments.

Pre-Isolation Phase

All break flows are ranked high in all three transients, because of their direct effect on the reactor-coolant inventory. Break flow entrainment also is ranked high, wherever it is expected to occur. Intact-steam-line flow is ranked high for the MSLB scenario, where it represents a break flow. It is also ranked high for the BDLB and GDLB scenarios, together with entrainment and flow at the turbine bypass or turbine stop valve, since the ensuant loss-of-coolant to the condenser represents the most significant loss of inventory during this time phase. The feedwater flow, providing some coolant inventory, is always ranked high in this time phase.

Flashing and void distribution in all vessel components and evaporation in the core are ranked high for the BDLB and GDLB scenarios, owing to their effect on the vessel pressure, and thus, on the loss of inventory. For the MSLB this time phase is very short and the above phenomena are ranked medium or low. Phase separation in the separators and entrainment in the downcomer are ranked high in the BDLB and GDLB scenarios, owing to their effect on break-flow entrainment.

In the containment all phenomena affecting the drywell pressure, a possible scram signal are ranked high for the BDLB and GDLB scenarios. For the MSLB scenario the time till the pressure reaches the scram signal level (0.14 bar) is only a fraction of a second, and only nonequilibrium mixing of $N_2$ and steam is ranked high. It is anticipated that the other phenomena, like condensation and heat transfer to the walls and structures, will not have a sufficient effect during such a short time.

Isolation Phase

All break flows and entrainment at the break as well as any remaining feedwater flow are ranked high in this phase, owing to their direct effect on the coolant inventory. For the MSLB scenario, this is the time phase in which most of the depressurization occurs. Correspondingly, flashing and void distribution in all vessel components and evaporation in the core are ranked high, owing to their effect on the vessel pressure, and thus, on the loss of inventory. Because of their effect on evaporation in the core, the release of sensible heat from the fuel and fuel to coolant heat transfer are also rated high for this scenario. Also ranked high for the MSLB scenario are phase separation and flooding in the separators, because of their effect on liquid entrainment in the break flows. In the small break scenarios of BDLB and GDLB the depressurization rate is reduced during this time phase and the above phenomena are ranked medium or low.

The isolation condensers remove a significant portion of the decay heat during this time period and all thermal and flow performance phenomena are ranked high in all three transients. With cold condensate returning from the ICs and with some feedwater possibly still entering, fluid mixing, direct contact condensation, and entrainment in the downcomer are all ranked high for all three transients.

Depressurization Phase

With the ADS valves opening, the main coolant flow leaving the vessel will now pass through these valves and their flow is ranked high in all three scenarios. The break flow is only ranked high in the MSLB scenario, since its break flow area is comparable to the ADS flow areas. Entrainment at the DPVs is ranked high in the BDLB and GDLB scenarios, because of its effect on the reactor- coolant inventory. (In the MSLB the pressures are already almost equalized at the beginning of this time phase and entrainment is not expected to occur any longer.)

In particular in the BDLB and GDLB scenarios, the depressurization rate increases with opening of the ADS valves. Therefore, flashing and void distribution in all vessel components are ranked high for all three scenarios, except for the lower-plenum void distribution, which is ranked high only in the BDLB scenario, because one break is directly connected to this component. Evaporation in the core, fuel-to-coolant heat transfer, and internal flow circulation in the core are ranked high in the MSLB scenario, because of their effect on the vessel pressure, and thus, on the loss of inventory. Phase separation in the separators is ranked high in all three scenarios, because of its effect on break flow and ADS flow entrainment.

Heat removal by the ICs is ranked high in the MSLB scenario, because of its effect vessel pressure and coolant inventory. Correspondingly, entrainment in the downcomer is ranked high for this scenario.

GDCS Refill Phase

All GDCS flow phenomena are ranked high, since vessel coolant refill is the main function of this time phase. Also ranked high is the spilling of coolant from the broken RWCU/SDC line in the BDLB scenario and from the broken GDCS line in the GDLB scenario.

Long-Term Cooling

Since PCCS operation is crucial in this time phase, all PCCS-related phenomena are ranked high. The PCCS operation is sensitive to pressure difference between the drywell and suppression chamber, which is readily affected by the distribution of noncondensibles. Therefore, the non-condensibles amount and distribution in the drywell as well as the noncondensibles amount in the suppression chamber are ranked high in all three scenarios.

Vacuum-breaker and equalization-line-flow phenomena are also ranked high for all three transients. Drywell water accumulation is ranked high in the BDLB scenario, owing to the bottom break discharging directly into the lower drywell.

Spilling of coolant early in this time phase from the broken RWCU/SDC line in the BDLB scenario and from the broken GDCS line in the GDLB scenario is ranked high.

## 5.2 Initial PIRT Validation Efforts

PIRTs and similar methods, like HAZOP and FMECA studies, traditionally have relied on expert judgement. The procedure of PIRT development used here, the internal BNL team, the available background information and the review by outside consultants are described in Chapter 2. The current rankings constitute expert judgement. Their value can be enhanced significantly by further validation efforts.

Such a PIRT validation process will have to use different methods, depending on the individual needs for a specific phenomenon. Typical available methods are:

- order-of-magnitude estimates, for instance of the relevant time constants of components or subassemblies,
- for some items special simplified models could effectively be applied to quantify the desired effect,
- specially tailored RELAP runs are an available option, where desired and practical,
- scaling methodology may be applied in cases where estimates of the order of magnitude of specific terms in the conservation equations can determine their impact,
- review of existing or new experimental data may assist in the evaluation of the importance of some phenomena.

The PIRTs of Chapter 4 contain a total of 1,230 rankings. To remain effective, not all can be reviewed, and any meaningful validation effort must be restricted to a subset of the phenomena. To some extent expert judgement will be the guidance where to extend future validation efforts.

Primary candidates for review are obviously the items currently ranked $H^*$, i.e., items where differences in judgement were noted, with at least one ranking being H.

Next, a systematic look at all H and M rankings should identify further candidates for validation. Once a phenomenon has clearly been accepted as ranking high in some time phase, little can be gained by extending validation efforts to how it should be ranked in other phases. Thus, secondary candidates would be phenomena, which are ranked H in only one or two time phases, and also phenomena currently only ranked M, but possibly deserving a higher rank, subject to review.

For some phenomena validation will clearly not be required. For example, core power is traditionally ranked high as the main energy source. Similarly, choked break flow is the main contributor to loss of inventory during the first two phases of the transients and it is consistently ranked high.

To date very little validation has been performed. One example of a validation effort is the simplified analysis of peak clad temperatures with gradual reduction of downcomer water level, which is presented in Section 4.1, where it was used to support the choice of coolant inventory as an assessment criterion.

As a typical example of rankings to be revised, the fuel sensible heat during the Pre-Isolation Phase in an MSLB scenario is ranked M, with the rationale that the phase duration of 5 s is short with respect to the fuel time constant (Ranking Rationale RM-16). The MSLB RELAP simulations, used for the scenario descriptions of Chapter 3, only became available after the MSLB PIRT was completed. Based on these results, a numerical estimate of the fuel time constant showed it to be about 10 s. Figure 5.2-1 shows typical fuel and clad temperatures for this time period. Considering the rapid initial fuel temperature gradients of about 40°C/s, estimates indicated that the fuel sensible heat release should be significant for the pre-isolation phase. Computing this energy release and comparing it to the decay heat, as shown in Fig. 5.2-2, it became obvious, that the fuel sensible energy exceeds the decay heat during the Pre-Isolation Phase, and must be ranked H for this phase.

The stored-energy release rankings for various internal structures, other than the fuel, were almost always ranked medium or low during the PIRT sessions. The total thermal capacitance of the reactor vessel and internal structures is 390 MJ/°C (Rohatgi et al., 1994). All solid structures cool down during the LOCA transient from the original saturation temperature of 285°C to a final temperature level of about 130°C. The total associated energy release is then about $6*10^{10}$ J, which corresponds to about 30 full-power seconds. For comparison, the decay-heat release during the pre-isolation and isolation phases amounts to 17 full-power seconds. Thus, the energy release from solid structures would appear to be important in some phases of the transient, and order-of-magnitude estimates for the various components should be made, comparing the release with the decay heat during the respective time periods. The rankings should then be revised correspondingly.

## Table 5.1-1 Combined PIRT for MSLB, BDLB and GDLB Scenarios

| Component Description | Phenomenon Description | Main Steam Line Break | | | | | Bottom Drain Line Break | | | | | GDCS Line Break | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre-Isolation | Isolation | Depressurization | GDCS Refill | Long Term Cooling | Pre-Isolation | Isolation | Depressurization | GDCS Refill | Long Term Cooling | Pre-Isolation | Isolation | Depressurization | GDCS Refill | Long Term Cooling |
| **Reactor** | | | | | | | | | | | | | | | | |
| Break No 1 | Critical Flow | H | H | H | | | H | H | M | | | H | H | M | | |
| | Subcritical Flow | | | H | M | L | | | M | M | M | | | M | M | L |
| | Entrainment | L | H | L | | | L | L | L | L | | H | H | M | | |
| | Spilling | | | | | | | | | | | | | | H | H |
| Break No 2 | Critical Flow | | | | | | H | H | M | | | | | | | |
| | Subcritical Flow | | | | | | | | M | M | L | | | | | |
| | Entrainment | | | | | | H | H | M | | | | | | | |
| | Spilling | | | | | | | | | H | H | | | | | |
| Intact Steam Line | Critical Flow | H | | | | | | | | | | | | | | |
| | Subcritical Flow | | | | | | H | | | | | H | | | | |
| | Entrainment | | | | | | H | | | | | H | | | | |
| | Inventory Depletion | L | | | | | | | | | | | | | | |
| DPV (ADS) | Critical Flow | | | H | | | | | H | | | | | H | | |
| | Subcritical Flow | | | H | M | L | | | H | M | L | | | H | M | L |
| | Entrainment | | | L | | | | | H* | | | | | H* | | |
| | Spilling | | | | L | | | | | L | | | | | L | |
| SRV (ADS) | Critical Flow | | | H | | | | | H | | | | | H | | |
| | Subcritical Flow | | | H | L | | | | M | L | | | | M | L | |
| | Entrainment | | | L | | | | | L | | | | | L | | |
| Turbine Stop Valve | Subcritical Flow | | | | | | H | | | | | H | | | | |
| Turbine Bypass Flow Valve | Critical Flow | | | | | | H | | | | | H | | | | |
| Feedwater Flow; CRD Flow | Flow/BC | H | H | | | | H | H | | | | H | H | | | |
| Core | Parallel Channel Flow Distribution | L | M | M | L | L | M | M | M | L | 'L | M | M | M | L | L |
| | Pressure Drop 2-Phase | L | M | M | L | L | L | L | M | L | L | L | L | M | L | L |
| | Flashing | M | H | H | L | L | H | M | H* | L | L | H | M | H* | L | L |
| | Evaporation | L | H | H | L | L | H* | L | L | L | L | H* | L | L | L | L |
| | Void Distribution | M | H | H | L | L | H* | M | H* | L | L | H* | M | H* | L | L |
| | Core Power: Critical/Decay | H | H | H | H | H | H | H | H | H | H | H | H | H | H | H |
| | Heat Transfer Coefficient | L | H | H | L | L | M | L | L | L | L | M | L | L | L | L |
| | Fuel Stored Energy | M | H | L | L | L | M | M | M | L | L | M | M | M | L | L |
| | Structure Stored Energy | L | M | L | L | L | L | L | M | L | L | L | L | M | L | L |
| | Internal Flow Circulation | | M | H | M | L | L | L | M | L | L | L | L | M | L | L |

Table 5.1-1 (continued)

| Component Description | Phenomenon Description | Main Steam Line Break | | | | | Bottom Drain Line Break | | | | | GDCS Line Break | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre-Isolation | Isolation | Depressurization | GDCS Refill | Long Term Cooling | Pre-Isolation | Isolation | Depressurization | GDCS Refill | Long Term Cooling | Pre-Isolation | Isolation | Depressurization | GDCS Refill | Long Term Cooling |
| Chimney | Flashing | M | H | H | L | L | H* | M | H* | L | L | H* | M | H* | L | L |
| | Level/Void Distribution | M | H | H | L | L | H* | M | H* | L | L | H* | M | H* | L | L |
| | Structure Stored Energy | L | M | L | L | L | L | L | M | L | L | L | L | M | L | L |
| Separator/Dryer | Phase Separation | M | H | H | L | L | H* | L | H* | L | L | H* | L | H* | L | L |
| | Friction - Two Phase | L | L | L | L | L | L | L | M | L | L | L | L | M | L | L |
| | Structure Stored Energy | L | M | L | L | L | L | L | M | L | L | L | L | M | L | L |
| | Flooding | L | H | L | | | M | L | M | | | M | L | M | | |
| Downcomer | Fluid Mixing | L | M | L | L | L | M | H* | M | L | L | M | H* | M | L | L |
| | Flashing | M | H | H | L | L | H | M | H* | L | L | H | M | H* | L | L |
| | Level/Void Distribution | M | H | H | L | L | H | M | H* | L | L | H | M | H* | L | L |
| | Direct Contact Condensation | L | H | M | L | L | M | H* | M | L | L | M | H* | M | L | L |
| | Structure Stored Energy | L | M | M | M | L | M | L | M | L | L | M | L | M | L | L |
| | Entrainment | L | H | H | L | L | H | H | M | L | L | H | H | M | L | L |
| Lower Plenum | Fluid Mixing | L | M | L | L | L | L | L | M | L | L | L | L | M | L | L |
| | Flashing | L | H | H | L | L | H | M | H* | L | L | H | M | M | L | L |
| | Structure Stored Energy | L | M | M | L | L | L | L | M | L | L | L | L | M | L | L |
| | Void Distribution | L | H* | L | L | L | H | M | H* | L | L | H | M | M | L | L |
| Isolation Condenser | Condensation inside tubes | | H | H | L | L | | H | M | L | L | | H | M | L | L |
| | Pool side heat transfer | | H | H | L | L | | H* | M | L | L | | H* | M | L | L |
| | Natural circulation | | H | H | L | L | | H | M | L | L | | H | M | L | L |
| | Degradation of condensation due to NCs | | M | M | L | L | | M | L | L | L | | M | L | L | L |

Table 5.1-1 (continued)

| Component Description | Phenomenon Description | Main Steam Line Break: Pre-Isolation | Main Steam Line Break: Isolation | Main Steam Line Break: Depressurization | Main Steam Line Break: GDCS Refill | Main Steam Line Break: Long Term Cooling | Bottom Drain Line Break: Pre-Isolation | Bottom Drain Line Break: Isolation | Bottom Drain Line Break: Depressurization | Bottom Drain Line Break: GDCS Refill | Bottom Drain Line Break: Long Term Cooling | GDCS Line Break: Pre-Isolation | GDCS Line Break: Isolation | GDCS Line Break: Depressurization | GDCS Line Break: GDCS Refill | GDCS Line Break: Long Term Cooling |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Containment** | | | | | | | | | | | | | | | | |
| Dry Well | Non-Condensibles Amount | M | L | M | L | H | H | L | M | L | H | H | L | M | L | H |
| | Non-Condensibles Distribution | M | L | M | L | H | H | L | M | L | H | H | L | M | L | H |
| | Condensation on wall with NC present | M | L | L | L | M | H | L | M | L | M | H | L | M | L | M |
| | Water Accumulation | L | L | L | L | H | L | L | M | M | H | L | L | M | M | M |
| | Transient Conduction in Structures | L | L | M | L | L | H | L | M | L | L | H | L | M | L | L |
| | Non-Equilibrium Mixing of N2 & Steam | H | L | M | | | H | L | L | | | H | L | L | | |
| | Surface Condensation (on Liquid Surfaces) | M | L | M | L | M | H | L | M | L | M | H | L | M | L | M |
| Horizontal Vent | Horizontal Vent Clearing | L | L | M | | | L | L | M | | | L | L | M | | |
| Suppression Pool | Suppression Pool Heat & MassTransfer | L | L | M | L | L | L | L | M | L | L | L | L | M | L | L |
| | Condensation for SRV Sparger flow | | | M | L | L | | | M | L | L | | | M | L | L |
| | Condensation with NC for PCC purge line flow | L | L | M | L | L | L | L | M | L | L | L | L | M | L | L |
| | Temperature Stratification | L | L | M | L | L | L | L | M | L | L | L | L | M | L | L |
| Suppression Chamber | Non-Condensibles Amount | L | L | M | L | H | L | L | M | L | H | L | L | M | L | H |
| | Non-Condensibles Distribution | L | L | L | L | M | L | L | L | L | M | L | L | L | L | M |
| | Condensation on wall with NC present | L | L | L | L | L | L | L | L | L | L | L | L | L | L | L |
| | Heat and Mass transfer at pool surface | L | L | L | L | L | L | L | L | L | L | L | L | L | L | L |
| GDCS | Friction/Form Losses | | | | H | L | | | | H | L | | | | H | L |
| | Hydrostatic Head | | | | H | L | | | | H | L | | | | H | L |
| | Pressure Difference from GDCS Tanks to RPV | | | | H | L | | | | H | L | | | | H | L |
| PCCS Heat Exchanger | Condensation inside tubes | L | L | M | L | H | L | L | L | L | H | L | L | L | L | H |
| | Pool side heat transfer | L | L | M | L | H | L | L | L | L | H | L | L | L | L | H |
| | Natural Circulation | L | L | M | L | H | L | L | L | L | H | L | L | L | L | H |
| | Degradation of condensation due to NCs | L | L | M | L | H | L | L | L | L | H | L | L | L | L | H |
| | Accumulation of NCs in tubes | L | L | M | L | H | L | L | L | L | H | L | L | L | L | H |
| | Submergence | L | L | M | L | H | L | L | L | L | H | L | L | L | L | H |
| | Condensate Draining | L | L | M | L | H | L | L | L | L | H | L | L | L | L | H |
| Vacuum Breakers (VB) | Friction and form losses for Steam & NCs | | | | L | H | | | | L | H | | | | L | H |
| | Pressure Drop across VB | | | | L | H | | | | L | H | | | | L | H |
| Equalization Lines | Flow | | | | | H | | | | | H | | | | | H |

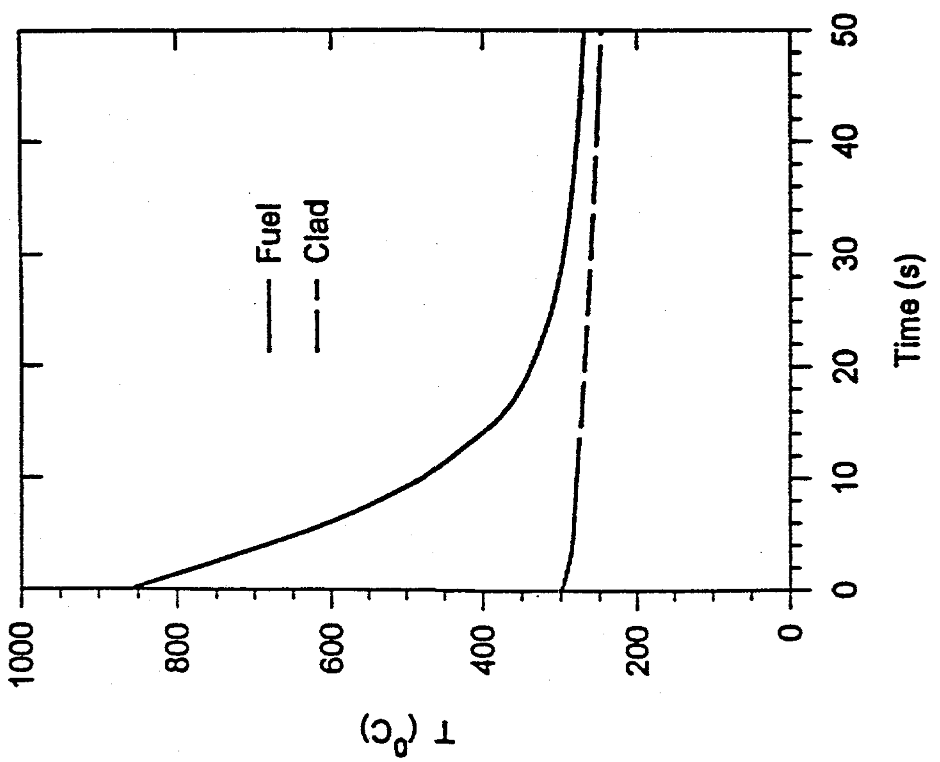


**Figure 5.2-1** Spatially Averaged Fuel and Clad Temperatures During a Main Steam Line Break

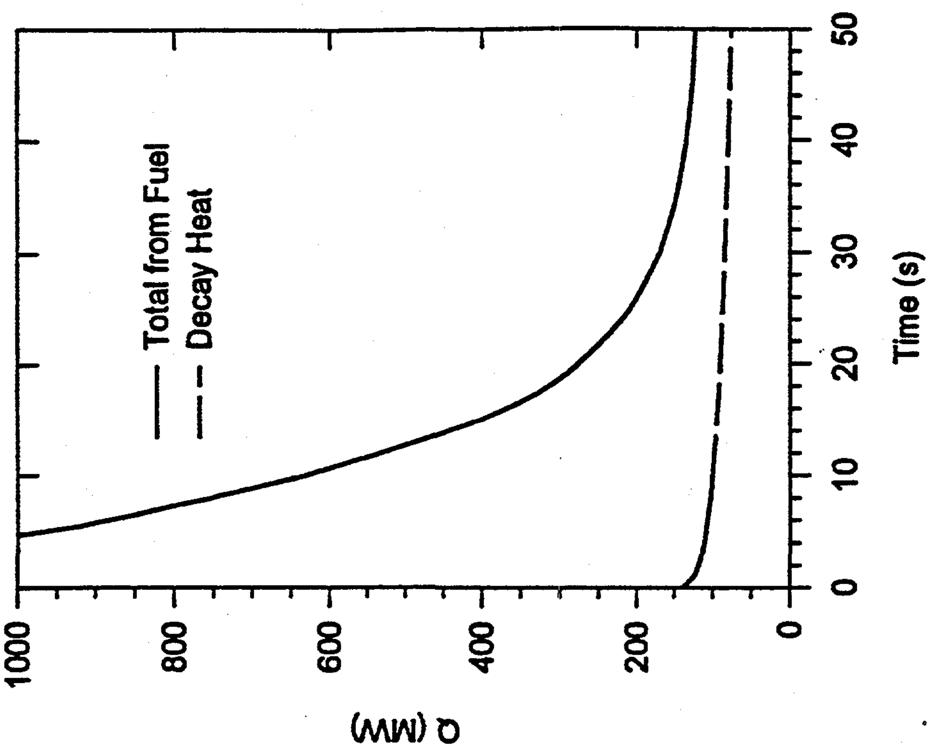


**Figure 5.2-2** Energy Release from Fuel During a Main Steam Line Break

# 6 SUMMARY AND FUTURE PLANS

## 6.1 Summary of SBWR PIRTS

A composite PIRT is presented in Table 6.1-1, showing for each phenomenon only the highest rank that it received in the three transients with five time phases each. This table can serve as a first overview of code modeling requirements and data base needs for LOCA analyses.

It should be noted that only two out of 82 phenomena in Table 6.1-1 show a ranking of H*, indicating a remaining difference between the rankings by BNL and the consultants. Thus, the current PIRT presents the best effort that was achievable with the current state of knowledge. While it can be enhanced by future validation, it is a conservative product that can be used, until an improved, validated version becomes available.

Of the 82 phenomena listed 60 had at least in one case been ranked high. The remainder consisted of 17 medium and five low rankings. This indicates that high fidelity models and a high quality data base must be available for most phenomena. The medium and low ranked phenomena included energy stored in structures, which was mentioned as a candidate for further review with future PIRT validation work. Core parallel channel flow distribution and two-phase pressure drop fell into this category, primarily because in the evaluations made to date, there was always strong internal core circulation, except during the refill phase, when the core is filled with subcooled liquid. In the containment, horizontal vent clearing and all suppression pool phenomena were only ranked medium, due to their relative effects on vessel coolant inventory.

In particular, validation of the PIRTs will further enhance the basis of the rankings and the understanding for SBWR LOCA scenarios, which can be used, in guiding code modeling requirements and in assessing the completeness of the existing experimental data base.

## 6.2 Future Plans

Having used the method, described in Chapter 2, the PIRTs present at this time a compilation of professional judgement of experienced BNL engineers and external consultants. In this respect it's status is comparable to the PWR LOCA PIRT efforts expanded as part of the CSAU program. While the current PIRTs can be used now, it is suggested that the value of these tables can be further enhanced by validating the PIRTs, through quantification of specific phenomena, where the results may affect the rankings. The methods available for such a validation effort are described in Section 5.2.

**Table 6.1-1 Composite PIRT for SBWR**

| Component Description | Phenomenon Description | Composite Rank |
|---|---|---|
| **Reactor** | | |
| Break No 1 | Critical Flow | H |
| | Subcritical Flow | H |
| | Entrainment | H |
| | Spilling | H |
| Break No 2 | Critical Flow | H |
| | Subcritical Flow | M |
| | Entrainment | H |
| | Spilling | H |
| Intact Steam Line | Critical Flow | H |
| | Subcritical Flow | H |
| | Entrainment | H |
| | Inventory Depletion | L |
| DPV (ADS) | Critical Flow | H |
| | Subcritical Flow | H |
| | Entrainment | H* |
| | Spilling | L |
| SRV (ADS) | Critical Flow | H |
| | Subcritical Flow | H |
| | Entrainment | L |
| Turbine Stop Valve | Subcritical Flow | H |
| Turbine Bypass Flow Valve | Critical Flow | H |
| Feedwater Flow; CRD Flow | Flow/BC | H |
| Core | Parallel Channel Flow Distribution | M |
| | Pressure Drop 2-Phase | M |
| | Flashing | H |
| | Evaporation | H |
| | Void Distribution | H |
| | Core Power: Critical/Decay | H |
| | Heat Transfer Coefficient | H |
| | Fuel Stored Energy | H |
| | Structure Stored Energy | M |
| | Internal Flow Circulation | H |

**Table 6.1-1 (continued)**

| Component Description | Phenomenon Description | Composite Rank |
|---|---|---|
| Chimney | Flashing | H |
| | Level/Void Distribution | H |
| | Structure Stored Energy | M |
| Separator/Dryer | Phase Separation | H |
| | Friction - Two Phase | M |
| | Structure Stored Energy | M |
| | Flooding | H |
| Downcomer | Fluid Mixing | H* |
| | Flashing | H |
| | Level/Void Distribution | H |
| | Direct Contact Condensation | H |
| | Structure Stored Energy | M |
| | Entrainment | H |
| Lower Plenum | Fluid Mixing | M |
| | Flashing | H |
| | Structure Stored Energy | M |
| | Void Distribution | H |
| Isolation Condenser | Condensation inside tubes | H |
| | Pool side heat transfer | H |
| | Natural circulation | H |
| | Degradation of condensation due to NCs | M |

**Table 6.1-1 (continued)**

| Component Description | Phenomenon Description | Composite Rank |
|---|---|---|
| **Containment** | | |
| Dry Well | Non-Condensibles Amount | H |
| | Non-Condensibles Distribution | H |
| | Condensation on wall with NC present | H |
| | Water Accumulation | H |
| | Transient Conduction in Structures | H |
| | Non-Equilibrium Mixing of $N_2$ & Steam | H |
| | Surface Condensation (on Liquid Surfaces) | H |
| Horizontal Vent | Horizontal Vent Clearing | M |
| Suppression Pool | Suppression Pool Heat & MassTransfer | M |
| | Condensation for SRV Sparger flow | M |
| | Condensation with NC for PCC purge line flow | M |
| | Temperature Stratification | M |
| Suppression Chamber | Non-Condensibles Amount | H |
| | Non-Condensibles Distribution | M |
| | Condensation on wall with NC present | L |
| | Heat and Mass transfer at pool surface | L |
| GDCS | Friction/Form Losses | H |
| | Hydrostatic Head | H |
| | Pressure Difference from GDCS Tanks to RPV | H |
| PCCS Heat Exchanger | Condensation inside tubes | H |
| | Pool side heat transfer | H |
| | Natural Circulation | H |
| | Degradation of condensation due to NCs | H |
| | Accumulation of NCs in tubes | H |
| | Submergence | H |
| | Condensate Draining | H |
| Vacuum Breakers (VB) | Friction and form losses for Steam & NCs | H |
| | Pressure Drop across VB | H |
| Equalization Lines | Flow | H |

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# APPENDIX A

# PRELIMINARY PHENOMENA IDENTIFICATION AND RANKING TABLES FOR SBWR LOCA SCENARIOS: DESCRIPTION OF THE SBWR

*(Proprietary—Under Separate Cover)*

# APPENDIX B

# PRELIMINARY PHENOMENA IDENTIFICATION AND RANKING TABLES

# APPENDIX B

# PRELIMINARY PHENOMENA IDENTIFICATION AND RANKING TABLES

## B.1 Assessment Criteria

The derivation rationale for the assessment criteria is given in Section 4.1. The resulting tables for the three transients and for each of the five time phases are shown here. Tables B.1-1 to 5 show the criteria for the five time phases of MSLB scenarios. The criteria for the BDLB and GDLB scenarios were identical in all time phases and are, therefore, presented in combined tables for BDLB and GDLB in Tables B.1-6 to 10.

