Resolution of T/H Uncertainty Issues
for AP600 Passive System Reliability

DECEMBER 1996 DRAFT

(Includes PRA Expanded Event Trees and
Definition of Low-Margin, Risk-Significant Cases)

**Executive Summary of
Resolution of T/H Uncertainty Issues,
December 1996 Status**

The final effort to resolve passive system reliability issues is to evaluate the potential impact of thermal/hydraulic uncertainties on the PRA. The central question is whether the consideration of uncertainty in success criteria analyses would significantly affect the conclusions of the PRA. The T/H uncertainty resolution process identifies a set of low-margin, risk-significant accident scenarios, and shows acceptable T/H performance when the uncertainties are bounded.

The first step of the T/H uncertainty resolution process is to expand the Focused PRA event trees and to quantify the frequency of the success paths. Expanding the event trees is necessary to differentiate between scenarios that are grouped together in the PRA. There are ten expanded event trees developed for T/H uncertainty resolution that encompass all the success paths that require ADS actuation for successful core cooling. The frequency of the success paths are quantified.

The next step is to categorize all the success paths based on similarities in the accident progressions. There are 20 categories, which are separated into two types: OK categories and UC categories. The OK categories are ones that are similar enough to design basis that it can be explained why they are not "low margin" scenarios, and they are not further considered within the T/H uncertainty resolution process. The UC categories are considered "low margin," and the frequency of each UC category is further assessed to determine whether it is risk-significant.

The categorization process considers the accident progression through two phases of water injection: 1) short term, when the accumulators and CMTs provide make-up inventory, and 2) IRWST gravity injection. The final phase of water injection -- long-term sump recirculation -- will be treated separately from the OK and UC categorization. The plan to address long-term recirculation for the PRA is outlined, but has not been implemented, pending further discussions between Westinghouse and the NRC.

Each UC category is assessed to determine whether it is risk-significant. This process considers the increase to the Focused PRA Core Damage Frequency (CDF) and Large Release Frequency (LRF) if the <u>success</u> path actually leads to core damage. Risk significance is defined as increasing the Focused PRA CDF or LRF by at least 1% if the UC category were counted as core damage. This process identifies five risk-significant categories that are summarized in the following table. More information on the accident scenarios represented by these categories is in Section 7.0 of the attached report. The impact of using the Focused PRA rather than the Baseline PRA as the comparison is also discussed within the report, but does not alter which categories are designated as risk-significant.

Risk-Significant, Low-Margin Categories (In Order of Risk Significance)				
Category	Initiating Events	Defining Equipment Conditions	If counted as core damage, increase to Focused PRA	
			ΔCDF	ΔLRF
UC4	LLOCA	1 Accumulator	1.1E-6	6.9E-8
UC5	NLOCA DVI Line Break SLOCA SGTR Transients	0 Accumulators	7.2E-7	7.6E-8
UC6	All	2 stage 4 ADS Containment Isolated	3.4E-7	7.5E-8
UC1	NLOCA DVI Line Break	0 CMTs	1.4E-7	8.2E-9
UC2B	MLOCA CMT Line Break	0 CMTs	1.2E-7	7.5E-9

From these risk-significant categories, a set of cases is defined for T/H analyses with uncertainties to complete the T/H uncertainty resolution process. A representative case for each category is defined by examining the success paths that dominate the frequency of that category. Table 8-3 within the attached document identifies the cases that will be analyzed. The determination of the limiting break sizes to be analyzed will be made after the MAAP4/NOTRUMP benchmarking is completed.

The final steps in the T/H uncertainty resolution process, that are not completed are:

- Identify the risk-significant long-term recirculation cases
- Perform T/H analyses with uncertainties on low-margin risk-significant cases from the UC categorization and on risk-significant long-term recirculation cases
- Assess T/H study results on the PRA

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1.0 INTRODUCTION

The AP600 design incorporates passive engineered safety features that perform safety-related functions to mitigate accidents and to establish safe shutdown conditions following an event. An extensive range of activities have been completed as part of the AP600 design certification process to provide confidence in the design capabilities and reliability of the safety-related, passive systems and components. An overview of these activities, and references to the appropriate documentation, is provided in Ref. 1. One of the remaining efforts to resolve passive system reliability issues, as identified in Ref. 1, is to evaluate the potential impact of thermal/hydraulic uncertainties on the PRA.

Thermal/hydraulic analyses have been performed to support multiple-failure success criteria definitions in the AP600 PRA. To define the cases for analyses, the PRA event trees were reviewed and success paths (i.e., paths that do not lead to core damage) were grouped based on similarities. Each group consists of the same functioning equipment and a range of break sizes and location. Within each group, bounding cases were identified. Bounding cases were chosen to be the most limiting break size, location and set of equipment to bound the group of cases.

Analyses of the bounding cases were performed with nominal assumptions, rather than conservatisms that are typical of design basis safety analyses. The purpose of using nominal conditions was to preserve plant behavior as it is most likely to occur, so that PRA insights may be gained on the risk importance of different systems. An issue has been raised on whether the consideration of uncertainty in the analyses would significantly affect the conclusions of the PRA. This issue is termed "T/H uncertainty resolution" and is the subject of this document. It is the final component to closing the passive system reliability issues for AP600.

2.0 DEFINITION OF THERMAL-HYDRAULIC (T/H) UNCERTAINTY

The term "T/H uncertainty" is used in relationship to predicting the behavior of passive systems in AP600. Because of the passive nature of the safety-related systems in AP600 and the reliance on small ΔP's, the concern is that uncertainties in predicting the small changes in the system conditions could lead to different conclusions on the success of core cooling. The small changes in system conditions could be due to different accident conditions than modelled, or uncertainty in analytical models. Specific sources of T/H uncertainty that have been identified as potential concerns are:

- initial and boundary conditions,
- code uncertainty (based on testing and scaling uncertainties),
- user-selected inputs and modeling methods.

If the success criteria are bounding, it must be shown that the consideration of T/H uncertainties does not significantly impact the PRA results. Furthermore, because the concern is passive system reliability, the Focused PRA (that does not include active systems) is the standard for comparison and determination of impact. Use of the Focused PRA ensures that active systems will not camouflage the importance of passive systems, or the uncertainty in predicting their performance. Section 4.3 provides more information on the impact of using the Focused PRA instead of the Baseline PRA as the comparison basis.

As described in the following sections, the T/H uncertainty resolution process does not quantify the sources of uncertainty, nor is it solely a T/H analysis exercise. Rather, the T/H uncertainty resolution process identifies a set of low margin, risk significant accident scenarios, and shows acceptable T/H performance when the uncertainties are bounded.

3.0 RESOLUTION PROCESS

The T/H uncertainty resolution process integrates information that can be obtained from the PRA and from T/H analyses. PRA methods can direct attention to accident scenarios that are most probable. PRA event trees show a breakdown of the possible equipment successes and failures, and provide a systematic method for assessing the accident configuration. The methods used to perform T/H analyses tend to direct attention to bounding accident scenarios that most greatly challenge core cooling. However, the T/H challenging scenarios may or may not have risk significance to the plant. The T/H uncertainty resolution process identifies the accident scenarios for further study that are both significantly high in frequency and consequences and which challenge core cooling. This process concentrates efforts and resources to the most important cases, and is an implementation of risk-informed decision making.

The T/H uncertainty resolution process is briefly outlined below. The details of the methods and results are in the following sections of this report.

1. Expand and quantify PRA event trees to further refine the equipment that is available in the accident scenarios that result in successful core cooling. (Section 4.0)
2. Assign success categories so that all accident scenarios can be systematically discussed. (Sections 5.0, 6.0 and 7.0)
3. Assess category frequency / consequence to determine risk significance of low-margin scenarios. (Section 8.0)
4. Define low margin, risk significant cases for further T/H study. (Sections 8.3 and 9.0)
5. Define assumptions to bound uncertainties in T/H analyses. (Section 10.1)
6. Perform T/H analyses. (Sections 10.2 and 10.3)
7. Assess impact of T/H study results on PRA. (Section 11.0)

4.0 EXPANDED EVENT TREES

4.1 Expanded PRA Event Tree Methodology

The first step of the T/H uncertainty resolution process is to expand the Focused PRA event trees and to quantify the frequency of the success paths. Success paths are not normally quantified in a PRA, since core damage is the focus. The purpose of quantifying the frequency of success paths for T/H uncertainty resolution is to gain perspective on the relative probability of specific success scenarios. This information will ultimately be used to define risk significant scenarios that could be impacted by T/H uncertainty.

"Expanding" the event trees is necessary to differentiate between scenarios that are grouped together in the PRA. A single success path in the AP600 PRA represents many combinations of equipment failures and successes. As an example, Figure 4-1 shows the MLOCA event tree as it appears in the Focused PRA. Table 4-1 lists the functioning equipment that are included within the top success path on the MLOCA event tree. Table 4-1 also identifies the equipment assumptions that are made in the corresponding accident analysis that supports the success path.

As shown in Table 4-1, the equipment configuration that is used in the success analysis to justify a specific success path is the most pessimistic set of functioning equipment for that path. Minimum functioning equipment leads to the most limiting accident progression. Even if the bounding scenario analysis shows core uncovery, there are many other accident scenarios (or sets of functioning equipment) represented by the same success path that may not result in core uncovery. Therefore, the success paths on the event trees need to be refined or expanded to show the various equipment success combinations so that differences in accident progressions can be assessed.

There are options of how to expand the success paths on an event tree. There are four key elements to the method that was developed to perform the expansion.

1. There are many top level events that could be used to ask questions and further refine the success paths. Table 4-2 summarizes the options that were considered, and why they were or were not selected.

2. The expansion of the event tree does not redefine the definition of success. All success paths on the expanded event tree are represented within an existing success path in the Focused PRA. All core damage paths on the expanded event tree are core damage paths in the Focused PRA.

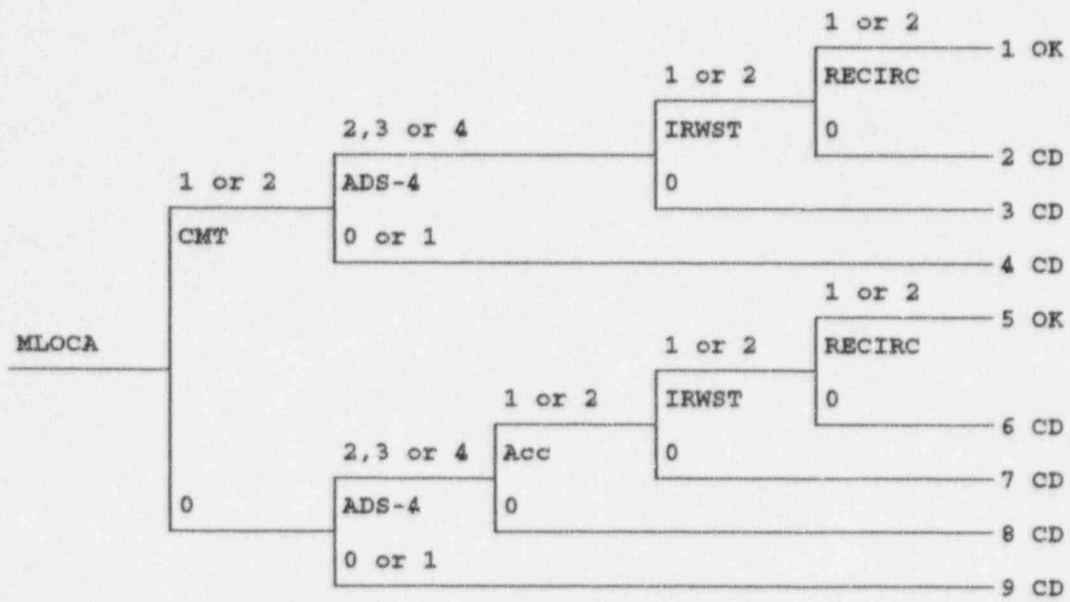
   Fundamental to the expansion is the necessity to ask additional equipment questions that are not explicitly modelled in the PRA. However, each question only differentiates between distinct successful accident progressions that are grouped within a success path in the PRA. The additional questions can better represent reality, but they cannot cause success definitions to become either more or less conservative.

3. Success paths containing more than 3 system failures are not further expanded in the present models. In general, three failures are deemed to decrease the frequency of a path sufficiently. Imposing the 3 failure limit also helps to restrict the event tree expansion to a manageable size. The net effect of this restriction is that paths toward the top of the expanded tree are broken into more detail than those toward the bottom.

   An alternative approach is to expand an event tree until the success paths reach a cut-off frequency. However, this would require quantification results to be integrated with the construction of the event tree. The 3 system failure expansion method was chosen because it is a systematic, understandable method that allows event tree development independent of the quantification results.

4. Top events were arranged in an order to minimize the number of paths. This changed the location of the injection and recirculation line question from the last top event in the Baseline and Focused PRA event trees to the first top event in the expanded event trees.

Figure 4-1
MLOCA Event Tree in Focused PRA



OK = Successful Core Cooling
CD = Core Damage

Table 4-1
Comparison of Equipment on Event Tree Success Path to Equipment Assumptions in Supporting Analysis

Equipment That May Function for Success Path 1 on MLOCA Event Tree in Focused PRA	Bounding Scenario Used for PRA Accident Analysis
1 or 2 CMTs 0, 1 or 2 stage 1 ADS * 0, 1 or 2 stage 2 ADS * 0, 1 or 2 stage 3 ADS * 2, 3 or 4 stage 4 ADS 0, 1 or 2 accumulators * 1 or 2 IRWST injection lines ≥ 1 recirculation line Success or failure of containment isolation *	1 CMT 0 stage 1 ADS 0 stage 2 ADS 0 stage 3 ADS 2 stage 4 ADS 0 accumulators 1 IRWST line ≥ 1 recirculation line Failure of complete containment isolation
* Not broken out by a top event question, but implicit within scenario possibilities.	

Table 4-2 Options for Expanding Event Tree Success Paths		
Option	Used?	Reason
Break size	No	Break size and location are already used to define different initiating events. Although within an initiating event there remains some variability in the plant response depending on the size and location of the break, there was no added benefit to further refinement.
Break location		
Number of CMTs	Yes	Whether there is 1 or 2 CMTs does not make a significant difference in the course of the accident progression. However, the CMTs are highly reliable, and make an important contribution to the refinement of the frequency of a given accident scenario. That is, for a given scenario, the most likely condition is both CMTs available.
Number of stage 1 ADS lines	No	Stage 1 ADS lines are small, and do not significantly impact the course of the accident progression.
Number of stage 2/3 ADS lines	Yes	Stage 2 and 3 ADS lines can impact the ability to achieve IRWST gravity injection.
Number of stage 4 ADS lines	Yes	Stage 4 ADS lines can impact the ability to achieve IRWST gravity injection.
Number of accumulators	Yes	The number of accumulators is important to the core uncovery issues discussed in Section 3.1.
Number of IRWST lines	No	The ability to achieve IRWST gravity injection and long-term recirculation is most dependent on the number of open ADS lines and whether the containment is isolated. The number of lines open, as long as there is a pathway for injection, is not as crucial an element to successful core cooling.
Number of recirculation lines		
Whether containment is fully isolated	Yes	The containment back pressure that occurs when the containment is isolated can impact the ability to achieve IRWST gravity injection. Also, containment isolation impacts the large release frequency calculation if the accident scenario is counted as core damage.

4.2 Scope of Expanded Event Trees

There are ten expanded event trees developed for T/H uncertainty resolution. They further define the equipment available for the majority of the success paths modelled in the Focused PRA. The relationship between the expanded event trees and the Focused PRA event trees is shown in Table 4-3

The success paths that are not included on the expanded event trees are ones in which successful core cooling can be achieved without ADS actuation. An example of this is a loss of main feedwater event, which is successful without ADS if the PRHR functions. The PRHR is the safety-related method of removing decay heat, and leads to successful core cooling as demonstrated in Chapter 15 of the SSAR. Primary coolant is not lost, and there is no need for inventory make-up from either the CMTs, accumulators, IRWST gravity injection or long-term recirculation. In addition to the PRHR, decay heat removal can occur from other active, nonsafety systems. These options are modelled in the Baseline PRA, but are conservatively neglected in Focused PRA.

Therefore, the success paths that are expanded for T/H uncertainty resolution are loss of coolant accidents. The loss of coolant can either be the initiating event, or can be the result of a loss of heat sink accident. The loss of coolant is severe enough to require inventory make-up, first from the CMTs and accumulators, then from IRWST gravity injection, and finally from long-term recirculation.

The quantification of the success path frequency on an event tree includes the consideration of any events that transition to that event tree. For example, if a pressurizer safety valve sticks open in a transient event (e.g., loss of feedwater), the accident progression transitions to the NLOCA event tree (Figure 4-6). The NLOCA success path quantification accounts for the transient events with loss of PRHR and a stuck open pressurizer safety valve. This is just an example of the consequential effects that have been included in the expanded event tree quantification.

Table 4-3 Correlation of Expanded Event Trees to Focused PRA Event Trees			
Initiating Event	Break Size Diameter	Expanded Event Tree Designator	Event Trees from Focused PRA
Large LOCA	> 9.0"	lloca	LLOCA
Medium LOCA	6.0" - 9.0"	mloca	MLOCA
CMT Line Break	≤ 8.0"	cmtlb	CMTLB
DVI Line Break	≤ 4.0"	silb	SI-LB
Intermediate LOCA	2.0" - 6.0"	nloca	NLOCA
Small LOCA with PRHR	< 2.0"	slocaw	SLOCA (1) RCS Leak (1)
Small LOCA without PRHR	< 2.0" Inventory loss can also occur through pressurizer safety valve	slocwo	SLOCA (2) RCS Leak (2) PRHR Tube Rupture
SGTRs with PRHR that Require ADS	1 tube	sgtrw	SGTR (1)
SGTRs without PRHR that Require ADS	1 tube	sgtrwo	SGTR (1)
Transients that Require ADS	Inventory loss through pressurizer safety valves	tran	Loss of MFW to both SGs (4) Loss of Offsite Power (4) Loss of Compressed Air (4) Loss of CCW/SWS (4) Loss of Condenser (4) Loss of MFW to 1 SG (4) Loss of Reactor Coolant Flow (4) Power Excursion Event Tree (4) SLB Downstream of MSIVs (4) SLB Upstream of MSIVs (4) Stuck-Open Secondary Side SV (4) Transients with MFW (4) ATWS (3)

Notes:
1) Portion of tree with PRHR
2) Portion of tree without PRHR
3) Includes success of PRHR and success of pressurizer safety valves
4) Includes failure of PRHR

4.3 Impact of Focused PRA vs. Baseline PRA

The Focused PRA results are the point of comparison for the T/H uncertainty resolution process. The Focused PRA models only the passive, safety-related systems in the AP600 plant. Active, nonsafety systems are not credited in the mitigation of the accident. For this reason, the Focused PRA most clearly demonstrates the importance of passive systems, and is the appropriate point of comparison for the T/H uncertainty issue related to passive system reliability.