## B.2 Ranking Procedure

The phenomena rankings can be expressed in a numerical scale, for instance from 0 to 9, with 9 the most important and 0 essentially meaning 'not applicable.' This method was employed in the General Electric PIRTs (see, for instance, TAPD Report). For the current work a verbal scale was employed, using the three ranks 'Low' (L), 'Medium' (M) and 'High' (H). The latter method is more appropriate in cases where our knowledge is of a preliminary nature. As more information becomes available, the finer numerical scale becomes more meaningful. Where a phenomenon was clearly not applicable (no second break, ADS not operating in the pre-isolation phase) or physically impossible (hydrostatic pressure too low to clear a vent), the designation 'not applicable' (n/a), was used.

To reduce some misunderstandings, which arose during the ranking process, definitions were developed, to clarify what rank should be assigned. In particular, to clarify the difference between L and n/a rankings, the rule used was:

> if something can happen, but does not matter, it is L;
> if something cannot or will not happen, it is n/a.

The detailed PIRT tables are given in:

| | | |
|---|---|---|
| Tables B.2-1 to 5 | for the | MSLB |
| Tables B.2-6 to 10 | for the | BDLB |
| Tables B.2-11 to 15 | for the | GDLB. |

The PIRTs of this section are augmented by several tables presented in Appendix C. Table C.1-1 defines the component and describes its geometry. Table C.1-2 gives an overview over break and ADS flow areas. Table C.2-1 defines the phenomena, considering the wide definition used for the word "phenomenon," as stated in Chapter 2. In Tables C.3-1 to C.3-3 the ranking rationale for the MSLB, BDLB and GDLB scenarios is described. The GDLB rankings were almost all identical to the BDLB rankings, except at the break, and the BDLB ranking rationale of Table C.3-2 was used in those cases. Only for few entries, where the ranking rationales differed, is a separate GDLB entry provided in Table C.3-3.

Originally, all phenomena were ranked by a BNL team. These rankings are identified as "BNL" in the detailed PIRT tables. After that, these rankings were presented to a group of outside consultants. The PIRT tables often do not show a ranking by consultants. Usually consultant comments and/or rankings were only received, if they either disagreed or very strongly agreed with the BNL ranking. Thus, a lack of an entry in the "Consultants" Column of the PIRTs essentially means a concurrence with the original BNL ranking, which then also becomes the final, combined rank for that phenomenon.

In most instances agreement was reached. But, this was not always the case. If the rankings by BNL and the advisors differed and the highest ranking was M, that rank is used in the preliminary PIRTs. Where differences persisted, and the highest rank was H, that rank was used, but this is emphasized in the PIRTs, by marking those cases as $H^*$.

To aid in the future refinement of these PIRTs, the most significant reasons for remaining disagreement should be listed below:

Most of the remaining disagreements, resulting in H* ranks, are due to lack of quantitative information and those items are targeted for resolution through future sensitivity studies, as described in Chapter 6. For instance, during a main steam line break scenario, the scram signal is anticipated to occur on high drywell pressure, within one or two seconds from the beginning of the accident. Heat transfer to the containment walls and condensation on the cool walls will affect the drywell pressure. Some participants felt, that these items should, therefore, be ranked H; others felt that the time is too short for this effect to contribute significantly. Quantitative evaluations will be used, to assess the importance of this phenomenon for this time phase, before revising the ranking at the next level of PIRT refinement.

Another typical difference in viewpoints can be explained by the following example: In the depressurization phase of the BDLB, two-phase mixture will rise into the separator region. If the separators successfully remove the liquid phase, ADS flow entrainment can be reduced, resulting in less loss of inventory. Therefore, some participants ranked the phase separation in the separator/dryer assembly as an important phenomenon. Others felt, that at the prevailing mass flows the separators will work as designed, eliminating carryover, and ranked phase separation as low. Some remaining H* entries are related to such differences in interpretation.

Other differences arose, based on the future use of the information. For instance, indications are, that the maximum clad temperature will essentially drop from a normal operation value of about 300°C to about 130°C during LOCA scenarios. The most important parameter affecting the clad temperature is the clad surface to coolant heat transfer coefficient. Therefore, some participants felt, that it should always be ranked high, since the peak clad temperature limit is a low level parameter, limited by regulation, and future uncertainty evaluations will only be performed on parameters ranked H. Others felt, that since the actual clad temperature remains about 1,000°C below the peak clad temperature limit of 1,200°C, and since we have substituted vessel coolant inventory for peak clad temperature as a lower level assessment criterion, the core heat transfer coefficient can be ranked low. Uncertainty evaluations should be made on the core coolant inventory. The latter view is consistent with the CSAU method, and prevailed. As long as we are assured, that with sufficient vessel inventory a dangerous level of peak clad temperature cannot be reached, the uncertainty evaluations will be based on the effect of phenomena ranked high with respect to vessel inventory. Only if cases are found, where the substitution of inventory for peak clad temperature is not acceptable, will uncertainty evaluations of this parameter be required, concurrent with a revision of our present rankings.

During the isolation phase unchoked break flow was considered as n/a by all reviewers. This phase extends to the opening of the DPV and SRV valves, following an $L_1$ downcomer water level signal. The more recent RELAP5 simulations of an MSLB transient, shown in Chapter 3, show that the $L_1$ signal may occur later than anticipated, with reactor pressures sufficiently low, that unchoking during this phase is a distinct possibility. A revision of this ranking with the future validation efforts is, therefore in order. Essentially all containment phenomena were ranked low for this time period, since with choked break flow they were of no essence for in-vessel events. However, with unchoking possible during this time period, the drywell pressure would affect the break flow toward the end of the isolation phase. Thus, the ranking of containment phenomena will also have to be reviewed, when this is taken up.

It should be noted, that such a reranking for the isolation phase is not expected to result in any phenomenon being ranked higher, than they are ranked in the current PIRT, considering all time phases. For instance, the phenomenon of unchoked break flow was rated high in the depressurization phase, and this might now have to be extended into the isolation phase.

The assumption commonly made in LOCA analyses is, that at time zero all preferred power (SSAR) is lost with the initiation of the accident. In particular this means that the feedwater pumps will coast down rapidly, providing a diminishing coolant flow for a short time, of the order of 10 to 30 s. Some transients, in particular small break scenarios, could follow a quite different scenario without this generally conservative assumption. The BNL PIRT predominantly concentrates on the commonly used case of loss of power coincident with the break. However, where it could readily be incorporated, consideration was also given to alternate scenario variations from the base scenario. For instance, in the Main Steam Line Break (MSLB) transient with loss of preferred power, scram at time zero is also assumed. In actuality, loss of preferred power could cause scram via the turbine trip signal within a fraction of a second. Without that assumption scram would occur most likely on high drywell pressure, also within a fraction of a second. This would mean, that for the scenario without loss of power, the drywell pressure could be an important parameter, while in case of loss of preferred power, it would not affect the vessel transient early in the accident. The more general and more physical case was chosen here, and the phenomena affecting early drywell pressure were, correspondingly, ranked high.

Following the detailed PIRTs a combined PIRT is given in Table B.2-16, summarizing all three transients and five time phases in one table for ready comparison. To improve readability, all "n/a" rankings have been left blank here.

**Table B.1-1 Assessment Criteria for the Pre-Isolation Phase of a Main Steam Line Break**

Accident: **Main Steam Line Break**

Event Phase: **Pre-Isolation**

Beginning of Phase: Break Time

End of Phase: MSIV Closure

| Parameter | Level 4 | Level 5 | Level 6 | Comments |
|---|---|---|---|---|
| Peak Clad Temperature | x | | | |
| Vessel Inventory | | x | | |
| Break Flows | | | x | |
| ADS Flows | | | | |
| Steam Line Flow | | | x | |
| Feedwater Flow | | | x | |
| Core Power | | | x | |
| Downcomer Level | | | x | Signal |
| Drywell Pressure | | | x | Signal |
| IC Flow | | | | |
| GDCS Injection | | | | |
| PCCS Heat Removal | | | | |
| Equalization Line Flow | | | | |

**Table B.1-2 Assessment Criteria for the Isolation Phase of a Main Steam Line Break**

Accident: **Main Steam Line Break**

Event Phase: **Isolation**

Beginning of Phase: MSIV Closure

End of Phase: ADS Initiation ($L_1$ + 10 s)

| **Parameter** | **Level 4** | **Level 5** | **Level 6** | **Comments** |
|---|---|---|---|---|
| Peak Clad Temperature | x | | | |
| Vessel Inventory | | x | | |
| Break Flows | | | x | |
| ADS Flows | | | | |
| Steam Line Flow | | | | |
| Feedwater Flow | | | x | |
| Core Power | | | x | |
| Downcomer Level | | | x | Signal/Head |
| Drywell Pressure | | | | |
| IC Flow | | | x | |
| GDCS Injection | | | | |
| PCCS Heat Removal | | | | |
| Equalization Line Flow | | | | |

**Table B.1-3 Assessment Criteria for the Depressurization Phase of a Main Steam Line Break**

Accident: **Main Steam Line Break**

Event Phase: **Depressurization**

Beginning of Phase: ADS Initiation ($L_1$ + 10 s)

End of Phase: Begin of GDCS Flow

| **Parameter** | **Level 4** | **Level 5** | **Level 6** | **Comments** |
|---|---|---|---|---|
| Peak Clad Temperature | x | | | |
| Vessel Inventory | | x | | |
| Break Flows | | | x | |
| ADS Flows | | | x | |
| Steam Line Flow | | | | |
| Feedwater Flow | | | | |
| Core Power | | | x | |
| Downcomer Level | | | x | |
| Drywell Pressure | | | x | |
| IC Flow | | | | |
| GDCS Injection | | | | |
| PCCS Heat Removal | | | | |
| Equalization Line Flow | | | | |

**Table B.1-4 Assessment Criteria for the GDCS Refill Phase of a Main Steam Line Break**

Accident: **Main Steam Line Break**

Event Phase: **GDCS Refill**

Beginning of Phase: Begin of GDCS Flow

End of Phase: Begin of PCCS Flow

| Parameter | Level 4 | Level 5 | Level 6 | Comments |
|---|---|---|---|---|
| Peak Clad Temperature | x | | | |
| Vessel Inventory | | x | | |
| Break Flows | | | | |
| ADS Flows | | | | |
| Steam Line Flow | | | | |
| Feedwater Flow | | | | |
| Core Power | | | x | |
| Downcomer Level | | | x | |
| Drywell Pressure | | | x | |
| IC Flow | | | | |
| GDCS Injection | | | x | |
| PCCS Heat Removal | | | | |
| Equalization Line Flow | | | | |

**Table B.1-5 Assessment Criteria for the Long-Term Cooling Phase of a Main Steam Line Break**

Accident: **Main Steam Line Break**

Event Phase: **Long-Term Cooling**

Beginning of Phase: Begin of PCCS Flow

End of Phase: 72 hr

| **Parameter** | **Level 4** | **Level 5** | **Level 6** | **Comments** |
|---|---|---|---|---|
| Peak Clad Temperature | x | | | |
| Vessel Inventory | | x | | |
| Break Flows | | | | |
| ADS Flows | | | | |
| Steam Line Flow | | | | |
| Feedwater Flow | | | | |
| Core Power | | | x | |
| Downcomer Level | | | x | |
| Drywell Pressure | | | x | |
| IC Flow | | | | |
| GDCS Injection | | | | |
| PCCS Heat Removal | | | x | |
| Equalization Line Flow | | | x | |

**Table B.1-6 Assessment Criteria for the Pre-Isolation Phase of BDLB and GDLB Scenarios**

Accident: **BDLB & GDLB**

Event Phase: **Pre-Isolation**

Beginning of Phase: Break Time

End of Phase: MSIV Closure

| **Parameter** | **Level 4** | **Level 5** | **Level 6** | **Comments** |
|---|---|---|---|---|
| Peak Clad Temperature | x | | | |
| Vessel Inventory | | x | | |
| Break Flows | | | x | |
| ADS Flows | | | | |
| Steam Line Flow | | | x | |
| Feedwater Flow | | | x | |
| Core Power | | | x | |
| Downcomer Level | | | x | Signal |
| Drywell Pressure | | | x | Signal |
| IC Flow | | | | |
| GDCS Injection | | | | |
| PCCS Heat Removal | | | | |
| Equalization Line Flow | | | | |

**Table B.1-7 Assessment Criteria for the Isolation Phase of BDLB and GDLB Scenarios**

Accident: **BDLB & GDLB**

Event Phase: **Isolation**

Beginning of Phase: MSIV Closure

End of Phase: ADS Initiation ($L_1$ + 10 s)

| Parameter | Level 4 | Level 5 | Level 6 | Comments |
|---|---|---|---|---|
| Peak Clad Temperature | x | | | |
| Vessel Inventory | | x | | |
| Break Flows | | | x | |
| ADS Flows | | | | |
| Steam Line Flow | | | | |
| Feedwater Flow | | | x | |
| Core Power | | | x | |
| Downcomer Level | | | x | Signal/Head |
| Drywell Pressure | | | | |
| IC Flow | | | x | |
| GDCS Injection | | | | |
| PCCS Heat Removal | | | | |
| Equalization Line Flow | | | | |

**Table B.1-8 Assessment Criteria for the Depressurization Phase of BDLB and GDLB Scenarios**

Accident: **BDLB & GDLB**

Event Phase: **Depressurization**

Beginning of Phase: ADS Initiation ($L_1$ + 10 s)

End of Phase: Begin of GDCS Flow

| Parameter | Level 4 | Level 5 | Level 6 | Comments |
|---|---|---|---|---|
| Peak Clad Temperature | x | | | |
| Vessel Inventory | | x | | |
| Break Flows | | | x | |
| ADS Flows | | | x | |
| Steam Line Flow | | | | |
| Feedwater Flow | | | | |
| Core Power | | | x | |
| Downcomer Level | | | x | |
| Drywell Pressure | | | x | |
| IC Flow | | | | |
| GDCS Injection | | | | |
| PCCS Heat Removal | | | | |
| Equalization Line Flow | | | | |

**Table B.1-9 Assessment Criteria for the GDCS Refill Phase of BDLB and GDLB Scenarios**

Accident: **BDLB & GDLB**

Event Phase: **GDCS Refill**

Beginning of Phase: Begin of GDCS Flow

End of Phase: Begin of PCCS Flow

| Parameter | Level 4 | Level 5 | Level 6 | Comments |
|---|---|---|---|---|
| Peak Clad Temperature | x | | | |
| Vessel Inventory | | x | | |
| Break Flows | | | x | |
| ADS Flows | | | | |
| Steam Line Flow | | | | |
| Feedwater Flow | | | | |
| Core Power | | | x | |
| Downcomer Level | | | x | |
| Drywell Pressure | | | x | |
| IC Flow | | | | |
| GDCS Injection | | | x | |
| PCCS Heat Removal | | | | |
| Equalization Line Flow | | | | |

**Table B.1-10 Assessment Criteria for the Long-Term Cooling Phase of BDLB and GDLB Scenarios**

Accident: **BDLB & GDLB**

Event Phase: **Long-Term Cooling**

Beginning of Phase: Begin of PCCS Flow

End of Phase: 72 hr

| Parameter | Level 4 | Level 5 | Level 6 | Comments |
|---|---|---|---|---|
| Peak Clad Temperature | x | | | |
| Vessel Inventory | | x | | |
| Break Flows | | | x | BDLB only |
| ADS Flows | | | | |
| Steam Line Flow | | | | |
| Feedwater Flow | | | | |
| Core Power | | | x | |
| Downcomer Level | | | x | |
| Drywell Pressure | | | x | |
| IC Flow | | | | |
| GDCS Injection | | | | |
| PCCS Heat Removal | | | x | |
| Equalization Line Flow | | | x | |

Table B.2-1 PIRT for the Pre-Isolation Phase of a Main Steam Line Break

| Break: Main Steam Line Break; | | Event Phase: Pre-Isolation | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| | | **Reactor** | | | | | |
| Break No 1 | C01 | Critical Flow | P01 | H | | H | RM-01 |
| | | Subcritical Flow | P02 | n/a | | n/a | RM-02 |
| | | Entrainment | P03 | L | | L | RM-03 |
| | | Spilling | P05 | n/a | | n/a | RM-129 |
| Break No 2 | C01 | Critical Flow | P01 | n/a | | n/a | RM-04 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Spilling | P05 | n/a | | n/a | |
| Intact Steam Line | C02 | Critical Flow | P01 | H | | H | RM-05 |
| | | Subcritical Flow | P02 | n/a | | n/a | RM-02 |
| | | Entrainment | P03 | n/a | | n/a | RM-127 |
| | | Inventory Depletion | P04 | L | | L | RM-06 |
| DPV (ADS) | C03 | Critical Flow | P01 | n/a | | n/a | RM-07 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Spilling | P05 | n/a | | n/a | |
| SRV (ADS) | C04 | Critical Flow | P01 | n/a | | n/a | RM-07 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| Turbine Stop Valve | C05 | Subcritical Flow | P06 | n/a | | n/a | RM-08 |
| Turbine Bypass Flow Valve | | Critical Flow | P06 | n/a | | n/a | RM-08 |
| Feedwater Flow; CRD Flow | C06 | Flow/BC | P07 | H | | H | RM-09 |
| Core | C07 | Parallel Channel Flow Distribution | P08 | L | | L | RM-10 |
| | | Pressure Drop 2-Phase | P09 | L | | L | RM-10 |
| | | Flashing | P10 | M | M | M | RM-11 |
| | | Evaporation | P11 | L | | L | RM-12 |
| | | Void Distribution | P12 | M | M | M | RM-13 |
| | | Core Power: Critical/Decay | P13 | H | | H | RM-14 |
| | | Heat Transfer Coefficient | P14 | L | L | L | RM-15 |
| | | Fuel Stored Energy | P15 | M | | M | RM-16 |
| | | Structure Stored Energy | P16 | L | | L | RM-17 |
| | | Internal Flow Circulation | P17 | n/a | | n/a | RM-18 |

## Table B.2-1 (continued)

**Break: Main Steam Line Break; Event Phase: Pre-Isolation**

| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
|---|---|---|---|---|---|---|---|
| Chimney | C08 | Flashing | P10 | M | L | M | RM-19 |
| | | Level/Void Distribution | P18 | M | L | M | RM-20 |
| | | Structure Stored Energy | P16 | L | | L | RM-21 |
| Separator/Dryer | C09 | Phase Separation | P19 | M | L | M | RM-22 |
| | | Friction - Two Phase | P20 | L | | L | RM-23 |
| | | Structure Stored Energy | P16 | L | | L | RM-24 |
| | | Flooding | P21 | L | | L | RM-25 |
| Downcomer | C10 | Fluid Mixing | P22 | L | | L | RM-26 |
| | | Flashing | P10 | M | L | M | RM-27 |
| | | Level/Void Distribution | P18 | M | L | M | RM-28 |
| | | Direct Contact Condensation | P23 | L | | L | RM-29 |
| | | Structure Stored Energy | P16 | L | | L | RM-30 |
| | | Entrainment | P24 | L | | L | RM-31 |
| Lower Plenum | C11 | Fluid Mixing | P22 | L | | L | RM-32 |
| | | Flashing | P10 | L | | L | RM-33 |
| | | Structure Stored Energy | P16 | L | | L | RM-34 |
| | | Void Distribution | P12 | L | | L | RM-35 |
| Isolation Condenser | C12 | Condensation inside tubes | P25 | n/a | | n/a | RM-07 |
| | | Pool side heat transfer | P26 | n/a | | n/a | |
| | | Natural circulation | P27 | n/a | | n/a | |
| | | Degradation of condensation due to NCs | P28 | n/a | | n/a | |

**Table B.2-1 (continued)**

| Break: Main Steam Line Break; | | Event Phase: Pre-Isolation | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Containment** | | | | | | | |
| Dry Well | C13 | Non-Condensibles Amount | P31 | M | L | M | RM-36 |
| | | Non-Condensibles Distribution | P32 | M | L | M | RM-36 |
| | | Condensation on wall with NC present | P33 | M | L | M | RM-36 |
| | | Water Accumulation | P34 | L | | L | RM-37 |
| | | Transient Conduction in Structures | P35 | L | | L | RM-38 |
| | | Non-Equilibrium Mixing of $N_2$ & Steam | P36 | H | | H | RM-39 |
| | | Surface Condensation (on Liquid Surfaces) | P37 | M | | M | RM-36 |
| Horizontal Vent | C14 | Horizontal Vent Clearing | P38 | L | | L | RM-40 |
| Suppression Pool | C15 | Suppression Pool Heat & MassTransfer | P39 | L | | L | RM-40 |
| | | Condensation for SRV Sparger flow | P40 | n/a | | n/a | RM-07 |
| | | Condensation with NC for PCC purge line flow | P41 | L | | L | RM-40 |
| | | Temperature Stratification | P42 | L | | L | RM-40 |
| Suppression Chamber | C16 | Non-Condensibles Amount | P31 | L | | L | RM-40 |
| | | Non-Condensibles Distribution | P32 | L | | L | |
| | | Condensation on wall with NC present | P33 | L | | L | |
| | | Heat and Mass transfer at pool surface | P43 | L | | L | |
| GDCS | C17 | Friction/Form Losses | P44 | n/a | | n/a | RM-07 |
| | | Hydrostatic Head | P45 | n/a | | n/a | |
| | | Pressure Difference from GDCS Tanks to RPV | P46 | n/a | | n/a | |
| PCCS Heat Exchanger | C18 | Condensation inside tubes | P25 | L | | L | RM-40 |
| | | Pool side heat transfer | P26 | L | | L | |
| | | Natural Circulation | P27 | L | | L | |
| | | Degradation of condensation due to NCs | P28 | L | | L | |
| | | Accumulation of NCs in tubes | P47 | L | | L | |
| | | Submergence | P48 | L | | L | |
| | | Condensate Draining | P49 | L | | L | |
| Vacuum Breakers (VB) | C19 | Friction and form losses for Steam & NCs | P50 | n/a | | n/a | RM-07 |
| | | Pressure Drop across VB | P51 | n/a | | n/a | |
| Equalization Lines | C20 | Flow | P52 | n/a | | n/a | RM-07 |

Table B.2-2 PIRT for the Isolation Phase of a Main Steam Line Break

| Break: Main Steam Line Break; | | Event Phase: Isolation | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Reactor** | | | | | | | |
| Break No 1 | C01 | Critical Flow | P01 | H | | H | RM-41 |
| | | Subcritical Flow | P02 | n/a | | n/a | RM-02 |
| | | Entrainment | P03 | H | | H | RM-42 |
| | | Spilling | P05 | n/a | | n/a | RM-129 |
| Break No 2 | C01 | Critical Flow | P01 | n/a | | n/a | RM-04 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Spilling | P05 | n/a | | n/a | |
| Intact Steam Line | C02 | Critical Flow | P01 | n/a | | n/a | RM-07 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Inventory Depletion | P04 | n/a | | n/a | |
| DPV (ADS) | C03 | Critical Flow | P01 | n/a | | n/a | RM-07 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Spilling | P05 | n/a | | n/a | |
| SRV (ADS) | C04 | Critical Flow | P01 | n/a | | n/a | RM-07 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| Turbine Stop Valve | C05 | Subcritical Flow | P06 | n/a | | n/a | RM-07 |
| Turbine Bypass Flow Valve | | Critical Flow | P06 | n/a | | n/a | |
| Feedwater Flow; CRD Flow | C06 | Flow/BC | P07 | H | | H | RM-09 |
| Core | C07 | Parallel Channel Flow Distribution | P08 | M | | M | RM-43 |
| | | Pressure Drop 2-Phase | P09 | M | | M | RM-43 |
| | | Flashing | P10 | H | | H | RM-44 |
| | | Evaporation | P11 | H | | H | RM-44 |
| | | Void Distribution | P12 | H | | H | RM-44 |
| | | Core Power: Critical/Decay | P13 | H | | H | RM-14 |
| | | Heat Transfer Coefficient | P14 | H | | H | RM-45 |
| | | Fuel Stored Energy | P15 | H | | H | RM-45 |
| | | Structure Stored Energy | P16 | M | L | M | RM-46 |
| | | Internal Flow Circulation | P17 | M | | M | RM-43 |

**Table B.2-2 (continued)**

| Break: Main Steam Line Break; Event Phase: Isolation | | | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| Chimney | C08 | Flashing | P10 | H | | H | RM-47 |
| | | Level/Void Distribution | P18 | H | | H | RM-47 |
| | | Structure Stored Energy | P16 | M | L | M | RM-46 |
| Separator/Dryer | C09 | Phase Separation | P19 | H | H | H | RM-48 |
| | | Friction - Two Phase | P20 | L | | L | RM-49 |
| | | Structure Stored Energy | P16 | M | L | M | RM-50 |
| | | Flooding | P21 | H | | H | RM-51 |
| Downcomer | C10 | Fluid Mixing | P22 | M | | M | RM-52 |
| | | Flashing | P10 | H | | H | RM-53 |
| | | Level/Void Distribution | P18 | H | | H | RM-53 |
| | | Direct Contact Condensation | P23 | H | H | H | RM-54 |
| | | Structure Stored Energy | P16 | M | | M | RM-55 |
| | | Entrainment | P24 | H | | H | RM-56 |
| Lower Plenum | C11 | Fluid Mixing | P22 | M | L | M | RM-57 |
| | | Flashing | P10 | H | | H | RM-58 |
| | | Structure Stored Energy | P16 | M | | M | RM-59 |
| | | Void Distribution | P12 | H | L | H* | RM-60 |
| Isolation Condenser | C12 | Condensation inside tubes | P25 | H | | H | RM-61 |
| | | Pool side heat transfer | P26 | H | | H | |
| | | Natural circulation | P27 | H | | H | |
| | | Degradation of condensation due to NCs | P28 | M | | M | |

**Table B.2-2 (continued)**

| Break: Main Steam Line Break; Event Phase: Isolation | | | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Containment** | | | | | | | |
| Dry Well | C13 | Non-Condensibles Amount | P31 | L | | L | RM-62 |
| | | Non-Condensibles Distribution | P32 | L | | L | |
| | | Condensation on wall with NC present | P33 | L | | L | |
| | | Water Accumulation | P34 | L | | L | |
| | | Transient Conduction In Structures | P35 | L | | L | |
| | | Non-Equilibrium Mixing of $N_2$ & Steam | P36 | L | | L | |
| | | Surface Condensation (on Liquid Surfaces) | P37 | L | | L | |
| Horizontal Vent | C14 | Horizontal Vent Clearing | P38 | L | | L | RM-62 |
| Suppression Pool | C15 | Suppression Pool Heat & MassTransfer | P39 | L | | L | RM-62 |
| | | Condensation for SRV Sparger flow | P40 | n/a | | n/a | RM-07 |
| | | Condensation with NC for PCC purge line flow | P41 | L | | L | RM-62 |
| | | Temperature Stratification | P42 | L | | L | RM-62 |
| Suppression Chamber | C16 | Non-Condensibles Amount | P31 | L | | L | RM-62 |
| | | Non-Condensibles Distribution | P32 | L | | L | |
| | | Condensation on wall with NC present | P33 | L | | L | |
| | | Heat and Mass transfer at pool surface | P43 | L | | L | |
| GDCS | C17 | Friction/Form Losses | P44 | n/a | | n/a | RM-07 |
| | | Hydrostatic Head | P45 | n/a | | n/a | |
| | | Pressure Difference from GDCS Tanks to RPV | P46 | n/a | | n/a | |
| PCCS Heat Exchanger | C18 | Condensation Inside tubes | P25 | L | | L | RM-62 |
| | | Pool side heat transfer | P26 | L | | L | |
| | | Natural Circulation | P27 | L | | L | |
| | | Degradation of condensation due to NCs | P28 | L | | L | |
| | | Accumulation of NCs in tubes | P47 | L | | L | |
| | | Submergence | P48 | L | | L | |
| | | Condensate Draining | P49 | L | | L | |
| Vacuum Breakers (VB) | C19 | Friction and form losses for Steam & NCs | P50 | n/a | | n/a | RM-07 |
| | | Pressure Drop across VB | P51 | n/a | | n/a | |
| Equalization Lines | C20 | Flow | P52 | n/a | | n/a | RM-07 |

**Table B.2-3 PIRT for the Depressurization Phase of a Main Steam Line Break**

| Break: Main Steam Line Break; | | Event Phase: Depressurization | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Reactor** | | | | | | | |
| Break No 1 | C01 | Critical Flow | P01 | H | | H | RM-64 |
| | | Subcritical Flow | P02 | H | | H | RM-64 |
| | | Entrainment | P03 | L | | L | RM-65 |
| | | Spilling | P05 | n/a | | n/a | RM-129 |
| Break No 2 | C01 | Critical Flow | P01 | n/a | | n/a | RM-04 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Spilling | P05 | n/a | | n/a | |
| Intact Steam Line | C02 | Critical Flow | P01 | n/a | | n/a | RM-07 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Inventory Depletion | P04 | n/a | | n/a | |
| DPV (ADS) | C03 | Critical Flow | P01 | H | | H | RM-64 |
| | | Subcritical Flow | P02 | H | | H | RM-64 |
| | | Entrainment | P03 | L | | L | RM-65 |
| | | Spilling | P05 | n/a | | n/a | RM-07 |
| SRV (ADS) | C04 | Critical Flow | P01 | H | | H | RM-64 |
| | | Subcritical Flow | P02 | H | | H | RM-64 |
| | | Entrainment | P03 | L | | L | RM-65 |
| Turbine Stop Valve | C05 | Subcritical Flow | P06 | n/a | | n/a | RM-07 |
| Turbine Bypass Flow Valve | | Critical Flow | P06 | n/a | | n/a | |
| Feedwater Flow; CRD Flow | C06 | Flow/BC | P07 | n/a | | n/a | RM-07 |
| Core | C07 | Parallel Channel Flow Distribution | P08 | M | L | M | RM-66 |
| | | Pressure Drop 2-Phase | P09 | M | L | M | RM-66 |
| | | Flashing | P10 | H | H | H | RM-67 |
| | | Evaporation | P11 | H | | H | RM-67 |
| | | Void Distribution | P12 | H | H | H | RM-67 |
| | | Core Power: Critical/Decay | P13 | H | | H | RM-14 |
| | | Heat Transfer Coefficient | P14 | H | | H | RM-68 |
| | | Fuel Stored Energy | P15 | L | L | L | RM-69 |
| | | Structure Stored Energy | P16 | L | L | L | RM-70 |
| | | Internal Flow Circulation | P17 | H | | H | RM-71 |

**Table B.2-3 (continued)**

| Break: Main Steam Line Break; | | Event Phase: Depressurization | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | | Phenomenon Description | | Rank | | | |
| | Component & Geometry Identifier | | Phenomenon Identifier | BNL | Consultants | Final | Ranking Rationale |
| Chimney | C08 | Flashing | P10 | H | H | H | RM-72 |
| | | Level/Void Distribution | P18 | H | H | H | RM-72 |
| | | Structure Stored Energy | P16 | L | L | L | RM-70 |
| Separator/Dryer | C09 | Phase Separation | P19 | H | H | H | RM-73 |
| | | Friction - Two Phase | P20 | L | | L | RM-74 |
| | | Structure Stored Energy | P16 | L | | L | RM-70 |
| | | Flooding | P21 | L | | L | RM-75 |
| Downcomer | C10 | Fluid Mixing | P22 | L | | L | RM-76 |
| | | Flashing | P10 | H | H | H | RM-77 |
| | | Level/Void Distribution | P18 | H | H | H | RM-77 |
| | | Direct Contact Condensation | P23 | M | M | M | RM-78 |
| | | Structure Stored Energy | P16 | M | | M | RM-79 |
| | | Entrainment | P24 | H | | H | RM-80 |
| Lower Plenum | C11 | Fluid Mixing | P22 | L | | L | RM-81 |
| | | Flashing | P10 | H | | H | RM-82 |
| | | Structure Stored Energy | P16 | M | | M | RM-79 |
| | | Void Distribution | P12 | L | | L | RM-83 |
| Isolation Condenser | C12 | Condensation inside tubes | P25 | H | | H | RM-84 |
| | | Pool side heat transfer | P26 | H | | H | RM-84 |
| | | Natural circulation | P27 | H | | H | RM-84 |
| | | Degradation of condensation due to NCs | P28 | M | | M | RM-62 |

**Table B.2-3 (continued)**

| Break: Main Steam Line Break; | | Event Phase: Depressurization | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Containment** | | | | | | | |
| Dry Well | C13 | Non-Condensibles Amount | P31 | M | | M | RM-85 |
| | | Non-Condensibles Distribution | P32 | M | | M | RM-85 |
| | | Condensation on wall with NC present | P33 | L | | L | RM-86 |
| | | Water Accumulation | P34 | L | | L | RM-37 |
| | | Transient Conduction in Structures | P35 | M | | M | RM-87 |
| | | Non-Equilibrium Mixing of $N_2$ & Steam | P36 | M | | M | RM-87 |
| | | Surface Condensation (on Liquid Surfaces) | P37 | M | | M | RM-87 |
| Horizontal Vent | C14 | Horizontal Vent Clearing | P38 | M | | M | RM-88 |
| Suppression Pool | C15 | Suppression Pool Heat & MassTransfer | P39 | M | | M | RM-88 |
| | | Condensation for SRV Sparger flow | P40 | M | | M | |
| | | Condensation with NC for PCC purge line flow | P41 | M | | M | |
| | | Temperature Stratification | P42 | M | | M | |
| Suppression Chamber | C16 | Non-Condensibles Amount | P31 | M | | M | RM-89 |
| | | Non-Condensibles Distribution | P32 | L | | L | |
| | | Condensation on wall with NC present | P33 | L | | L | |
| | | Heat and Mass transfer at pool surface | P43 | L | | L | |
| GDCS | C17 | Friction/Form Losses | P44 | n/a | | n/a | RM-07 |
| | | Hydrostatic Head | P45 | n/a | | n/a | |
| | | Pressure Difference from GDCS Tanks to RPV | P46 | n/a | | n/a | |
| PCCS Heat Exchanger | C18 | Condensation inside tubes | P25 | M | | M | RM-90 |
| | | Pool side heat transfer | P26 | M | | M | |
| | | Natural Circulation | P27 | M | | M | |
| | | Degradation of condensation due to NCs | P28 | M | | M | |
| | | Accumulation of NCs in tubes | P47 | M | | M | |
| | | Submergence | P48 | M | | M | |
| | | Condensate Draining | P49 | M | | M | |
| Vacuum Breakers (VB) | C19 | Friction and form losses for Steam & NCs | P50 | n/a | | n/a | RM-07 |
| | | Pressure Drop across VB | P51 | n/a | | n/a | |
| Equalization Lines | C20 | Flow | P52 | n/a | | n/a | RM-07 |

**Table B.2-4 PIRT for the GDCS Refill Phase of a Main Steam Line Break**

| Break: Main Steam Line Break; | | Event Phase: GDCS Refill | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Reactor** | | | | | | | |
| Break No 1 | C01 | Critical Flow | P01 | n/a | | n/a | RM-91 |
| | | Subcritical Flow | P02 | M | | M | RM-92 |
| | | Entrainment | P03 | n/a | | n/a | RM-93 |
| | | Spilling | P05 | n/a | | n/a | RM-129 |
| Break No 2 | C01 | Critical Flow | P01 | n/a | | n/a | RM-04 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Spilling | P05 | n/a | | n/a | |
| Intact Steam Line | C02 | Critical Flow | P01 | n/a | | n/a | RM-07 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Inventory Depletion | P04 | n/a | | n/a | |
| DPV (ADS) | C03 | Critical Flow | P01 | n/a | | n/a | RM-91 |
| | | Subcritical Flow | P02 | M | | M | RM-92 |
| | | Entrainment | P03 | n/a | | n/a | RM-93 |
| | | Spilling | P05 | L | | L | RM-94 |
| SRV (ADS) | C04 | Critical Flow | P01 | n/a | | n/a | RM-91 |
| | | Subcritical Flow | P02 | L | | L | RM-95 |
| | | Entrainment | P03 | n/a | | n/a | RM-91 |
| Turbine Stop Valve | C05 | Subcritical Flow | P06 | n/a | | n/a | RM-07 |
| Turbine Bypass Flow Valve | | Critical Flow | P06 | n/a | | n/a | |
| Feedwater Flow; CRD Flow | C06 | Flow/BC | P07 | n/a | | n/a | RM-07 |
| Core | C07 | Parallel Channel Flow Distribution | P08 | L | | L | RM-96 |
| | | Pressure Drop 2-Phase | P09 | L | | L | RM-96 |
| | | Flashing | P10 | L | | L | RM-96 |
| | | Evaporation | P11 | L | | L | RM-96 |
| | | Void Distribution | P12 | L | | L | RM-96 |
| | | Core Power: Critical/Decay | P13 | H | | H | RM-14 |
| | | Heat Transfer Coefficient | P14 | L | L | L | RM-97 |
| | | Fuel Stored Energy | P15 | L | | L | RM-69 |
| | | Structure Stored Energy | P16 | L | | L | RM-70 |
| | | Internal Flow Circulation | P17 | M | | M | RM-98 |

**Table B.2-4 (continued)**

| Break: Main Steam Line Break; | | Event Phase: GDCS Refill | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| Chimney | C08 | Flashing | P10 | L | | L | RM-99 |
| | | Level/Void Distribution | P18 | L | | L | RM-99 |
| | | Structure Stored Energy | P16 | L | | L | RM-70 |
| Separator/Dryer | C09 | Phase Separation | P19 | L | | L | RM-99 |
| | | Friction - Two Phase | P20 | L | | L | RM-99 |
| | | Structure Stored Energy | P16 | L | | L | RM-70 |
| | | Flooding | P21 | n/a | | n/a | RM-100 |
| Downcomer | C10 | Fluid Mixing | P22 | L | | L | RM-101 |
| | | Flashing | P10 | L | | L | RM-99 |
| | | Level/Void Distribution | P18 | L | | L | RM-99 |
| | | Direct Contact Condensation | P23 | L | | L | RM-99 |
| | | Structure Stored Energy | P16 | M | L | M | RM-79 |
| | | Entrainment | P24 | L | | L | RM-99 |
| Lower Plenum | C11 | Fluid Mixing | P22 | L | | L | RM-99 |
| | | Flashing | P10 | L | | L | RM-99 |
| | | Structure Stored Energy | P16 | L | L | L | RM-79 |
| | | Void Distribution | P12 | L | | L | RM-99 |
| Isolation Condenser | C12 | Condensation inside tubes | P25 | L | L | L | RM-102 |
| | | Pool side heat transfer | P26 | L | L | L | |
| | | Natural circulation | P27 | L | L | L | |
| | | Degradation of condensation due to NCs | P28 | L | L | L | |

Table B.2-4 (continued)

| Break: Main Steam Line Break; | | Event Phase: GDCS Refill | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Containment** | | | | | | | |
| Dry Well | C13 | Non-Condensibles Amount | P31 | L | | L | RM-103 |
| | | Non-Condensibles Distribution | P32 | L | | L | RM-103 |
| | | Condensation on wall with NC present | P33 | L | | L | RM-104 |
| | | Water Accumulation | P34 | L | | L | RM-37 |
| | | Transient Conduction in Structures | P35 | L | | L | RM-104 |
| | | Non-Equilibrium Mixing of $N_2$ & Steam | P36 | n/a | | n/a | RM-105 |
| | | Surface Condensation (on Liquid Surfaces) | P37 | L | | L | RM-104 |
| Horizontal Vent | C14 | Horizontal Vent Clearing | P38 | n/a | | n/a | RM-106 |
| Suppression Pool | C15 | Suppression Pool Heat & MassTransfer | P39 | L | | L | RM-104 |
| | | Condensation for SRV Sparger flow | P40 | L | | L | RM-107 |
| | | Condensation with NC for PCC purge line flow | P41 | L | | L | RM-104 |
| | | Temperature Stratification | P42 | L | | L | RM-104 |
| Suppression Chamber | C16 | Non-Condensibles Amount | P31 | L | | L | RM-103 |
| | | Non-Condensibles Distribution | P32 | L | | L | RM-104 |
| | | Condensation on wall with NC present | P33 | L | | L | RM-104 |
| | | Heat and Mass transfer at pool surface | P43 | L | | L | RM-104 |
| GDCS | C17 | Friction/Form Losses | P44 | H | | H | RM-108 |
| | | Hydrostatic Head | P45 | H | | H | |
| | | Pressure Difference from GDCS Tanks to RPV | P46 | H | | H | |
| PCCS Heat Exchanger | C18 | Condensation inside tubes | P25 | L | | L | RM-109 |
| | | Pool side heat transfer | P26 | L | | L | |
| | | Natural Circulation | P27 | L | | L | |
| | | Degradation of condensation due to NCs | P28 | L | | L | |
| | | Accumulation of NCs in tubes | P47 | L | | L | |
| | | Submergence | P48 | L | | L | |
| | | Condensate Draining | P49 | L | | L | |
| Vacuum Breakers (VB) | C19 | Friction and form losses for Steam & NCs | P50 | L | | L | RM-110 |
| | | Pressure Drop across VB | P51 | L | | L | |
| Equalization Lines | C20 | Flow | P52 | n/a | | n/a | RM-07 |

**Table B.2-5 PIRT for the Long-Term Cooling Phase of a Main Steam Line Break**

| Break: Main Steam Line Break; | | Event Phase: Long Term Cooling | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Reactor** | | | | | | | |
| Break No 1 | C01 | Critical Flow | P01 | n/a | | n/a | RM-91 |
| | | Subcritical Flow | P02 | L | | L | RM-111 |
| | | Entrainment | P03 | n/a | | n/a | RM-93 |
| | | Spilling | P05 | n/a | | n/a | RM-129 |
| Break No 2 | C01 | Critical Flow | P01 | n/a | | n/a | RM-04 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Spilling | P05 | n/a | | n/a | |
| Intact Steam Line | C02 | Critical Flow | P01 | n/a | | n/a | RM-07 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Inventory Depletion | P04 | n/a | | n/a | |
| DPV (ADS) | C03 | Critical Flow | P01 | n/a | | n/a | RM-91 |
| | | Subcritical Flow | P02 | L | | L | RM-111 |
| | | Entrainment | P03 | n/a | | n/a | RM-93 |
| | | Spilling | P05 | n/a | | n/a | RM-112 |
| SRV (ADS) | C04 | Critical Flow | P01 | n/a | | n/a | RM-113 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a. | |
| Turbine Stop Valve | C05 | Subcritical Flow | P06 | n/a | | n/a | RM-07 |
| Turbine Bypass Flow Valve | | Critical Flow | P06 | n/a | | n/a | |
| Feedwater Flow; CRD Flow | C06 | Flow/BC | P07 | n/a | | n/a | RM-07 |
| Core | C07 | Parallel Channel Flow Distribution | P08 | L | | L | RM-114 |
| | | Pressure Drop 2-Phase | P09 | L | | L | RM-114 |
| | | Flashing | P10 | L | | L | RM-114 |
| | | Evaporation | P11 | L | L | L | RM-114 |
| | | Void Distribution | P12 | L | | L | RM-115 |
| | | Core Power; Critical/Decay | P13 | H | | H | RM-14 |
| | | Heat Transfer Coefficient | P14 | L | L | L | RM-96 |
| | | Fuel Stored Energy | P15 | L | | L | RM-69 |
| | | Structure Stored Energy | P16 | L | | L | RM-70 |
| | | Internal Flow Circulation | P17 | L | | L | RM-115 |

**Table B.2-5 (continued)**

| Break: Main Steam Line Break; | | Event Phase: Long Term Cooling | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| Chimney | C08 | Flashing | P10 | L | | L | RM-99 |
| | | Level/Void Distribution | P18 | L | | L | RM-99 |
| | | Structure Stored Energy | P16 | L | | L | RM-70 |
| Separator/Dryer | C09 | Phase Separation | P19 | L | | L | RM-99 |
| | | Friction - Two Phase | P20 | L | | L | RM-99 |
| | | Structure Stored Energy | P16 | L | | L | RM-70 |
| | | Flooding | P21 | n/a | | n/a | RM-116 |
| Downcomer | C10 | Fluid Mixing | P22 | L | | L | RM-101 |
| | | Flashing | P10 | L | | L | RM-99 |
| | | Level/Void Distribution | P18 | L | | L | RM-99 |
| | | Direct Contact Condensation | P23 | L | | L | RM-99 |
| | | Structure Stored Energy | P16 | L | | L | RM-117 |
| | | Entrainment | P24 | L | | L | RM-99 |
| Lower Plenum | C11 | Fluid Mixing | P22 | L | | L | RM-101 |
| | | Flashing | P10 | L | | L | RM-99 |
| | | Structure Stored Energy | P16 | L | | L | RM-117 |
| | | *Void Distribution* | P12 | L | | L | *RM-99* |
| Isolation Condenser | C12 | Condensation inside tubes | P25 | L | | L | RM-102 |
| | | Pool side heat transfer | P26 | L | | L | |
| | | Natural circulation | P27 | L | | L | |
| | | Degradation of condensation due to NCs | P28 | L | | L | |

Table B.2-5 (continued)

| Break: Main Steam Line Break; | | Event Phase: Long Term Cooling | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Containment** | | | | | | | |
| Dry Well | C13 | Non-Condensibles Amount | P31 | H | | H | RM-118 |
| | | Non-Condensibles Distribution | P32 | H | | H | RM-118 |
| | | Condensation on wall with NC present | P33 | M | | M | RM-119 |
| | | Water Accumulation | P34 | H | | H | RM-120 |
| | | Transient Conduction in Structures | P35 | L | | L | RM-121 |
| | | Non-Equilibrium Mixing of $N_2$ & Steam | P36 | n/a | | n/a | RM-105 |
| | | Surface Condensation (on Liquid Surfaces) | P37 | M | | M | RM-119 |
| Horizontal Vent | C14 | Horizontal Vent Clearing | P38 | n/a | | n/a | RM-106 |
| Suppression Pool | C15 | Suppression Pool Heat & MassTransfer | P39 | L | | L | RM-122 |
| | | Condensation for SRV Sparger flow | P40 | L | | L | |
| | | Condensation with NC for PCC purge line flow | P41 | L | | L | |
| | | Temperature Stratification | P42 | L | | L | |
| Suppression Chamber | C16 | Non-Condensibles Amount | P31 | H | | H | RM-118 |
| | | Non-Condensibles Distribution | P32 | M | | M | RM-128 |
| | | Condensation on wall with NC present | P33 | L | | L | RM-123 |
| | | Heat and Mass transfer at pool surface | P43 | L | | L | RM-123 |
| GDCS | C17 | Friction/Form Losses | P44 | L | | L | RM-124 |
| | | Hydrostatic Head | P45 | L | | L | |
| | | Pressure Difference from GDCS Tanks to RPV | P46 | L | | L | |
| PCCS Heat Exchanger | C18 | Condensation inside tubes | P25 | H | | H | RM-125 |
| | | Pool side heat transfer | P26 | H | | H | |
| | | Natural Circulation | P27 | H | | H | |
| | | Degradation of condensation due to NCs | P28 | H | | H | |
| | | Accumulation of NCs in tubes | P47 | H | | H | |
| | | Submergence | P48 | H | | H | |
| | | Condensate Draining | P49 | H | | H | |
| Vacuum Breakers (VB) | C19 | Friction and form losses for Steam & NCs | P50 | H | | H | RM-118 |
| | | Pressure Drop across VB | P51 | H | | H | |
| Equalization Lines | C20 | Flow | P52 | H | | H | RM-126 |

## Table B.2-6 PIRT for the Pre-Isolation Phase of a Bottom Drain Line Break

| Break: Bottom Drain Line Break; | | Event Phase: Pre-Isolation | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Reactor** | | | | | | | |
| Break No 1 (Lower Break) | C01 | Critical Flow | P01 | H | | H | RB-01 |
| | | Subcritical Flow | P02 | n/a | | n/a | RB-02 |
| | | Entrainment | P03 | L | | L | RB-03 |
| | | Spilling | P05 | n/a | | n/a | RB-130 |
| Break No 2 (Upper Break) | C01 | Critical Flow | P01 | H | | H | RB-01 |
| | | Subcritical Flow | P02 | n/a | | n/a | RB-02 |
| | | Entrainment | P03 | H | | H | RB-04 |
| | | Spilling | P05 | n/a | | n/a | RB-05 |
| Intact Steam Line | C02 | Critical Flow | P01 | n/a | | n/a | RB-06 |
| | | Subcritical Flow | P02 | H | | H | RB-07 |
| | | Entrainment | P03 | H | | H | RB-129 |
| | | Inventory Depletion | P04 | n/a | | n/a | RB-08 |
| DPV (ADS) | C03 | Critical Flow | P01 | n/a | | n/a | RB-09 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Spilling | P05 | n/a | | n/a | |
| SRV (ADS) | C04 | Critical Flow | P01 | n/a | | n/a | RB-09 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| Turbine Stop Valve | C05 | Subcritical Flow | P06 | H | | H | RB-07 |
| Turbine Bypass Flow Valve | | Critical Flow | P06 | H | | H | |
| Feedwater Flow; CRD Flow | C06 | Flow/BC | P07 | H | | H | RB-10 |
| Core | C07 | Parallel Channel Flow Distribution | P08 | L | M | M | RB-11 |
| | | Pressure Drop 2-Phase | P09 | L | L | L | RB-12 |
| | | Flashing | P10 | H | H | H | RB-13 |
| | | Evaporation | P11 | H | M | H* | RB-14 |
| | | Void Distribution | P12 | H | M | H* | RB-15 |
| | | Core Power: Critical/Decay | P13 | H | | H | RB-16 |
| | | Heat Transfer Coefficient | P14 | L | M | M | RB-17 |
| | | Fuel Stored Energy | P15 | M | M | M | RB-18 |
| | | Structure Stored Energy | P16 | L | | L | RB-19 |
| | | Internal Flow Circulation | P17 | L | L | L | RB-20 |

Table B.2-6 (continued)

| Break: Bottom Drain Line Break; | | Event Phase: Pre-Isolation | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank BNL | Rank Consultants | Rank Final | Ranking Rationale |
| Chimney | C08 | Flashing | P10 | H | L | H* | RB-21 |
| | | Level/Void Distribution | P18 | H | M | H* | RB-15 |
| | | Structure Stored Energy | P16 | L | | L | RB-22 |
| Separator/Dryer | C09 | Phase Separation | P19 | H | M | H* | RB-23 |
| | | Friction - Two Phase | P20 | L | | L | RB-24 |
| | | Structure Stored Energy | P16 | L | | L | RB-25 |
| | | Flooding | P21 | M | | M | RB-26 |
| Downcomer | C10 | Fluid Mixing | P22 | M | M | M | RB-27 |
| | | Flashing | P10 | H | H | H | RB-28 |
| | | Level/Void Distribution | P18 | H | H | H | RB-28 |
| | | Direct Contact Condensation | P23 | M | M | M | RB-29 |
| | | Structure Stored Energy | P16 | L | M | M | RB-30 |
| | | Entrainment | P24 | H | | H | RB-28 |
| Lower Plenum | C11 | Fluid Mixing | P22 | L | | L | RB-31 |
| | | Flashing | P10 | H | | H | RB-32 |
| | | Structure Stored Energy | P16 | L | | L | RB-33 |
| | | Void Distribution | P12 | H | | H | RB-32 |
| Isolation Condenser | C12 | Condensation Inside tubes | P25 | n/a | | n/a | RB-09 |
| | | Pool side heat transfer | P26 | n/a | | n/a | |
| | | Natural circulation | P27 | n/a | | n/a | |
| | | Degradation of condensation due to NCs | P28 | n/a | | n/a* | |

Table B.2-6 (continued)

Break: Bottom Drain Line Break; Event Phase: Pre-Isolation

| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
|---|---|---|---|---|---|---|---|
| **Containment** | | | | | | | |
| Dry Well | C13 | Non-Condensibles Amount | P31 | H | H | H | RB-34 |
| | | Non-Condensibles Distribution | P32 | H | | H | RB-34 |
| | | Condensation on wall with NC present | P33 | H | | H | RB-34 |
| | | Water Accumulation | P34 | L | | L | RB-35 |
| | | Transient Conduction in Structures | P35 | H | H | H | RB-34 |
| | | Non-Equilibrium Mixing of $N_2$ & Steam | P36 | H | H | H | RB-36 |
| | | Surface Condensation (on Liquid Surfaces) | P37 | H | H | H | RB-34 |
| Horizontal Vent | C14 | Horizontal Vent Clearing | P38 | L | | L | RB-37 |
| Suppression Pool | C15 | Suppression Pool Heat & MassTransfer | P39 | L | | L | RB-37 |
| | | Condensation for SRV Sparger flow | P40 | n/a | | n/a | |
| | | Condensation with NC for PCC purge line flow | P41 | L | | L | |
| | | Temperature Stratification | P42 | L | | L | |
| Suppression Chamber | C16 | Non-Condensibles Amount | P31 | L | | L | RB-37 |
| | | Non-Condensibles Distribution | P32 | L | | L | |
| | | Condensation on wall with NC present | P33 | L | | L | |
| | | Heat and Mass transfer at pool surface | P43 | L | | L | |
| GDCS | C17 | Friction/Form Losses | P44 | n/a | | n/a | RB-09 |
| | | Hydrostatic Head | P45 | n/a | | n/a | |
| | | Pressure Difference from GDCS Tanks to RPV | P46 | n/a | | n/a | |
| PCCS Heat Exchanger | C18 | Condensation inside tubes | P25 | L | | L | RB-37 |
| | | Pool side heat transfer | P26 | L | | L | |
| | | Natural Circulation | P27 | L | | L | |
| | | Degradation of condensation due to NCs | P28 | L | | L | |
| | | Accumulation of NCs in tubes | P47 | L | | L | |
| | | Submergence | P48 | L | | L | |
| | | Condensate Draining | P49 | L | | L | |
| Vacuum Breakers (VB) | C19 | Friction and form losses for Steam & NCs | P50 | n/a | | n/a | RB-09 |
| | | Pressure Drop across VB | P51 | n/a | | n/a | |
| Equalization Lines | C20 | Flow | P52 | n/a | | n/a | RB-09 |

**Table B.2-7 PIRT for the Isolation Phase of a Bottom Drain Line Break**

| Break: Bottom Drain Line Break; | | Event Phase: Isolation | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Reactor** | | | | | | | |
| Break No 1 (Lower Break) | C01 | Critical Flow | P01 | H | | H | RB-01 |
| | | Subcritical Flow | P02 | n/a | | n/a | RB-02 |
| | | Entrainment | P03 | L | | L | RB-03 |
| | | Spilling | P05 | n/a | | n/a | RB-130 |
| Break No 2 (Upper Break) | C01 | Critical Flow | P01 | H | | H | RB-01 |
| | | Subcritical Flow | P02 | n/a | | n/a | RB-02 |
| | | Entrainment | P03 | H | | H | RB-04 |
| | | Spilling | P05 | n/a | | n/a | RB-05 |
| Intact Steam Line | C02 | Critical Flow | P01 | n/a | | n/a | RB-09 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Inventory Depletion | P04 | n/a | | n/a | |
| DPV (ADS) | C03 | Critical Flow | P01 | n/a | | n/a | RB-09 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Spilling | P05 | n/a | | n/a | |
| SRV (ADS) | C04 | Critical Flow | P01 | n/a | | n/a | RB-09 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| Turbine Stop Valve | C05 | Subcritical Flow | P06 | n/a | | n/a | RB-09 |
| Turbine Bypass Flow Valve | | Critical Flow | P06 | n/a | | n/a | |
| Feedwater Flow; CRD Flow | C06 | Flow/BC | P07 | H | | H | RB-38 |
| Core | C07 | Parallel Channel Flow Distribution | P08 | L | M | M | RB-39 |
| | | Pressure Drop 2-Phase | P09 | L | L | L | RB-12 |
| | | Flashing | P10 | M | L | M | RB-40 |
| | | Evaporation | P11 | L | L | L | RB-41 |
| | | Void Distribution | P12 | M | L | M | RB-40 |
| | | Core Power: Critical/Decay | P13 | H | H | H | RB-16 |
| | | Heat Transfer Coefficient | P14 | L | L | L | RB-42 |
| | | Fuel Stored Energy | P15 | M | L | M | RB-43 |
| | | Structure Stored Energy | P16 | L | L | L | RB-44 |
| | | Internal Flow Circulation | P17 | L | | L | RB-20 |