The choice of the Focused PRA versus the Baseline PRA affects the frequency values that are quantified for the success paths. Because active systems are ignored in the Focused PRA, the passive-only accident progressions are often quantified with higher-than-realistic frequencies of occurrence. For example, most LOCA events lead to RCS inventory make-up from the IRWST. The IRWST water can be supplied from either a pumped system (RNS) or gravity draining of the IRWST. The reliability of the RNS is such that it operates approximately 9 out of 10 times needed. Therefore, for a given success scenario with a frequency of 1E-7/year, the passive-only accident progression with IRWST gravity injection would occur approximately 1E-8/year. However, in the Focused PRA, the IRWST gravity injection success path is the only option considered, and the frequency of this passive-only accident progression is over-estimated at 1E-7/year.

The above example illustrates the impact of crediting or not crediting the RNS, assuming that the scenario is one where the RCS pressure is low enough for either RNS injection or IRWST gravity injection to work. However, if the RNS were credited, there are additional possible success paths with fewer ADS lines open than required for IRWST gravity injection. Therefore, even more of the postulated accident progressions would end with the utilization of active systems; passive-only scenarios are much less frequent.

So that the importance and uncertainties of the passive systems can be studied without being skewed by the contributions of the nonsafety active systems, the Focused PRA is chosen for the expanded event tree development and quantification. The frequency of a success path that is calculated based on the Focused PRA assumptions cannot be compared to frequencies calculated based on the Baseline PRA conditions. As illustrated above, the frequency can be an order of magnitude different. This becomes very important when the frequencies are compared to the core damage frequency and large release frequency to determine risk significance.

The above discussion has been based on the majority of the LOCA accident progressions and event tree structures. However, when considering the impact of using the Focused PRA versus the Baseline PRA, there are some additional effects on some of the initiating events. If the Baseline PRA were used instead of the Focused PRA, the following two effects would be seen.

1) Transients and SGTRs would decrease in relative importance to other events because there are multiple operator actions and nonsafety systems that can prevent core damage, and are credited

in the Baseline PRA. It is the failure of these other systems that leads to the LOCA-like accident progression that requires ADS for successful mitigation.

2) Large LOCAs would increase in relative importance to other events. This is because all equipment credited in the Baseline PRA LLOCA event tree are safety systems, and are the same options considered in the Focused PRA. The LLOCA quantification does not change, while the frequency of the passive-only success paths for other initiating events decreases in the Baseline PRA. Therefore, the LLOCA relative contribution is larger in the Baseline PRA than in the Focused PRA. This aspect will be considered when the LLOCA success paths are examined for risk significance, and when the assessment of T/H uncertainty results on the PRA is made.

4.4 Results of Expanded Event Trees and Frequency Quantification

The expanded event trees are contained in Figures 4-2 through 4-11. The figures include not only the event tree structure, but quantification results and success path designators. The success path designators are discussed in Sections 5.0, 6.0 and 7.0.

The quantification method used to calculate the success path frequencies is the same method used to quantify the core damage paths in the Focused PRA. ADS cases are treated in more detail and SLOCA, SGTR and similar events are modeled with or without PRHR to capture the effects of this system.