**Table B.2-7 (continued)**

| Break: Bottom Drain Line Break; | | Event Phase: Isolation | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| Chimney | C08 | Flashing | P10 | M | L | M | RB-45 |
| | | Level/Void Distribution | P18 | M | L | M | RB-45 |
| | | Structure Stored Energy | P16 | L | L | L | RB-44 |
| Separator/Dryer | C09 | Phase Separation | P19 | L | | L | RB-46 |
| | | Friction - Two Phase | P20 | L | | L | |
| | | Structure Stored Energy | P16 | L | | L | |
| | | Flooding | P21 | L | | L | |
| Downcomer | C10 | Fluid Mixing | P22 | H | L | H* | RB-47 |
| | | Flashing | P10 | M | L | M | RB-48 |
| | | Level/Void Distribution | P18 | M | L | M | RB-48 |
| | | Direct Contact Condensation | P23 | H | L | H* | RB-47 |
| | | Structure Stored Energy | P16 | L | L | L | RB-49 |
| | | Entrainment | P24 | H | | H | RB-50 |
| Lower Plenum | C11 | Fluid Mixing | P22 | L | | L | RB-51 |
| | | Flashing | P10 | M | | M | RB-52 |
| | | Structure Stored Energy | P16 | L | | L | RB-49 |
| | | Void Distribution | P12 | M | L | M | RB-52 |
| Isolation Condenser | C12 | Condensation inside tubes | P25 | H | | H | RB-53 |
| | | Pool side heat transfer | P26 | H | H | H* | RB-53 |
| | | Natural circulation | P27 | H | | H | RB-53 |
| | | Degradation of condensation due to NCs | P28 | L | M | M* | RB-54 |

Table B.2-7 (continued)

| Break: Bottom Drain Line Break; | | Event Phase: Isolation . | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Containment** | | | | | | | |
| Dry Well | C13 | Non-Condensibles Amount | P31 | L | | L | RB-55 |
| | | Non-Condensibles Distribution | P32 | L | | L | |
| | | Condensation on wall with NC present | P33 | L | | L | |
| | | Water Accumulation | P34 | L | | L | |
| | | Transient Conduction in Structures | P35 | L | | L | |
| | | Non-Equilibrium Mixing of $N_2$ & Steam | P36 | L | | L | |
| | | Surface Condensation (on Liquid Surfaces) | P37 | L | | L | |
| Horizontal Vent | C14 | Horizontal Vent Clearing | P38 | L | | L | RB-55 |
| Suppression Pool | C15 | Suppression Pool Heat & MassTransfer | P39 | L | | L | RB-55 |
| | | Condensation for SRV Sparger flow | P40 | n/a | | n/a | RB-09 |
| | | Condensation with NC for PCC purge line flow | P41 | L | | L | RB-55 |
| | | Temperature Stratification | P42 | L | | L | RB-55 |
| Suppression Chamber | C16 | Non-Condensibles Amount | P31 | L | | L | RB-55 |
| | | Non-Condensibles Distribution | P32 | L | | L | |
| | | Condensation on wall with NC present | P33 | L | | L | |
| | | Heat and Mass transfer at pool surface | P43 | L | | L | |
| GDCS | C17 | Friction/Form Losses | P44 | n/a | | n/a | RB-09 |
| | | Hydrostatic Head | P45 | n/a | | n/a | |
| | | Pressure Difference from GDCS Tanks to RPV | P46 | n/a | | n/a | |
| PCCS Heat Exchanger | C18 | Condensation inside tubes | P25 | L | | L | RB-55 |
| | | Pool side heat transfer | P26 | L | | L | |
| | | Natural Circulation | P27 | L | | L | |
| | | Degradation of condensation due to NCs | P28 | L | | L | |
| | | Accumulation of NCs in tubes | P47 | L | | L | |
| | | Submergence | P48 | L | | L | |
| | | Condensate Draining | P49 | L | | L | |
| Vacuum Breakers (VB) | C19 | Friction and form losses for Steam & NCs | P50 | n/a | | n/a | RB-09 |
| | | Pressure Drop across VB | P51 | n/a | | n/a | |
| Equalization Lines | C20 | Flow | P52 | n/a | | n/a | RB-09 |

**Table B.2-8 PIRT for the Depressurization Phase of a Bottom Drain Line Break**

| Break: Bottom Drain Line Break; | | Event Phase: Depressurization | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Reactor** | | | | | | | |
| Break No 1 (Lower Break) | C01 | Critical Flow | P01 | M | L | M | RB-56 |
| | | Subcritical Flow | P02 | M | L | M | RB-56 |
| | | Entrainment | P03 | L | | L | RB-03 |
| | | Spilling | P05 | n/a | | n/a | RB-130 |
| Break No 2 (Upper Break) | C01 | Critical Flow | P01 | M | | M | RB-56 |
| | | Subcritical Flow | P02 | M | | M | RB-56 |
| | | Entrainment | P03 | M | | M | RB-56 |
| | | Spilling | P05 | n/a | | n/a | RB-05 |
| Intact Steam Line | C02 | Critical Flow | P01 | n/a | | n/a | RB-09 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Inventory Depletion | P04 | n/a | | n/a | |
| DPV (ADS) | C03 | Critical Flow | P01 | H | | H | RB-57 |
| | | Subcritical Flow | P02 | H | | H | RB-57 |
| | | Entrainment | P03 | H | M | H* | RB-58 |
| | | Spilling | P05 | n/a | | n/a | RB-05 |
| SRV (ADS) | C04 | Critical Flow | P01 | H | | H | RB-57 |
| | | Subcritical Flow | P02 | M | | M | RB-59 |
| | | Entrainment | P03 | L | | L | RB-60 |
| Turbine Stop Valve | C05 | Subcritical Flow | P06 | n/a | | n/a | RB-09 |
| Turbine Bypass Flow Valve | | Critical Flow | P06 | n/a | | n/a | |
| Feedwater Flow; CRD Flow | C06 | Flow/BC | P07 | n/a | | n/a | RB-09 |
| Core | C07 | Parallel Channel Flow Distribution | P08 | M | L | M | RB-61 |
| | | Pressure Drop 2-Phase | P09 | M | L | M | RB-62 |
| | | Flashing | P10 | H | M | H* | RB-63 |
| | | Evaporation | P11 | L | L | L | RB-41 |
| | | Void Distribution | P12 | H | L | H* | RB-63 |
| | | Core Power: Critical/Decay | P13 | H | | H | RB-16 |
| | | Heat Transfer Coefficient | P14 | L | L | L | RB-42 |
| | | Fuel Stored Energy | P15 | M | L | M | RB-64 |
| | | Structure Stored Energy | P16 | M | L | M | RB-64 |
| | | Internal Flow Circulation | P17 | M | | M | RB-61 |

**Table B.2-8 (continued)**

| Break: Bottom Drain Line Break; | | Event Phase: Depressurization | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| Chimney | C08 | Flashing | P10 | H | L | H* | RB-65 |
| | | Level/Void Distribution | P18 | H | L | H* | RB-65 |
| | | Structure Stored Energy | P16 | M | L | M | RB-66 |
| Separator/Dryer | C09 | Phase Separation | P19 | H | L | H* | RB-67 |
| | | Friction - Two Phase | P20 | M | L | M | RB-68 |
| | | Structure Stored Energy | P16 | M | L | M | RB-66 |
| | | Flooding | P21 | M | L | M | RB-69 |
| Downcomer | C10 | Fluid Mixing | P22 | M | | M | RB-70 |
| | | Flashing | P10 | H | M | H* | RB-71 |
| | | Level/Void Distribution | P18 | H | L | H* | RB-71 |
| | | Direct Contact Condensation | P23 | M | | M | RB-70 |
| | | Structure Stored Energy | P16 | M | | M | RB-66 |
| | | Entrainment | P24 | M | | M | RB-72 |
| Lower Plenum | C11 | Fluid Mixing | P22 | L | M | M | RB-73 |
| | | Flashing | P10 | H | M | H* | RB-74 |
| | | Structure Stored Energy | P16 | M | M | M | RB-66 |
| | | Void Distribution | P12 | H | M | H* | RB-74 |
| Isolation Condenser | C12 | Condensation inside tubes | P25 | M | | M | RB-75 |
| | | Pool side heat transfer | P26 | M | | M | RB-75 |
| | | Natural circulation | P27 | M | | M | RB-75 |
| | | Degradation of condensation due to NCs | P28 | L | | L* | RB-76 |

Table B.2-8 (continued)

| Break: Bottom Drain Line Break; Event Phase: Depressurization | | | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Containment** | | | | | | | |
| Dry Well | C13 | Non-Condensibles Amount | P31 | M | | M | RB-77 |
| | | Non-Condensibles Distribution | P32 | M | | M | RB-77 |
| | | Condensation on wall with NC present | P33 | M | | M | RB-77 |
| | | Water Accumulation | P34 | M | | M | RB-78 |
| | | Transient Conduction in Structures | P35 | M | | M | RB-77 |
| | | Non-Equilibrium Mixing of $N_2$ & Steam | P36 | L | | L | RB-79 |
| | | Surface Condensation (on Liquid Surfaces) | P37 | M | | M | RB-77 |
| Horizontal Vent | C14 | Horizontal Vent Clearing | P38 | M | | M | RB-80 |
| Suppression Pool | C15 | Suppression Pool Heat & MassTransfer | P39 | M | | M | RB-80 |
| | | Condensation for SRV Sparger flow | P40 | M | M | M | |
| | | Condensation with NC for PCC purge line flow | P41 | M | L | M | |
| | | Temperature Stratification | P42 | M | L | M | |
| Suppression Chamber | C16 | Non-Condensibles Amount | P31 | M | | M | RB-81 |
| | | Non-Condensibles Distribution | P32 | L | L | L | RB-82 |
| | | Condensation on wall with NC present | P33 | L | | L | RB-82 |
| | | Heat and Mass transfer at pool surface | P43 | L | | L | RB-82 |
| GDCS | C17 | Friction/Form Losses | P44 | n/a | | n/a | RB-09 |
| | | Hydrostatic Head | P45 | n/a | | n/a | |
| | | Pressure Difference from GDCS Tanks to RPV | P46 | n/a | | n/a | |
| PCCS Heat Exchanger | C18 | Condensation inside tubes | P25 | L | | L | RB-83 |
| | | Pool side heat transfer | P26 | L | | L | |
| | | Natural Circulation | P27 | L | | L | |
| | | Degradation of condensation due to NCs | P28 | L | | L | |
| | | Accumulation of NCs in tubes | P47 | L | | L | |
| | | Submergence | P48 | L | | L | |
| | | Condensate Draining | P49 | L | | L | |
| Vacuum Breakers (VB) | C19 | Friction and form losses for Steam & NCs | P50 | n/a | | n/a | RB-09 |
| | | Pressure Drop across VB | P51 | n/a | | n/a | |
| Equalization Lines | C20 | Flow | P52 | n/a | | n/a | RB-09 |

**Table B.2-9 PIRT for the GDCS Refill Phase of a Bottom Drain Line Break**

| Break: Bottom Drain Line Break; | | Event Phase: GDCS Refill | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| | | **Reactor** | | | | | |
| Break No 1 (Lower Break) | C01 | Critical Flow | P01 | n/a | | n/a | RB-84 |
| | | Subcritical Flow | P02 | M | | M | RB-85 |
| | | Entrainment | P03 | L | | L | RB-03 |
| | | Spilling | P05 | n/a | | n/a | RB-130 |
| Break No 2 (Upper Break) | C01 | Critical Flow | P01 | n/a | | n/a | RB-84 |
| | | Subcritical Flow | P02 | M | | M | RB-86 |
| | | Entrainment | P03 | n/a | | n/a | RB-87 |
| | | Spilling | P05 | H | | H | RB-88 |
| Intact Steam Line | C02 | Critical Flow | P01 | n/a | | n/a | RB-09 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Inventory Depletion | P04 | n/a | | n/a | |
| DPV (ADS) | C03 | Critical Flow | P01 | n/a | | n/a | RB-84 |
| | | Subcritical Flow | P02 | M | | M | RB-86 |
| | | Entrainment | P03 | n/a | | n/a | RB-87 |
| | | Spilling | P05 | L | | L | RB-89 |
| SRV (ADS) | C04 | Critical Flow | P01 | n/a | | n/a | RB-84 |
| | | Subcritical Flow | P02 | L | | L | RB-90 |
| | | Entrainment | P03 | n/a | | n/a | RB-87 |
| Turbine Stop Valve | C05 | Subcritical Flow | P06 | n/a | | n/a | RB-09 |
| Turbine Bypass Flow Valve | | Critical Flow | P06 | n/a | | n/a | |
| Feedwater Flow; CRD Flow | C06 | Flow/BC | P07 | n/a | | n/a | RB-09 |
| Core | C07 | Parallel Channel Flow Distribution | P08 | L | L | L | RB-91 |
| | | Pressure Drop 2-Phase | P09 | L | | L | RB-91 |
| | | Flashing | P10 | L | | L | RB-91 |
| | | Evaporation | P11 | L | L | L | RB-91 |
| | | Void Distribution | P12 | L | | L | RB-91 |
| | | Core Power: Critical/Decay | P13 | H | | H | RB-16 |
| | | Heat Transfer Coefficient | P14 | L | L | L | RB-92 |
| | | Fuel Stored Energy | P15 | L | | L | RB-93 |
| | | Structure Stored Energy | P16 | L | | L | RB-94 |
| | | Internal Flow Circulation | P17 | L | | L | RB-95 |

**Table B.2-9 (continued)**

| Break: Bottom Drain Line Break; | | Event Phase: GDCS Refill | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| Chimney | C08 | Flashing | P10 | L | | L | RB-96 |
| | | Level/Void Distribution | P18 | L | | L | RB-96 |
| | | Structure Stored Energy | P16 | L | | L | RB-94 |
| Separator/Dryer | C09 | Phase Separation | P19 | L | | L | RB-96 |
| | | Friction - Two Phase | P20 | L | | L | RB-96 |
| | | Structure Stored Energy | P16 | L | | L | RB-94 |
| | | Flooding | P21 | n/a | | n/a | RB-97 |
| Downcomer | C10 | Fluid Mixing | P22 | L | L | L | RB-98 |
| | | Flashing | P10 | L | | L | RB-96 |
| | | Level/Void Distribution | P18 | L | L | L | RB-96 |
| | | Direct Contact Condensation | P23 | L | | L | RB-98 |
| | | Structure Stored Energy | P16 | L | | L | RB-99 |
| | | Entrainment | P24 | L | | L | RB-96 |
| Lower Plenum | C11 | Fluid Mixing | P22 | L | | L | RB-98 |
| | | Flashing | P10 | L | | L | RB-96 |
| | | Structure Stored Energy | P16 | L | | L | RB-99 |
| | | Void Distribution | P12 | L | | L | RB-96 |
| Isolation Condenser | C12 | Condensation inside tubes | P25 | L | | L | RB-100 |
| | | Pool side heat transfer | P26 | L | | L | |
| | | Natural circulation | P27 | L | | L | |
| | | Degradation of condensation due to NCs | P28 | L | | L | |

Table B.2-9 (continued)

| Break: Bottom Drain Line Break; | | Event Phase: GDCS Refill | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Containment** | | | | | | | |
| Dry Well | C13 | Non-Condensibles Amount | P31 | L | | L | RB-101 |
| | | Non-Condensibles Distribution | P32 | L | | L | RB-101 |
| | | Condensation on wall with NC present | P33 | L | | L | RB-102 |
| | | Water Accumulation | P34 | M | | M | RB-78 |
| | | Transient Conduction in Structures | P35 | L | | L | RB-102 |
| | | Non-Equilibrium Mixing of $N_2$ & Steam | P36 | n/a | | n/a | RB-103 |
| | | Surface Condensation (on Liquid Surfaces) | P37 | L | | L | RB-102 |
| Horizontal Vent | C14 | Horizontal Vent Clearing | P38 | n/a | | n/a | RB-104 |
| Suppression Pool | C15 | Suppression Pool Heat & MassTransfer | P39 | L | | L | RB-102 |
| | | Condensation for SRV Sparger flow | P40 | L | | L | RB-105 |
| | | Condensation with NC for PCC purge line flow | P41 | L | | L | RB-102 |
| | | Temperature Stratification | P42 | L | | L | RB-102 |
| Suppression Chamber | C16 | Non-Condensibles Amount | P31 | L | | L | RB-101 |
| | | Non-Condensibles Distribution | P32 | L | | L | RB-102 |
| | | Condensation on wall with NC present | P33 | L | | L | RB-102 |
| | | Heat and Mass transfer at pool surface | P43 | L | | L | RB-102 |
| GDCS | C17 | Friction/Form Losses | P44 | H | | H | RB-106 |
| | | Hydrostatic Head | P45 | H | | H | |
| | | Pressure Difference from GDCS Tanks to RPV | P46 | H | | H | |
| PCCS Heat Exchanger | C18 | Condensation inside tubes | P25 | L | | L | RB-107 |
| | | Pool side heat transfer | P26 | L | | L | |
| | | Natural Circulation | P27 | L | | L | |
| | | Degradation of condensation due to NCs | P28 | L | | L | |
| | | Accumulation of NCs in tubes | P47 | L | | L | |
| | | Submergence | P48 | L | | L | |
| | | Condensate Draining | P49 | L | | L | |
| Vacuum Breakers (VB) | C19 | Friction and form losses for Steam & NCs | P50 | L | | L | RB-108 |
| | | Pressure Drop across VB | P51 | L | | L | |
| Equalization Lines | C20 | Flow | P52 | n/a | | n/a | RB-09 |

**Table B.2-10 PIRT for the Long-Term Cooling Phase of a Bottom Drain Line Break**

| Break: Bottom Drain Line Break; Event Phase: Long Term Cooling | | | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Reactor** | | | | | | | |
| Break No 1 (Lower Break) | C01 | Critical Flow | P01 | n/a | | n/a | RB-84 |
| | | Subcritical Flow | P02 | M | | M | RB-109 |
| | | Entrainment | P03 | n/a | | n/a | RB-110 |
| | | Spilling | P05 | n/a | | n/a | RB-130 |
| Break No 2 (Upper Break) | C01 | Critical Flow | P01 | n/a | | n/a | RB-84 |
| | | Subcritical Flow | P02 | L | | L | RB-111 |
| | | Entrainment | P03 | n/a | | n/a | RB-87 |
| | | Spilling | P05 | H | | H | RB-112 |
| Intact Steam Line | C02 | Critical Flow | P01 | n/a | | n/a | RB-09 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Inventory Depletion | P04 | n/a | | n/a | |
| DPV (ADS) | C03 | Critical Flow | P01 | n/a | | n/a | RB-84 |
| | | Subcritical Flow | P02 | L | | L | RB-111 |
| | | Entrainment | P03 | n/a | | n/a | RB-87 |
| | | Spilling | P05 | n/a | | n/a | RB-113 |
| SRV (ADS) | C04 | Critical Flow | P01 | n/a | | n/a | RB-114 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| Turbine Stop Valve | C05 | Subcritical Flow | P06 | n/a | | n/a | RB-09 |
| Turbine Bypass Flow Valve | | Critical Flow | P06 | n/a | | n/a | |
| Feedwater Flow; CRD Flow | C06 | Flow/BC | P07 | n/a | | n/a | RB-09 |
| Core | C07 | Parallel Channel Flow Distribution | P08 | L | | L | RB-115 |
| | | Pressure Drop 2-Phase | P09 | L | | L | RB-115 |
| | | Flashing | P10 | L | | L | RB-115 |
| | | Evaporation | P11 | L | L | L | RB-115 |
| | | Void Distribution | P12 | L | | L | RB-116 |
| | | Core Power: Critical/Decay | P13 | H | | H | RB-16 |
| | | Heat Transfer Coefficient | P14 | L | L | L | RB-92 |
| | | Fuel Stored Energy | P15 | L | | L | RB-93 |
| | | Structure Stored Energy | P16 | L | | L | RB-94 |
| | | Internal Flow Circulation | P17 | L | L | L | RB-116 |

**Table B.2-10 (continued)**

| Break: Bottom Drain Line Break; | | Event Phase: Long Term Cooling | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| Chimney | C08 | Flashing | P10 | L | | L | RB-96 |
| | | Level/Void Distribution | P18 | L | L | L | RB-96 |
| | | Structure Stored Energy | P16 | L | | L | RB-94 |
| Separator/Dryer | C09 | Phase Separation | P19 | L | | L | RB-96 |
| | | Friction - Two Phase | P20 | L | | L | RB-96 |
| | | Structure Stored Energy | P16 | L | | L | RB-94 |
| | | Flooding | P21 | n/a | | n/a | RB-117 |
| Downcomer | C10 | Fluid Mixing | P22 | L | | L | RB-98 |
| | | Flashing | P10 | L | | L | RB-96 |
| | | Level/Void Distribution | P18 | L | L | L | RB-96 |
| | | Direct Contact Condensation | P23 | L | | L | RB-98 |
| | | Structure Stored Energy | P16 | L | | L | RB-118 |
| | | Entrainment | P24 | L | | L | RB-96 |
| Lower Plenum | C11 | Fluid Mixing | P22 | L | | L | RB-98 |
| | | Flashing | P10 | L | | L | RB-96 |
| | | Structure Stored Energy | P16 | L | | L | RB-118 |
| | | Void Distribution | P12 | L | | L | RB-96 |
| Isolation Condenser | C12 | Condensation inside tubes | P25 | L | | L | RB-100 |
| | | Pool side heat transfer | P26 | L | | L | |
| | | Natural circulation | P27 | L | | L | |
| | | Degradation of condensation due to NCs | P28 | L | | L | |

**Table B.2-10 (continued)**

| Break: Bottom Drain Line Break; Event Phase: Long Term Cooling | | | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Containment** | | | | | | | |
| Dry Well | C13 | Non-Condensibles Amount | P31 | H | | H | RB-119 |
| | | Non-Condensibles Distribution | P32 | H | | H | RB-119 |
| | | Condensation on wall with NC present | P33 | M | | M | RB-120 |
| | | Water Accumulation | P34 | H | | H | RB-121 |
| | | Transient Conduction in Structures | P35 | L | | L | RB-122 |
| | | Non-Equilibrium Mixing of $N_2$ & Steam | P36 | n/a | | n/a | RB-103 |
| | | Surface Condensation (on Liquid Surfaces) | P37 | M | | M | RB-120 |
| Horizontal Vent | C14 | Horizontal Vent Clearing | P38 | n/a | | n/a | RB-104 |
| Suppression Pool | C15 | Suppression Pool Heat & MassTransfer | P39 | L | | L | RB-123 |
| | | Condensation for SRV Sparger flow | P40 | L | | L | |
| | | Condensation with NC for PCC purge line flow | P41 | L | | L | |
| | | Temperature Stratification | P42 | L | | L | |
| Suppression Chamber | C16 | Non-Condensibles Amount | P31 | H | | H | RB-119 |
| | | Non-Condensibles Distribution | P32 | M | | M | RB-124 |
| | | Condensation on wall with NC present | P33 | L | | L | RB-125 |
| | | Heat and Mass transfer at pool surface | P43 | L | | L | RB-125 |
| GDCS | C17 | Friction/Form Losses | P44 | L | L | L | RB-126 |
| | | Hydrostatic Head | P45 | L | L | L | |
| | | Pressure Difference from GDCS Tanks to RPV | P46 | L | L | L | |
| PCCS Heat Exchanger | C18 | Condensation inside tubes | P25 | H | | H | RB-127 |
| | | Pool side heat transfer | P26 | H | | H | |
| | | Natural Circulation | P27 | H | | H | |
| | | Degradation of condensation due to NCs | P28 | H | | H | |
| | | Accumulation of NCs in tubes | P47 | H | | H | |
| | | Submergence | P48 | H | | H | |
| | | Condensate Draining | P49 | H | | H | |
| Vacuum Breakers (VB) | C19 | Friction and form losses for Steam & NCs | P50 | H | | H | RB-119 |
| | | Pressure Drop across VB | P51 | H | | H | |
| Equalization Lines | C20 | Flow | P52 | H | | H | RB-128 |

### Table B.2-11 PIRT for the Pre-Isolation Phase of a GDCS Line Break

| Break: GDCS Line Break; | | Event Phase: Pre-Isolation | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Reactor** | | | | | | | |
| Break No 1 | C01 | Critical Flow | P01 | H | | H | RB-01 |
| | | Subcritical Flow | P02 | n/a | | n/a | RB-02 |
| | | Entrainment | P03 | H | | H | RB-04 |
| | | Spilling | P05 | n/a | | n/a | RB-05 |
| Break No 2 | C01 | Critical Flow | P01 | n/a | | n/a | RG-01 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Spilling | P05 | n/a | | n/a | |
| Intact Steam Line | C02 | Critical Flow | P01 | n/a | | n/a | RB-06 |
| | | Subcritical Flow | P02 | H | | H | RB-07 |
| | | Entrainment | P03 | H | | H | RB-129 |
| | | Inventory Depletion | P04 | n/a | | n/a | RB-08 |
| DPV (ADS) | C03 | Critical Flow | P01 | n/a | | n/a | RB-09 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Spilling | P05 | n/a | | n/a | |
| SRV (ADS) | C04 | Critical Flow | P01 | n/a | | n/a | RB-09 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| Turbine Stop Valve | C05 | Subcritical Flow | P06 | H | | H | RB-07 |
| Turbine Bypass Flow Valve | | Critical Flow | P06 | H | | H | |
| Feedwater Flow; CRD Flow | C06 | Flow/BC | P07 | H | | H | RB-10 |
| Core | C07 | Parallel Channel Flow Distribution | P08 | L | M | M | RB-11 |
| | | Pressure Drop 2-Phase | P09 | L | L | L | RB-12 |
| | | Flashing | P10 | H | H | H | RB-13 |
| | | Evaporation | P11 | H | M | H* | RB-14 |
| | | Void Distribution | P12 | H | M | H* | RB-15 |
| | | Core Power: Critical/Decay | P13 | H | | H | RB-16 |
| | | Heat Transfer Coefficient | P14 | L | M | M | RB-17 |
| | | Fuel Stored Energy | P15 | M | M | M | RB-18 |
| | | Structure Stored Energy | P16 | L | | L | RB-19 |
| | | Internal Flow Circulation | P17 | L | L | L | RB-20 |

**Table B.2-11 (continued)**

| Break: GDCS Line Break; | Event Phase: Pre-Isolation | | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| Chimney | C08 | Flashing | P10 | H | L | H* | RB-21 |
| | | Level/Void Distribution | P18 | H | M | H* | RB-15 |
| | | Structure Stored Energy | P16 | L | | L | RB-22 |
| Separator/Dryer | C09 | Phase Separation | P19 | H | M | H* | RB-23 |
| | | Friction - Two Phase | P20 | L | | L | RB-24 |
| | | Structure Stored Energy | P16 | L | | L | RB-25 |
| | | Flooding | P21 | M | | M | RB-26 |
| Downcomer | C10 | Fluid Mixing | P22 | M | M | M | RB-27 |
| | | Flashing | P10 | H | H | H | RB-28 |
| | | Level/Void Distribution | P18 | H | H | H | RB-28 |
| | | Direct Contact Condensation | P23 | M | M | M | RB-29 |
| | | Structure Stored Energy | P16 | L | M | M | RB-30 |
| | | Entrainment | P24 | H | | H | RB-28 |
| Lower Plenum | C11 | Fluid Mixing | P22 | L | | L | RB-31 |
| | | Flashing | P10 | H | | H | RG-32 |
| | | Structure Stored Energy | P16 | L | | L | RB-33 |
| | | Void Distribution | P12 | H | | H | RG-32 |
| Isolation Condenser | C12 | Condensation inside tubes | P25 | n/a | | n/a | RB-09 |
| | | Pool side heat transfer | P26 | n/a | | n/a | |
| | | Natural circulation | P27 | n/a | | n/a | |
| | | Degradation of condensation due to NCs | P28 | n/a | | n/a | |

Table B.2-11 (continued)

| Break: GDCS Line Break; Event Phase: Pre-Isolation | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank BNL | Rank Consultants | Rank Final | Ranking Rationale |
| **Containment** | | | | | | | |
| Dry Well | C13 | Non-Condensibles Amount | P31 | H | H | H | RB-34 |
| | | Non-Condensibles Distribution | P32 | H | | H | RB-34 |
| | | Condensation on wall with NC present | P33 | H | | H | RB-34 |
| | | Water Accumulation | P34 | L | | L | RG-35 |
| | | Transient Conduction in Structures | P35 | H | H | H | RB-34 |
| | | Non-Equilibrium Mixing of $N_2$ & Steam | P36 | H | H | H | RB-36 |
| | | Surface Condensation (on Liquid Surfaces) | P37 | H | H | H | RB-34 |
| Horizontal Vent | C14 | Horizontal Vent Clearing | P38 | L | | L | RB-37 |
| Suppression Pool | C15 | Suppression Pool Heat & MassTransfer | P39 | L | | L | RB-37 |
| | | Condensation for SRV Sparger flow | P40 | n/a | | n/a | |
| | | Condensation with NC for PCC purge line flow | P41 | L | | L | |
| | | Temperature Stratification | P42 | L | | L | |
| Suppression Chamber | C16 | Non-Condensibles Amount | P31 | L | | L | RB-37 |
| | | Non-Condensibles Distribution | P32 | L | | L | |
| | | Condensation on wall with NC present | P33 | L | | L | |
| | | Heat and Mass transfer at pool surface | P43 | L | | L | |
| GDCS | C17 | Friction/Form Losses | P44 | n/a | | n/a | RB-09 |
| | | Hydrostatic Head | P45 | n/a | | n/a | |
| | | Pressure Difference from GDCS Tanks to RPV | P46 | n/a | | n/a | |
| PCCS Heat Exchanger | C18 | Condensation inside tubes | P25 | L | | L | RB-37 |
| | | Pool side heat transfer | P26 | L | | L | |
| | | Natural Circulation | P27 | L | | L | |
| | | Degradation of condensation due to NCs | P28 | L | | L | |
| | | Accumulation of NCs in tubes | P47 | L | | L | |
| | | Submergence | P48 | L | | L | |
| | | Condensate Draining | P49 | L | | L | |
| Vacuum Breakers (VB) | C19 | Friction and form losses for Steam & NCs | P50 | n/a | | n/a | RB-09 |
| | | Pressure Drop across VB | P51 | n/a | | n/a | |
| Equalization Lines | C20 | Flow | P52 | n/a | | n/a | RB-09 |

**Table B.2-12 PIRT for the Isolation Phase of a GDCS Line Break**

| Break: GDCS Line Break; | | Event Phase: Isolation | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Reactor** | | | | | | | |
| Break No 1 | C01 | Critical Flow | P01 | H | | H | RB-01 |
| | | Subcritical Flow | P02 | n/a | | n/a | RB-02 |
| | | Entrainment | P03 | H | | H | RB-04 |
| | | Spilling | P05 | n/a | | n/a | RB-05 |
| Break No 2 | C01 | Critical Flow | P01 | n/a | | n/a | RG-01 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Spilling | P05 | n/a | | n/a | |
| Intact Steam Line | C02 | Critical Flow | P01 | n/a | | n/a | RB-09 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Inventory Depletion | P04 | n/a | | n/a | |
| DPV (ADS) | C03 | Critical Flow | P01 | n/a | | n/a | RB-09 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Spilling | P05 | n/a | | n/a | |
| SRV (ADS) | C04 | Critical Flow | P01 | n/a | | n/a | RB-09 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| Turbine Stop Valve | C05 | Subcritical Flow | P06 | n/a | | n/a | RB-09 |
| Turbine Bypass Flow Valve | | Critical Flow | P06 | n/a | | n/a | |
| Feedwater Flow; CRD Flow | C06 | Flow/BC | P07 | H | | H | RB-38 |
| Core | C07 | Parallel Channel Flow Distribution | P08 | L | M | M | RB-39 |
| | | Pressure Drop 2-Phase | P09 | L | L | L | RB-12 |
| | | Flashing | P10 | M | L | M | RB-40 |
| | | Evaporation | P11 | L | L | L | RB-41 |
| | | Void Distribution | P12 | M | L | M | RB-40 |
| | | Core Power: Critical/Decay | P13 | H | H | H | RB-16 |
| | | Heat Transfer Coefficient | P14 | L | L | L | RB-42 |
| | | Fuel Stored Energy | P15 | M | L | M | RB-43 |
| | | Structure Stored Energy | P16 | L | L | L | RB-44 |
| | | Internal Flow Circulation | P17 | L | | L | RB-20 |

Table B.2-12 (continued)

| Break: GDCS Line Break; | | Event Phase: Isolation | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| Chimney | C08 | Flashing | P10 | M | L | M | RB-45 |
| | | Level/Void Distribution | P18 | M | L | M | RB-45 |
| | | Structure Stored Energy | P16 | L | L | L | RB-44 |
| Separator/Dryer | C09 | Phase Separation | P19 | L | | L | RB-46 |
| | | Friction - Two Phase | P20 | L | | L | |
| | | Structure Stored Energy | P16 | L | | L | |
| | | Flooding | P21 | L | | L | |
| Downcomer | C10 | Fluid Mixing | P22 | H | L | H* | RB-47 |
| | | Flashing | P10 | M | L | M | RB-48 |
| | | Level/Void Distribution | P18 | M | L | M | RB-48 |
| | | Direct Contact Condensation | P23 | H | L | H* | RB-47 |
| | | Structure Stored Energy | P16 | L | L | L | RB-49 |
| | | Entrainment | P24 | H | | H | RB-50 |
| Lower Plenum | C11 | Fluid Mixing | P22 | L | | L | RB-51 |
| | | Flashing | P10 | M | | M | RG-52 |
| | | Structure Stored Energy | P16 | L | | L | RB-49 |
| | | Void Distribution | P12 | M | L | M | RG-52 |
| Isolation Condenser | C12 | Condensation inside tubes | P25 | H | | H | RB-53 |
| | | Pool side heat transfer | P26 | H | H | H* | RB-53 |
| | | Natural circulation | P27 | H | | H | RB-53 |
| | | Degradation of condensation due to NCs | P28 | L | M | M | RB-54 |

Table B.2-12 (continued)

| Break: GDCS Line Break; Event Phase: Isolation | | | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Containment** | | | | | | | |
| Dry Well | C13 | Non-Condensibles Amount | P31 | L | | L | RB-55 |
| | | Non-Condensibles Distribution | P32 | L | | L | |
| | | Condensation on wall with NC present | P33 | L | | L | |
| | | Water Accumulation | P34 | L | | L | |
| | | Transient Conduction in Structures | P35 | L | | L | |
| | | Non-Equilibrium Mixing of $N_2$ & Steam | P36 | L | | L | |
| | | Surface Condensation (on Liquid Surfaces) | P37 | L | | L | |
| Horizontal Vent | C14 | Horizontal Vent Clearing | P38 | L | | L | RB-55 |
| Suppression Pool | C15 | Suppression Pool Heat & MassTransfer | P39 | L | | L | RB-55 |
| | | Condensation for SRV Sparger flow | P40 | n/a | | n/a | RB-09 |
| | | Condensation with NC for PCC purge line flow | P41 | L | | L | RB-55 |
| | | Temperature Stratification | P42 | L | | L | RB-55 |
| Suppression Chamber | C16 | Non-Condensibles Amount | P31 | L | | L | RB-55 |
| | | Non-Condensibles Distribution | P32 | L | | L | |
| | | Condensation on wall with NC present | P33 | L | | L | |
| | | Heat and Mass transfer at pool surface | P43 | L | | L | |
| GDCS | C17 | Friction/Form Losses | P44 | n/a | | n/a | RB-09 |
| | | Hydrostatic Head | P45 | n/a | | n/a | |
| | | Pressure Difference from GDCS Tanks to RPV | P46 | n/a | | n/a | |
| PCCS Heat Exchanger | C18 | Condensation inside tubes | P25 | L | | L | RB-55 |
| | | Pool side heat transfer | P26 | L | | L | |
| | | Natural Circulation | P27 | L | | L | |
| | | Degradation of condensation due to NCs | P28 | L | | L | |
| | | Accumulation of NCs in tubes | P47 | L | | L | |
| | | Submergence | P48 | L | | L | |
| | | Condensate Draining | P49 | L | | L | |
| Vacuum Breakers (VB) | C19 | Friction and form losses for Steam & NCs | P50 | n/a | | n/a | RB-09 |
| | | Pressure Drop across VB | P51 | n/a | | n/a | |
| Equalization Lines | C20 | Flow | P52 | n/a | | n/a | RB-09 |

Table B.2-13 PIRT for the Depressurization Phase of a GDCS Line Break

| Break: GDCS Line Break; | Event Phase: Depressurization | | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Reactor** | | | | | | | |
| Break No 1 | C01 | Critical Flow | P01 | M | | M | RB-56 |
| | | Subcritical Flow | P02 | M | | M | RB-56 |
| | | Entrainment | P03 | M | | M | RB-56 |
| | | Spilling | P05 | n/a | | n/a | RB-05 |
| Break No 2 | C01 | Critical Flow | P01 | n/a | | n/a | RG-01 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Spilling | P05 | n/a | | n/a | |
| Intact Steam Line | C02 | Critical Flow | P01 | n/a | | n/a | RB-09 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Inventory Depletion | P04 | n/a | | n/a | |
| DPV (ADS) | C03 | Critical Flow | P01 | H | | H | RB-57 |
| | | Subcritical Flow | P02 | H | | H | RB-57 |
| | | Entrainment | P03 | H | M | H* | RB-58 |
| | | Spilling | P05 | n/a | | n/a | RB-05 |
| SRV (ADS) | C04 | Critical Flow | P01 | H | | H | RB-57 |
| | | Subcritical Flow | P02 | M | | M | RB-59 |
| | | Entrainment | P03 | L | | L | RB-60 |
| Turbine Stop Valve | C05 | Subcritical Flow | P06 | n/a | | n/a | RB-09 |
| Turbine Bypass Flow Valve | | Critical Flow | P06 | n/a | | n/a | |
| Feedwater Flow; CRD Flow | C06 | Flow/BC | P07 | n/a | | n/a | RB-09 |
| Core | C07 | Parallel Channel Flow Distribution | P08 | M | L | M | RB-61 |
| | | Pressure Drop 2-Phase | P09 | M | L | M | RB-62 |
| | | Flashing | P10 | H | M | H* | RB-63 |
| | | Evaporation | P11 | L | L | L | RB-41 |
| | | Void Distribution | P12 | H | L | H* | RB-63 |
| | | Core Power: Critical/Decay | P13 | H | | H | RB-16 |
| | | Heat Transfer Coefficient | P14 | L | L | L | RB-42 |
| | | Fuel Stored Energy | P15 | M | L | M | RB-64 |
| | | Structure Stored Energy | P16 | M | L | M | RB-64 |
| | | Internal Flow Circulation | P17 | M | | M | RB-61 |

**Table B.2-13 (continued)**

| Break: GDCS Line Break; | | Event Phase: Depressurization | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| Chimney | C08 | Flashing | P10 | H | L | H* | RB-65 |
| | | Level/Void Distribution | P18 | H | L | H* | RB-65 |
| | | Structure Stored Energy | P16 | M | L | M | RB-66 |
| Separator/Dryer | C09 | Phase Separation | P19 | H | L | H* | RB-67 |
| | | Friction - Two Phase | P20 | M | L | M | RB-68 |
| | | Structure Stored Energy | P16 | M | L | M | RB-66 |
| | | Flooding | P21 | M | L | M | RB-69 |
| Downcomer | C10 | Fluid Mixing | P22 | M | | M | RB-70 |
| | | Flashing | P10 | H | M | H* | RB-71 |
| | | Level/Void Distribution | P18 | H | L | H* | RB-71 |
| | | Direct Contact Condensation | P23 | M | | M | RB-70 |
| | | Structure Stored Energy | P16 | M | | M | RB-66 |
| | | Entrainment | P24 | M | | M | RB-72 |
| Lower Plenum | C11 | Fluid Mixing | P22 | L | M | M | RB-73 |
| | | Flashing | P10 | M | M | M | RG-74 |
| | | Structure Stored Energy | P16 | M | M | M | RB-66 |
| | | Void Distribution | P12 | M | M | M | RG-74 |
| Isolation Condenser | C12 | Condensation inside tubes | P25 | M | | M | RB-75 |
| | | Pool side heat transfer | P26 | M | | M | RB-75 |
| | | Natural circulation | P27 | M | | M | RB-75 |
| | | Degradation of condensation due to NCs | P28 | L | | L | RB-76 |

**Table B.2-13 (continued)**

| Break: GDCS Line Break; | | Event Phase: Depressurization | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Containment** | | | | | | | |
| Dry Well | C13 | Non-Condensibles Amount | P31 | M | | M | RB-77 |
| | | Non-Condensibles Distribution | P32 | M | | M | RB-77 |
| | | Condensation on wall with NC present | P33 | M | | M | RB-77 |
| | | Water Accumulation | P34 | M | | M | RG-78 |
| | | Transient Conduction in Structures | P35 | M | | M | RB-77 |
| | | Non-Equilibrium Mixing of $N_2$ & Steam | P36 | L | | L | RB-79 |
| | | Surface Condensation (on Liquid Surfaces) | P37 | M | | M | RB-77 |
| Horizontal Vent | C14 | Horizontal Vent Clearing | P38 | M | | M | RB-80 |
| Suppression Pool | C15 | Suppression Pool Heat & MassTransfer | P39 | M | | M | RB-80 |
| | | Condensation for SRV Sparger flow | P40 | M | M | M | |
| | | Condensation with NC for PCC purge line flow | P41 | M | L | M | |
| | | Temperature Stratification | P42 | M | L | M | |
| Suppression Chamber | C16 | Non-Condensibles Amount | P31 | M | | M | RB-81 |
| | | Non-Condensibles Distribution | P32 | L | L | L | RB-82 |
| | | Condensation on wall with NC present | P33 | L | | L | RB-82 |
| | | Heat and Mass transfer at pool surface | P43 | L | | L | RB-82 |
| GDCS | C17 | Friction/Form Losses | P44 | n/a | | n/a | RB-09 |
| | | Hydrostatic Head | P45 | n/a | | n/a | |
| | | Pressure Difference from GDCS Tanks to RPV | P46 | n/a | | n/a | |
| PCCS Heat Exchanger | C18 | Condensation inside tubes | P25 | L | | L | RB-83 |
| | | Pool side heat transfer | P26 | L | | L | |
| | | Natural Circulation | P27 | L | | L | |
| | | Degradation of condensation due to NCs | P28 | L | | L | |
| | | Accumulation of NCs in tubes | P47 | L | | L | |
| | | Submergence | P48 | L | | L | |
| | | Condensate Draining | P49 | L | | L | |
| Vacuum Breakers (VB) | C19 | Friction and form losses for Steam & NCs | P50 | n/a | | n/a | RB-09 |
| | | Pressure Drop across VB | P51 | n/a | | n/a | |
| Equalization Lines | C20 | Flow | P52 | n/a | | n/a | RB-09 |

**Table B.2-14 PIRT for the GDCS Refill Phase of a GDCS Line Break**

| Break: GDCS Line Break; | | Event Phase: GDCS Refill | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Reactor** | | | | | | | |
| Break No 1 | C01 | Critical Flow | P01 | n/a | | n/a | RB-84 |
| | | Subcritical Flow | P02 | M | | M | RB-86 |
| | | Entrainment | P03 | n/a | | n/a | RB-87 |
| | | Spilling | P05 | H | | H | RB-88 |
| Break No 2 | C01 | Critical Flow | P01 | n/a | | n/a | RG-01 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Spilling | P05 | n/a | | n/a | |
| Intact Steam Line | C02 | Critical Flow | P01 | n/a | | n/a | RB-09 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Inventory Depletion | P04 | n/a | | n/a | |
| DPV (ADS) | C03 | Critical Flow | P01 | n/a | | n/a | RB-84 |
| | | Subcritical Flow | P02 | M | | M | RB-86 |
| | | Entrainment | P03 | n/a | | n/a | RB-87 |
| | | Spilling | P05 | L | | L | RB-89 |
| SRV (ADS) | C04 | Critical Flow | P01 | n/a | | n/a | RB-84 |
| | | Subcritical Flow | P02 | L | | L | RB-90 |
| | | Entrainment | P03 | n/a | | n/a | RB-87 |
| Turbine Stop Valve | C05 | Subcritical Flow | P06 | n/a | | n/a | RB-09 |
| Turbine Bypass Flow Valve | | Critical Flow | P06 | n/a | | n/a | |
| Feedwater Flow; CRD Flow | C06 | Flow/BC | P07 | n/a | | n/a | RB-09 |
| Core | C07 | Parallel Channel Flow Distribution | P08 | L | L | L | RB-91 |
| | | Pressure Drop 2-Phase | P09 | L | | L | RB-91 |
| | | Flashing | P10 | L | | L | RB-91 |
| | | Evaporation | P11 | L | L | L | RB-91 |
| | | Void Distribution | P12 | L | | L | RB-91 |
| | | Core Power: Critical/Decay | P13 | H | | H | RB-16 |
| | | Heat Transfer Coefficient | P14 | L | L | L | RB-92 |
| | | Fuel Stored Energy | P15 | L | | L | RB-93 |
| | | Structure Stored Energy | P16 | L | | L | RB-94 |
| | | Internal Flow Circulation | P17 | L | | L | RB-95 |

Table B.2-14 (continued)

| Break: GDCS Line Break; | | Event Phase: GDCS Refill | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| Chimney | C08 | Flashing | P10 | L | | L | RB-96 |
| | | Level/Void Distribution | P18 | L | | L | RB-96 |
| | | Structure Stored Energy | P16 | L | | L | RB-94 |
| Separator/Dryer | C09 | Phase Separation | P19 | L | | L | RB-96 |
| | | Friction - Two Phase | P20 | L | | L | RB-96 |
| | | Structure Stored Energy | P16 | L | | L | RB-94 |
| | | Flooding | P21 | n/a | | n/a | RB-97 |
| Downcomer | C10 | Fluid Mixing | P22 | L | L | L | RB-98 |
| | | Flashing | P10 | L | | L | RB-96 |
| | | Level/Void Distribution | P18 | L | L | L | RB-96 |
| | | Direct Contact Condensation | P23 | L | | L | RB-98 |
| | | Structure Stored Energy | P16 | L | | L | RB-99 |
| | | Entrainment | P24 | L | | L | RB-96 |
| Lower Plenum | C11 | Fluid Mixing | P22 | L | | L | RB-98 |
| | | Flashing | P10 | L | | L | RB-96 |
| | | Structure Stored Energy | P16 | L | | L | RB-99 |
| | | Void Distribution | P12 | L | | L | RB-96 |
| Isolation Condenser | C12 | Condensation inside tubes | P25 | L | | L | RB-100 |
| | | Pool side heat transfer | P26 | L | | L | |
| | | Natural circulation | P27 | L | | L | |
| | | Degradation of condensation due to NCs | P28 | L | | L | |

Table B.2-14 (continued)

| Break: GDCS Line Break; Event Phase: GDCS Refill | | | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Containment** | | | | | | | |
| Dry Well | C13 | Non-Condensibles Amount | P31 | L | | L | RB-101 |
| | | Non-Condensibles Distribution | P32 | L | | L | RB-101 |
| | | Condensation on wall with NC present | P33 | L | | L | RB-102 |
| | | Water Accumulation | P34 | M | | M | RG-78 |
| | | Transient Conduction in Structures | P35 | L | | L | RB-102 |
| | | Non-Equilibrium Mixing of $N_2$ & Steam | P36 | n/a | | n/a | RB-103 |
| | | Surface Condensation (on Liquid Surfaces) | P37 | L | | L | RB-102 |
| Horizontal Vent | C14 | Horizontal Vent Clearing | P38 | n/a | | n/a | RB-104 |
| Suppression Pool | C15 | Suppression Pool Heat & MassTransfer | P39 | L | | L | RB-102 |
| | | Condensation for SRV Sparger flow | P40 | L | | L | RB-105 |
| | | Condensation with NC for PCC purge line flow | P41 | L | | L | RB-102 |
| | | Temperature Stratification | P42 | L | | L | RB-102 |
| Suppression Chamber | C16 | Non-Condensibles Amount | P31 | L | | L | RB-101 |
| | | Non-Condensibles Distribution | P32 | L | | L | RB-102 |
| | | Condensation on wall with NC present | P33 | L | | L | RB-102 |
| | | Heat and Mass transfer at pool surface | P43 | L | | L | RB-102 |
| GDCS | C17 | Friction/Form Losses | P44 | H | | H | RB-106 |
| | | Hydrostatic Head | P45 | H | | H | |
| | | Pressure Difference from GDCS Tanks to RPV | P46 | H | | H | |
| PCCS Heat Exchanger | C18 | Condensation inside tubes | P25 | L | | L | RB-107 |
| | | Pool side heat transfer | P26 | L | | L | |
| | | Natural Circulation | P27 | L | | L | |
| | | Degradation of condensation due to NCs | P28 | L | | L | |
| | | Accumulation of NCs in tubes | P47 | L | | L | |
| | | Submergence | P48 | L | | L | |
| | | Condensate Draining | P49 | L | | L | |
| Vacuum Breakers (VB) | C19 | Friction and form losses for Steam & NCs | P50 | L | | L | RB-108 |
| | | Pressure Drop across VB | P51 | L | | L | |
| Equalization Lines | C20 | Flow | P52 | n/a | | n/a | RB-09 |

**Table B.2-15 PIRT for the Long-Term Cooling Phase of a GDCS Line Break**

| Break: GDCS Line Break; | | Event Phase: Long Term Cooling | | | | | |
|---|---|---|---|---|---|---|---|
| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
| **Reactor** | | | | | | | |
| Break No 1 | C01 | Critical Flow | P01 | n/a | | n/a | RB-84 |
| | | Subcritical Flow | P02 | L | | L | RB-111 |
| | | Entrainment | P03 | n/a | | n/a | RB-87 |
| | | Spilling | P05 | H | | H | RB-112 |
| Break No 2 | C01 | Critical Flow | P01 | n/a | | n/a | RG-01 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Spilling | P05 | n/a | | n/a | |
| Intact Steam Line | C02 | Critical Flow | P01 | n/a | | n/a | RB-09 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| | | Inventory Depletion | P04 | n/a | | n/a | |
| DPV (ADS) | C03 | Critical Flow | P01 | n/a | | n/a | RB-84 |
| | | Subcritical Flow | P02 | L | | L | RB-111 |
| | | Entrainment | P03 | n/a | | n/a | RB-87 |
| | | Spilling | P05 | n/a | | n/a | RB-113 |
| SRV (ADS) | C04 | Critical Flow | P01 | n/a | | n/a | RB-114 |
| | | Subcritical Flow | P02 | n/a | | n/a | |
| | | Entrainment | P03 | n/a | | n/a | |
| Turbine Stop Valve | C05 | Subcritical Flow | P06 | n/a | | n/a | RB-09 |
| Turbine Bypass Flow Valve | | Critical Flow | P06 | n/a | | n/a | |
| Feedwater Flow; CRD Flow | C06 | Flow/BC | P07 | n/a | | n/a | RB-09 |
| Core | C07 | Parallel Channel Flow Distribution | P08 | L | | L | RB-115 |
| | | Pressure Drop 2-Phase | P09 | L | | L | RB-115 |
| | | Flashing | P10 | L | | L | RB-115 |
| | | Evaporation | P11 | L | L | L | RB-115 |
| | | Void Distribution | P12 | L | | L | RB-116 |
| | | Core Power: Critical/Decay | P13 | H | | H | RB-16 |
| | | Heat Transfer Coefficient | P14 | L | L | L | RB-92 |
| | | Fuel Stored Energy | P15 | L | | L | RB-93 |
| | | Structure Stored Energy | P16 | L | | L | RB-94 |
| | | Internal Flow Circulation | P17 | L | L | L | RB-116 |

Table B.2-15 (continued)

**Break: GDCS Line Break; Event Phase: Long Term Cooling**

| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
|---|---|---|---|---|---|---|---|
| Chimney | C08 | Flashing | P10 | L | | L | RB-96 |
| | | Level/Void Distribution | P18 | L | L | L | RB-96 |
| | | Structure Stored Energy | P16 | L | | L | RB-94 |
| Separator/Dryer | C09 | Phase Separation | P19 | L | | L | RB-96 |
| | | Friction - Two Phase | P20 | L | | L | RB-96 |
| | | Structure Stored Energy | P16 | L | | L | RB-94 |
| | | Flooding | P21 | n/a | | n/a | RB-117 |
| Downcomer | C10 | Fluid Mixing | P22 | L | | L | RB-98 |
| | | Flashing | P10 | L | | L | RB-96 |
| | | Level/Void Distribution | P18 | L | L | L | RB-96 |
| | | Direct Contact Condensation | P23 | L | | L | RB-98 |
| | | Structure Stored Energy | P16 | L | | L | RB-118 |
| | | Entrainment | P24 | L | | L | RB-96 |
| Lower Plenum | C11 | Fluid Mixing | P22 | L | | L | RB-98 |
| | | Flashing | P10 | L | | L | RB-96 |
| | | Structure Stored Energy | P16 | L | | L | RB-118 |
| | | Void Distribution | P12 | L | | L | RB-96 |
| Isolation Condenser | C12 | Condensation inside tubes | P25 | L | | L | RB-100 |
| | | Pool side heat transfer | P26 | L | | L | |
| | | Natural circulation | P27 | L | | L | |
| | | Degradation of condensation due to NCs | P28 | L | | L | |

**Table B.2-15 (continued)**

| Component Description | Component & Geometry Identifier | Phenomenon Description | Phenomenon Identifier | Rank: BNL | Rank: Consultants | Rank: Final | Ranking Rationale |
|---|---|---|---|---|---|---|---|
| **Break: GDCS Line Break;** | | **Event Phase: Long Term Cooling** | | | | | |
| | | **Containment** | | | | | |
| Dry Well | C13 | Non-Condensibles Amount | P31 | H | | H | RB-119 |
| | | Non-Condensibles Distribution | P32 | H | | H | RB-119 |
| | | Condensation on wall with NC present | P33 | M | | M | RB-120 |
| | | Water Accumulation | P34 | M | | M | RG-121 |
| | | Transient Conduction in Structures | P35 | L | | L | RB-122 |
| | | Non-Equilibrium Mixing of $N_2$ & Steam | P36 | n/a | | n/a | RB-103 |
| | | Surface Condensation (on Liquid Surfaces) | P37 | M | | M | RB-120 |
| Horizontal Vent | C14 | Horizontal Vent Clearing | P38 | n/a | | n/a | RB-104 |
| Suppression Pool | C15 | Suppression Pool Heat & MassTransfer | P39 | L | | L | RB-123 |
| | | Condensation for SRV Sparger flow | P40 | L | | L | |
| | | Condensation with NC for PCC purge line flow | P41 | L | | L | |
| | | Temperature Stratification | P42 | L | | L | |
| Suppression Chamber | C16 | Non-Condensibles Amount | P31 | H | | H | RB-119 |
| | | Non-Condensibles Distribution | P32 | M | | M | RB-124 |
| | | Condensation on wall with NC present | P33 | L | | L | RB-125 |
| | | Heat and Mass transfer at pool surface | P43 | L | | L | RB-125 |
| GDCS | C17 | Friction/Form Losses | P44 | L | L | L | RB-126 |
| | | Hydrostatic Head | P45 | L | L | L | |
| | | Pressure Difference from GDCS Tanks to RPV | P46 | L | L | L | |
| PCCS Heat Exchanger | C18 | Condensation inside tubes | P25 | H | | H | RB-127 |
| | | Pool side heat transfer | P26 | H | | H | |
| | | Natural Circulation | P27 | H | | H | |
| | | Degradation of condensation due to NCs | P28 | H | | H | |
| | | Accumulation of NCs in tubes | P47 | H | | H | |
| | | Submergence | P48 | H | | H | |
| | | Condensate Draining | P49 | H | | H | |
| Vacuum Breakers (VB) | C19 | Friction and form losses for Steam & NCs | P50 | H | | H | RB-119 |
| | | Pressure Drop across VB | P51 | H | | H | |
| Equalization Lines | C20 | Flow | P52 | H | | H | RB-128 |

**Table B.2-16 Combined PIRT for MSLB, BDLB and GDLB Scenarios**

| Component Description | Phenomenon Description | Main Steam Line Break | | | | | Bottom Drain Line Break | | | | | GDCS Line Break | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre-Isolation | Isolation | Depressurization | GDCS Refill | Long Term Cooling | Pre-Isolation | Isolation | Depressurization | GDCS Refill | Long Term Cooling | Pre-Isolation | Isolation | Depressurization | GDCS Refill | Long Term Cooling |
| **Reactor** | | | | | | | | | | | | | | | | |
| Break No 1 | Critical Flow | H | H | H | | | H | H | M | | | H | H | M | | |
| | Subcritical Flow | | | H | M | L | | | M | M | M | | | M | M | L |
| | Entrainment | L | H | L | | | L | L | L | L | | H | H | M | | |
| | Spilling | | | | | | | | | | | | | | H | H |
| Break No 2 | Critical Flow | | | | | | H | H | M | | | | | | | |
| | Subcritical Flow | | | | | | | | M | M | L | | | | | |
| | Entrainment | | | | | | H | H | M | | | | | | | |
| | Spilling | | | | | | | | | H | H | | | | | |
| Intact Steam Line | Critical Flow | H | | | | | | | | | | | | | | |
| | Subcritical Flow | | | | | | H | | | | | H | | | | |
| | Entrainment | | | | | | H | | | | | H | | | | |
| | Inventory Depletion | L | | | | | | | | | | | | | | |
| DPV (ADS) | Critical Flow | | | H | | | | | H | | | | | H | | |
| | Subcritical Flow | | | H | M | L | | | H | M | L | | | H | M | L |
| | Entrainment | | | L | | | | | H* | | | | | H* | | |
| | Spilling | | | | L | | | | | L | | | | | L | |
| SRV (ADS) | Critical Flow | | | H | | | | | H | | | | | H | | |
| | Subcritical Flow | | | H | L | | | | M | L | | | | M | L | |
| | Entrainment | | | L | | | | | L | | | | | L | | |
| Turbine Stop Valve | Subcritical Flow | | | | | | H | | | | | H | | | | |
| Turbine Bypass Flow Valve | Critical Flow | | | | | | H | | | | | H | | | | |
| Feedwater Flow; CRD Flow | Flow/BC | H | H | | | | H | H | | | | H | H | | | |
| Core | Parallel Channel Flow Distribution | L | M | M | L | L | M | M | M | L | L | M | M | M | L | L |
| | Pressure Drop 2-Phase | L | M | M | L | L | L | L | M | L | L | L | L | M | L | L |
| | Flashing | M | H | H | L | L | H | M | H* | L | L | H | M | H* | L | L |
| | Evaporation | L | H | H | L | L | H* | L | L | L | L | H* | L | L | L | L |
| | Void Distribution | M | H | H | L | L | H* | M | H* | L | L | H* | M | H* | L | L |
| | Core Power: Critical/Decay | H | H | H | H | H | H | H | H | H | H | H | H | H | H | H |
| | Heat Transfer Coefficient | L | H | H | L | L | M | L | L | L | L | M | L | L | L | L |
| | Fuel Stored Energy | M | H | L | L | L | M | M | M | L | L | M | M | M | L | L |
| | Structure Stored Energy | L | M | L | L | L | L | L | M | L | L | L | L | M | L | L |
| | Internal Flow Circulation | | M | H | M | L | L | L | M | L | L | L | L | M | L | L |