FIGURE 4-2

EXPANDED LLOCA EVENT TREE

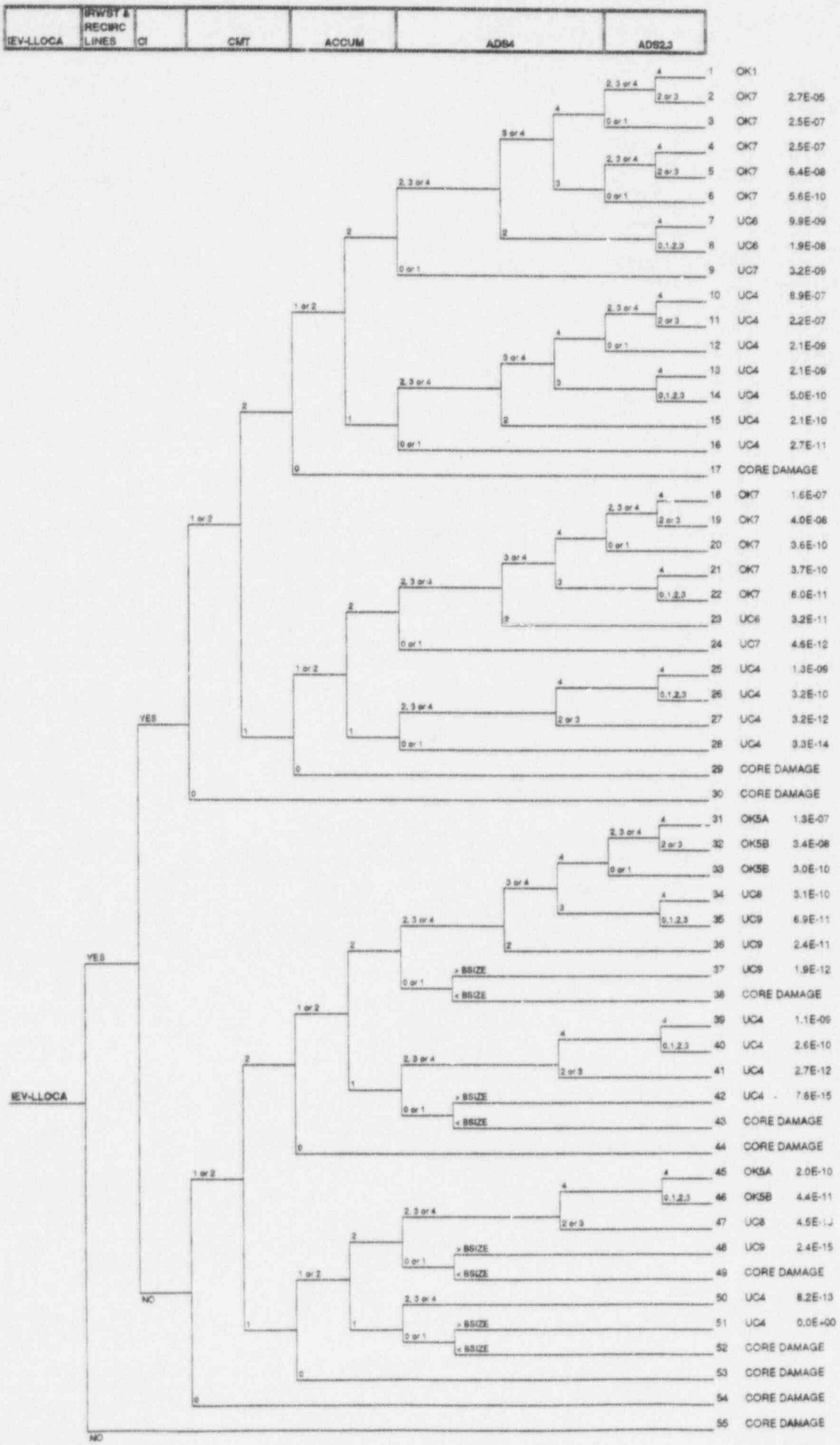


FIGURE 4-3

EXPANDED MLOCA EVENT TREE

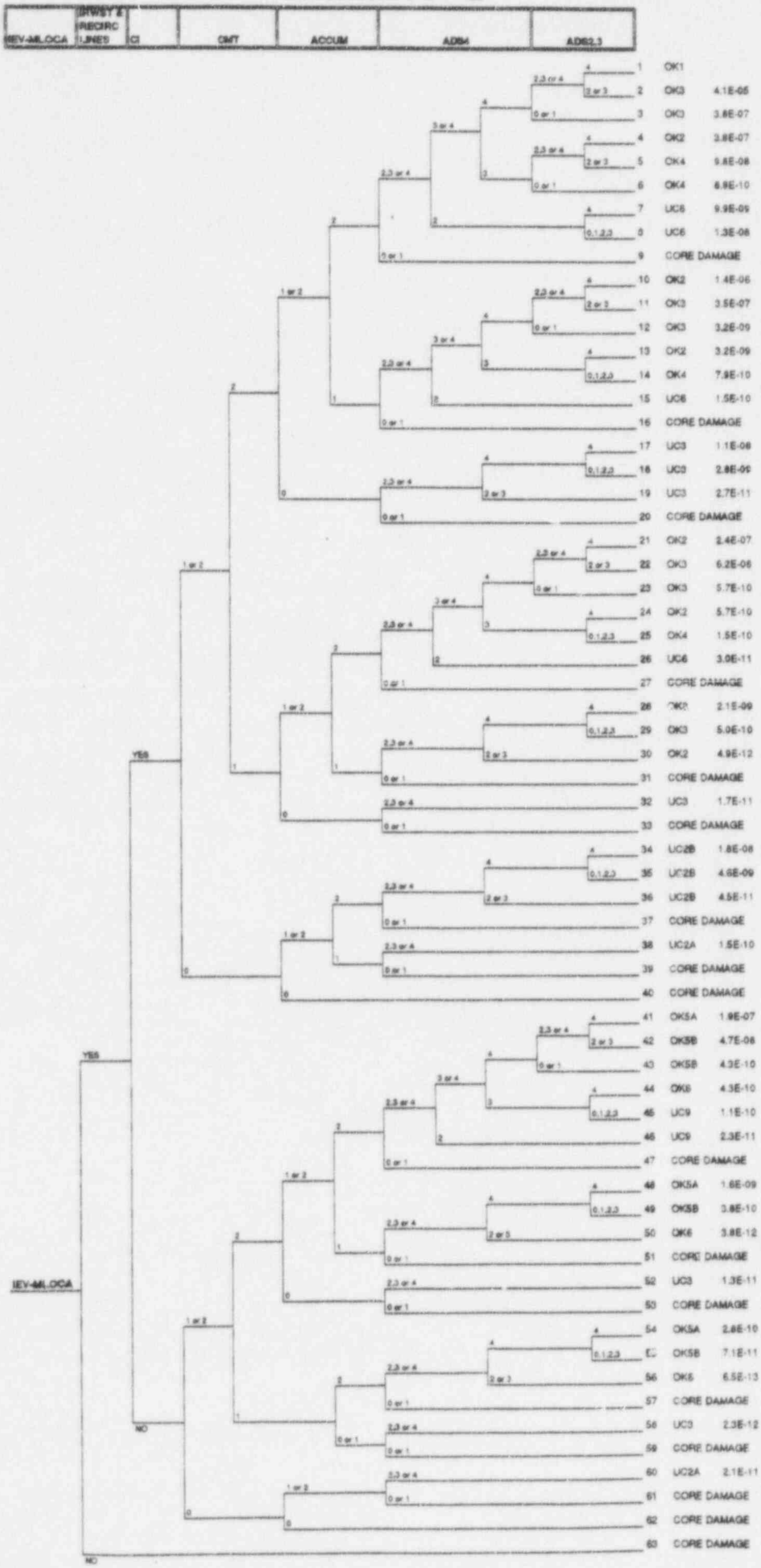


FIGURE 4-4

EXPANDED CMTLB EVENT TREE

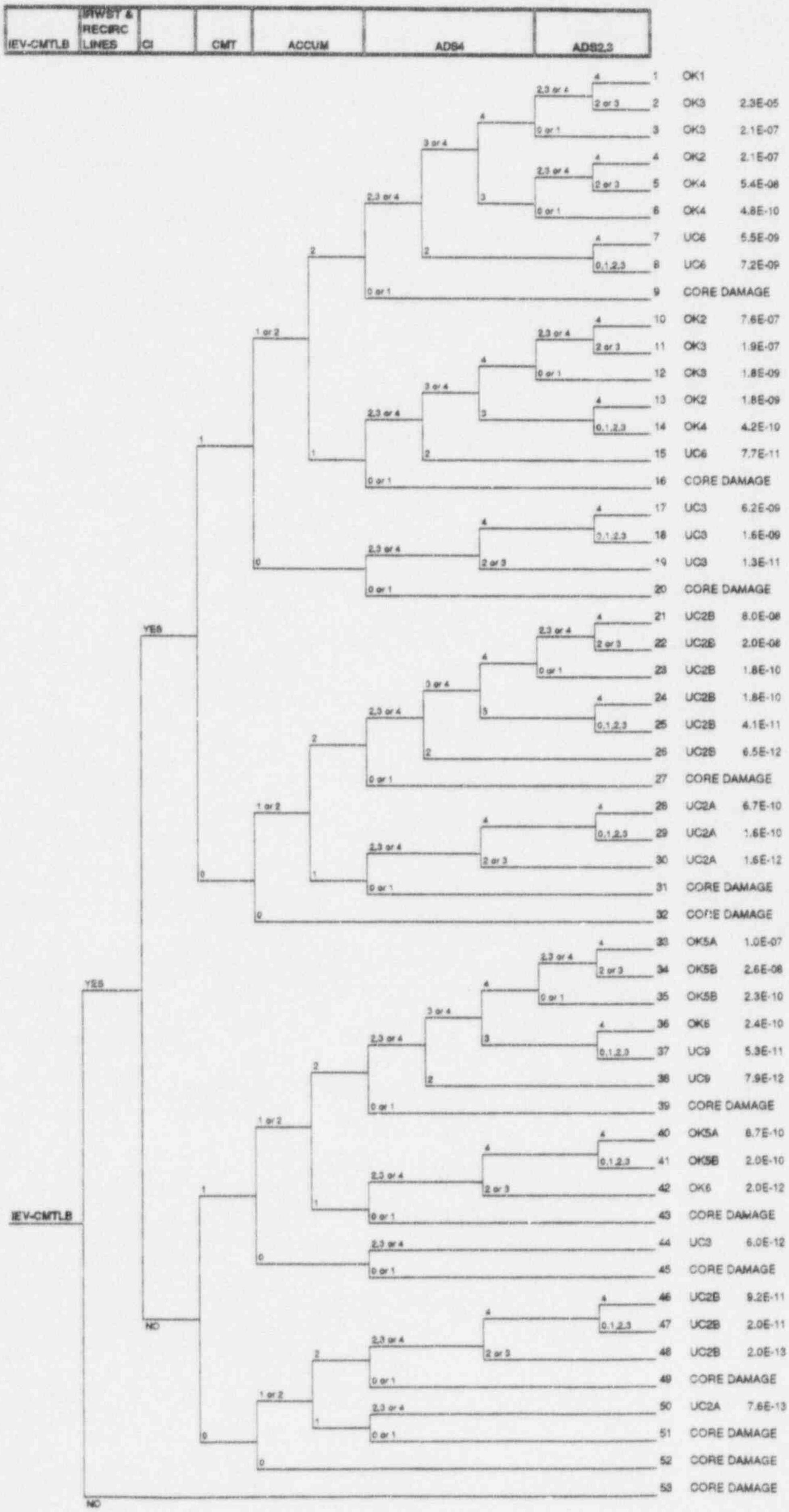


FIGURE 4-5

EXPANDED SILB EVENT TREE

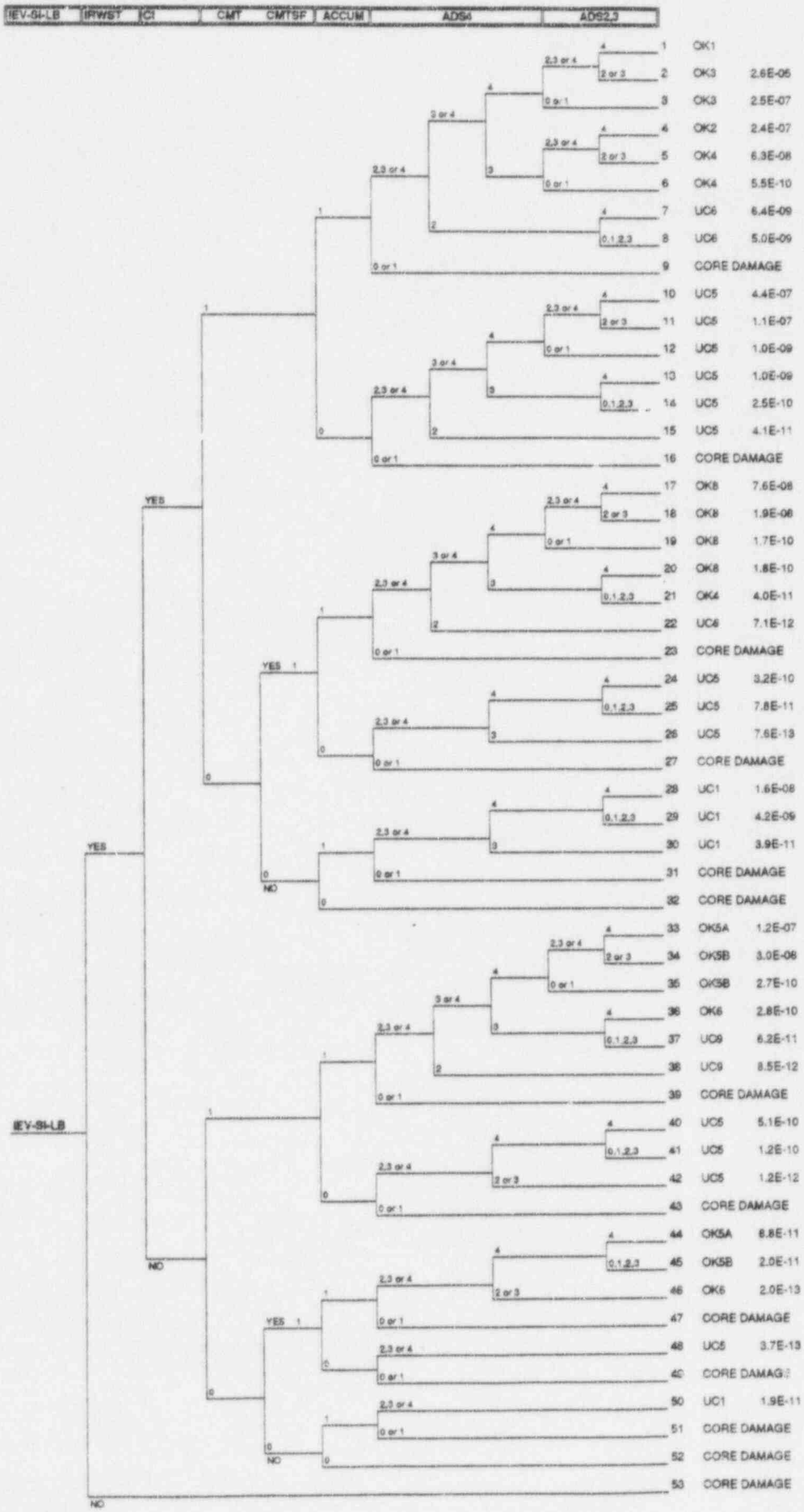


FIGURE 4-6

EXPANDED NLOCA EVENT TREE

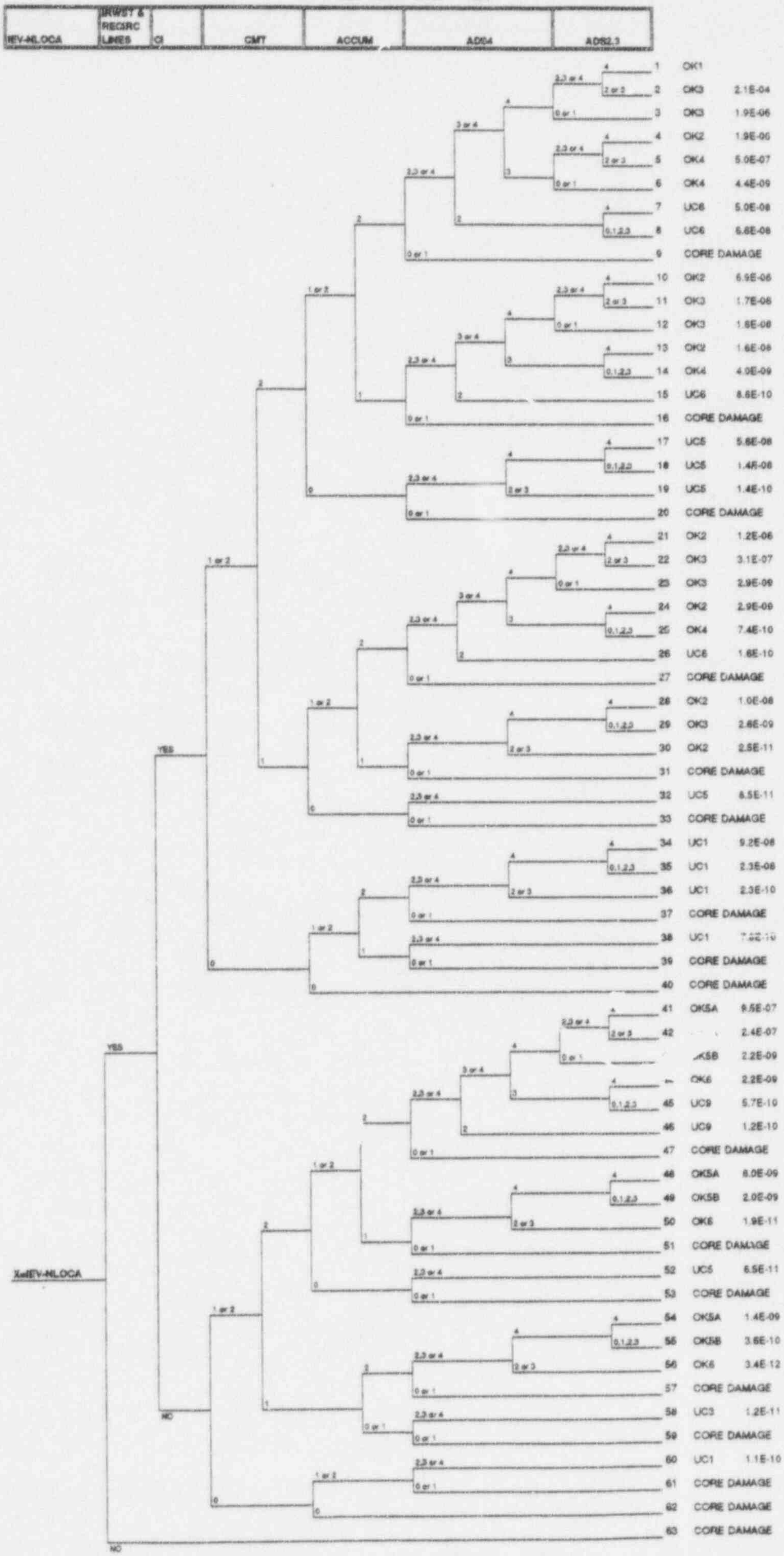


FIGURE 4-

EXPANDED SLOCAW EVENT TREE WITH SUCCESS OF PRHR

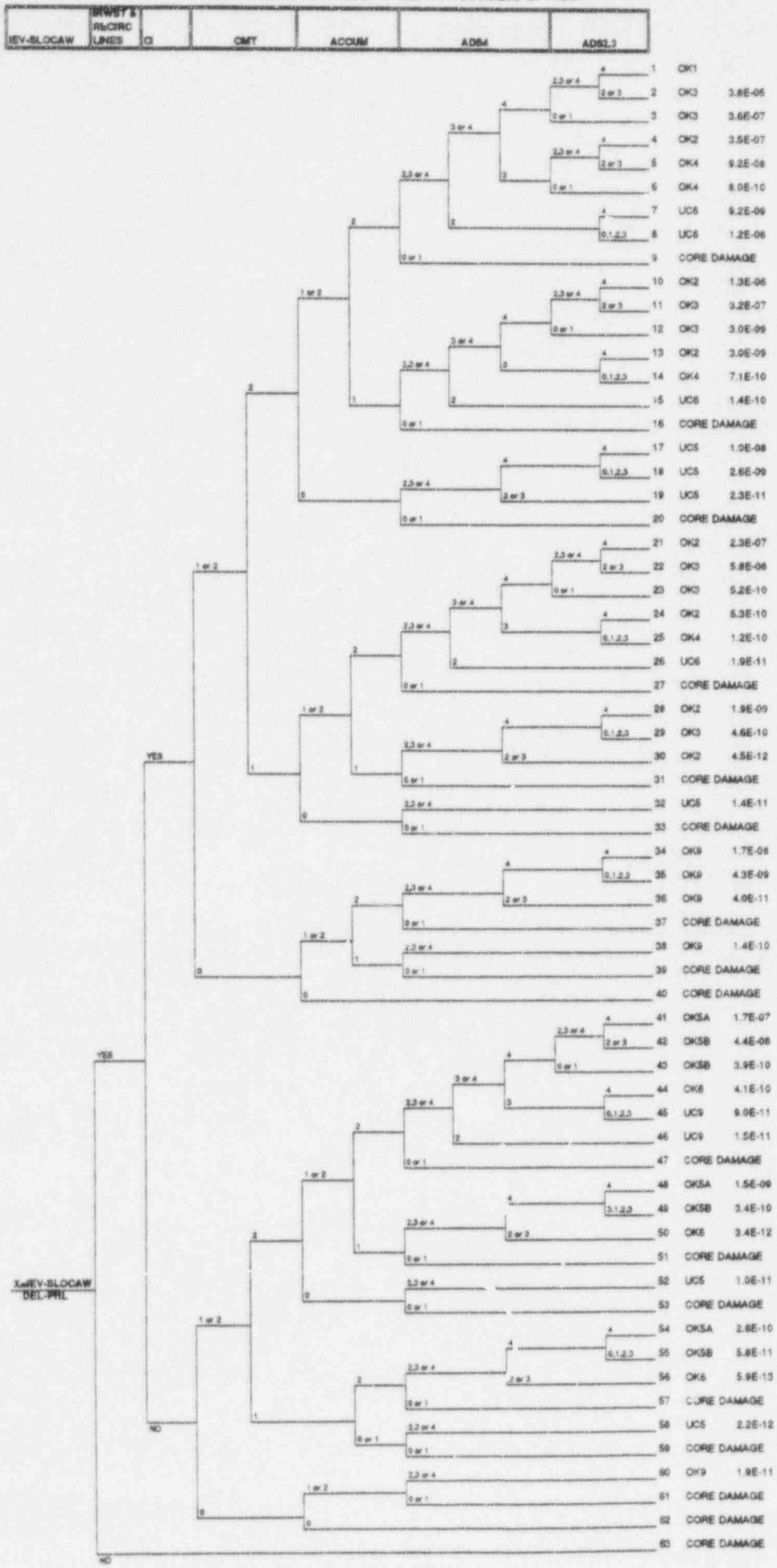


FIGURE 4-6

EXPANDED SLOCWO EVENT TREE WITH FAILURE OF PRHR

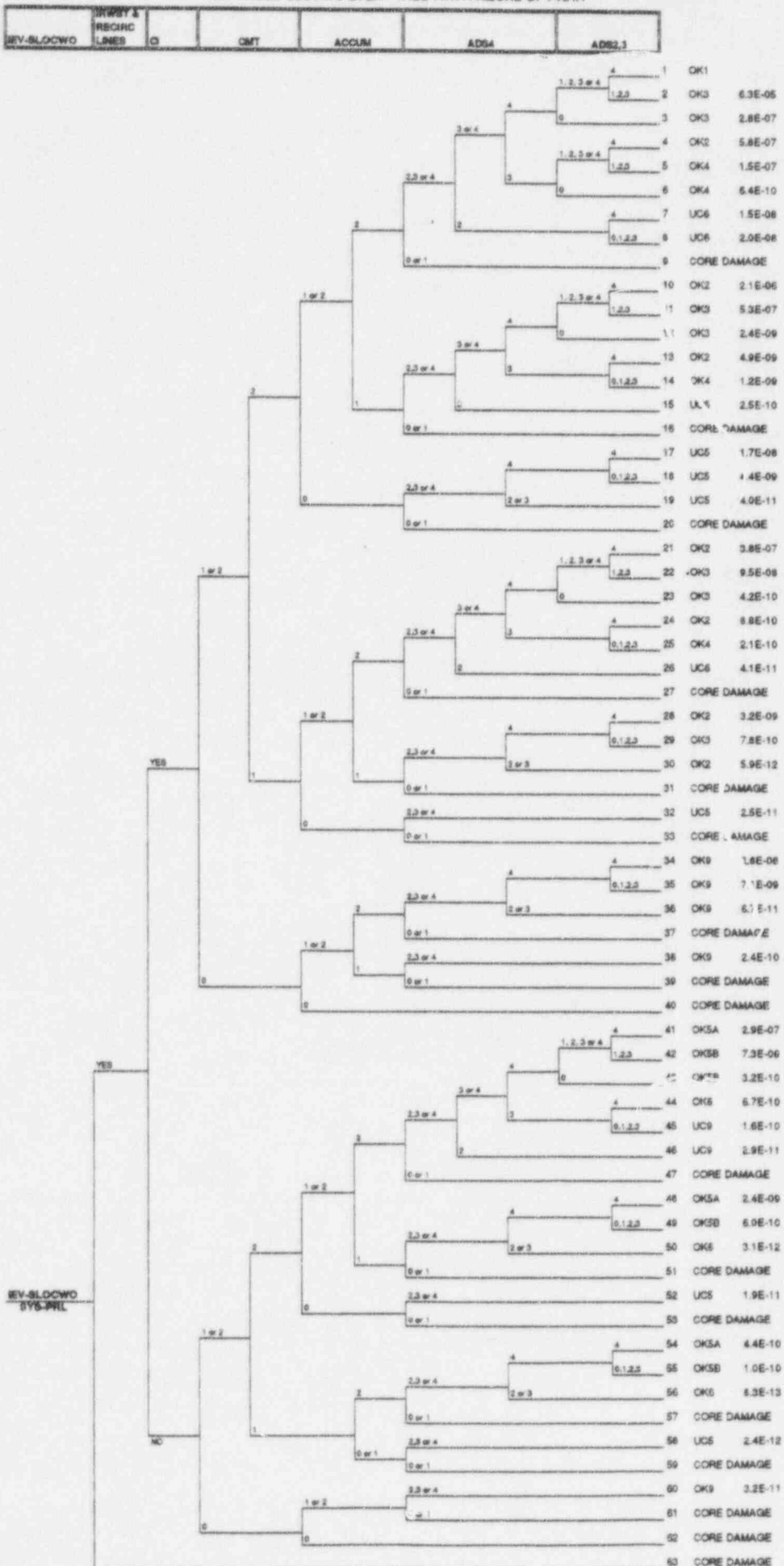
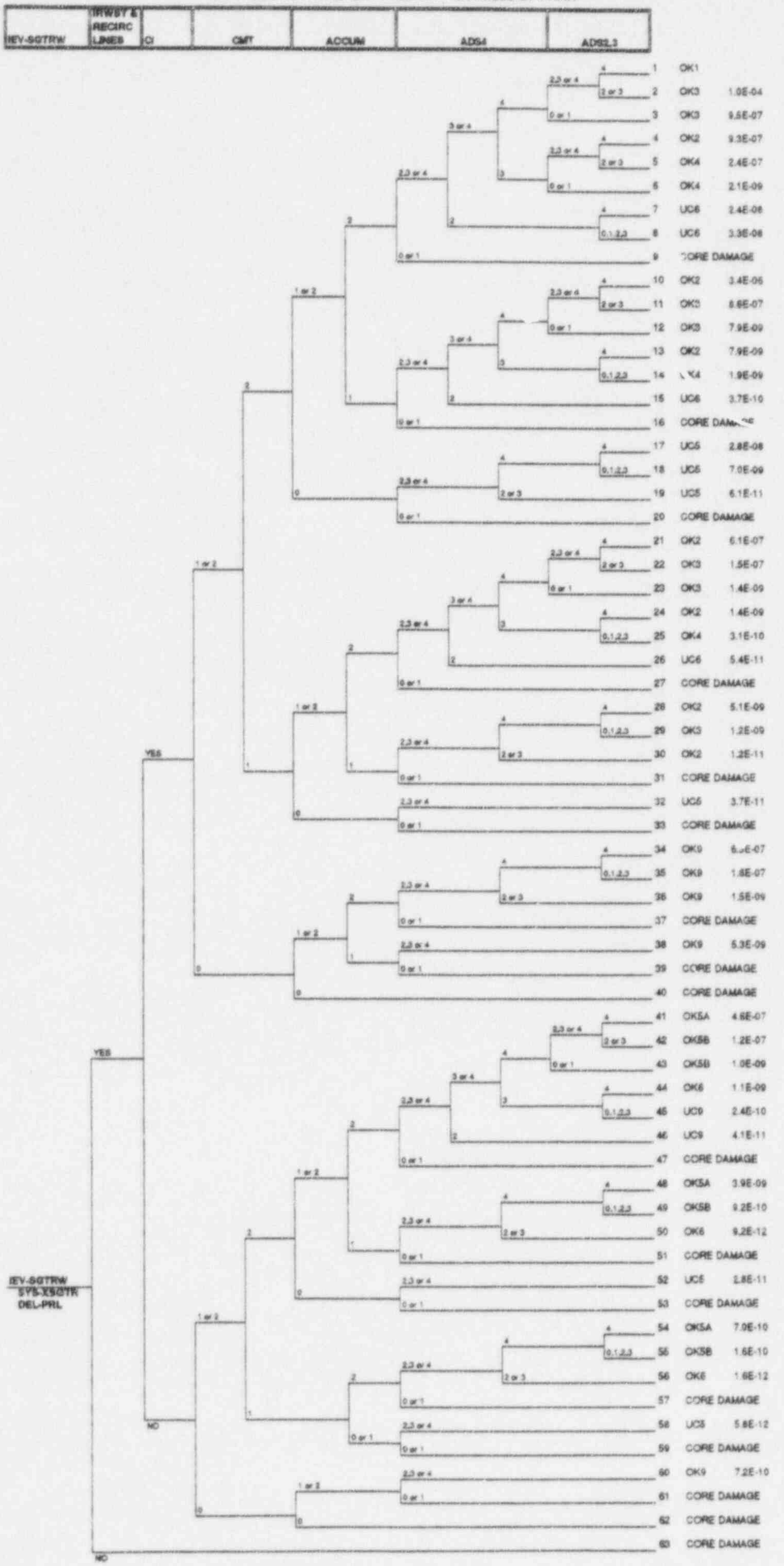


FIGURE 4-9

EXPANDED SGTRW EVENT TREE WITH SUCCESS OF PRHR



EXPANDED SGTRWO EVENT TREE WITH FAILURE OF PRHR

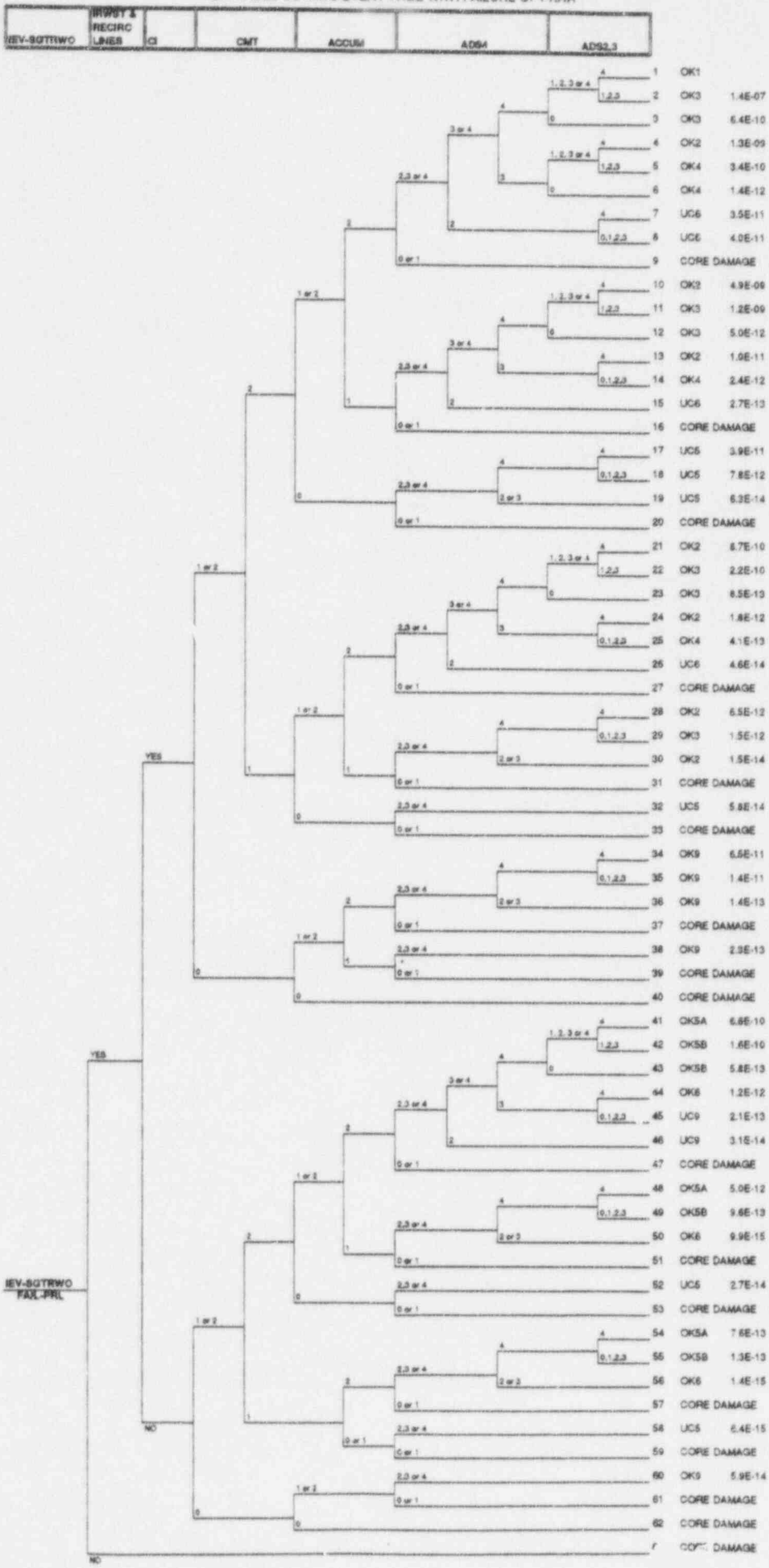
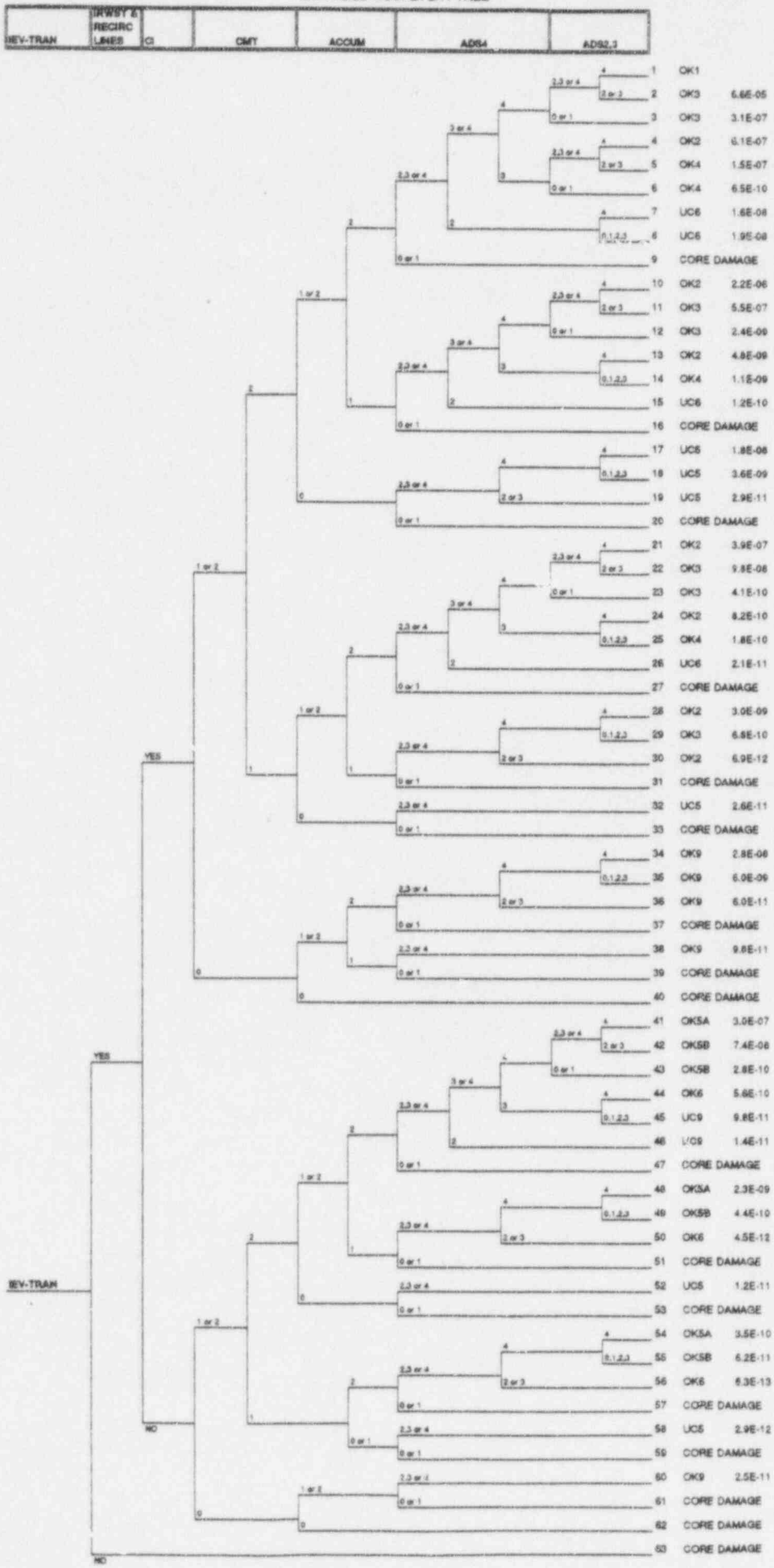