Table B.2-16 (continued)

| Component Description | Phenomenon Description | Main Steam Line Break | | | | | Bottom Drain Line Break | | | | | GDCS Line Break | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre-Isolation | Isolation | Depressurization | GDCS Refill | Long Term Cooling | Pre-Isolation | Isolation | Depressurization | GDCS Refill | Long Term Cooling | Pre-Isolation | Isolation | Depressurization | GDCS Refill | Long Term Cooling |
| Chimney | Flashing | M | H | H | L | L | H* | M | H* | L | L | H* | M | H* | L | L |
| | Level/Void Distribution | M | H | H | L | L | H* | M | H* | L | L | H* | M | H* | L | L |
| | Structure Stored Energy | L | M | L | L | L | L | L | M | L | L | L | L | M | L | L |
| Separator/Dryer | Phase Separation | M | H | H | L | L | H* | L | H* | L | L | H* | L | H* | L | L |
| | Friction - Two Phase | L | L | L | L | L | L | L | M | L | L | L | L | M | L | L |
| | Structure Stored Energy | L | M | L | L | L | L | L | M | L | L | L | L | M | L | L |
| | Flooding | L | H | L | | | M | L | M | | | M | L | M | | |
| Downcomer | Fluid Mixing | L | M | L | L | L | M | H* | M | L | L | M | H* | M | L | L |
| | Flashing | M | H | H | L | L | H | M | H* | L | L | H | M | H* | L | L |
| | Level/Void Distribution | M | H | H | L | L | H | M | H* | L | L | H | M | H* | L | L |
| | Direct Contact Condensation | L | H | M | L | L | M | H* | M | L | L | M | H* | M | L | L |
| | Structure Stored Energy | L | M | M | M | L | M | L | M | L | L | M | L | M | L | L |
| | Entrainment | L | H | H | L | L | H | H | M | L | L | H | H | M | L | L |
| Lower Plenum | Fluid Mixing | L | M | L | L | L | L | L | M | L | L | L | L | M | L | L |
| | Flashing | L | H | H | L | L | H | M | H* | L | L | H | M | M | L | L |
| | Structure Stored Energy | L | M | M | L | L | L | L | M | L | L | L | L | M | L | L |
| | Void Distribution | L | H* | L | L | L | H | M | H* | L | L | H | M | M | L | L |
| Isolation Condenser | Condensation inside tubes | | H | H | L | L | | H | M | L | L | | H | M | L | L |
| | Pool side heat transfer | | H | H | L | L | | H* | M | L | L | | H* | M | L | L |
| | Natural circulation | | H | H | L | L | | H | M | L | L | | H | M | L | L |
| | Degradation of condensation due to NCs | | M | M | L | L | | M | L | L | L | | M | L | L | L |

Table B.2-16 (continued)

| Component Description | Phenomenon Description | Main Steam Line Break | | | | | Bottom Drain Line Break | | | | | GDCS Line Break | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre-Isolation | Isolation | Depressurization | GDCS Refill | Long Term Cooling | Pre-Isolation | Isolation | Depressurization | GDCS Refill | Long Term Cooling | Pre-Isolation | Isolation | Depressurization | GDCS Refill | Long Term Cooling |
| **Containment** | | | | | | | | | | | | | | | | |
| Dry Well | Non-Condensibles Amount | M | L | M | L | H | H | L | M | L | H | H | L | M | L | H |
| | Non-Condensibles Distribution | M | L | M | L | H | H | L | M | L | H | H | L | M | L | H |
| | Condensation on wall with NC present | M | L | L | L | M | H | L | M | L | M | H | L | M | L | M |
| | Water Accumulation | L | L | L | L | H | L | L | M | M | H | L | L | M | M | M |
| | Transient Conduction in Structures | L | L | M | L | L | H | L | M | L | L | H | L | M | L | L |
| | Non-Equilibrium Mixing of N2 & Steam | H | L | M | | | H | L | L | | | H | L | L | | |
| | Surface Condensation (on Liquid Surfaces) | M | L | M | L | M | H | L | M | L | M | H | L | M | L | M |
| Horizontal Vent | Horizontal Vent Clearing | L | L | M | | | L | L | M | | | L | L | M | | |
| Suppression Pool | Suppression Pool Heat & MassTransfer | L | L | M | L | L | L | L | M | L | L | L | L | M | L | L |
| | Condensation for SRV Sparger flow | | | M | L | L | | | M | L | L | | | M | L | L |
| | Condensation with NC for PCC purge line flow | L | L | M | L | L | L | L | M | L | L | L | L | M | L | L |
| | Temperature Stratification | L | L | M | L | L | L | L | M | L | L | L | L | M | L | L |
| Suppression Chamber | Non-Condensibles Amount | L | L | M | L | H | L | L | M | L | H | L | L | M | L | H |
| | Non-Condensibles Distribution | L | L | L | L | M | L | L | L | L | M | L | L | L | L | M |
| | Condensation on wall with NC present | L | L | L | L | L | L | L | L | L | L | L | L | L | L | L |
| | Heat and Mass transfer at pool surface | L | L | L | L | L | L | L | L | L | L | L | L | L | L | L |
| GDCS | Friction/Form Losses | | | | H | L | | | | H | L | | | | H | L |
| | Hydrostatic Head | | | | H | L | | | | H | L | | | | H | L |
| | Pressure Difference from GDCS Tanks to RPV | | | | H | L | | | | H | L | | | | H | L |
| PCCS Heat Exchanger | Condensation Inside tubes | L | L | M | L | H | L | L | L | L | H | L | L | L | L | H |
| | Pool side heat transfer | L | L | M | L | H | L | L | L | L | H | L | L | L | L | H |
| | Natural Circulation | L | L | M | L | H | L | L | L | L | H | L | L | L | L | H |
| | Degradation of condensation due to NCs | L | L | M | L | H | L | L | L | L | H | L | L | L | L | H |
| | Accumulation of NCs in tubes | L | L | M | L | H | L | L | L | L | H | L | L | L | L | H |
| | Submergence | L | L | M | L | H | L | L | L | L | H | L | L | L | L | H |
| | Condensate Draining | L | L | M | L | H | L | L | L | L | H | L | L | L | L | H |
| Vacuum Breakers (VB) | Friction and form losses for Steam & NCs | | | | L | H | | | | L | H | | | | L | H |
| | Pressure Drop across VB | | | | L | H | | | | L | H | | | | L | H |
| Equalization Lines | Flow | | | | | H | | | | | H | | | | | H |

# APPENDIX C

# PIRT SUPPORT TABLES

**Table C.1-1 Component and Geometry Description**

| Number | Name | Component Description |
|---|---|---|
| C01 | Break | A break in a line, which is part of the RCPB, is the accident initiator. The break is generally postulated to occur instantaneously at time zero in the form of a "double guillotine" break. Depending on the break location, both sides of the ruptured pipe may be connected to the RPV, resulting effectively in a double break. Three types of breaks are considered here:<br><br><u>1. Main Steam Line Break (MSLB)</u><br>This break constitutes a Large Break LOCA. The steam line is assumed to have ruptured inside the containment. In the part of the steamline coming from the RPV there will be an initial discharge of inventory, and thereafter the flow will be controlled by the flow restrictors mounted integral to the reactor vessel. Until isolation (MSIV closure) coolant will also be discharged from the other side of the break (see C02).<br><br><u>2. Bottom Drain Line Break (BDLB)</u><br>The Bottom Drain Line Break is a Small Break LOCA. The bottom drain line is connected to the bottom of the reactor vessel, and therefore, such a break could in principle result in complete draining of the RPV. The bottom drain line is also connected to the RWCU/SDC line, resulting in simultaneous coolant discharge from this second side of the break, which is connected to the RPV at the downcomer level.<br><br><u>3. GDCS Injection Line Break (GDLB)</u><br>This break is also a Small Break LOCA, resulting in the effective loss of one of the three GDCS tanks. The break is assumed to occur between the last line valve and the reactor vessel. It generally does not result in any second break flow from the RPV.<br><br>For the actual break sizes see Table C.1-2. |
| C02 | Intact Steam Line | The SBWR has two steam lines leaving the reactor and passing through the containment penetrations. The two lines are connected in a T, ahead of the turbine. Thus, until MSIV closure back-flow from the intact steamline will be discharged into the drywell. Initially the steam line inventory will be discharged, with flow choked at the break. Thereafter the flow restrictor at the connection of the intact steam line to the RPV will control the flow. |
| C03 | DPV | The DPVs are part of the ADS. There are six depressurization valves. Four are mounted horizontally on stub lines slightly below the elevation of the main steam lines. The other two are mounted horizontally, one on each steam line. The DPVs are arranged to open in banks of two during ADS operation. All of them discharge into the drywell. |
| C04 | SRV | The SRVs are also part of the ADS. There are a total of eight SRVs, four on each steam line. ADS activation locks open the valves in groups of 4. The SRVs discharge into the suppression pool. |

**Table C.1-1 (continued)**

| Number | Name | Component Description |
|---|---|---|
| C05 | Turbine Stop Valve & Turbine Bypass Valve | In LOCA simulations these valves essentially present boundary conditions. With turbine trip both turbine stop valves close immediately. The Turbine bypass valves open at the same time, to allow diversion of remaining steam directly to the condenser. In general the turbine bypass valves are modulated to match feedwater flow. However, in most accident simulations the feedwater flow is also assumed to be tripped at time zero, with rapid feedwater pump coastdown. |
| C06 | Feedwater Flow | During a LOCA, depending on the type of break, the feedwater flow might actually continue for some time. The general conservative assumption being made is loss of all preferred power at time zero, resulting in tripping of the feedwater pumps and coasts down. Recent information from GE indicates that they assume a 5 s coast down. The PIRT development considered the SSAR data of about 90 s coast down, assuming that feedwater flow will occur during the Pre-Isolation Phase and during the Isolation Phase. |
| C07 | Core | The core consists of 732 fuel assemblies, each with an 8 x 8 rod configuration, containing 60 fuel rods. The fuel rod length is 2.743 m. The fuel rod outer diameter is 12.27 mm. The coolant flow area in each assembly is 0.01011 $m^2$, for a total active core flow area of 7.4 $m^2$. Most of the coolant flows through the fuel assembly channels, with some bypass flow, being directed into the bypass region through holes in the lower tie plate. The flow area of the bypass region is 5.6 $m^2$. The bypass flow is orificed, to amount to about 19% of the total core flow during normal full power operation. |
| C08 | Chimney | On top of the core, the SBWR has a chimney section, which is 9 m long to provide the required buoyancy force for natural circulation. The chimney region is partitioned into 25 separate flow channels, generally with 36 fuel assemblies each. |
| C09 | Separator/Dryer | During normal operation, two phase mixture flows from the chimney to the separator/dryer component. In the separator section swirl vanes separate the liquid from the vapor by centrifugal force. In the dryer section the steam flows horizontally outward through corrugated vanes, with any remaining liquid being collected on these vanes, flowing downward, to be returned to the downcomer region, while vapor exits into the steam dome. |
| C10 | Downcomer | The downcomer consists of the annular region between the core and chimney on the inside and the RPV wall on the outside. Saturated water from the separator/dryer and feedwater flow downward to the lower plenum. The feedwater lines, IC condensate return lines, the GDCS injection lines and equalization lines, as well as the RWCU/SDC lines feed into it. Also, several safety system are actuated on the basis of the collapsed liquid level between wide range level instrument connection points in the downcomer. The liquid level during steady state operation is at 18.3 m. The downcomer average cross section area is 8.2 $m^2$. |

**Table C.1-1 (continued)**

| Number | Name | Component Description |
|---|---|---|
| C11 | Lower Plenum | The lower plenum consists of the close-to-semi-spherical space below the core and the downcomer. The coolant from the downcomer passes through the lower plenum before entering the core. This region also contains the control rods with the required penetrations and associated hardware. |
| C12 | Isolation Condenser | Three ICs are rated at 30 MW each, containing 248 vertical tubes 1.8 m long. They are submerged in small water pools open to ambient conditions. The steam flows to the IC from 12" pipes connected to the DPV stubs. The condensate is returned to the downcomer through condensate return line. The IC steam lines are opened on MSIV closure, beginning to open when the MSIVs are 10% closed. |
| C13 | Drywell (DW) | The Dry Well is a large volume of the containment, inerted with nitrogen. It consists of the upper (UDW) and lower DW (LDW). Eight vertical vents, each with three horizontal vents, communicate with the suppression pool. The total volume of the dry well is 5490 $m^3$. The UDW is connected to three PCCS units and to the GDCS pool cover gas. The DPVs discharge into the UDW. The UDW is also connected to the suppression chamber through three vacuum breakers, see C19. During a steam line break reactor coolant is discharged into the UDW while a bottom drain line break results in coolant discharge into the LDW. |
| C14 | Horizontal vents | The discharge of nitrogen and vapor to the suppression pool and to the Suppression Chamber is effected through a set of vertical and horizontal vents. There are eight vertical pipes of 1.2 m ID in the UDW. Each vertical pipe connects to three horizontal vents of 0.7 m ID. These vents act as passive valves to balance the pressure between the DW and SP. The horizontal vents are located 1.95, 3.32, and 4.69 m below the initial suppression pool level.. The first row of horizontal vents uncovers when the pressure difference between DW and SC reaches 0.182 bar (2.6 psi). |
| C15 | Suppression Pool (SP) | The Suppression Pool is a large pool of water in the containment, which serves to condense and hold most of the reactor coolant, discharged into the containment under accident conditions. The initial volume of water is 3255 $m^3$ with a surface area of 588 $m^2$. The SC serves as cover gas for this water. The SP provides a heat sink to directly condense steam discharged from the SRVs, while vapor/nitrogen mixtures from the drywell enter the SP through the system of vertical and horizontal vents. The pool can also serve as a direct source of coolant for the RPV during some LOCAs, if the reactor inventory reaches a level of about 1 m above TAF. For this purpose, the pool is connected to the RPV through three equalization lines (see C20). |
| C16 | Suppression Chamber (SC) | The Suppression Chamber consists of the gas volume above the suppression Pool. Initially this space is inerted with nitrogen. Its volume is 3819 $m^3$. Three vacuum breakers connect this space to the UDW (see C19). |

**Table C.1-1 (continued)**

| Number | Name | Component Description |
|---|---|---|
| C17 | Gravity Driven Core Cooling System (GDCS) | The GDCS consists of three tanks filled with water and open to the drywell. The Tanks are connected to the RPV downcomer by pipes. There is a loop seal in each of the pipes at the RPV entrance. The condensate from the PCCS is returned to the GDCS for drainage from there to the RPV. The normal level in the GDCS tanks is 22.3 m while TAF is 6.493 m. The total water inventory of the three tanks is 1044 $m^3$. |
| C18 | Passive Containment Cooling System (PCCS) (including purge line and condensate return line) | The PCCS consists of three condenser units each rated at 10 MW. Each unit contains 492 vertical tubes, 1.8 m long (50.8 mm OD/47.5 mm ID). The tube banks end in inlet and outlet headers. The PCCS units are submerged in individual pools, essentially exposed to ambient conditions. Each PCCS unit has a purge line, connecting the bottom header to the SP. These 10 in. pipes have no valves or orifices and are submerged .75 m below the initial SP water level. This serves to control the required pressure difference between drywell and suppression chamber, at which the PCCS purging occurs, automatically removing $N_2$ from the unit.<br>Each PCCS unit has a condensate return line which drains into a GDCS tank. The exit end has a 2.5 m loop seal to isolate the condensate return system from the DW pressure. |
| C19 | Vacuum Breakers (VB) | Three Vacuum Breakers are located on the diaphragm floor connecting the UDW to the SC. Each is 0.5 m ID. The actual VBs are essentially check valves, opening when the SC pressure exceeds the DW pressure by 3.5 kPa (≈0.035 bar; ≈0.5 psi). |
| C20 | Equalization Lines | Three lines connect the suppression pool directly to the RPV. These lines 7.5 m above the bottom of the vessel and 1 m above TAF. In case of very low RPV coolant inventory, its valves will be opened, and the SP water will be used to flood the core. |

**Table C.1-2 Break and ADS Flow Areas**

| Break/Valve | Location | | Flow Area (cm$^2$) |
|---|---|---|---|
| Main Steam Line | Broken Leg | at the break | 3206 |
| | | at the flow restrictor | 983 |
| | Intact Leg | at the break | 3206 |
| | | at the flow restrictor | 983 |
| Bottom Drain Line | Bottom Drain Line | | 20.3 |
| | RWCU/SDC Line | | 45.6 |
| GDCS Line | Close to RPV | | 45.6 |
| DPV (6) | on stub lines | | each 248.5 |
| SRV (8) | on main steam lines | | each 67 |

**Table C.2-1 Phenomena Description**

| Phenomena Identifier | Name | Phenomena Description |
|---|---|---|
| P01 | Critical Flow | Choked Flow in an upstream flow restrictor or at the break. The flow can be single phase or Two Phase. Note that with gradual expansion at a flow restrictor the upstream to downstream pressure ratio can be significantly smaller than the usual 2.0, with the flow still remaining choked. |
| P02 | Subcritical Flow | Subsonic single or two phase flow with smaller pressure differences. The flow is generally controlled by pressure difference and friction/form losses. |
| P03 | Entrainment | High velocities at the break may induce entrainment of liquid from upstream components such as separators or downcomer.<br>Level swell during depressurization may bring liquid phase to the break. |
| P04 | Inventory Depletion | The initial steam inventory in the intact steam line will deplete before the flow becomes choked at the flow restrictor and/or is terminated by MSIV closure. |
| P05 | Spilling | As the reactor vessel fills up during GDCS injection, the liquid level can reach the elevation of the DPVs and/or of the break, resulting in liquid overflow from the RPV into the drywell. |
| P06 | Turbine Stop Valve (TSV) & Turbine Bypass Valves (TBV) Flow | Depending on the details of accident scenarios, the TSVs will close rapidly with turbine trip, generally resulting in the opening of the TBVs, directing remaining steam directly to the condenser. The TBVs are generally modulated, to match feedwater flow. |
| P07 | Flow/BC | The feedwater flow enters as a boundary condition in accident simulations. With most LOCA scenarios it is generally assumed, that preferred power is lost at accident initiation, resulting in a feedwater pump coast down during the early phases of the accident. Other possible pump trip signals would be on high reactor water level and on loss of suction. As a convention we assume here, that there is an initial coastdown which generally can extend beyond the pre-isolation phase, and that there is no feedwater flow beyond the isolation phase. |
| P08 | Parallel Channel Flow Distribution | The core inlet flow is distributed among fuel channels and bypass regions. The distribution to the various flow passages depends on core inlet flow, as well as friction and power in each core flow path. In particular, negative (downward) flow is possible during parts of transient scenarios, with internal coolant circulation within the core (see P17). |
| P09 | Pressure Drop | Pressure drop due to wall friction and local losses, such as orifices. This pressure drop will control the flow in individual flow passages and the natural circulation flow in the core. The available correlations must cover single phase and two-phase flow. |

**Table C.2-1 (continued)**

| Phenomena Identifier | Name | Phenomena Description |
|---|---|---|
| P10 | Flashing | Vapor generation due to the depressurization. |
| P11 | Evaporation | Vapor generation due to heat transfer from fuel and other solid structures to the coolant. |
| P12 | Void Distribution | Spatial and temporal distribution of voids in the core. |
| P13 | Core Power Critical/Decay | Core fission power and decay heat, as applicable. |
| P14 | Heat Transfer | Convective heat transfer from a solid surface to the adjacent coolant. The heat transfer correlations must cover single phase and two phase flow. |
| P15 | Fuel Stored Energy | Energy stored in the solid structures of fuel and clad. |
| P16 | Structure Stored Energy | Energy stored in solid structures other the fuel. |
| P17 | Core Internal Flow Circulation | The SBWR core is designed to allow core internal circulation during LOCA conditions, with the hotter heated regions providing for upflow and the cooler regions, predominantly the bypass region, experiencing downflow. While this phenomenon is driven by several of the items covered above (in particular P08, P09, P13), it is an important characteristic of the SBWR and is, therefore, here broken out as a separate phenomenon. |
| P18 | Level/ Void Distribution | In the chimney and downcomer sections a two phase level can exist. This level is characterized by a sharp change in void fraction. The location of the level will depend upon interfacial shear and flow regime. Several of the safety signals are based on the "Downcomer Wide Range Level," which is a measurement of hydrostatic head across two taps. This is effectively a "collapsed level," i. e., the level of integrated liquid above the bottom tap. |
| P19 | Phase Separation | This phenomenon is specific to separators. The phases are separated by swirl vanes exerting centrifugal force on the fluid, driving the liquid to the outer wall, for withdrawal to the downcomer. |
| P20 | Friction-Two-phase | Friction pressure drop in the separator section requires special consideration, due to the special geometry with centrifugal flow. |
| P21 | Flooding in Separators | Due to level swell during depressurization the liquid coolant carried into the separator can possibly exceed levels at which the separating function with return of liquid to the downcomer can be performed, resulting in liquid accumulation in this region. |
| P22 | Fluid Mixing | Mixing of fluid streams at different temperatures, in particular with returning IC condensate in the downcomer and lower plenum regions. |

**Table C.2-1 (continued)**

| Phenomena Identifier | Name | Phenomena Description |
|---|---|---|
| P23 | Direct Contact Condensation | Condensation, occurring when a two phase mixture or steam comes in contact with subcooled fluid, which again, can be important as cold condensate from the ICs mixes with flashing coolant in the downcomer. |
| P24 | Entrainment | Level swell, caused by flashing, may lead to liquid being carried upward, inhibiting downward circulation and potentially carrying liquid to the break region, thus increasing loss of inventory. |
| P25 | Condensation Inside Tubes | Steam entering tubes, submerged in cold water; downward vapor flow with condensation occurring on tube inside surface. |
| P26 | Pool Side Heat Transfer | The IC and PCCS heat exchanger tubes are submerged in a pool of initially subcooled water. Heat transfer here is from the outside surface of the tubes to the pool water. The heat transfer is by natural convection which depends upon the wall temperature and the heat transfer regime. Changes from single phase natural convection to other heat transfer regimes of the pool boiling curve, such as subcooled or nucleate boiling, may occur. |
| P27 | IC & PCCS Natural Circulation | The net flow to the condensers is driven by the condensation induced low pressure in the tubes and by the gravity head between steam supply lines and condensate return lines. The pressure reduction due to condensation also affects the flows, by increasing the inflow of gases and impeding the outflow of the condensate and noncondensible gases. |
| P28 | Degradation of Condensation due to NCs | The presence of non-condensible gases during condensation tends to reduce the condensation rate below that obtained with pure steam. This degradation in performance is caused by the accumulation of noncondensible gases at the vapor/liquid interface, imposing an additional heat and mass transfer resistance. |
| P31 | Concentration of Noncondensible | The open spaces in the containment, primarily the drywell and the suppression chamber, contain under LOCA conditions mixtures of nitrogen, possibly hydrogen, and water vapor. At times these will be ideal gas mixtures, particularly during the Long Term Cooling Period. During blowdown the water may also be present as a two-phase mixture and spatially non-uniform distributions are anticipated. The presence of NCs affects the heat transfer with condensation to the cool walls and other structures in these volumes, which has a direct impact on cell pressures. During some time phases only the total concentration of the species is of essence (this item). During other time phases the spatial distribution of the phases may have to be determined (see P32). |
| P32 | Distribution of Noncondensibles | As detailed above, under P31, during some time phases the spatial concentration of the various gas species has to be known. |

**Table C.2-1 (continued)**

| Phenomena Identifier | Name | Phenomena Description |
|---|---|---|
| P33 | Condensation on Walls with NCs present | As energy is being absorbed by the walls and internal structures of the containment cells, condensation of the vapor phase may occur. In the presence of NCs the condensation process will be degraded, as the NCs accumulate at the gas/liquid interface, imposing an additional heat and mass transfer resistance. This process is in principle equivalent to item P28, except that for the different geometry here, different correlations apply. |
| P34 | Water Accumulation | The containment system has been designed to recycle the coolant to flow back into the vessel as condensate via the GDCS drain lines or via the equalization lines. However, in some breaks the coolant will not return to the vessel but accumulate in the lower drywell. This accumulation will assist in long term cooling only after the containment is flooded and the water level in the containment is above the inlet to the vertical vents in the drywell, or above the top of active fuel, if any of the breaks is at an elevation below the vertical vent inlet. |
| P35 | Transient Conduction in Structures | During energy discharge from the RPV to the containment with increasing gas temperatures and pressures in the containment, heat will be transferred to the cell walls and other internal structures. Modeling requirements include sufficient knowledge of the material properties and information on gap geometries, for instance, between liners and concrete. Depending on the time scale, different nodalization requirements arise for the initial response, of the order of seconds, and for the long term cooling response, where the time scale is in hours. |
| P36 | Non-Equilibrium Mixing of $N_2$ and Steam | In particular during the first few seconds of a blowdown transient, the steam entering the drywell will in part mix with the original $N_2$ atmosphere. Assuming complete mixing can result in underprediction of the drywell pressure. Accurate early drywell pressure predictions, therefore, depend on high fidelity (or bounding) modeling of this partial mixing of the gas streams. |
| P37 | Surface Condensation on Liquid Surfaces | The GDCS pools and potential water pools in the lower drywell provide water surfaces in the drywell, on which incoming steam can condense. The associated mass and energy removal from the drywell atmosphere can have a significant effect on the drywell pressure and on the transient scenario. Again, inhibition by condensation due to the presence of non-condensibles will have to be considered in modeling the process. |

**Table C.2-1 (continued)**

| Phenomena Identifier | Name | Phenomena Description |
|---|---|---|
| P38 | Horizontal Vent Clearing | Each of the nine vertical vents in the drywell is connected to three horizontal vents at different elevations, connecting the drywell to the suppression chamber via the suppression pool. During blowdown from the RPV into the drywell, as the drywell pressure increases, the water level is depressed on the drywell side, and eventually clearing the horizontal vents. The gases will then flow into the suppression pool alleviating the pressure in the drywell. As the pressure continues to increase, the second and then the third row of the vents will clear. Initial vent clearing can occur very fast, and the water inertia is a controlling parameter in the vent clearing time, which in turn affects the drywell pressure and potential safety signals. |
| P39 | Suppression Pool Heat and Mass Transfer | The horizontal vent clearing due to pressure build up in the drywell allows a mixture of steam and noncondensibles to flow into the suppression pool. Of the gases entering the pool most of the steam will condense. The remaining gases will accumulate in the suppression chamber. The pool will also cool the gas mixture. The gas flow discharging from the horizontal vents into the pool could be in form of jets which may break into bubbles. Oscillatory behavior has been observed in test simulations. |
| P40 | Condensation for SRV Sparger Flow | During operation of the ADS, RPV steam is discharged through the SRVs into the suppression pool, through spargers with nozzles. The steam condensation will take place due to direct contact. The rate of condensation will depend on the subcooling of the pool water, bubble sizes, and the bubbles residence time. However, full condensation is anticipated. |
| P41 | Condensation with NC for PCCS Purge Line Flow | At the bottom of the PCCS gases are separated from the condensate and purged intermittently through the purge line into the suppression pool, as the pressure in the PCCS rises and falls. The gases may include some steam which will condense in the pool. Condensation will depend upon the concentration of NC, bubble size, and the residence time of the bubbles. Again, full condensation is anticipated. |
| P42 | Temperature Stratification | Since there are several sources for injecting of hot gas into the suppression pool at different elevations, a complex temperature distribution in the pool can result, which can affect the condensation process as well as the partial pressure of the steam in the suppression chamber. |
| P43 | Heat and Mass Transfer at the Pool Surface | There will be some condensation when steam or a mixture of steam and noncondensible comes in contact with the cold water pool surface. |
| P44 | Friction and Form Losses | Flow in the pipe sections of the GDCS is affected by wall friction and form losses across the orifices and valves. |
| P45 | Hydrostatic Head | The major driving force for liquid flow from the GDCS tanks to the RPV is the hydrostatic head of the water in the GDCS tanks. |