FIGURE 4-11

EXPANDED TRAN EVENT TREE



5.0 CATEGORIZATION OF SUCCESS SCENARIOS

In the expanded event trees, the success paths on the AP600 PRA event trees are further refined to differentiate the functioning equipment in each scenario. The success paths are then binned into categories that distinguish the accident progression. This process of "binning" the end-states is the same concept used in the Level 1 / Level 2 PRA interface. Core damage paths from Level 1 are identified as different accident classes for further study in Level 2. In the expanded event trees for T/H uncertainty resolution, this same concept is applied, but the categorization is made of success paths rather than core damage paths. The categorization of the success paths is a systematic method of defining different types of possible accident progressions that lead to successful core cooling. The categorization enables a thorough assessment and greater understanding of the different successful equipment combinations.

The nomenclature of the categories defines two main groups of success paths: OK categories and UC categories. OK categories are accident progressions that are similar to design basis accidents. Although most OK categories are not identical to design basis, the differences can be defined and the similarities explained. Accident scenarios that are defined within an OK category are not "low margin" and are not further considered within the T/H uncertainty resolution process. Success scenarios that do not fit within OK categories are grouped into UC categories. The categorization as a UC category occurs for two reasons: 1) analyses of the accident progression predicts core uncovery, or 2) analyses have not been done to support the accident scenario. The UC categories are accident scenarios that are considered "low margin" and will be further considered in the T/H uncertainty resolution process.

There are 10 OK categories and the same number of UC categories. The number of categories was not pre-defined, rather categories were created based on the need to group similar accident progressions together. The consideration of the accident progression includes two phases of water injection: 1) short term, when the accumulators and CMTs provide make-up inventory, and 2) IRWST gravity injection. Sections 5.1 and 5.2 discuss these phases of injection and some of the considerations that went into the classification process. The final phase of water injection -- long-term recirculation -- is treated separately from the OK and UC categorization, and is discussed in Sections 5.3 and 9.0.

First, however, there are some general comments about the method of categorization and choices that had to be made.

1. Each success path is classified in only one category, although there are some success paths that fit the definition of multiple categories. A choice was made to generally include these success paths in a category based on the loss of CMTs or accumulators. However, success paths with enough failures to fit multiple category definitions are low frequency scenarios, and choice of where to include them does not impact the results of the process.

2. Expanded event trees do not always separate the success path to differentiate the exact equipment defined by the category. Once again, this only occurs in success paths of low frequency. The

choice of where to categoriz· ·'·is type of success path does not impact the results of the T/H uncertainty resolution proce. However, generally the success path is categorized with the equipment success/failure that is known to be most probable. For example, a success path that does not distinguish between 2 and 3 stage 4 ADS valves may be included within a category that is defined as having at least 3 stage 4 ADS valves. In all such cases, the frequency of the success path is low, and the fraction that is 2 stage 4 ADS is negligible.

3. The expanded event trees differentiate the number of stage 2 and 3 ADS valves. The fault trees used in the event tree construction can distinguish the number of lines that are open, and this is interpreted as:

4 stage 2, 3	All
2 or 3 stage 2, 3	At least half
0 or 1 stage 2, 3	None

The number of stage 1 ADS lines is not separated because the valves are much smaller than all the other stages, and by themselves do not impact the course of the accident progression. However, the operation of stage 1 is estimated based on information about stages 2 and 3. The interpretations of all, at least half, or none are extended to include stage 1 in addition to stages 2 and 3.

5.1 CMT and Accumulator Injection

The first phase, when the accumulators and CMTs provide make-up inventory, is similar to design basis accident conditions as long as there is at least one CMT and one accumulator. CMTs and accumulators are tanks, each containing 2000 ft^3 or approximately 100,000 lbm of water. Accumulators are designed for rapid inventory make-up when the RCS pressure falls below 700 psig. CMTs also play a role in early inventory make-up, starting at higher pressures, but injection rates are not as rapid as accumulators. Furthermore, CMTs are important because low CMT levels provide the actuation signal for ADS. There are 2 CMTs and 2 accumulators, and the loss of one CMT and/or accumulator leaves the remaining tanks to fulfill the plant functions described. Therefore, a scenario with at least one CMT and at least one accumulator experiences a similar accident progression to a scenario with all CMTs and accumulators functioning. This observation is supported by the MAAP4/NOTRUMP benchmarking effort.

The ability to lose up to 1 CMT and 1 accumulator without significantly impacting the accident progression is one of the foundation elements in the categorization of the success paths. The categorization requires that judgements be made on which equipment losses have the largest impact on the accident progression. Although the loss of a CMT and/or accumulator may impact the event and its timing slightly, this impact is less significant than other equipment losses. The loss of 1 CMT and/or 1 accumulator does not jeopardize the ability to successfully cool the core. Therefore, categories are defined based on other distinctions, and the following CMT/accumulator possibilities can be grouped into the same category:

- 2 CMTs and 2 accumulators
- 2 CMTs and 1 accumulator
- 1 CMT and 2 accumulators
- 1 CMT and 1 accumulator

The exception to this method of grouping is for Large LOCAs. For a LLOCA, the operation of 1 accumulator versus 2 accumulators can have an impact on the accident progression, and these possibilities are considered separately. Also note that the DBA analysis of the double-ended guillotine DVI line break only includes 1 CMT and 1 accumulator; the other CMT and accumulator spill out the break.

The loss of both CMTs or both accumulators becomes a basis for defining a success category. This is because the loss of both CMTs or the loss of both accumulators removes a specific function from the plant response. Furthermore, the accident progression may be different depending on whether the initiating event is a SLOCA, NLOCA, MLOCA, LLOCA or other event. Therefore, the following success categories are defined to address the accident scenarios with the loss of both CMTs or accumulators: OK7, OK8, OK9, UC1, UC2A, UC2B, UC3, UC4. Detailed discussion of each of these categories is given in Sections 6.0 and 7.0. Category UC5 also addresses the loss of accumulators, but relates to the second phase of the accident progression, and is discussed below.

5.2 IRWST Gravity Injection

The second injection phase of the accident progression, IRWST gravity injection, is generally dominated by the number of ADS lines open and whether containment is isolated. The remaining success categories (OK1, OK2, OK3, OK4, OK5A, OK5B, OK6, UC6, UC7, UC8, UC9) consider combinations of different ADS failures and containment isolation status. ADS stages 1, 2 and 3 vent from the pressurizer to the IRWST, while ADS stage 4 vents from the hot leg directly to containment. Therefore, the plant response to ADS 1-3 is different from the plant response to ADS-4, and this is considered within the categorization.

The plant's response to ADS actuation can also be dependent on whether there is an accumulator available in a high pressure (> 700 psig) scenario. Without either accumulator, analyses have shown that core uncovery can occur when a large depressurization is needed, ADS is actuated, and there is no make-up inventory to offset the inventory loss through the ADS lines. Category UC5 has been defined to address this accident progression possibility.

One of the items that is not differentiated on the expanded event trees is the number of DVI lines that are available for IRWST gravity injection. The PRA success criterion is that 1 out of 2 lines is sufficient. All analyses related to supporting the PRA have been done with 1 line, and have shown this to be a successful option for IRWST gravity injection.

5.3 Long-term Recirculation

Long-term recirculation is the safety-related, passive cooling method for LOCA events after the IRWST is drained. This mode of cooling occurs only in LOCA events that have lost enough inventory to submerge the reactor vessel cavity with water. This natural circulation method is the back-up to a forced-flow recirculation with the RNS pumps.

The elements that may impact long-term cooling by natural circulation are the height of the water pool, the steam venting capability from the RCS, the resistance in the injection lines, the containment pressure, and the decay heat to be removed. All of these factors are potentially impacted by PRA scenarios when compared to DBA. The T/H uncertainty resolution process addresses the outstanding long-term cooling phase of the accident progression.

Within the T/H uncertainty resolution process, scenarios that are not supported by existing analyses are generally included within the UC categories. If the scenario is risk-significant, it "rises to the top" and further analysis -- including the consideration of uncertainties -- is done to support the claim of successful core cooling. For long-term cooling, risk-significant cases are defined from all success paths, including both the UC and OK categories. All success paths are grouped based on equipment failures that may impact long-term recirculation. Table 5-1 summarizes the potential differences in PRA scenarios when compared to DBA scenari and identifies the equipment loss that may cause an impact.

From the grouping of the long-term recirculation success paths, the risk significant scenarios can be identified. The most risk-significant scenarios are anticipated to be ones with up to 1 single failure, that are already addressed by DBA analyses. The remaining risk-significant long-term recirculation scenarios are used to define a set of analytical cases to support long-term cooling in the PRA. The results of this process are documented in Section 9.0.

Table 5-1
Summary of Potential PRA Impacts on Long-term Recirculation

Element	Equipment Loss in PRA
Height of the water pool impacts the driving head for natural circulation	The failure of one or more CMTs and/or accumulators to drain may result in a lower water level in containment.
	The failure of a containment isolation line may allow water inventory to be lost.
RCS Steam Venting Capability	The failure of lines of ADS causes there to be less venting capability, which may impact the ability to maintain the RCS pressure low enough.
Resistance of injection lines	The failure of valves to open in injection / recirculation lines may impact the system flow resistance and influence the recirculation flow rate.
Containment Pressure	The failure of a containment isolation line may lower the containment back pressure.
Decay Heat	The failure of one or more CMTs and/or accumulators can impact the timing of the accident progression, and cause an earlier transition into long-term recirculation, thereby being at a higher decay heat.
	1979 ANS best estimate decay heat is typically used for analyses that support the PRA. Uncertainties on the decay heat need to be considered for T/H uncertainty resolution.

6.0 OK CATEGORIES SIMILAR TO DESIGN BASIS

OK categories are accident progressions that are similar to design basis accidents. Although most OK categories are not identical to design basis, the differences can be defined and the similarities further explained. Accident scenarios that are defined within an OK category are not "low margin" and are not further considered within the T/H uncertainty resolution process. Generally, the OK categories are similar enough to design basis that the conservative SSAR Chapter 15 analyses address the dominant phenomena within the accident progression.

Table 6-1 provides an overview of the ten OK categories, and the frequencies that have been quantified for each category. Following Table 6-1 is a more detailed discussion of each of the OK categories. For each OK category, there is also a table that lists all the applicable success paths from the expanded event trees and the calculated frequency of each path.

Table 6-1
Summary of OK Categories

Number	Description, Relative to Design Basis	Detailed Description	Total Frequency (per year)
OK1	More ADS-4	No Failures Beyond Initiating Event	6.9E-3
OK2	Design Basis	$\geq$ DBA ADS $\geq$ 1 CMT, 1 Acc Containment Isolated	2.6E-5
OK3	More ADS-4 Less ADS 1, 2, 3	> DBA ADS-4 < DBA ADS 1, 2, 3 $\geq$ 1 CMT, 1 Acc Containment Isolated	5.8E-4
OK4	Less ADS 1, 2, 3	DBA ADS-4 < DBA ADS 1, 2, 3 $\geq$ 1 CMT, 1 Acc Containment Isolated	1.4E-6
OK5A	More ADS-4 CI Fails	> DBA ADS $\geq$ 1 CMT, 1 Acc CI Failure	2.7E-6
OK5B	More ADS-4 Less ADS 1, 2, 3 CI Fails	> DBA ADS-4 < DBA ADS 1, 2, 3 $\geq$ 1 CMT, 1 Acc CI Failure	7.0E-7
OK6	CI Fails	DBA ADS $\geq$ 1 CMT, 1 Acc CI Failure	5.9E-9
OK7	2 Accumulators - Design Basis for LLOCA	2 Accumulators $\geq$ DBA ADS-4 $\leq$ DBA ADS 1, 2, 3 $\geq$ 1 CMT Containment Isolated	2.7E-5
OK8	DVI Line Break with Automatic ADS Actuation from Faulted CMT	0 CMTs 1 Injecting Accumulator $\geq$ DBA ADS-4 $\leq$ DBA ADS 1, 2, 3 Containment Isolated	9.6E-8
OK9	Loss of CMTs for Smaller Breaks	0 CMTs	8.8E-7

Notes:

1. "DBA ADS" is all stage 1, 2 and 3 ADS and 3 out of 4 stage 4 ADS

Category OK1

These accident scenarios are ones in which all equipment functions, except equipment disabled as part of the initiating event. These are the "top paths" on the expanded event trees, and are bounded by the LOCA design basis accident scenarios. They include the actuation of more ADS-4 lines than considered in the design basis analyses. The total frequency of the accident scenarios in this category is 6.9E-3/year. This category applies to all the initiating events, and the applicable success paths are listed in Table 6-2.

Category OK2

These accident scenarios are collectively considered as the design basis accident scenarios. They include all accident scenarios with at least 3 stage 4 ADS, and all stages 1, 2 and 3 ADS with successful containment isolation. Accident scenarios that meet the design basis ADS conditions are included within this category if they have at least 1 functioning CMT and 1 functioning accumulator. The MAAP4/NOTRUMP benchmarking demonstrates that 1 CMT and 1 accumulator provides a similar accident progression to 2 CMTs and 2 accumulators.

The total frequency of the accident scenarios in this category is 2.6E-5/year. The applicable success paths are listed in Table 6-3. Note that although this category can generally be considered as "design basis," many of the highest frequency success paths have more ADS-4 than design basis.

This category applies to all the initiating events except for Large LOCA. LLOCA is excluded because its results are dependent on the number of accumulators, and thus is considered in separate categories.

Category OK3

Success category OK3 is a minor deviation from design basis. These accident scenarios have more ADS-4 lines (4 rather than 3) but less ADS 1, 2 and 3 lines. Containment isolation must be successful, and there must be at least 1 functioning CMT and 1 functioning accumulator. The MAAP4/NOTRUMP benchmarking results demonstrate the importance of ADS-4 lines compared to ADS 1, 2 and 3 lines, and support this categorization.

The total frequency of the accident scenarios in this category is 5.8E-4 / year. The applicable success paths are listed in Table 6-4. This category applies to all the initiating events except for Large LOCA. LLOCA is excluded because its results are dependent on the number of accumulators, and thus is considered in separate categories.

Category OK4

Success category OK4 is similar to category OK3, except stage 4 ADS is the same as design basis. The only difference in category OK4 when compared to design basis is the loss of some ADS 1, 2 and 3 lines. This category definition extends to the loss of all ADS 1, 2 and 3 lines, although the frequency is less than 5E-9 for this possibility; the highest frequency success paths in category OK4 have the loss of no more than half of the stage 1, 2 and 3 ADS lines. The frequency for the total category is 1.4E-6/year, and the success scenarios are listed in Table 6-5.

The number of stage 1, 2 and 3 ADS lines that actuate has minimal impact on the ability to achieve IRWST gravity injection. The number of stage 4 ADS lines that actuate determines whether the RCS is depressurized fast enough to achieve IRWST injection prior to core uncovery. Stage 4 lines are on the hot legs and vent directly to containment, providing a more effective depressurization than the stage 1, 2 and 3 lines which vent from the top of the pressurizer to the IRWST. The highest frequency success paths in category OK4 also have both accumulators and both CMTs, providing ample short-term water supply until IRWST gravity injection is established.

This category applies to all the initiating events except for Large LOCA. LLOCA is excluded because its results are dependent on the number of accumulators, and thus is considered in separate categories.

Categories OK5A, OK5B

Success categories OK5A and OK5B consider the failure of complete containment isolation. The failure of containment isolation lowers the containment back pressure, which can have an impact on the accident progression. The distinction between categories OK5A and OK5B is the number of ADS lines that are assumed. The separation of the categories is done to illustrate that the highest frequency success paths have more successful ADS lines:

		Category Frequency
OK5A	No ADS failure	2.7E-6
OK5B	Some ADS 1, 2, 3 failure	7.0E-7

The failure of containment isolation is offset by the success of more ADS-4 lines than are credited in design basis analyses. All initiating events are included within these categories. The success paths corresponding to these categories are listed in Tables 6-6 and 6-7.

Note that as with other OK categories, a requirement for these categories is that there must be at least one functioning CMT and one functioning accumulator. However, there are two exceptions to this. 1) The LLOCA success paths must have at least 2 accumulators; success paths with only 1 accumulator are classified in category UC4. 2) The DVI line break does not have to have a CMT that injects to the RCS. This is noted on Tables 6-6 and 6-7 and the details of this possibility are explained in the discussion of category OK8.

Category OK6

Category OK6 also assumes the failure of containment isolation. While categories OK5A and OK5B had a compensating effect with more ADS-4 than design basis, category OK6 does not. Category OK6 is the LOCA design basis scenario with the additional failure of containment isolation.

Although the design basis scenario includes containment isolation, no credit is taken in most of the DBA analyses for a containment back pressure. The SSAR Chapter 15 small-break LOCA analyses show successful core cooling through the IRWST gravity injection phase with no elevated containment back pressure. The Chapter 15 small-break LOCA break sizes correspond to the PRA LOCA initiating events smaller than LLOCA. The Chapter 15 large-break LOCA analyses do take credit for a containment back pressure. For this reason, LLOCA is not included in category OK6, while all other initiating events are. The success paths corresponding to this category are listed in Table 6-8. The total frequency of this success category is 5.9E-9/year.

Category OK7

Success category OK7 considers most large LOCA accident scenarios with 2 accumulators. The other requirements for classification within this category are successful containment isolation, at least 1 functioning CMT, and at least 3 lines of ADS-4 (design basis). There can be failures of stages 1, 2 and 3 ADS.

This category is considered to be design basis for LLOCA. The plant response in the first hundreds of seconds is dictated by the plant and fuel design, and the number of accumulators. CMT performance does not impact the limiting portion of the accident progression. However, at least one CMT is needed so that a low-low CMT level actuation signal will open the squib valves to the IRWST. IRWST gravity injection has been demonstrated in design basis analyses supporting SSAR Chapter 15. Thus containment isolation and at least 3 lines of ADS-4 are required for a success path to be included within this category. Stages 1, 2 and 3 ADS have a negligible impact, especially for a large LOCA that provides additional venting capability through the break.

The total frequency of the accident scenarios in this category is 2.7E-5/year. The applicable success paths are listed in Table 6-9.

Category OK8

Success category OK8 addresses an accident scenario that is unique to a break in the DVI line. If the CMT isolation valve on the faulted loop opens, the water inventory from that CMT will be lost through the break. If the intact CMT fails, there are no CMTs to provide make-up inventory to the RCS. However, the CMT spilling out the break will drain and provide the low level signals for ADS actuation. This is the only initiating event that can have "no CMTs," and yet automatic ADS actuation occurs without operator intervention.

The success paths in this category have successful containment isolation, 1 accumulator, and DBA ADS (failure of 1 line of ADS-4) or all ADS-4 with the possible failure of some stages 1, 2 and 3 ADS. The ADS conditions are the same as categories OK2 and OK3, which is no worse than design basis. The only other distinction from the design basis DVI line break scenario is the failure of the CMT on the intact loop. As can be seen in Chapter 15 of the SSAR, the role of the intact CMT is minimal. It is not responsible for the ADS actuation signals, and provides very little make-up inventory to the RCS. The failure of the intact CMT does not have a significant impact on the accident progression.

Table 6-10 lists the accident scenarios in category OK8. The total frequency of the success paths in this category is 9.6E-8/year.

Category OK9

Success category OK9 consists of scenarios that require manual ADS actuation because both CMTs fail. However, only initiating events with relatively small breaks are included within this category. The significance of the small break area is that inventory loss is relatively slow, and the operator has sufficient time to open the ADS lines before much RCS inventory is lost. The initiating events within category OK9 are transients, SLOCA, and SGTR. Larger breaks, with the same conditions of both CMTs failing, are classified within UC categories.

The additional requirements for this category are intended to be DBA ADS (failure of 1 line of ADS-4) or all ADS-4 with the possible failure of some stages 1, 2 and 3 ADS. However, when 2 CMTs fail, the expanded event trees only differentiate one more failure. Therefore, some of the success paths listed on Table 6-11 include the possibility of 1 more stage 4 ADS line failure. The frequency of these paths are small, and the effect of including them within this category is negligible, and do not impact the definition of this category. The total frequency of this category is 8.8E-7/year.

It is also worth noting that this category includes success scenarios with and without PRHR. It is questionable that some of the very small break scenarios with PRHR actually need ADS to achieve successful core cooling. However, the need for ADS has been conservatively included within the PRA modelling (i.e., if ADS fails, core damage is assumed), and thus this assumption is maintained in the expanded event trees for T/H uncertainty resolution.

Table 6-2 Success category OK1 (Sorted by Descending Frequency)						
Success Path	Equipment Assumptions					Frequency (per year)
	CI	CMT	Acc	ADS-4	ADS 2.3	
sgtrw01	Yes	2	2	4	4	5.5E-3
nloca01	Yes	2	2	4	4	5.9E-4
tran01	Yes	2	2	4	4	1.9E-4
slocwo01	Yes	2	2	4	4	1.8E-4
mloca01	Yes	2	2	4	4	1.2E-4
slocaw01	Yes	2	2	4	4	1.1E-4
lloca01	Yes	2	2	4	4	7.6E-5
silb01	Yes	1	1	4	4	7.6E-5
cmtlb01	Yes	1	2	4	4	6.5E-5
sgtrwo01	Yes	2	2	4	4	4.2E-7
TOTAL						6.9E-3
Notes:						

Table 6-3 Success category OK2 (Sorted by Descending Frequency)						
Success Path	Equipment Assumptions					Frequency (per year)
	CI	CMT	Acc	ADS-4	ADS 2,3	
nloca10	Yes	2	1	4	4	6.9E-6
sgtrw10	Yes	2	1	4	4	3.4E-6
tran10	Yes	2	1	4	4	2.2E-6
slocwo10	Yes	2	1	4	4	2.1E-6
nloca04	Yes	2	2	3	4	1.9E-6
mloca10	Yes	2	1	4	4	1.4E-6
slocaw10	Yes	2	1	4	4	1.3E-6
nloca21	Yes	1	2	4	4	1.2E-6
sgtrw04	Yes	2	2	3	4	9.3E-7
cmtlb10	Yes	1	1	4	4	7.6E-7
tran04	Yes	2	2	3	4	6.1E-7
sgtrw21	Yes	1	2	4	4	6.1E-7
slocwo04	Yes	2	2	3	4	5.8E-7
tran21	Yes	1	2	4	4	3.9E-7
slocwo21	Yes	1	2	4	4	3.8E-7
mloca04	Yes	2	2	3	4	3.8E-7
slocaw04	Yes	2	2	3	4	3.5E-7
mloca21	Yes	1	2	4	4	2.5E-7
silb04	Yes	1	1	3	4	2.4E-7
slocaw21	Yes	1	2	4	4	2.3E-7
cmtlb04	Yes	1	2	3	4	2.1E-7
nloca13	Yes	2	1	3	4	1.6E-8
nloca28	Yes	1	1	4	4	1.0E-8
sgtrw13	Yes	2	1	3	4	7.9E-9
sgtrw28	Yes	1	1	4	4	5.1E-9
slocwo13	Yes	2	1	3	4	4.9E-9
sgtrwo10	Yes	2	1	4	4	4.9E-9
tran13	Yes	2	1	3	4	4.8E-9
slocwo28	Yes	1	1	4	4	3.2E-9

Table 6-3
Success category OK2
(Sorted by Descending Frequency)

Success Path	Equipment Assumptions					Frequency (per year)
	CI	CMT	Acc	ADS-4	ADS 2,3	
mloca13	Yes	2	1	3	4	3.2E-9
tran28	Yes	1	1	4	4	3.0E-9
slocaw13	Yes	2	1	3	4	3.0E-9
nloca24	Yes	1	2	3	4	2.9E-9
mloca28	Yes	1	1	4	4	2.1E-9
slocaw28	Yes	1	1	4	4	1.9E-9
cmtlb13	Yes	1	1	3	4	1.8E-9
sgtrw24	Yes	1	2	3	4	1.4E-9
sgtrwo04	Yes	2	2	3	4	1.3E-9
slocwo24	Yes	1	2	3	4	8.8E-10
sgtrwo21	Yes	1	2	4	4	8.7E-10
tran24	Yes	1	2	3	4	8.2E-10
mloca24	Yes	1	2	3	4	5.7E-10
slocaw24	Yes	1	2	3	4	5.3E-10
nloca30	Yes	1	1	2,3 *	0 - 4 *	2.5E-11
sgtrw30	Yes	1	1	2,3 *	0 - 4 *	1.2E-11
sgtrwo13	Yes	2	1	3	4	1.1E-11
tran30	Yes	1	1	2,3 *	0 - 4 *	7.0E-12
sgtrwo28	Yes	1	1	4	4	6.6E-12
slocwo30	Yes	1	1	2,3 *	0 - 4 *	5.9E-12
mloca30	Yes	1	1	2,3 *	0 - 4 *	4.9E-12
slocaw30	Yes	1	1	2,3 *	0 - 4 *	4.5E-12
sgtrwo24	Yes	1	2	3	4	1.8E-12
sgtrwo30	Yes	1	1	2,3 *	0 - 4 *	1.5E-14
TOTAL						2.6E-5

Notes:

* These success paths include accident scenarios with more failures than defined by category OK2. The inclusion of additional equipment failures in these paths is of negligible importance because of the low frequency of the paths.

Table 6-4 Success category OK3 (Sorted by Descending Frequency)						
Success Path	Equipment Assumptions					Frequency (per year)
	CI	CMT	Acc	ADS-4	ADS 2,3	
nloca02	Yes	2	2	4	2,3	2.1E-4
sgtrw02	Yes	2	2	4	2,3	1.0E-4
tran02	Yes	2	2	4	2,3	6.6E-5
slocwo02	Yes	2	2	4	2,3	6.3E-5
mloca02	Yes	2	2	4	2,3	4.1E-5
slocaw02	Yes	2	2	4	2,3	3.8E-5
silb02	Yes	1	1	4	2,3	2.6E-5
cmtlb02	Yes	1	2	4	2,3	2.3E-5
nloca03	Yes	2	2	4	0,1	1.9E-6
nloca11	Yes	2	1	4	2,3	1.7E-6
sgtrw03	Yes	2	2	4	0,1	9.5E-7
sgtrw11	Yes	2	1	4	2,3	8.6E-7
tran11	Yes	2	1	4	2,3	5.5E-7
slocwo11	Yes	2	1	4	2,3	5.3E-7
mloca03	Yes	2	2	4	0,1	3.9E-7
slocaw03	Yes	2	2	4	0,1	3.6E-7
mloca11	Yes	2	1	4	2,3	3.5E-7
slocaw11	Yes	2	1	4	2,3	3.2E-7
nloca22	Yes	1	2	4	2,3	3.1E-7
tran03	Yes	2	2	4	0,1	3.1E-7
slocwo03	Yes	2	2	4	0,1	2.8E-7
silb03	Yes	1	1	4	0,1	2.5E-7
cmtlb03	Yes	1	2	4	0,1	2.1E-7
cmtlb11	Yes	1	1	4	2,3	1.9E-7
sgtrw22	Yes	1	2	4	2,3	1.5E-7
sgtrwo02	Yes	2	2	4	2,3	1.5E-7
tran22	Yes	1	2	4	2,3	9.8E-8
slocwo22	Yes	1	2	4	2,3	9.5E-8
mloca[illegible]	Yes	1	2	4	2,3	6.2E-8

Table 6-4 Success category OK3 (Sorted by Descending Frequency)						
Success Path	Equipment Assumptions					Frequency (per year)
	CI	CMT	Acc	ADS-4	ADS 2,3	
slocaw22	Yes	1	2	4	2,3	5.8E-8
nloca12	Yes	2	1	4	0,1	1.6E-8
sgtrw12	Yes	2	1	4	0,1	7.9E-9
mloca12	Yes	2	1	4	0,1	3.2E-9
slocaw12	Yes	2	1	4	0,1	3.0E-9
nloca23	Yes	1	2	4	0,1	2.9E-9
nloca29	Yes	1	1	4	0 - 3	2.6E-9
tran12	Yes	2	1	4	0,1	2.4E-9
slocwo12	Yes	2	1	4	0,1	2.4E-9
cmtlb12	Yes	1	1	4	0,1	1.8E-9
sgtrw23	Yes	1	2	4	0,1	1.4E-9
sgtrwo11	Yes	2	1	4	2,3	1.2E-9
sgtrw29	Yes	1	1	4	0 - 3	1.2E-9
slocwo29	Yes	1	1	4	0 - 3	7.8E-10
tran29	Yes	1	1	4	0 - 3	6.8E-10
sgtrwo03	Yes	2	2	4	0,1	6.4E-10
mloca23	Yes	1	2	4	0,1	5.7E-10
slocaw23	Yes	1	2	4	0,1	5.2E-10
mloca29	Yes	1	1	4	0 - 3	5.0E-10
slocaw29	Yes	1	1	4	0 - 3	4.6E-10
slocwo23	Yes	1	2	4	0,1	4.2E-10
tran23	Yes	1	2	4	0,1	4.1E-10
sgtrwo22	Yes	1	2	4	2,3	2.2E-10
sgtrwo12	Yes	2	1	4	0,1	5.0E-12
sgtrwo29	Yes	1	1	4	0 - 3	1.5E-12
sgtrwo23	Yes	1	2	4	0,1	8.5E-13
TOTAL						5.8E-4
Notes:						

Table 6-5
Success category OK4
(Sorted by Descending Frequency)

Success Path	Equipment Assumptions					Frequency (per year)
	CI	CMT	Acc	ADS-4	ADS 2,3	
nloca05	Yes	2	2	3	2,3	5.0E-7
sgtrw05	Yes	2	2	3	2,3	2.4E-7
tran05	Yes	2	2	3	2,3	1.5E-7
slocwo05	Yes	2	2	3	2,3	1.5E-7
mloca05	Yes	2	2	3	2,3	9.8E-8
slocaw05	Yes	2	2	3	2,3	9.2E-8
silb05	Yes	1	1	3	2,3	6.3E-8
cmtlb05	Yes	1	2	3	2,3	5.4E-8
nloca06	Yes	2	2	3	0,1	4.4E-9
nloca14	Yes	2	1	3	0 - 3	4.0E-9
sgtrw06	Yes	2	2	3	0,1	2.1E-9
sgtrw14	Yes	2	1	3	0 - 3	1.9E-9
slocwo14	Yes	2	1	3	0 - 3	1.2E-9
tran14	Yes	2	1	3	0 - 3	1.1E-9
mloca06	Yes	2	2	3	0,1	8.8E-10
slocaw06	Yes	2	2	3	0,1	8.1E-10
mloca14	Yes	2	1	3	0 - 3	7.9E-10
nloca25	Yes	1	2	3	0 - 3	7.4E-10
slocaw14	Yes	2	1	3	0 - 3	7.2E-10
tran06	Yes	2	2	3	0,1	6.5E-10
slocwo06	Yes	2	2	3	0,1	6.5E-10
silb06	Yes	1	1	3	0,1	5.5E-10
cmtlb06	Yes	1	2	3	0,1	4.8E-10
cmtlb14	Yes	1	1	3	0 - 3	4.2E-10
sgtrwo05	Yes	2	2	3	2,3	3.4E-10
sgtrw25	Yes	1	2	3	0 - 3	3.1E-10
slocwo25	Yes	1	2	3	0 - 3	2.1E-10
tran25	Yes	1	2	3	0 - 3	1.8E-10
mloca25	Yes	1	2	3	0 - 3	1.5E-10

Table 6-5
Success category OK4
(Sorted by Descending Frequency)

Success Path	Equipment Assumptions					Frequency (per year)
	CI	CMT	Acc	ADS-4	ADS 2,3	
slocaw25	Yes	1	2	3	0 - 3	1.2E-10
silb21	Yes	0 (1)	1	3	0 - 3	4.0E-11
sgtrwo14	Yes	2	1	3	0 - 3	2.4E-12
sgtrwo06	Yes	2	2	3	0,1	1.4E-12
sgtrwo25	Yes	1	2	3	0 - 3	4.1E-13
TOTAL						1.4E-6

Notes:

(1) Although no CMT injection to the RCS is credited, ADS actuation occurs from the faulted CMT blowing down through the break.

Table 6-6
Success category OK5A
(Sorted by Descending Frequency)

Success Path	Equipment Assumptions					Frequency (per year)
	CI	CMT	Acc	ADS-4	ADS 2,3	
lloca41	No	2	2	4	4	9.5E-7
sgtrw41	No	2	2	4	4	4.6E-7
tran41	No	2	2	4	4	3.0E-7
slocwo41	No	2	2	4	4	2.9E-7
mloca41	No	2	2	4	4	1.9E-7
slocaw41	No	2	2	4	4	1.8E-7
lloca31	No	2	2	4	4	1.3E-7
silb33	No	1	1	4	4	1.2E-7
cmtlb33	No	1	2	4	4	1.0E-7
nloca48	No	2	1	4	4	8.0E-9
sgtrw48	No	2	1	4	4	3.9E-9
slocwo48	No	2	1	4	4	2.5E-9
tran48	No	2	1	4	4	2.3E-9
mloca48	No	2	1	4	4	1.6E-9
slocaw48	No	2	1	4	4	1.5E-9
nloca54	No	1	2	4	4	1.4E-9
cmtlb40	No	1	1	4	4	8.7E-10
sgtrw54	No	1	2	4	4	7.0E-10
sgtrwo41	No	2	2	4	4	6.6E-10
slocwo54	No	1	2	4	4	4.4E-10
tran54	No	1	2	4	4	3.5E-10
mloca54	No	1	2	4	4	2.8E-10
slocaw54	No	1	2	4	4	2.6E-10
lloca45	No	1	2	4	4	2.0E-10
silb44	No	0 [1]	1	4	4	8.8E-11
sgtrwo48	No	2	1	4	4	5.0E-12
sgtrwo54	No	1	2	4	4	7.6E-13
TOTAL						2.7E-6

Table 6-6 Success category OK5A (Sorted by Descending Frequency)						
Success Path	Equipment Assumptions					Frequency (per year)
	CI	CMT	Acc	ADS-4	ADS 2,3	

Notes:

(1) Although no CMT injection to the RCS is credited, ADS actuation occurs from the faulted CMT blowing down through the break.