**Table C.2-1 (continued)**

| Phenomena Identifier | Name | Phenomena Description |
|---|---|---|
| P46 | Pressure Difference from GDCS Tanks to RPV | The overall driving force for GDCS tank flow into the RPV is controlled by the above hydrostatic head plus the pressure difference between the top of the GDCS Tanks and RPV at the level of the GDCS inlet nozzle. |
| P47 | Accumulation of NCs in Tubes | A mixture of steam and NCs flows into the PCCS tubes and a portion of steam condenses while the NCs accumulate. The impact of this NC accumulation is to degrade the condensation process, which will force the drywell pressure to rise. The total concentration as well as the spatial distribution of NCs in the tube will affect the process. |
| P48 | Submergence | The PCCS purge line is submerged in the pool. This submergence imposes a back pressure on the PCCS purge line and thus affects the initiation and the frequency of the purging process. It also affects the residence time for the NCs in the PCCS. |
| P49 | Condensate Draining | The condensate in the PCCS will drain into the GDCS tank through condensate return lines. There is a U-tube connected at the end of this line. It acts as a loop seal and prevents the venting of gases through this path. |
| P50 | Friction & Form Losses | The vacuum breakers are essentially lines with check valves, which open and close at pre-set pressure differences. The flow consists of NCs with some vapor. The flow rate at any time depends upon the friction in the flow path, however, regardless of friction, the flow will commence and terminate based on the preset pressure differences, i.e. the line will remain open until sufficient mass has been discharged, to satisfy the desired pressure reduction. |
| P51 | Pressure Difference Across Vacuum Breakers | The flow through the vacuum breakers will depend on the pressure differences between the suppression chamber and the drywell. |
| P52 | Equalization Line Flow | In case of very low water level in the RPV, the Equalization Lines will open at Level $L_{0.5}$ which is 1 m above TAF. Once opened, they will remain open, resulting in inflow from the suppression pool into the reactor vessel. Similar to the Vacuum Breakers, the flow at any time will depend on the line friction losses, but line flow will continue until the levels between the RPV and the suppression pool are equalized. |

**Table C.3-1 Ranking Rationale for MSLB**

| Identifier | Rank | Rationale |
|---|---|---|
| RM-01 | H | The break flow is ranked high, as this is the primary phenomenon during this phase and has a significant impact on the vessel inventory and on the dry well high pressure scram signal. |
| RM-02 | n/a | No unchoked flow during this time period |
| RM-03 | L | Entrainment is not considered significant during the pre-isolation period, since there is not enough time for level swell to reach the break region. |
| RM-04 | n/a | No second break in this scenario (back flow from intact steam line handled separately as item C2) |
| RM-05 | H | The coolant discharge from the intact steam line is rated high, due to its potential contribution to early dry well pressure and scram time. |
| RM-06 | L | The effect of inventory depletion in the steam line has no significant effect on the vessel inventory and is, therefore, rated low. |
| RM-07 | n/a | Component not active during this time period.. |
| RM-08 | n/a | These components are beyond the intact steam line and are not of interest in this break scenario. |
| RM-09 | H | Boundary conditions to the RPV; pump may or may not be tripped; if tripped, it would be in coast-down mode during this time period; rated high as it directly affects the vessel inventory. |
| RM-10 | L | The core mass flow rate is still close to the original full power flow rate. |
| RM-11 | M | With a high depressurization rate, the flashing rate is high, however, the time for this phase is short and the effect on the inventory is low to medium. |
| RM-12 | L | Since the power initially drops significantly faster than the coolant flow rate, the evaporation rate has decreased below that at full power. |
| RM-13 | M | The void distribution here mainly follows the vapor generation due to flashing; it is, therefore, ranked low to medium. |
| RM-14 | H | Core power, as the main energy source, is always rated high. |
| RM-15 | L | The clad to coolant convective heat transfer coefficient characterizes the dominant heat transfer resistance, and has, therefore, in principle a strong effect on the peak clad temperature. However, the actual peak clad temperatures remained very low at all times and since vessel coolant inventory is used as the higher level assessment criterion, the heat transfer coefficient was ranked low. |
| RM-16 | M | The time constant of the solid capacitance in the fuel rods is large compared to the phase duration, therefore, the energy transfer is of low concern.[1] |

[1] See Section 5 for future revision of this ranking.

**Table C.3-1 (continued)**

| Identifier | Rank | Rationale |
|---|---|---|
| RM-17 | L | Following RM-16, the energy release from structures, which were originally essentially at coolant temperatures, is ranked low. |
| RM-18 | n/a | With significant upward core mass flows, flow reversal is not yet possible. during this time phase. |
| RM-19 | M | Following RM-11, and considering the effect of this long section on the system buoyancy force, flashing in the chimney was ranked medium. |
| RM-20 | M | Level and void distribution are coupled with flashing and ranked equal with RM-19. |
| RM-21 | L | With the structures being originally at coolant saturation temperature and the coolant temperature drop remaining relatively small during this short phase, structure stored energy was ranked low. |
| RM-22 | M | There will not be enough time for flashing and level swell to reach the elevation of the separator. Therefore it was rated low/medium. |
| RM-23 | L | The pressure drop here will have no significant effect on the choked break flow and loss of inventory. |
| RM-24 | L | Follows RM-21. |
| RM-25 | L | Follows RM-22, without presence of excessive liquid, flooding is not expected. |
| RM-26 | L | Mixing will only be essential, once cold IC condensate enters the downcomer. But that does not occur during this phase. The IC valves only open as the MSIVs close. |
| RM-27 | M | In general, follows RM-19. But if anywhere, flashing in upper downcomer might have some effect on break flow due to possible level swell. |
| RM-28 | M | Follows RM-20. |
| RM-29 | L | Direct contact condensation between vapor and subcooled liquid is expected to occur with cold IC return flow, see RM-26. |
| RM-30 | L | Follows RM-21. |
| RM-31 | L | Entrainment of liquid, being carried upward with flashing vapor was not considered important during this short initial phase of the transient. |
| RM-32 | L | Follows RM-26. |
| RM-33 | L | This effect was ranked low here, following the rationale of RM-11. |
| RM-34 | L | Follows RM-21. |
| RM-35 | L | Follows RM-28 and RM-20. |

**Table C.3-1 (continued)**

| Identifier | Rank | Rationale |
|---|---|---|
| RM-36 | M | The focus in this PIRT development is on the reactor pressure vessel, and containment phenomena are only to be considered, if they have a significant feedback on the scenario inside the vessel. During the pre-isolation time period, the scram signal is most likely on high drywell pressure. Therefore, phenomena affecting the pressure can be important. Whether condensation and non-condensible distributions can have a significant effect during the applicable time period of about 1 s was an item of debate, and a decision was deferred, subject to future sensitivity evaluations. See Section 5. In the meantime, a ranking of medium was assigned. |
| RM-37 | L | Not of interest in this accident scenario. |
| RM-38 | L | Not of significance during such short duration. |
| RM-39 | H | The degree of mixing between the incoming steam jet and the original nitrogen in the drywell will have a direct effect on the drywell pressure. (In particular it has been shown in the model development for Mark III containments, that the assumption of uniform mixing can underestimate the drywell pressure.) |
| RM-40 | L | Since the drywell pressure scram signal (≈0.14 bar pressure rise) is less than the hydrostatic head for vent clearing (0.195 bar), the vent clearing process as well as the suppression chamber and PCCS phenomena were rated low for this time phase. |
| RM-41 | H | The break flow is ranked high, as this is the primary phenomenon during this phase with a significant impact on vessel inventory. |
| RM-42 | H | During this time period, with significant flashing, enough time is available for level swell to occur and for liquid to reach the elevation of the break. Therefore, this phenomenon is rated high. |
| RM-43 | M | During a large part of this time period, there will be internal flow circulation in the core, with reverse flow in the colder regions. Thus, the parallel flow distribution and in core two-phase pressure drop is essential for in core flows, but the main flow circulation in the downcomer/core loop remains strong. |
| RM-44 | H | Due to strong depressurization, flashing is significant during this period, as is evaporation, since both through the void distribution affect the main core flow and the reactor vessel pressure, with its direct effect on break flow and loss of inventory. The resulting void distribution, in particular, has an effect on the buoyancy forces, driving the core-internal flow circulation as well as the core/downcomer flow loop. |
| RM-45 | H | Release of sensible heat stored in the fuel and the fuel to coolant heat transfer are rated high, due to their direct effect on evaporation, which was rated high, above. |
| RM-46 | M | The energy release from non-fuel solid structures in the core and chimney region is less in magnitude than the fuel contribution and was, therefore, rated lower. |
| RM-47 | H | Follows RM-44. |
| RM-48 | H | With significant level swell and with the vessel mass f low still relatively high early in this phase, the amount of liquid entering the separator may exceed design limits. Its performance under such conditions can have a significant effect on the quality of the break flow, and thus, on loss of inventory. |

**Table C.3-1 (continued)**

| Identifier | Rank | Rationale |
|---|---|---|
| RM-49 | L | Compared to the phenomenon of phase separation, RM-48 above, friction pressure drop was not considered to be important. Its effect on steam dome pressure and loss of inventory is expected to be minor. |
| RM-50 | M | While some structure stored energy will be released during this time period, the amount was considered moderate with respect to the decay heat release. |
| RM-51 | H | With excessive liquid possibly entering the separator during this phase (see RM-48), liquid accumulation and flooding may occur. |
| RM-52 | M | The ICs begin to operate early in this phase, resulting in draining of the original inventory of liquid from the ICS, followed by return of relatively cool condensate, entering the reactor vessel in the downcomer. At the same time, the feed water flow is still coasting down, adding more liquid at the time of flashing and level swell due to depressurization. The effect of both liquid streams on the downcomer level swell will affect the break flow quality and the loss of inventory. It may also further affect the $L_1$ signal, since it may lead to condensation in the lower downcomer, below the wide range level taps. |
| RM-53 | H | Follows RM-44. |
| RM-54 | H | Contact of flashing steam with relatively cool liquid from the ICS and feedwater flow from the pumps, still coasting down during the early phase of this time period, can lead to direct contact condensation, again affecting the level swell and the loss of inventory. |
| RM-55 | M | The structure stored energy release ranking rationale follows that for chimney and separators, with the added consideration, that such release will last much longer in the downcomer and in the lower plenum, due to the vessel walls being significantly thicker than the solid structures in the chimney and in the core. |
| RM-56 | H | With significant flashing during this phase and with two liquid streams entering the downcomer region (see RM-52 and RM-54), incoming liquid can be entrained by the rising vapor and carried to the break region. |
| RM-57 | M | If the fluid streams entering the downcomer are not fully mixed there, mixing can continue as the coolant enters the lower plenum. The ranking follows RM-52. |
| RM-58 | H | Follows flashing in the downcomer, RM-53. |
| RM-59 | M | Follows RM-55. |
| RM-60 | H* | The spatial void distribution in the lower plenum would have an effect on the quality of the coolant entering the core, thus affecting the core thermo-hydraulics and ultimately the reactor circulation. Some felt this to be of high importance, others felt, that the void distribution will be rather uniform. This is an item to be resolved through separate sensitivity evaluations. |
| RM-61 | H | The ICS begin to operate during this time phase, with closing of the MSIVs. The resulting removal of energy from the system and return of relatively cool condensate has a significant effect on the mass and energy discharge from the vessel to the drywell. All thermal-hydraulic IC phenomena are, therefore, ranked high during this time period. |

**Table C.3-1 (continued)**

| Identifier | Rank | Rationale |
|---|---|---|
| RM-62 | M | During normal operation noncondensible concentrations in the reactor coolant are controlled by coolant deaeration and also by hydrogen removal in the BOP portion of the coolant loop. While the ICS do not have a purge system for the separation of noncondensibles when they are in operation, there is under normal operating conditions a purge system, which will draw continuously a small amount of vapor from the top of the ICS into the main steam lines, to prevent accumulation of light gasses, in particular hydrogen, in that region. During the first three time phases of LOCA scenarios containment nitrogen cannot reach the ICS. However, hydrogen generated by radiolytic decomposition of water during the accident can be a possible concern, reducing the thermal performance of the ICs. This effect was ranked M. |
| RM-63 | L | With choked break flow, there is no interaction between the containment and the reactor vessel during this time phase and all containment phenomena, which are not n/a are ranked L. |
| RM-64 | H | During the depressurization phase critical or subcritical flow at the break or from the ADS valves controls the loss of inventory for this time phase. |
| RM-65 | L | With reduced vessel pressure and coolant inventory as well as a lower rate of pressure decrease, less opportunity for entrained liquid to reach the break is anticipated. |
| RM-66 | M | During this time period, internal flow circulation in the core, with reverse flow in the colder regions, is anticipated. Thus, the parallel flow distribution and in core two-phase pressure drops are essential for in core flows, but the main flow circulation in the downcomer/core loop remains relatively strong. |
| RM-67 | H | While the pressure has decreased significantly during the depressurization phase and the pressure/time derivative is less during this phase, the ratio of pressure derivative to pressure (P dot over P) remains significant, and flashing continues. Equally, evaporation due to heating from decay heat is expected to be significant, with both effects contributing to vessel pressure and, thus, to loss of inventory. The resulting void distribution has an effect on the buoyancy forces, driving the core-internal flow circulation as well as the core/downcomer flow loop. |
| RM-68 | H | The fuel to coolant convective heat transfer has an essential effect on vapor generation due to evaporation, see RM-67, and is rated accordingly. |
| RM-69 | L | It is expected, that the fuel stored energy has been conducted into the coolant during the previous time phase(s) and that the fuel temperature profiles now correspond to decay heat levels. |
| RM-70 | L | Internal structures in the reactor, other than fuel, with wall thicknesses of about two to three centimeter or less, are expected to have released their energy into the coolant earlier, and now their temperature would essentially be equal to the coolant saturation temperature. |
| RM-71 | H | In addition to a net mass flow loop between core and downcomer, there is internal flow circulation in the core, with upflow in most core channels and down flow in the bypass channels and possibly also in some of the cooler core channels, both loops being driven by natural circulation. Since maintenance of a strong core flow is required to protect the fuel, this internal core flow is ranked high. |

**Table C.3-1 (continued)**

| Identifier | Rank | Rationale |
|---|---|---|
| RM-72 | H | The rationale for flashing and void distribution in the chimney region is the same as that for the core, see RM-67. |
| RM-73 | H | Even though the core mass flow has decreased from its value in the preceding phase, phase separation is still important, since its effectiveness will have an effect on the break flow quality and thus, on the loss of inventory. |
| RM-74 | L | Compared to the phenomenon of phase separation, RM-74 above, friction pressure drop was not considered to be important. Its effect on steam dome pressure and loss of inventory is expected to be minor. |
| RM-75 | L | It is expected that with the decrease in total mass flow, flooding in the separators is no longer a concern. |
| RM-76 | L | The IC heat removal rate has decreased at this time, and the condensate is returning essentially at saturation temperature. The feedwater pumps are assumed to have stopped by now. Mixing of fluid streams of differing temperatures is, therefore, not of much concern any longer. |
| RM-77 | H | Follows RM-72 and RM-67. |
| RM-78 | M | Contact of flashing steam with liquid returning from the ICS can lead to direct contact condensation, again affecting any level swell and loss of inventory. With less condensate returning during this time period, compared to the preceding time phase, and with the condensate being closer to saturation temperature, this effect was ranked M. |
| RM-79 | M&L | Since the thermal time constant of the reactor vessel is significantly larger than that of other, relatively thin, internal core structures, there will still be some stored energy release during this time phase, but it is no longer as significant as in earlier time phases. |
| RM-80 | H | With significant flashing still occurring during this phase, incoming liquid can be entrained by the rising vapor and carried to the break region. |
| RM-81 | M | Follows RM-76. |
| RM-82 | H | Follows flashing in the downcomer, RM-77. |
| RM-83 | L | It is expected that spatial void distribution in the lower plenum is fairly uniform at this time and does no longer constitute a significant parameter. |
| RM-84 | H | The ICS still operate during this time phase, even though at a lower heat removal rate. Their operation still results in a significant part of the decay heat being removed, thus having an effect on the break flow and loss of inventory. All thermal-hydraulic IC phenomena, therefore, remain ranked high for this time period. |
| RM-85 | M | During this time phase the containment pressure can affect the break flow and ADS flows, once they unchoke. The amount of NCs remaining in the drywell and their distribution will have an effect on the drywell pressure. But since the flows from the reactor vessel are now much smaller than earlier in the blowdown period, and since most of the inventory loss has already occurred, these effects are only ranked M. |

**Table C.3-1 (continued)**

| Identifier | Rank | Rationale |
|---|---|---|
| RM-86 | L | With phenomena having a more direct effect on dry well pressure being ranked M, wall condensation was ranked L. |
| RM-87 | M | Following the rationale of RM-85. |
| RM-88 | M | While some gas transport through the vents into the suppression pool is still taking place, the flow rate is much reduced with respect to flow rates earlier in the transient. Consistent with the ranking of RM-85, horizontal vent flow and all suppression pool phenomena are, therefore, ranked M. |
| RM-89 | M&L | Consistent with the ranking of drywell phenomena affecting the containment pressures, the non-condensibles amount in the suppression chamber was ranked M, but all other suppression chamber phenomena, affecting the pressure less directly were ranked L. |
| RM-90 | M | The PCCS does contribute to the removal of decay heat during this time period, thus, reducing containment pressure. Its heat removal rate is lower than that of the ICS at this time. Consistent with other rankings having a direct effect on containment pressures, all its phenomena were ranked M. |
| RM-91 | n/a | Flows at the break and ADS valves is no longer critical. |
| RM-92 | M | The break and ADS valve openings now serve as gas exchange passages, with very little pressure differential between the RPV and the drywell, and with the flow being primarily driven by in-vessel or in-drywell fluid expansion or contraction. |
| RM-93 | n/a | With flows only due to fluid expansion and contraction, entrainment at the openings does no longer occur. |
| RM-94 | L | As the vessel fills, liquid spilling out of the open DPVs is expected late during the refill phase, but it is not of much concern. |
| RM-95 | L | Following RM-92, the SRV flow is less significant than the other break and ADS flows, since it is directed to the SRV spargers, submerged in the suppression pool. |
| RM-96 | L | This phase is dominated by the gradual refilling of the reactor vessel with subcooled liquid from the GDCS pools. Although some subcooled boiling may locally occur, this phase is dominated by single phase liquid flow in the core. |
| RM-97 | L | The fuel to coolant heat transfer coefficient during this time phase is not important. The clad temperature is about 1000 $^0$C below its safety limit. |
| RM-98 | M | There could be some internal flow circulation of subcooled liquid between hotter and colder regions of the core. The ranking of this phenomenon was, therefore, left at M rather than L. |
| RM-99 | L | Flashing is not anticipated during this time period and the reactor vessel components are either exposed to subcooled liquid, below the refill level or to saturated vapor, above the liquid level. Since flashing, void distribution, phase separation, etc. are not necessarily physically impossible, their ranking was set to low rather than n/a. |

**Table C.3-1 (continued)**

| Identifier | Rank | Rationale |
|---|---|---|
| RM-100 | n/a | No significant amounts of two-phase mixture are expected to enter the separator during this time phase. It will initially contain vapor only and it will fill with liquid during this time phase, but the flooding phenomenon no longer occurs. |
| RM-101 | L | The relatively cold GDCS fluid or PCCS condensate may mix with slightly hotter liquid, returning from the separator region or from the ICs, but this mixing does not have any significant effect on the vessel inventory, the main assessment criterion |
| RM-102 | L | The ICs may still remove some energy during this period. However, after equalization of pressures between the RPV and the drywell, it is anticipated that some NCs from the drywell can enter the RPV gas space and the ICs, thus causing significant deterioration in their performance. They are not designed for this time phase and they are not required. Therefore, all phenomena associated with the ICs are ranked L. |
| RM-103 | L | With the vacuum breakers possibly opening during this time period, some redistribution of NCs can occur. However, since the RPV and drywell pressures are essentially equalized, the effect of this on the vessel inventory remains negligible. |
| RM-104 | L | Condensation and heat transfer to colder structures and/or to pool surfaces may slightly reduce the pressure in various components, but it is not expected, to be a significant effect. |
| RM-105 | n/a | There is no more high speed steam flow from breaks or ADS openings entering the drywell. |
| RM-106 | n/a | The pressure difference between drywell and wetwell is insufficient for the vents to open at this time. |
| RM-107 | L | No more SRV flow is expected. |
| RM-108 | H | This phase is dominated by the discharge of coolant from the GDCS tanks into the reactor vessel. All GDCS phenomena are ranked H. |
| RM-109 | L | The PCCS may be operating at the beginning of this time phase, but it is not counted on or required during this time. By definition, the end of this time phase is reached, when PCCS operation begins again. All its phenomena are ranked L. |
| RM-110 | L | The vacuum breakers might open during this time period, releasing NCs from the suppression chamber back to the drywell. Following RM-103 this effect is ranked L. |
| RM-111 | L | Flow through the break and DPVs is relatively small during this time phase, corresponding to the steam being produced from decay heat and transported to the containment for energy removal, primarily in the PCCS. |
| RM-112 | n/a | Spilling does no longer occur, once refill is completed. |
| RM-113 | n/a | There is no more SRV flow into the suppression pool at this time, due to the pressure differential between the compartments and the SRV sparger submergence in the suppression pool. |

**Table C.3-1 (continued)**

| Identifier | Rank | Rationale |
|---|---|---|
| RM-114 | L | Evaporation and parallel channel flow distribution do occur during this time period. But, with this phase dominated by some evaporation from decay heat and return of the coolant as PCCS condensate, their effect on the vessel inventory remains minor, as long as PCCS function is maintained. |
| RM-115 | L | There is an internal flow circulation within the core during this time period, with liquid downflow in the colder core regions. This flow, driven by gravity, assures effective cooling of all core channels. However, since this internal flow circulation and the void distribution, with its effect on the buoyancy, have no direct effect on the coolant inventory, they were ranked L. |
| RM-116 | L | Flooding is no longer possible, as the separator is either submerged in liquid, or exposed to saturated steam, depending on the reactor vessel water level. |
| RM-117 | L | Due to the relatively large thermal time constant of the reactor vessel, there may still be some stored energy release early in this time phase, but it is no longer as significant as in earlier time phases. |
| RM-118 | H | During this time phase heat rejection is predominantly to the PCCS. Its operation depends on the pressure differential between the drywell, from which the steam is drawn to the PCCS, and the suppression chamber, to which the noncondensibles are diverted. Intermittently the vacuum breakers will open, returning non-condensibles from the suppression chamber to the drywell. With this sensitivity of the PCCS on the compartment pressures, the noncondensible amounts and distribution in the drywell, as well as the amount in the suppression chamber and the vacuum breaker flow were rated H. |
| RM-119 | M | Some of the steam from the reactor vessel will condense on wall surfaces as well as on liquid surfaces in the drywell. This has an effect on heat removal and on the drywell pressure and is, therefore, ranked M. |
| RM-120 | H | While water accumulation is more of a concern in other transients, like the Bottom Drain Line Break, any water lost here and going to the lower drywell is no longer available for core cooling. This effect, is unlikely, and is ranked M. |
| RM-121 | L | At this time the surface temperatures of wall surfaces have risen sufficiently for transient conduction into structures to be no longer essential. |
| RM-122 | L<br>n/a | The suppression pool does not participate much in this part of the transient, except that its coolant remains available as a source in case the equalization lines open. Its phenomena are ranked L or n/a. |
| RM-123 | L | Condensation and wall heat transfer in the suppression chamber are not essential during this time period. |
| RM-124 | L | The GDCS tanks, designed for the refill phase now carry only a much lower PCCS condensate return flow, which is well below its design limit. The GDCS flow phenomena are, therefore, ranked L. |
| RM-125 | H | The PCCS is the major heat sink during this period and all its phenomena are ranked H. |

**Table C.3-1 (continued)**

| Identifier | Rank | Rationale |
|---|---|---|
| RM-126 | H | The equalization lines are not expected to open during this transient. But, if they were to open, this phenomenon could be very important, since they only open at a water level of $L_{0.5}$ which is 1 m above TAF.. |
| RM-127 | n/a | This phenomenon is not applicable in this accident scenario. (Entrainment in the intact steamline was added as a phenomenon for small break scenarios, where the pre-isolation phase can be sufficiently long to let level swell in the reactor reach the main steam line, with liquid being carried into it, resulting in increased loss of inventory.) |
| RM-128 | M | Since the suppression chamber atmosphere is predominantly nitrogen, most likely saturated with vapor, the distribution of NCs can be ranked lower than the absolute amount, which has a direct impact on the chamber pressure. |
| RM-129 | n/a | Since this break is at a higher elevation than the ADS openings, spilling will not occur here during this accident scenario. |

**Table C.3-2 Ranking Rationale for BDLB**

| Identifier | Rank | Rationale |
|---|---|---|
| RB-01 | H | Both break flows are ranked high, as they are part of the primary phenomena during this phase and have a significant impact on the vessel inventory as well as on the dry well high pressure scram signal. |
| RB-02 | n/a | No unchoked break flow during this time period |
| RB-03 | L | Entrainment is defined as liquid being carried up to the break with the upward gas flow, for instance with level swell. The bottom break will see either liquid or two-phase inflow to the break, which does not really follow the definition of P03, Entrainment. However, it was ranked here as L, since with this configuration, coolant inflow to the break, including liquid phase, will essentially always occur. The importance of increased loss of inventory in case of liquid entering the break was already covered with RB-01, above. |
| RB-04 | H | During the relatively long pre-isolation phase sufficient time is available for liquid to reach the break, and this phenomenon is, therefore, ranked H. |
| RB-05 | n/a | Spilling, as defined in P04, is not occurring at this time. |
| RB-06 | n/a | Due to the steam line design, the flow to the turbine stop and bypass valves is expected to remain subsonic. |
| RB-07 | H | The coolant discharge via the intact steam line to the turbine bypass valves and the condenser remains significant during this time period, having a strong effect on the loss of coolant inventory. |
| RB-08 | n/a | The transient effect of inventory depletion in the steam line is expected to occur with a steam line break only, and is, therefore not applicable here. |
| RB-09 | n/a | Component not active during this time period.. |
| RB-10 | H | Boundary conditions to the RPV; pump may or may not be tripped; if tripped, it would be in coast-down mode during this time period; rated high as it directly affects the vessel inventory. |
| RB-11 | M | The core mass flow rate will coast down and partial core-internal flow reversal will occur in the core bypass region. With significant internal core flow recirculation being possible, there is no concern of core flow stagnation. The parallel flow distribution affects the internal core recirculation and, thus, the overall core flow distribution. But it does not have a significant effect on the reactor coolant inventory. Most participants felt, it should be ranked L, but some consultant(s) suggested M, resulting in a current rank of M. |
| RB-12 | L | The two-phase pressure drop drives the parallel channel flow distribution and the internal core flow circulation. It is ranked correspondingly. |
| RB-13 | H | With a high depressurization rate, the flashing rate during this time phase is high, and its effect on level swell and loss of coolant inventory can be high. |

**Table C.3-2 (continued)**

| Identifier | Rank | Rationale |
|---|---|---|
| RB-14 | H* | The power generation has decreased to decay heat levels, but the core mass flow also decreases significantly early in this time phase. Some participants felt that evaporation would be small with respect to vapor generation by flashing. Others felt it might still be significant. A side calculation is suggested to quantify the effect. The current ranking is H*. |
| RB-15 | H* | The void distribution through core and chimney will control the buoyancy for internal as well as external core flow circulation. It will also affect the level swell and liquid carry-over to the open steam line. There remained considerable disagreement between various contributors, how important this factor would be. It is currently ranked H* and is one of the prime candidates for review, based on future sensitivity calculations. |
| RB-16 | H | Core power, as the main energy source, is always rated high. |
| RB-17 | M | The clad to coolant convective heat transfer will affect the vapor generation in the core. (See RB-14). Depending on the magnitude of the convective heat transfer, the distribution of the released decay heat between vapor generation and energy stored in the fuel may change. Most participants ranked this item low, but some suggested M. Subject to future sensitivity calculations, the current ranking is M. |
| RB-18 | M | The time constant of the solid capacitance in the fuel rods is of the order of the phase duration, but it is not a major contributor to energy transfer to the coolant, compared to decay heat, Therefore, the fuel stored energy is ranked M.[2] See also RB-17. |
| RB-19 | L | The core structures without a heat source, which were originally essentially at coolant temperatures, undergo a smaller temperature change than the fuel. Following RB-18, the energy release from these structures is ranked low. |
| RB-20 | L | Significant internal core flow recirculation is possible during this time phase, but its effect on the vessel inventory is not significant. With RB-11 and RB-12 it was ranked L. |
| RB-21 | H* | Following RB-13, flashing in the chimney was ranked H by some participants. Another viewpoint is, that most of the coolant has already flashed in the core, so that little flashing is possible in the chimney. Subject to future quantification, the effect is currently ranked H*. |
| RB-22 | L | With the structures being originally at coolant saturation temperature and the coolant temperature drop remaining relatively small during this phase, structure stored energy was ranked low. (See also RB-19.) |
| RB-23 | H* | With significant mass flow out of the reactor into the main steam line during this time phase, the performance of the separators is important. If they function satisfactorily, almost no liquid will be carried on into the steam line. However, if the mass flow entering the separators exceeds the design envelope and they cannot remove all liquid, a significant increase in the loss of inventory via the steam line could occur. Subject to quantification in future sensitivity evaluations the effect is currently ranked H*. Comparison of the velocity head of the incoming coolant to the velocity head during normal full power operation was suggested for this quantification. |

[2]See Section 5 for future revision of this ranking.