Table 6-7
Success category OK5B
(Sorted by Descending Frequency)

Success Path	Equipment Assumptions					Frequency (per year)
	CI	CMT	Acc	ADS-4	ADS 2,3	
nloca42	No	2	2	4	2,3	2.4E-7
sgtrw42	No	2	2	4	2,3	1.2E-7
tran42	No	2	2	4	2,3	7.4E-8
slocwo42	No	2	2	4	2,3	7.3E-8
mloca42	No	2	2	4	2,3	4.7E-8
slocaw42	No	2	2	4	2,3	4.4E-8
lloca32	No	2	2	4	2,3	3.4E-8
silb34	No	1	1	4	2,3	3.0E-8
cmtlb34	No	1	2	4	2,3	2.6E-8
nloca43	No	2	2	4	0,1	2.2E-9
nloca49	No	2	1	4	0 - 3	2.0E-9
sgtrw43	No	2	2	4	0,1	1.1E-9
sgtrw49	No	2	1	4	0 - 3	9.2E-10
slocwo49	No	2	1	4	0 - 3	6.0E-10
tran49	No	2	1	4	0 - 3	4.4E-10
mloca43	No	2	2	4	0,1	4.3E-10
slocaw43	No	2	2	4	0,1	3.9E-10
mloca49	No	2	1	4	0 - 3	3.8E-10
nloca55	No	1	2	4	0 - 4	3.6E-10
slocaw49	No	2	1	4	0 - 3	3.5E-10
slocwo43	No	2	2	4	0,1	3.2E-10
lloca33	No	2	2	4	0,1	3.0E-10
tran43	No	2	2	4	0,1	2.8E-10
silb35	No	1	1	4	0,1	2.7E-10
cmtlb35	No	1	2	4	0,1	2.3E-10
cmtlb41	No	1	1	4	0 - 3	2.0E-10
sgtrwo42	No	2	2	4	2,3	1.6E-10
sgtrw55	No	1	2	4	0 - 4	1.6E-10
slocwo55	No	1	2	4	0 - 4	1.0E-10

Table 6-7 Success category OK5B (Sorted by Descending Frequency)						
Success Path	Equipment Assumptions					Frequency (per year)
	CI	CMT	Acc	ADS-4	ADS 2,3	
mloca55	No	1	2	4	0 - 4	7.2E-11
tran55	No	1	2	4	0 - 4	6.2E-11
slocaw55	No	1	2	4	0 - 4	5.8E-11
lloca46	No	1	2	4	0 - 3	4.4E-11
silb45	No	0 [1]	1	4	0 - 3	2.0E-11
sgtrwo49	No	2	1	4	0 - 3	9.6E-13
sgtrwo43	No	2	2	4	0,1	5.8E-13
sgtrwo55	No	1	2	4	0 - 4	1.3E-13
TOTAL						7.0E-7

Notes:

(1) Although no CMT injection to the RCS is credited, ADS actuation occurs from the faulted CMT blowing down through the break.

Table 6-8 Success category OK6 (Sorted by Descending Frequency)						
Success Path	Equipment Assumptions					Frequency (per year)
	CI	CMT	Acc	ADS-4	ADS 2,3	
nloca44	No	2	2	3	4	2.2E-9
sgtrw44	No	2	2	3	4	1.1E-9
slocwo44	No	2	2	3	4	6.7E-10
tran44	No	2	2	3	4	5.6E-10
mloca44	No	2	2	3	4	4.4E-10
slocaw44	No	2	2	3	4	4.1E-10
silb36	No	1	1	3	4	2.8E-10
cmtlb36	No	1	2	3	4	2.4E-10
nloca50	No	2	1	2,3	0 - 4	1.9E-11
sgtrw50	No	2	1	2,3	0 - 4	9.2E-12
tran50	No	2	1	2,3	0 - 4	4.5E-12
mloca50	No	2	1	2,3	0 - 4	3.8E-12
slocaw50	No	2	1	2,3	0 - 4	3.4E-12
nloca56	No	1	2	2,3	0 - 4	3.4E-12
slocwo50	No	2	1	2,3	0 - 4	3.1E-12
cmtlb42	No	1	1	2,3	0 - 4	2.0E-12
sgtrw56	No	1	2	2,3	0 - 4	1.6E-12
sgtrwo44	No	2	2	3	4	1.2E-12
slocwo56	No	1	2	2,3	0 - 4	8.3E-13
mloca56	No	1	2	2,3	0 - 4	6.5E-13
tran56	No	1	2	2,3	0 - 4	6.3E-13
slocaw56	No	1	2	2,3	0 - 4	5.9E-13
silb46	No	0 (2)	1	2,3	0 - 4	2.0E-13
sgtrwo50	No	2	1	2,3	0 - 4	9.9E-15
sgtrwo56	No	1	2	2,3	0 - 4	1.4E-15
TOTAL						5.9E-9

Notes:

(2) Although no CMT injection to the RCS is credited, ADS actuation occurs from the faulted DMT blowing down through the break.

Table 6-9 Success category OK7 (Sorted by Descending Frequency)						
Success Path	Equipment Assumptions					Frequency (per year)
	CI	CMT	Acc	ADS-4	ADS 2,3	
lloca02	Yes	2	2	4	2,3	2.7E-5
lloca03	Yes	2	2	4	0,1	2.5E-7
lloca04	Yes	2	2	3	4	2.5E-7
lloca18	Yes	1	2	4	4	1.6E-7
lloca05	Yes	2	2	3	2,3	6.4E-8
lloca19	Yes	1	2	4	2,3	4.0E-8
lloca06	Yes	2	2	3	0,1	5.6E-10
lloca21	Yes	1	2	3	4	3.7E-10
lloca20	Yes	1	2	4	0,1	3.6E-10
lloca22	Yes	1	2	3	0 - 3	8.0E-11
TOTAL						2.7E-5
Notes:						

Table 6-10 Success category OK8 (Sorted by Descending Frequency)						
Success Path	Equipment Assumptions					Frequency (per year)
	CI	CMT	Acc	ADS-4	ADS 2,3	
silb17	Yes	0 (1)	1	4	4	7.6E-8
silb18	Yes	0 (1)	1	4	2,3	1.9E-8
silb20	Yes	0 (1)	1	3	4	1.8E-10
silb19	Yes	0 (1)	1	4	0,1	1.7E-10
TOTAL						9.6E-8
Notes: (1) Although no CMT injection to the RCS is credited, ADS actuation occurs from the faulted CMT blowing down through the break.						

Table 6-11 Success category OK9 (Sorted by Descending Frequency)						
Success Path	Equipment Assumptions					Frequency (per year)
	CI	CMT	Acc	ADS-4	ADS 2,3	
sgtrw34	Yes	0	2	4	4	6.3E-7
sgtrw35	Yes	0	2	4	0 - 3	1.6E-7
slocwo34	Yes	0	2	4	4	2.8E-8
tran34	Yes	0	2	4	4	2.8E-8
slocaw34	Yes	0	2	4	4	1.7E-8
slocwo35	Yes	0	2	4	0 - 3	7.1E-9
tran35	Yes	0	2	4	0 - 3	6.0E-9
sgtrw38	Yes	0	1	2 - 4	0 - 4	5.3E-9
slocaw35	Yes	0	2	4	0 - 3	4.3E-9
sgtrw36	Yes	0	2	2,3	0 - 4	1.5E-9
sgtrw60	No	0	1	2 - 4	0 - 4	7.2E-10
slocwo38	Yes	0	1	2 - 4	0 - 4	2.4E-10
slocaw38	Yes	0	1	2 - 4	0 - 4	1.4E-10
tran38	Yes	0	1	2 - 4	0 - 4	9.8E-11
slocwo36	Yes	0	2	2,3	0 - 4	6.7E-11
sgtrwo34	Yes	0	2	4	4	6.5E-11
tran36	Yes	0	2	2,3	0 - 4	6.0E-11
slocaw36	Yes	0	2	2,3	0 - 4	4.0E-11
slocwo60	No	0	1	2 - 4	0 - 4	3.2E-11
tran60	No	0	1	2 - 4	0 - 4	2.5E-11
slocaw60	No	0	1	2 - 4	0 - 4	1.9E-11
sgtrwo35	Yes	0	2	4	0 - 3	1.4E-11
sgtrwo38	Yes	0	1	2 - 4	0 - 4	2.3E-13
sgtrwo36	Yes	0	2	2,3	0 - 4	1.4E-13
sgtrwo60	No	0	1	2 - 4	0 - 4	5.9E-14
TOTAL						8.8E-7
Notes:						

7.0 UC CATEGORIES OF LOW-MARGIN ACCIDENT SCENARIOS

The categorization method of the success paths in the expanded event trees started with the concept of needing to define low-margin accident scenarios. As the process evolved, the low-margin scenarios were grouped into "UC" categories. The purpose of defining UC categories is to develop a list of PRA accident scenarios that are closest to the limits of acceptability, and thus would be most susceptible to T/H uncertainty having an impact on the conclusions of successful core cooling versus core damage.

Low-margin is defined as a scenario that experiences core uncovery. Core uncovery is defined as the predicted coolant two-phase mixture level falling below the top of the active fuel. The occurrence of core uncovery is used only as a screening criterion for an accident scenario to be further considered within the T/H uncertainty resolution process. The acceptance criterion for considering an accident scenario as successful core cooling in the PRA is that the PCT remains below 2200°F, which is consistent with the Appendix K criterion for LOCAs.

The process of identifying the types of core uncovery extends from the same process that was used to develop the PRA Phenomena Identification and Ranking Tables (PIRTs) to support the MAAP4/NOTRUMP benchmarking effort. To develop the PIRTs, a spectrum of PRA scenarios were examined by a group of experts with experience in AP600 systems design, small-break LOCA analyses, PRA and PIRTs. Key thermal-hydraulic phenomena which could impact challenges to core coolant inventory were identified (with an "H" for high importance). These same challenges can also be defined in terms of the equipment loss that causes them to occur. This process lead to the definition of categories UC1 through UC5.

Categories UC6 through UC9 are developed slightly differently. These UC categories include accident scenarios that cannot be directly supported by existing analyses, and are therefore assumed to result in core uncovery in the categorization process. Rather than perform additional analyses to determine whether the core remains covered, the information from the expanded event trees permits a risk-informed decision to be made on whether additional analyses are needed.

Table 7-1 provides an overview of the ten UC categories, and the impact on the Focused PRA if these categories were counted as core damage rather than successful core cooling. The impact is provided in terms of the change in the Focused PRA Core Damage Frequency (CDF) and Large Release Frequency (LRF), if the accident were core damage rather than successful core cooling. The method for determing the CDF and LRF impact is explained in Section 8.1. Following Table 7-1 is a more detailed discussion of each of the UC categories. For each UC category, there is also a table that lists all the applicable success paths from the expanded event trees and the calculated frequency of each path. Summaries and conclusions on the risk significance of each category can be found in Section 8.0.

Table 7-1 Summary of UC Categories					
Number	Description	Initiating Event	Defining Equipment Conditions	If counted as core damage, increase to Focused PRA	
				ΔCDF	ΔLRF
UC1	No Make-up Inventory if RCS Pressure is Greater than 700 psig	NLOCA DVI LB	0 CMTs	1.4E-7	8.2E-9
UC2A	1 Accumulator Depletes Prior to Operator Intervention	MLOCA CMT LB	0 CMTs 1 Accumulator	1.0E-9	8.1E-11
UC2B	2 Accumulators Deplete Prior to Operator Intervention	MLOCA CMT LB	0 CMTs 2 Accumulators	1.2E-7	7.5E-9
UC3	No Rapid Inventory Make-up During Blowdown	MLOCA CMTLB	0 Accumulators	2.2E-8	1.3E-9
UC4	Reduced Inventory Make-up During LLOCA Reflood	LLOCA	1 Accumulator	1.1E-6	6.9E-8
UC5	No Make-up When ADS is Actuated at Higher Pressure	NLOCA DVI LB SLOCA SGTR Transients	0 Accumulators	7.2E-7	7.6E-8
UC6	Reduced ADS-4	All	2 stage 4 ADS Cont Isolation	3.4E-7	7.5E-8
UC7	No ADS-4	LLOCA	0 stage 4 ADS Cont Isolation	3.2E-9	1.9E-10
UC8	No Containment Isolation	LLOCA	CI Failure	3.1E-10	3.1E-10
UC9	No Containment Isolation Reduced ADS	All		1.7E-9	1.7E-9

Category UC1

Category UC1 contains scenarios with the failure of both CMTs. Without CMTs, operator action is the only means of opening ADS lines to depressurize the RCS to achieve IRWST gravity injection. Prior to operator intervention, the only source of make-up water is the accumulators. However, accumulators can inject only after the RCS pressure falls below 700 psig. For LOCA break sizes that do not depressurize below this point, there is the potential for core uncovery due to the lack of make-up water.

The potential for this type of core uncovery is also impacted by operator action time. The question to be considered is whether core uncovery occurs prior to the break depressurizing the RCS below 700 psig and before the operator manually opens ADS lines. With operator action times of 20 or 30 minutes credited in the PRA success scenarios, the core may uncover prior to accumulator injection, as shown in Figure 7-1. Accumulator injection starts shortly after the core uncovers, but the RCS depressurization rate is not sufficient to provide rapid accumulator injection to recover the core. The period of core uncovery ends when the operator opens ADS lines, allowing the accumulators to inject rapidly.

The LOCA break sizes that lead to this type of core uncovery are approximately 2" to 4" in diameter. The corresponding initiating events are Intermediate LOCAs (NLOCAs) and DVI Line breaks. Smaller break sizes lose inventory at a slow enough rate that the coolant inventory is not challenged prior to operator action; they are classified in category OK9. Larger breaks depressurize so that the accumulator(s) can inject prior to core uncovery, and are classified in categories UC2A and UC2B.

Table 7-2 shows the applicable success paths, and the impact on the Focused PRA CDF and LRF if the scenario were counted as core damage.

Category UC2A, UC2B

Like category UC1, categories UC2A and UC2B address the failure of both CMTs. Without CMTs, operator action is the only means of opening ADS lines to depressurize the RCS to achieve IRWST gravity injection. Prior to operator intervention, the only source of make-up water is the accumulators. However, for relatively large breaks, accumulator inventory may deplete prior to operator action to open ADS. This can create a period of core uncovery after accumulators empty and prior to operator intervention. This type of core uncovery applies to breaks from approximately 7" to 9" diameter, as shown in Figure 7-1. The corresponding initiating events are Medium LOCAs (MLOCAs) and CMT line breaks. Larger breaks do not rely on ADS lines opening to achieve gravity injection since the break will depressurize the RCS to IRWST injection. Furthermore, larger breaks count failure of both CMTs as core damage.

The distinction between category UC2A and category UC2B is the number of accumulators available for injection to the RCS. The depth and duration of core uncovery is greater when there is only one accumulator (category UC2A). With two accumulators, the operator has more time to take action to open

ADS before core uncovery would occur. However, for the largest breaks in category UC2B, core uncovery may still occur.

Table 7-3 and Table 7-4 show the applicable success paths and the impact on the Focused PRA CDF and LRF if the scenarios were counted as core damage.

Category UC3

Category UC3 is a type of core uncovery that occurs in scenarios with the failure of both accumulators. The rapid make-up capability of the accumulators is essential for large breaks, and the failure of both accumulators is counted as core damage in the PRA large loss-of-coolant accident (LLOCA) event tree. However, for breaks smaller than a LLOCA, the PRA success paths do not require any accumulators if at least 1 CMT functions. The CMT, although a similarly-sized large tank of water, does not provide the rapid make-up capability. Therefore, core uncovery can occur for breaks a little smaller than LLOCA. The corresponding initiating events are MLOCA and CMT Line Break. For smaller break sizes, inventory loss through the break is at a slower rate, and the CMT can perform an inventory make-up function in time to prevent this type of core uncovery.

Table 7-5 shows the applicable success paths, and the impact on the Focused PRA CDF and LRF if the scenarios were counted as core damage.

Category UC4

The fourth type of core uncovery occurs in Large LOCAs (LLOCAs) due to the high rate of inventory loss from the break. LLOCA is a design basis accident (DBA) analyzed and documented in Chapter 15 of the SSAR. The DBA scenario includes 2 accumulators, and core uncovery occurs due to the large inventory loss through the break. The success of this accident scenario has been demonstrated, including conservative assumptions, and is not subject to further investigation in this T/H uncertainty resolution process. However, the LLOCA success criterion for the PRA only requires 1 accumulator. The failure of an accumulator could impact the PCT during reflood.

Table 7-6 shows the applicable success paths, and the impact on the Focused PRA CDF and LRF if the scenarios were counted as core damage.

Category UC5

Category UC5 is a type of core uncovery also due to the loss of accumulators. Categories UC3 and UC4 were associated with the accumulators and their ability to provide rapid make-up for medium and large breaks. Category UC5 completes the examination of the effect of losing accumulators for the remaining initiating events.

The initiating events to be considered are all those with breaks smaller than MLOCA (6"), including Transients with loss of heat removal that can result in loss of inventory through the pressurizer safety valve. The accumulator cannot function until the RCS pressure is less than 700 psig, which happens when ADS lines are opened. The RCS pressure is relatively high (between 700 psig and 2500 psig) when ADS is opened, and the mass lost through the ADS is high. Accumulators provide rapid inventory make-up for this condition. However, if both accumulators fail, thermal-hydraulic analyses show that core uncovery can occur. This type of core uncovery applies to NLOCA, SLOCA, SGTR and Transients.

Table 7-7 shows the applicable success paths, and the impact on the Focused PRA CDF and LRF if the scenarios were counted as core damage.

Category UC6

Category UC6 contains accident scenarios from all initiating events with 2 stage 4 ADS and successful containment isolation. The concern for this category is whether the reduced ADS capacity influences the ability to achieve and maintain IRWST gravity injection with the increased injection capability afforded by containment isolation.

There are currently no analyses that support this accident scenario. Preliminary MAAP4 analyses were performed with 2 stage 4 ADS. However, the MAAP4/NOTRUMP benchmarking effort determined that the ADS stage 4 model implemented in MAAP4 had not adequately accounted for the line resistances. Subsequently, benchmarking cases were modified to model the more probable condition of 3 stage 4 ADS, although the pessimism of no containment isolation was maintained.

Because of the lack of analytical support for the 2 stage 4 ADS scenario, it is conservatively assumed to result in core uncovery and the possibility of core damage is entertained through this T/H uncertainty resolution process. When comparing this category to other analyzed scenarios, the main issue becomes whether the positive effect of the containment back pressure compensates for the loss of ADS venting capability.

Table 7-8 shows the applicable success paths, and the impact on the Focused PRA CDF and LRF if the scenarios were counted as core damage.

Category UC7

Category UC7 addresses the special scenario of a large LOCA without any ADS, but with the success of containment isolation. Large LOCA is the only PRA initiating event that credits IRWST gravity injection without the actuation of any ADS. The size of the LOCA break is believed to be large enough to provide the needed venting for IRWST gravity injection. However, analyses to support this have not been performed.

Table 7-9 shows the applicable success paths, and the impact on the Focused PRA CDF and LRF if the scenarios were counted as core damage. Note that although the desire is to separately consider the impact of no ADS, the expansion of the LLOCA event tree is not refined to the isolation of this option. The result is that the estimated numerical values listed for the frequency of this category are high. However, this still results in a non-risk-significant frequency.

Category UC8

Category UC8 is defined as the loss of containment isolation for the large LOCA initiating event. Another defining criterion of this category is design basis ADS assumptions. With the additional failure of containment isolation, no analyses have been done for large LOCA to show either the short term or long term effects. All other initiating events with smaller break sizes have been analyzed, and are within category OK6.

Table 7-10 shows the applicable success paths, and the impact on the Focused PRA CDF and LRF if the scenarios were counted as core damage.

Category UC9

Category UC9 is defined as the loss of containment isolation along with ADS losses that reduce the ADS venting capacity below that assumed in design basis conditions. This category is defined to encompass all initiating events. It includes the most limiting success paths (i.e., ones with the most failures) on all the event trees.

Although preliminary MAAP4 analyses had been done to support most of the success paths applicable to this category, no analyses have been done since the MAAP4 code was benchmarked. Therefore, no attempt is made to draw distinctions between which of the initiating events and break sizes would result in core uncovery. They are all pessimistically assumed to result in core uncovery. Table 7-11 lists the success paths, and the impact on the Focused PRA CDF and LRF if the scenarios were counted as core damage.

Figure 7-1

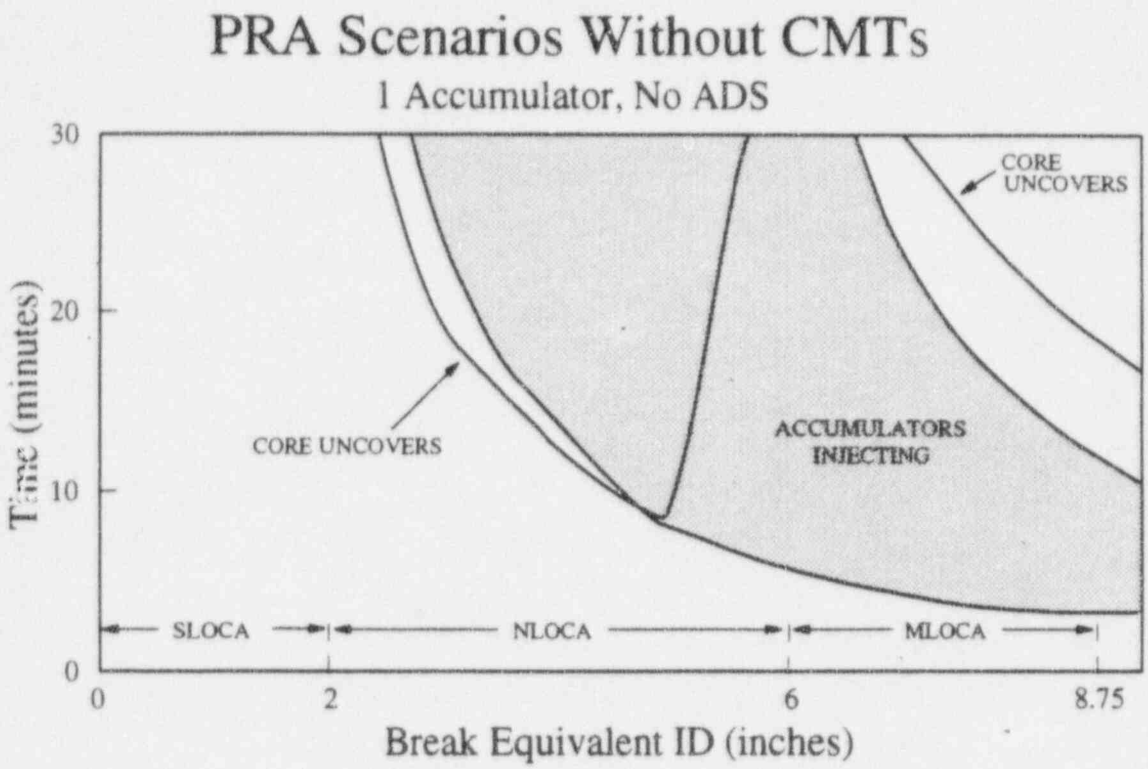

PRA Scenarios Without CMTs
1 Accumulator, No ADS
30
20
10
0
Time (minutes)
CORE UNCOVERS
CORE UNCOVERS
ACCUMULATORS INJECTING
SLOCA
NLOCA
MLOCA
0
2
6
8.75
Break Equivalent ID (inches)

Table 7-2 Success category UC1 (Sorted by Descending Frequency)								
Success Path	Equipment Assumptions					Frequency (per year)	If counted as core damage, increase to Focused PRA	
	CI	CMT	Acc	ADS-4	ADS 2,3		Δ CDF	Δ LRF (1)
nloca34	Yes	0	2	4	4	9.2E-8	9.2E-8	5.5E-9
nloca35	Yes	0	2	4	0 - 3	2.3E-8	2.3E-8	1.4E-9
silb28	Yes	0	1	4	4	1.6E-8	1.6E-8	9.8E-10
silb29	Yes	0	1	4	0 - 3	4.2E-9	4.2E-9	2.5E-10
nloca38	Yes	0	1	2 - 4	0 - 4	7.8E-10	7.8E-10	4.7E-11
nloca36	Yes	0	2	2,3	0 - 4	2.3E-10	2.3E-10	1.4E-11
nloca60	No	0	1	2 - 4	0 - 4	1.1E-10	1.1E-10	6.4E-12
silb30	Yes	0	1	2,3	0 - 4	3.9E-11	3.9E-11	2.3E-12
silb50	No	0	1	2 - 4	0 - 4	1.9E-11	1.9E-11	1.1E-12
TOTAL						1.4E-7	1.4E-7	8.2E-9

Notes:

(1) LRF for scenarios with containment isolation is estimated at 6% of core damage. Scenarios without containment isolation increase the LRF by 100% of the core damage frequency.

Table 7-3 Success category UC2A (Sorted by Descending Frequency)								
Success Path	Equipment Assumptions					Frequency (per year)	If counted as core damage, increase to Focused PRA	
	CI	CMT	Acc	ADS-4	ADS 2,3		Δ CDF	Δ LRF [1]
cmtlb28	Yes	0	1	4	4	6.7E-10	6.7E-10	4.0E-11
cmtlb29	Yes	0	1	4	0 - 3	1.6E-10	1.6E-10	9.5E-12
mloca38	Yes	0	1	2 - 4	0 - 4	1.5E-10	1.5E-10	9.2E-12
mloca60	No	0	1	2 - 4	0 - 4	2.1E-11	2.1E-11	2.1E-11
cmtlb30	Yes	0	1	2,3	0 - 4	1.6E-12	1.6E-12	9.5E-14
cmtlb50	No	0	1	2 - 4	0 - 4	7.6E-13	7.6E-13	7.6E-13
TOTAL						1.0E-9	1.0E-9	8.1E-11

Notes:

(1) LRF for scenarios with containment isolation is estimated at 6% of core damage. Scenarios without containment isolation increase the LRF by 100% of the core damage frequency.

Table 7-4 Success category UC2B (Sorted by Descending Frequency)								
Success Path	Equipment Assumptions					Frequency (per year)	If counted as core damage, increase to Focused PRA	
	CI	CMT	Acc	ADS-4	ADS 2,3			
							Δ CDF	Δ LRF [(1)]
cmtlb21	Yes	0	2	4	4	8.0E-8	8.0E-8	4.8E-9
cmtlb22	Yes	0	2	4	2,3	2.0E-8	2.0E-8	1.2E-9
mloca34	Yes	0	2	4	4	1.8E-8	1.8E-8	1.1E-9
mloca35	Yes	0	2	4	0 - 3	4.6E-9	4.6E-9	2.8E-10
cmtlb24	Yes	0	2	3	4	1.9E-10	1.9E-10	1.1E-11
cmtlb23	Yes	0	2	2,3	0 - 4	1.8E-10	1.8E-10	1.1E-11
cmtlb46	No	0	2	2,3	0 - 4	9.2E-11	9.2E-11	9.2E-11
mloca36	Yes	0	2	2,3	0 - 4	4.5E-11	4.5E-11	2.7E-12
cmtlb25	Yes	0	2	2,3	0 - 4	4.1E-11	4.1E-11	2.5E-12
cmtlb47	No	0	2	2,3	0 - 4	2.0E-11	2.0E-11	2.0E-11
cmtlb26	Yes	0	2	2,3	0 - 4	6.5E-12	6.5E-12	3.9E-13
cmtlb48	No	0	2	2 - 4	0 - 4	2.0E-13	2.0E-13	2.0E-13
TOTAL						1.2E-7	1.2E-7	7.5E-9

Notes:

(1) LRF for scenarios with containment isolation is estimated at 6% of core damage. Scenarios without containment isolation increase the LRF by 100% of the core damage frequency.

Table 7-5 Success category UC3 (Sorted by Descending Frequency)								
Success Path	Equipment Assumptions					Frequency (per year)	If counted as core damage, increase to Focused PRA	
	CI	CMT	Acc	ADS-4	ADS 2,3		Δ CDF	Δ LRF [1]
mloca17	Yes	2	0	4	4	1.1E-8	1.1E-8	6.7E-10
cmtlb17	Yes	1	0	4	4	6.2E-9	6.2E-9	3.7E-10
mloca18	Yes	2	0	4	0 - 3	2.8E-9	2.8E-9	1.7E-10
cmtlb18	Yes	1	0	4	0 - 3	1.6E-9	1.6E-9	9.3E-11
mloca19	Yes	2	0	2,3	0 - 4	2.7E-11	2.7E-11	1.6E-12
mloca32	Yes	1	0	2 - 4	0 - 4	1.7E-11	1.7E-11	1.0E-12
cmtlb19	Yes	1	0	2,3	0 - 4	1.3E-11	1.3E-11	8.0E-13
mloca52	No	2	0	2 - 4	0 - 4	1.3E-11	1.3E-11	1.3E-11
nloca58	No	1	0	2 - 4	0 - 4	1.2E-11	1.2E-11	1.2E-11
cmtlb44	No	1	0	2 - 4	0 - 4	6.0E-12	6.0E-12	6.0E-12
mloca58	No	1	0	2 - 4	0 - 4	2.3E-12	2.3E-12	2.3E-12
TOTAL						2.2E-8	2.2E-8	1.3E-9

Notes:

(1) LRF for scenarios with containment isolation is estimated at 6% of core damage. Scenarios without containment isolation increase the LRF by 100% of the core damage frequency.

Table 7-6 Success category UC4 (Sorted by Descending Frequency)								
Success Path	Equipment Assumptions					Frequency (per year)	If counted as core damage, increase to Focused PRA	
	CI	CMT	Acc	ADS-4	ADS 2,3		Δ CDF	Δ LRF [1]
lloca10	Yes	2	1	4	4	8.9E-7	8.9E-7	5.3E-8
lloca11	Yes	2	1	4	2,3	2.2E-7	2.2E-7	1.3E-8
lloca13	Yes	2	1	3	4	2.1E-9	2.1E-9	1.2E-10
lloca12	Yes	2	1	4	0,1	2.1E-9	2.1E-9	1.2E-10
lloca25	Yes	1	1	4	4	1.3E-9	1.3E-9	8.0E-11
lloca39	No	2	1	4	4	1.1E-9	1.1E-9	1.1E-9
lloca14	Yes	2	1	3	0 - 3	5.0E-10	5.0E-10	3.0E-11
lloca26	Yes	1	1	4	0 - 3	3.2E-10	3.2E-10	1.9E-11
lloca40	No	2	1	4	0 - 3	2.6E-10	2.6E-10	2.6E-10
lloca15	Yes	2	1	2	0 - 4	2.0E-10	2.0E-10	1.2E-11
lloca16	Yes	2	1	0,1	0 - 4	2.7E-11	2.7E-11	1.6E-12
lloca27	Yes	1	1	2,3	0 - 4	3.2E-13	3.2E-13	1.9E-13
lloca41	No	2	1	2,3	0 - 4	2.7E-13	2.7E-13	2.7E-12
lloca50	No	1	1	2 - 4	0 - 4	8.2E-13	8.2E-13	8.2E-13
lloca28	Yes	1	1	0,1	0 - 4	3.3E-14	3.3E-14	2.0E-15
lloca42	No	2	1	0,1	0 - 4	7.6E-15	7.6E-15	7.6E-15
lloca51	No	1	1	0,1	0 - 4	0.0	0.0	0.0
TOTAL						1.1E-6	1.1E-6	6.9E-8

Notes:

(1) LRF for scenarios with containment isolation is estimated at 6% of core damage. Scenarios without containment isolation increase the LRF by 100% of the core damage frequency.

Table 7-7 Success category UC5 (Sorted by Descending Frequency)								
Success Path	Equipment Assumptions					Frequency (per year)	If counted as core damage, increase to Focused PRA	
	CI	CMT	Acc	ADS-4	ADS 2,3		Δ CDF	Δ LRF [1]
silb10	Yes	1	0	4	4	4.4E-7	4.4E-7	2.6E-8
silb11	Yes	1	0	4	2,3	1.1E-7	1.1E-7	6.7E-9
nloca17	Yes	2	0	4	4	5.6E-8	5.6E-8	3.4E-9
sgtrw17	Yes	2	0	4	4	2.8E-8	2.8E-8	2.8E-8
tran17	Yes	2	0	4	4	1.8E-8	1.8E-8	1.1E-9
slocwo17	Yes	2	0	4	4	1.7E-8	1.7E-8	1.0E-9
nloca18	Yes	2	0	4	0 - 3	1.4E-8	1.4E-8	8.6E-10
slocaw17	Yes	2	0	4	4	1.0E-8	1.0E-8	6.3E-10
sgtrw18	Yes	2	0	4	0 - 3	7.0E-9	7.0E-9	7.0E-[illegible]
slocwo18	Yes	2	0	4	0 - 3	4.4E-9	4.4E-9	2.6E-10
tran18	Yes	2	0	4	0 - 3	3.6E-9	3.6E-9	2.2E-10
slocaw18	Yes	2	0	4	0 - 3	2.6E-9	2.6E-9	1.6E-10
silb13	Yes	1	0	3	4	1.0E-9	1.0E-9	6.1E-11
silb12	Yes	1	0	4	0,1	1.0E-9	1.0E-9	6.1E-11
silb40	No	1	0	4	4	5.1E-10	5.1E-10	5.1E-10
silb24	Yes	0 [2]	0	4	4	3.2E-10	3.2E-10	1.9E-11
silb14	Yes	1	0	3	0 - 3	2.5E-10	2.5E-10	1.5E-11
nloca19	Yes	2	0	2,3	0 - 4	1.4E-10	1.4E-10	8.3E-12
silb41	No	1	0	4	0 - 3	1.2E-10	1.2E-10	1.2E-10
nloca32	Yes	1	0	2 - 4	0 - 4	8.5E-11	8.5E-11	5.1E-12
silb25	Yes	0 [2]	0	4	0 - 3	7.8E-11	7.8E-11	4.7E-12
nloca52	No	2	0	2 - 4	0 - 4	6.5E-11	6.5E-11	6.5E-11
sgtrw19	Yes	2	0	2,3	0 - 4	6.1E-11	6.1E-11	6.1E-11
silb15	Yes	1	0	2	0 - 4	4.1E-11	4.1E-11	2.5E-12
slocwo19	Yes	2	0	2,3	0 - 4	4.0E-11	4.0E-11	2.4E-12
sgtrwo17	Yes	2	0	4	4	3.9E-11	3.9E-11	3.9E-11
sgtrw32	Yes	1	0	2 - 4	0 - 4	3.7E-11	3.7E-11	3.7E-11
tran19	Yes	2	0	2,3	0 - 4	2.9E-11	2.9E-11	1.7E-12

Table 7-7 Success category UC5 (Sorted by Descending Frequency)								
Success Path	Equipment Assumptions					Frequency (per year)	If counted as core damage, increase to Focused PRA	
	CI	CMT	Acc	ADS-4	ADS 2,3		Δ CDF	Δ LRF (1)
sgtrw52	No	2	0	2 - 4	0 - 4	2.8E-11	2.8E-11	2.8E-11
tran32	Yes	1	0	2 - 4	0 - 4	2.6E-11	2.6E-11	1.6E-12
slocwo32	Yes	1	0	2 - 4	0 - 4	2.5E-11	2.5E-11	1.5E-12
slocaw19	Yes	2	0	2,3	0 - 4	2.3E-11	2.3E-11	1.4E-12
slocwo52	No	2	0	2 - 4	0 - 4	1.9E-11	1.9E-11	1.9E-11
slocaw32	Yes	1	0	2 - 4	0 - 4	1.4E-11	1.4E-11	8.4E-13
tran52	No	2	0	2 - 4	0 - 4	1.2E-11	1.2E-11	1.2E-11
slocaw52	No	2	0	2 - 4	0 - 4	1.0E-11	1.0E-11	1.0E-11
sgtrwo18	Yes	2	0	4	0 - 3	7.8E-12	7.8E-12	7.8E-12
sgtrw58	No	1	0	2 - 4	0 - 4	5.8E-12	5.8E-12	5.8E-12
tran58	No	1	0	2 - 4	0 - 4	2.9E-12	2.9E-12	2.9E-12
slocwo58	No	1	0	2 - 4	0 - 4	2.4E-12	2.4E-12	2.4E-12
slocaw58	No	1	0	2 - 4	0 - 4	2.2E-12	2.2E-12	2.2E-12
silb42	No	1	0	2,3	0 - 4	1.2E-12	1.2E-12	1.2E-12
silb26	Yes	0 (2)	0	2,3	0 - 4	7.6E-13	7.6E-13	4.6E-14
silb48	No	0 (2)	0	2 - 4	0 - 4	3.7E-13	3.7E-13	3.7E-13
sgtrwo19	Yes	2	0	2,3	0 - 4	6.3E-14	6.3E-14	6.3E-14
sgtrwo32	Yes	1	0	2 - 4	0 - 4	5.8E-14	5.8E-14	5.8E-14
sgtrwo52	No	2	0	2 - 4	0 - 4	2.7E-14	2.7E-14	2.7E-14
sgtrwo58	No	1	0	2 - 4	0 - 4	6.5E-15	6.5E-15	6.5E-15
TOTAL						7.2E-7	7.2E-7	7.6E-8

Notes:

(1) LRF for scenarios with containment isolation is estimated at 6% of core damage. SGTRs and scenarios without containment isolation increase the LRF by 100% of the core damage frequency.

(2) Although no CMT injection to the RCS is credited, ADS actuation occurs from the faulted CMT blowing down through the break.