**Table C.3-2 (continued)**

| Identifier | Rank | Rationale |
|---|---|---|
| RB-24 | L | The two-phase pressure drop in this component would only have a very minor effect on the steam dome pressure and on the outflow into the steam line. |
| RB-25 | L | Follows RB-22. |
| RB-26 | M | This item is essentially coupled to RB-23. If future evaluations indicate, that overloading of the separators does not occur, then its ranking can be reduced. Subject to revision with the RB-23 ranking, it is currently set to M. |
| RB-27 | M | Mixing will be essential once cold IC condensate enters the downcomer, which does not yet occur during this phase. But with some subcooled feedwater still entering, this effect was ranked M. |
| RB-28 | H | With the rapid pressure decrease during this phase, significant flashing is expected to occur in the downcomer. In particular with the upper break flow exiting from this component, level swell and entrainment can occur. |
| RB-29 | M | Following RB-27, some direct contact condensation of vapor in contact with the incoming feedwater is possible, counteracting the flashing. As the amount of incoming feedwater is uncertain, the effect was ranked M. |
| RB-30 | M | With the downcomer solid structures of significantly higher thermal capacitance than the core and chimney regions, this effect was ranked low to medium for this time phase. |
| RB-31 | L | Following RB-27, but with mixing most likely completed in the downcomer, it is expected to be of lesser importance here. |
| RB-32 | L | With rapid pressure decrease, flashing and void distribution were ranked high, in particular for this component, connected to the lower break, where the void distribution can directly affect the break flow. |
| RB-33 | L | Follows RB-30. |
| RB-34 | H | The focus in this PIRT is on the reactor pressure vessel. Containment phenomena are only to be considered, if they have a significant feedback on the scenario inside the vessel. During the pre-isolation time period, the scram signal is most likely on high drywell pressure. Therefore, phenomena affecting the pressure can be important. Condensation in the presence of non-condensibles on structures or on liquid surfaces as well as heat transfer into the solid structures were, therefore considered important. |
| RB-35 | L | Water accumulation will occur during this time phase, in particular in the lower drywell. Since it is not expected to have any significant effect on the dry well pressure, it is ranked L. |
| RB-36 | H | The degree of mixing between the incoming steam jet and the original nitrogen in the drywell will have a direct effect on the drywell pressure. (In particular it has been shown in the model development for Mark III containments, that the assumption of uniform mixing can lead to an underestimate of the drywell pressure.) |
| RB-37 | L | Since the drywell pressure scram signal ($\approx$0.14 bar pressure rise) is less than the hydrostatic head for vent clearing (0.195 bar), the vent clearing process as well as the suppression chamber and PCCS phenomena were rated low for this time phase. |

**Table C.3-2 (continued)**

| Identifier | Rank | Rationale |
|---|---|---|
| RB-38 | H | There can still be some feedwater flow entering the reactor vessel, as the pumps may still be coasting down. The subcooled water adds to the inventory and possibly condenses vapor. |
| RB-39 | M | Core coolant flow during this time phase will be dominated by internal core flow recirculation, with upflow in most fuel channels and downflow in the bypass channels as well as in some of the peripheral coolant channels. But, this internal flow circulation does not have a significant influence on the reactor coolant inventory and was ranked M. |
| RB-40 | M | The rate of pressure decrease is much slower in this time phase, but at a lower absolute pressure level. Some flashing will still occur, but the $\dot{p} / p$ term, affecting the flashing rate is about one order lower than in the preceding time phase. Due to its limited effect on the reactor coolant inventory, flashing and void distribution in the core are ranked M. |
| RB-41 | L | Vapor generation due to decay heat was expected not to have a significant effect on the loss of core coolant inventory in this time phase. |
| RB-42 | L | The fuel to coolant heat transfer rate was rated low, since its magnitude would only affect the actual fuel temperature, which remains in all cases significantly below any levels of concern. |
| RB-43 | M | The energy release from the fuel may still be moderately significant during the early portion of this time phase. |
| RB-44 | L | The energy release from non-fuel solid structures in the core and chimney region is less in magnitude than the fuel contribution and was, therefore, rated lower. |
| RB-45 | M | With the reduced flashing rate during this time phase, flashing and level/void distribution in the chimney were considered to be less significant in this time phase, relative to the pre-isolation phase and were ranked medium. |
| RB-46 | L | With the flow to the steam line now stopped, and the pressure decreasing much slower than in the preceding phase, there is no significant concern about separator/dryer performance. |
| RB-47 | H* | The ICs begin to operate early in this phase, resulting in draining of the original inventory of liquid from the ICS, followed by return of relatively cool condensate, entering the reactor vessel in the downcomer region. At the same time, the feed water flow might also still be coasting down, adding more liquid at the time of flashing and level swell due to depressurization. The effect of both liquid streams on the downcomer level swell can directly affect the break flow quality and the loss of inventory. It may also further affect the $L_1$ signal, since it could lead to condensation in the lower downcomer, below the wide range level taps. Both, fluid mixing and direct contact condensation were ranked H by most participants, with some reservations by others, resulting in a composite H* ranking. |
| RB-48 | M | Flashing is still occurring, but at a much lower rate than in the preceding time phase. Both, flashing and level/void distribution were ranked M. |
| RB-49 | L | With relatively little coolant temperature change, the contribution from downcomer and lower plenum structures stored energy to the energy addition to the coolant was expected to be minor. |

**Table C.3-2 (continued)**

| Identifier | Rank | Rationale |
|---|---|---|
| RB-50 | H | Even though flashing itself was only ranked M, the effect of any level swell, carrying liquid into the upper downcomer regions, can have a significant effect on the quality of the break flow, and thus, on loss of inventory. |
| RB-51 | L | It is expected that mixing of the downcomer coolant with the IC return stream is essentially completed in the downcomer and that mixing in the lower plenum can be ranked L. |
| RB-52 | M | Following RB-48, but also considering the connection of the bottom break to this component, flashing and void distribution in the lower plenum were ranked M. |
| RB-53 | H | The ICS begin to operate during this time phase, with closing of the MSIVs. The resulting removal of energy from the system and return of relatively cool condensate has a significant effect on the mass and energy discharge from the vessel to the drywell. All thermal-hydraulic IC phenomena are, therefore, ranked high during this time period. |
| RB-54 | M | During normal operation noncondensible concentrations in the reactor coolant are controlled by coolant deaeration and also by hydrogen removal in the BOP portion of the coolant loop. While the ICs do not have a purge system for the separation of noncondensibles when they are in operation, there is under normal operating conditions a purge system, which will draw continuously a small amount of vapor from the top of the ICs into the main steam lines, to prevent accumulation of light gasses, in particular hydrogen, in that region. During the first three time phases of LOCA scenarios containment nitrogen cannot reach the ICs. However, hydrogen generated by radiolytic decomposition of water during the accident can be a possible concern, reducing the thermal performance of the ICs. This effect was ranked M. |
| RB-55 | L | With choked break flow, there is no interaction between the containment and the reactor vessel during this time phase and all containment phenomena, which are not n/a are ranked L. |
| RB-56 | M | Both break flows, whether the flow is critical and/or subcritical, are ranked M during this phase, since the break flows are small compared to the much larger ADS flows. |
| RB-57 | H | The DPV and SRV flows during this time phase will be initially critical, with unchoking and subcritical flow towards the end of the time phase. Since these flows constitute the most significant loss of inventory for the time phase, they are ranked H. (Except as noted under RB-59.) |
| RB-58 | H* | If entrained liquid can reach the DPV elevation, the resulting increased loss of inventory would be important. Some participants wanted to rank this effect H. Others felt, that since the ADS is designed to open its valves in sequence, to minimize potential level swell, and since the separators would be expected to eliminate any up-flowing liquid from the stream, this effect should be ranked M, resulting in an H* ranking. (See also RB-67, below.) |
| RB-59 | M | Once the flow unchokes towards the end of this period, the mass discharge through the DPVs outweighs the contributions of the SRVs, due to the higher flow area. |
| RB-60 | L | Entrainment at the SRVs was considered to be less important than at the DPVs, due to their higher elevation and lower flow area. |
| RB-61 | M | During this time period, internal flow circulation in the core, with reverse flow in the colder regions, is anticipated. Thus, the parallel flow distribution and in core two-phase pressure drops are essential for in core flows, but their effect on the coolant inventory is not major. |

**Table C.3-2 (continued)**

| Identifier | Rank | Rationale |
|---|---|---|
| RB-62 | M | The two phase flow pressure drop drives the core flow distribution and is ranked in accordance with RB-61. |
| RB-63 | H* | With the increased rate of depressurization, the flashing rate is expected to increase, resulting in possible level swell, carrying liquid coolant upwards, towards the ADS openings. Correspondingly, in-core flashing and void distribution were ranked H to M, with a final rank of H*. |
| RB-64 | M | With final, relatively rapid depressurization the coolant temperature is dropping, resulting in additional stored energy release from the fuel as well as from other in-core solid structures. |
| RB-65 | H* | Analogous to the discussion with RB-21, flashing in the chimney was felt to be important, but most of the coolant may already have flashed in the core. Subject to future quantification, it is currently ranked H*. |
| RB-66 | M | Follows RB-64. |
| RB-67 | H* | Following the discussions with RB-58, the separator performance during this time phase can have an important impact on the loss of inventory during final depressurization. Some participants felt that it is, therefore, an important phenomenon, to be ranked high. Others felt, that since the mass flows are expected to remain within the design basis envelope, the separators will perform well and no liquid will be carried over, and that, therefore, it should be ranked L. For quantification, the inlet velocity head of the peak ADS flows should be compared to the normal steady state performance velocity head. |
| RB-68 | M | With increased flow rates and with the flow finally unchoking, the pressure drop in the separator/dryer was expected to have a moderate effect on the mass flow to the ADS towards the end of the time phase and was ranked M. |
| RB-69 | M | Massive overloading of the separators with liquid was not expected, and flooding was ranked L to M. |
| RB-70 | M | The ICs performance will decrease with depressurization, but some mixing of the remaining condensate flow with downcomer coolant will still occur. Mixing and direct contact condensation are ranked M for this time period. |
| RB-71 | H* | With the increase in depressurization rate, significant flashing and level swell may occur in the downcomer during this time phase. With some disagreement between the participants, both effects are ranked H*, subject to future quantification. |
| RB-72 | M | With flashing and level swell in the downcomer, entrainment of liquid in the upper break coolant flow is expected to occur. The reason for it being ranked only M is the fact that the break flows are not dominant during this time of ADS operation. |
| RB-73 | M | Fluid mixing during this time phase is most likely completed in the downcomer. It is ranked L to M. |
| RB-74 | H* | Flashing is expected to occur in the lower plenum during this time phase. The resulting void distribution will affect the lower break flow quality as well as core inlet flow quality. However, as in the downcomer, the break flow is not ranked H, since ADS flows dominate. (See also RB-56). |

**Table C.3-2 (continued)**

| Identifier | Rank | Rationale |
|---|---|---|
| RB-75 | M | The IC performance will decrease during the depressurization period, and will most likely stop at the end of this phase, as noncondensibles from the drywell can enter the ICs. |
| RB-76 | L | With decreased emphasis on IC performance, the concern of performance degradation due to NCs was downgraded to L. |
| RB-77 | M | Towards the end of this time phase, as the ADS flows unchoke, the containment pressures will begin to have an effect on the flow rates and on the vessel pressure and inventory. However, the final absolute value of the equalization pressure is not of significant concern for in-vessel events, and all phenomena affecting containment pressures are ranked M. |
| RB-78 | M | With continuing water accumulation in the lower drywell, from the lower break, this level is now of some concern, as it will determine when an equilibrium liquid level will be established between the drywell and the reactor vessel, finally terminating break flow from the lower break. Most likely, this will only occur during the long term cooling phase. |
| RB-79 | L | At this time, most of the nitrogen has been transported to the suppression chamber, and $N_2$ and steam mixing is not much of a concern. |
| RB-80 | M | There will be coolant flow via the vent system to the suppression pool, with vapor condensation in the pool. In accordance with RB-77, with its effect on the containment pressures, these phenomena are ranked M. |
| RB-81 | M | The NC amount in the suppression chamber has a direct effect on the chamber pressure. |
| RB-82 | L | NC distribution and surface condensation and wall heat transfer are of less concern here, with the atmosphere being predominantly nitrogen. |
| RB-83 | L | No significant PCCS performance is expected during this time phase. |
| RB-84 | n/a | Flow at the break and ADS valves is no longer critical. |
| RB-85 | M | The lower break flow is expected to continue during the refill phase. Except possibly for a short period at the beginning of this phase, there will be subcooled liquid flow out of the break only, gradually increasing in flow rate, as the vessel fills, increasing the drive head. |
| RB-86 | M | The upper break and ADS valve openings now serve as gas exchange passages, with very little pressure differential between the RPV and the drywell, and with the flow being primarily driven by in-vessel or in-drywell fluid expansion or contraction. |
| RB-87 | n/a | With flows only due to fluid expansion and contraction, entrainment at the openings does no longer occur. |
| RB-88 | H | As the vessel is refilled from three GDCS tanks through six downcomer headers, the water level will rise above the upper break, with coolant then spilling out of this opening, increasing in flow rate, as the head rises above the break. Since this loss of inventory is significant and will continue beyond this phase, until the water level has receded to the break elevation, the effect is ranked H. |
| RB-89 | L | As the vessel fills, liquid spilling out of the open DPVs may occur late during the refill phase, but it is not of much concern. |

**Table C.3-2 (continued)**

| Identifier | Rank | Rationale |
|---|---|---|
| RB-90 | L | Following RB-86, the SRV flow is less significant than the other break and ADS flows, since it is directed to the SRV spargers, submerged in the suppression pool. |
| RB-91 | L | This phase is dominated by the gradual refilling of the reactor vessel with subcooled liquid from the GDCS pools. Although some subcooled boiling may locally occur, this phase is dominated by single phase liquid flow in the core. |
| RB-92 | L | The fuel to coolant heat transfer rate during this time phase is not important. The clad temperature is about 1000 $^0$C below its safety limit. |
| RB-93 | L | It is expected, that the fuel stored energy has been conducted into the coolant during the previous time phase(s) and that the fuel temperature profiles now correspond to decay heat levels. |
| RB-94 | L | Internal structures in the reactor, other than fuel, with wall thicknesses of about two to three centimeter or less, are expected to have released their energy into the coolant earlier, and now their temperature would essentially be equal to the coolant saturation temperature. |
| RB-95 | L | There could be some internal flow circulation of subcooled liquid between hotter and colder regions of the core. This phenomenon was ranked L, since the flow is predominantly subcooled liquid flow and is of little effect on the vessel inventory. |
| RB-96 | L | Flashing is not anticipated during this time period and the reactor vessel components are either exposed to subcooled liquid, below the refill level or to saturated vapor, above the liquid level. Since flashing, void distribution, phase separation, etc. are not necessarily physically impossible, their ranking was set to low rather than n/a. |
| RB-97 | n/a | No significant amounts of two-phase mixture are expected to enter the separator during this time phase. It will initially contain vapor only and it will fill with liquid during this time phase, but the flooding phenomenon no longer occurs. |
| RB-98 | L | The relatively cold GDCS fluid or PCCS condensate may mix with slightly hotter liquid, returning from the separator region or from the ICs, but this mixing does not have any significant effect on the vessel inventory, the main assessment criterion |
| RB-99 | L | Since the thermal time constant of the reactor vessel is significantly larger than that of other, relatively thin, internal core structures, there will still be some stored energy release during this time phase, but it is no longer as significant as in earlier time phases. |
| RB-100 | L | The ICs may still remove some energy during this period. However, after equalization of pressures between the RPV and the drywell, it is anticipated that some NCs from the drywell can enter the RPV gas space and the ICs, thus causing significant deterioration in their performance. They are not designed for this time phase and they are not required. Therefore, all phenomena associated with the ICs are ranked L. |
| RB-101 | L | With the vacuum breakers possibly opening during this time period, some redistribution of NCs can occur. However, since the RPV and drywell pressures are essentially equalized, the effect of this on the vessel inventory remains negligible. |
| RB-102 | L | Condensation and heat transfer to colder structures and/or to pool surfaces may slightly reduce the pressure in various components, but it is not expected, to be a significant effect. |

**Table C.3-2 (continued)**

| Identifier | Rank | Rationale |
|---|---|---|
| RB-103 | n/a | There is no more high speed steam flow from breaks or ADS openings entering the drywell. |
| RB-104 | n/a | The pressure difference between drywell and wetwell is insufficient for the vents to open at this time. |
| RB-105 | L | No more SRV flow is expected. |
| RB-106 | H | This phase is dominated by the discharge of coolant from the GDCS tanks into the reactor vessel. All GDCS phenomena are ranked H. |
| RB-107 | L | The PCCS may be operating at the beginning of this time phase, but it is not counted on or required during this time. By definition, the end of this time phase is reached, when PCCS operation begins again. All its phenomena are ranked L. |
| RB-108 | L | The vacuum breakers might open during this time period, releasing NCs from the suppression chamber back to the drywell. Following RB-101 this effect is ranked L. |
| RB-109 | M | The lower break flow is expected to continue until an equilibrium has been reached between the water levels in the reactor and in the drywell. There will be liquid flow at the break only, since the lower plenum is now filled with water. |
| RB-110 | n/a | There is single phase flow now at this break. |
| RB-111 | L | Flow through the break and DPVs is relatively small during this time phase, corresponding to the steam being produced from decay heat and transported to the containment for energy removal, primarily in the PCCS. (Applies at the upper break only after the water level in the vessel has receded below the break elevation.) |
| RB-112 | H | Early during the long term cooling phase, the water level in the reactor will decrease, with spilling out of the upper break opening. Even though the water level is significantly above the core, this constitutes a loss of inventory and is, therefore, ranked H. |
| RB-113 | n/a | Spilling does no longer occur, once refill is completed. |
| RB-114 | n/a | There is no more SRV flow into the suppression pool at this time, due to the pressure differential between the compartments and the SRV sparger submergence in the suppression pool. |
| RB-115 | L | Flashing, evaporation and parallel channel flow distribution can occur during this time period. But, with this phase dominated by some evaporation from decay heat and return of the coolant as PCCS condensate, their effect on the vessel inventory remains minor, as long as PCCS function is maintained. |
| RB-116 | L | There is an internal flow circulation within the core during this time period, with liquid downflow in the colder core regions. This flow is driven by gravity and assures effective cooling of all core channels. Since its effect on the coolant inventory is minor, it is ranked L. |
| RB-117 | L | Flooding is no longer possible, as the separator is either submerged in liquid, or exposed to saturated steam, depending on the reactor vessel water level. |

**Table C.3-2 (continued)**

| Identifier | Rank | Rationale |
|---|---|---|
| RB-118 | L | Due to the relatively large thermal time constant of the reactor vessel, there may still be some stored energy release early in this time phase, but it is no longer as significant as in earlier time phases. |
| RB-119 | H | During this time phase heat rejection is predominantly to the PCCS. Its operation depends on the pressure differential between the drywell, from which the steam is drawn to the PCCS, and the suppression chamber, to which the noncondensibles are diverted. Intermittently the vacuum breakers will open, returning non-condensibles from the suppression chamber to the drywell. With this sensitivity of the PCCS on the compartment pressures, the noncondensible amounts and distribution in the drywell, as well as the amount in the suppression chamber and the vacuum breaker flow were rated H. |
| RB-120 | M | Some of the steam from the reactor vessel will condense on wall surfaces as well as on liquid surfaces in the drywell. This has an effect on heat removal and on the drywell pressure and is, therefore, ranked M. |
| RB-121 | H | The break flow out of the bottom break will continue until the drywell water level is in equilibrium with the reactor vessel water level, which is expected to occur at some time during this phase. Tracking of this level, with its impact on reactor coolant inventory is ranked H. |
| RB-122 | L | At this time the surface temperatures of wall surfaces have risen sufficiently for transient conduction into structures to be no longer essential. |
| RB-123 | L | The suppression pool does not participate much in this part of the transient, except that its coolant remains available as a source in case the equalization lines open. Its phenomena are ranked L. |
| RB-124 | M | Since the suppression chamber atmosphere is predominantly nitrogen, most likely saturated with vapor, the distribution of NCs can be ranked lower than the absolute amount, which has a direct impact on the chamber pressure. |
| RB-125 | L | Condensation and wall heat transfer in the suppression chamber are not essential during this time period. |
| RB-126 | L | The GDCS tanks, designed for the refill phase now carry only a much lower PCCS condensate return flow, which is well below its design limit. The GDCS flow phenomena are, therefore, ranked L. |
| RB-127 | H | The PCCS is the major heat sink during this period and all its phenomena are ranked H. |
| RB-128 | H | The equalization lines are not expected to open during this transient. But, if they were to open, this phenomenon could be very important, since they only open at a water level of $L_{0.5}$ which is 1 m above TAF. |
| RB-129 | H | During the pre-isolation phase, the largest loss of inventory is through the steam line to the condenser. With sufficient time for flashing and level swell to reach the steam line elevation, liquid entrainment with the steam line coolant flow is possible, mainly depending on the functioning of the separator/dryer during this time phase. If entrainment were to occur, it could have a significant effect on the loss of inventory. |
| RB-130 | n/a | With the definition of P05, spilling does not occur at the bottom break. |

**Table C.3-3 Ranking Rationale for GDLB**

| Identifier | Rank | Rationale |
|---|---|---|
| RG-01 | n/a | There is no second break in this scenario. |
| RG-32 | L | With rapid pressure decrease, flashing and void distribution were ranked high. |
| RG-35 | L | Some water accumulation may occur during this time phase in the lower drywell. Since it is not expected to have any significant effect on the dry well pressure, it is ranked L. |
| RG-52 | M | Following RB-48, flashing and void distribution in the lower plenum were ranked M. |
| RG-74 | M | Flashing is expected to occur in the lower plenum during this time phase. The resulting void distribution will affect the core inlet flow quality. |
| RG-78 | M | Some of the break and ADS flow may accumulate in the lower drywell in a liquid pool, together with the drained contents of one GDCS tank. Since this water is lost as reactor coolant, the effect is ranked M. |
| RG-121 | H | Early in this time phase spilling from the break will increase the coolant accumulation in a liquid pool in the drywell. As in RG-78, the effect is ranked M. |

# APPENDIX D

# PIRT MEETINGS AGENDA AND ATTENDANCE LISTS

## Agenda for First SBWR PIRT Meeting at BNL

May 12, 1994

| | |
|---|---|
| Opening (NRC & BNL) | 8:30 - 9:00 |
| Introduction to SBWR | 9:00 - 10:15 |
| Break | 10:15 - 10:30 |
| Description of Transients | 10:30 - 12:00 |
| Assessment Criteria | 12:00 - 12:30 |
| Lunch | 12:30 - 1:30 |
| Phenomena Identification for MSLB | 1:30 - 4:00 |
| Phenomena Ranking for MSLB | 4:30 - 5:30 |

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## Agenda for First SBWR PIRT Meeting

May 13, 1994

| | |
|---|---|
| Phenomena Ranking for MSLB | 8:30 - 11:30 |
| Closing Session | 11:30 - 12:30 |

# FIRST SBWR PIRT MEETING
# MAY 12-13, 1994
# at
# BROOKHAVEN NATIONAL LABORATORY

## Attendance Sheet

| NAME | ORGANIZATION | PHONE |
|---|---|---|
| Vijay Dhir | UCLA (ACRS) | Tel #(310)825-8507<br>Fax #(310)206-4830 |
| Ramin Dowlati | Purdue University | (317)496-1738 |
| Don Fletcher | INEL | Tel #(208)526-7652<br>Fax #(208)526-6971 |
| Peter Griffith | MIT | Tel #(617)253-2248<br>Fax #(617)258-5802 |
| Norm Lauben | NRC/RES | (301)492-3573 |
| Tim M. Lee | NRC/RES | (301)415-6479 |
| Zoran Musicki | BNL | (516)282-4158 |
| Gregory C. Slovik | BNL | (516)282-7983 |
| John Vandenkieboom | BNL | (516)282-5403 |
| Ken Washington | Sandia | (505)844-0231<br>Email kewashi@sandia.gov |
| David C. Williams | Sandia | (505)844-5370 |
| Bob Youngblood | BNL | (516)282-2363 |
| Upendra S. Rohatgi | BNL | Tel #(516)282-2475<br>Fax #(516)282-7650 |

# AGENDA FOR SECOND PIRT MEETING:

**August 23, 1994**

| | |
|---|---|
| Review of SBWR | 8:30 - 9:00 AM |
| Review of MSLB | 9:00 -10:00 AM |
| Break | 10:00 - 10:15 AM |
| Description of BDLB | 10:15 - 11:00 AM |
| PIRT for BDLB | 11:00 - 12:00 AM |
| Lunch | 12:00 - 1:00 PM |
| PIRT for BDLB | 1:00 - 5:00 PM |

**August 24, 1994**

| | |
|---|---|
| Description of GDLB | 8:30 - 9:00 AM |
| PIRT for GDLB | 9:00 - 10:00 AM |
| Break | 10:00 - 10:15 AM |
| PIRT for GDLB | 10:15 - 12:00 AM |
| PIRT Assessment Plan | 12:00 - 12:30 PM |

# SECOND SBWR PIRT MEETING
# AUGUST 23, 1994
# at
# BROOKHAVEN NATIONAL LABORATORY

## Attendance Sheet

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NRC FORM 335 (2-89) NRCM 1102, 3201, 3202

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# BIBLIOGRAPHIC DATA SHEET

*(See instructions on the reverse)*

**1. REPORT NUMBER** (Assigned by NRC, Add Vol., Supp., Rev., and Addendum Numbers, if any.)

NUREG/CR-6472
BNL-NUREG-52501

**2. TITLE AND SUBTITLE**

Preliminary Phenomena Identification and Ranking Tables for Simplified Boiling Water Reactor Loss-of-Coolant Accident Scenarios

**3. DATE REPORT PUBLISHED**

| MONTH | YEAR |
|---|---|
| April | 1998 |

**4. FIN OR GRANT NUMBER**

W6092

**5. AUTHOR(S)**

P. G. Kroger, U. S. Rohatgi, J. H. Jo, G. C. Slovik

**6. TYPE OF REPORT**

Technical

**7. PERIOD COVERED** *(Inclusive Dates)*

05/15/93 - 12/31/96

**8. PERFORMING ORGANIZATION - NAME AND ADDRESS** *(If NRC, provide Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address; if contractor, provide name and mailing address.)*

Brookhaven National Laboratory
Upton, NY 11973-5000

**9. SPONSORING ORGANIZATION - NAME AND ADDRESS** *(If NRC, type "Same as above"; if contractor, provide NRC Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address.)*

Division of Systems Technology
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

**10. SUPPLEMENTARY NOTES**

G. S. Rhee, NRC Project Manager

**11. ABSTRACT** *(200 words or less)*

A set of Phenomena Identification and Ranking Tables (PIRT) for three potential Loss-of-Coolant Accident (LOCA) scenarios in the General Electric Simplified Boiling Water Reactor is presented. The selected LOCA scenarios are typical for the class of small and large breaks generally considered in Safety Analysis Reports. The method used to develop the PIRTs is described. Following a discussion of the transient scenarios, the PIRTs are presented and discussed in detailed and summarized form. A procedure for future validation of the PIRTs, to enhance their value, is outlined.

**12. KEY WORDS/DESCRIPTORS** *(List words or phrases that will assist researchers in locating the report.)*

BWR Type Reactors - Loss-of-Coolant Accident
BWR Type Reactors - Scale Models
Loss-of-Coolant Accident - Computerized Simulation
Computer Codes
General Electric Standard Reactor
Heat Transfer
Hydraulics

**13. AVAILABILITY STATEMENT**

unlimited

**14. SECURITY CLASSIFICATION**

*(This Page)* unclassified

*(This Report)* unclassified

**15. NUMBER OF PAGES**

**16. PRICE**

NRC FORM 335 (2-89)