Table 7-8 Success category UC6 (Sorted by Descending Frequency)								
Success Path	Equipment Assumptions					Frequency (per year)	If counted as core damage, increase to Focused PRA	
	CI	CMT	Acc	ADS-4	ADS 2,3		Δ CDF	Δ LRF [1]
nloca08	Yes	2	2	2	0 - 3	6.6E-8	6.6E-8	4.0E-9
nloca07	Yes	2	2	2	4	5.0E-8	5.0E-8	3.0E-9
sgtrw08	Yes	2	2	2	0 - 3	3.3E-8	3.3E-8	3.3E-8
sgtrw07	Yes	2	2	2	4	2.5E-8	2.5E-8	2.5E-8
slocwo08	Yes	2	2	2	0 - 3	2.0E-8	2.0E-8	1.2E-9
lloca08	Yes	2	2	2	0 - 3	1.9E-8	1.9E-8	1.1E-9
tran08	Yes	2	2	2	0 - 3	1.9E-8	1.9E-8	1.1E-9
tran07	Yes	2	2	2	4	1.6E-8	1.6E-8	9.6E-10
slocwo07	Yes	2	2	2	4	1.5E-8	1.5E-8	9.2E-10
mloca08	Yes	2	2	2	0 - 3	1.3E-8	1.3E-8	7.8E-10
slocaw08	Yes	2	2	2	0 - 3	1.2E-8	1.2E-8	7.3E-10
mloca07	Yes	2	2	2	4	9.9E-9	9.9E-9	5.9E-10
lloca07	Yes	2	2	2	4	9.9E-9	9.9E-9	5.9E-10
slocaw07	Yes	2	2	2	4	9.2E-9	9.2E-9	5.5E-10
cmtlb08	Yes	1	2	2	0 - 3	7.2E-9	7.2E-9	4.3E-10
silb07	Yes	1	1	2	4	6.4E-9	6.4E-9	3.8E-10
cmtlb07	Yes	1	2	2	4	5.5E-9	5.5E-9	3.3E-10
silb08	Yes	1	1	2	0 - 3	5.0E-9	5.0E-9	3.0E-10
nloca15	Yes	2	1	2	0 - 4	8.6E-10	8.6E-10	5.1E-11
sgtrw15	Yes	2	1	2	0 - 4	3.7E-10	3.7E-10	3.7E-10
slocwo15	Yes	2	1	2	0 - 4	2.5E-10	2.5E-10	1.5E-11
mloca15	Yes	2	1	2	0 - 4	1.6E-10	1.6E-10	9.3E-12
nloca26	Yes	1	2	2	0 - 4	1.6E-10	1.6E-10	9.3E-12
slocaw15	Yes	2	1	2	0 - 4	1.4E-10	1.4E-10	8.3E-12
tran15	Yes	2	1	2	0 - 4	1.2E-10	1.2E-10	7.3E-12
cmtlb15	Yes	1	1	2	0 - 4	7.7E-11	7.7E-11	4.6E-12
sgtrw26	Yes	1	2	2	0 - 4	5.4E-11	5.4E-11	5.4E-11
slocwo26	Yes	1	2	2	0 - 4	4.1E-11	4.1E-11	2.5E-12

Table 7-8 Success category UC6 (Sorted by Descending Frequency)								
Success Path	Equipment Assumptions					Frequency (per year)	If counted as core damage, increase to Focused PRA	
	CI	CMT	Acc	ADS-4	ADS 2,3		Δ CDF	Δ LRF [1]
sgtrwo08	Yes	2	2	2	0 - 3	4.0E-11	4.0E-11	4.0E-11
sgtrwo07	Yes	2	2	2	4	3.5E-11	3.5E-11	3.5E-11
lloca23	Yes	1	2	2	0 - 4	3.2E-11	3.2E-11	2.0E-12
mloca26	Yes	1	2	2	0 - 4	3.1E-11	3.1E-11	1.8E-12
tran26	Yes	1	2	2	0 - 4	2.1E-11	2.1E-11	1.3E-12
slocaw26	Yes	1	2	2	0 - 4	2.0E-11	2.0E-11	1.2E-12
silb22	Yes	0 [2]	1	2	0 - 4	7.1E-12	7.1E-12	4.3E-13
sgtrwo15	Yes	2	1	2	0 - 4	2.7E-13	2.7E-13	2.7E-13
sgtrwo26	Yes	1	2	2	0 - 4	4.6E-14	4.6E-14	4.6E-14
TOTAL						3.4E-7	3.4E-7	7.5E-8

Notes:

(1) LRF for scenarios with containment isolation is estimated at 6% of core damage. SGTRs increase the LRF by 100% of the core damage frequency.

(2) Although no CMT injection to the RCS is credited, ADS actuation occurs from the faulted CMT blowing down through the break.

Table 7-9 Success category UC7 (Sorted by Descending Frequency)								
Success Path	Equipment Assumptions					Frequency (per year)	If counted as core damage, increase to Focused PRA	
	CI	CMT	Acc	ADS-4	ADS 2,3		Δ CDF	Δ LRF (1)
lloca09	Yes	2	2	0,1	0 - 4	3.2E-9	3.2E-9	1.9E-10
lloca24	Yes	1	2	0,1	0 - 4	4.6E-12	4.6E-12	2.7E-13
TOTAL						3.2E-9	3.2E-9	1.9E-10

Notes:

(1) LRF for scenarios with containment isolation is estimated at 6% of core damage.

Table 7-10 Success category UC8 (Sorted by Descending Frequency)								
Success Path	Equipment Assumptions					Frequency (per year)	If counted as core damage, increase to Focused PRA	
	CI	CMT	Acc	ADS-4	ADS 2,3		Δ CDF	Δ LRF (1)
lloca34	No	2	2	3	4	3.1E-10	3.1E-10	3.1E-10
lloca47	No	1	2	2,3	0 - 4	4.5E-13	4.5E-13	4.5E-13
TOTAL						3.1E-10	3.1E-10	3.1E-10

Notes:

(1) Scenarios without containment isolation increase the LRF by 100% of the core damage frequency.

Table 7-11
Success category UC9
(Sorted by Descending Frequency)

Success Path	Equipment Assumptions					Frequency (per year)	If counted as core damage, increase to Focused PRA	
	CI	CMT	Acc	ADS-4	ADS 2,3		Δ CDF	Δ LRF [1]
nloca45	No	2	2	3	0 - 3	5.7E-10	5.7E-10	5.7E-10
sgtrw45	No	2	2	3	0 - 3	2.4E-10	2.4E-10	2.4E-10
slocwo45	No	2	2	3	0 - 3	1.6E-10	1.6E-10	1.6E-10
nloca46	No	2	2	2	0 - 4	1.2E-10	1.2E-10	1.2E-10
mloca45	No	2	2	3	0 - 3	1.1E-10	1.1E-10	1.1E-10
tran45	No	2	2	3	0 - 3	9.8E-11	9.8E-11	[illegible].8E-11
slocaw45	No	2	2	3	0 - 3	9.0E-11	9.0E-11	9.0E-11
lloca35	No	2	2	3	0 - 3	6.9E-11	6.9E-11	6.9E-11
silb37	No	1	1	3	0 - 3	6.2E-11	6.2E-11	6.2E-11
cmtlb37	No	1	2	3	0 - 3	5.3E-11	5.3E-11	5.3E-11
sgtrw46	No	2	2	2	0 - 4	4.1E-11	4.1E-11	4.1E-11
slocwo46	No	2	2	2	0 - 4	2.9E-11	2.9E-11	2.9E-11
lloca36	No	2	2	2	0 - 4	2.4E-11	2.4E-11	2.4E-11
mloca46	No	2	2	2	0 - 4	2.3E-11	2.3E-11	2.3E-11
slocaw46	No	2	2	2	0 - 4	1.5E 11	1.5E-11	1.5E-11
tran46	No	2	2	2	0 - 4	1.4E-11	1.4E-11	1.4E-11
silb38	No	1	1	2	0 - 4	8.5E-12	8.5E-12	8.5E-12
cmtlb38	No	1	2	2	0 - 4	7.9E-12	7.9E-12	7.9E-12
lloca37	No	2	2	0,1	0 - 4	1.9E-12	1.9E-12	1.9E-12
sgtrwo45	No	2	2	3	0 - 3	2.2E-13	2.2E-13	2.2E-13
sgtrwo46	No	2	2	2	0 - 4	3.1E-14	3.1E-14	3.1E-14
lloca48	No	1	2	0,1	0 - 4	2.4E-15	2.4E-15	2.4E-15
TOTAL						1.7E-9	1.7E-9	1.7E-9

Notes:

(1) Scenarios without containment isolation increase the LRF by 100% of the core damage frequency.

8.0 IDENTIFICATION OF LOW-MARGIN, RISK-SIGNIFICANT SCENARIOS

The climax of the T/H uncertainty resolution process is identifying the risk-significant, low-margin scenarios that will be further defended with T/H analyses including bounding uncertainties. This section documents this process, which starts with summarizing results from the UC categories in Section 7.0, and concludes with the definition of the cases for further T/H analysis.

8.1 Comparison Method to Focused PRA CDF and LRF

Section 7.0 contains discussion of the low-margin categories of success paths from the expanded event trees. Within Section 7.0, tables of the success paths contained information on the increase to the Focused PRA core damage frequency (CDF) and large release frequency (LRF) if the path were counted as core damage. It should be emphasized that these are success paths in the Baseline and Focused PRAs. However, this process considers the possibility that the path is incorrectly categorized as success, and should actually be counted as core damage. This allows a determination of the impact that would be seen on the Focused PRA CDF and LRF.

If a success path is counted as core damage, the increase to the CDF is simply the addition of the frequency of that path to the Focused PRA CDF. To determine the impact on the LRF, some estimates had to be made. The cases of no containment isolation and SGTR scenarios are straight-forward, since all core damage are assumed to result in a large release to the environment. Thus, the increase to the LRF is the same as the increase to the CDF. If the containment is isolated, however, only a fraction of the core damage accidents result in a large release to the environment. The determination of this fraction is done by binning core damage accidents into an appropriate PRA accident class, and the sequence frequency is multiplied by the containment matrix for the accident class to determine the contribution to the large release frequency. The accidents being considered in this T/H uncertainty resolution process, if they resulted in core damage, would have minimal core damage which would neither relocate debris to the lower head nor generate significant hydrogen. Based on Level 2 PRA work, it was estimated that 6% of the core damage scenarios with containment isolation could lead to a large release. This is a conservative estimate, overestimating the threat to containment integrity for many of the scenarios.

The impact of counting success paths as core damage was considered for each category. Individual success paths were treated as just described with respect to the determination of LRF, but the entire category is considered as a unit when determining risk significance. This is because the UC categories are defined around a specific issue that is common to all the success paths that fit that category. Therefore, if it were incorrect to credit success in one success path, this would likewise apply to the other success paths with the same conditions defined by the category. Although there are probably exceptions to this rule, it is a conservative limitation to apply to the definition of risk significance.

Risk significance for the T/H uncertainty resolution process is defined as increasing the Focused PRA CDF or LRF by at least 1% if the success category were counted as core damage. The at-power, Focused PRA

CDF is 7.7E-6/year and the LRF is 5.5E-7/year. Therefore, the cut-off frequency of a success category to determine risk significance is 7.7E-8/year for CDF and 5.5E-9/year for LRF.

8.2 Risk Significant Categories

The results of the UC categories from Section 7.0 are summarized in Table 8-1, and a determination of whether the category is risk significant is made. The five categories that are risk significant are briefly discussed below, in order of their risk significance. As committed to in Section 4.3, LLOCA success paths are compared not only to the Focused PRA, but also to the Baseline PRA.

1. Category UC4

   If this category is counted as core damage, the impact on the Focused PRA corresponds to a 14% increase in CDF and a 13% increase in LRF. This category consists of the LLOCA initiating event with only 1 accumulator. The impact on the Baseline PRA would be approximately an order of magnitude larger than the Focused PRA impact. However, since the category is already defined as risk-significant, further T/H analyses will be performed, and the magnitude of risk significance is only a concern if acceptable results are not obtained.

2. Category UC5

   If this category is counted as core damage, the impact on the Focused PRA corresponds to a 9% increase in CDF and a 14% increase in LRF. This category applies to initiating events with breaks no larger than the NLOCA (6" diameter) with the loss of both accumulators.

3. Category UC6

   If this category is counted as core damage, the impact on the Focused PRA corresponds to a 4% increase in CDF and 14% increase in LRF. This category applies to all initiating events with the actuation of 2 stage 4 ADS to achieve IRWST gravity injection. The LLOCA success paths, if counted as core damage, would result in an increase of 2.9E-8 to the CDF and 1.7E-9 to the LRF. The impact of this change on the Baseline PRA is a 17% increase in CDF and a 9% increase in LRF.

4. Category UC1

   If this category is counted as core damage, the impact on the Focused PRA corresponds to a 2% increase in CDF and 2% increase in LRF. This category applies to NLOCA and DVI line breaks with the failure of both CMTs.

5. Category UC2B

If this category is counted as core damage, the impact on the Focused PRA corresponds to a 2% increase in CDF and 1% increase in LRF. This category applies to MLOCA and CMT line breaks with the failure of both CMTs.

To complete the assessment of the LLOCA impact on the Baseline PRA, other UC categories that are applicable to LLOCA need to be examined. The non-risk-significant categories that include LLOCA are UC7, UC8 and UC9. With the Baseline At-Power PRA CDF of 1.7E-7 and the LRF of 1.8E-8, the following summary shows the LLOCA Baseline PRA impact for these categories.

		Impact if counted as core damage	
Category	Description	Baseline CDF	Baseline LRF
UC7	LLOCA 0 or 1 ADS-4 Containment Isolated	3.2E-9 2%	1.9E-10 1%
UC8	LLOCA DBA ADS Containment Unisolated	3.1E-10 <1%	3.1E-10 2%
UC9	LLOCA < DBA ADS Containment Unisolated	9.5E-11 <1%	9.5E-11 <1%

Although some of the impacts are 1% or 2% of the Baseline PRA, these LLOCA scenarios are not classified as risk-significant. The impact of considering these scenarios as core damage in the Baseline PRA will be further discussed in Section 11.0.

Table 8-1
Risk Significance of UC Categories

Number	Initiating Event	Defining Equipment Conditions	If counted as core damage, increase to Focused PRA		Risk Significant?
			ΔCDF	ΔLRF	
UC1	NLOCA DVI Line Break	0 CMTs	**1.4E-7**	**8.2E-9**	Yes
UC2A	MLOCA CMT Line Break	0 CMTs	1.0E-9	8.1E-11	No
UC2B	MLOCA CMT Line Break	0 CMTs	**1.2E-7**	**7.5E-9**	Yes
UC3	MLOCA CMTLB	0 Accumulators	2.2E-8	1.3E-9	No
UC4	LLOCA	1 Accumulator	**1.1E-6**	**6.9E-8**	Yes
UC5	NLOCA DVI Line Break SLOCA SGTR Transients	0 Accumulators	**7.2E-7**	**7.6E-8**	Yes
UC6	All	2 stage 4 ADS Cont Isolation	**3.4E-7**	**7.5E-8**	Yes
UC7	LLOCA	0 stage 4 ADS Cont Isolation	3.2E-9	1.9E-10	No
UC8	LLOCA	CI Failure	3.1E-10	3.1E-10	No
UC9	All	CI Failure < DBA ADS	1.7E-9	1.7E-9	No

Notes:

- The bold numbers indicate values that are greater than 1% of the Focused PRA CDF or LRF.

8.3 Representative Cases to Address Low-Margin, Risk Significant Scenarios

From the five risk significant categories that are defined, a set of cases is defined for T/H analyses with uncertainties to complete the T/H uncertainty resolution process. The list of risk significant cases is augmented by long-term recirculation considerations discussed in Section 9.0.

First, the risk significant categories are further examined to define representative cases for analysis. This was done by looking at the dominant scenarios in each of the categories. For this purpose, dominant is defined as one that contributes to the category CDF or LRF exceeding 1% of the Focused PRA CDF or LRF. The residual effect of all scenarios not identified as dominant for a given category adds up to less than 1% of the Focused PRA CDF or LRF. The dominant scenarios are listed in Table 8-2.

For most categories, the information in Table 8-2 provides a clear definition of the equipment assumptions for each analysis case. There are two exceptions.

- For categories UC5 and UC6, there are several initiating events in the dominant scenarios and a decision was made to choose the path with the highest frequency, having the largest impact on the risk significance. However, in category UC6, the Baseline PRA impact of the LLOCA event did not cause it to be selected. This is because venting area to achieve IRWST gravity injection is not as challenging for a LLOCA due to the venting capability through the break.

- Most of the categories include dominant scenarios with the failure of some ADS stage 1, 2 and 3 lines, yet the expanded event trees are not refined to define the exact number. (In some cases, all possible combinations of stage 1, 2 and 3 failures are included.) To balance the desire to be conservative from the T/H viewpoint with the desire to consider risk significance, it was decided to assume that half of the ADS stage 1, 2 and 3 lines function.

The resulting cases for T/H analyses with uncertainties are listed in the top portion of Table 8-3.

Table 8-2 Dominant Scenarios in Risk Significant Categories								
Category	Success Path	Equipment Assumptions					If counted as core damage, increase to Focused PRA	
		CI	CMT	Acc	ADS-4	ADS 2,3	Δ CDF	Δ LRF
UC1	nloca34	Yes	0	2	4	4	9.2E-8	5.5E-9
UC2B	cmtlb21	Yes	0	2	4	4	8.0E-8	4.8E-9
UC4	lloca10,11	Yes	2	1	4	2 - 4	1.1E-6	6.6E-8
UC5	silb10,11	Yes	1	0	4	2 - 4	5.5E-7	3.3E-8
	nloca17	Yes	2	0	4	4	5.6E-8	3.4E-9
	sgtrw17,18	Yes	2	0	4	0 - 4	3.5E-8	3.5E-8
	tran17	Yes	2	0	4	4	1.8E-8	1.1E-9
UC6	nloca07,08	Yes	2	2	2	0 - 4	1.2E-7	7.0E-9
	sgtrw07,08	Yes	2	2	2	0 - 4	5.8E-8	5.8E-8
	slocwo07,.08	Yes	2	2	2	0 - 3	3.5E-8	2.1E-9
	tran07,08	Yes	2	2	2	0 - 4	3.5E-8	2.1E-9
	lloca08	Yes	2	2	2	0 - 3	1.9E-8 [a]	1.1E-9 [a]
	mloca08	Yes	2	2	2	0 - 3	1.3E-8	7.8E-10

Notes:

- Dominant scenarios are defined as ones that contribute to the category CDF or LRF exceeding 1% of the Focused PRA CDF or LRF. The residual effect of all scenarios not identified as dominant for a given category adds up to less than 1% of the Focused PRA CDF or LRF.

- Shaded blocks indicate accident scenarios that individually exceed 1% of the Focused PRA CDF or LRF.

(a) Other LLOCA success paths, which are not dominant scenarios based on the Focused PRA impact, increase these values to 2.9E-8 CDF and 1.7E-9 LRF. This is a 17% CDF and 9% LRF increase to the Baseline PRA, if they are counted as core damage rather than successful core cooling.

Table 8-3 Cases for T/H Analysis with Uncertainties Applied								
Case	Break Size	Equipment Assumptions					Code	Injection Phase of Interest
		CI	CMT	Acc	ADS -4	ADS 1,2,3		
Case UC1	NLOCA *	Yes	0	2	4	all	NOTRUMP / LOCTA	Accumulator
Case UC2B	Largest CMT LB	Yes	0	2	4	all	NOTRUMP / LOCTA	Accumulator
Case UC4	LBLOCA	Yes	2	1	4	half	WCOBRA/TRAC	Accumulator
Case UC5	DVI LB *	Yes	1	0	4	half	NOTRUMP / LOCTA	Accumulator / IRWST Inject
Case UC6	NLOCA *	Yes	2	2	2	half	NOTRUMP / LOCTA	IRWST Inject

* Limiting break size to be determined by MAAP4 analyses when MAAP4 benchmarking is completed.

9.0 IDENTIFICATION OF RISK-SIGNIFICANT LONG-TERM RECIRCULATION CASES

To be done.

10.0 T/H ANALYSES OF LOW-MARGIN, RISK-SIGNIFICANT SCENARIOS

10.1 Assumptions for T/H Uncertainty Analyses

To be done

10.2 NOTRUMP Results

To be done.

10.3 WCOBRA/TRAC Results

To be done.

11.0 ASSESSMENT OF T/H UNCERTAINTY RESULTS ON PRA

To be done.

12.0 CONCLUSION

To be done.

13.0 REFERENCES

1. NSD-NRC-96-4796/DCP/NRC0576, Docket Number STN-52-003, Letter from Brian McIntyre (Westinghouse) to T. R. Quay (NRC) on "AP600 Passive System Reliability Roadmap," 8/9/96.